Current Trends and Future Prospects in Cattle Production

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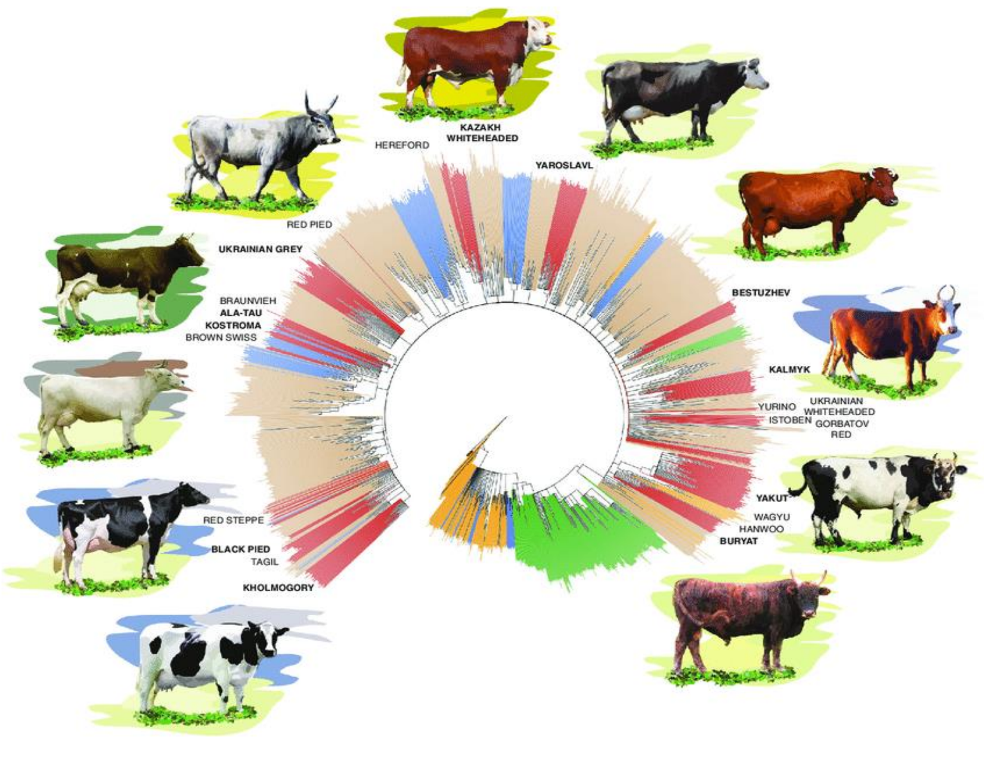

Baghdad, Iraq - 2026

636.08
R257Al-Rawi, Abdulrazaq
Current Trends and future prospects in cattle Production /Abdulrazaq Al-Rawi, Nasr Noori Al-Anbari, Nasr Noori -B- titl
ط1-1.- Baghdad : الدار الجامعية ، 2026
(531) ص ، (18في 25) سم ،
1- Cattle farming – A-Al-Anbari, Nasr Noori
رقم الايداع 2145 / 2026
المكتبة الوطنية / الفهرسة اثناء النشر

رقم الايداع في دار الكتب والوثائق ببغداد (2145) لسنة 2026

9789922779195

ISBN: 978 9922 779 195
الرقم المعياري الدولي

الدار الجامعية للطباعة والنشر والترجمة
الأشراف الفني د.عباس كويش
العراق – بغداد – الجادرية
www.bookstore-mohesr.gov.iq
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Preface:

There is currently no book dealing with cattle in Iraq. Therefore, this book brings together the latest research on cattle farming. The textbook contains scientific information on cattle breeding and management. The 15 chapters of this book were written by two professors specialized in breeding and management from college of agriculture, University of Baghdad. So, the basis of this book is originally stemmed from their experience in teaching and doing research in the field of animal breeding for more than 40 years. As the world moves further into digital age, this book aim to develop better knowledge for both graduate and undergraduate students, investors, conservationists of cattle genetic resources and related people. Moreover, there will be greater need to access texts with outdated technology for future generations. This book contains 15 chapters, focusing on various aspects of cattle farming as listed below:

Chapter 1: discuss Cattle: Importance and Classifications.
Chapter 2: reviews The World's Cattle and their Production Systems.
Chapter 3: presents Key Issues in Milk Production and Growth of Cattle.
Chapter 4: illustrates The Roles of Livestock in Developing Countries.
Chapter 5: deals with Dairy and Beef Cattle Management / Challenges and Prospective Opportunities in Smart Animal Husbandry.
Chapter 6: gives an overview of Diseases and Health.
Chapter 7: assigns to provides Genetic Improvement of Cattle, from Conventional Breeding to Biotechnological Approaches.
Chapter 8: clarifies the Strategies to Improve the Efficiency of Beef Cattle Production.
Chapter 9: proposes Strategies to Improve Economic Efficiency of the Dairy Cattle.

Chapter 10: reviews the Strategies to Lower Feed Costs and Boost Efficiency of Cattle, Production / The Role of the Gut Microbiome in Cattle Production and Health.
Chapter 11: shows the Factors that Optimize Reproductive Efficiency in Dairy cattle.
Chapter 12: explains Exploration of Extension Research to Promote Improvement of Cattle Production.
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The Authors

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Iraq, 2026

ACKNOWLEDGMENT

We would like to express our gratitude to all people who support, offered comments, evaluation and assisted in the editing, and proof reading of this book.

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Chapter 1

Cattle:

Importance and Classifications

Cattle: Importance and Classifications

1-1: Importance of Cattle

Cattle are large, domesticated, bovid ungulates widely kept as livestock. Cattle are commonly raised for meat, for dairy products, and for leather. As draft animals, they pull carts and farm implements. Mature female cattle are called cows and mature male cattle are bulls. Young female cattle are called heifers, young male cattle are oxen or bullocks, and castrated male cattle are known as steers. Taurine cattle are widely distributed across Europe and temperate areas of Asia, the Americas, and Australia. Zebus are found mainly in India and tropical areas of Asia, America, and Australia. Sanga cattle are found primarily in sub-Saharan Africa. Over 1000 breeds of cattle are recognized worldwide, some of which adapted to the local climate, others which were bred by humans for specialized uses. Cattle breeds fall into two main types, which are regarded as either two closely related species, or two subspecies of one species. *Bos indicus* cattle, commonly called zebu, are adapted to hot climates and originated in the tropical parts of the world such as India, Sub-Saharan Africa, China, and Southeast Asia. *Bos taurus* typically referred to as "taurine" cattle, are generally adapted to cooler climates and include almost all cattle breeds originating from Europe and northern Asia. In some parts of the world further species of cattle are found (both as wild and domesticated animals), and some of these are related so closely to taurine and indicus cattle that interspecies hybrids have been bred. Wikipedia listed most breeds of cattle (online encyclopedia, https://en.wikipedia.org/wiki/List_of_cattle_breeds).

Cattle have contributed to the survival of human for many thousands of years, initially as animals our hunter-gatherer ancestors pursued for food, tools, and leather, and which farmers raised for the past hundred years as livestock for meat, milk, and as draft animals. Cattle also have become an indicator of economic status. Cattles play significant role in urban and rural livelihoods as well as the economies of countries. They are providing employment for many workers and income for producers. They are a crucial asset and safety net for the poor, especially for women and pastoralist groups, and they provide an important source of nourishment for billions of rural and urban households. These socio-economic roles and others are increasing in importance as the sector grows because of increasing human populations, incomes and urbanization rates. To provide these benefits, the sector uses a significant amount of land, water, biomass and other resources and emits a considerable quantity of greenhouse gases. There is concern on how to manage the sector's growth, so that these benefits can be attained at a lower environmental cost. Cattle and environment interactions in developing countries can be both positive and negative. On the one hand, manures from ruminant systems can be a valuable source of nutrients for smallholder crops, whereas in more industrial systems, or where there are large concentrations of animals, they can pollute water sources. On the other hand, ruminant systems in developing countries can be considered relatively resource-use inefficient. Because of the high yield gaps in most of these production systems, increasing the efficiency of the livestock sector through sustainable intensification practices presents a real opportunity where research and development can contribute to provide more sustainable solutions. After sheep, and goats, cattle were domesticated next, starting many thousand years ago, and ahead of horses, pigs and chickens. Bovines are associated with human survival, and vice versa. Cattle convert grass into protein better than most any other farm-raised animals. Moreover. Cattle industry is an efficient and prosperous animal agriculture historically has been the mark of a strong, well-developed nation. Such an agriculture permits a nation to store large quantities of grains and other foodstuffs in concentrated form to be utilized to raise animals for human consumption during such emergencies as war or natural calamity. Furthermore, meat has long been known for its high nutritive value, producing stronger, healthier people. Ruminant (cud-chewing) animals such as cattle, sheep, and goats convert large quantities of pasture forage, harvested roughage, or by-product feeds, as well as non-protein nitrogen such as urea, into meat, milk, and wool. Ruminants are therefore extremely important; more than 60 percent of the world's farmland is in meadows and pasture. Milk is one of the most complete and oldest known as one of the most essential human foods.

1-2: Consumption of Beef

In a different way today, consumption of beef is an indicator of socioeconomic status and gastronomic preference. Increases in beef consumption have been documented in many nations as their economies have improved. Beef has become a favored gastronomic taste. In colder regions of the northern hemisphere the descendants of aurochs were Bos taurus cattle, the primary ancestors of most popular breeds today. *Bos taurus* bloodlines were sometimes crossed with Zebu cattle to improve their handling and dispositions. Americans eat a lot of beef today, estimated at 79.3 lbs. per person, but not as much per capita as in 1976 (94.3 lbs.). The U.S. is fourth on the 2016 list of per capita beef consumption world-wide, after Uruguay (124.2 lbs.), Argentina (120.2 lbs.), and Hong Kong (114.3 lbs.). Health concerns about cholesterol from eating beef, competition from cheaper sources of meat like pork and poultry, and changing tastes influence some consumers from purchasing beef as food. Critics also say cattle are not efficient converters of feed into usable protein. It takes about six pounds of feed to produce a pound of beef. Today's well-bred pigs take about 2.5-3.5 pounds of feed to produce a pound of edible meat, while chickens and turkeys in commercial U.S. enterprises require about 1.5-2.5 pounds of feed; farm-raised fish-like salmon take closer to one pound of feed to produce a pound of edible flesh. There are cyclic patterns to affordability of beef as food, as well as their production and market prices. Beef prices are mostly in the doldrums for producers currently even though grocery store prices for beef remain relatively high. Efficient producers of high-quality beef and desired breeds, especially those who furnish the most desired cuts like prime steaks, and organic beef, currently are doing well financially. Natural selection and human-directed breeding strategies have led to the development of phenotypically distinct breeds adapted to specific breeding goals. Genetic improvements cannot happen in an individual animal's lifetime but have the advantage of being additive over subsequent generations. Genetic selection in cattle has often focused on **Production Key Performance Indicators**, which are easier to evaluate than behavioral traits which have subjective measurement and variation in how they are defined. Animal temperament is a quantitative trait controlled by an animal's genetic predisposition for behavior. There is a range of traits indicative of an animal's behavior, and thus a range of measurements which can be assessed through restrained or non-restrained methods. Restrained techniques monitor behavior when the animal is restricted and non-restrained monitor behavior when they have the ability to move freely.

The Major Functional Traits Important in Beef Production include body size, milking potential, age at puberty, hot climate adaptability, fleshing ability, muscle expression, cut ability, and marbling. Details of these traits are:

-Body size: Body size is best evaluated as weight at a stated level of condition or body fatness. Although there are exceptions, weight at all ages tends to be positively related—cattle heavier at birth tend to be heavier throughout life. Genetically larger animals usually gain weight faster, and weight and nutritional requirements for body maintenance are closely related.
-Milking potential: Milking potential is the genetic capability to produce milk. This is not the actual volume of milk produced, which also is influenced by the cow's nutrition and the calf's growth potential and nursing pressure. To characterize milking potential accurately, it should be evaluated relative to body size.

Higher-milking females need more nutrients for body maintenance and require higher-quality diets, even when not lactating.
-Age at puberty: Age at puberty relates to body size, milking potential, and genetic classification. Smaller cows and higher milking types usually mature earlier, whereas *Bos indicus* mature relatively late. Although higher milking females, even large ones, often reach puberty and conceive when relatively young, subsequent fertility can suffer because they may become thin after beginning lactation. While *Bos indicus* types reach puberty relatively late, their productive life is usually longer.
-Hot climate/tropical adaptability: Adaptability to hot climates is highest in cattle with Bos indicus inheritance, but some Bos taurus are reasonably heat tolerant. Animals with lighter colored, short hair coats and dark skin are best adapted.
High humidity intensifies the effects of heat, especially because hot, humid climates often add the stresses of parasites and low-quality forage. Heat with humidity stresses cattle that fail to shed long, thick hair coats, particularly dark colored ones. As might be expected, animals tolerant to hot climates are less adapted to cold.
-Fleshing ability: Fleshing ability is the body's capacity to fatten and retain fat. Fleshing ability tends to drop with increases in genetic body size, maintenance requirements relative to size, milking level, and inherent muscularity. Animals poorly adapted to their environment generally are low in fleshing ability. *Bos indicus* often flesh more easily than other types on low-quality forage and roughage. Easy-fleshing cattle tolerate periods of nutritional energy deficiency more easily and, therefore, may reproduce more consistently, but they also over fatten more readily in the feed yard unless properly managed.
-Muscle expression: Muscle expression is inherent muscularity, independent of other body tissues. Muscling is the second most important factor in cutability. Heavy-muscled types often are low in fleshing ability, so reproductive efficiency may be reduced.
-Cutability: Cutability, or the percentage of lean, is usually evaluated in beef carcasses as USDA Yield Grade. Cutability

depends on relative amounts of fat (which varies greatly), muscle, and bone (which varies least). When genetic types or breeds are compared for differences in cutability, it is assumed that the breeds have similar nutrition levels. But inherent cutability differences can be readily altered by varying nutrition to achieve similar degrees of fatness.
-Marbling: Marbling, or intramuscular fat, is the primary factor determining USDA Quality Grade, an indicator of the palatability factors of tenderness, juiciness, and flavor. Marbling increases with age up to physiological maturity and generally is higher in earlier maturing and higher milking types. Feeding high-energy rations starting early in life for extended periods generally increases marbling. *Bos indicus* and most heavy-muscled, low milking types have relatively low marbling. Because marbling relates somewhat to body fatness, especially in comparing breeds or types, there is usually a trade-off between Yield Grade and Quality Grade. As one improves, the other tends to decline. For a discussion of carcass genetic considerations.
Characters of Dairy Cattle are characterized by special features, which can be classified into two main groups, morphological and productive characters.

Morphological characters include:

1. Large and well-developed udder: extended forwards and backwards but not downwards (suspended or pendulous). 2. Prominent, and well developed and well-formed mammary (milk) veins. 3. Elongation of the body, enlargement of abdomen with pinned bone appearance. 4. Thinness of head and neck with their homogeneity. 5. The body has triangular, wedge shape due to narrow shoulder, moderate chest, deep abdomen and broad hind quarter. This triangular shape can be observed at upper, front, and back view.

Productive Characters It is more important than morphological characters from practical point of view. The parameters depend mainly upon different "production record" of the farm (if available) 1. Quantity of milk produced. 2. Fat percentage of milk. 3. Time of milk produced (date of production) at fist calving. 4. Period of milk produced (month). 5. Length of dry period (days). 6. Intervals between two deliveries and mating. 7. Intervals between two successive calving. 8. Persistency of production. 9. Calmness at milking process.

1-3: Selection Basis of Suitable Cattle Breeds

a. The capacity to produced milk: The ability of cow the use local feedstuff and convert it into mainly milk. b. Body traits: Cows should be characterized by body depth, large heart girth (broad chest girth) enable these cows to consume huge amount of feedstuffs. c. Udder characters: Large and sound (healthy) udder with its extension forwards and backwards but not swing, teat-balanced with the prominence of mammary (milk) veins. d. The follow of pedigree, lifetime and production concerning with milk yield (production) if available.

1-4: Main Characteristics of *Bos taurus* Dairy Cattle

Dairy Character is signified by freeness of flesh; sharpness at the withers; flat thighs set wide apart; loose and pliable skin; smooth blending neck; and flat and well-spaced ribs. Below some characteristics of distinguished breeds:

- Holstein: This breed originated in Europe. This breed has the highest milk production of all dairy breeds. The Holstein cow produces around 10000 - 15000 kg of milk each lactation, with a standard lactation period of 305 days. The Holstein, which is large, spotted black and white (some cows can be mostly black or mostly white) with short inward-curving horns.
- Jersey: This breed originated from the island of Jersey, 15 miles off the coast of France. Jersey produces more butterfat in their milk than other dairy breeds. Average milk production is 7500kg per lactation, with a high butterfat content of 4.9%, total protein 3.7%. The Jersey, which is small and fawn or dun colored with a dark face, or eye patches, black nose, hooves and front part of the lower legs. Some Jerseys are also black

with a fawn saddle patch over their back. They do not give, as much milk as the other breeds, but it is famous for cream they produce. Jerseys can be horned or polled, with horns often being short and curving upwards.

- Brown Swiss: This breed originated in the Alp Mountains. Brown Swiss cows are known for being hearty and rugged, having superior feet and legs. This breed is very quiet and docile. Average output is 9000kg of milk per lactation with 4.0% butterfat, 3.5% total protein. The Brown Swiss, which is large, (smaller than the Holstein), brownish-grey to dark brown (often grey as well) with a light-colored muzzle, belly and udder.
- Guernsey: This breed originated in the English Channel, 30 miles off the coast of France. Guernsey is small, about three-fifths the size of a Holstein, but produce up to 6500kg of milk with 4.5% butterfat, 3.5% total protein. The Guernsey, which is pale red to yellow and white, and give a lot of cream.
- Ayrshire: This breed originated in Scotland. Ayrshire is known for vigor and efficiency of milk production. Average output is 8000kg of milk per 305 day-cycle/year, with 3.9% butterfat, 3.3% total protein. The Ayrshire, which is large, irregularly spotted red and white with short up-curving horns, or polled.
- Milking Shorthorns: This breed originated in England. The Milking Shorthorn has a wide range of adaption and the reputation of being a good milker. A typical cow produces 7000kg of milk per lactation with a butterfat content of 3.8%, total protein 3.3%. The Milking Shorthorn, which is medium-sized to large, deep red to roan and short, upturned horns or polled.

1-5: Main Characteristics of *Bos indicus* Dairy Cattle

Bos indicus Cattle (Zebus), sometimes known as humped cattle, are a type of domestic cattle originating in South Asia. They are characterized by a fatty hump on their shoulders, drooping ears and a large dewlap. They are used primarily to create crossbred females that are adapted to hot climates and have the most longevity, hybrid vigor, and calving ease. Generally, these females are best used in terminal crossing systems. The main physiological differences that *Bos indicus* cattle present relative to *Bos taurus* cattle include: delayed age at puberty. The most dairy breed in Asia is Sahiwal cattle (is a breed of *Bos indicus*, zebu sometimes known as humped cattle).

Sahiwal cattle.

The cattle is mainly found in Pakistan and India. Sahiwal is considered a heat-tolerant cattle and Dual-purpose Dairy/Draft breed. Today the Sahiwal is one of the best dairy breeds in India and Pakistan. Sahiwal is calm when milking. Due to their heat tolerance and high milk production they have been exported to other Asian countries as well as Africa, the Caribbean and Australia. In Australia, the Sahiwal breed was initially selected as a dual-purpose breed. It played a valuable role in the development of the two Australian tropical dairy breeds, the Australian Milking Zebu and the Australian Friesian Sahiwal.

Australian Milking Zebu

Sahiwals have been crossed with *Bos taurus* breeds that have a high response capability for milk and beef production as well as adaptability to tropical pasture conditions. It is a combination of the Sahiwal, a dairy breed of *Bos indicus* from Pakistan and Holstein (*Bos taurus*) breeds, designed for the tropical regions of Australia. Cows produce approximately 3,000 liters of milk per lactation under tropical pasture conditions with a high resistance to heat, humidity, ticks and other parasites.

1-6: Cattle Classification and Breeds

1-6-1: Beef Cattle

The British Isles led the world in the development of the principal beef breeds; Herefords, Angus, beef Shorthorns, and Galloways all originated in either England or Scotland. Other breeds of greatest prominence today originated in India (Brahman), France (Charolais; Limousin; Normandy), Switzerland (Simmental), and Africa (Africander).

The Hereford breed, considered to be the first to be developed in England, probably descended from white-faced, red-bodied cattle of Holland crossed with the smaller black Celtics that were native to England and especially to Herefordshire. By the middle of the 18th century the slow process of selective breeding that resulted in the smooth, meaty, and prolific Herefords had begun. The United States statesman Henry Clay of Kentucky imported the first purebred Herefords to America in 1817.

Hereford bull.

The Hereford, which became the most popular beef breed of the United States, is distinguished by its white face, white flanks and underline, white stockings and tail, and white crest on the neck. Its body color ranges from cherry to mahogany red. It is of medium size, with present-day breeders making successful efforts to increase both its rate of weight gain and mature size, in keeping with the demand for cheaper, leaner beef. The Polled Hereford is a separate breed of cattle originating from hornless mutations in 1901. It has the same general characteristics as the horned Hereford and has gained substantial favor because of its hornlessness and often faster rate of weight gain.

Characteristics of Hereford cattle are:

Place of Origin:	England
Bull (Male) Size:	59.8 inches
Cow (Female) Size:	52 inches
Color:	Dark to yellowish-red
Lifespan:	13-18 years
Climate Tolerance:	Arctic snows to moderate heat

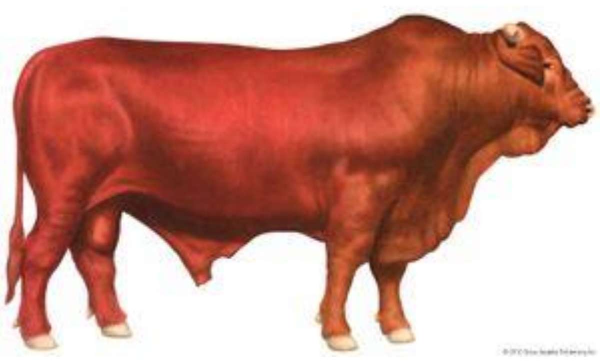
The Aberdeen Angus breed originated in Scotland from naturally hornless aboriginal cattle native to the counties of Aberdeen and Angus. Solid black, occasionally with a spot of white underneath the rear flanks, the breed is noted for its smoothness, freedom from waste, and high quality of meat. Because of their native environment, the cattle are very hardy and can survive the Scottish winters, which are often harsh, with snowfall and storms. Cows weigh about 550 kilograms (1,210 lbs.) and bulls some 850 kilograms (1,870 lbs.). Calves are usually born smaller than is acceptable for the market, so crossbreeding with dairy cattle is needed for veal production. The cattle are naturally polled and may be either black or red. They reach maturity earlier than some other native British breeds such as the Hereford or North Devon. The Aberdeen Angus, sometimes simply Angus, is a Scottish breed of small beef cattle. It derives from cattle native to the counties of Aberdeen, Banff, Kincardine and Angus in north-eastern Scotland. In 2018 the breed accounted for over 17% of the beef production in the United Kingdom. The Angus is naturally polled and solid black or red; the udder may be white. The cattle have been exported to many countries of the world; there are large populations in Australia, Canada, New Zealand, South America and the United States, where it has developed into two separate and distinct breeds, the American Angus and Red Angus. In some countries it has been bred to be taller than the native Scottish stock.

Aberdeen Angus bull

Shorthorn breed developed from early cattle of England and northern Europe, selected for heavy milk production and generally known as Durham cattle. These were later selected for the compact, beefy type by the Scottish breeders. Emphasis on leaner, high-quality carcasses in the second half of the 20th century has diminished the popularity of this breed. The Polled Shorthorn originated in 1888 from purebred, hornless mutations of the Shorthorn breed. The milking, or dual-purpose, Shorthorn, representing another segment of the parent Shorthorn breed, also was developed in England to produce an excellent flow of milk as well as an acceptable carcass, therefore resembling the original English type of Shorthorn. Shorthorns range in color from red through roan, to white- or red-and-white-spotted.

Shorthorn bull.

The Santa Gertrudis was developed by crossing Brahman and Shorthorn cattle to obtain large, hearty, tick-resistant, red cattle that have proved to be popular not only in Texas but in many regions along the semitropical Gulf Coast. Until the tick was eradicated in the southern and southwestern United States, Brahman crosses were raised almost exclusively there.



Santa Gertrudis bull.

The Brahman breed originated in India, where 30 or more separate varieties exist, which are characterized by a pronounced hump over the shoulders and neck; excessive skin on the dewlap and underline; large, droopy ears; and horns that tend to curve upward and rearward. Their color ranges from near white through brown and brownish red to near black. Their popularity in other areas such as South America and Europe, into which they have been imported, is attributable mainly to their heat tolerance, drought resistance, and resistance to fever ticks and other insects. The Brahman is reared for the meat industry, particularly in areas where good resistance to hot or tropical conditions is needed. As with other zebuine cattle, the meat is of lower quality than that of specialized European beef cattle breeds. For this reason it is commonly cross-bred with cattle of those breeds, either by raising hybrid calves born to pure-bred parents, or by creating a composite or hybrid breed, of which there are many. Some of them, such as the Brahmousin (Brahman x Limousin), Brangus (Brahman x Angus) and Simbrah (Brahman x Simmental) have acquired breed status in their own right, but many others have not. These include the Brahorn (Brahman x Shorthorn), the Bravon (Brahman x Devon) and South Bravon (Brahman x South Devon), the Bra-Swiss (Brahman x Brown Swiss), the Sabre (Brahman x Sussex) and the Braford (Brahman x Hereford).

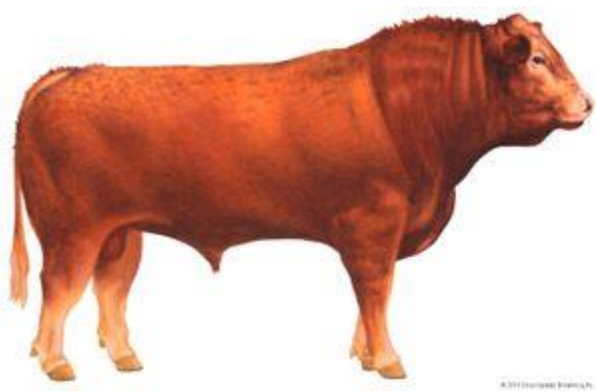
The Brahman breed

The Charolais breed, which originated in the Charolais region of France, has become quite popular in the United States for crossing on the British breeds for production of market cattle. The superior size, rate of gain, and heavy muscling of the pure French Charolais and the hybrid vigor accruing from the crossing of nonrelated breeds promise an increased popularity of this breed. Many American Charolais, however, carry significant amounts of Brahman blood, with a corresponding reduction in size, rate of gain, and muscling. Important in France, the Charolais is the foremost meat-cattle breed in Europe.

Traits	
Weight	• Male: 1000–1650 kg • Female: 700–1200 kg
Height	• 135–150 cm
Coat	White
Horn status	Horned in both sexes

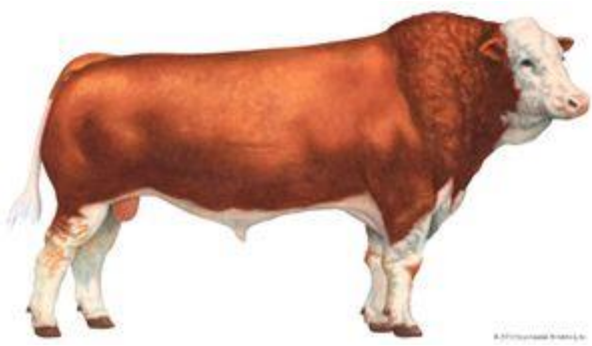
Charolais Cow and calf

The Limousin breed, which originated in west central France, is second in importance to the Charolais as a European meat breed. Limousin cattle, often longer, finer boned, and slightly smaller than the Charolais, are also heavily muscled and relatively free from excessive deposits of fat.



Limousin bull.

The Simmental accounts for nearly half of the cattle of Switzerland, Austria, and the western areas of Germany. Smaller than the Charolais and Limousin, the Simmental was developed for milk, meat, and draft. It is yellowish brown or red with characteristic white markings.



Simmental bull.

1-6-2: Dairy Cattle

There are many different breeds of cows. A breed is a group of animals with a similar appearance and behavior. The two most recognized and well-known breeds of dairy cattle are the Holstein cow and the Jersey cow. Holsteins are the best known of the types of cows belonging to the dairy breeds, with her black-and-white spotted body.

- Holstein-Friesian: Mean of milk production in 5000kg in 305 days of 3.5 % butterfat. Color of milk is more whitish than other dairy breeds due to high efficiency to convert carotene (colorless). The Holstein Friesian is an international breed or group of breeds of dairy cattle. It originated in Frisia, stretching from the Dutch province of North Holland to the German state of Schleswig-Holstein. It is the dominant breed in industrial dairy farming worldwide, and is found in more than 160 countries. It is known by many names, among them Holstein, Friesian and Black and White. With the growth of the New World, a demand for milk developed in North America and South America, and dairy breeders in those regions at first imported their livestock from the Netherlands. However, after about 8,800 Friesians (black pied

German cows) had been imported, Europe stopped exporting dairy animals due to disease problems. Today, the breed is used for milk in the north of Europe, and for meat in the south of Europe. After 1945, European cattle breeding and dairy products became increasingly confined to certain regions due to the development of national infrastructure. This change led to the need to designate some animals for dairy production and others for beef production; previously, milk and beef had been produced from dual-purpose animals. Today's European breeds, national derivatives of the Dutch Friesian, have become very different animals from those developed by breeders in the United States, who use Holsteins only for dairy production. As a result, breeders have imported specialized dairy Holsteins from the United States to cross-breed them with European black-and-whites. Today, the term "Holstein" is used to describe North or South American stock and the use of that stock in Europe, particularly in Northern Europe. "Friesian" is used to describe animals of traditional European ancestry that are bred for both dairy and beef use. Crosses between the two are described as "Holstein-Friesian".

Holstein cattle

Nevertheless, Holsteins are famed for their high dairy production, averaging 22,530 pounds (10,220 kg) of milk per year. Of this milk, 858 pounds (3.7%) are butterfat and 719 pounds (3.1%) are protein. A healthy calf weighs 40 to 50 kg (75–110 lb) or more at birth. A mature Holstein cow typically weighs 680–770 kg (1500–1700 lb), and stands 145–165 cm (58–65 in) tall at the shoulder.

Holstein heifers should be bred by 11 to 14 months of age, when they weigh 317–340 kg (700–750 lb) or 55% of adult weight. Generally, breeders plan for Holstein heifers to calve for the first time between 21 and 24 months of age and 80% of adult body weight. The gestation period is about nine and a half months.

Traits	
Weight	• 680–770 kg (1500–1700 lb)
Height	• 145–165 cm (58–65 in)
Coat	black and white pied; also red and white.
Horn	horned, mainly dehorned as calves

Famous Cows of the World (Holstein)

- **The Jersey:** Milk produces 2500kg in 305 days with 5.3 - 5.5% butterfat. Milk of Jersey is yellowish due to high containing of butter fat. Jerseys are known for their large eyes and brown color. They also give milk that is high in butterfat and perfect for ice cream. Jersey Cattle Breed Characteristics: Jersey Cattle are smaller than most other cattle breeds out there, but that doesn't mean they're "small." Bulls can reach an impressive 1,800 pounds. While the cows are lighter, they can still reach 1,200 pounds. They have a fawn, cream, red-tinted, or dark shades of brown in their coloring. They also don’t have a hunchback. They do have a black tail and black hooves. Jersey Cows typically have large udders, which makes sense because they’re high-producing dairy cows. A purebred Jersey Cow will have a light band of color around their muzzle. Jersey Cattle are a small cattle variety, but they only have one purpose: to produce dairy. A single dairy Jersey Cow can produce 10 times their weight in milk during each lactation, making them one of the best-producing cows out there.

Facts About Jersey Cattle Breed

Breed Name:	*Bos taurus*
Bull (Male) Size:	1,200 to 1,800 pounds
Cow (Female) Size:	800 and 1,200 pounds
Color:	Fawn, cream, red-tinted, or dark brown
Lifespan:	25 to 30 years
Climate Tolerance:	Adapts well to different climates, has a high heat tolerance
Production:	10,000 to 17,500 pounds of milk per year

Jersey Cow

- **The Ayrshire**: This type produced 4100kg milk with 4% butter fat. Ayrshire cows feature beautiful reddish-brown mahogany-colored spots on their white body. Ayrshires are medium-sized cattle weigh over 1200lbs at maturity. These cows are highly popular for their versatility. Ayrshires are highly adaptable and can manage to cope with any management system. Among their physical characteristics, Ayrshires have

- Longhorns
- Stout physique
- Reddish-brown to mahogany skin color

Ayrshire Cows in a grass field

Below listed some essential characteristics of Ayrshire cows.

Color	A combination of white, brown, and cherry red
Built	Stout body; short & elongated head; well-developed muscle mass; short; stable and string limbs
Horns	Long upward built; curved; widely spaced any yellowish
Weight	1000- 1200lbs
Length	Up to 155 cm
Growth	Up o 125 cm
Udder	Neat; large; wide; and with a silky texture
Milk production	Around 8500 litters

Ayrshire Cows

- Brown Swiss: Milk production is 2570 kg with 4 % fat. Many dairy historians consider Brown Swiss cows to be the oldest of all the types of milk cows or dairy

Origin: The Alps of Switzerland.

Characteristics: The Brown Swiss is considered the oldest of the dairy breeds. Brown Swiss can vary in color, from silver to dark brown, and are large with large ears. Their milk is ideal for making cheese because of its high protein-to-fat ratio. Because of their adaptability, Ayrshires are found in most parts of the world, including Southern Africa. The Brown Swiss or American Brown Swiss is an American breed of dairy cattle. It derives from the traditional triple-purpose Braunvieh ("Swiss Brown") of the Alpine region of Europe, but has diverged substantially from it. It was selectively bred for dairy qualities only, and its draft and beef capabilities were lost. Milk yield was measured in 2013 at 10231 kg (22600 lb) per year; the milk has about 4% butterfat and 3.5% protein and is suitable for making cheese. In the twentieth century the Brown Swiss became a world breed, with a global population estimated in 1990 at seven million head.

Brown Swiss Cow

-Guernsey cows are brown or fawn (light yellowish tan) with white spots of various sizes on the body or face.

Facts about the Guernsey

Place of Origin:	Isle of Guernsey, Channel Islands
Bull (Male) Size:	2,000 pounds
Cow (Female) Size:	1,400 pounds
Color:	Fawn and white
Lifespan:	10-12 years
Climate Tolerance:	Any climate
Milk color:	Golden yellow
Productivity:	10231 kg (22600 lb) per year
Milk composition:	4.68% butterfat, 3.57% protein

Guernsey Cows

-Red and White Holstein cows are the most recently recognized breed and were first seen in 1964. Characteristics and traits of Red and White Holstein cows:

1. Appearance: Red and White Holsteins have a vibrant red coat with white markings, making them unique and eye-catching.
2. Size and Weight: They are large in frame, weighing about 1,400 pounds in maturity.
3. Milk Production and Temperament: Like their black and white counterparts, Red and White Holsteins offer exceptional milk production and have a gentle temperament

Red and White Holstein

-Milking Shorthorn cows were the first breed to enter the United States in the early 1780's. The Milking Shorthorn cattle (are also known as the Dairy Shorthorn cattle) are one of the oldest recognized breeds in the world that originated in the Great Britain. As the name suggests, it is dairy cattle breed and primarily used for milk production. The breed was developed from the Shorthorn cattle in the 18th century in Northeastern England. The Shorthorn cattle breed came from County Durham, Northumberland and Yorkshire in north eastern England. The breed is known as Dairy Shorthorn cattle in the United Kingdom, Australia, South Africa and Ireland. And as Milking Shorthorn in Canada, New Zealand and the United States. Many popular cattle breeds have descended from the Milking Shorthorn cattle genetics. Today the Milking Shorthorn cattle are popular and available in many countries throughout the world. Read some more information about the breed below. The Milking Shorthorn cattle are medium sized animals. They are generally red, red with white markings, white or roan colored. Red and white coat color genes in purebred Milking Shorthorns are co-dominant, resulting in the roan coloration and unique color patterns seen in the breed. Average height of the cows is about 140 cm at the tail head. And average body weight of the cows is between 640 and 680 kg. The bulls are pretty larger and heavier than the cows. Milking Shorthorn cattle are dairy cattle breed and mainly used for milk production. But they are also good for meat production. The Milking Shorthorn cattle breed is the most versatile of all breeds and this is one of its greatest attributes. They are known for their high levels of fertility, grazing efficiency and ease of management. They are also known for their durability, longevity and ease of calving. These animals are usually docile and relatively calm in temperament. The cows are capable of producing large volumes of nutritious milk. They can produce about 7000 kg of milk in an annual lactation of about 305 days. Their milk is of pretty good quality containing about 3.3 percent protein and about 3.8 percent butterfat. Review full breed profile of this breed in the following chart.

Breed Purpose	Mainly milk also meat
Special Notes	Strong, hardy, well adapted to harsh climates, good milkers
Breed Size	Medium
Bulls	700 – 750 kg
Cows	640-680 kg
Climate Tolerance	All Climates
Coat Color	Red, red with white markings, white, or roan
Horned	No
Country/Place of Origin	Great Britain

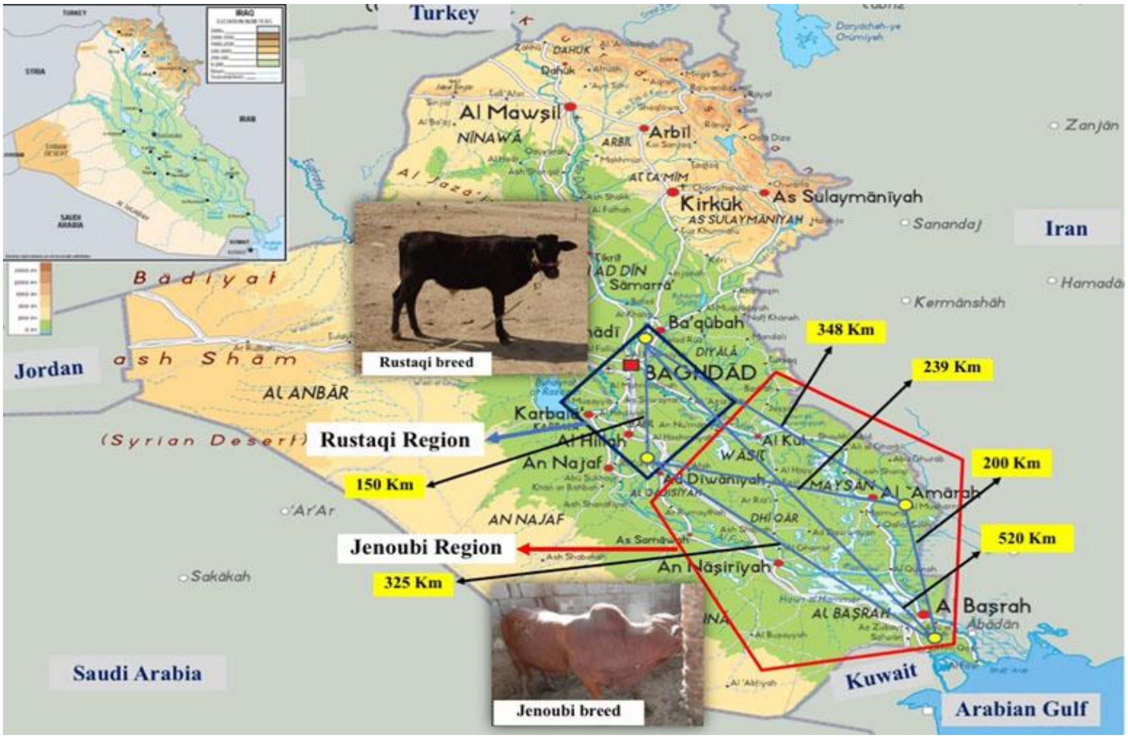
Milking Shorthorn

1-7: Cattle in Iraq

Archeological and genetic studies support two centers of cattle domestication, the Fertile Crescent and the Northern part of the India. From these two heartlands of domestication, two main cattle types, *Bos taurus* (humpless taurine) and *Bos indicus* (humped zebu), dispersed across the world, with taurine cattle reaching Africa, Europe, and East Asia and indicine cattle migrating to Africa, South Asia, and South-East Asia. Cattle husbandry was part of the ancient civilizations of Mesopotamia, modern-day Iraq, at an early time with the earliest available evidence of domestic cattle in this region. Despite the high cattle number worldwide, it is estimated that 17% of cattle breeds are facing extinction, following changing environmental and production conditions. Endangered breeds of cattle are mostly found in developing countries. For instance, 32% of the recognized indigenous African breeds are at risk of extinction, and another 22% are already considered extinct. Animal production in Iraq Animal husbandry and livestock production has been traditionally practiced in most parts of Iraq and provided animal products to a large segment of the population for generations. Livestock production comprised 30-40 percent of the total value of agricultural production and contributed heavily to meet nutritional requirements. Livestock production in Iraq mainly includes cattle, sheep and goats. Buffalo and camel rearing are carried out at a limited scale. Cattle production: Approximately 85 percent of the cattle population in the country is local breeds with rather low milk yields per lactation. *Bos indicus* cattle are distributed all over the world. Among them are that found in Middle East (Iraq).

Local Cattle in Iraq.

The rest are crosses of foreign breeds. The local cattle breeds are Sharabie and Junobie. Attempts to improve the local breeding stock through artificial insemination (AI) when established artificial insemination center in Baghdad. No official data are available on the composition of the regional herd by breed. It is estimated that there are no more than 1000 purebred Friesian cattle in the area. While local breeds predominate, there are a significant number of crossbred cattle. The main local breeds of cattle are Karadi and Sharabi, which produce between one and five liters of milk per day for a lactation length of 150 days



1. Al Junobi cattle: It is found in the southern part in Iraq. These cattle are characterized by the presence of both hump and dewlap due to presence of a ratio of Zebu (Indian) cattle blood. Their colors are bright to dark red with sleek coat (smooth hair and skin) and small horns. Their legs are long due to nature of rearing on pasture (grazing). It is characterized by their ability of heat tolerance.

2. Sharabi cattle: It is reared in basin of Tigris River between Fishkhabour and Zammar. The color is dark (black) with white line on the back abdomen. the legs are short but the body is full which is similar to beef - cattle breeds

3. Karadi cattle: It is regarded as low - produced cattle. It is characterized by small size, small horns, short strong legs which assist these cattle to live and thrive in mountainous region. The common color is black, red, grey. It is used as a beast of burden. Adult animal weight 300 - 350 kg. Milk production is very low and not exceed 2 kg per day in relatively short lactation period.

4. Ristaki cattle: It is found in middle and some southern part of Iraq. It is present in little number with various colors. Mean animal weight of adult is 450 kg. Milk production ranges between 3 - 4 kg/day. It is used as a beast of burden.

5. Cross bred: Due to inefficient productive parameters of Iraqi cattle cross, breeding with original dairy is followed. The aim of cross breeding is to improve production of local breed. However, Friesian is selected to fulfill this goal to improve milk production and an increase in body growth and weight. *Bos indicus* and *Bos taurus* are brought together in a systematic and orderly breeding program, they are able to contribute effectively to increased milk and meat production from cattle in the tropics. Inter se mating from any crossbred group can form a synthetic population (may be new breed). The simplest form of synthetic, with two parental breeds, is formed from the F_1 generation, through grading-up *Bos indicus* female with exotic *Bos taurus* genes, mainly Holstein (to produce an F_1 generation contain 50% gene from each parental breed, and therefore have half of the additive effect, and consequently heterosis).

Local *Bos indicus* "Jenubi" and crossbred (50% exotic, and 50% Jenubi cattle).

If a higher degree of exotic genes is required in the next generation, exotic bulls are mated to selected F_1 females' generation (backcrossed to the exotic to produce three-quarter crossbred). Research results showed that all crossbreds produced 50 to 80% more milk than local *Bos indicus* cattle. Furthermore, crossbreds calved at a considerably younger age than native females, and had slightly shorter calving intervals.

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Chapter 2

The World's Cattle and their Production Systems

The World's Cattle and their Production Systems

2-1: Potential of Cattle

The current world population is estimated to have exceeded eight billion as of mid-November 2022. World population is expected to increase and reach some 9.7 billion people by 2050. Projected growth in the world's population is likely to be concentrated in Africa and South Asia and in the world's cities. Should this expansion materialize, it could seriously jeopardize the overall development prospects of these regions, as they rely on agriculture for employment and income generation and yet cannot expand agriculture because of stressed land and water resources. By mid-century, two-thirds of the global population will live in urban areas. Population dynamics will radically change demographics over the coming decades and towards the end of the century. Cattle (Bos indicus and B. taurus) are the most common and widespread species of large ruminant livestock and are raised primarily to produce milk, meat and hides and to provide draft power. Can cattle production systems capable of meeting the needs of a global population growth? In grass-based systems livestock play an important role in nutrient recycling and convert human-inedible plant matter into protein. Cattle are raised in diverse production systems ranging from capital-intensive, specialized beef and dairy grass-based and feed-lot systems; through multi-purpose cattle in labor-intensive, mixed crop-livestock systems; to extensive pastoral and agro-pastoral systems. Cause for hope and concern over the past century, enormous progress has been made in improving human welfare worldwide. Societies have changed radically due to technology, rapid urbanization, and innovations in production systems. Yet conditions today are a far cry from the world 'free of fear and want' envisioned by the United Nations. In fact, much remains to be done to fulfil the vision of the Food and Agriculture Organization of the United Nations (FAO), which is to create 'a world free of hunger and malnutrition and one in which food and agriculture contribute to improving the living standards of all, especially the poorest, in an economically, socially and environmentally sustainable manner'. Amid great plenty, billions of people still face pervasive poverty, gross inequalities, joblessness, environmental degradation, disease and deprivation. Displacement and migratory flows are at their highest levels since the Second World War. While many armed conflicts have been resolved, new ones have emerged. Much of humanity's progress has come at a considerable cost to the environment. The impacts of climate change are already being felt, and if left unabated, will intensify considerably in the years ahead. Globally integrated production processes have brought many benefits. However, challenges in regulating those processes highlight the need to steer them towards more equitable and sustainable outcomes. As global trends influence food security and the overall sustainability of food and agricultural systems, they give rise to a number of questions. Are today's food and agricultural systems capable of meeting the needs of a global population that is projected to reach more than nine billion by mid-century? Can breeders achieve the required production increases, even if this implies adding pressure to already dwindling land and water resources, and do so in a context of climate change? The future of food and agriculture trends and challenges, tries to answer these questions, laying out and analyzing key global trends that are influencing and will influence food and agriculture in the coming decades, together with the associated challenges to face ahead. The nutrient requirements of human beings include macronutrients (carbohydrates, protein, and fat) and micronutrients (vitamins and minerals). Malnutrition is defined as a deficiency, excess, or imbalance in nutrient intake versus nutrient requirements. Both undernutrition and overnutrition may have serious consequences. Undernutrition during infancy and childhood is widespread in low- and middle-income countries and is most commonly classified as stunting (low height-for-age) or wasting (low weight-for-height). Stunting usually reflects chronic malnutrition and frequent infections while wasting indicates acute significant food shortages and/or diseased status, and is a strong predictor of mortality. About 1 in 5 or 151 million children in the world are stunted, and more than 50 million are wasted. Therefore, animal-sourced foods provide many of the nutrients that are completely lacking (or less bioavailable) in plant-based foods. Animal-sourced foods also provide multiple micronutrients simultaneously. This can be important in the diets of the poor in low- and middle-income countries, which typically lack several nutrients. For example, about one-third of women globally are anemic; the prevalence is greatest in low- and middle-income countries. Vitamin A and riboflavin are both needed for iron mobilization and hemoglobin synthesis; therefore, iron supplementation or fortification alone may not successfully treat anemia if these other nutrients are deficient. Consumption of even small amounts of animal-sourced foods contributes substantially to ensuring dietary quality. In fact, a woman would have to eat about 8 and over 3 times as much spinach as liver and beef to meet her daily iron needs, respectively. Protein-energy malnutrition, iron-deficiency anemia, and vitamin A deficiency can be prevented if enough animal-sourced foods are included in the diet. The foregoing clearly indicates that animal-sourced foods can significantly enhance nutritional quality and reduce malnutrition for vulnerable populations in low- and middle-income countries, especially young children and pregnant and lactating women. Animal-sourced foods are also important in meeting the nutrient needs of those in developed countries and moderate intakes may reduce the high rates of obesity and diabetes due to consumption of “empty” calories based on carbohydrate-dense foods in some of such countries. In conclusion, livestock production contributes to environmental sustainability through conversion of human-unusable energy into highly nutritious animal-sourced foods, thereby contributing to the reduction in organic waste and pollution in the world, but also provide food and nutrition security. However, the potential and actual contribution of various livestock production systems to environmental sustainability varies according to production system. Various nutritional, genetic, management, and health-related strategies exist for reducing the environmental impact of livestock and making them contribute positively to sustainable livelihoods. Livestock contribute directly and indirectly to environmental and economic sustainability via various pathways. Some livestock systems are particularly effective at carbon sequestration and hence reducing greenhouse gas emissions that contribute to global warming. Assessment of the impact of livestock on the environment and livelihood should not focus on single criteria such as greenhouse gas emissions, but should balance ecological, social, and nutritional costs and benefits. Sustainable livestock systems contribute to food security, economic, environmental stewardship, and sociocultural needs and are vital for improving human nutrition, health, and economic productivity.

Potential For Beef Farms to Make Better Use of Grass

2-2: Livestock / Cattle Production Systems

Livestock provide many goods and services to people, such as meat milk, eggs, hides, feathers, fibers, traction and manure. As well as these they serve many social and financial roles in different societies. They may be raised primarily for subsistence or local sales, or may be raised to supply international markets with large quantities of produce. The scale, purpose and nature of the farming enterprise is known as the production system. Ruminant livestock, such as cattle, sheep and goats, tend to be dependent directly on the land. Their production systems therefore are largely determined by agro-ecology and land-use. Production systems for monogastric species such as chickens depend more on consumer demand and the level of capital investment. Livestock play important roles depending on the social, cultural, economic, political, and scientific settings of the geographical regions with human settlements. This part of the book aims to assemble growing literature on the world's livestock production systems to describe their classification, status, trends, driving factors, and other major issues that could have a profound impact. It was suggested that livestock production system is categorized in two main groups of global livestock production systems:

-Solely Based Livestock Production / Intensive animal farming, **industrial livestock production**, **and macro-farms**.

This specifically an approach to animal husbandry designed to maximize production while minimizing costs. To achieve this, agribusinesses keep livestock such as cattle at high stocking densities, at large scale, and using modern machinery, biotechnology, and global trade. The main products of this industry are meat and milk for human consumption. There is a continuing debate over the benefits, risks and ethics of intensive animal farming. The issues include the efficiency of food production, animal welfare, health risks and the environmental impact (e.g. agricultural pollution and climate change). There are also concerns as to whether intensive animal farming is sustainable in the long-run, given its costs in resources. Intensive animal farming is more controversial than local farming and meat consumption in general. Advocates of factory farming claim that factory farming has led to the betterment of housing, nutrition, and disease control over the last twenty years; however, these claims have been debunked. It has been shown that factory farming harms wildlife, the environment, creates health risks, abuses animals, exploits workers (in particular undocumented workers), and raises very severe ethical issues. The most common interactions with cattle involve daily feeding, cleaning and milking. Many routine husbandry practices involve ear tagging, dehorning, loading, medical operations, vaccinations and hoof care, as well as training and sorting for agricultural shows and sales.

-Cropping with livestock farming / Combining Plant and Animal Production

Interactions between system components primarily refer to how context-appropriate combinations of plant and animal production could increase farm-scale productivity and resource-use efficiency. For instance, in a network of 66 beef cattle farms of the Charolais area, organic farmers who grow crops on farms to feed cattle and efficiently exploit the diversity of feed resources had good technical performances (e.g., the highest percentage of calves weaned per cow service), and the lowest GHG emissions and non-renewable energy consumption per hectare. Conversely, conventional mixed crop–livestock farmers that sell both meat and cereals were, on average, less efficient than the specialized grassland-based farmers. This example reveals that farm-scale diversity is not sufficient to increase resource-use efficiency and that interactions between components of APSs are needed. There are some other demonstrations of the benefits of resource diversification on farm self-sufficiency, environmental performance and farm resilience in ruminant systems. In Australia, increasing the length of the alfalfa phase in the rotation decreased the variability in production and ecosystem services value. This is because annual crops display more inter-annual variation in production due to variations in timing and amount of rainfall than perennial pastures. Another farm-scale simulation analyzed the forage autonomy of four dairy farms located on a NW-SE diagonal across France over a succession of 4 years and under varying weather conditions. A change in the variety of and balance between crops and grasslands grown on the farms was shown to promote redundancy in forage resources and to buffer year-to-year variations in forage yields. Crop diversification increased the self-sufficiency for forage and resilience of dairy farms after two unfavorable years, while changing the calving period only had a minor additional effect. There are benefits of grazing cover crops in rotation with cash crops for primary and secondary production and for soil physical, chemical, and biological parameters. However, careful management of grazing intensity is needed as overgrazing can lead to soil deterioration. In organic farms, crop rotations are 15% longer than those in conventional systems and result in higher diversity and more even crop species distributions. These changes are largely driven by a higher abundance of temporary fodders and cover crops. Indeed, several legume or non-legume cover crops have a high nutritive value for ruminants and provide ecosystem services, such as soil fertility and weed control. Some of them also have the potential to decrease GHG emissions by the animals.

Integrated Crop-Livestock System

Furthermore, there are different types of livestock production systems, depending on availability of resources, environmental conditions, and social and economic contexts, and they vary considerably in sustainability. These livestock systems include the grassland-based extensive systems, intensive landless systems, and mixed farming systems among others. These systems contribute significantly to human nutrition and livelihoods and provide important ecosystem services. However, if not properly managed, they can also cause nutrient and environmental pollution and land degradation. Meanwhile, crop-livestock farming is an agricultural production system which combines one or more crops (intended for sale and/or feeding of animals) and at least one type of livestock. Such a system tends towards agroecology when animals are fed by crops and grasslands, which are fertilized in return by their faeces. Therefore, the implications of livestock / cattle Production Systems can be summarized as follows:

- Sustainable livestock systems contribute to food security, economic and environmental stewardship, and sociocultural needs.
- Livestock production contributes to sustainability through use of uncultivable land for food production, conversion of energy and protein sources that cannot be used by humans into highly nutritious animal-sourced food and reduction of environmental pollution with agro-industrial by-products, while generating income and supporting livelihoods of millions of people all over the world.
- Livestock production offers the greatest potential to reduce greenhouse gas emissions from agriculture and animal scientists have devised several effective strategies that can reduce such emissions from livestock systems by up to 30%.
- While livestock systems generally contribute to sustainability, poorly managed livestock systems may have adverse effects on the environment and human and animal health and welfare.

However, the main features of various cattle production systems are based on:

- The economic growth,
- Food preferences,
- The purchasing power of consumer,
- Demographic and land-use changes and
- Technological integration in livestock farming systems.

2-3: Revolutionizing Livestock Farming

Automation and mechanization have streamlined many processes, reducing the need for manual labor and increasing output. Advanced machinery and equipment have improved feeding, milking, and waste management systems, resulting in farmers' higher yields and cost savings. Livestock farming is a crucial industry that provides food, jobs, and economic benefits to people worldwide. According to the Food and Agriculture Organization (FAO), livestock production contributes to around 40% of the global agricultural gross domestic product (GDP). As of 2020, the global meat production reached 335.4 million tons, contributing USD 1,329.1 million to the global economy. With the advancements in digital technology and implementation of automation, the global livestock farming is estimated to grow at a Compound Annual Growth Rate (CAGR) of 10.7% to reach USD 2,445.9 Million by the year 2028. Today, the agri-food system and the livestock sector are facing significant challenges as a result of global changes. Firstly, the increasing population, estimated to reach 9.5 billion by 2050 (UN statistics), is an added pressure to produce more food. This should be achieved despite the worsening conditions of climate change, biodiversity collapse, and reduced availability of resources like soil, fresh water, and other minerals. Secondly, the agriculture sector must swiftly adopt new livestock production systems that respect animal welfare and minimize environmental harm. This should also involve reducing input usage, such as antimicrobials, fertilizers, and pesticides, and making judicious use of natural resources like water, reducing soil compaction, greenhouse gas emissions, and applying biological regulations. The goal for countries and industrial players is to arrive at a multi-objective optimized solution involving the parameters of Animal welfare, Climate impact, and sustainable food production. Automation is looked at as a solution to the complex issues in livestock farming. The use of technologies such as automated feeding systems, robotic milking systems, and drones for animal monitoring is becoming increasingly prevalent. In this article, we will explore the current scenario of livestock farming, impact of automation and digital technologies, the challenges it faces, business case studies of automation in livestock farming, and the future scope of this industry.

2-3-1: Livestock Farming - Current Scenario and Challenges

Traditionally, livestock farming involves raising animals such as cattle, pigs, sheep, and poultry for meat, milk, eggs, and other products. Farmers typically keep their animals in barns or outdoor pastures, where they are fed and cared for by hand. The animals are generally monitored by visual inspection, and their health is assessed by a veterinarian as needed. They also should estimate the environmental impact of their operations, and comply with local, state, and federal regulations related to animal welfare, food safety, and environmental protection. Therefore, before jumping on to how Automation can help the livestock industry and the farmers, let us quickly discuss the critical issues faced by the livestock industry, and what is the need for Automation?

2-3-2: Challenges in the Livestock Industry - The Need for Automation

The use of automation in livestock farming is necessary to address certain practical, on-field challenges faced by the industry, such as:

1. Labor hardships, shortages and efficiency: Farmers are responsible for all aspects of the business, including feeding, watering, and caring for the animals, as well as marketing and selling the products they produce. This often involves long hours of manual labor and can be physically demanding. Also, the shortage of skilled labor is a significant challenge for the industry, particularly in countries such as the US, where labor costs are high.

2. Animal welfare concerns: Monitoring and caring for large herds or flocks of animals can be challenging, particularly when they are spread across a vast area.
3. Disease control: Disease outbreaks can have a devastating impact on livestock farming. Early detection of diseases is crucial to prevent their spread and minimize their impact.
4. Cost of production: The cost of producing and sustaining a livestock farm can be high, including expenses for feed, labor, and equipment.
5. Environmental impact: The livestock industry can have a significant impact on the environment, including water pollution, soil compaction, and greenhouse gas emissions.

With such challenges expected to increase in severity to meet the global food consumption demands, farmers must strive to ensure a balanced investment of time and resources, and find simpler solutions for animal care, business management, and environmental stewardship. Therefore, the need for Digital technologies, and Automation in Livestock farming is paramount, primarily to lessen the farmers burden and to improve the economics.

2-3-3: Automation in Livestock Farming

Automation in livestock can be deployed at various stages starting from breeding, feeding, grazing, housing, health management, reproduction, milking, cleaning and sanitation, slaughtering and processing. One or more of the following strategies can be implemented depending on the farmers' needs or to address a specific need:

- Genetic testing and analysis: This involves using genetic testing and analysis to identify desirable traits and select animals with those traits for breeding. This technology helps farmers produce offspring with better genetics, increasing productivity and profitability. Examples include breeding for livestock with higher mature weights or those less vulnerable to certain health issues.

- Precision livestock monitoring and control: This is a system that involves using Geospatial or motion sensors, integrated with IoT Gateways, and data analytics to monitor animal behavior, grazing patterns, health, and reproduction. This technology allows farmers to make data-driven decisions about the healthy distance of grazing per day, weight of the livestock according to its age to determine if it is underweight or overweight, temperature variations indicating diseases, and to monitor reproduction cycles.
- Reproductive technologies: This includes the use of artificial insemination, embryo transfer, and other reproductive technologies to improve breeding outcomes. These technologies can increase the success rate of breeding and help farmers produce more high-quality offspring.
- Automated feeding systems: These systems use sensors, solenoid valves, and other programmed IoT controllers to precisely control a defined amount and timing of feed to individual animals (or for categorized groups of livestock) based on their nutritional needs. This can help improve growth rates and reduce feed waste, leading to more efficient breeding and genetic outcomes.
- Robotic milking systems: These systems use robotic technology to milk dairy animals, reducing labor costs and increasing milking efficiency. The data collected by the systems can also be used for breeding and genetics decisions.
- Data analytics and Industry 4.0 technologies: This refers to the integration of automation, data analytics, and IoT across the entire livestock farming process. Industry 4.0 technologies can improve health monitoring, identification of diseases, monitoring drinking behaviors, posture analysis, vocalizations, weighing systems, breeding and

genetics outcomes by providing farmers with real-time data and insights to inform decision-making.

- Climate control systems: These use sensors and automation to regulate temperature, humidity, and ventilation in animal housing, providing a more comfortable environment for livestock and improving productivity.
- Automated or Robotic cleaning systems: These use robotics and high-pressure water jet and drain systems to clean animal housing, reducing labor costs and improving sanitation. With defined time controls and solenoid valves, water or cleaning fluids can be used to clean the shelters.
- Robotic slaughter systems: These use robotics and automation to perform humane slaughter of livestock, improving efficiency and reducing labor costs.
- Automated vaccination systems: These use robotics and sensors to administer vaccines to livestock, reducing labor costs and improving vaccination accuracy.

2-4: Selection Criteria of Automated Systems

Most middle and small-scale livestock farmers assume that automation is difficult and a complex process, requiring huge initial investments. But contrary to this belief, automation can be selected, as per the requirements and the problem to be solved. Though integrated smart farm solutions are available, often these may not be the optimal solution for small or medium scale farms. Imagine implementing an automated slaughter system for a farm of 15 cows and 10 pigs! Therefore, there can never be an ‘one size fits all’ automated solution. Therefore, while selecting an appropriate solution, the following parameters need to be considered:

- Objective / problem statement: Specific livestock needs, pain-area of farmer, or the farm

- Compatibility: Type of livestock, existing farm infrastructure and equipment
- Size and capacity: Quantity of livestock end products and number of livestock to monitor
- IoT, RFID Sensors and Data analysis: Number of sensors required. Often motion, temperature, and proximity are used to track and monitor livestock movement
- Software and hardware capabilities: Server capacity, data or parameters to be monitored in real-time (periodic and occasional), integrations with alarm and visual notifications
- IP rating and certifications: Ruggedness, certifications, based on use case, climate and topographic conditions
- Cost: Automated systems can be expensive to purchase and maintain, so it's important to consider the upfront and ongoing costs of the system.
- Ease of use: Complex automated systems may require dedicated manpower to operate and maintain. Selection of easy-to-use interfaces can be considered.

After identifying the extent of automation required in a farm, the following section describes the components used in Smart / automated Livestock farming.

Advantages of Automation in Livestock Farming

The advantages of automation in livestock farming are numerous and can be summarized as follows:

1. Increased productivity: Automation can help to increase productivity by improving the efficiency of livestock farming operations. For example, automated feeding systems can help to ensure that livestock receive the right amount of feed at the right time, which can lead to better growth rates and higher yields.
2. Improved animal welfare: Automation can help to improve animal welfare by providing more consistent care and

reducing stress on the animals. For example, automated systems can monitor the temperature and humidity in barns to ensure that animals are kept in optimal conditions.

3. Reduced labor costs: Automation can help to reduce labor costs by automating repetitive tasks such as feeding, cleaning, and milking. This can free up labor for more skilled tasks and reduce the need for manual labor.
4. Data driven decision making: Automation can help to collect more accurate and comprehensive data on livestock farming operations, which can be used to make better decisions and optimize production processes.
5. Increased food safety: Automation can help to increase food safety by reducing the risk of contamination and improving traceability. For example, automated systems can help to ensure that animals are handled in a safe and sanitary manner during slaughtering and processing.
6. Optimal utilization of resources and Environmental sustainability: Automation can help to improve the efficiency of livestock farming operations by reducing waste, optimizing resource use, and minimizing downtime. This can lead to cost savings and increased profitability. This can enhance environmental sustainability by reducing waste, minimizing the use of resources such as water and energy, and reducing greenhouse gas emissions.
7. Enhanced biosecurity: Automation can help to enhance biosecurity by reducing the risk of disease transmission between animals and between farms. For example, automated systems can monitor and control access to barns and other facilities, and can help to detect and isolate sick animals.
8. Social benefits: Automation can help farmers improve their working conditions and increase their social and economic opportunities.

2-5: Challenges While Implementing Iot & Automation Solutions

Although automation provides several long-term benefits, farmers must overcome particular operation challenges to implement IoT and automation in agriculture, such as:

1. High Initial Investment: The initial cost of setting up the IoT and automation systems can be high for a short ROI, which may be a challenge for farmers with limited financial resources.
2. Technical Expertise: Implementing and operating IoT and automation solutions require technical knowledge and expertise, which may not be available to all farmers.
3. Dependence on technology: Over-reliance on technology can be a risk, as system failures can lead to significant losses in productivity and revenue.
4. Maintenance and Repair: IoT devices and automation systems require regular maintenance and repair to ensure optimal performance, which can be a challenge for farmers who may not have the necessary skills or resources.
5. Ease of operation and dependence on technology: Over-reliance on technology can be a risk, as system failures can lead to significant losses in productivity and revenue.

2-6: The Dynamics of Livestock Production Systems

This text analyses the key drivers of change in the global livestock sector and assesses how they are influencing current trends and future prospects in the world's diverse livestock production systems and market chains; and what are their consequent impacts on the management of animal genetic resources for food and agriculture. The trends are occurring in both developing and industrialized countries, but the responses are different. In the developing world, the trends are affecting the ability of livestock to contribute to improving livelihoods and reducing poverty as well as the use of natural resources. In the industrialized world, the narrowing animal genetic resource base in industrial livestock production systems raises the need to maintain a broader range of animal genetic resources to be able to deal with future uncertainties, such as climate change and zoonotic diseases. Therefore, this text discusses:

• What are the global drivers of change for livestock systems? Economic development and globalization; changing market demands and the "livestock revolution"; environmental impacts including climate change; and science and technology trends.

• How are the livestock production systems responding to the global drivers of change? Trends in the three main livestock production systems (industrial, crop-livestock and pastoral systems); the range and rate of changes occurring in different systems and how these affect animal genetic resources. The implications are that breeds cannot adapt in time to meet new circumstances. Hence new strategies and interventions are necessary to improve the management of animal genetic resources in situations where these genetic resources are most at risk.

• What are the implications for animal genetic resources diversity and for future prospects of their use. Industrial livestock production systems are expected to have a limited demand for biodiversity, while crop-livestock and pastoral systems will rely on biodiversity to produce genotypes of improved productivity under changing environmental and socio-economic conditions. All systems will rely on biodiversity, albeit to varying degrees, to cope with expected climate change.

• What immediate steps are possible to improve animal genetic resources characterization, use and conservation? Appropriate institutional and policy frameworks are required to improve animal genetic resources management and these issues are being addressed at national and intergovernmental levels, in a process led by FAO to promote greater international collaboration on animal genetic resources. Based on an analysis of the current situation, the continuing loss of indigenous breeds and new developments in science and technology, there are several complementary actions that can begin to improve the management of animal genetic resources and maintain future options in an uncertain world.

2-7: Economic Impacts of Sustainable Livestock Systems

Livestock products (meat, milk, and eggs) are among the top 10 globally traded commodities with a value of US $6.5 million. Livestock generate income for farmers of all categories via sale of animals and livestock products. In low- and middle-income countries, millions of farmers keep livestock as a status symbol, with more indicating greater status or as insurance against emergencies and sell them to meet cash needs; the animals are commonly referred to as a “savings bank on hooves”. Livestock also provide opportunities to capitalize on underutilized family labor. As the income from livestock is less seasonal (compared with crops), farmers, particularly women, depend on these animals as a vital source of income for household essentials, including payment of school fees and medical expenses. Livestock also serve to empower women who have important and varied roles in raising them in many low- and middle-income countries. The manure and draft power from livestock represent assets that can be used or sold as fuel for cooking or heating or building materials, or exchanged for needed commodities, respectively. Furthermore, income from livestock allows farmers to make better dietary and health choices and provide the necessary resources to pay for medical care.

According to the International Labor Organization, the livestock sector is an integral part of agriculture, which contributes 60% to 70% of total employment in low- and middle-income countries, mainly in Africa and Asia. The jobs in the sector are not limited to just farm production but extend to include aggregation, processing/value addition, distribution, transportation, food storage, retailing, food marketing. Studies in Bangladesh and India have shown that raw milk collection and distribution creates 20 to 40 full time jobs per 1,000 liters of milk traded. Milk processing generates another 60 to 100 jobs per 1,000 liters of processed milk with around 15% of the traded milk being processed, leading to around 32 additional full-time jobs per 1,000 liters of marketed milk. It is to be noted that few comprehensive studies are currently available on the aggregate direct and indirect employment generation and socio-economic impacts of the livestock sector in low- and middle-income countries at the country or regional level.

2-8: Incorporating Diversity into Animal Production Systems Can Increase Their Performance and Strengthen Their Resilience

Animal production systems (APSs) have long been transformed through intensification, specialization and geographical concentration, leading them to become major anthropogenic drivers of pollution, climate change, and biodiversity loss. Agroecology, organic farming and sustainable intensification have been proposed as alternative models to invert those trends. Diversity is highly valued in agroecology and organic farming, in which it is assumed not only to increase farm performance but also to strengthen farm resilience. The question is how the diversity of system components and interactions among these components can increase productivity, resource-use efficiency and farm resilience in ruminant systems. In doing so, research revealed that the same processes can occur in very different systems. For instance, the higher performance of multi-species ruminant grazing systems results from (i) the complementary feeding habits of animal species that exploit resources from different ecological niches more efficiently; and (ii) facilitation or competitive exclusion, which results in a species increasing or decreasing resource availability for another species.

The benefits of diversity are observed not only in relatively extensive systems but also in intensive indoor systems. For instance, genetic diversity is associated with herd and social immunity in animal production, while trade-offs between life functions play a major role in dairy herd performance. The livestock sector has received particular attention in the news and scientific media and is considered a major anthropogenic driver of climate change, water pollution, and biodiversity losses. Although the best transition options are still strongly debated, there is a consensus on the need for animal production systems (APSs) to reduce the use of inputs, to emit less greenhouse gasses (GHG) and to increase their mitigation potential, e.g., through carbon sequestration in grassland and crop soils. Over the past 60 years, APSs have been primarily transformed through the top-down structuring of linear value chains, intensification, specialization and geographical concentration. When intensification and specialization were the two primary drivers of APSs, the focus was primarily on short-term efficiency to make the best use of high-yielding breeds and cultivars under optimal production conditions. Intensification led to a dramatic reduction in within-system diversity, i.e., the diversity of animal species and breeds, the genetic diversity within breeds, the diversity of feed resources, and even the diversity of management practices. Recently, the methods for analyzing system sustainability have increasingly accounted for a wider perspective on the functions and services livestock farming systems provide to society. A number of these functions and ecosystem services (recycling of nutrients, forage yield, pollination, etc.) are closely linked to agrobiodiversity, and their persistence depends largely on maintaining biological diversity in APSs. Sustainable intensification of tropical forage-based systems is likely to increase their productivity, while saving land from further deforestation. Incorporating diversity in these systems mainly relies on the integration of forage leys into cropping systems to enhance the coupling of carbon and nitrogen cycles within grasslands and soils, while minimizing environmental losses toward the atmosphere and hydrosphere.

Beyond this, the value of diversity in agroecological or organic farming systems is based on the need to fortify their internal capacity to face perturbations because these systems are not secured with external inputs (e.g., concentrated feed and veterinary products) as they are in conventional systems. For instance, individual response variability and interactions among system components could enhance the long-term herd and system performances. In addition, rearing different species in a pastoral system could be seen as a risk-spreading strategy against disease outbreaks, feed shortages and market price fluctuations. Within-farm diversity is thus assumed to affect not only the system's productive yield but also its stability and ability to cope with uncertainty. Therefore, the primary outcome related to an increase in system diversity may be an increase in system resilience.

There has been an important research effort to determine how multispecies grasslands could benefit sward productivity, animal performance, and farm fodder autonomy and resilience in grassland-based systems. Research revealed that mixtures of species produce an average of 1.7 times more biomass than that of species monocultures. These authors also showed that the contribution of biological processes involving multiple species equals or exceeds the contribution of the most productive species, with an increase over time. The intrinsic individual variability in animals within a herd or a flock is a source of diversity, which has a key role in the production process and may also have positive effects on system resilience. Such positive effects are grounded in the diversity of the trade-offs between life functions that induce specific adaptive responses of animals to suboptimal environments. For instance, a multi-trait and dynamic method was proposed by some researchers to describe the trade-offs between life functions in dairy cows. These researchers used phenotypic traits during the first 13 weeks postpartum, when dairy cows experience a negative energy balance, and distinguished four trade-off profiles independently of the cattle breed (i.e., Holstein, Montbéliarde and Normande) and cow age (parity order). Profile one (n = 53 cows) corresponded to high yielding cows [average weekly milk yield (AMY): 487 kg]. These animals mobilized much of their body reserves to sustain their milk yield at the expense of fertility [the pregnancy rate (PR) during current lactation was 64%]. The three other profiles corresponded to cows with a lower milk yield and contrasted reproduction performance. Cows in profile two (n = 111; AMY: 320 kg) mobilized body reserves but were able to maintain an acceptable PR at 71%. Profile three (n = 67; AMY: 331 kg) corresponded to cows with a low body condition and high body reserve mobilization resulting in very thin animals at the start of the breeding period. Their fertility was thus very low (PR: 30%). Profile four (n = 103; AMY: 331 kg) corresponded to cows with the most stable body condition score and the best fertility among all the profiles (PR: 92%). Each profile was linked to a specific adaptive response by the daily milk yield to perturbation, cows with profiles 2 and 4 showing no fluctuation. At herd level, the diversity of trade-offs and adaptive response of animals is assumed to buffer the effect of random environmental perturbations in the long term. This assumption was tested, where simulated the annual milk yield produced by dairy herds composed of cows with either a single or different types of theoretical adaptive profiles (the ability to cope with feed shortages, heat stress or diseases). One simulated perturbation occurred every 3 years over a 50-year period and it was randomly related to either feed availability, heat or diseases. Simulation runs were repeated 50 times to account for the random effect of perturbation sequences. After 50-years, the results showed that while the annual milk yield was very stable across groups, the inter-annual variability was 25% less in the herd composed of cows with diverse adaptive profiles.

2-9: Livestock / Cattle Farming Systems *in Iraq*

Native breeds of cattle are well adapted to local environment (high ambient temperature up to 50º c during summer and low ambient temperature, down to –10º c during winter, poor farming hygiene and deficient diets). Furthermore, the products of these native breeds are of high quality (good taste and flavor) as compared with products of exotic breeds. The main native (local) cattle breeds are the Jenubi, Karadi, Sharabi and Rustagi. It was reported that local cattle are genetically resistant to endemic diseases (especially theileriosis) and harsh environment (wide range of ambient temperature and low quantity of feed and water). Most cattle and buffaloes are found in and around the irrigated areas. At late forties and later until 1988 many exotic breeds were imported (Friesian, Currency, Ayrshire, Jersey, Brown Swiss, Sindi, Simental, Normandy, Tarentes, Abundance, Holstein, Herford, Charolais. Brahman). Traces of genes of these breeds is encountered here and there through crossing with local breeds. Though all these exotic breeds (as purebreds) suffered severely from acclimatization problems. Holstein-Friesian crossbred cattle were more tolerant to local environmental condition and was enjoying a fair rate of demand by breeders in Iraq. The AI service was planned during seventies to produce Holstein-Friesian × local cattle crossbred. Holstein frozen semen was imported from USA and West Europe to upgrade both Holstein-Friesian purebred as well as the Holstein-Friesian × local cattle crossbred. Selection and genetic evaluation using Animal Model technique was applied on Friesian and Holstein breeds, where there is recording system in the large-scale commercial farms. Screening young bulls was practiced in 2001 and 2002. Performance test was conducted on a number of young bulls. Superior young bulls based on the performance test (feed efficiency and growth rate) were selected and dispatched at AI center in Abu-Ghraib for semen collection and evaluation. Semen of Holstein or Friesian breeds are disseminated to grade-up local breeds. Most large-scale commercial farms with Friesian breed nowadays inseminating their breed with Holstein semen. It is worthwhile to mention that no selection was practiced on local cattle as the herder has 2-4 cows (household), which make it unpractical to carry out selection. In conclusion, there is not sustainable long run breeding plan. However, some tools of breeding program are in operation. AI is mainly used in cattle to produce crossbreds (Friesian or Holstein × local) to improve milk production and growth rate. Recording is practiced in the large scale-commercial dairy farms (about 10 farms, with a total of 20000 cows). No embryo transfer is carried out. The livestock sector has a special importance to the Iraqi economy. It plays a fundamental role in the gross domestic product as well as in supplying foodstuffs for the people, and that livestock contributed to one fifth of the gross domestic product in agriculture. It is estimated that Iraq has a population of 8.981 million sheep, 1.476 million goats, 1.578 million dairy cattle (70 % indigenous of the Zebu type, 5 % Holstein – Friesian and 20 % of crossbred) and 141 thousand buffaloes as well as few thousands of others livestock. The available animal protein per capita was (18 g) per capita / day, which is below to the figure recommended by WHO. The population estimate of Iraq is 41 million. Average population growth rate is about 2.3%. It is estimated that Iraq currently produces 1.4 million MT of milk, 100 thousand MT of red meat per year. Furthermore, the estimated annual per capita consumption of milk and red meat are around 40 kg and 6 kg, respectively. It can be concluded that although the livestock population is relatively numerous, its production potential is very low. This could be due to severe climatic condition, feed shortage, poor genetic make-up for production and several other factors. Insufficiency in all animal products is a trend accompanied the production in livestock sector. Demand which is always higher than supply of animal products caused importation of some strategic animal products. Moreover, livestock production systems generally lag behind crop production ones in terms of development, standards of management and husbandry and mechanization. Traditionally, crop farming and livestock production are carried out as separate activities, proper mixed farming is rare. Livestock feeding generally depends on natural pastures (range land) and crop residues. Forage is produced in only very limited scale. The total area of Iraq is 43.5 million ha in which about 102 thousand ha (0.3 %) covered by water. Total arable land is 12 million ha, in which 50.2 % falls under irrigation and 49.8 % under rain fed area. The permanent pasture estimated to be about 17 million ha. Livestock production systems operated in Iraq are:

The Intensive System: This system is characterized by some modern methodologies that allow intensification. It is usually practiced in most of the large- scale projects, especially dairy cattle state-built projects and some other private enterprises. The introduction and usage of new technologies is usually expanding continuously. Fodder is mostly locally produced and supplemented with bought concentrate according to nutritional requirements. The standards of hygiene, management, pest and disease control are of a quality that allowed better productivity in comparison with other production systems. Moreover, under this system, mixed farming or an integrated crop / livestock production is also practiced on limited scale. This system is characterized by high-capital and high inputs. There is no noticeable change toward an increase in implementation of high-input systems in cattle / livestock sector due to discouraging input-output pricing policy, which is not meet requirements of producers.

The Semi-Intensive System: Farmers usually keep 15-20 crossbred cattle for commercial milk production. Fodder is mostly locally produced and may supplemented with concentrates or wheat bran several hundred farmers are practiced mixed farming or integrated crop / livestock production under this system. This system is familiar in central Iraq and around big cities. This system is characterized by low-capital and medium inputs.

The Household System: Under this system, sheep and goats are kept around the houses by most farmers, in all over the country, to produce milk mainly for family use. Cattle are also kept for the same purpose, but in very limited numbers (2-5 heads per family). This system is usually practiced in the villages; it also exists in towns and cities, but on a limited scale. In this system, farmers usually keep 2-5 cows of local or crossbred with Friesian and 10-40 sheep and goat. Moreover, turkey, duck, geese and local chicken may raise in the backyard. Animals are usually kept in enclosures round the family living area; feed is purchased sometimes supplemented by occasional browsing and grazing where available. Productivity of animals under this system is extremely low and the overall standards and measures of management, hygiene, disease and pest control are far below satisfactory. This system is characterized by low-capital and minimum inputs.

Fattening System: This covers fattening of lambs and calves for meat production. Lambs of 4-5 months (after weaning), weighing 15-20 kg, that are produced (under traditional system) bought and are fattened for few months to reach a slaughter weight of about 40 kg. In case of fattening local calves, they are usually bought at weaning age of about 6 months from rural farms, are fattened to 200 kg. While calves bought from large-scale farms (under intensive system) usually at their first week of age fattened to about 250 kg. Fattening diets are usually of high energy concentrate based on barley. Fattening usually takes place in feed lots. Most people, practicing this production system, do not possess their own flocks but they rely on getting lambs and calves from the local market. This operation is characterized by low capital and medium inputs.

Traditional System: The operation of this system takes place under sedentary, transhumant and nomadic system. In the nomadic and transhumant, flocks of sheep and goats, sometimes even few cows, are grazed extensively on natural vegetation. Some transhumant make use of crop residues available in the nearby cropping area. Supplementary feeding is virtually unknown and the animals suffer under nutrition during the dry season. The movement of the majority of flocks in the transhumant system is restricted to closed zones compared to the wide range movement of the nomadic flocks where they cover long distance following the availability of pasture and water according to seasons. In the sedentary system, livestock and crop production is combined but not integrated. The main sources of animal feeds are stubble and crop residues supplemented with roughages of cultivated land where some flocks have an access for forage crops, included in the rotation program. In this system the practice of keeping cattle for milk production is noticeable. The traditional system covers 90 % of sheep and goat production in Iraq. Steppe and grazing areas utilized by this system are very arid or semi-arid where rainfall is unpredictable and scarce and only during winter. Such areas are not suitable for other agricultural purpose. This system is characterized by low-capital and minimum inputs.

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Chapter 3

Key Issues in
Milk Production and Growth of Cattle

Key Issues in Milk Production and Growth of Cattle

3-1: Outlook on Milk Production

Continuous selection in dairy breeds toward higher milk yield along with improvements in management, housing, feeding, and veterinary care resulted in high-yielding dairy cows with individuals producing more than 35,000 kg of milk per year. Worldwide, yearly milk production in dairy cows increases almost linearly since many decades. In the last three decades, world milk production has increased by more than 77 percent, from 524 million tons in 1992 to 930 million tons in 2022. India is the world's largest milk producer, with 22 percent of global production, followed by the United States of America, Pakistan, China and Brazil. Since the 1970s, most of the expansion in milk production has been in South Asia, which is the main driver of milk production growth in the developing world. Approximately 150 million households around the globe are engaged in milk production. In most developing countries, milk is produced by smallholders, and milk production contributes to household livelihoods, food security and nutrition. Milk provides relatively quick returns for small-scale producers and is an important source of cash income. In recent decades, developing countries have increased their share in global dairy production. This growth is mostly the result of an increase in numbers of producing animals rather than a rise in productivity per head. In many developing countries, dairy productivity is constrained by poor-quality feed resources, diseases, limited access to markets and services (e.g., health, credit and training) and dairy animals' low genetic potential for milk production. Unlike developed countries, many developing countries have hot and/or humid climates that are unfavorable for dairying. Some countries in the developing world have a long tradition of milk production, and milk or its products have an important role in the diet. Other countries have established significant dairy production only recently. Most of the former countries are located in the Mediterranean and Near East, the Indian subcontinent, the savannah regions of West Africa, the highlands of East Africa and parts of South and Central America. Countries without a long tradition of dairy production are in Southeast Asia (including China) and tropical regions with high ambient temperatures and/or humidity. The per capita consumption of milk and milk products is higher in developed countries, but the gap with many developing countries is narrowing. Demand for milk and milk products in developing countries is growing with rising incomes, population growth, urbanization and changes in diets. This trend is pronounced in East and Southeast Asia, particularly in highly populated countries such as China, Indonesia and Viet Nam. The growing demand for milk and milk products offers a good opportunity for producers (and other actors in the dairy chain) in high-potential, peri-urban areas to enhance their livelihoods through increased production. By volume, liquid milk is the most consumed dairy product throughout the developing world. Traditionally, demand is for liquid milk in urban centers and fermented milk in rural areas, but processed products are becoming increasingly important in many countries. More than 6 billion people worldwide consume milk and milk products; the majority of these people live in developing countries. Since the early 1960s, per capita milk consumption in developing countries has increased almost twofold. However, the consumption of milk has grown more slowly than that of other livestock products; meat consumption has more than tripled and egg consumption has increased fivefold. Over the last two decades, per capita milk consumption decreased in sub-Saharan Africa.

It is worth wise to mention that:

1) Per capita milk supply is:

* High (> 150 kg/capita/year) in Argentina, Armenia, Australia, Costa Rica, Europe, Israel, Kyrgyzstan, Mongolia and North America;

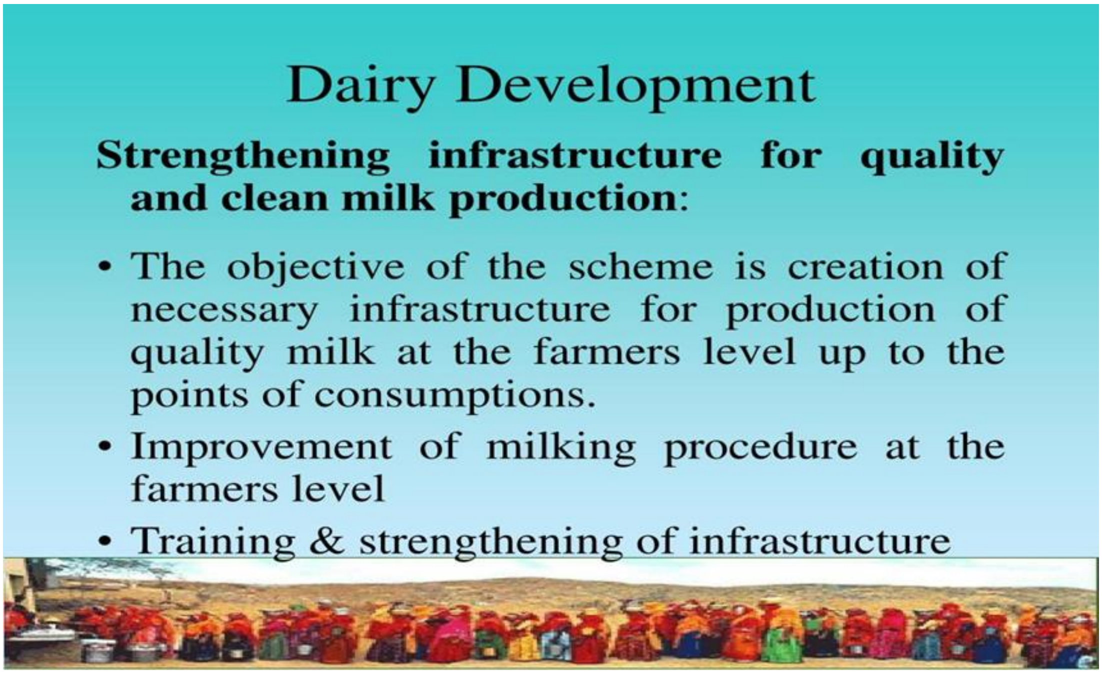
* Medium (30 to 150 kg/capita/year) in India, Japan, Kenya, Mexico, New Zealand, Pakistan, North and Southern Africa, most of the Near East and most of Latin America and the Caribbean;

* Low (< 30 kg/capita/year) in Islamic Republic of Iran, Senegal, Thailand, most of Central Africa and most of East and Southeast Asia.

2) Milk provides 3 to 4 percent of dietary energy supply in Africa and Asia, compared with 11 to 8 percent in Europe and Oceania; 5 to 8 percent of dietary protein supply in Africa and Asia, compared with 20 percent in Europe; and 6 to 9 percent of dietary fat supply in Africa and Asia, compared with 12 to 16 percent in Europe, Oceania and the Americas.

3) Dairy development is a sustainable, equitable and powerful tool for achieving economic growth, food security and poverty reduction because dairying:

- provides a regular source of income;
- provides nutritious food;
- diversifies risk;
- improves the use of resources;
- generates on- and off-farm employment;
- creates opportunities for women (e.g., milk money);
- provides financial stability and social standing (e.g., store savings, asset creation).



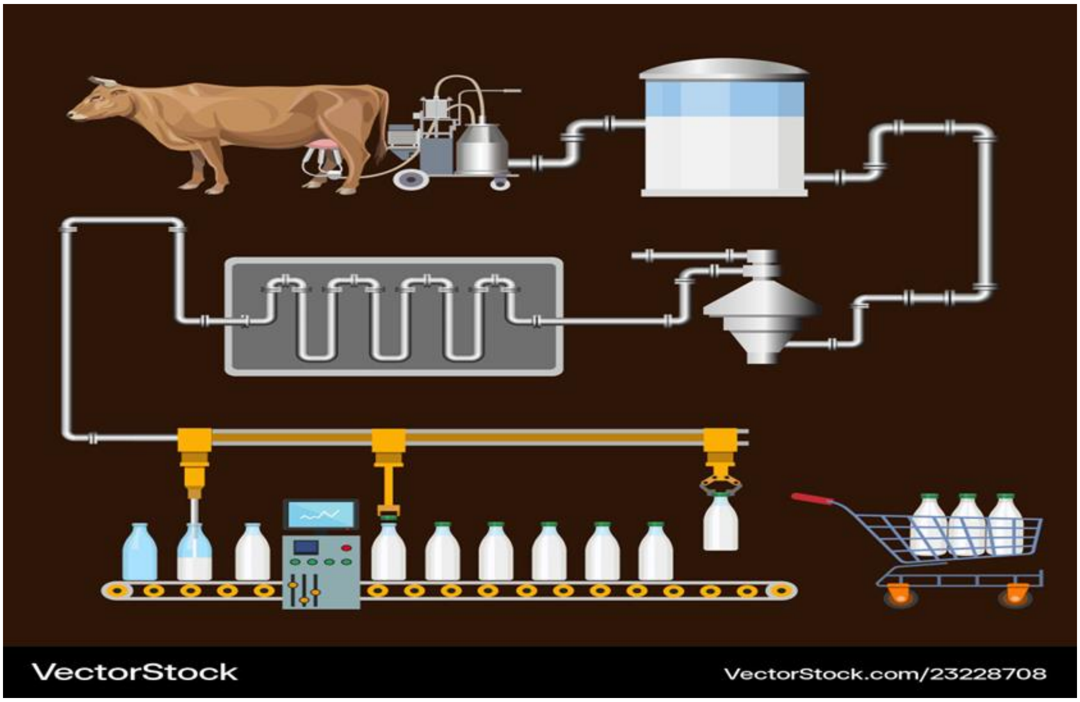
4) Factors that drive dairy development include changes in demand; advances in production, transportation and communication technology; improved on-farm productivity; and more efficient dairy chains. To achieve sustainable smallholder dairy development, it is vital to form active producer associations and establish reliable dairy chains (it is important to create value in every activity of the dairy chain). The success of dairy development programs in developing countries is largely influenced by traditional dairy consumption habits.

5) In many developing countries, dairy development is constrained by refrigeration, marketing, processing, transportation, nutritional and husbandry issues. In addition, small-scale dairy producers lack the skills to manage their farms as enterprises; have poor access to services such as health, breeding, training and credit; have little or no capital for investment; and are thwarted by small herd/flock sizes, low milk yields and poor milk quality.

6) The development of the dairy sector generally results in an increased workload for women, but it also increases women's participation in income-generating activities and the process of change. Dairy development can also contribute to reducing the time women spend in low-productive activities. For example, with better organization of milk collection and marketing, women can be released from selling small quantities of surplus milk in the informal market.

7) Milk is a valuable nutritious food that has a short shelf-life and requires careful handling. Milk is highly perishable because it is an excellent medium for the growth of microorganisms – particularly bacterial pathogens – that can cause spoilage and diseases in consumers. Milk processing allows the preservation of milk for days, weeks or months and helps to reduce food-borne illness. The usable life of milk can be extended for several days through techniques such as cooling (which is the factor most likely to influence the quality of raw milk) or fermentation. Pasteurization is a heat treatment process that extends the usable life of milk and reduces the numbers of possible pathogenic microorganisms to levels at which they do not represent a significant health hazard. Milk can be processed further to convert it into high-value, concentrated and easily transportable dairy products with long shelf-lives, such as butter, cheese and ghee.

Processing of dairy products gives small-scale dairy producers higher cash incomes than selling raw milk and offers better opportunities to reach regional and urban markets. Milk processing can also help to deal with seasonal fluctuations in milk supply. The transformation of raw milk into processed milk and products can benefit entire communities by generating off-farm jobs in milk collection, transportation, processing and marketing.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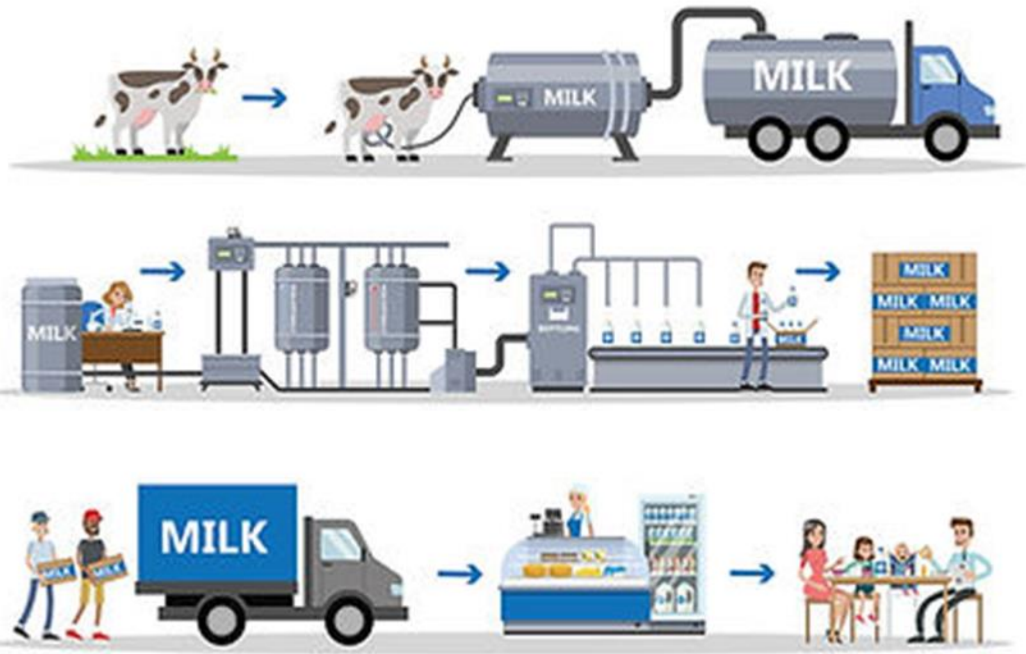
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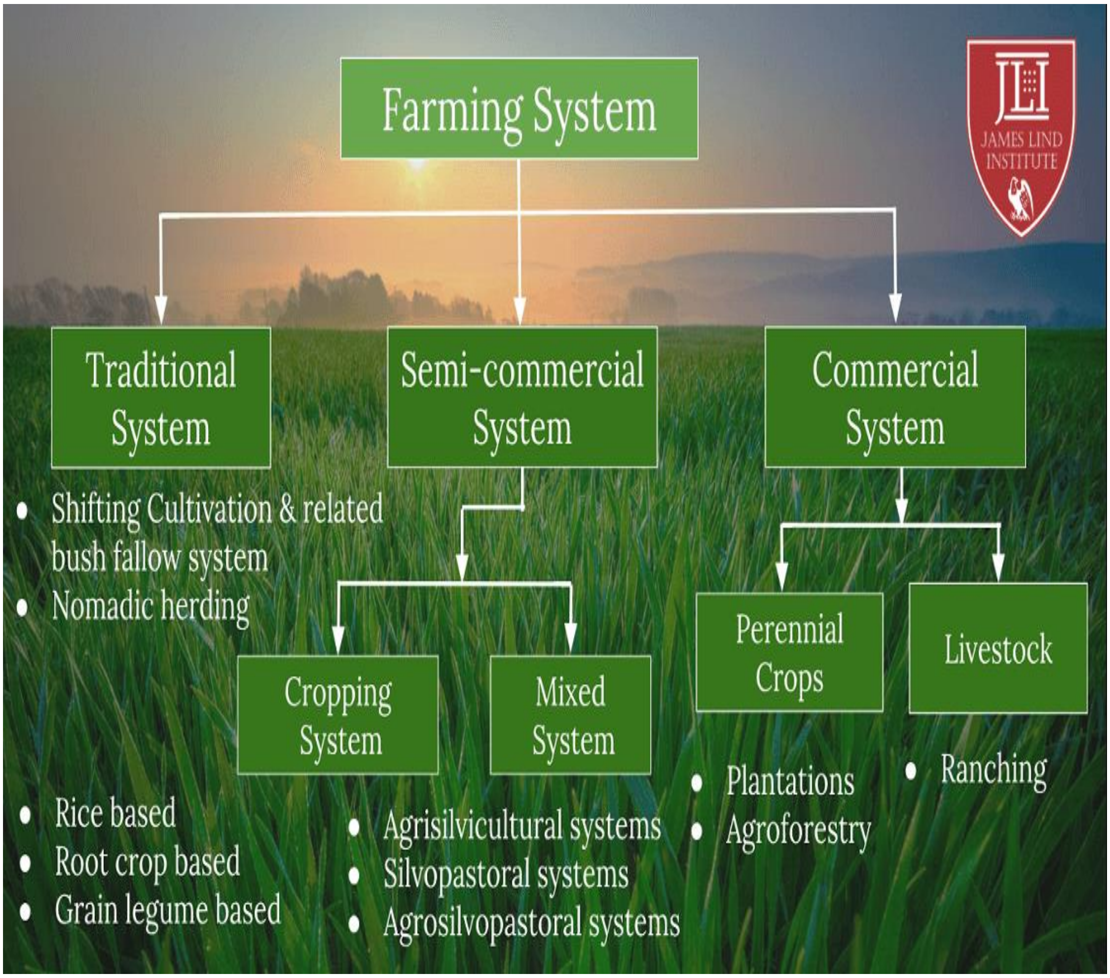
8) An estimated 80 to 90 percent of milk in developing countries is produced in small-scale farming systems. These operations are based on low inputs, so production per dairy animal is quite low. Most milk produced by smallholders in developing countries comes from one of the following production systems:



- Rural smallholder dairying: Dairying is often part of a mixed farming system in which manure is used for cash crop production. Dairy animals are fed on grass, crop residues and cultivated fodder. Supplementary feeding is practiced only when feasible.

- Pastoral/agropastoral dairying: These systems are land-based and milk is often the most important subsistence item. Dairy production is generally associated with cropping, but nomadic pastoralists practice little or no agriculture and roam the land in search of grazing grounds and water.

- Landless peri-urban dairying: This is a purely market-oriented production system located within and close to the boundaries of cities. Peri-urban dairy producers benefit from their closeness to markets, but their production is based on purchased inputs and may encounter problems of feed supply and waste disposal. In recent decades, a peri-urban dairy sector has developed very rapidly around the larger cities of many developing countries, in response to expanding market demand. The concentration of milk production in close proximity to urban centres may threaten human health.

In addition to these traditional small-scale milk production systems, some developing countries have large-scale dairy enterprises. Generally, large-scale producers do not account for a large share of national milk production.

- Mixed farming systems are those in which either more than 10 percent of the dry matter fed to animals comes from crop by-products or stubble, or more than 10 percent of the total value of production comes from non-livestock farming activities. It is estimated that more than 90 percent of the world's milk supply is produced in mixed farming systems. In Africa and Asia, milk is generally produced in mixed farming systems with fewer than five cows. In South America, milk producers generally raise at least ten cattle with a dual-purpose function (meat and milk). In developing countries, up to one-third of milk is produced in urban and peri-urban areas.

- Milk production is a function of the number and activity of secretory epithelial cells, where potential limiting factors may exert direct and indirect effects. The essential role of glucose and amino acids (AA) with regard to milk production is well recognized. However, how much milk can a dairy cow produce? Where are the physiological limits? These and similar questions did not arise recently, but already much earlier, when the scientific picture of the relationships between endocrine and metabolic processes and lactation outcome became more comprehensive. Already researchers discussed if the cows' genetic capacity for milk production was reached and if further increases of milk yield would provoke the antagonism to fitness traits. Now, almost 40 years later, average milk production per cow more than doubled in many countries, and nowadays, performance level pushes us to investigate the issue when the overall capacity of the lactating dairy cow would be finally reached. Moreover, many dairy cows are suffering from health disorders that are primarily attributed to the high-performance level and associated failures of metabolic and immunological adaptation, although the relationship between the occurrence of the so-called production diseases and high milk yield is not definitely clarified. The awareness and a deeper knowledge about physiological constraints may help to further improve animal health and produce milk more efficient and sustainable.

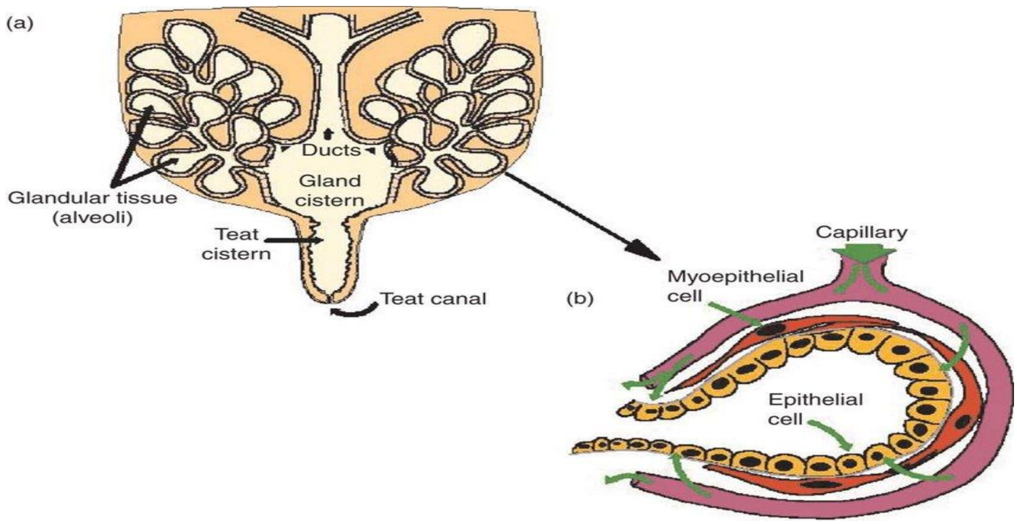
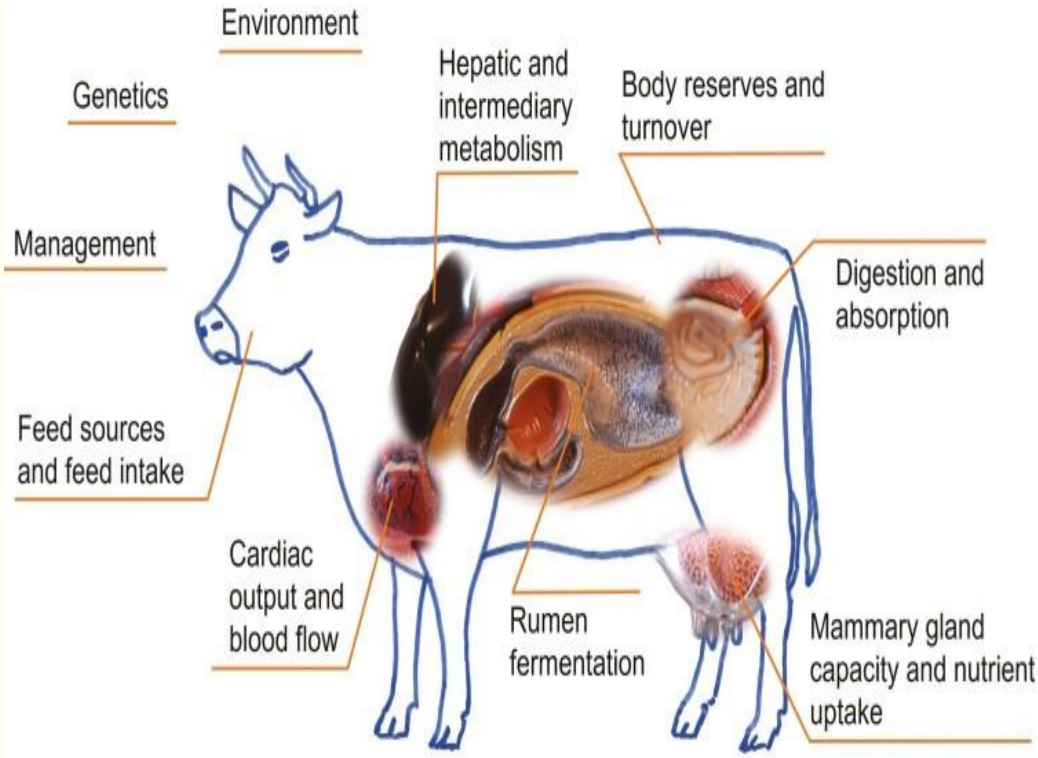
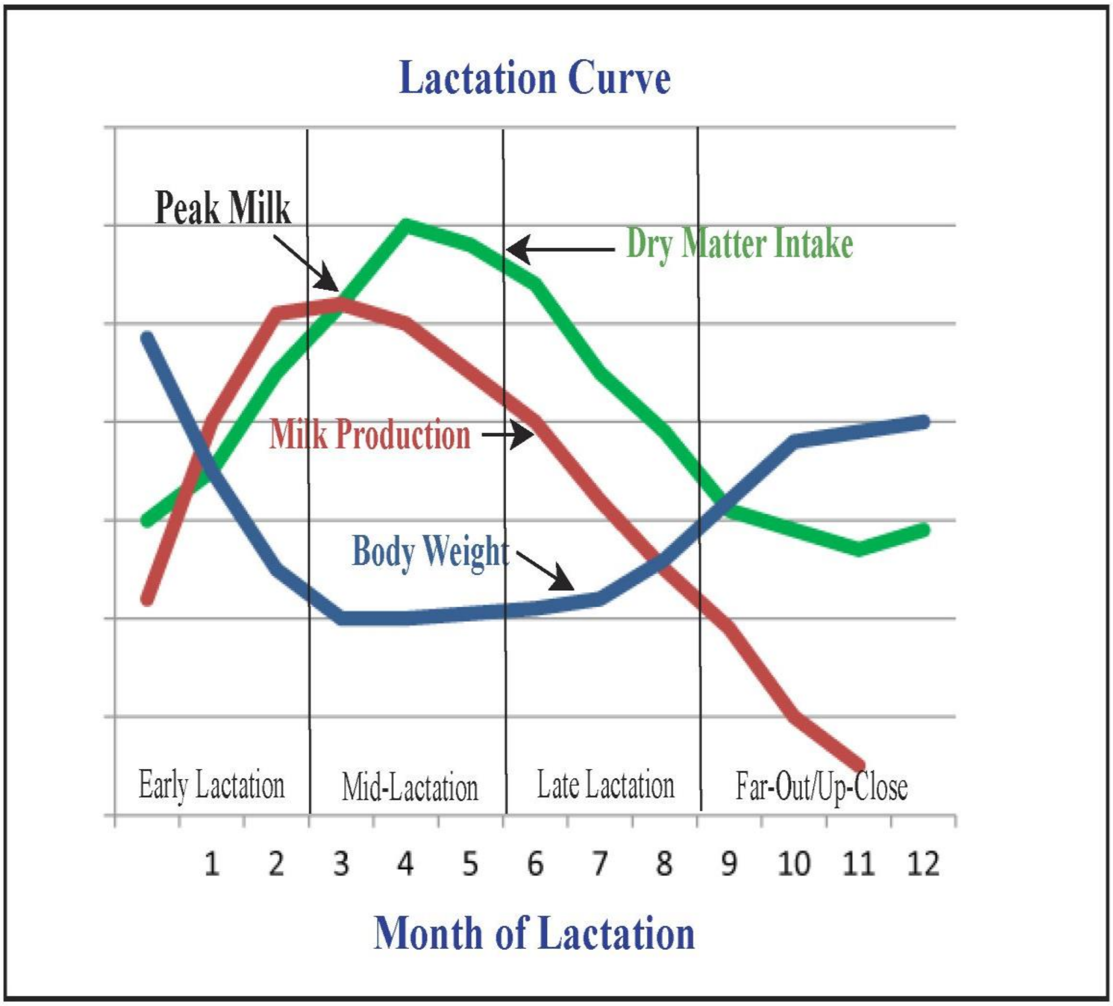


Diagram of a mammary quarter illustrating the glandular tissue alveoli

The scope of this text is to give in short, an overview on various factors that are presently considered limiting milk production in dairy cows from a physiological perspective. The question how much milk a cow can actually produce cannot be answered here. Depending on the stage of lactation, the focus is set on factors that are currently considered as physiological and nutritional boundaries for milk production in general with respect to further negative impacts on animal health, reproductive performance, and environment. Besides these physiological constraints, selected exogenous environmental and management-related factors affecting animal performance and physiology are factors imposing limitations to milk production in dairy cows. Potential solutions and strategies to overcome or to alleviate physiological constraints can only be presented briefly in passing and are thought to address existing shortcomings and to identify possibilities for optimization. The implementation of targeted measures related to physiological limits, however, shall not primarily pursue the aim of further pushing milk production, though positive effects are very likely along with improvements of animal health, reproductive performance, etc. Despite a scientific-based view on physiological limits, we should keep in mind that only healthy animals feeling comfortable could use their genetic capacity and produce high amounts of milk.



Factors related to limitations of milk production in dairy cows.



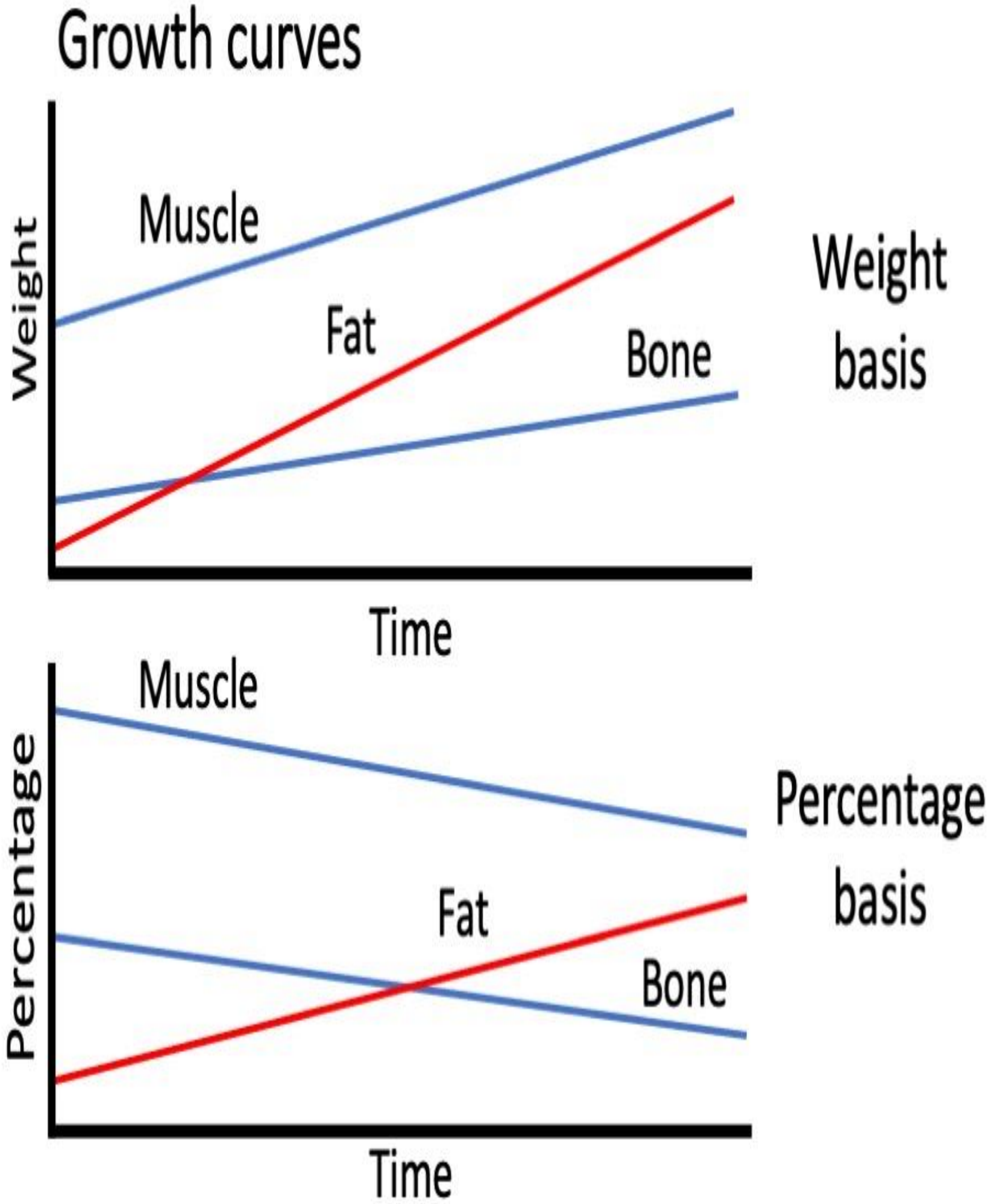
Milk Secretion: Absorbed and de novo synthesized nutrients are transported and distributed via the blood stream to the target tissues including the mammary gland. Besides concentrations of substrates in blood, the mammary blood flow determines the supply of the mammary gland. It is noteworthy that cardiac output and blood flow are not constant throughout the lactation–gestation cycle. Substantial increases in both mammary blood flow and cardiac output were observed about the time of parturition affecting the exchange of nutrients across the capillaries into the mammary gland for the subsequent synthesis of milk components. In addition, vascularization of the mammary gland increases during pregnancy. Although the endocrine mechanisms involved in vascularization and blood flow are out of the scope of the present review, the use of bovine somatotropin is of practical relevance as it increases both cardiac output and mammary blood flow accompanied by an increase of milk production. However, an elevated mammary blood flow does not causally increase daily milk yield. Many other limiting factors as partly outlined here must be taken into account. As pointed out, the rate of nutrient transport into the mammary epithelial cells rather than delivery to the cells may be another rate-limiting step for milk production. Experimental data showed that elevated glucose concentrations in plasma did not linearly increase glucose entry rate into the mammary gland. There are a number of specific transport systems enabling the uptake of AAs, glucose, or FAs into the mammary gland. Besides substrate availability, also kinetics and endocrine regulation of transporters depending on the physiological stage of the cow must be assumed to be limiting for milk synthesis. For instance, glucose transporters express a differential sensitivity toward endocrine mediators such as insulin manifesting in, for example, insulin-dependent and insulin-independent representatives. Furthermore, their expression within a certain tissue such as the mammary gland or AT changes with the lactational stage of the cow. Consequently, overall tissue responsiveness and glucose utilization can be regulated and adjusted to the current needs and substrate availability. Given the enormous differences in dairy cow feeding, housing, and management conditions, it is hardly possible to determine the maximum genetic capacity for yearly milk production of dairy cows. Cows of breeds intensively selected toward milk production such as Holsteins are likely to produce more milk than dual-purpose or beef cows, although long-term selection of strains within a breed kept under different environmental conditions may result in a divergent lactational performance. Moreover, a considerable variation of metabolic adaptation to identical feeding and management conditions exists among animals within a herd although selection targets were identical. Therefore, it is not surprising that metabolic stress is not necessarily related to the overall lifetime performance. Obviously, there is no negative relationship between increased yearly milk production, disease occurrence, and culling, although culling risk increases in high-yielding dairy cows with a greater likelihood to develop health disorders. Higher milk yields are undoubtedly more demanding in terms of dairy cow nutrition and management. Furthermore, a greater milk production is associated with a greater metabolic load particularly in early lactation, which increases the risk and susceptibility toward different production diseases. Moreover, management of dairy cows exerts significant constraints on milk production. Early metabolic and fetal programming, respectively, may affect the production outcome of the offspring. Recently, studies showed that e.g., heat stress in pregnant dairy cows impairs lifetime milk production of daughters and granddaughters. Also, at an early stage of life in calves, feeding level with milk until weaning determines their future milk production. In comparison with calves receiving a restricted amount of milk, calves fed milk or milk replacer ad libitum produced more milk during their first lactation. Furthermore, the rearing intensity of heifers during the pre-pubertal period impacts the future lifetime performance. Being more specific, overfeeding during this phase promotes the development of greater fat pad instead of parenchymal tissue due to lower circulating Bovine Somatotropin (BST) concentrations. (is a natural peptide hormone produced in the pituitary gland of cows. It is produced in small quantities and circulating concentrations of BST are positively correlated with the level of milk production). Increasing milking frequency (e.g., three or more times vs. two times daily) was shown to increase daily milk production, whereas once-daily milking reduced daily milk yield in dairy cows. Similarly, cows in automatic milking systems are milked on average more than two times daily and have a higher milk yield than cows milked only two times a day. The impact of dry period length on dairy cow heath and milk yield in the subsequent lactation was shown in a number of research and review papers. This aspect gained more attention in dairy cow management as with the overall increasing milk yields during the last decade's cows needed to be dried-off while still producing considerable amounts of milk. Not only economic interests are decisive for adjusting dry period length. Furthermore, the start into lactation is a challenging period for dairy cows, particularly for over conditioned dairy cows. Hence, a shortening or omission of the dry period goes along with a reduced milk production but concomitantly lowers the metabolic load after parturition in the subsequent lactation. In conclusion, currently, selection targets in dairy cows consider primarily traits related to longevity and fitness and are less oriented toward higher performance. However, milk production will further continue to increase as the physiological constraints addressed in this review give space for improvements. Of course, boundaries are set by the farming system, climate, etc. that cannot be overcome. Overall, dietary nutrient and energy availability seems the major limiting factor for milk production. Hence, glucose and AAs are the most limiting nutrients determining the amounts of milk volume and milk components, but also essential for the immune system. Efforts in improving welfare, husbandry, feeding, and management are likely to further enhance milk production, but will simultaneously improve other traits like reproductive performance and animal health. The existing variation in metabolic adaptation to different environmental stimuli provides further potential for appropriately selecting cows fitting best to the respective conditions. However, increasing milk yields must not be dismissed as driving forces worsening animal health. Only healthy animals can perform well and produce high amounts of milk.

3-2: Outlook on Growth

Livestock growth (in body mass, size, lengths and circumference) and development (of composition, structure and capacity, hence differentiations in body qualities and functions) are processes influenced by a series of internal and external factors, in the context of factual heredity. In the prospect of both heredity and impacting factors, both growth and development are controllable ontological processes. Body growth and development must be permanently controlled (by scheduled weighing and physical checkups).

3-2-1: Biological Bases of Growth and Development

Live organisms are the product of the interaction between the heredity basis (the genotype) and the environment wherein such genotype developed. In such interaction, at times hereditary basis prevail over the environmental factors; at other times, the environment prevails. Since the very start up, since amphimixis of spermatozoon with ovum (when the zygote is formed) up to old age, organisms undergo complex processes: ontogenesis. Definition. Ontogenesis is the growth and development process of a live being, covering all of the transformations, since embryo stage up to life end. Growth and development are the two distinct sides of the ontogenesis process, based on the impact of the factors exerting a bearing on such process. In theory, four are such factors, differentiated by the individual animal’s development rate and by the specific ratio growth/development:


Growth curves
Weight
Muscle
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Weight basis
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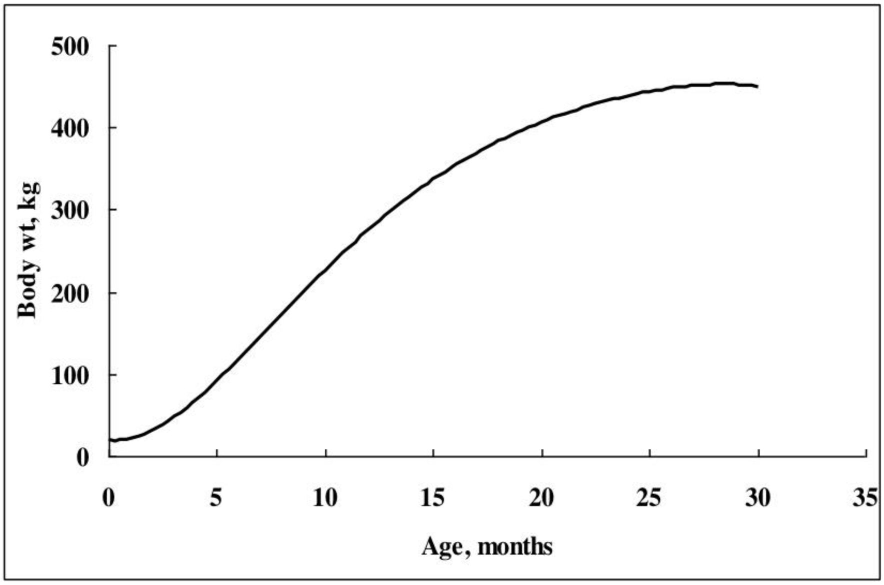
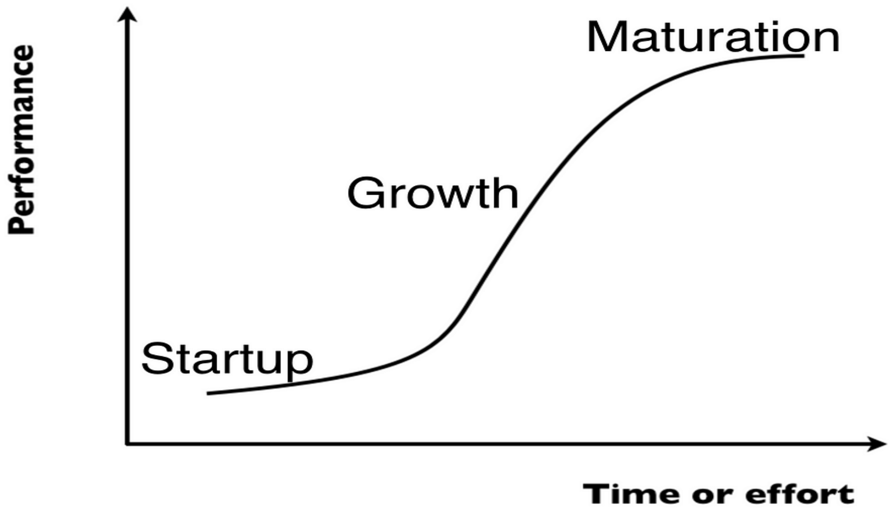
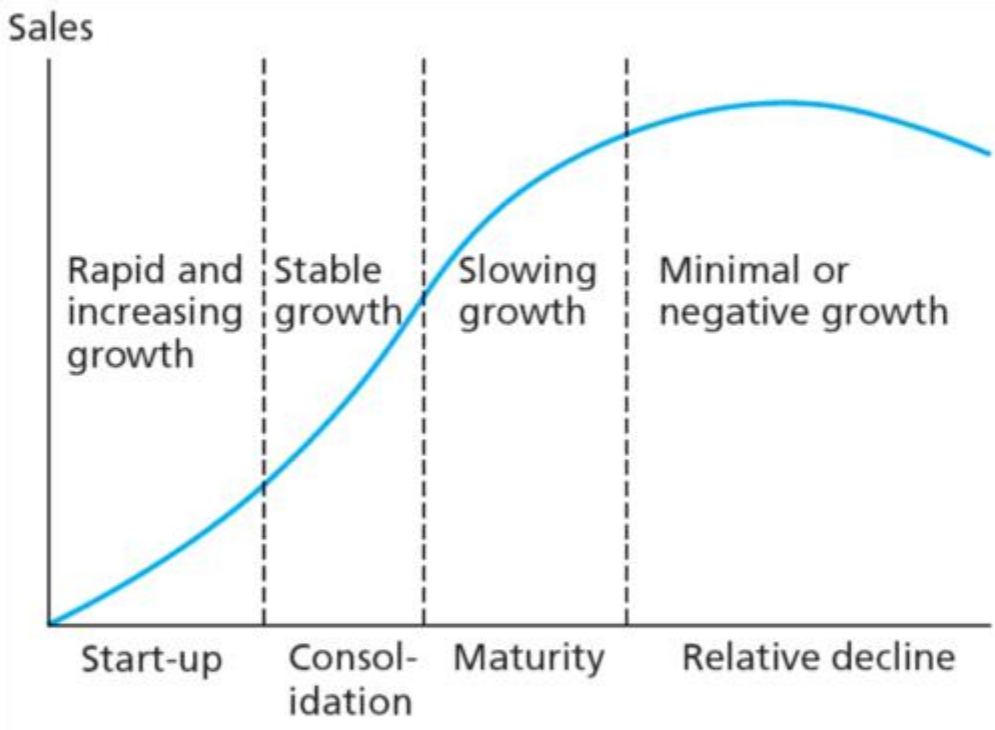
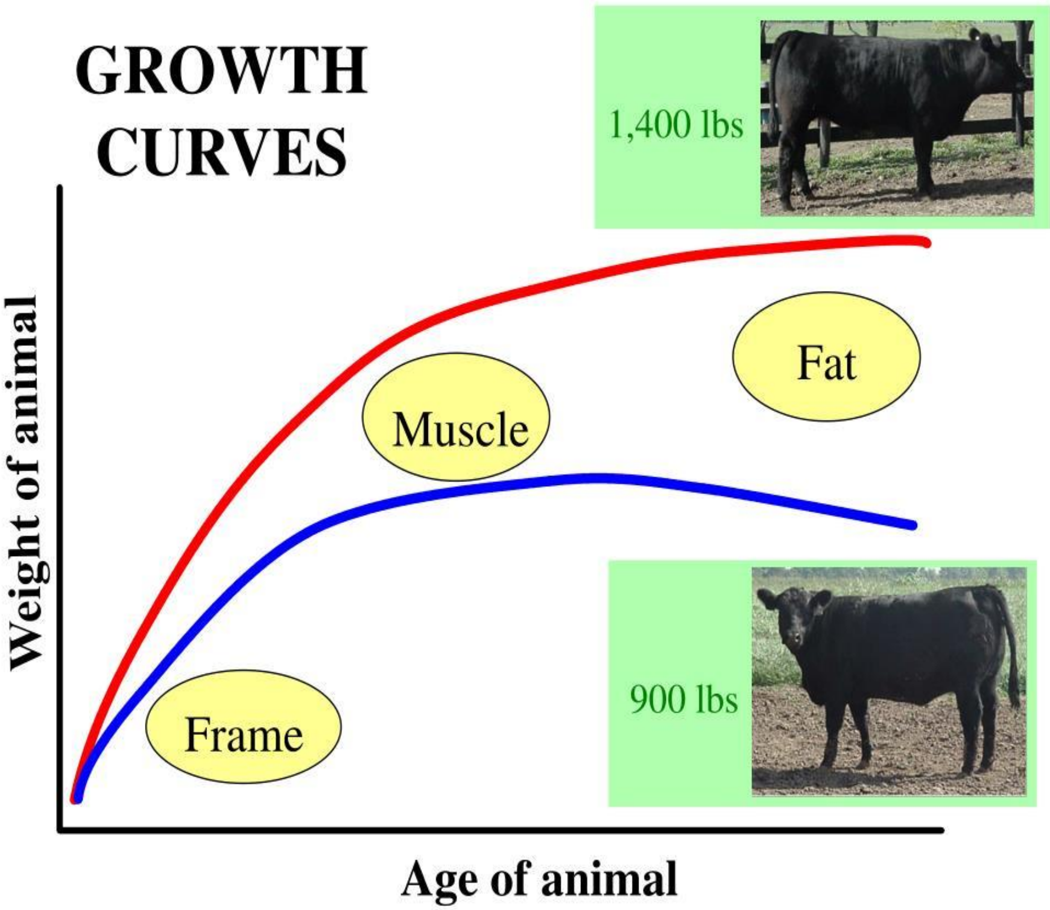
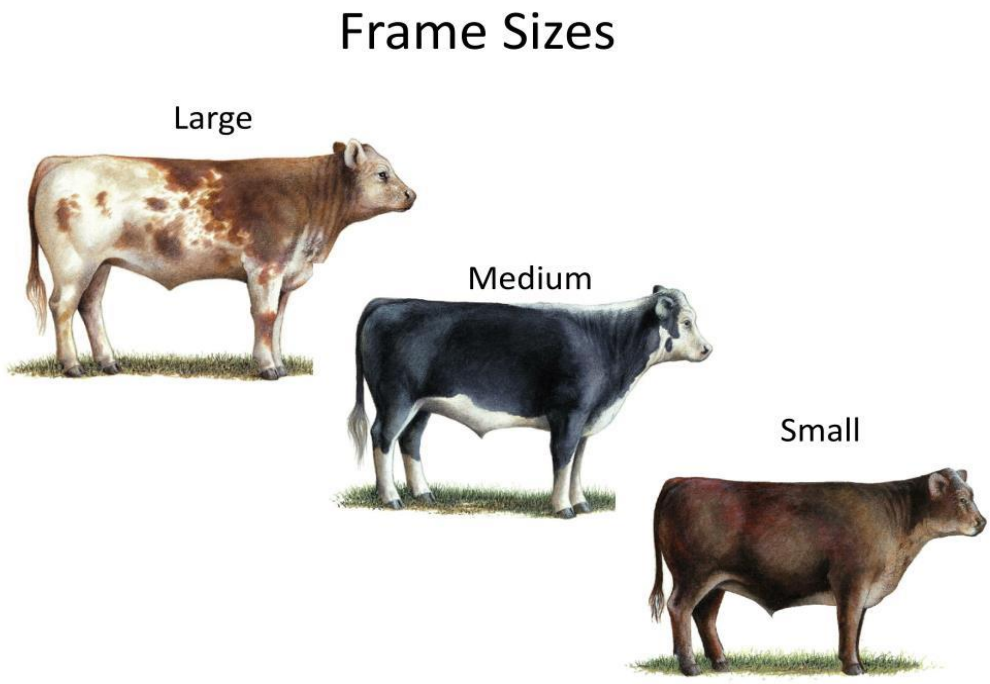
Growth curves






Sales
Rapid and increasing growth
Stable growth
Slowing growth
Minimal or negative growth
Start-up
Consol-idation
Maturity
Relative decline


GROWTH
CURVES
1,400 lbs
Fat
Muscle
Weight of animal
900 lbs
Frame
Age of animal



- fast growth/slow development: the body mass is reached fast and the specific transformations processes take long; such case is desirable in meat and fat animals, which can reach high gains if fattened early;

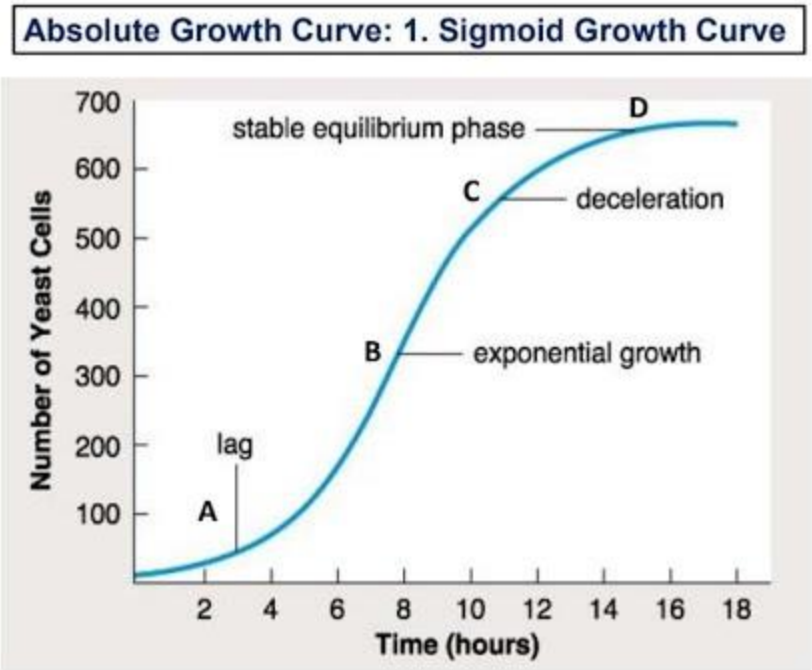
- fast growth/fast development: specific in precocious animals;

- slow growth/fast development: the body mass takes long to be reached, while development comes fast; frequent in dairy cows and poultry specialized for eggs production;

- slow growth/slow development: specific in primitive breeds (and a few local); retarded and low economic efficiency animals.

3-2-2: Growth Characteristics

Growth implies increased mass, size, lengths, and circumferences. Growth occurs in both intrauterine and extra uterine respective periods, resulting from three major processes: hyperplasia, which implies cellular multiplication by mitotic division; hypertrophy which implies growth in volume of the tissue cells; and gradual accumulation of substances, causing accretion. Definition Growth covers the coordinated interaction of the biological and chemical processes, which start by ovum fertilization and end in adult age, so that the animal organism should be built. Assessment of body mass and conformation growth is expressed in a number of growth indices, i.e. of energy, speed, and intensity. Growth energy expresses the organism's capacity to reach a breed specific weight in adult age. Growth energy is influenced by species, breed and individuality, and by the ontogenetic environment. Energy growth is uneven: low at first, then gradually higher to a maximum peak and, finally, in a stagnation stage. The graphical expression of energy growth is the sigmoid body mass growth curve in two distinct segments: the former expressing growth accelerated through multiplication and size growth, with the inflection point in puberty (in calf: 8-9 months of age), when 40% of adult weight is reached; the latter segment expresses retarded weight growth. Growth speed expresses the unit growth per time unit, expressed as relative (the ratio growth vs. initial mass) and absolute (daily average gain). Similarly, to growth energy, growth gains manifest a rising trend up to puberty time, after which growth gain is specifically dropping. Growth intensity expresses body mass growth per time unit. Intensity of growth in body size varies; a number of measured sizes manifest high growth intensity in the prebirth period, and comparatively lower in the post birth; while others vice versa. No matter the intensity, growth causes irreversible changes of the body indices e.g. in intrauterine state calves: body mass growth is 6% of adult weight, croup height is 55-60% of adult size, lengths are 40-50% and widths 30-40% of the same in adult age. Consequently, to differing growth intensity of body areas, at birth the calf weighs little, is tall or medium tall, and less wide, than specific measurements data of the adult animal.



Absolute Growth Curve

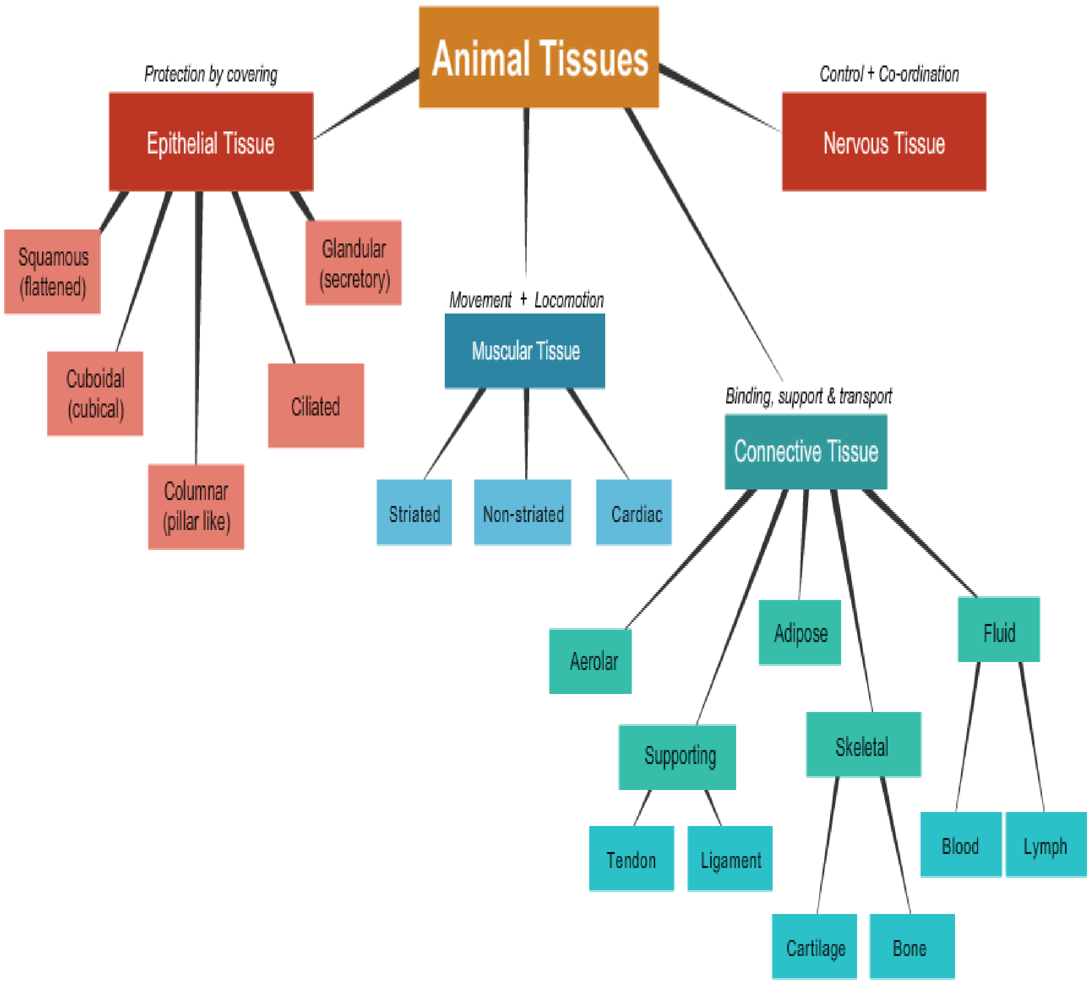
3-3: Development Characteristics

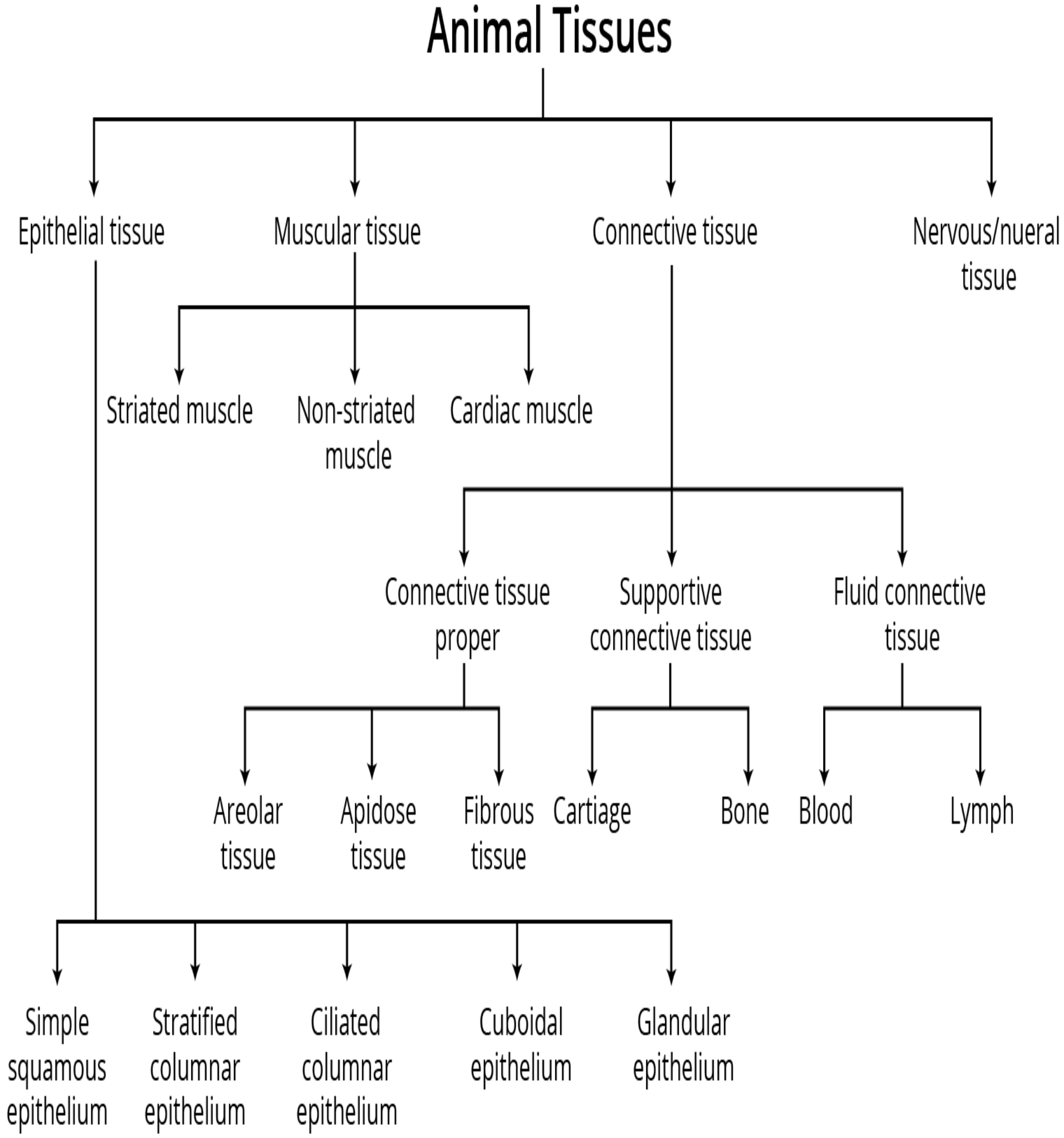
Development occurs over two distinct growth periods, i.e. intrauterine (pre-birth) and the extra uterine (post birth), as further detailed:

- pre-birth period stages: zygote, embryo and fetus; all of the organs develop, a number of such start functioning (e.g. the heart, the liver, and such like) while others do not yet (e.g. the lung); based on such stages, diverse raising conditions and feeding levels are needed in gestating females, so that the products may result well developed;

- post birth stages: young, adult and old age; young stage (youth) is species specific, differentiated into four phases: colostrum, suckling, weaning, and puberty; adult stage manifests slowed down growth and development, at such stage end the organism fully working, with all functions active and development maximum level; old age stage manifests growth and development stop, and slowed down vital functions; post-uterine development is granted by the interference of neurohormonal system with the environmental factors impacting it.

Development manifests cellular differentiation and tissue specialization, organs gradually and irreversibly growing adult by a series of changes in terms of shapes, proportions, and chemical composition and organism functions. Such stage also highlights a number of specific peculiarities: actually, all of the organs grow over the uterine stage (in mammals) or inside the egg (in fowls); consequently, intrauterine stage benefits of constant environmental conditions difficult to influence. Based on the specific functional systems (e.g. the locomotor system) development may ensue in direct answer to body mass growth (nervous, bones muscle and fat tissues e.g. as the animal grows, intense use is required of the muscular system to oppose gravitation and, consequently, changes may surge in terms of muscle mass physiological traits. Similar functional changes also occur, in the skeleton, in the digestive and cardiovascular system. When the adult stops growing, development changes continue, as the animal advances from maturity into old age. Development causes changes directed towards mature compositions, as also towards structures or abilities surged. Nevertheless, retrogressive changes associated with old age cause drop in composition, structure and abilities, which are also developmental changes, associated to old age for this once. Thus, development and old age are the early and the late stages of ontogeny, expressing an animal's life course. Even though a number of the growth aspects (e.g. fat deposition) seem reversible, the development processes rarely are. As the animal grows, numerous simultaneous developmental changes surge, which do not reverse if the animal loses weight; e.g. growth generated by a reversible accumulation of triglycerides stocked in the adipose cells may be accompanied by growing numbers and sizes of the adipose cells. At the same time, loss of triglycerides may also appear in all of the cells, which moderately release a part of the triglycerides. Thus, even though some diminution occurred, the animal did not come back to developmental state (as number of adipose cells) it was in before growth period debut.





3-4: Factors influencing Growth and Development

By identifying the impact factors on the growth process, and by providing for each its own due, there may be determined the useful growth changes which make possible to direct growth of the animal organism. The factors influencing the growth process can be viewed as internal vs. external.

- **Internal Factors** depend on the individual animal's hereditary basis; inherited by the new organisms from the parent organisms, the internal factors take over the growth processes limits of their ascendants, expressing the genotype/ the neurohormonal system, as further detailed. The genotype intervenes in body growth and development process by the numerous genes associated to the quantitative characters; the genetic factors associated with the growth process are the breed, the genes associated to tolerance and resilience to diseases, and the genes associated to the growth factors. The nervous system intervenes in the growth process by direct general action and by local action; however, the nervous system intervenes indirectly as well, by coordinating the glands of internal secretion. The nervous system's direct action is also noted in case of spinal lesions, avitaminoses and such like; or in various nerves, when growth stagnation occurs in subjacent areas, caused by function alteration. Indirect action is explained by the nervous system coordinating the endocrine system; the glands of internal secretion play an important role governing growth, in associated processes of the hypophysis, thyroid, parathyroid, thymus and the sexual glands. The hypophysis (the pituitary gland) influences growth by coordinating the activity of the other glands of internal secretion, and through the somatotropic hormone (the growth hormone). Changes in hypophyseal activity cause a number of growth anomalies. Thus, in case of hyper function the anomaly called gigantism manifests, respective animals resulting much larger than normal; in case of hypo function, the anomaly called dwarfism manifests, the animals resulting abnormally small. The thyroid is particularly important for the growth process as, for lack of thyroidal activity, growth may stop, while sexual maturity (puberty) and somatic maturity (cartilage ossification) may result retarded. Thyroidal hormones used in high quantity led to weight loss, consequently to catabolic processes' intensified rate. The thymus is a gland present and functional only in animal young age, playing a major role in growth/development of the sexual glands. The sexual glands secrete the estrogenic hormones which inhibit growth of the long bones, hurrying the cartilages' epiphyseal ossification. Such aspect occurs phenotypically in neutered animals, whose legs' bones are quite long and yet growing over a comparatively longer time, the animals getting a mesomorphic, or dolichomorphic, aspect. The high estrogen secretion stimulates growth and the specific consumption (food assimilation) capacity; hyperestrogenic animals' carcasses manifest comparatively more muscular mass and less fat. The parathyroid's influence increases by adjusting mineral metabolism, mainly the calcium and phosphate balance.

-External Factors are most important for growth and development, by acting directly and by providing a series of options for being amended, more than what the genetically determined internal factors would allow. Feeding, in terms of level and quality, is one of the most important factors influencing growth, in both uterine and post-uterine stage. In the intrauterine stage, feeding the mother inadequately over the last gestation quarter may lead to underweight offspring, with a digestive system poorly developed, poorly working temperature regulation, weak organic resilience and poor adaptation capacity, all such flaws due to poor development of the neurohormonal system. Post partum, the influence of the food factor is much higher; post-birth fodders being administered adequately to each animal category (i.e. by rations where contents and ratios of ingredients are optimized, for energy/ protein/minerals/vitamins); by quantity (level) and structure (contents in nutrients) the rations influence both body mass growth (see Figure 5.3), and run of the vital functions and processes. The proteins influence growth and development especially by presence of the basic amino acids, which cannot be synthesized by the organism; consequently, in all of the animal categories but especially in the young, optimal amino acids proportions1 must be provided (e.g. in intensive raising of pigs and fowls the basic amino acids required are lysine in pigs, and lysine, methionine cysteine in fowls) hence proteins in rations are mandatory. Carbohydrates are the energy ingredients required for sustaining the organisms' metabolic processes. Cereals, the main energy providers, are rich in starch. Initially the young livestock consume short chained carbohydrates; consequently, often hydrolytic (semi liquid mixture) or caramelized (fried) cereal starch in food are used. Minerals and microelements; Ca and P are minerals contributing to skeleton growth and development; and the microelements implied in growth are Co, Fe, Cu, Zn, Mn, Mg and such like. Vitamins (biocatalysts); the biochemical processes in an organism depend on vitamins, for both growth and health of the young organisms. The vitamins playing a basic role in growth are: A, B1, B, B, C, D and E. Temperature must be adjusted to each species, breed, hybrid and category; the optimal temperature swings between temperature values defining the temperature comfort area. In young animals (like chicks), whose homoeothermic mechanisms are incompletely developed, the raising shelters must be warmed to temperatures adequate to specific age and category, as also adequate to humidity level. Ideal protein implies optimal ratios granted, of the essential amino acids in ration vs. (normally) lysine.

It is concluded that: -

1. Ontogenesis is the process of growth and development of a living being, encompassing all transformations, from the embryonic stage to the end of life.

2. Growth is the coordinated interaction of biological and chemical processes, which begin with fertilization of the egg and end in adulthood, with the aim of building the animal body.

3. Development represents cell differentiation and specialization of tissues and organs; it is achieved progressively and irreversibly

towards adulthood, and retrogressively towards senescence, leading to changes in shapes, proportions, chemical composition and functions of the body.

4. Internal factors that influence growth and development are represented by genotype and neurohormonal system: Nervous system and thymus glands, thyroid, parathyroid, pituitary gland, sex glands.

5. External factors that influence growth and development are represented by feeding, temperature, light and ultraviolet radiation; during the ontogenetic stages there are environmental influences and events that influence the growth, development and performance of phenotypic values

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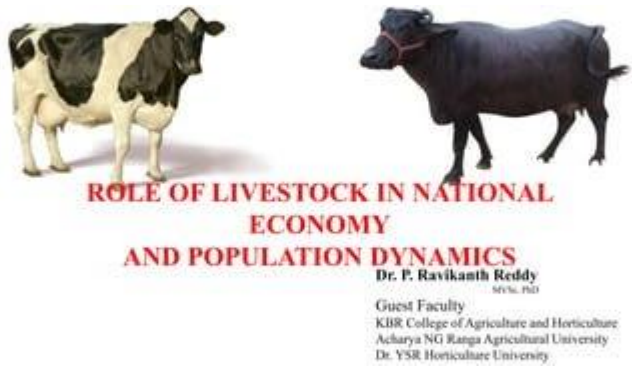
Chapter 4

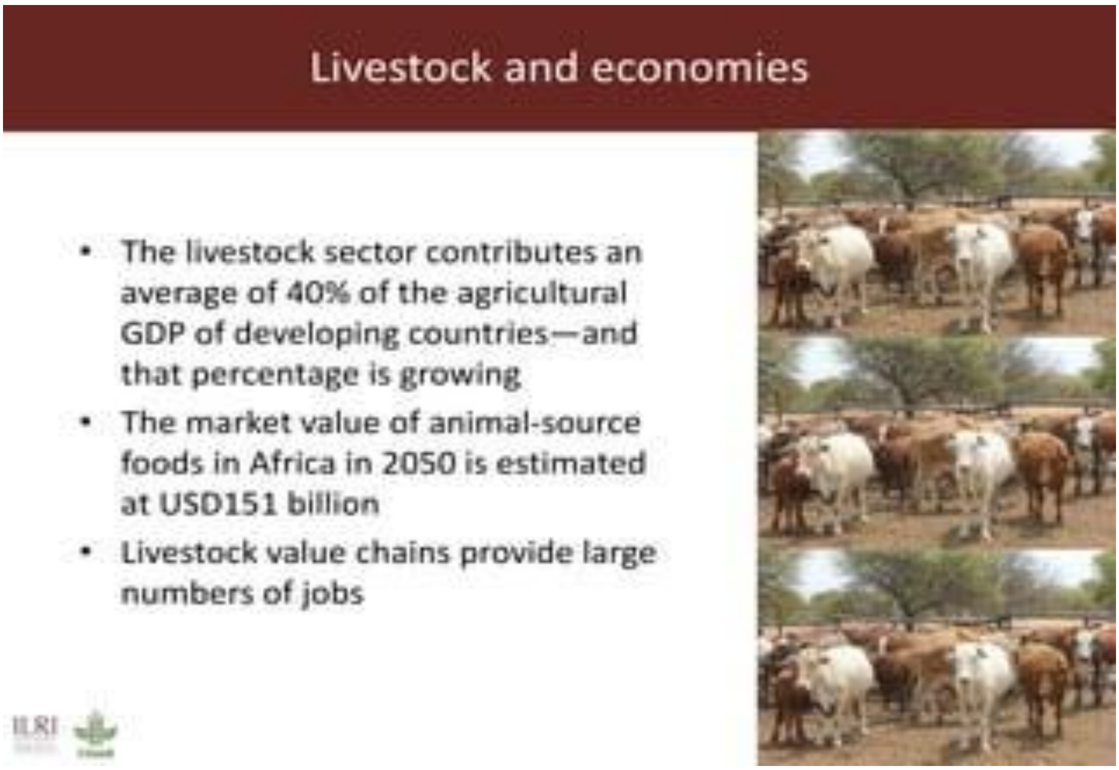
The Roles of Livestock in Developing Countries

The Roles of Livestock in Developing Countries

4-1: Introduction

Livestock play a significant role in rural livelihoods and the economies of developing countries. They are providers of income and employment for producers and others working in, sometimes complex, value chains. They are a crucial asset and safety net for the poor, especially for women and pastoralist groups, and they provide an important source of nourishment for billions of rural and urban households. These socio-economic roles and others are increasing in importance as the sector grows because of increasing human populations, incomes and urbanization rates. To provide these benefits, the sector uses a significant amount of land, water, biomass and other resources and emits a considerable quantity of greenhouse gases. There is concern on how to manage the sector's growth, so that these benefits can be attained at a lower environmental cost. Livestock and environment interactions in developing countries can be both positive and negative. On the one hand, manures from ruminant systems can be a valuable source of nutrients for smallholder crops, whereas in more industrial systems, or where there are large concentrations of animals, they can pollute water sources. On the other hand, ruminant systems in developing countries can be considered relatively resource-use inefficient. Because of the high yield gaps in most of these production systems, increasing the efficiency of the livestock sector through sustainable intensification practices presents a real opportunity where research and development can contribute to provide more sustainable solutions. In order to achieve this, it is necessary that production systems become market-orientated, better regulated in cases, and socially acceptable so that the right mix of incentives exists for the systems to intensify. Managing the required intensification and the shifts to new value chains is also essential to avoid a potential increase in zoonotic, food-borne and other diseases. New diversification options and improved safety nets will also be essential when intensification is not the primary avenue for developing the livestock sector.





The challenge: Is attaining global food security and sustainable food production possible?

How will the world feed itself sustainably by the time the population stabilizes about 2050?

- 60% more food than is produced now will be needed
- 75% of this must come from producing more food from the same amount of land
- The higher production must be achieved while reducing poverty and addressing environmental, social and health concerns
- This greater production will have to be achieved with temperatures that may be 2–4 degrees warmer than today's

- **Demand for animal source foods rising fastest**

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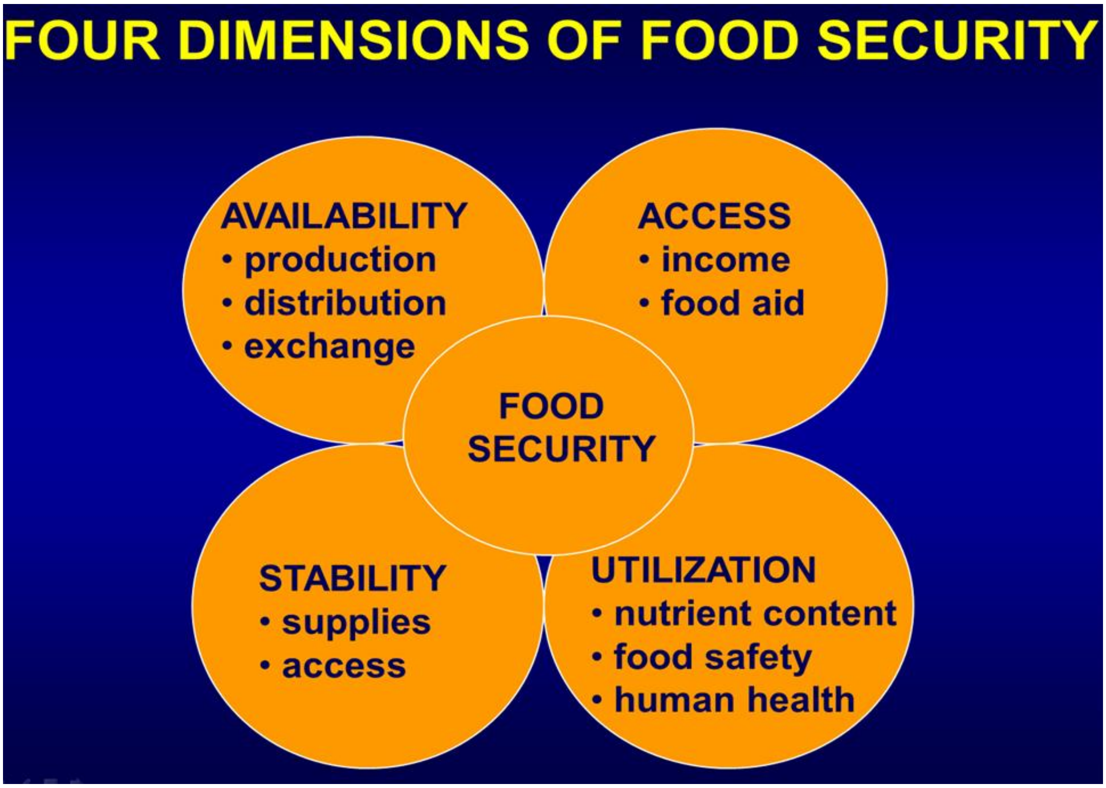
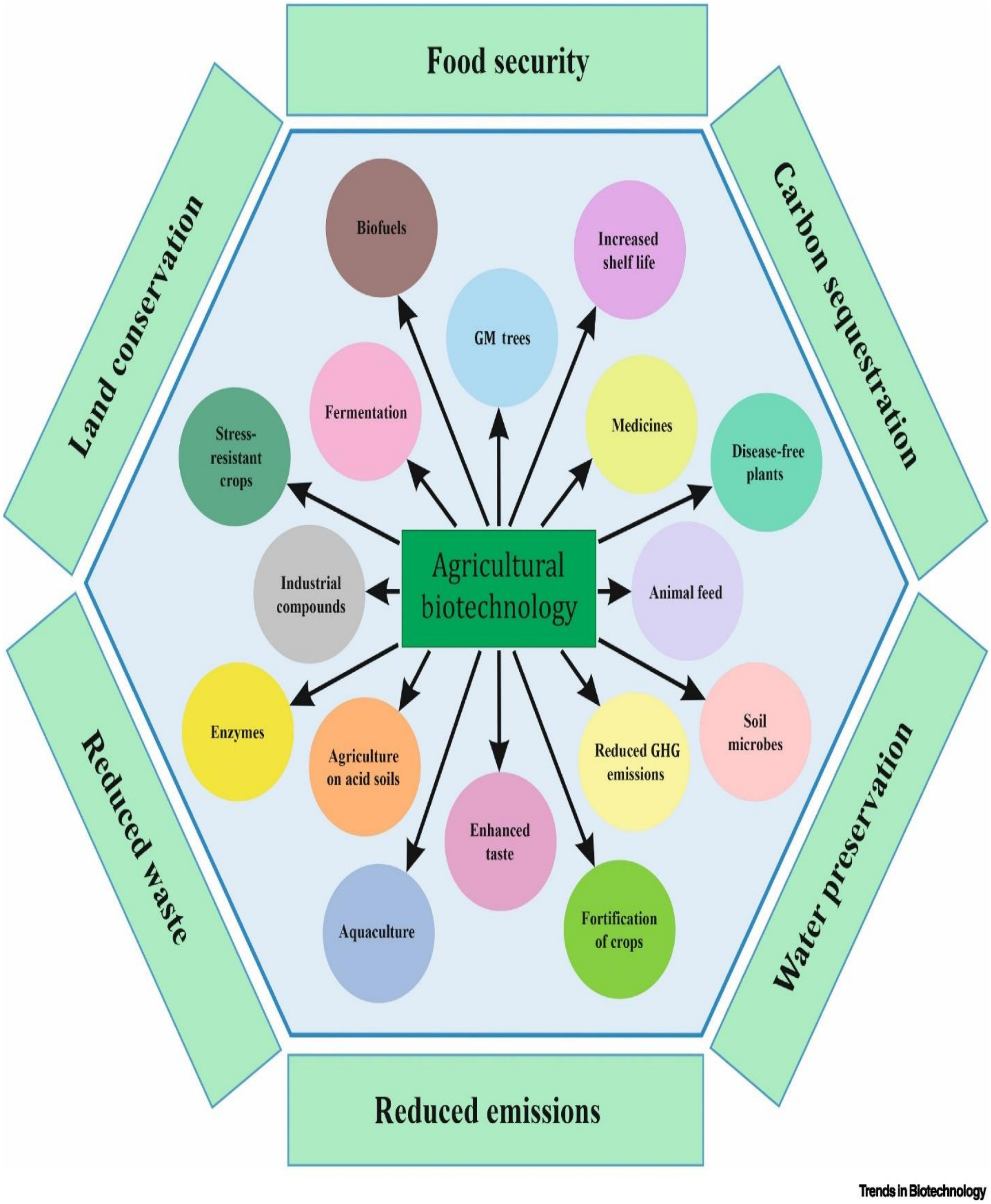
4-2: Food Security

Food security, is when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Food security is the state of having reliable access to a sufficient quantity of affordable, nutritious food. The availability of food for people of any class, gender or religion is another element of food security. Similarly, household food security is considered to exist when all the members of a family, at all times, have access to enough food for an active, healthy life. Food security includes resilience to future disruptions of food supply. Such a disruption could occur due to various risk factors such as droughts, floods, economic instability, and wars. The concept of food security has evolved over time. The four pillars of food security include availability, access, utilization, and stability. As of 2015, the concept of food security has mostly focused on food calories rather than the quality and nutrition of food. The concept of nutrition security or nutritional security evolved as a broader concept. In 1995, it was defined as adequate nutritional status in terms of protein, energy, vitamins, and minerals for all household members at all times. It is also related to the concepts of nutrition education and nutritional deficiency. Food insecurity, on the other hand, defined as a situation of limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways. Food insecurity is the opposite of food security: a state where there is only limited or uncertain availability of suitable food. There are many possible causes of food insecurity. The most important ones are high food prices and disruptions in global food supplies for example due to war. There is also climate change, water scarcity, land degradation, agricultural diseases, pandemics and disease outbreaks that can all lead to food insecurity. The effects of food insecurity can include hunger and even famines. Chronic food insecurity translates into a high degree of vulnerability to hunger and famine. Human populations can respond to chronic hunger and malnutrition by decreasing the body size of children, known in medical terms as stunting or stunted growth.[10] Once stunting has occurred, improved nutritional intake after the age of about two years is unable to reverse the damage. Severe malnutrition in early childhood often leads to defects in cognitive development. Chronic (or permanent) food insecurity is defined as the long-term, persistent lack of adequate food. In this case, households are constantly at risk of being unable to acquire food to meet the needs of all members. Chronic and transitory food insecurity are linked since the reoccurrence of transitory food security can make households more vulnerable to chronic food insecurity. Globally and in every region, the prevalence of food insecurity is higher among women than among men.




Food security
Carbon sequestration
Water preservation
Reduced emissions
Reduced waste
Land conservation
Agricultural biotechnology
Biofuels
Increased shelf life
GM trees
Fermentation
Medicines
Stress-resistant crops
Disease-free plants
Industrial compounds
Animal feed
Enzymes
Soil microbes
Agriculture on acid soils
Reduced GHG emissions
Enhanced taste
Aquaculture
Fortification of crops
Trends in Biotechnology

4-3: An Overview of the Trends in Asian Food Security

The Asian region has about 60% of the world's population, the greatest number of poor and under-nourished people, but only 34% of the world's arable land and 36% of the world's water resources. The world's population reached eight billion in mid-November 2022, with the two most populous countries being in Asia — China and India. Population pressure together with limited land and water resources mean that Asia will face increasing pressures to feed itself. Therefore, in the 21st century, one of the most dynamic regions of the world with many fast-growing economies spearheading techno-logical innovations in different sectors of the largest producers of food and feed are in this region, as are some of the largest importers. The complex social, political, and economic dynamics in Asia have led to large differences in the level of food security amongst its 48 countries. And underpinning this complexity are the eco-geographic differences in agricultural production as Asia has large intra-regional variations in climate and soils. This complexity underscores the issues and dilemmas facing food security in the region, some of which are unique to the region and others which are common to other geographic regions. Asia's food security has been and remains under pressure from a variety of factors that include population growth and urbanization, the declining performance of agriculture, natural resource constraints, climate change, high and volatile food and fuel prices, and the rapid transformation of supply chains. The world's population is expected to increase from 8.0 billion in 2022 to 9.3 billion in 2050, with Asia capturing the lion's share. At the same time, the population living in urban areas is projected to gain 2.9 billion, passing from 3.4 billion in 2009 to 6.3 billion in 2050 with most growth concentrated in the cities and towns of the less developed regions. Urbanization, in combination with rising incomes, will increase food demand and accelerate the diversification of diets. As incomes rise, diets will come to include more resource-intensive food products, such as meat, dairy, eggs, fruits and vegetables, thus unleashing a rapid increase in demand for raw agriculture commodities. It is unlikely that the Asian region can produce enough to meet these increases. Agricultural performance in the Asian region has declined over the last few decades. Annual growth in crop productivity, measured in terms of average aggregate yield, has been slowing over the years. Global aggregate yield growth of grains and oilseeds averaged 2.0% per year between 1970 and 1990, but declined to 1.1% between 1990 and 2007. Crop yield growth is projected to continue declining over the next ten years to less than 1.0% per year, including in Asia. As an economic activity, the share of agriculture to gross domestic product has fallen across the region, for example, from 43% to 15% between 1961 and 2019 in South Asia. The number of people working in agriculture has also steadily declined from 70% to 55% between 1980 and 2010, and is projected to further fall to 29% in 2019. This is largely due to the structural transformation occurring in the rural sector, and attributed to the fact that farmers are getting older across Asia, rural to urban migration has increased, and the replacement rate by young farmers is not happening fast enough. Many of the agroecosystems being used as food production systems in Asia are already showing worrying signs of stress.

4-4: Food Availability

This term means that country/ nation having sufficient food available to meet growing demand, and is commonly based on the amount of food produced. Most countries have two major sources of food- domestic production and imports. There are a few economies that, even without significant agriculture, are still able to secure food through imports (trade). Singapore, for instance, only produces about 10% of its food needs and yet is considered one of the most food-secure countries in Asia. It does so by having the financial and logistical capacity to import food from over 170 countries worldwide. However, because all imports draw from the global pool of commodities for export, it is important that production as a whole keeps up with the demand of a global population of ten billion by 2050. For the majority of countries in Asia, domestic production still makes up a large proportion of total consumption, making the performance of the agricultural sector critical. Production is driven by the land available and the yield or amount of harvest for every unit of space planted/allocated for production. The production base for agriculture, traditionally done in rural areas, has been shrinking over the past decades due to multiple factors like soil degradation, industrialization and urbanization and has led to the search for new spaces to farm, such as in urban areas and in oceans. Having food available by whatever means is a top priority in every Asian country.

4-5: Physical Food Access

Even if food is available, the countries that need it may not always have physical access to it, especially if it needs to be transported from long distances through complex supply chains. During the 2007–2008 crisis, countries like Thailand and India banned the export of rice in order to meet domestic demand and this precipitated supply shortages and price hikes which affected millions of rice consumers in Asia. More recently, the Russia-Ukraine crisis, preceded by the COVID-19 pandemic, prevented or slowed physical access to food in countries which were net importers by disrupting activities along supply chains such as the loading of grain shipments and the movement of ships along trade routes. At the domestic level, measures to control the spread of the COVID-19 pandemic caused much raw produce to rot in farms and storage facilities as there was no labor to move the goods.

4-6: Food Utilization

This generally involves the way in which food addresses hunger and brings about desirable nutritional and health outcomes among the populace. Concerns about food utilization have led to work on “nutrition security”, focusing on not just the adequacy of food to meet the calories per day, but also to supply essential minerals and vitamins needed for health. The “triple burden” of malnutrition as expressed by the International Food Policy Research Institute is of particular interest when manifested through under-nutrition (stunting, slow cognitive development), over-nutrition (obesity, non-communicable diseases) and mineral deficiencies. Even before the COVID-19 pandemic in 2020, the Asia-Pacific region had been confronting high burdens of food insecurity and all forms of malnutrition as high-lighted repeatedly by the FAO reports on State of Food Security and Nutrition [FAO, 2022]. 375 million people in the region were malnourished in 2020, an increase of 53.9 million people over 2019 — most of them in South Asia. 40% of the population in this region cannot afford a healthy diet. Overweight and obesity are also rising in the region. This is paradoxical in a region that is the engine of the world’s economic growth and is a large producer of major food commodities such as rice, fish, pork, milk, eggs, fruits and vegetables, among many others.

4-7: The Demand for Animal Meat

In recent decades, meat production and consumption have increased in Asia, for example, in China where, following market reforms in 1978, per capita meat consumption jumped almost six-fold in four decades alongside the rise of domestic production. The three biggest beef-eating countries in Asia — China, India and Japan- are expected to further increase consumption to an estimated 10.2, 2.9, and 1.3 million metric tons, respectively in 2022. Other Asian countries such as Japan and South Korea as well as the ASEAN economies of Indonesia, Malaysia, the Philippines, Vietnam and Thailand are also part of the ‘metrification’ process of Asia.

Meat production requires feed, of which the main components are corn and soybean. Asian countries generally do not produce enough corn or soybean, despite countries like China, the

Philippines and Thailand having substantial areas of corn. Any reduction in feed availability will affect Asia's meat production.

4-8: Sustainability Issues

Sustainable agriculture does not have a generally accepted definition, although Crosson's captures succinctly the aspirations for sustainable agriculture: "A sustainable agricultural system is one that can indefinitely meet the requirements for food and fiber at socially acceptable, economic and environmental costs." This suggests that sustainable agriculture may be described using three rubrics, Environment, Economics and Social (EES), expanded as follows: environmentally friendly (conserves natural resource base, mini-misses negative externalities like pesticides, etc.), economically viable (enables farmer livelihood) and socially just (benefits small and large farms, benefits producers and consumers).

4-9: Opportunities to Ensure Future Food Security

When the issues of climate change, sustainable agriculture, food security and farmer livelihoods are considered together, they represent a "wicked problem". Can a wicked problem be unpacked into parts which can be addressed separately and, in their solutions, contribute to the overall solution? Pragmatically, this may be the only approach. Agriculture contributes to climate change and climate change affects agriculture. The "whole is more than the sum of its parts", and food production is only one component of food systems. The FAO views food systems as comprising "the entire range of actors and their interlinked value-adding activities". This involves "the production, aggregation, processing, distribution, consumption and disposal of food products that originate from agriculture, forestry or fisheries, and parts of the broader economic, societal and natural environments in which they are embedded". So, the hope for humankind may be to unpack a big wicked problem into its components. Then follow this by solving the component issues through cooperative efforts. This in the hope that they may lead at least to a partial solution of the bigger wicked problem. In response to the many challenges posed by a complex situation, governments in Asia have put forward measures to safeguard food security amidst fear of food shortages and social and political instability.

4-10: Disruptive Technologies

Asian agriculture faces many challenges that lend themselves to technological solutions. While political and social solutions meet some of these challenges, experts generally agree that technological innovations offer much potential. A perfect example of this is the "Green Revolution" which in the 1960s saw many large Asian countries increase yields with new rice and wheat varieties and agricultural inputs. China and India staved off mass starvation. If not for the positive impact of these disruptive innovations, Asia would not have had the food security necessary for economic development. Agriculture is now strongly influenced by agricultural technology or "agtech", which is the milieu of exciting new technologies that have already started to make a difference to small farmers in Asia.

These include the following:

- Agronomy and agricultural biotechnology to innovate inputs for crop and animal agriculture such as seeds, pest control, seeds with new genetics, microbiome and animal health;

- Mechanization, robotics and equipment such as on-farm machinery, automation, drones guided by Global Positioning Systems or Geographic Information Systems, environmental sensors, and growing equipment;

- Farm management software, Internet of Things (IoT) systems with sensing and intervening — these include environmental, farming data capture devices, decision support software, big data analytics and miniaturised portable applications; most from the so-called fourth Industrial Revolution;

• Novel farming systems such as indoor farms, plant factories with controlled environment, aquaculture systems, and grow out facilities for insects, algae and microbes; and

• Novel, future foods made using precision fermentation and biotechnology processes, as exemplified by plant-based protein and cultivated meat.

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Chapter 5

Challenges and Prospective Opportunities in Smart Animal Husbandry

Challenges and Prospective Opportunities in Smart Animal Husbandry

5-1: Insightful Overview of Dairy and Beef Cattle Husbandry

The term husbandry or management involve a set of practices and theories on how to be a successful manager / cattleman. The key aspects include:

- Planning: Setting goals and working with people to achieve them.
- Organizing: Creating an environment that empowers people / cattleman to work efficiently.
- Staffing: Managing resources and personnel.
- Leading: Influencing people to accomplish desired objectives.
- Controlling: Monitoring and adjusting processes to meet farms goals.

The objectives of this chapter are to highlight the importance of cattle management, and provide an overview of the impact of cattle farming on productivity and the environment. Cattle management involves various practices aimed at ensuring the health, welfare, and productivity of cows. These practices include feeding, breeding, housing, and healthcare management. The management of cattle is essential for maintaining a sustainable and profitable animal industry. Cattles were domesticated thousands of years ago, and have contributed greatly to human welfare, supplying draft power, milk, meat, hides, fuel, and a variety of other products. Dairy cattle have been genetically selected for greater milk production. Animal husbandry as agricultural practice of raising livestock in the domain of agriculture is a strenuous task that involves so many challenges. The introduction of technology to farming is imperative for mitigating these challenges for animal traceability, health information, and performance recording. Also, as the world keeps experiencing increase in population growth, there is a need to expand production of food (mainly milk and meat) by ensuring good welfare of farm animals in order to commensurate with the population growth. Farm animals' welfare will ensure availability of nutritional food of high quality all over the world. However, unguarded expansion of farm animals and improper monitoring of their activities can pose a challenge to their productivity. Therefore, there is a need to protect and understand the changeable agricultural systems by employing farming procedures that are sustainable an continuously monitoring the different physical happenings.


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THE 12-MONTH PRODUCTION CYCLE FOR COWS. CRITICAL CONTROL POINTS ARE IDENTIFIED FOR EACH OF THE PRODUCTION PERIODS
V-PLAN
Period 1: Calving and preparation for breeding
Period 2: Breeding and pre-weaning growth of calves
Period 3: Weaning of the calves and pregnancy diagnosis
Period 4: Dry cow management and preparation for calving
Critical control points
Correct management just before and during calving.
Survival of newborn and young calves.
Test bulls for venereal diseases and fertility before breeding.
Prepare cows for the breeding season.
Critical control points
Correct management of cows during the breeding season.
Correct management of bulls during the breeding season.
Effective vaccination of calves.
Optimal growth before weaning.
Critical control points
Weaning and marketing of the calves.
Pregnancy diagnosis and testing for brucellosis.
Select replacement heifers.
Yearly replanning.
Critical control points
Active marketing of cull cows and management of dry cows.
Start the three-year heifer replacement programme.
Prepare cows for the calving season.
Train stockmen.
Calving to breeding
Cow gestates for nine months before calving.

Currently, the best dairy cows are capable for producing over 15000 kg of milk in a single lactation. Dairy cows are bred for their ability to produce milk from which dairy foods are made. Dairy cattle considered as a productive economical unit, their feeding depends upon feedstuffs, mostly unfit for human consumption. After eating of these plants and by-products, cows produce essential food e.g.: meat, milk having high nutritive and economic value. Cattle farming stands at the intersection of two critical global challenges: the need to meet rising demands for high-quality dairy products and the imperative to reduce its environmental impact. Cattle management plays a crucial role in agriculture due to its significance in milk and meat production.

On the other hand, beef cattle are cattle raised for meat production (as distinguished from dairy cattle, used mainly for milk production). The meat of mature or almost mature cattle is mostly known as beef. In beef production there are three main stages: cow-calf operations, backgrounding, and feedlot operations. The production cycle of the animals starts at cow-calf operations; this operation is designed specifically to breed cows for their offspring. From here the calves are backgrounded for a feedlot. Animals grown specifically for the feedlot are known as feeder cattle, the goal of these animals is fattening. Animals not grown for a feedlot are typically female and are commonly known as replacement heifers. While the principal use of beef cattle is meat production, other uses include leather, and beef by-products used in candy, shampoo, cosmetics and insulin. Due to reproductive phenomenon of cattle, e.g. nonseasonal polyestrous, it is possible to regulate, organize and synchronize the delivery of cattle in different period of the year, and subsequently, availability of milk at different times. In many countries cattle play important role in the economy of these countries due to high ability of to consume huge amounts of feeds and high capacity of feed conversion ratio (the ability to convert feed into milk / meat).

5-2: Dairy Cattle Management Involves:

- Nutritional management, which is the most important determinant of herd productivity. The relationship between nutrition and productivity begins at birth.
- Reproductive management
- Replacement management
- Herd size, composition, and culling and
- Environmental conditions

5-3: Characters of Dairy Cattle

Dairy cattle are characterized by special features, which can be classified into two groups, morphological and productive characters. 1. Large and well-developed udder: extended forwards and backwards but not downwards (suspended or pendulous). 2.

Prominent, and well-developed and well-formed mammary (milk) veins. 3. Elongation of the body, enlargement of abdomen with pinned bone appearance. 4. Thinness of head and neck with their homogeneity. 5. The body has triangular, wedge shape due to narrow shoulder, moderate chest, deep abdomen and broad hind quarter. This triangular shape can be observed at upper, front, and back view. Its productive characters are more important than morphological characters from practical point of view. The parameters depend mainly upon different "production record" of the farm (if available) 1. Quantity of milk produced. 2. Fat percentage of milk. 3. Time of milk produced (date of production) at fist calving. 4. Period of milk produced (month). 5. Length of dry period (days). 6. Intervals between two deliveries and mating. 7. Intervals between two successive calving. 8. Persistency of production. 9. Calmness at milking process. Selection basis of suitable cattle breeds is: a. The capacity to produced milk: The ability of cow the use local feedstuff and convert it into mainly milk. b. Body traits: Cows should be characterized by body depth, large heart girth (broad chest girth) enable these cows to consume huge amount of feedstuffs. c. Udder characters: Large and sound (healthy) udder with its extension forwards and backwards but not swing, teat- balanced with the prominence of mammary (milk) veins. d. The follow of pedigree, lifetime and production concerning with milk yield (production) if available.

Some productive parameters: Age at first calving (months). Milk produced (305 day) kg/day (1st. parity, 2nd parity………etc), Lactation period (day). iv. Dry period. v. Interval period between two successive calving (days).

5-4: Constraints of Cattle Development

Improvement faces many constraints, among them are:

1- Shortage of feed: Available information indicates that animals rarely get more than 70% of their nutritional requirements specially with the nomadic, sedentary and transhumant systems.

2- Harsh environment: The harsh arid and semi-arid climate with its extreme temperatures, humidity and sandstorms, adversely affect animals. The limited and irregular rainfall limits the availability of fodder as part of the cropping program. The recurrent or persistent draught is a common feature of many regions in the world.

3- Health: The instability of flocks and continuous movement made veterinary services difficult. Endemic diseases are the cause of high mortality, morbidity and reduced productivity.

4- Marketing: Marketing practices are improper and do not offer the producer any protection or incentives. They are not sufficiently flexible to encourage introduction of new technologies and management practices. Credit facilities, especially those offered by the government, may be inadequate and not always available specially for small producers and transhumant.

5- Prices: The current pricing policies for livestock products, though follow the general low of availability of supply and demand, may not geared towards meeting the requirements of producers. The feed / product price ratio should favor the producer, a case which is not existing.

6- Instability of agriculture policies: This situation impedes the implementation of long-term breeding plans and the introduction and use of new technologies that add to the cost and need stability to be fruitful.

7- lack of recording: Proper recording, in the field of animal production, especially on the national level may nearly absent. The bureaucracy in handling or keeping records and their availability hinder timely action and endanger the efficiency of the production process that depends on analyzing related records.

8- Lack of coordination between research activities and production level prevents the implementation of research results by the targeted producers and impede orientation of research toward solving field problems.

9- Extension services and articulation may be very weak and improper.

5-5: Beef Cattle Management

Beef cattle management involves:

- Feeding: The key to profitable finishing is feed conversion efficiency (FCE), by maintaining high dry matter intakes of high energy feeds. Improving FCE reduces the feed cost/kg gain.
- Handling animals: Sensitive handling is vital for animal welfare and to minimize damage that shows up after slaughter.
- Healthy animals produce better returns.
- The major challenges face on beef cattle production; management and marketing are: 1. Poor animal health 2. Shortage of adequate grazing 3. High livestock mortality rate (20% per year) 4. Poor animal husbandry skills 5. Weak support from public and private institutions 6. Poor access to markets 7. Uneconomic Livestock prices.

- Reproduction in Beef Cattle: Most communal farmers run bulls with the cows throughout the year, claiming that higher calving rates can be obtained and that bull requirements are reduced. This is however, not desirable since controlled breeding can be practiced resulting in restricted calving season - even more - batches of animals produced and routine management practices become easy. It is desirable to separate heifers during bulling and calving and for mating 4 to 6 weeks earlier than the cows to allow closer supervision during calving. Appropriate calving time is 6-8 weeks before adequate green grazing can be expected. Calves born later than this are too small to utilize fully the milk potential of its dam grazing on the early green lush. The late calf is susceptible to scours, sweating sickness and parasites. Therefore, it is clear that calving season should be centered approximately 2 months before adequate green grazing can be expected.

- The growing bull is much more susceptible to nutritional stress than the mature bull. When mature bulls are fed, low energy feeds for prolonged periods, libido and testosterone are affected much earlier than semen production. The effects of underfeeding may be corrected in mature bulls, whereas it is less successful in young animals because of permanent damage to the testis. Obesity and over-feeding reduce libido and sexual activity in bulls, particularly during hot weather. Mature males should be restricted to a maintenance diet. When not in the breeding herds, bulls should preferably be run as a separate group in two or three small paddocks where they can be closely monitored. The number of cows per bull is an important factor as it affects the calving percentage. A bulling ratio of one bull to 25 cows is recommended. When selecting a bull for breeding purposes the bull's performance records have to be checked on the basis of its offspring. Therefore, the performance of its progeny will determine its performance as well.

- There are other features (body conformation), which can be selected for. Such features include: • Strong and straight legs • The penis and scrotum should not be pendulous • It should have a wide and moist muzzle • The bull should be masculine.

- Nutrition in beef cattle: Animals need food to grow and maintain their body activities. The natural grassland provides the most of the feed which cattle use. In sweet veld areas, cattle would be expected to gain weight at least during the early part of the dry season. Breeders should be familiar with: • All the essential nutrients and their importance • Fodder production for beef cattle • Urea treatment of straw • - Classification of feeds into roughage, concentrates and succulents Materials: Hay, crop residues, beef concentrates, urea, water. The amount of feed consumed daily by beef cattle varies according to their age, live mass, condition and the type of feed available. In general, cattle will consume feeds containing about 90% dry matter in daily amounts equal to between 2.5 and 3% of their live mass. The amounts usually decrease with increasing age and condition until, for example, an old cow or bull in heavy condition may consume feeds equal to about 1.5% of its live body weight. At the same time, a mature cow on dry grazing may consume feeds equal to about 1.5% of live mass, whereas the same animal would consume a readily available and easily digested concentrate mixture in amounts equal to more than 3% of its live mass.

- The following nutrients are needed by the animal for maintenance, growth and production. Energy from substances such as carbohydrates, fats and oils. They are energy producing nutrients expressed by terms such as total digestible nutrients (TDN) or metabolizable energy (ME). Proteins Provides amino acids. They are nitrogen containing nutrients expressed as crude protein (CP), digestible crude protein (DCP), or digestible protein. Minerals These are specified as elements such as calcium, phosphorous, copper and iodine. They are grouped into major minerals and trace elements. Water Needed in many biochemical reactions and facilitate feed intake. Fat-soluble vitamins include vitamin A, D, E, K. Water-soluble vitamins include the vitamin B-Complex.

- Characteristics of animal feeds: Feed for livestock are classified into three broad groups: roughage, concentrates and succulents. Roughages These provide energy which can be used for movement and producing heat. They are also used in building up reserves. They are a cheap form of basal diet in beef cattle. Carbohydrates are low in moisture, fibrous and low digestibility. Energy is required in large amounts by the animal for physical activity, maintaining body temperature, growth, reproduction and lactation. Cereal grains such as maize, sorghum, millet and some of their milling by-products provide the richest sources of highly digestible starches and sugars. The bulk of the energy consumed by most cattle comes from grazing and natural forages, which have energy content of 45-55% total digestible nutrients (TDN). Concentrates These feeds are low in fiber and rich in digestible nutrients. Concentrates usually have low moisture content (about 10%) and over 70% total digestible nutrients. Calcium levels are usually relatively low (0.05 to 0.2%) and phosphorous levels relatively high (0.4 to 1.2%). Concentrates are sub-divided according to the most important nutrients they contribute in compounded rations, e.g. protein concentrates such as the oil seed cakes (30 to 50 % CP) and energy concentrates such as the cereal grains (80% or more TDN). Concentrates are expensive feeds for ruminants since they have to be purchased. Because of this, they are only fed as supplements to achieve high production. Succulents They include all feeds with high moisture content (10 to 30% dry matter). Most succulent feeds are highly palatable to stock and can be consumed in relatively large quantities by ruminants (up to three times as much as dry feeds by mass). Examples of succulent feeds include green grass, silage, pumpkins and melons. Fodder establishment How to make hay. Hay is fodder, which has been dried and stored without further processing. When dried, hay can be stored indoors and fed to cattle in the dry season when feed is scarce. Dried feeds such as hay are an important part of the diet for young and old livestock alike. Making hay.

- Animal Health Management: Good animal health management is important to improve beef production. As a result, there is need to control and prevent the spread of diseases. Tickborne diseases, for example, pose a major challenge to beef production and management to smallholder farmers, particularly those in the communal areas - through lack of adequate tick control. Breeders should be familiar with: • Internal and external parasite control measures • Identifying a diseased animal and be able to come up with the recommended treatment for the specific disease • A vaccination program for prevention of certain common diseases Materials: Flip chart, magic markers, pictures of common diseases The main signs of worm infestation in cattle are diarrhea, emaciation, rough coat, swollen abdomen and bottle jaw (swelling under the jaws). Worms cause heavy economic losses hence the need to control them. There are three main methods of controlling internal parasites in cattle, namely: a) Dosing Cattle should be dosed at stipulated intervals using a broad-spectrum dewormer. It is best to use a different type of worm remedy than the one used last time each time cattle are dewormed. The most important group of animals to be dewormed are young animals, animals being kept for fattening and pregnant animals. A strategic dosing program has been in use in the past whereby cattle are dosed twice a year – that is at the beginning of the dry season (when cattle are being fed on maize stover soon after harvesting) and at the onset of the first rains. Beef cattle need proper health management However, cattle can be dosed when they are showing signs of worm infestation. Also, all new brought in animals should be dewormed before they are introduced to the rest of the herd. 34 Beef cattle production and management Practical Action b) Feeding animals properly Healthy, well-fed animals can fight off infections and can develop a good immunity against worms. c) Good pasture management to reduce build up of parasites.

- Good pasture management involves the following: • Avoid over-stocking as it causes the pasture to have large numbers of worm larvae on it if the animals grazing on it are suffering from worm infestations. When other animals graze on the same pasture they easily get infected. • Practice rotational grazing as it allows the pasture to rest and most of the worm larvae die before they infect other cattle. • Grazing different kinds of animals together on the same pasture. Worms are known to be species specific. • Graze different age groups of animals on different pastures. Young animals are more likely to get infection from older animals and are affected more severely than older animals. Pasture management reduces parasites. Cut along grass so that sunlight will kill many worm eggs in faces on the ground For liver flukes • Fence off swampy areas to keep cattle away • Use water from boreholes, wells or from fast moving rivers • Some farmers keep ducks. These ducks eat snails which are the intermediate host of the immature liver flukes.

- Tick control: Ticks cause the following problems to animals: they are transmitters of tick borne diseases, loss of blood, irritation and also animals become prone to other bacterial, fungal and other parasite infections, hence the need to control them. - Vaccinations A vaccine is a preparation containing an infectious agent in a form, which does not cause disease, and when given to an animal it will produce resistance to that specific disease. When exposed to that infectious agent, the animal will not suffer from that disease. Farmers routinely vaccinate against the common diseases.

- Identification and Record Keeping: There is need for any beef cattle farmer to have an identification system to be able to keep production records. Ideally, the system or method of marking animals for identifying or recording must be permanent, easily applied and clear enough to read from a reasonable distance. Breeders should be able to: • Articulate the different methods of identifying beef cattle • Appreciate the importance of information and records management in beef cattle production and management. Pedigree cattle that can be identified individually are exempted from these regulations. Cattle need to be marked for ready ownership identification and prevention of stock theft and recovery of stolen and stray animals. Marking is usually done with hot iron brand and comprises a set of numbers, or letters. Each individual cattle owner has to have this brand. Ownership brands provide an important source of protection to the legal cattle owner. Methods of marking animals Many different methods and combinations are used to identify animals since no ideal method has yet been found. Branding This involves the cauterization of the skin to kill the hair follicles and so leave a visible scar or mark on the skin of the animal. This can be done using hot iron branding, chemical branding and freeze branding. Over cauterization restricts blood supply to the enclosed area and results in wounds that heal very slowly. Hot iron branding Hot iron branding requires skillful use. Good hot brands are recommended and can be read from a fair distance although they may be less satisfactory if the animal's coat is woolly. The dimensions of the branding irons are specified in the respective branding regulations, which give a good guide for management brands.

- Marketing of beef and beef products: Livestock and livestock products play a significant role in the economy of the industry. Foreign currency is also received through exports of beef and hides and skins of different livestock species. The export revenue mainly comes from the large-scale commercial farming sector. Sales of livestock and livestock products are an important source of farm income and make a valuable contribution to foreign currency earnings for the country. Breeders should be appreciating the following: • Market chains available in their market • Roles played by various actors and business development services in the market chain • Existing opportunities for commercialization of beef cattle production. Marketing is a social and managerial process by which individuals and groups obtain what they need and want through creating and exchanging products and value with others. Marketing aims to service three distinct groups of need, which are: • Basic physical needs, eg food, shelter • Social needs • Individual needs Supply and demand Supply is the quantity of products that producers can offer for sale whilst demand is the quantity of products that consumers can buy. The market operates using the above laws of supply and demand.

5-6: The Artificial Intelligence

The advent of artificial intelligence (AI) has revolutionized livestock farm management. In animal and poultry farm management, AI technology is employed to collect and analyze data for enhanced decision-making and optimization of farming operations. Through the use of sensors, IoT devices, and data analytics, AI systems can monitor and assess animal behavior, health parameters, and production performance. IoT devices use sensors and actuators to connect the digital and physical worlds. Sensors are the foundation of an IoT ecosystem, providing devices with the ability to collect the data used to make things happen. Some of the most common types of sensors include optical sensors for automatic street lights, temperature sensors for thermostats, and internal sensors embedded in industrial machinery. IoT devices specialize in gathering environmental data. To transmit IoT data from sensors and actuators to the cloud, IoT devices need to be connected to the internet. Real-time data analysis enables early detection of diseases, precise feeding schedules, and optimized resource allocation, resulting in improved animal welfare, productivity, and cost-effectiveness. AI has the potential to significantly impact animal breeding programs by revolutionizing genetic selection and optimization. Utilizing machine learning algorithms, AI can process vast amounts of genetic data, enabling breeders to identify desirable traits and predict breeding outcomes accurately. This facilitates the selection of superior animals for reproduction, genetic diversity preservation, and the development of healthier and more productive livestock. In conclusion, AI technology offers immense potential for improving animal farm management as well as animal breeding. With the ability to analyze, and utilize data in real time, AI enables better decision-making, enhanced efficiency, and improved animal welfare. Smart Animal Husbandry has what it takes when it comes to individual animal analysis with sensors-acquired enormous amounts of data and perception tools smartly occupying its core. The aim of smart animal husbandry is to address the stagnation in animal husbandry productivity caused by mixed traditional practice, instability in climate, and environmental and socio-economic phenomena. Smart animal husbandry is considering the applications and techniques that are involved in it in addition to the prevailing challenges and prospective opportunities that are comprehensively identified. Therefore, the main goal of this chapter is to reveal and bridge the gap in the existing works.

Some research questions applicable to this chapter are:

(a) How can breeders address the existing questions on smart animal husbandry data?

(b) What are the applications of animal measures in smart animal husbandry?

(c) What are the mainstream techniques used in (b)?

(d) What are the prevailing challenges and opportunities therein for future research and more effective smart animal husbandry? The research questions raised in this chapter are appropriately addressed and the findings are presented in the subsequent section.

5-7: Components of a Smart Livestock Farm or Automated System

Though, as explained above the components can vary depending on the specific needs and goals of the farm, any automated livestock system consists of four component framework - physical structure (hardware), data acquisition, data processing, & analytics (software), embedded system, and control systems (i.e. solenoid valves), as explained below:

1. Hardware: Selection and installation of hardware components such as motorized ball valves, robots, drones, conveyor belts, gateways, image processing lenses, and system integration, calibration, testing, and maintenance lie under the hardware category.
2. Software: ML (machine learning), cloud storage, AI (artificial intelligence) algorithms, application development for remote monitoring, SMS, and E-mail alert configurations.
3. Embedded Systems: RFID devices, Micro-controllers, sensors, communication protocols, and PLC firmware.
4. Control systems: closed loop, open loop system, plant specification, and decision loops

As depicted above, every one of these systems generally has a set of smaller components that interact together. A programmed system links the constituents harmoniously to initiate an automated stage or tackle a farm problem...

Automation Components Used in Livestock Automation or Smart Farms

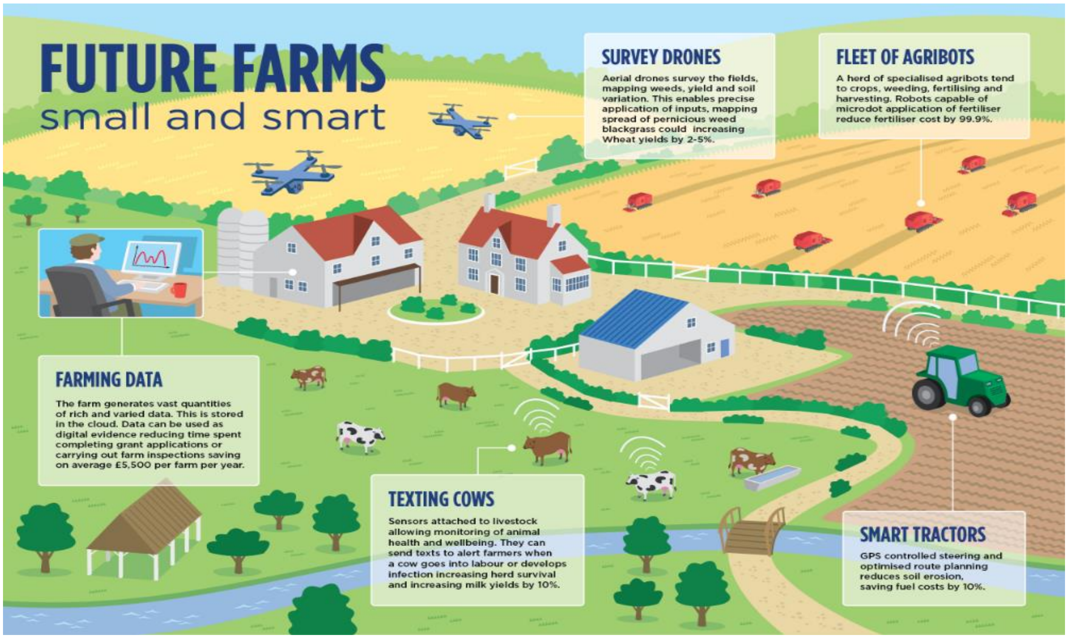
The most common automation technologies used in livestock farms:

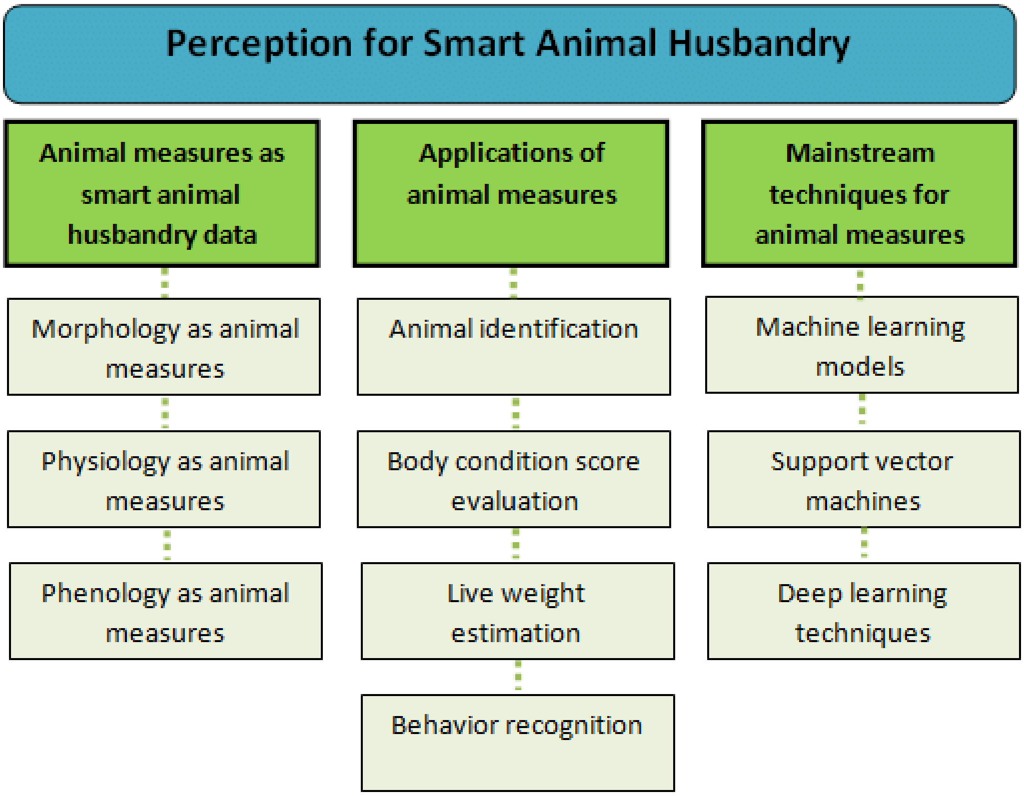
1. Sensors (RFID, Motion, Geo spatial, Thermal and motion): Sensors can be used to collect data on various aspects of animal health and behavior, including temperature, humidity, air quality, water quality, and feed consumption.
2. Automated feeding systems: Automated feeding systems can deliver feed to animals based on their individual needs, reducing waste and improving productivity.
3. Environmental / weather control systems: Environmental control systems can regulate temperature, humidity, and ventilation in animal housing, creating optimal conditions for animal health and productivity.
4. Data management systems: Data management systems can collect and analyze data from sensors and other sources, providing insights into animal health, behavior, and production.
5. Robotic milking and shearing systems: Robotic milking and shearing systems can automatically milk and shear animals, reducing labor costs and improving efficiency.
6. Automated cleaning systems: Automated cleaning systems can clean animal housing and equipment, reducing the risk of disease and improving animal health.
7. Electronic identification systems: Electronic identification systems can track individual animals, allowing farmers to monitor their health and productivity.
8. Remote monitoring and control: Remote monitoring and control systems allow farmers to monitor and control farm operations from a distance, improving efficiency and reducing labor costs.
9. Artificial intelligence and machine learning: Artificial intelligence and machine learning technologies can analyze data from sensors and other sources, providing insights into

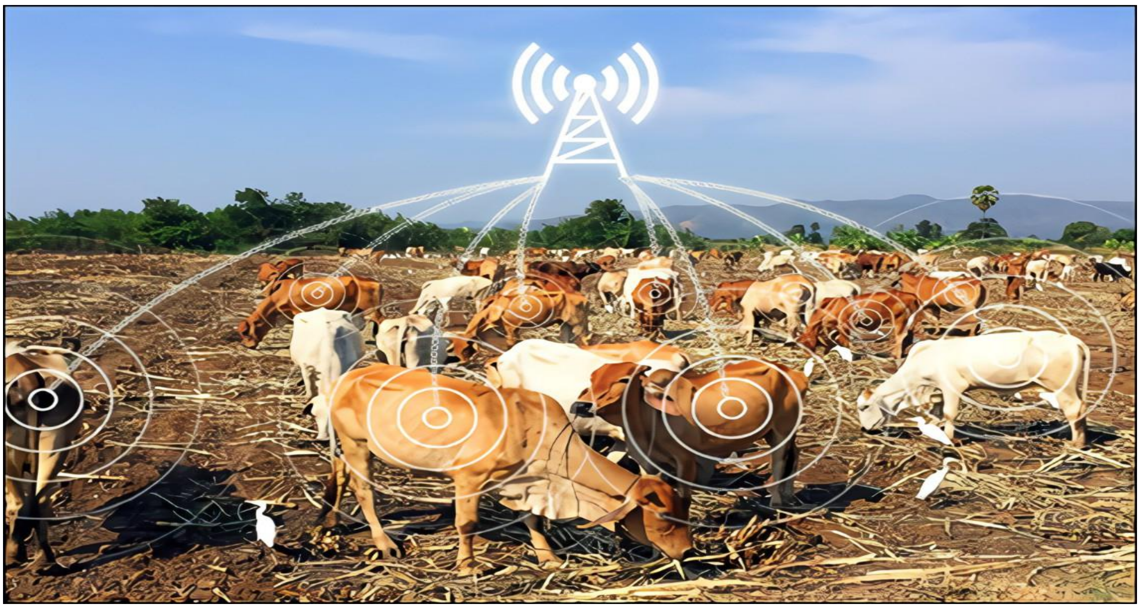
animal health, behavior, and production and allowing farmers to make data-driven decisions.

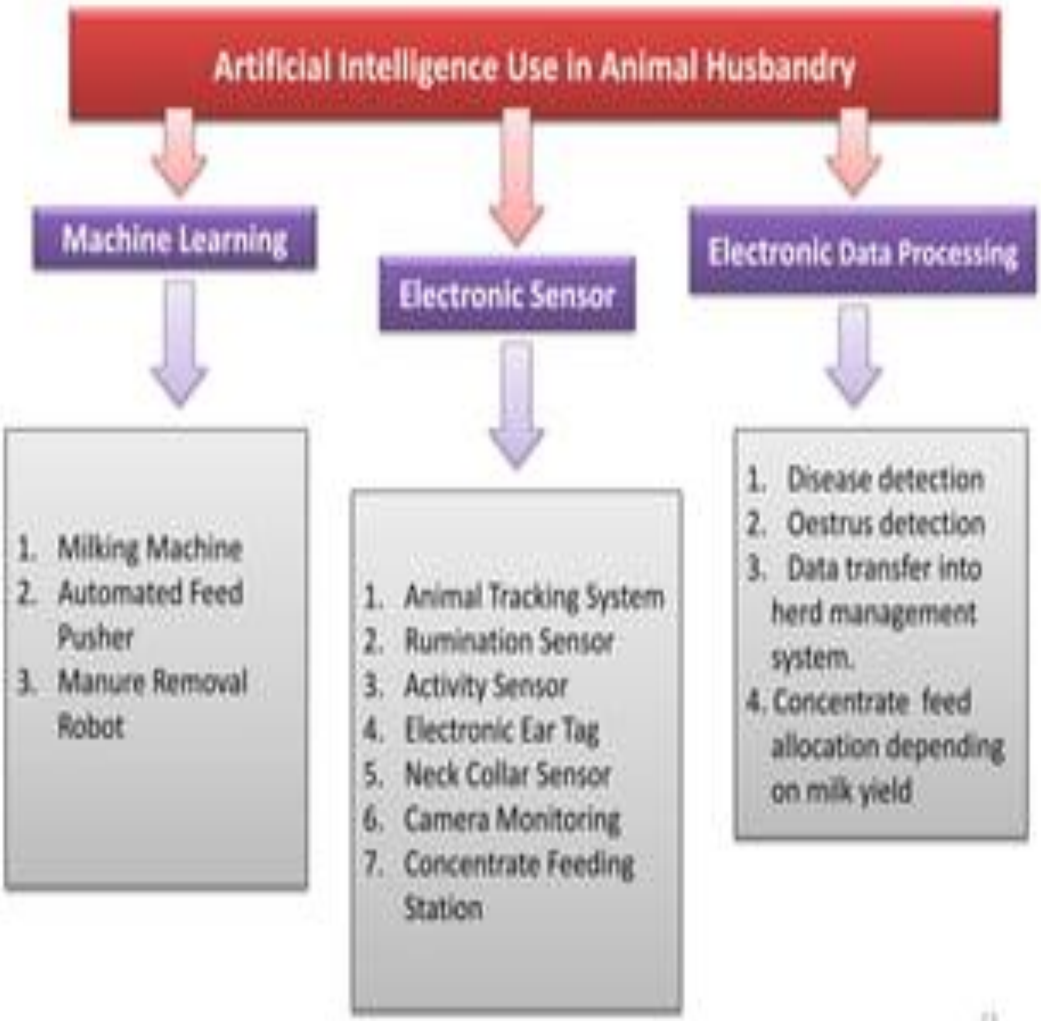
10. Energy management systems: Energy management systems can optimize energy use on the farm, reducing costs and environmental impact.
11. Robotic Actuators: These devices execute the decisions made by the control system, such as adjusting the temperature or humidity levels, opening and closing gates, and administering feed or medication.
12. Livestock / precision Monitoring Systems: Automated systems that track the health and location of livestock using sensors, GPS, and EID (electronic identification). These systems help farmers manage their herds more effectively, reducing labor costs and animal stress.
13. Robotic slaughtering and processing systems: Robotic arms and conveyors are to perform the tasks of slaughtering, cutting, and packaging of meat products in a livestock farm.

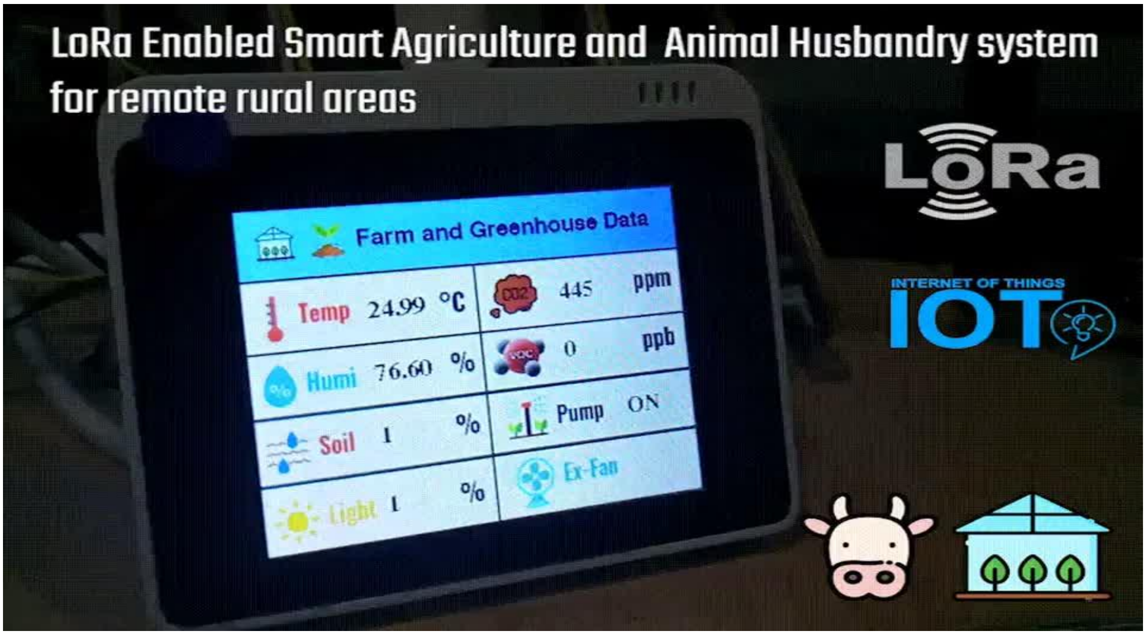
Images 1 to 10 summarize the Intelligent Perception for Smart Animal Husbandry.




Perception for Smart Animal Husbandry
Animal measures as smart animal husbandry data
Morphology as animal measures
Physiology as animal measures
Phenology as animal measures
Applications of animal measures
Animal identification
Body condition score evaluation
Live weight estimation
Behavior recognition
Mainstream techniques for animal measures
Machine learning models
Support vector machines
Deep learning techniques

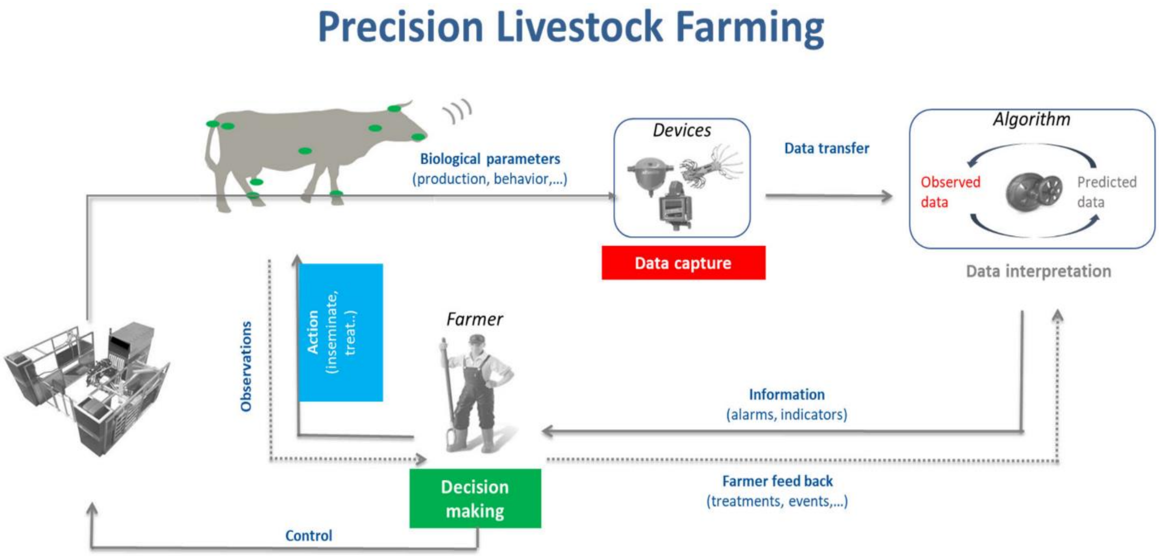



Artificial Intelligence Use in Animal Husbandry
Machine Learning
Electronic Sensor
Electronic Data Processing
1. Milking Machine
2. Automated Feed Pusher
3. Manure Removal Robot
1. Animal Tracking System
2. Rumination Sensor
3. Activity Sensor
4. Electronic Ear Tag
5. Neck Collar Sensor
6. Camera Monitoring
7. Concentrate Feeding Station
1. Disease detection
2. Oestrus detection
3. Data transfer into herd management system.
4. Concentrate feed allocation depending on milk yield



Livestock Monitoring Using IoT / Smart Animal Husbandry Sensor.


A Smart Way To Monitor Your Livestock
With IoT


Precision Livestock Farming
Biological parameters
(production, behavior,...)
Devices
Data capture
Data transfer
Algorithm
Observed data
Predicted data
Data interpretation
Observations
Action (inseminate, treat..)
Farmer
Information
(alarms, indicators)
Decision making
Farmer feed back
(treatments, events,...)
Control

Historically, dairy cattle management practices were primarily oriented towards optimizing milk production and ensuring the health and well-being of the animals. The primary goal was to meet the demands of growing populations for dairy products. The nurturing and care of dairy cattle formed the bedrock of this endeavor, with a focus on maximizing milk yields while safeguarding the animals' welfare. The increase in efficiency and yield in dairy farms cannot take place without the development of innovations and exploitation of using SMART management as follows:

- For the breeding of animals exploited for milk production is strictly necessary under the current conditions imposed many breed societies and unions. In this way, the dairy cattle breeding sector demonstrates a commitment to responsible food production, with direct results on sustainable agriculture and the environment.

Advancements in breeding techniques have also left an indelible mark on the annals of dairy cattle management history. Selective breeding emerged as a powerful tool for improving milk production, enhancing the quality of milk, and developing breeds that were better adapted to specific environmental conditions. These strategic breeding practices translated into tangible benefits for the dairy industry, contributing significantly to heightened productivity and enhanced profitability. Over time, the dairy cattle themselves became emblematic of specialized traits and characteristics that had been honed through generations of careful breeding. Moreover, historical perspectives on dairy cattle management encompass the development of essential technologies and infrastructure to support the industry. The introduction of milking machines revolutionized the labor-intensive process of hand milking, significantly increasing efficiency and reducing the burden on dairy farmers. Refrigeration systems enabled the safe storage and transportation of dairy products, extending their shelf life and facilitating access to distant markets. Improved transportation methods further bolstered the dairy industry's reach, allowing dairy products to traverse wider geographical boundaries. In essence, the historical evolution of dairy cattle management reflects a dynamic interplay between tradition and innovation, where the industry's enduring commitment to enhancing productivity, animal welfare, and food safety has driven a continuous cycle of adaptation and progress. These historical insights provide a valuable backdrop for understanding the facets of contemporary dairy cattle management practices. Modern dairy cattle breeding and genetics has wrought a revolution in the dairy industry, ushering in an era where the selection and enhancement of desirable traits in dairy cattle are not just aspirations but achievable realities. This transformation has yielded an array of benefits, ranging from increased milk production to heightened reproductive performance, bolstered disease resistance, and an overall upswing in genetic progress within dairy herds. Contemporary scientific inquiry has played a pivotal role in advancing our understanding of the genetic underpinnings of various traits essential to dairy cattle. These studies have also paved the way for the application of cutting-edge genomic technologies in the realm of dairy cattle breeding. By unraveling the genetic tapestry, researchers have enabled the precise targeting of traits that matter most to the industry and the animals. Genetic selection for reproductive performance stands as a linchpin in dairy cattle breeding programs. Research highlighted the tantalizing prospect of simultaneous genetic selection for augmented milk/meat yield and enhanced reproductive performance, underscoring the industry's quest for multifaceted gains. The advent of genomic technologies has ushered in an era of unprecedented precision in selecting for reproductive traits, resulting in enhanced genetic gains that drive the industry forward. Disease resistance, with a particular emphasis on mastitis, has assumed a paramount position in the breeding objectives of dairy cattle. Research also championed the inclusion of mastitis resistance in breeding goals, and genetic mapping and the identification of quantitative trait loci (QTL) related to mastitis resistance have furnished vital insights into the genetic determinism of this trait. Selection for mastitis resistance, based on somatic cell counts, has been widely implemented, fortifying the industry's battle against this costly malady.

- Understanding of diseases and their transmission improved over time, the paradigms of dairy cattle management underwent significant evolution. A pivotal shift occurred as management practices began to incorporate robust disease prevention and control measures. The previous work underscored the paramount importance of monitoring and addressing the prevalence of pathogens in dairy cattle populations. These pathogens not only posed health risks to the animals themselves but also had implications for human health through zoonotic transmission. The integration of disease management strategies into dairy cattle management practices marked a critical turning point in ensuring the sustainability of the industry and safeguarding public health.

- As global temperatures continue to rise due to climate change, heat tolerance has surged in significance. Researcher elucidated the necessity of integrating genomic information with environmental and physiological parameters to breed heat-tolerant dairy cattle capable of thriving in future climatic conditions . Genetic evaluation and selection for thermotolerant traits have emerged as cornerstones in fortifying the resilience of dairy cattle in challenging environments.

- Moreover, functional traits, such as longevity, fertility, and workability, have garnered heightened attention in contemporary dairy cattle breeding programs, championed the incorporation of functional traits into selection criteria, recognizing their profound potential to enhance the economic viability of dairy farming. The integration of these traits into selection indices has engendered a more holistic breeding approach, aiming not only for enhanced productivity but also for robust and sustainable dairy herds. The proliferation of genomic technologies has emerged as the fulcrum upon which modern dairy cattle breeding and genetics pivot. Genomic selection, which harnesses genomic information to predict an animal's genetic merit, has engendered a seismic shift in breeding programs. Researcher offered a comprehensive exploration of these emerging technologies and their transformative impact on breeding strategies, heralding a future where genetic diversity flourishes, and selection efficiency reaches unprecedented heights. In the ensuing sections, breeders delve deeper into the specific facets of modern dairy cattle breeding, unraveling the intricate web of genetic progress and technological innovation that drives the industry's evolution. As the dairy industry continually seeks avenues for optimization, nutrition emerges as a fundamental pillar in the pursuit of enhanced feed efficiency and the holistic well-being of dairy cattle. In this modern era of dairy cattle management, nutrition has evolved far beyond the simple provisioning of sustenance.

- It has embraced a multifaceted approach aimed at optimizing nutrient intake, streamlining feed efficiency, and ultimately bolstering the robustness of dairy cattle. Scientific exploration, through a multitude of studies, has unearthed profound insights into the profound impact of nutrition on various facets of dairy cattle management. One remarkable stride in nutritional advancement revolves around the optimization of immune function through nutrition. Moreover researcher underscored the pivotal role of nutritional strategies in fine-tuning dairy cattle immunity. The study illuminated the intricate interplay between the immune system and nutrient metabolism, emphasizing the imperative of maintaining nutritional and immunological equilibrium. This equilibrium acts as a bulwark against health disorders and production losses, ensuring the dairy cattle remain healthy and productive.

- Heat stress, a formidable challenge in dairy cattle production, takes center stage in regions characterized by scorching climates. Other research delved into the ramifications of heat stress on dairy cattle and charted the promising avenues for nutritional interventions. The study elucidated the paramount importance of energy status and the pivotal role of nutrition in mitigating the detrimental effects of heat stress on milk production and overall performance. In dietary formulation and evaluation, advancements in computer software programs have wrought transformative changes. It was expounded upon the development of computer programs tailored for the least-cost formulation and evaluation of diets-a veritable boon to the feed industry. These programs seamlessly integrate feed inventory with precise feed formulations, facilitating more accurate and efficient diet planning, thereby elevating the precision and efficacy of dairy cattle nutrition. Genomic technologies have cast their transformative shadow upon nutritional strategies in dairy cattle management.

- Research cast a spotlight on the potential of cattle genomics in forging nutritional strategies aimed at optimizing efficiency and sustainability in milk production. The integration of genomic and phenotypic data through the prism of systems biology has expanded our comprehension of the biological mechanisms governing nutrient utilization.

The emergence of precision dairy farming technologies is a transformative tool for enhancing efficiency, productivity, and sustainability. These technologies, utilizing advanced sensors and data analytics, are instrumental in monitoring various aspects of dairy cattle production. System dynamics approaches have been employed to model farm dynamics, providing insights into ranch profitability and environmental considerations. Feed efficiency, as defined by the fraction of feed energy or dry matter captured in products, has more than doubled for the dairy industry in the past 100 yr. This increased feed efficiency was the result of increased milk production per cow achieved through genetic selection, nutrition, and management with the desired goal being greater profitability. With increased milk production per cow.

5-8: Reference

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Chapter 6

Diseases and Health

Diseases and Health

6-1: Spotlight on Livestock Health Management

Keeping cattle healthy is a top priority for livestock owners. As a veterinary professional specializing in herd health. Veterinarians often asked about the fundamentals of cattle wellness, from providing proper nutrition to utilizing vaccinations and maintaining disease prevention protocols. The key aspects of livestock health management include good nutrition, vaccinations, sanitation, housing, and disease prevention and treatment. By proactively supporting wellness in these core areas, cattle owners can optimize growth, productivity and longevity within their herd with the followings:

1- Nutrition is the foundation of livestock wellness, providing the nutrients cattle need for bone, tissue, and muscle development. As ruminants, cattle require fibrous roughage and high-quality forage.

2- Vaccinating beef and dairy cattle is crucial for preventing illness and death losses. By administering vaccines, cattle develop antibodies and immunities against dangerous infectious diseases. The main categories of cattle vaccines include:

* Killed vaccines: Contain inactivated disease antigens. Stimulate antibody production.

* Modified live vaccines: Utilize attenuated pathogens. Induce antibody.

* Subunit vaccines: Use specific antigenic proteins from pathogens.

When designing a vaccination plan, cattle owners and veterinarians consider:

* Age: Calves vs adult cattle require different vaccine types and timing.

* Production Type: Dairy vs beef cattle have some varying vaccine needs.

* Geography**:** Regional diseases may necessitate location-specific protocols.

3- Biosecurity and sanitation practices safeguard herd health by limiting disease transmission routes. By maintaining cleanliness, cattle owners bolster wellness through reduced pathogen exposure. Biosecurity protocols prevent infectious illnesses from entering or spreading within a herd by:

* Quarantining new arrivals to check for illnesses
* Isolating sick cattle
* Restricting guest access to cattle
* Sanitizing equipment, shoes, clothing after contact
* Avoiding interactions with outside herds

4- Cleaning and Disinfection: Proper sanitation limits bacteria, viruses and parasites through regular cleaning and disinfection efforts. Key practices include:

* Manure removal from housing
* Cleaning feeding equipment like troughs
* Disinfecting surfaces using soap, water and chemical disinfectant
* Checking water systems for clean microbial quality

5- Cattle Housing and Facilities: Proper housing keeps animals comfortable while also enabling quality care and health management. Facilities should have good ventilation, space allocation and bedding.

6-2: Most Common Cattle Diseases

Cows are important to society for many reasons. They are a wellspring of meat, milk and other dairy items, just as calfskin and other side-effects. Cattle can be reared in scavenging, semi-intensive, and intensive methods. Products and bi-products play a vital role in the development of human civilization. Cattle diseases are very common problems in farms. As a farm owner, you are facing frequent diseases and the management aspects of cattle rearing. A well-managed and disease-free herd can provide optimum production. Dairy cattle give work and nourishment security to a considerable lot of the world's least fortunate individuals. Scientific knowledge will help to improve the condition of cattle farms and reduce the incidence of diseases. The management of cattle, better housing, balanced nutrition, good breeding policy, resource management, and marketing will ensure a profitable farm.

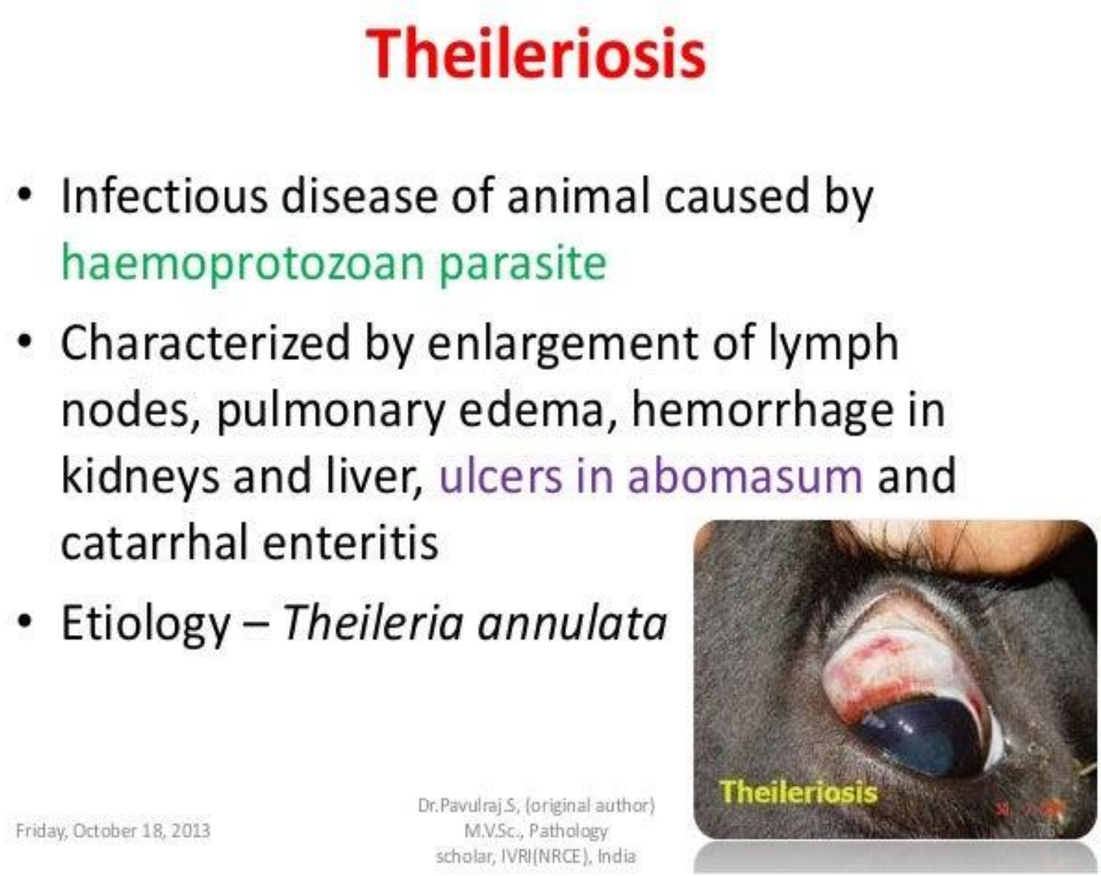
6-2-1: Theileriosis in Cattle

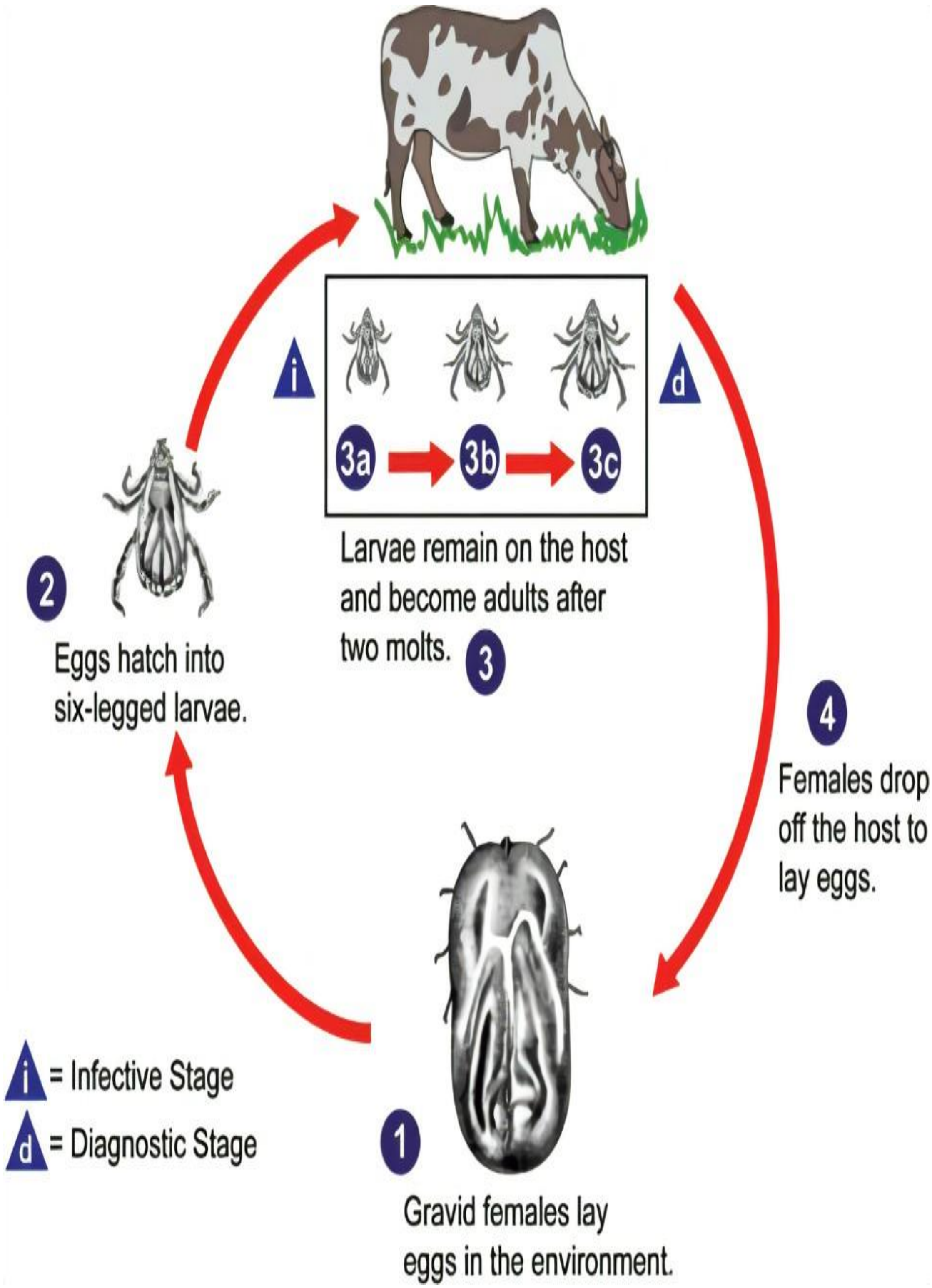
Theileriosis in cattle is a tick-borne disease caused by haemoprotozoa *Theileria spp*. The disease is manifested by high fever, enlarged lymph nodes, severe anemia, and death in some infected animals. The disease is highly endemic in South Asian countries. The Theileria infected cattle are ubiquitous in distribution and are the main reservoir of infection. Theileriosis has been recorded in animals of all ages. Calves are equally susceptible but are very mild in adult indigenous cattle. Though the indigenous cattle suffer only in appearance, they cause extensive damage to exotic cattle and their crossbreeds by being asymptomatic carriers of this infection.

Theileriosis is a disease of cattle caused by a blood protozoan parasite Theileria of which the following species are common.

- *Theirelia Parva* is highly pathogenic and causes East Coast Fever (ECF). The organism is a rod and comma-shaped but pleomorphic during a recovery phase. Approximately 80% of erythrocytes are seen parasitized with 1 to 12 organisms. Immunity persists after natural infection. The cross-immunity with *T lawrenci* only and not with others.
- *Theileria annulata* is moderately to highly pathogenic, lethal for cattle but mild for buffaloes. The organism causes Mediterranian Coast Fever or Tropical Theileriosis. The erythrocytic forms are predominantly oval or annular.

- *Theileria mutans* piroplasma is pleomorphic rods, 2.0 to 5.0micron, long numerous of the first infection, rare in blood for years. Schizonts are absent within the RBC.
- *Theileria lawrenci* causes a highly fatal disease in cattle called Corridor or Rhodesian theileriosis.

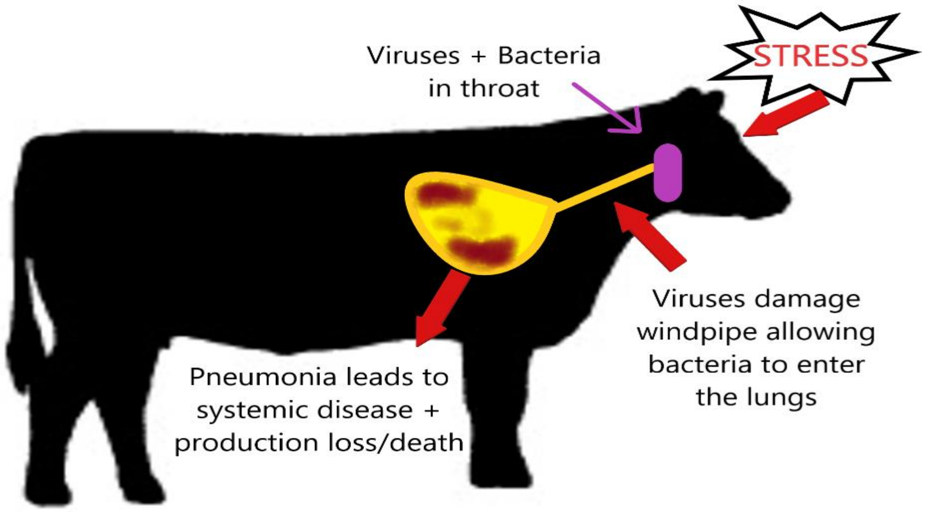




i
3a
3b
3c
d
Larvae remain on the host and become adults after two molts.
3
2
Eggs hatch into six-legged larvae.
4
Females drop off the host to lay eggs.
i = Infective Stage
d = Diagnostic Stage
1
Gravid females lay eggs in the environment.

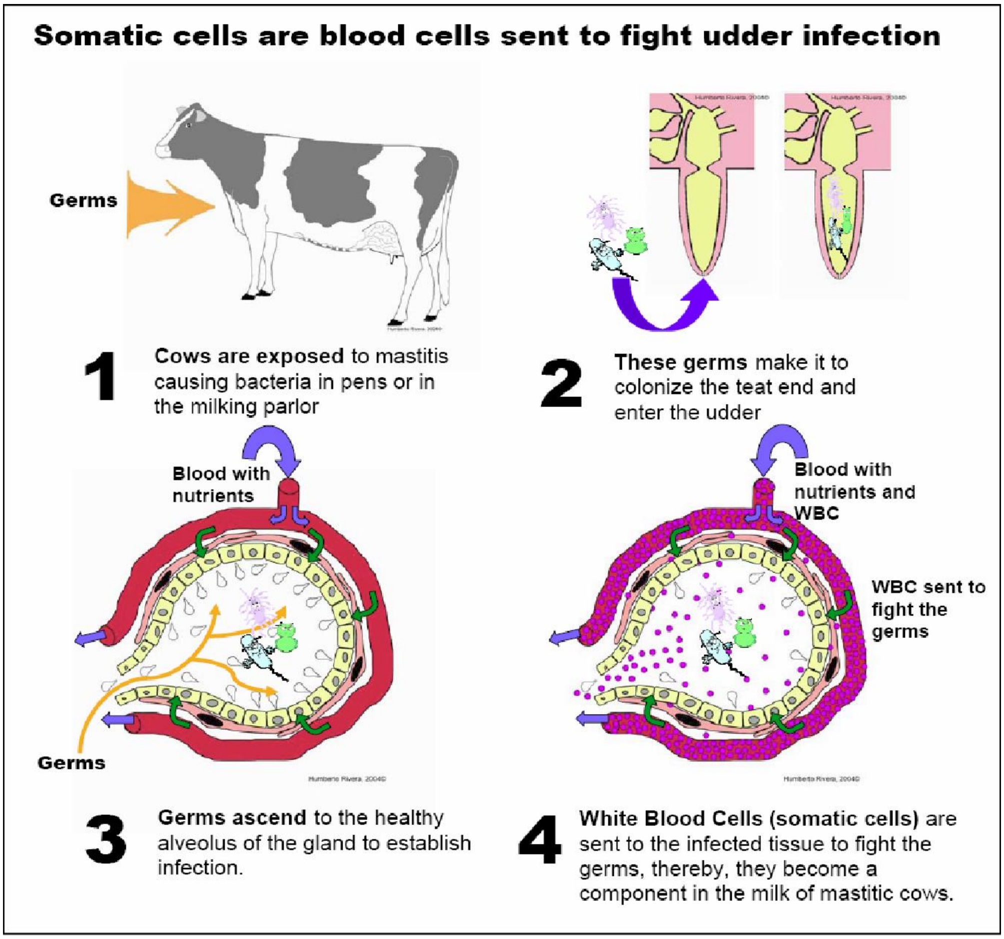
6-2-2: Bovine Respiratory Disease

Bovine respiratory disease is the most common and costly disease of beef cattle. The other name of the disease is called "Shipping Fever" as the disease appears mainly after shifting of young calves at the age of 4 weeks. The causal agents of the disease are multiple like bacteria (Pasteurella, Mycoplasma, Histophilus), virus (Parainfluenza, Bovine Viral Diarrhea), and fungus or parasites. The common signs are pneumonia, respiratory distress, coughing, weight loss, and death. The treatment includes antibiotics, expectorants, and reduction of stress. Vaccination is also available but will not give complete protection from the BRD.



6-2-3: Mastitis in Cows

Mastitis is the most deadly and costly bacterial disease of dairy cattle. Mastitis is the inflammation of udder tissue and causes a physical change of milk. There are several bacteria involved in mastitis, including *Pseudomonas, Streptococcus, Staphylococcus, E Coli, Pseudomonas, Mycoplasma*, and many more. There are many types of mastitis like clinical, sub-clinical, acute, per acute, subacute, and chronic. The clinical signs are swelling and redness of the udder changes the quality of milk, reduced milk production, and blindness of the udder. The treatment of mastitis done by antibiotics, anti-inflammatory, and antihistaminic drugs. The disease is prevented by improving milking hygiene, cow management, and adequate nutrition supply.



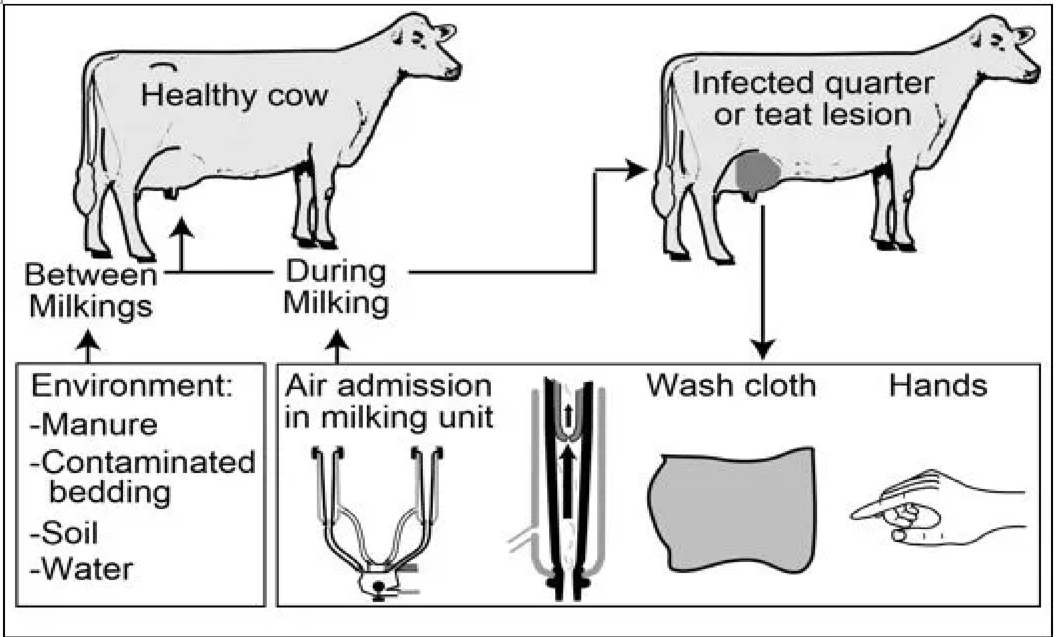
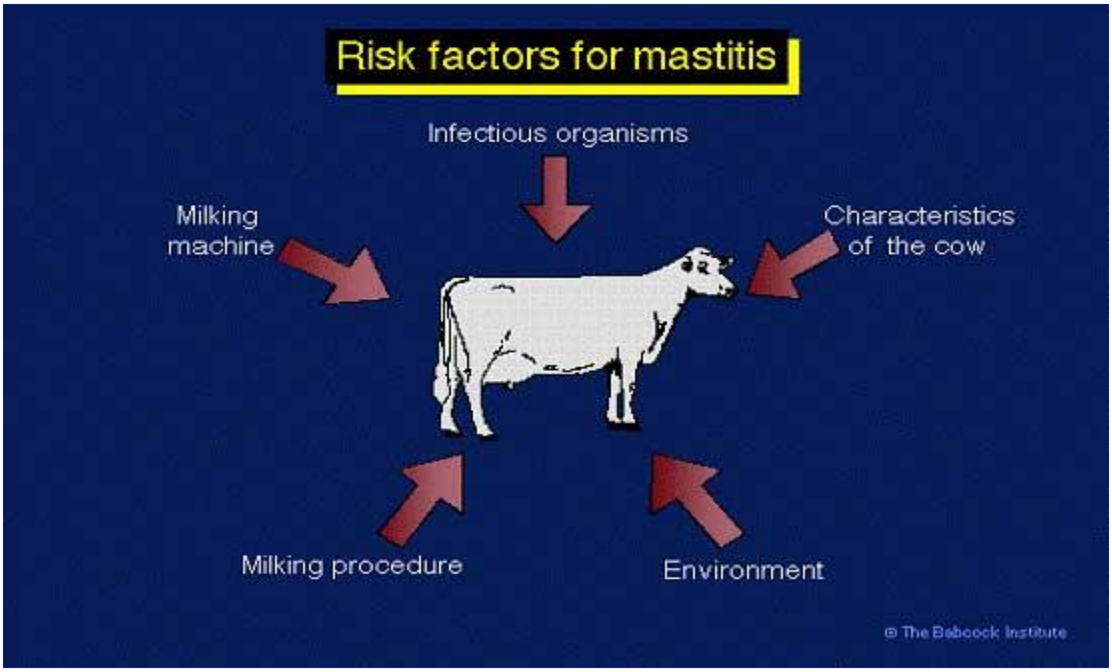


Figure 2: The major routes of bacterial transmission



6-2-3: Calf Scour

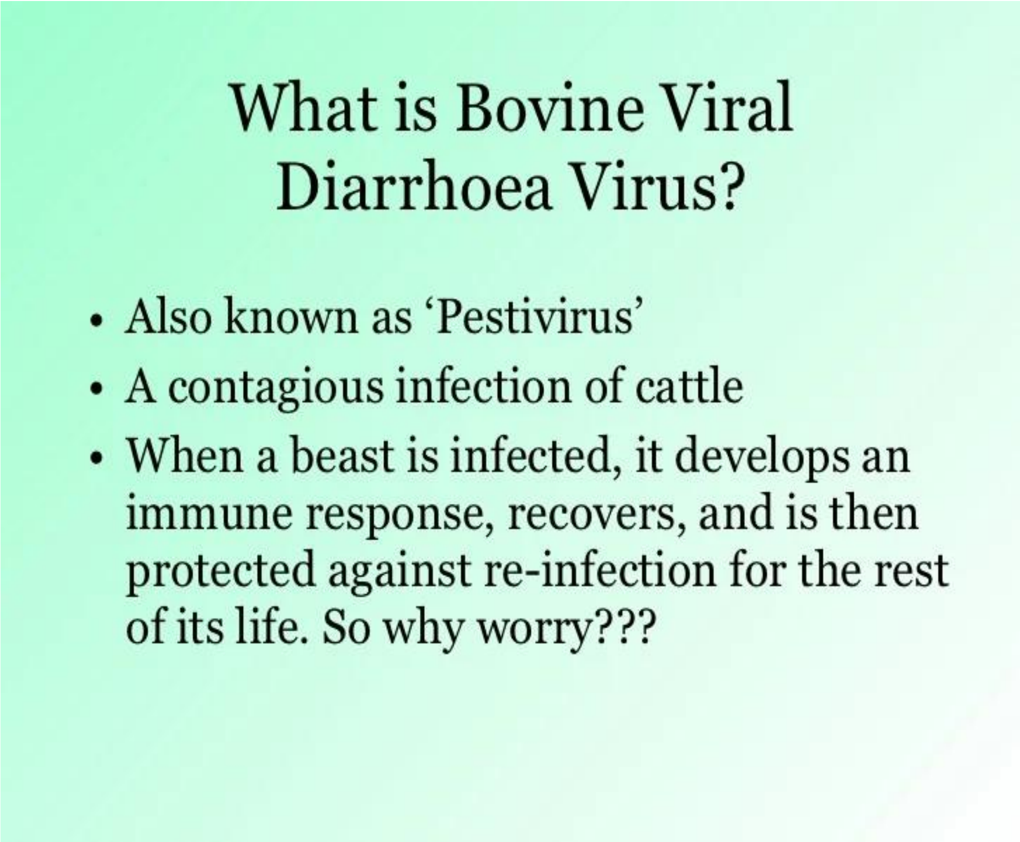
Calf scours are the main causes of calf death in dairy farms. The calf-scour is not a disease rather it is the clinical signs of many diseases. The causes of calf-scour are both infectious and non-infectious. The non-infectious causes are inadequate nutrition of the pregnant dam, inadequate environment for the newborn calf, and poor nutrition status of the calf. The infectious causes are Salmonella, E Coli, Clostridium, Rotavirus, Coronavirus, Infectious Bovine Rhinotracheitis virus, Bovine Viral Diarrhea virus, Cryptococcus and coccidiosis protozoa, and few fungal species. The clinical sign of calf-scour is diarrhea, loss of body weight, irregular hairs, weakness, poor body condition, respiratory distress, and death. The prevention includes improving the nutritional status of the pregnant cow, improving the management of the calf, proper hygiene of calf pan, supplying an adequate amount of milk, and ensuring colostrum feeding to the newborn calf.

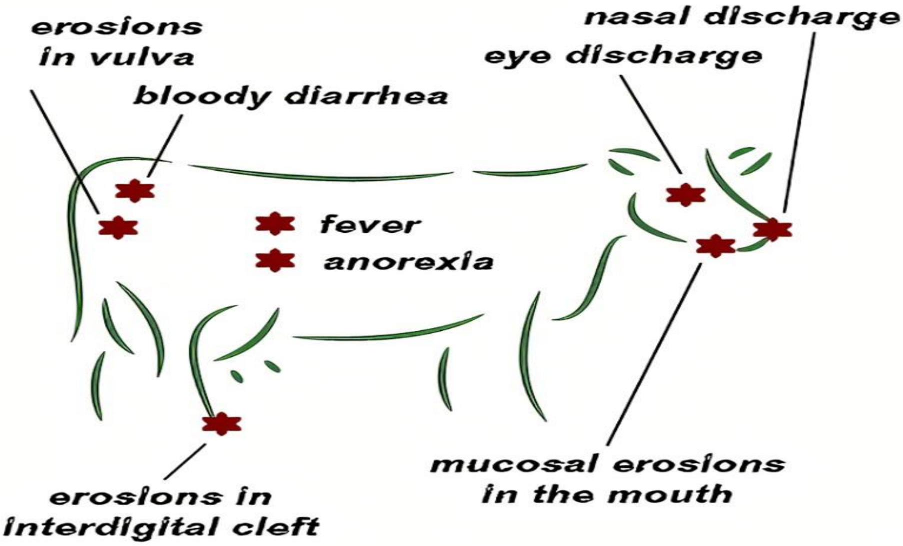
6-2-4: Pink Eye in cattle

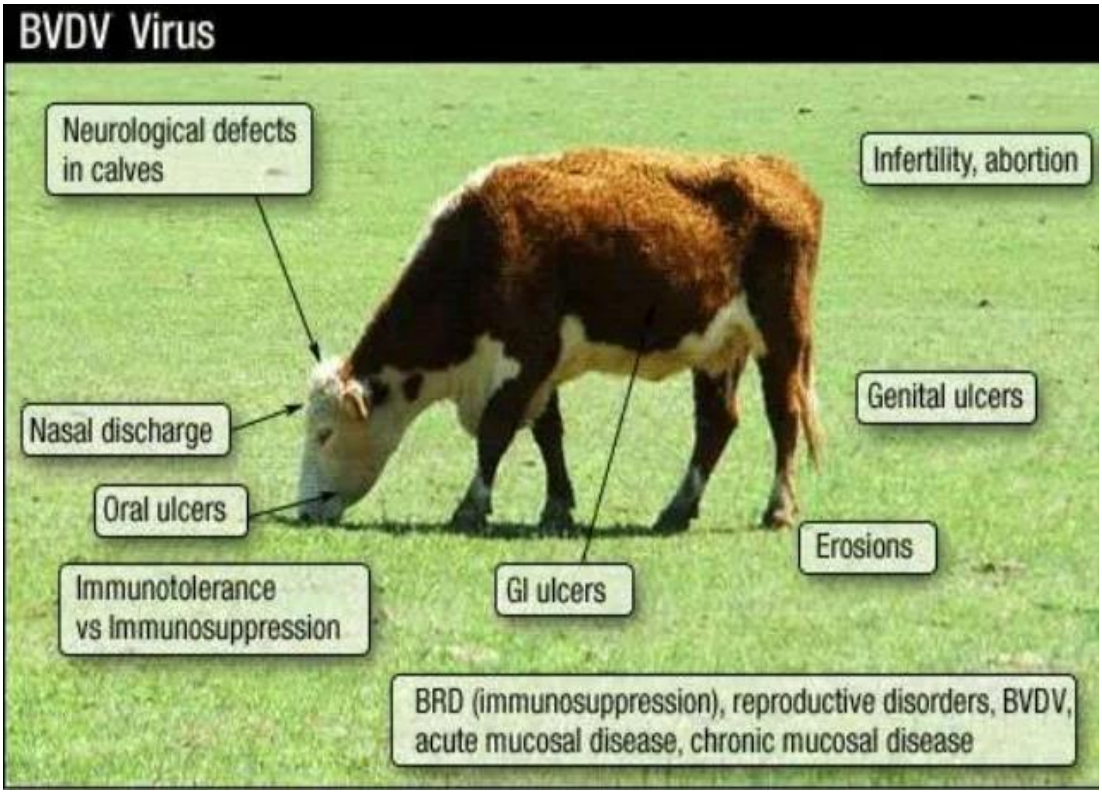
Pink eye is the bacterial inflammation of the conjunctiva of beef cattle. The disease is caused by a bacterium species *Moraxella bovis*, which is transmitted by domestic flies. The disease is mostly seen during summer. The clinical signs include pink eye, lacrimation, tearing, irritation in eyes, loss of body weight, and may lead to permanent blindness. Antibiotics (Oxytetracycline) in the sub-conjunctival region may be given for successful treatment with antihistaminic drugs. Controlling the flies in the barn will help to prevent pink eyes in cattle.

6-2-5: Bovine Viral Diarrhea (BVD) in Cattle

BVD in cattle is a very economic and reproductive important disease. BVD is caused by the BVD virus. The virus is transmitted by congenital infection after birth, direct contact with infected calves, and from the environment. The affected cow may give birth to a dead calf, infected calf, abortion, or resorption. The clinical signs include fever, diarrhea, weight loss, and death. Some calves carry the virus lifetime and spread to the next generation. There is no specific treatment of BVD. You must cull positive cases of the calf or adult cattle from your farm. The vaccines are available against BVD both live and killed virus vaccines.

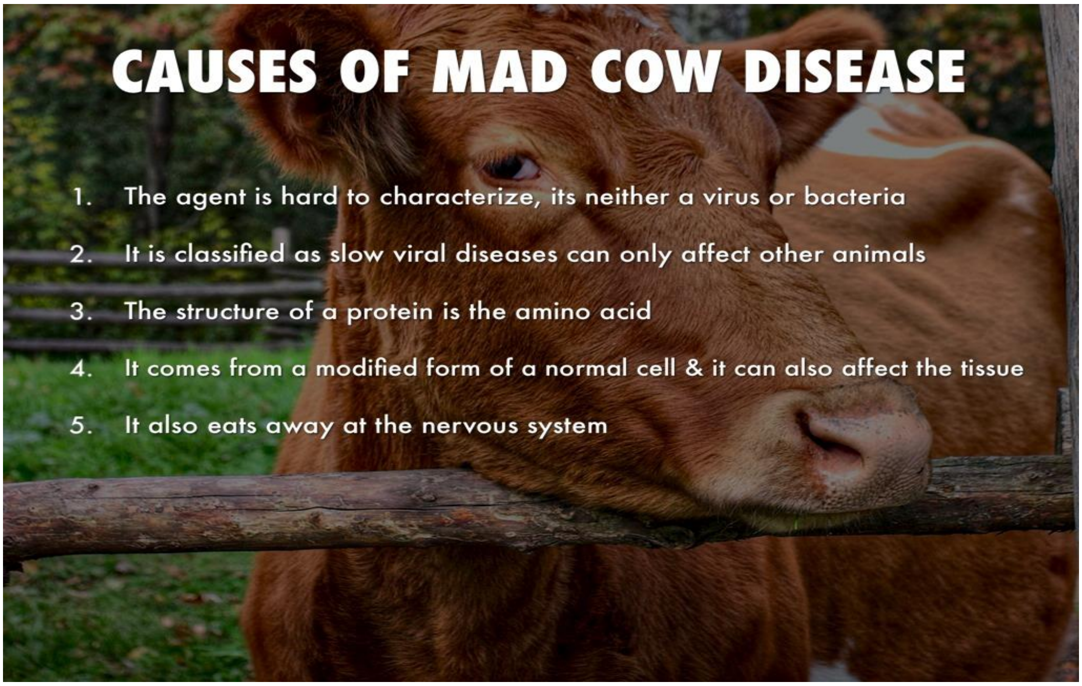

What is Bovine Viral Diarrhoea Virus?
• Also known as 'Pestivirus'
• A contagious infection of cattle
• When a beast is infected, it develops an immune response, recovers, and is then protected against re-infection for the rest of its life. So why worry???

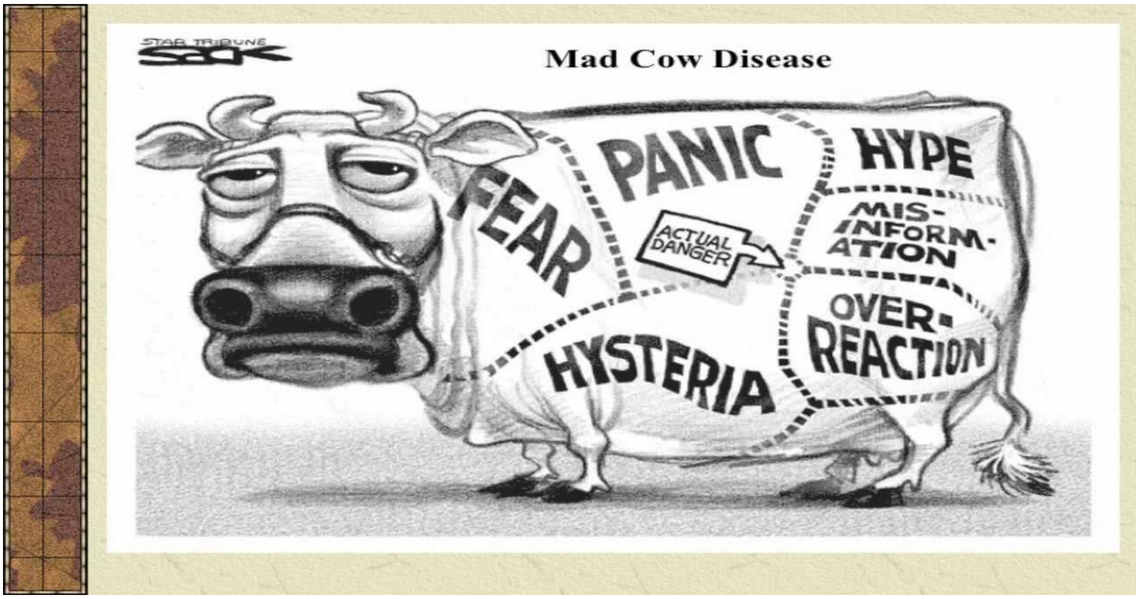

erosions in vulva
bloody diarrhea
nasal discharge
eye discharge
fever
anorexia
erosions in interdigital cleft
mucosal erosions in the mouth

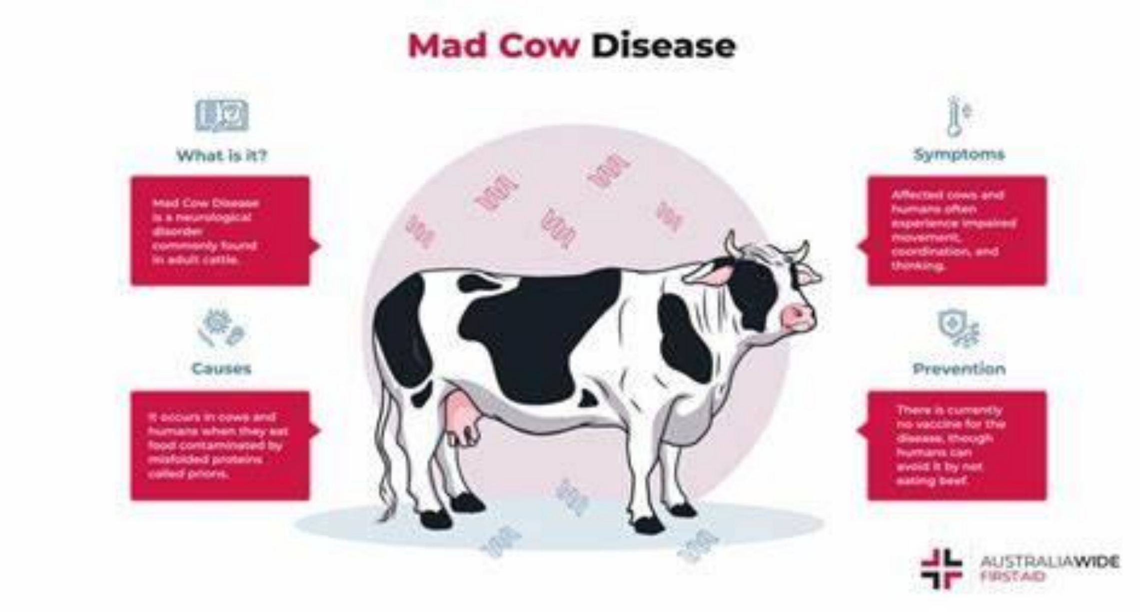


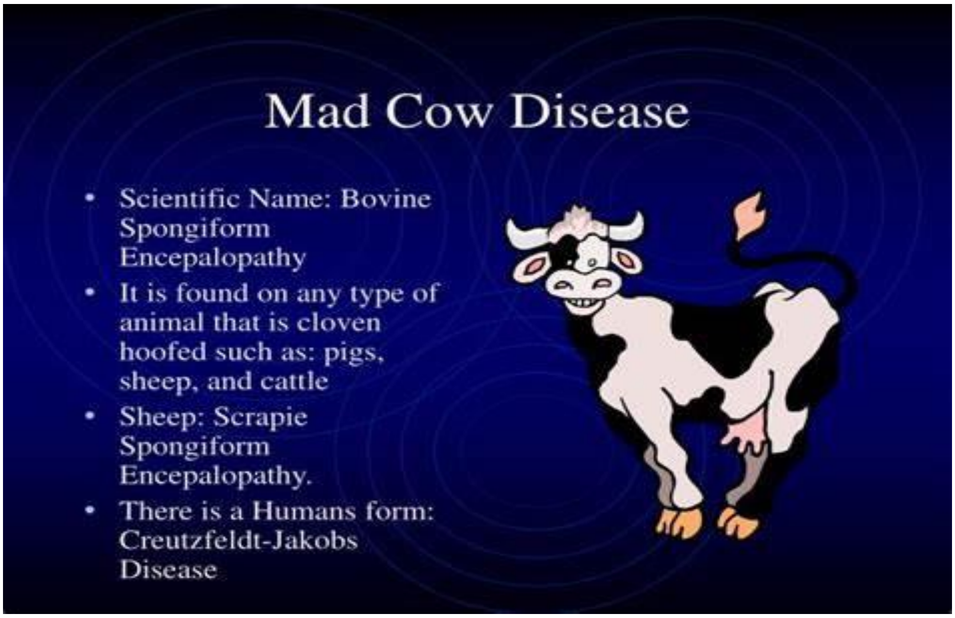
6-2-6: Mad Cow Diseases

Bovine Spongiform Encephalopathy (BSE) or mad cow is a central nervous system disease of beef cattle. The causal agent of the disease is a protein molecule prion. The disease is transmitted to humans by the consumption of meat from affected cattle. Mad cow in human beings is called variant Creutzfeldt-Jakob disease (vCJD). Milk and milk products don't transmit vCJD.


CAUSES OF MAD COW DISEASE
1. The agent is hard to characterize, its neither a virus or bacteria
2. It is classified as slow viral diseases can only affect other animals
3. The structure of a protein is the amino acid
4. It comes from a modified form of a normal cell & it can also affect the tissue
5. It also eats away at the nervous system

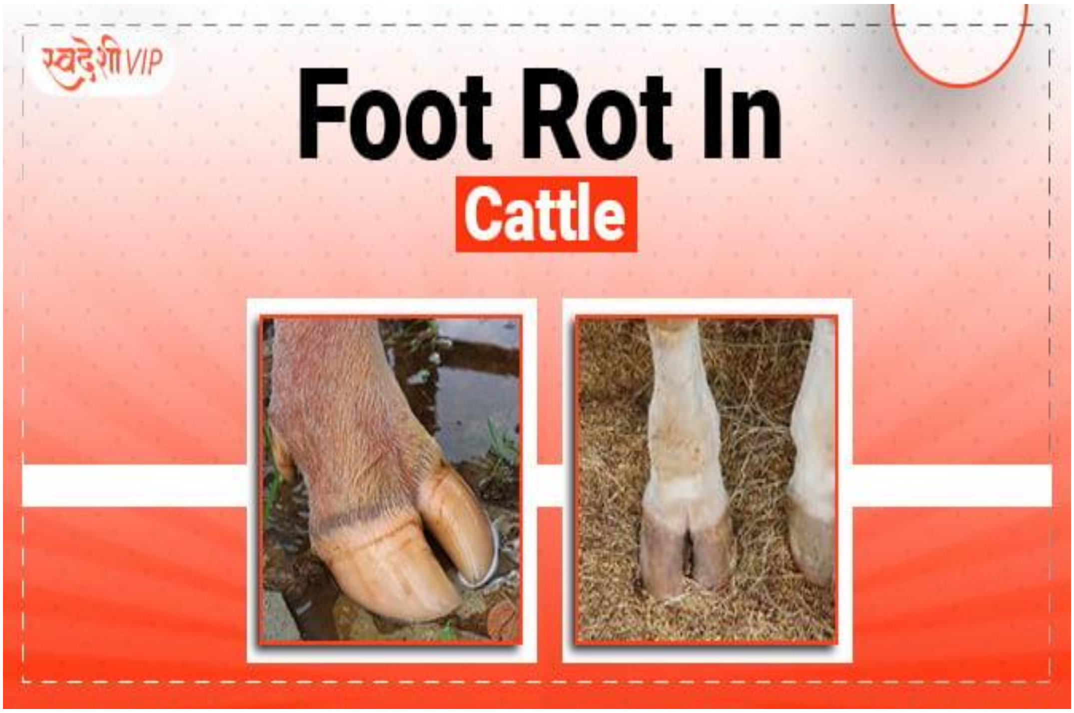

STAR TRIBUNE
SACK
Mad Cow Disease
FEAR
PANIC
HYPE
ACTUAL DANGER
MIS-INFORM-ATION
HYSTERIA
OVER-REACTION


Mad Cow Disease
What is it?
Mad Cow Disease is a neurological disorder commonly found in adult cattle.
Causes
It occurs in cows and humans when they eat food contaminated by misfolded proteins called prions.
Symptoms
Affected cows and humans often experience impaired movement, coordination, and thinking.
Prevention
There is currently no vaccine for the disease, though humans can avoid it by not eating beef.
AUSTRALIAWIDE FIRSTAID


Mad Cow Disease
• Scientific Name: Bovine Spongiform Encepalopathy
• It is found on any type of animal that is cloven hoofed such as: pigs, sheep, and cattle
• Sheep: Scrapie Spongiform Encepalopathy.
• There is a Humans form: Creutzfeldt-Jakobs Disease

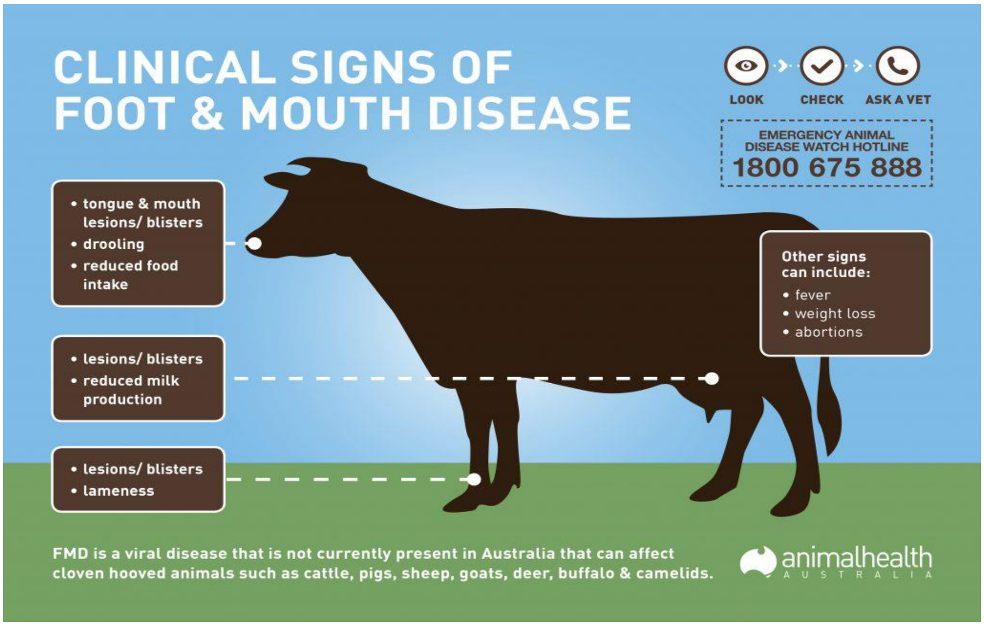
6-2-7: Foot rot in Cattle

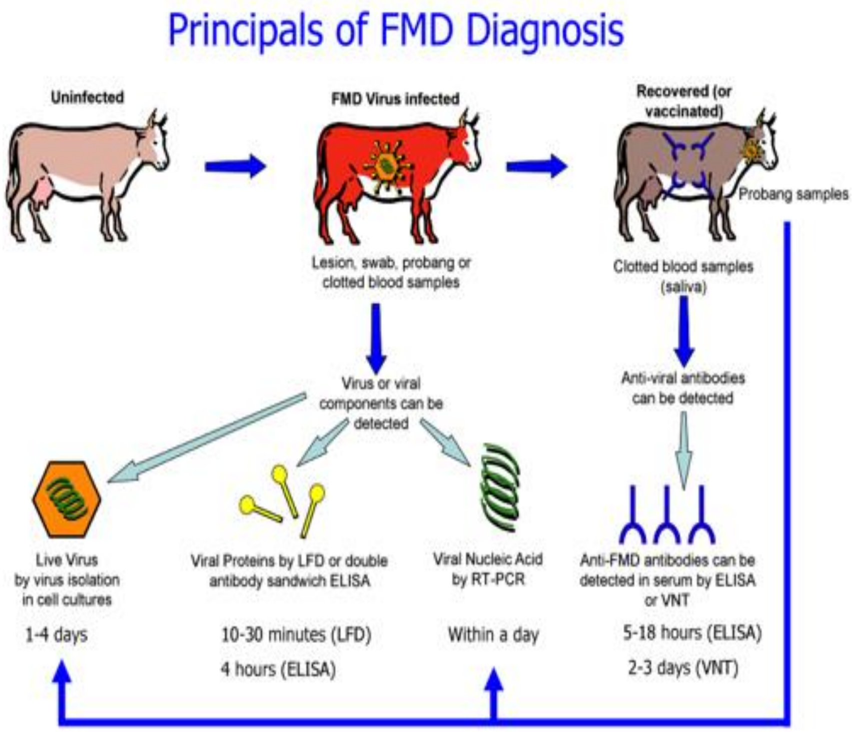
Foot rot is a very common infectious cattle disease that causes lameness at least in one foot. The causal agent is *Fusobacterium necrophorum* and *Bacteroides melaninogenicus*. The bacteria invade through the lacerated or wet skin of the foot. The disease is extremely painful and contagious. The redness, necrosis of the skin of digits, swelling, and lameness are the clinical signs of footrot in cattle. The treatment is done by antibiotics, dressing with antiseptics, and antihistamines.



6-2-8: Foot and Mouth Disease (FMD) in Cattle

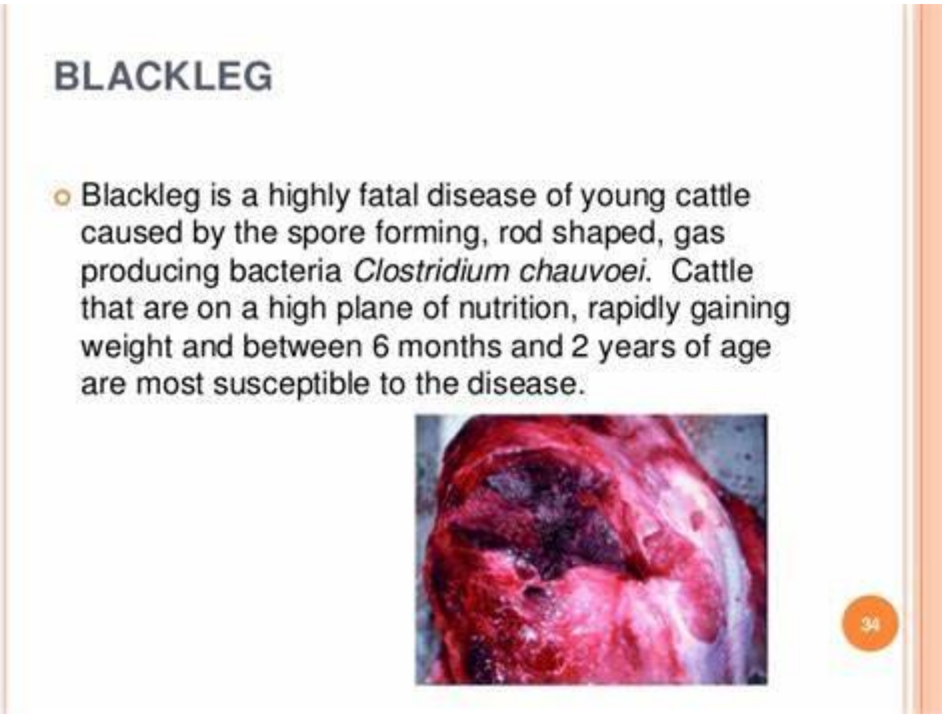
Foot and Mouth Disease (FMD) is a highly contagious viral disease of cattle and all cloven-hoofed animals caused by the FMD virus. The virus has seven different serotypes (O, A, C, Asia1, SAT-1, SAT-2, and SAT3) and is distributed worldwide. The FMD virus transmitted through air, direct contact, infected animals, contaminated farm utensils, and feeds. The clinical signs are high fever, the formation of blisters at foot and mouth, loss of appetite, weight loss, reduced milk production, and death of young animals. The vaccination is the only way to prevent the disease in cattle farms.


CLINICAL SIGNS OF
FOOT & MOUTH DISEASE
LOOK
CHECK
ASK A VET
EMERGENCY ANIMAL DISEASE WATCH HOTLINE
1800 675 888
• tongue & mouth lesions/ blisters
• drooling
• reduced food intake
• lesions/ blisters
• reduced milk production
• lesions/ blisters
• lameness
Other signs can include:
• fever
• weight loss
• abortions
FMD is a viral disease that is not currently present in Australia that can affect cloven hooved animals such as cattle, pigs, sheep, goats, deer, buffalo & camelids.
animalhealth
AUSTRALIA


Principals of FMD Diagnosis
Uninfected
FMD Virus infected
Recovered (or vaccinated)
Probang samples
Lesion, swab, probang or clotted blood samples
Clotted blood samples (saliva)
Virus or viral components can be detected
Anti-viral antibodies can be detected
Live Virus by virus isolation in cell cultures
1-4 days
Viral Proteins by LFD or double antibody sandwich ELISA
10-30 minutes (LFD)
4 hours (ELISA)
Viral Nucleic Acid by RT-PCR
Within a day
Anti-FMD antibodies can be detected in serum by ELISA or VNT
5-18 hours (ELISA)
2-3 days (VNT)

6-2-9: Blackleg in Cattle

Blackleg or Back quarter or quarter ill is a highly fatal, contagious, and acute bacterial disease of healthy cattle and sheep caused by *Clostridium chauvoei*. The bacterial spore normally presents in the soil, ingested by the cattle, and deposited in muscle and other organs. The clinical signs including high fever, swelling of muscle, crepitating sound in the swollen muscle, and sudden death of healthy cattle. Treatment includes intravenous antibiotics and antipyretics. The killed bacterial vaccine is widely used to prevent the disease at the age of 4-6 months of age and repeat annually.

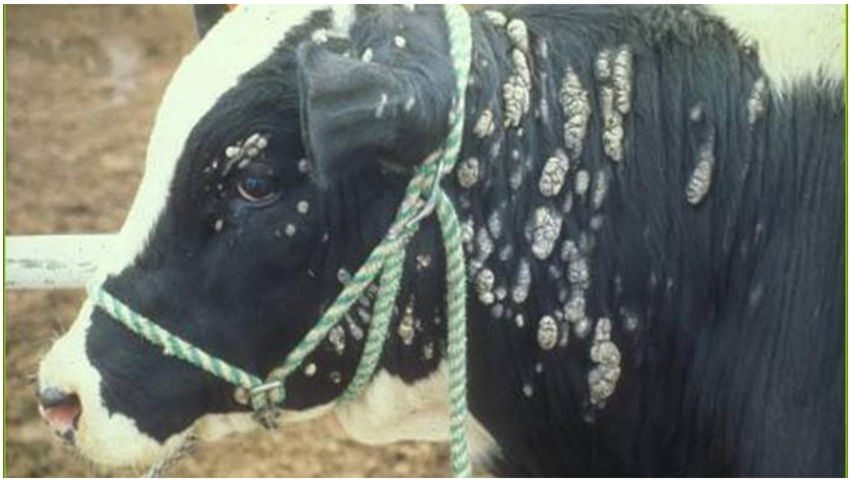


6-2-10: Lumpy Skin Disease

Lumpy skin disease (LSD) is a very serious viral disease of cattle and buffalo. The disease is caused by the Capripoxvirus of Poxviridae. The Holstein-Friesian and Jersey cattle breeds are more susceptible to LSD. The lesion includes swelling of superficial lymph nodes of skin, udder, heads, and ear; high fever, and in severe cases mucopurulent discharge from the lesions. The disease is transmitted by blood-sucking arthropods, flies, and mosquitos. Vaccination is an effective method of prevention from LSD in cattle. Natural immunity developed from the recovered animals.

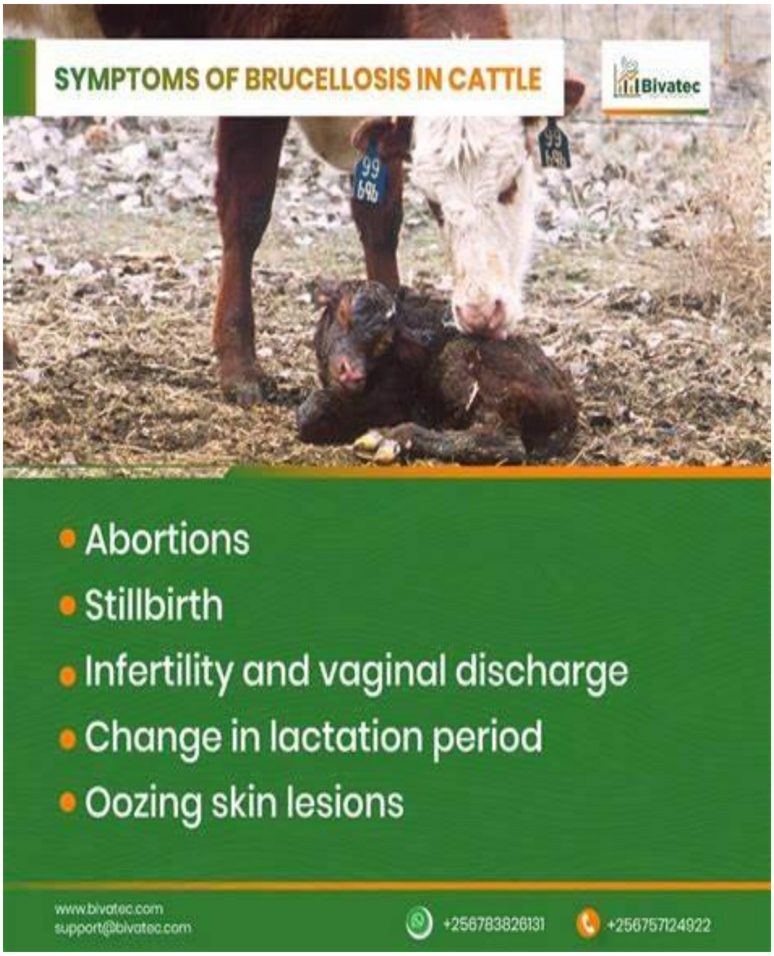
6-2-11: Cattle Diseases: Ringworm

Ringworm in cattle is a highly contagious infectious fungal disease affecting cattle, buffalo, and goats. The causal agent of ringworm is the *Trichophyton verrucosum*. The clinical signs are circular skin lesions, loss of hair, itching, and damage to skin quality. The disease is transmitted by direct contact to affected animals and contaminated soils. The organism can survive in a dry environment for more than three years. There is no specific treatment but antifungal drugs may be effective in both tropical and systemic applications.



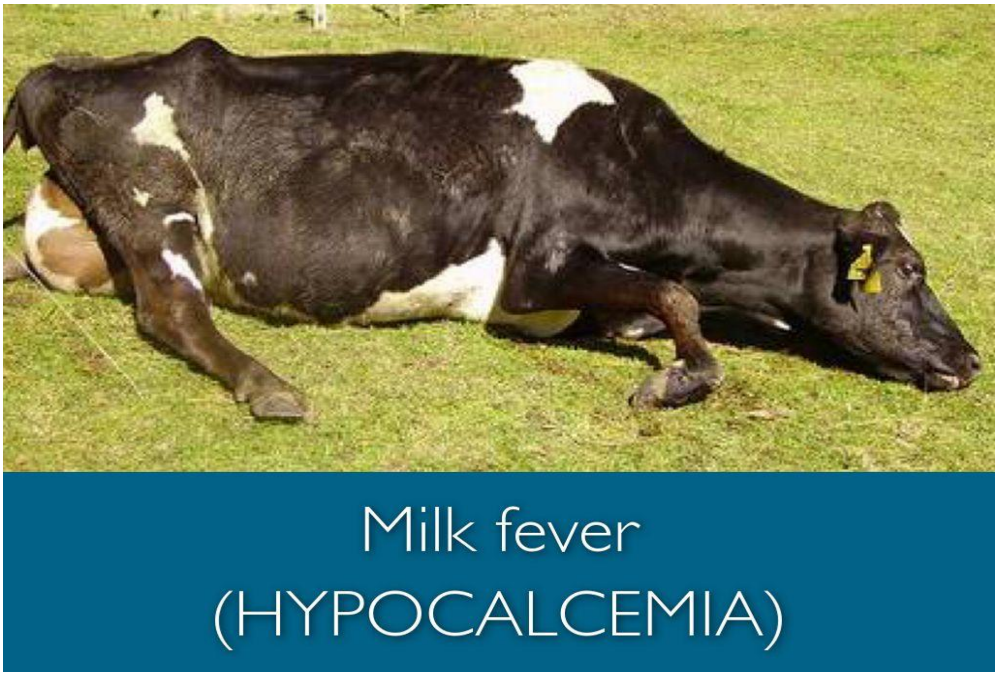
6-2-12: Brucellosis in Cattle

Brucellosis is a highly contagious, economic as well as reproductive importance disease of cattle, buffalo, sheep, goat, and other mammals. The causal agent is *Brucella abortus, B ovis, B suis, B canis, and B melintensis*. The clinical signs in cows are abortion, stillbirth, reduced milk production, and producing weak calf. The bulls are normally a carrier of brucellosis and transmit organisms through semen during breeding. There is no specific treatment of Brucellosis. Culling of animals after the identification of the organism in the herd. Vaccination is also available and found effective in some countries.



6-2-13: Milk Fever in Cows

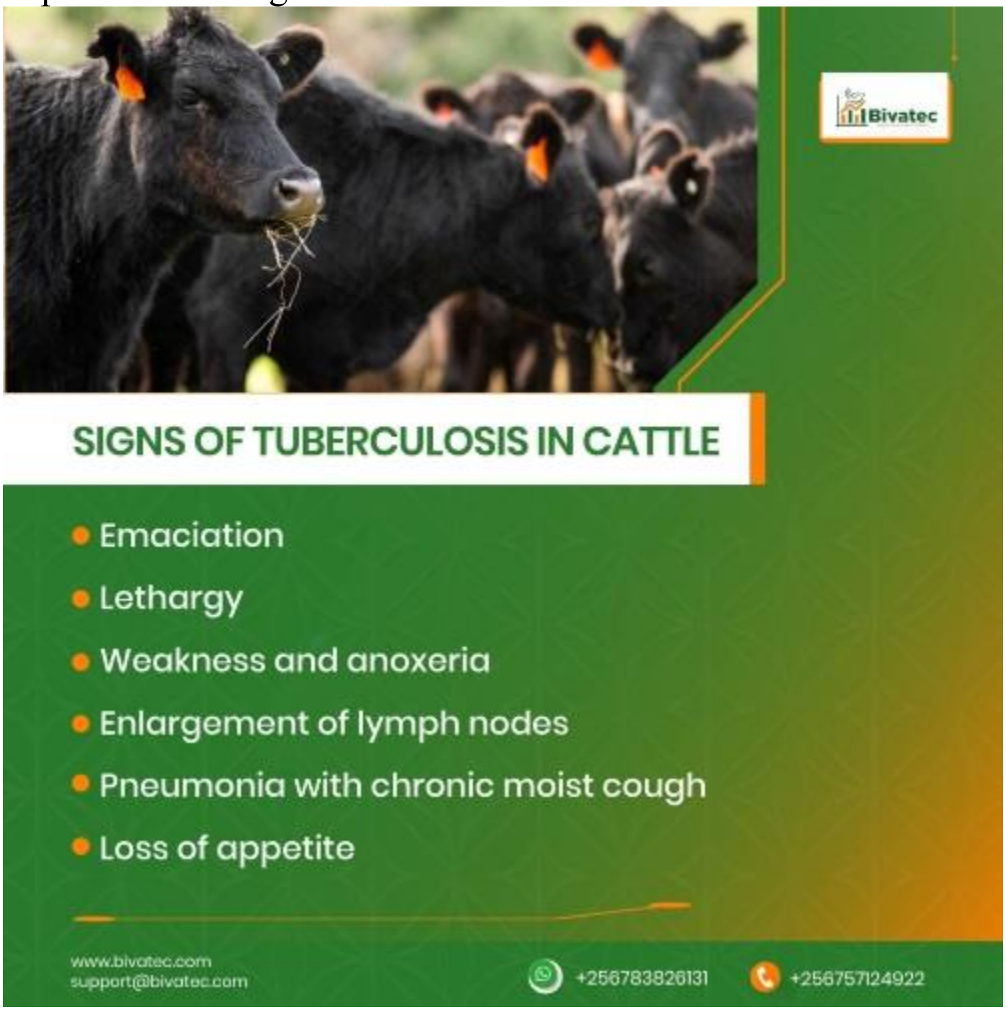
Milk fever or hypocalcemia or parturient paresis is a common metabolic disorder of high-yielding dairy cattle. The causes of the disease are the deficiency of dietary calcium and increased release of calcium through milk. The clinical signs are weakness, reduced milk production, paresis, and falls on the ground. Injection of calcium is the main treatment of Milk fever. Prevention of milk fever by the supply of adequate calcium during pregnancy and after birth, balanced nutrition, and proper management of the herd.


Milk fever
(HYPOCALCEMIA)


How Milk Fever
Is Treated
The typical treatment for milk
fever is to use 300 milliliters
or more of a 40% solution
of calcium borogluconate.

6-2-14: Bovine Tuberculosis

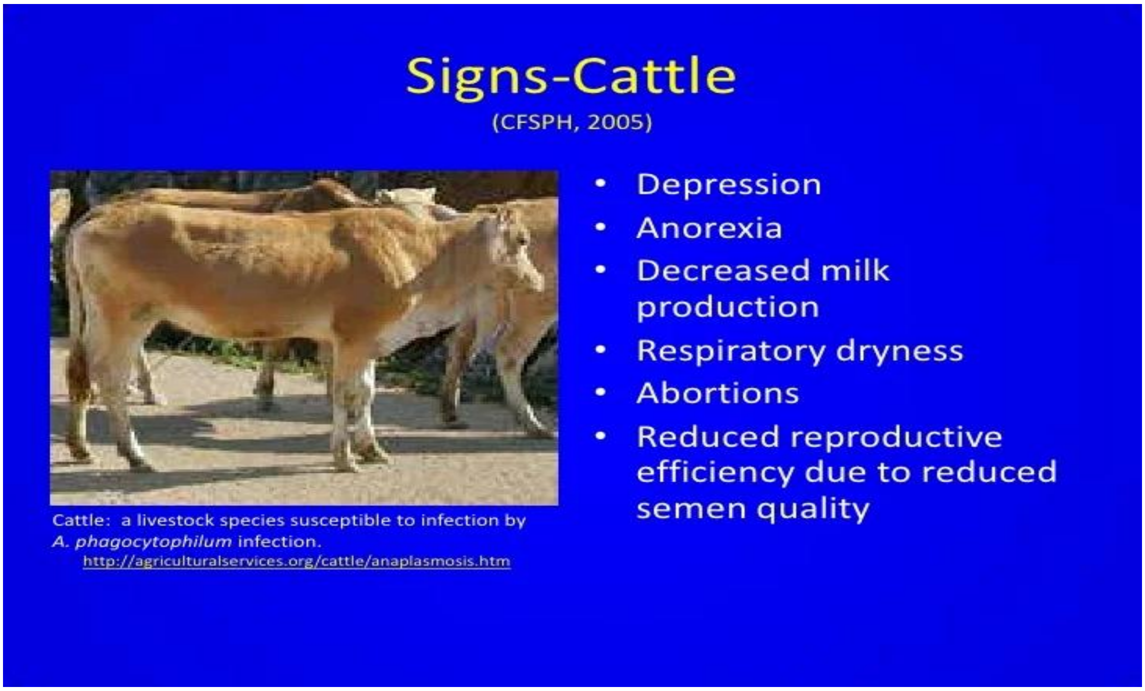
Bovine tuberculosis (TB) is a chronic bacterial disease of cattle and all mammals. The causal agent is Mycobacterium tuberculosis. The disease is zoonotic and humans got infected by drinking raw milk of affected cows. The clinical signs are weakness, debility, the formation of a tuberculous nodule in the affected organs, cachexia, and death. The disease is identified by a simple **tuberculin test**. Long time antibiotic treatment may cure Bovine TB. It is better to cull the positive cases from the farm due to public health significance.



6-2-15: Anaplasmosis in Cattle

Anaplasmosis is a tick-borne infectious disease of cattle, sheep, goat, camel, horse, and mammals. The causal agent of the disease is rickettsial parasite *Anaplasma marginale* and *A centrale*. The organism infects and propagates within the RBC of the host. The clinical manifestations of the disease are high fever, weakness, coffee color urine, lethargy, recumbency, and death. The disease is diagnosed by the direct smear of blood. Oxytetracycline is the drug of choice for the treatment of Anaplasmosis. Reducing the tick population in herd and pasture is the effective mode of prevention of Anaplasmosis.

Fig: Infestation of ticks in cattle



6-2-16: Leptospirosis in Cattle

Leptospirosis is a zoonotic bacterial disease of cattle caused by *Leptospira species*. There are several serovars of Leptospira are hard, Canicula, Pomona, ichtero hemorrhage, and grippotyphosa. The disease is transmitted by direct contact with the infected animal or contaminated environment. The clinical signs of the disease are a sudden drop in milk production, infertility, and early abortion. Antibiotics are used to treat leptospirosis. Vaccination, separation of the sick animal, and reducing the contact of wild animals may prevent the disease in the healthy herd.

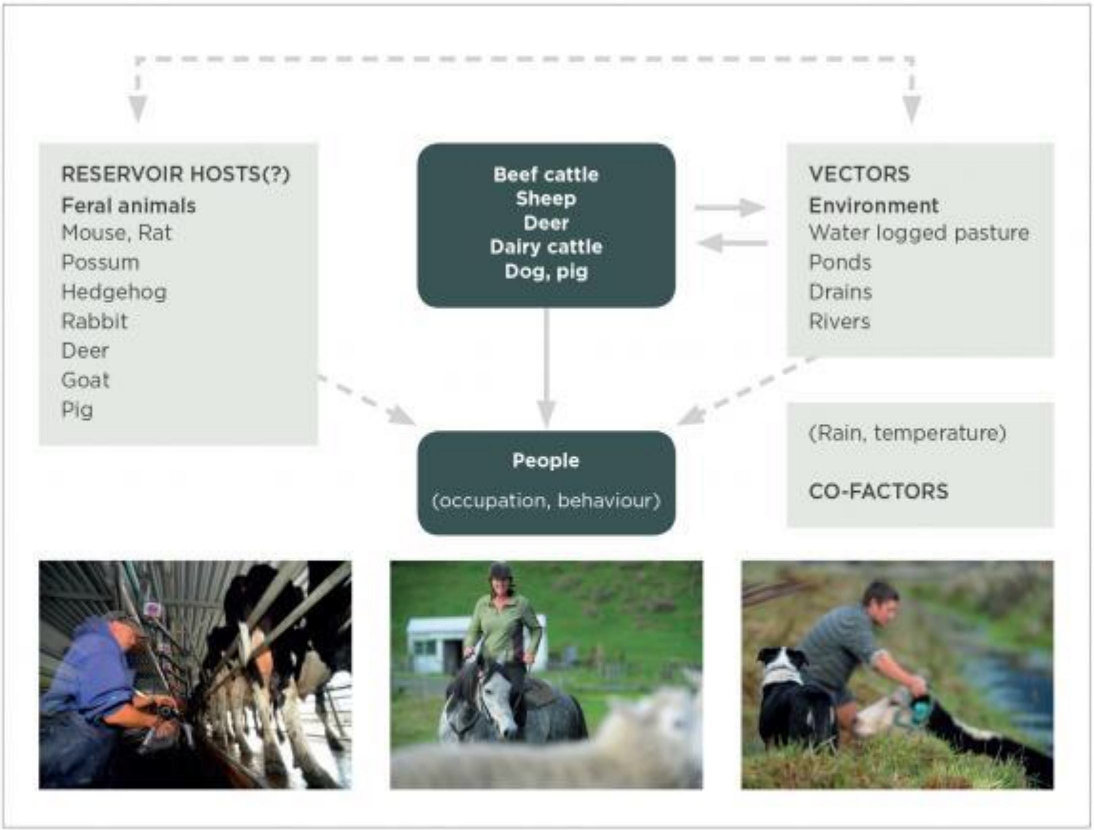
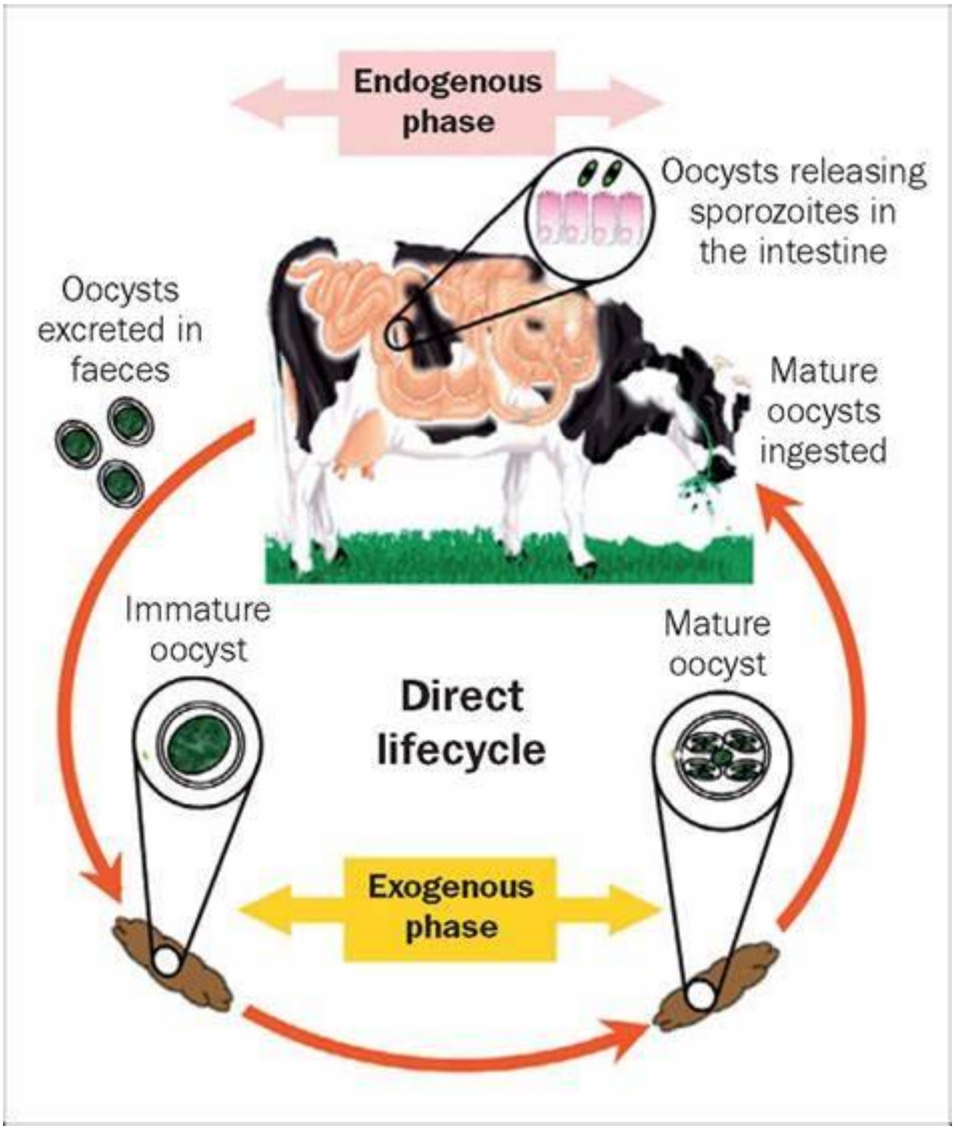


Figure 1: Ecological model of leptospirosis in New Zealand[1]

6-2-17: Cattle Diseases: Coccidiosis

Coccidiosis is a protozoal disease of young cattle caused by *Eimeria juerni, E bovis,* and *E auburnensis*. The young calved showing diarrhea, weight loss, bloody feces, dehydration, dysentery, and death. Coccidiosis may occur during summer or winter when animals are under stress due to overcrowding. Antiprotozoal drugs sulfaquinoxaline and amprolium are used to treat coccidiosis. The preventive measures are isolation of affected animals, avoid overcrowding, reduce stress, and improve the immune status of calves.



6-2-18: Infectious Bovine Rhinotracheitis (IBR)

IBR is an acute, highly contagious, respiratory infectious viral disease of cattle caused by Bovine Herpes Virus-1. The clinical signs are sudden onset of fever, coughing, sneezing, respiratory distress, nasal discharge, conjunctivitis, abortion, and infertility in cows. There is no specific treatment for viral diseases. Anti Inflammatory drugs and antibiotics are given to prevent secondary infections. Vaccination and isolation of sick animals are the effective methods of controlling Infectious Bovine Rhinotracheitis in cattle.

Cause

bovine herps virus *

it is highly infectious disease of cattle & buffaloes-

:ch` clinically by*

rhinotracheitis -conjunctivitis -

fever -encephalitis -abortion -

highly fatal in calves less than 2 weeks of age***

:Clinical signs

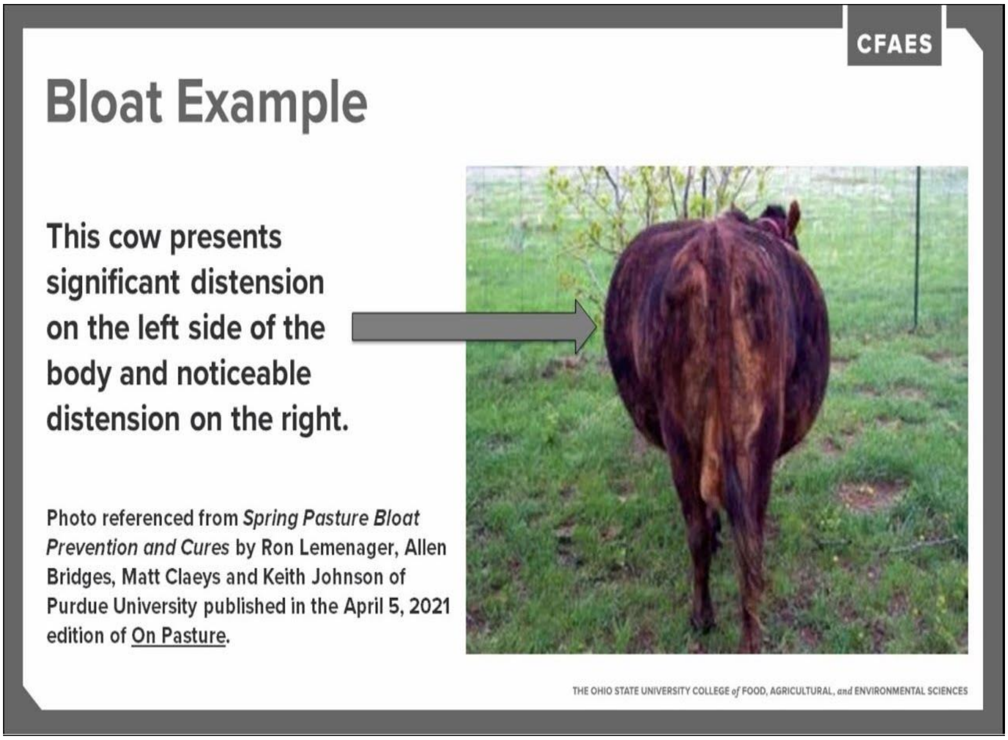
:respiratory form-1

- fever (40-42 c) , shallow rapid respiration •
- persistant cough & dyspnoea •
- serous to mucopurulent nasal discharge •
- hyperemia & hemorrhagic focal necrosis of nasal mucosa •
) (red nose

Abdominal bloating (or simply **bloating**) is a short-term disease that affects the gastrointestinal tract. Bloating is generally characterized by an excess buildup of gas, air or fluids in the stomach. A person may have feelings of tightness, pressure or fullness in the stomach; it may or may not be accompanied by a visibly distended abdomen. Bloating can affect anyone of any age range and is usually self-diagnosed, in most cases does not require serious medical attention or treatment. Although this term is usually used interchangeably with abdominal distension, these symptoms probably have different pathophysiological processes, which are not fully understood.

The first step for the management is to find a treatment for the underlying causes that produce it through a detailed medical history and a physical examination. The discomfort can be alleviated by the use of certain drugs and dietary modifications. Bloating can also be caused by chronic conditions and in rare cases can be a reoccurring life-threatening problem. The most common symptom associated with bloating is a sensation that the abdomen is full or distended. Rarely, bloating may be painful or cause shortness of breath. Pains that are due to bloating will feel sharp and cause the stomach to cramp. These pains may occur anywhere in the body and can change locations quickly. They are so painful that they are sometimes mistaken for heart pains when they develop on the upper left side of the chest. Pains on the right side are often confused with problems in the appendix or the gallbladder. One symptom of gas that is not normally associated with it is the hiccup. Hiccups are harmless and will diminish on their own; they also help to release gas that is in the digestive tract before it moves down to the intestines and causes bloating. Important but uncommon causes of abdominal bloating include ascites and tumors. There are many causes of bloating, including: diet, irritable bowel syndrome, lactose intolerance, reflux, and constipation. Specific medical conditions like Crohn's disease or bowel obstruction can also contribute to the amount of stomach bloating experienced. Common causes of abdominal bloating are:

- Overeating
- Gastric distension
- Lactose intolerance, fructose intolerance and other food intolerances
- Premenstrual syndrome
- Food allergy
- Aerophagia (air swallowing, a nervous habit)
- Irritable bowel syndrome



6-3: The Concluding Remarks on Cattle Diseases

Cattle are the most important farm animals in the world. They gave meat, milk, hides, and manure to human society. Farm owners are suffering from the problems of different cattle diseases. In the above article, I have given only a little information for your knowing. These will help you to study further and take the necessary precautions for your farm.

6-4: References

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Chapter 7

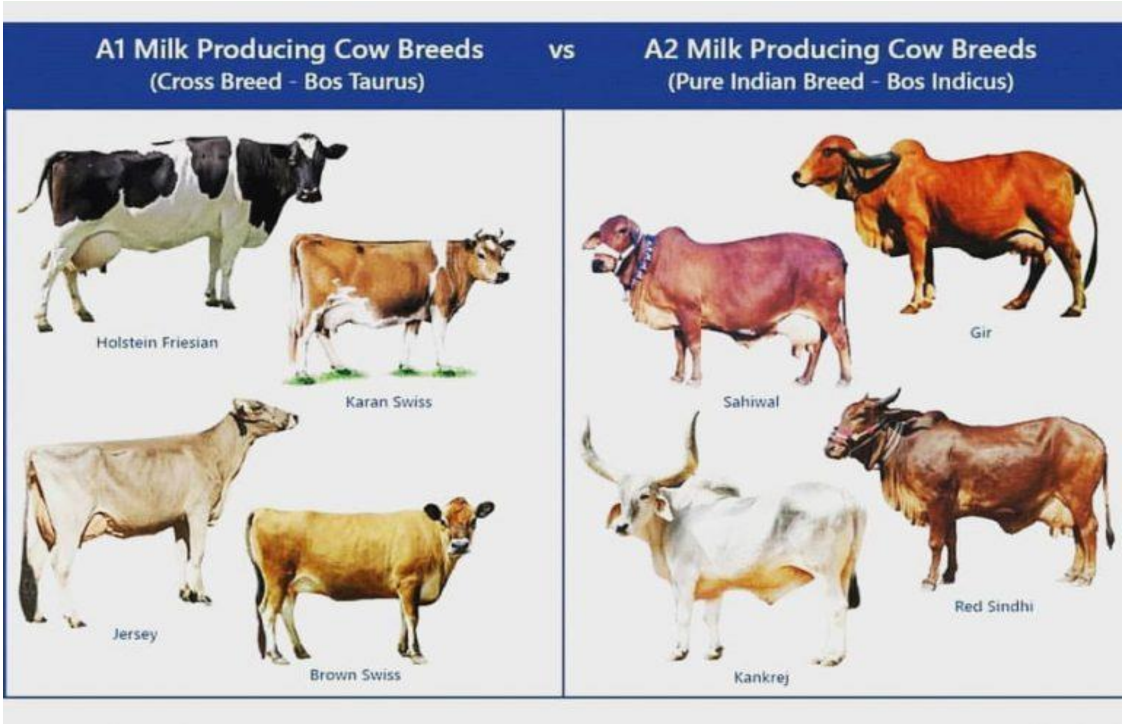
Genetic Improvement of Cattle from Conventional Breeding to Biotechnological Approaches

Genetic Improvement of Cattle from Conventional Breeding to Biotechnological Approaches

7-1: Conventional Genetic Improvement of Livestock

A- Breeding Dairy Cattle

Livestock production and efficiency has improved dramatically due to improvements in nutrition, animal health, and breeding and genetics. Genetic improvement of livestock has and continues to play a crucial role in the advancement of livestock by increasing the efficiency and sustainability of production for all livestock species. This chapter explores the broad contributions made by traditional breeding schemes, genomics, and biotechnologies such as assisted reproductive technologies and genetic engineering. The main aim of breeding dairy cattle is producing offspring that will also be used mainly for dairy production purpose. Raising dairy cattle for milk production requires close attention to bred them so that they produce the most milk possible. Breeding dairy cattle will require some prior planning, close attention and observation and recordings of mating and regular recording of the daily milk production of all of the cows in the herd. Breeding program for the dairy cattle is as important to the large commercial cattle farming company with many herds as the small-scale individual farmer with a single herd with only a few animals. In order to make milk, the cows need to produce calves. And in order to produce both milk and calves, the cows need to be bred timely. In most dairy farms, the heifers are born and used to a dairy operation and they are used for replacing the old cows. On the other hand, the males and old cows are generally used for beef production. Along with calve and milk production, another aim of breeding dairy cattle is also to improve the commercial production of the farm stock and genetic improvement. First of all, select cows that you want to be bred (these cows are generally called as the ‘foundation stock ‘. Then breeders have to determine the breeding method, either using a bull or by artificial insemination (AI). However, here we are describing more about the steps of breeding dairy cattle. First of all, select the cow that you want to breed. The cow which will be used for breeding purpose is called as foundation stock. Breeders must have to select good cows for having good quality calve with good features. Actually, all cows can produce some milk and the amount of milk may be enough for family consumption, but at the same time it can be too little to be worth collecting for sale. So, breeding dairy cattle is important to increase milk production also. Breeders can use your existing cows for producing improved calves with good qualities. In such case you have to use bull of a good dairy cattle type for breeding dairy cattle. Then breeders should determine breeding method. They can either use a bull or use artificial insemination system for breeding dairy cattle.



Whichever method breeders choose, they have to check the quality of the bull. Below are describing more about both system for breeding dairy cattle.

Breeding through a Bull: Most of the bulls which are generally found on most of the small farms are not useful for upgrading your existing herd. The most efficient and safest way to obtain a good breeding bull is to raise only one bull on your farm, or use a good dairy type bull from a respected breeding farm (such as private, or government breeding farm). In case of choosing bull if breeders can't get a pure-bred, they can use one which has at least half dairy blood. If breeders follow this, they can expect offspring of the bull will be superior in milk production. Along with increased milk production, breeders can also expect increased carcass value of the new calves.

The steps mentioned below for selecting and using a dairy breeding bull.

- Always try to select and find a good bull from a known source ((such as private, or government breeding farm).
- Ensure that the bull is sound and it can serve properly.
- If you already have many bulls in your herd, then consider castrating all of them.
- Always try to avoid inbreeding (don't allow your bulls to mate with his daughter). It is a good idea to replace the bull after three years for avoiding inbreeding.

Breeding by Artificial Insemination: Artificial insemination is a very good system for breeding dairy cattle. Artificial insemination is used at most dairy farms since the 1950s, and it can be a good choice for you if you don't want to bear the extra expenses for raising breeding bulls. And artificial insemination is good if your herd size is less than 5-6 cows. The dairy bulls can also be extremely dangerous and unpredictable, so keeping bulls for breeding purpose is not good always.

The steps below are for breeding dairy cows through artificial insemination system.

- Need to hire an expert artificial insemination technician to breed the cows. Need to find an experienced technician, because the more experienced the technician is, the higher the success rate of cows getting pregnant.

- Will need to have a schedule for determining which cows need to be bred and when. For this purpose, a gestation table or pinwheel will be helpful. The schedule should include the time when cows need to be bred by when they go into estrus. Generally artificial insemination process is done 12 hours after the cows have showed the signs of estrus.

- If everything seems perfect, AI technician will do this part.

- Monitor all cows regularly after successful breeding. If any of cows go back into heat or not. Owners should record those that do go back into heat, and that have been bred and the projected time they will calve.

Over the last century, and particularly the last 50 years, large gains have been made in livestock production and efficiency due to improvements made in nutrition, animal health (veterinary care, housing and husbandry practices) and breeding and genetics. Although all of these fields have made significant contributions, genetic improvement has and continues to play a substantial role in increasing the efficiency, sustainability and productivity of all livestock species. In modern production settings, applied breeding and genetics programs select for animals that have increased yield, utilize fewer resources, and are less susceptible to environmental stressors such as heat and disease. From the first breeding schemes and the advent of artificial insemination (AI) to the use of genomics and gene editing technologies, animal scientists have combined basic breeding principles with emerging technologies to make huge strides forward in capturing the genetic potential of our livestock species. Genetic improvement programs have been a powerful driving force for increasing the efficiency of animal production systems, while concomitantly decreasing the environmental footprint and emission intensities of animal-source foods. By combining objective phenotyping, genomic information, statistical methodologies and reproductive techniques, breeders have been able to more precisely select genetically superior parents and intensely utilize them to create the next generation, thereby accelerating the rate of genetic progress toward a given breeding objective. As a result, for example, dairy cows today produce more than four times the amount of milk of their predecessors in 1944, even as the dairy cattle population in the United States has fallen from 26 million to 9 million cows over that same period.

These remarkable changes have been achieved using conventional selection based on naturally occurring genetic variation. As a result of this selection, the carbon footprint associated with producing a glass of milk has fallen by two-thirds over the last half century. Genetic improvement programs require significant investments. Although well-designed genetic improvement can be expected to eventually provide positive returns on investments, in local breeds the costs will often be relatively high on a per-animal basis. The breeding strategy and system that maximize genetic response may not be optimal from an economic standpoint. Recording of performance and pedigrees may not be economically sustainable, even if restricted to a portion of the population (e.g., the nucleus). Lack of infrastructure in marginal areas where local breeds are often found may impair the introduction of genetic improvement programs, and the development of the infrastructure may be costly. When considering artificial insemination, the production of few semen doses per donor, as expected in small populations, can substantially increase per-dose semen costs relative to large populations. Therefore, a cost–benefit analyses should be conducted before implementing selection in local breeds to determine the optimal approach. In genetic improvement programs, economic returns should be evaluated in the long term, given generation intervals and genetic cumulative effects. Additionally, organizational and infrastructural shortcomings are often associated to local breeds: these could be circumvented by taking advantage of existing organizations and infrastructures developed by larger breeding organizations.

B. Breeding Beef Cattle

To breed beef cattle, Owners need to know:

- Determine breeding program. There are two different options for breeding beef cattle; by using bull or by using artificial insemination method.
- Most beef cattle are mated naturally, whereby a bull is released into a herd of cows approximately 55 days after

the calving period, depending on the cows' body condition score (BCS).

- Monitor bulls and cows during breeding season

Breeding beef cattle involves producing offspring that are primarily used for the beef market. Fundamentally, it's all about getting cows bred to produce calves to sell either for beef or replacements.

Beef owners should follow the below steps:

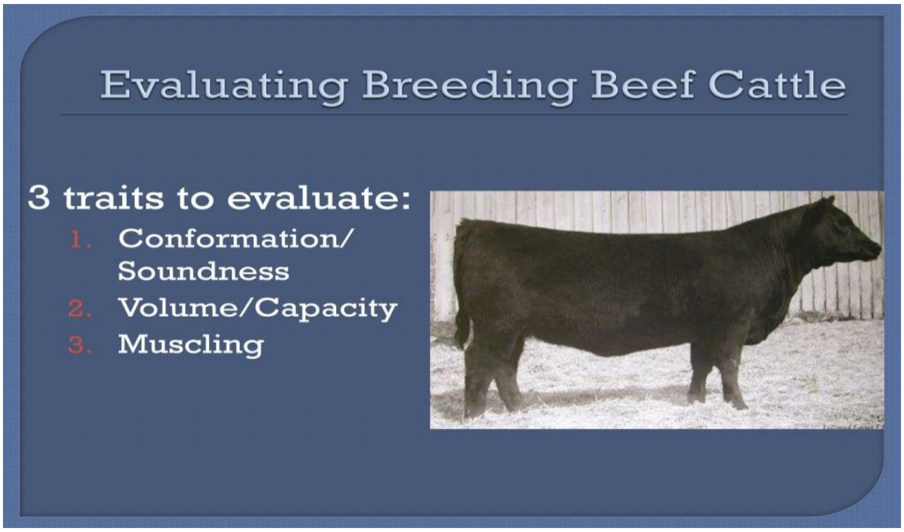
- Buy the quality of cows that meet your standards, as far as having a good breeding herd is concerned.
- Your herd bull should be selected to improve your herd, as he will be providing half of the genetic potential of your calf crop. Knowing conformation at this point will really help in determining how good a herd bull is needed.
- Fertility and live calves are key to profitability. One live calf is worth more than 100 dead ones. A bull that sires calves that are larger than your cow can safely give live birth to is economic suicide.

Choose best breeding program. There are two types to choose from, and both can be integrated into the other, If the herd is too small to have a herd bull or you do not want to have to deal with bulls, use artificial insemination to breed your herd. If owners have a herd of 10 or more cows and you do not want to go the extra mile of having to AI them, a good herd bull is the way to go. The rule of thumb is 1 bull per 25 cows. High fertility bulls with high libido can service 50 cows with no drop-in conception rates. Bulls reach peak fertility by 20 months of age, after 20 months of age it can only drop, barring illness or injury, with proper nutrition most bulls fertility will not start to decline until after 6-7 years of age.

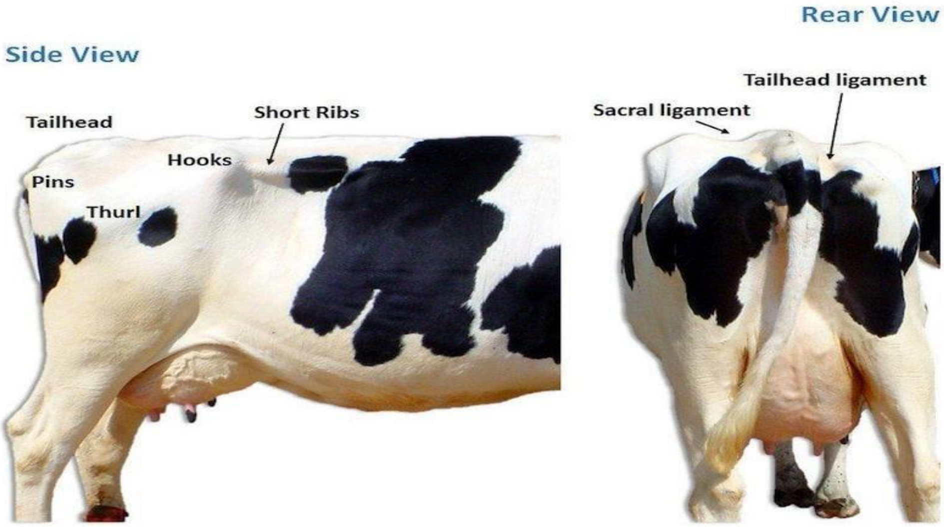
- Know when cows go into estrus, when they're ready to breed, and go from there. If owners are using a herd bull, they will not need to worry about when your cows go into heat, only when they have been bred for record keeping.

- Monitor bulls and cows during breeding season. If you have one too many bulls for the herd, there may be more fighting than mating. Running bull[s] under 4 years of age with older bull[s] may prevent cows from being serviced by the bull with the highest fertility. Other times you may end up with a bull that has a broken penis, a leg/foot injury, or that just doesn't seem to be getting the job done. Monitor the cows as well. If you see tails being held out or crooked tails when they're walking, that means they've been bred within the 24 to 48 hours you first noticed that physical sign.

- Pull the bull[s] out 64 to 85 days after they've been put in. Unless you choose to do year-round breeding and calving where the bulls are in with the cows all the time, pulling the bulls out after 2 to 3 months both ensures that all your cows get 3-4 chances of being covered and is also not long enough for your less fertile females to get away from being culled. Owners must let the cow have a rest and recovery period of 60 to 90 days after calving before breeding again. This allows their uterus to get back into its normal pre-fetus shape, and lets them get back into their normal estrus cycling. Their estrus cycling will be out of whack immediately after calving.



Genetic Variation within Breeds: In conservation genetics, maintenance of both within-breed and across-breed genetic diversity are primary aims, as they play different but critical roles in sustaining animal production. Selection can negatively affect both these components, and breeding programs should cautiously monitor genetic variation. Within a breed, the level and rate of inbreeding, which is negatively correlated with effective population size, is generally used as parameter of within breed variation. Index selection based on information from relatives leads to the reduction of effective population size and increases the probability of co-selecting close relatives. This is particularly true for traits with low heritability. In designing selection programs for small populations, a main challenge is to maximize genetic gain at an acceptable inbreeding rate. Inbreeding rate per generation should be below 1.0%, which may preclude selection when the population size is particularly small. However, as the population size increases, selection intensity can be increased, resulting in a continuum of situations with respect to selection differential. Different strategies are available to achieve genetic response with control of inbreeding, ranging from the earlier methods using sub-optimal criteria of selection, to considering genetic relationships among selected animals, to the most-sophisticated selection with optimal contributions.



Genetic Variation among Breeds: The genetic diversity of a livestock species is generally addressed by keeping a sufficient number of breeds. However, species-wide diversity must also be considered during selection within a breed. In general, FAO suggested that selection should conserve breeds as genetically and cultural distinct genetic resources. Selection for increased output while ignoring traits correlated to traits of conservation interest such as adaptation, specific genetic variants, and quality of products, can reduce breed distinctiveness and between-breed variation. Identification of selection traits in local breeds should be accurate and based upon knowledge of the trait biology. Advances in genomics and bioinformatics have allowed the identification of genomic similarities/differences among livestock breeds. Some of these genomic signatures may contribute to explain the phenotypic uniqueness of breeds and facilitate prioritization and the use of genomic breeding tools to preserve these important traits. A further option is the landscape genomics approach, whereby the association between alleles and geographic locations and/or climatic variables is targeted and assumed to be suggestive of signatures of adaptation, giving information on the environmental forces acting on the genome.

Crossbreeding Effects on Efficiency of Cattle: The importance of crossbreeding in livestock species has been known for a long time; it has been used heavily in cattle to improve productivity for several decades. Crossbreeding allows to combine favorable characteristics from the breeds involved and to exploit heterosis. Crossbreeding system is of two types viz. terminal and continuous depending on retention of crossbred female in the herd or not. In cattle crossbreeding is mainly used to improve milk production, through crossbreeding with local cattle to improve adoptability and disease resistant ability. The ideal exotic inheritance to be maintained in the indigenous cattle is 50% where there is scarcity of green fodder and 62.5% is suggested where there is adequate feed and fodder along with good marketing facilities. Though crossbreeding with exotic germplasm resulted in improves production and reproduction potential but it also resulted in dilution of indigenous livestock. Exotic breeds are more susceptible to tropical diseases, harsh climate and poor-quality feed and fodder and as the crossbreds which required constant input of good manage mental conditions in comparison to the native cattle. Therefore, it is advisable to use crossbreeding with caution based on tested bulls or semen, quality fodder and suitable breeds for particular region. Crossbreeding is the most effective and rapid approach for genetically improving the non-descript local cattle population by crossing with exotic dairy cattle breeds particularly in milk shed areas around peri urban and industrial towns. In these areas there are good marketing facilities for milk and milk products and also green fodder and quality feed are present around the year. Crossbreeding experiences with exotic dairy cattle breeds like Holstein Friesian, Brown Swiss and Jersey has proved that there is rapid genetic improvement in the non-descript cattle and marked improvement in productivity. Holstein Friesian cattle have been recommended as the breed of choice in the irrigated plains and Jersey cattle as breed of choice in hilly terrain and coastal areas for crossbreeding. Exotic inheritance in crossbred cattle should be maintained in between 50 and 62.5%. Beyond this exotic inheritance the crossbred acquires the problem of adoptability and other diseases like mastitis, milk fever, FMD etc. Therefore, the reason for crossbreeding is to increase the overall efficiency of a production system through crossing breeds which have their genetic merits in different traits and to produce individual dairy cattle with intermediate performance between that of two breeds.

Crossbreeding mostly done in animals due to: -

1. To take advantage of complementation- Crossbreeding allows combining of the traits from both the breeds which are better in one another or from sire and dam breed. This increases the efficiency of the whole production system. For example: Reduce

age at first calving, high milk production from sire breed and good adaptability, disease resistant ability from dam breed.

2. Averaging breed effect- Crossbred animals are having traits which are the result of crossing of two distinct breeds and they are intermediate for each trait which might be more profitable overall. So, crossbreeding increases the efficiency of each animal in the production system.

3. Crossbreeding is done to grade up the non-descript breeds and thus improving their performance.

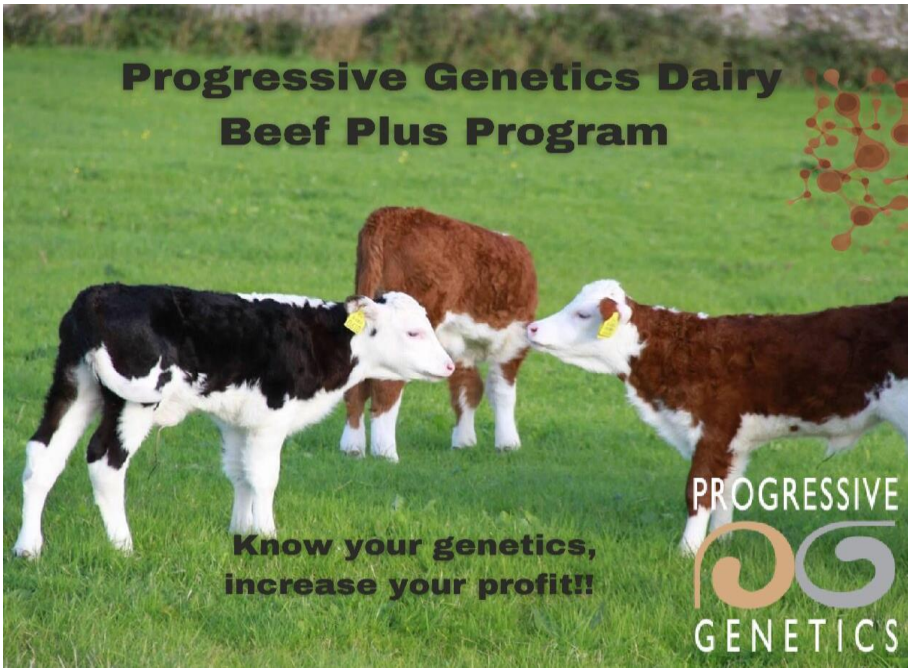
4. Crossbreeding is a step forward to create a new synthetic breed or composite breed.

5. Crossbreeding is done sometime to introduce a specific gene. For example: Brahma breed is used in crossbreeding to introduce tick resistance in European breed.

6. Finally, the most important reason for crossbreeding is to exploit heterosis. Heterosis is usually more for traits which are low heritable i.e. fitness, reproductive and production traits.

Moreover, in beef cattle the diversity of breeds and crosses raised in cow–calf production systems result in phenotypic differences related to biological type, weight, growth, and milk yield within and between herds. These differences may produce economically relevant outcomes, such as weaning weight (WW). Currently there is an increasing use of crossbreeding in many countries. Acknowledging that heterosis depends on the genetic distance between the paternal breeds, the evaluation of the different crosses between taurine × zebu, can be useful to support informed breeding decisions of the cattlemen. In many countries, pasture-based production systems predominate and measuring feed consumed by the cows is not feasible. However, energy intake (EI) by cows can be estimated from their body weight mass and milk production. The objective of this text is to determine breed additive and heterosis effects on growth curves, total milk yield (TMY), calf weaning weight (WW), predicted energy intake (EI), and cow efficiency (CE) of purebred and crossbred beef cows. Taurine– zebu heterosis effects were significant for all traits. In general, crossbred cows were heavier at maturity, matured earlier, produced more milk, weaned heavier calves, and were predicted to consume more energy. Despite the importance of red meat as a basic substance in human nutrition because it contains a high percentage of proteins, and the percentage of what red meat contains of protein is greater compared to the protein that people get from plant products that the individual eats in all countries of the world. Local production of red meat in Iraq needs to be improved. Iraq owns four local groups of cows (Jenobi, Sharabi, Rustaki, and Karadi) as well as crossbred. The total number of cattle in Iraq is estimated at 2 million cows. However, the expected a per capita daily meat consumption, is around 6 kg / person and around 125 kg of milk / person / year. Therefore, it is important to increase meat and milk consumption per capita through improving both genetic and environmental factors (type of feed, and veterinary care). To increase meat production, the owners of cattle should know that:

1. The rates of total weight gain increase with the increase in fattening periods, but daily body weight gain decreased to a certain extent, which causes costs may exceed revenues.
2. There are other factors related to the fattening process other than the optimal number of days that negatively affect the fattening process, including the animal species, age, type of feed and vaccinations.
3. The quality of calves is not suitable for the local environment because the Iraqi local market is linked to the regional markets in this field.
4. The lack of control over vaccines and imported calves, which is reflected in the efficiency of food conversion, which makes it difficult to determine the optimal period for fattening.
5. The owners should not to sell and market fattened animals until they reach at least 6 months.
6. Providing a diet with balanced nutritional components, the results of which are reflected positively on the weight gain of calves.



7-2: New techniques in Cattle Breeding / Using Genomic Technology

Genomics as Tools for Cattle Improvement: In the last decade, low- and high-density genomic tools have been broadly used to study and characterize the genetic diversity and population structure of livestock. However, genomic information has contributions beyond characterization to make to the management and conservation of AnGR. In addition to identifying genomic regions subject to natural selection, signatures of artificial selection have been identified applying statistical approaches to genomic data. Other uses of genomic information with potentially high impacts on management include: the estimation of genome-based relationships and inbreeding coefficients, from single nucleotide polymorphisms, from runs of homozygosity, or unifying different sources of information; genetic approaches for breed-based product identification and traceability, for authentication and quality assurance; and the identification of recessive lethal or other specific mutations of interest. All of the above can be applied to small breeds at relatively low cost. However, as is the case for the analysis of any breed that had not been considered in the development of the SNP chips, ascertainment bias should be carefully taken into account. In terms of economics, the greatest impact of genomics in livestock has been its application to breeding (i.e., genomic selection, GS). However, a large number of phenotypes (i.e., directly or through daughter/relative performances) and genotyped individuals are necessary to obtain accurate genomic breeding values. Breeding schemes combining traditional and genomic information have been proven to obtain good results in medium-scale breeds. However, considering the low number of individuals in small populations, only small gains from the use of genomic information can be expected. One possible solution is multi- or across-breed prediction, although its utility depends on various factors, including genetic distances among populations and the trait(s) considered. Such strategies have been successfully tested on relatively large dairy cattle breeds, but are yet untested on small breeds. Given that application of GS in small breeds would require high-density genotyping, once again a specific cost–benefit analysis should be carefully considered. To face this issue, statistical methods that integrate genotyped and ungenotyped individuals could be adopted. Another option, especially in populations where pedigree information is known, could be to genotype key ancestors at high-density and the rest of the population at low-medium density. Imputation methods, also with a multi-breed reference population, can then be applied to obtain high genotyping accuracies for all animals. Technological developments in agriculture have impacted not only the field of genomics, but also the collection of phenotypes. Animal phenotyping has mainly taken two directions: on one hand, the measurement of an increasingly large array of new phenotypes; on the other, the development of systems for automatic trait measurement and recording.

Genomic selection, in which trait measurement is limited to the reference population, contributed to put emphasis on the collection of novel phenotypes. For instance, milk quality traits now include not only total protein and fat content but also sub-components like lactoferrin and fatty acids. Mid- and near-infrared spectroscopy (MIR/NIR) allow quantitative evaluation of the composition of biological samples and have found wide application in dairy cattle breeding. Health-related traits represent yet another field of phenotypic investigation and include direct veterinary records, indirect measures of mastitis (e.g., milk electrical conductivity, milk mineral content) and female fertility (e.g., milk hormone assays, physical activity), and traits related to lameness or metabolic syndromes. Growing interest is being placed on behavioral traits like cow temperament. Falling genotyping prices have left trait measurement as the major economically limiting factor in livestock selection schemes, thereby motivating active research in the (semi)automatic acquisition of phenotypes on a large scale. Automated milk-recording systems are becoming popular. The industry has been developing sensors to automatically measure many traits of direct or indirect interest. Pedometers for ambulatory activity indirectly measure fertility and lameness, and rumination tags monitor rumination time, which is related to metabolic activity and methane emissions. Image and video analysis can yield predictors of meat yield and quality or body condition. The combination of novel phenotypes and automatic trait recording is a powerful tool to improve both herd management and breeding schemes. Unfortunately, similar to GS (and conventional selection, for that matter), economies of scale are usually important in making the application of these technologies affordable and, therefore, innovative phenotyping is currently affecting mainly large commercial livestock populations. Nevertheless, this trend can still be a very promising development for smaller local breeds, inasmuch as the new technologies can be developed and perfected in larger populations, increasing their efficiency and decreasing costs so that can eventually help fill the gap toward optimized breeding and management practices in small breeds.

Case Study in some developing countries: In recent years, new techniques that utilize information about the genomic sequence of animals have been developed. These modern biotechnological methods enable the direct alteration of genomic sequences and offer the potential to accelerate the rate of genetic improvement further through the targeted introgression of useful genetic variants and alleles to improve carcass and meat quality traits. The availability of the complete genome sequence of several livestock species including cattle, pigs, goats and sheep and the application of genomic selection has allowed for an acceleration in the rate of progress in genetic improvement programs. These improvements in genetic progress have been accompanied by a reduction in the environmental footprint and emission intensities of animal-source foods produced by these systems. Meat quality is a multifaceted trait. It not only encompasses characteristics that result from a large number of genes, each having a small, cumulative and complex effect, but is also influenced by the animal's environment and nutritional status. Newer biotechnologies, including gene editing and notably the CRISPR/Cas system, provide an approach to introduce useful genetic changes in an animal's genome. This system could be employed to selectively inactivate target genes that are known to be negatively associated with meat quality or allow for intraspecies allele substitutions whereby a desirable meat quality allele from one breed is introgressed into another breed. When gene editing is used to introduce desirable alleles rather than crossbreeding, the breeder can avoid the negative effects of linkage drag. This review focuses on the genetics of meat quality and provides examples of how modern biotechnology tools could be used to improve meat quality traits. We also briefly discuss the global animal biotechnology regulatory landscape. The practice of importing dairy animals from developed temperate nations, for both pure breeding and crossbreeding purposes, is frequently employed to boost milk production in tropical low- and middle-income countries (LMICs). However, this approach often proves inadequate in smallholder dairy systems (SHDS) in LMICs because the imported animals, typically selected and bred for high-input environments, are not adequately adapted to the conditions and needs of smallholder systems. The African Asian Dairy Genetic Gains (AADGG) program is addressing this gap by identifying and promoting the use of dairy seedstocks suitable for SHDS. This involves using genomic information to predict the performance and suitability of foreign evaluated dairy seedstock within smallholder systems. Genomic models from AADGG predict genomic breeding values (GEBVs) for imported animals and their performance in SHDS?'. In Tanzania and Ethiopia, advanced statistical techniques known as genomic best linear unbiased prediction (GBLUP) were used with single nucleotide polymorphism (SNP) data to calculate the estimated genomic breeding values (GEBVs) for milk yields of Holstein-Friesian and Jersey breeds in a foreign exporting country. The GBLUP method is generally used for genomic prediction in animal breeding. This method helps understand how an animal's genes could influence milk production and other traits based on their DNA.

Key messages:

• Utilizing genomic breeding values (GEBVs) derived from single nucleotide polymorphisms (SNP) solutions in eastern Africa significantly improves the selection process.

• Animals with GEBVs about one standard deviation above the mean milk yield in the exporting country are more likely to perform well in smallholder dairy systems. • As governments enhance their genomic infrastructure and capabilities for genomic evaluation, they should consider importing bulls whose daughters' milk yield performance is roughly one standard deviation above the mean in the foreign country, rather than opting for those with higher deviations from the mean.

• Animals in the foreign exporting country were ranked based on the national index and GEBV for milk yield in the foreign country and subsequently, same animals were ranked based on GEBV for

Tanzania or Ethiopia using SNP solutions specific to each country.

• Animals selected based on national index or GEBV of foreign country were above the mean by 1.09 to 1.13 standard deviations for Holstein breed and 1.18 to 1.23 for the Jersey breed in the foreign country.

• Corresponding GEBV for Tanzania or Ethiopia showed very low or negative standard deviation, indicating potential average or poor performance in Tanzania and Ethiopia.

• However, selecting imported animals based on GEBV for Tanzania or Ethiopia led to significantly higher performance of approximately 25% to 30% standard deviation above the average animals in both countries.

• The corresponding animals in the foreign exporting country were average or just above average animal (daughters of these animals were 0.89 to 1.05 standard deviation above the mean). This suggests that animals likely to excel under SHDS are those with approximately one standard deviation above the mean TD milk yield in the exporting foreign country, rather than those with higher deviations from the mean. The results showed that selecting animals based on their foreign genetic merits and importing them for crossbreeding with local breeds may lead to average or poor performance in LMIC's SHDS. However, utilizing GEBVs from the genomic models developed for Tanzania or Ethiopia enables the selection of foreign animals with significantly higher performance in SHDS. Importantly, animals performing well in SHDS are those with GEBVs close to the mean milk yield in the exporting country. This highlights the importance of genomic information in selecting better-performing animals for smallholder dairy systems that lead to improved productivity and sustainability. Policy implications and recommendations Dairy industry stakeholders including policymakers in LMICs should prioritize the adoption of genomic selection methods and support evaluations based on locally generated data to identify, select and certify the most genetically superior and appropriate animals for their local production environments. Investments in infrastructure to enable adequate phenotyping and application of genomic technologies, and capacity building to promote their wider adoption are crucial to sustained implementation of these methods and approaches. Appropriate incentives should be created to enhance adoption. As genomic evaluation becomes increasingly routine, appropriate national policies and certification systems need be put in place and used to guide the importation of foreign bred dairy seedstock. For LMICs, it is better to import genetics that are slightly above average in temperate environments. Opting for top-ranked bulls from temperate environments and more intensive commercialized dairy systems could jeopardize the competitiveness and profitability of smallholder dairy systems. It is important to establish training programs to build/strengthen the capacity of national livestock organizations in utilizing genomic information for selection of elite animals for breeding. At the same time, fostering collaboration between research institutions, government agencies and stakeholders in the private sector will ensure the sustainable adoption and use of genomic technologies in dairy production. Conclusion The use of genomic information offers a promising solution to enhance milk yield in small holder dairy systems of lower- and middle-income countries in the tropics. By utilizing this technology, facilitated by appropriate phenotyping of uniquely identified animals, policymakers can make well-informed decisions aimed at enhancing both the productivity and sustainability of dairy farming in the region. Sufficient genetic variation in livestock populations is necessary both for adaptation to future changes in climate and consumer demand, and for continual genetic improvement of economically important traits. Unfortunately, the current trend is for reduced genetic variation, both within and across breeds. The latter occurs primarily through the loss of small, local breeds. Inferior production is a key driver for loss of small breeds, as they are replaced by high-output international transboundary breeds. Selection to improve productivity of small local breeds is therefore critical for their long term survival. The objective of this paper is to review the technology options available for the genetic improvement of small local breeds and discuss their feasibility. Most technologies have been developed for the high-input breeds and consequently are more favorably applied in that context. Nevertheless, their application in local breeds is not precluded and can yield significant benefits, especially when multiple technologies are applied in close collaboration with farmers and breeders. Breeding strategies that require cooperation and centralized decision-making, such as optimal contribution selection, may in fact be more easily implemented in small breeds.

The small census size of local breeds does bring potential advantages. For example, implementation of Operating characteristic (OC) selection requires decision-making to be centralized, which is impossible in large commercial populations where autonomy is widely dispersed and breeding organizations compete. (by the way OC curve describes how well an acceptance breeding plan. In local breeds, fewer stakeholders are involved, so such coordination may be possible. Research proposed a practical method to maximize genetic gain and minimize inbreeding by selection of dairy bulls on the genetic index of their progeny weighted by the cost of their expected inbreeding, a method that—due to its simplicity—could be promoted in local breeds. However, to date the OC method has been mainly analyzed in simplified populations with high selection intensities and rarely in multi stage selection schemes and under the conditions encountered in local breeds. When pedigree and performance recording is limited, as often it occurs in the local breed scenario, genetic improvement can be generated in a small fraction of the population, the nucleus and then disseminated to the whole population, with or without the use of artificial insemination. Annual genetic gains ranging from a minimum of 0.073 SD/generation (100-female nucleus for a commercial population of 500 females) to a maximum of 0.138 SD/generation (400-female nucleus for a commercial population of 5,000 females) have been simulated in small ruminant populations. A limitation with some nucleus schemes can be the genetic lag occurring between the commercial population and the nucleus.

In conclusion, small local breeds face many challenges in maintaining or increasing their population sizes in order to avoid extinction. Their inferior productivity (relative to larger breeds) is a common reason why many small breeds are small. In turn, their size inhibits small breeds from exploiting economies of scale afforded to large breeds in genetic selection. Nevertheless, some form of genetic improvement is almost necessary for small breeds to have any hope for long-term survival. Although small breeds may not be able to fully utilize technological advances such as GS and innovative phenotyping, they can benefit from the ongoing development and use of these technologies in large breeds. Advanced methods to optimize genetic response and maintenance of diversity may actually be more easily applied in breeds with small population sizes and fewer stakeholders. Application of a battery of genetic tools, along with close cooperation with breeders and utilization of other tools such as innovative product marketing (FAO, 2013) may allow small breeds to not only survive, but also thrive.

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Chapter 8

Strategies to Improve the Efficiency of Beef Cattle Production

Strategies to Improve the Efficiency of Beef Cattle Production

8-1: Highlight on Efficiency of Beef Cattle

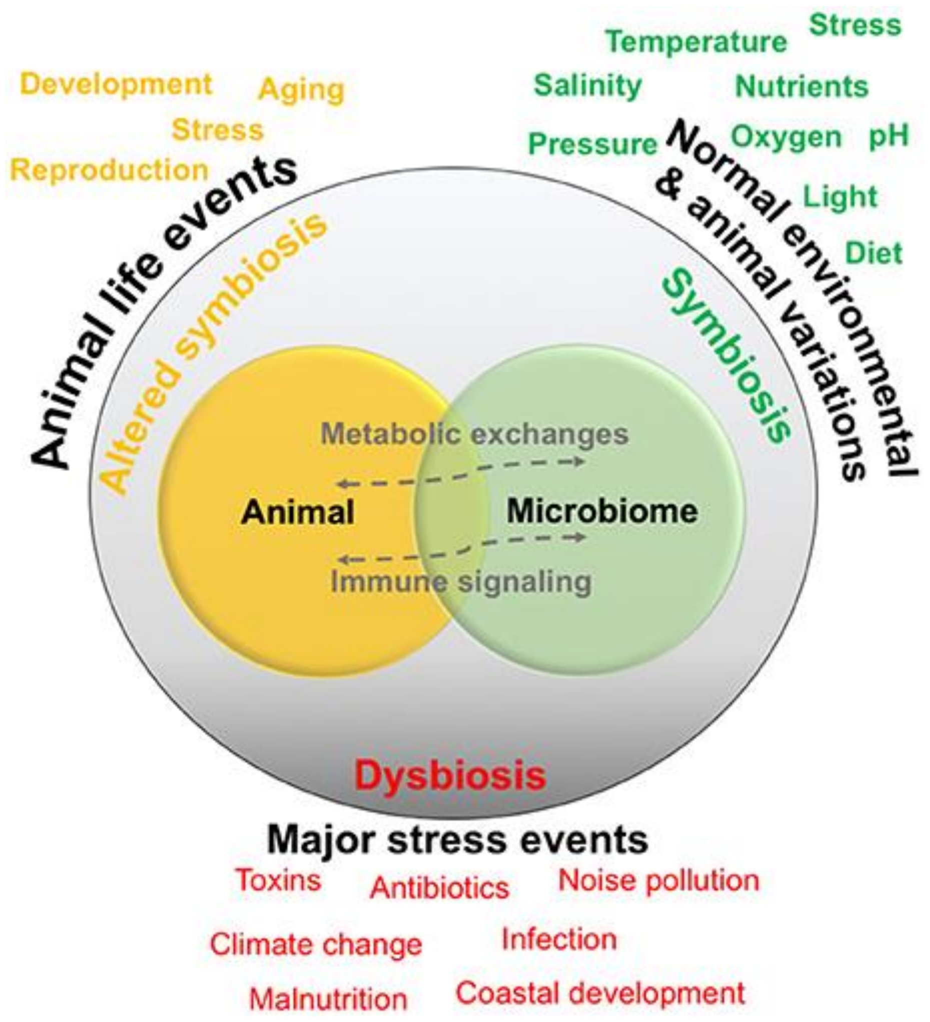
Globally, there are approximately one billion beef cattle, and compared with poultry and swine, beef cattle have the poorest conversion efficiency of feed to meat. However, these metrics fail to consider that beef cattle produce high-quality protein from feeds that are unsuitable for other livestock species. Strategies to improve the efficiency of beef cattle are focusing on operational and breeding management, host genetics, functional efficiency of rumen and respiratory microbiomes, and the structure and composition of feed. These strategies must also consider the health and immunity of the herd as well as the need for beef cattle to thrive in a changing environment. Genotyping can identify hybrid vigor with positive consequences for animal health, productivity, and environmental adaptability. The role of microbiome–host interactions is key in efficient nutrient digestion and host health. Microbial markers and gene expression patterns within the rumen microbiome are being used to identify hosts that are efficient at fiber digestion. Plant breeding and processing are optimizing the feed value of both forages and concentrates. Strategies to improve the efficiency of cattle production are a prerequisite for the sustainable intensification needed to satisfy the future demand for beef. Furthermore, across the world, beef cows are an important source of cattle for the beef industry and frequently serve a unique role in converting low quality forage to high quality protein for human consumption. In addition, the land type typically used to maintain beef cow herds is generally not suitable support intensive dairy or crop production. Beef cow systems vary enormously across countries in terms of herd size, stocking density, and level of output. Irrespective of the system of production, herd reproductive performance is a key driver of efficiency and profitability. Unlike dairy production systems, where cows frequently have less well-defined calving patterns, the vast majority of beef cow herds tend to be on the basis of seasonal calving with calving occurring at, or around, the time of onset of pasture growth. As the calf is largely the sole output in beef cow enterprises, reproductive efficiency is a key determinant of profitability, irrespective of the system of production used.

8-2: Biological Efficiency and End Product Value

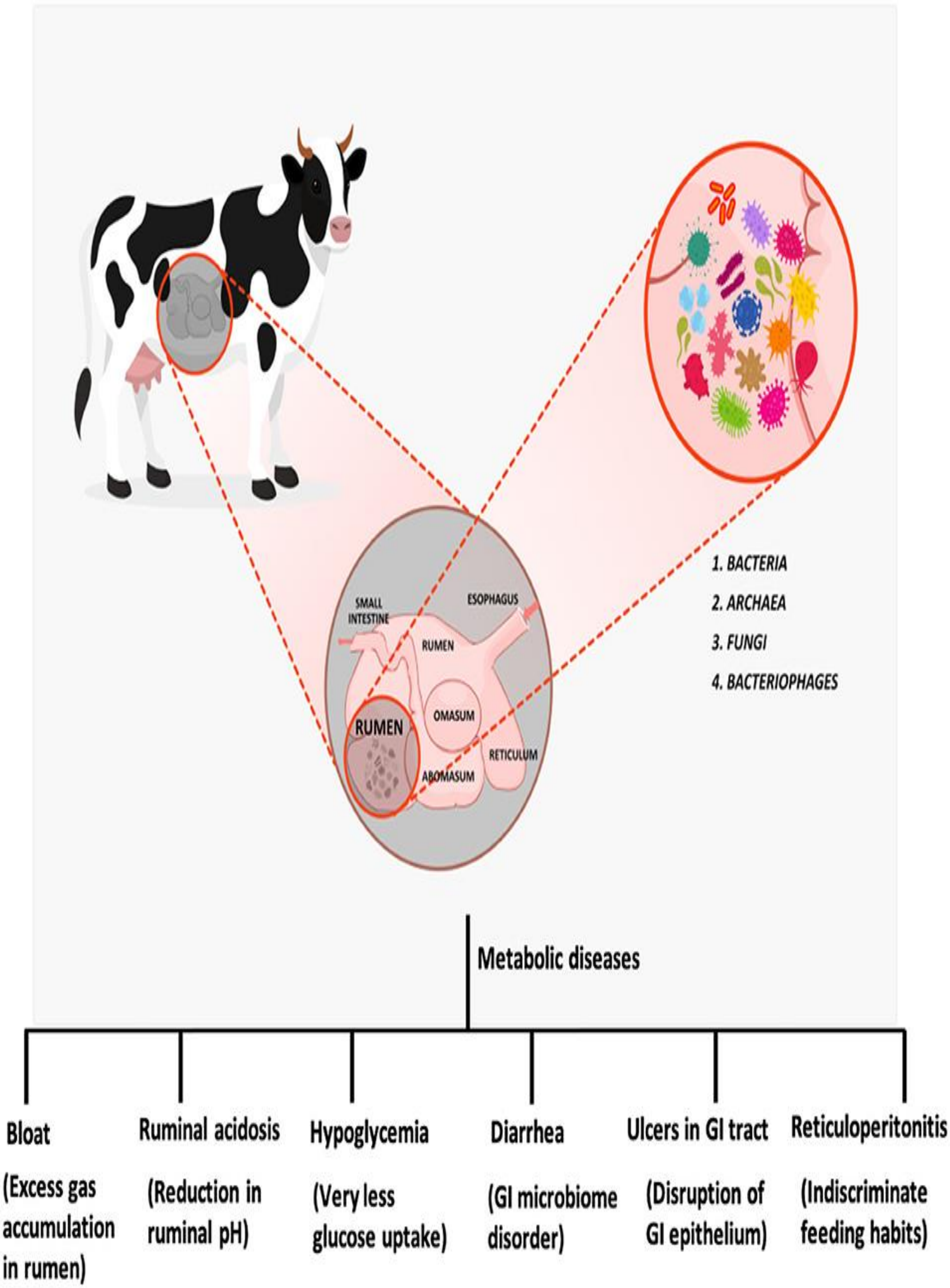
Efficiency, defined as the ratio of output to input, can be calculated for any product, and for any of the resources employed to generate that particular product. "Weight of calf weaned per unit cow live weight" is commonly used to measure biological efficiency in the beef cow herd, based partly on the assumption that feed intakes and hence costs are related to live weight. A more direct measure, and the one used here, is "weight of carcass produced per unit of feed intake". The biological efficiency of the traditional beef breeding cow, determined in this manner, is low compared to that of other beef cow systems (e.g. twinning cows, once-bred heifers). This is primarily because of the relatively low reproductive rate in traditional cow herds and the high proportion of annual feed consumption used to maintain the breeding female and her replacements. Furthermore, in a seasonal pasture production system, where the supply of feed is likely to limit production at certain times of the year, feed does not have fixed value. Feed costs therefore become an important component of the efficiency equation. Utilization by other livestock of a scarce resource (e.g. winter feed) is also likely to have an influence on the economic efficiency of the system. For example, if biological efficiency is ignored then output (weight of calf weaned) may be increased simply by increasing cow size but with no consideration of the extra feed inputs necessary to maintain larger cows, or the pressure that additional feed requirements may place on other components of the system at particular times of the year. In this paper, the relevance of biological efficiency is explored by comparing both biological and economic efficiencies of four cattle systems - traditional beef cows, beef x dairy cows (with and without twinning) and once-bred heifers - alone and in mixed sheep and cattle policies. It was concluded that biological efficiency is a relevant concept, primarily because its components (carcass weight and feed consumed) are also important determinants of economic efficiency. However marked differences between systems in the value of the carcass produced and/or feed consumed can lead to a poor correlation between the efficiency ranking of systems by biological and economic criteria. The producer must provide management to control the reproduction of the cow-calf operation. Reproductive performance is influenced more by management and environment than through genetics. The cow-calf producer must exercise control over the factors that impact reproduction: nutrition, age, health and management. New technologies in reproduction offer the producer opportunity to have greater control over reproduction. However, the benefit of these technologies cannot be realized unless the basic management practices are executed. To have control over the factors that impact performance and profitability, the producer must manage reproduction of the commercial cow-calf herd.

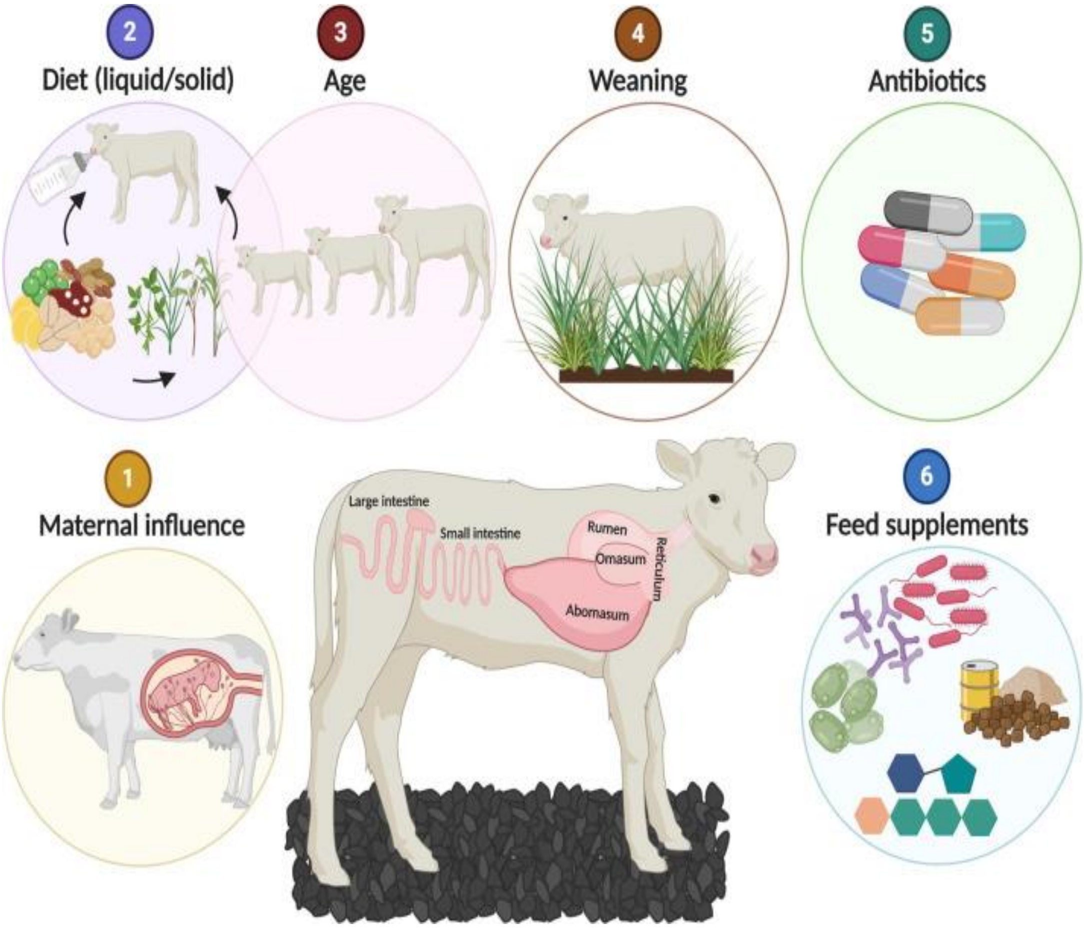
A microbiome

The microbiome refers to the collection of all microbes (bacteria, fungi, viruses) that naturally live on and inside living organisms. It includes both helpful and potentially harmful microbes. Bacteria have the first opportunity to utilize nutrients consumed by cattle. Pre-gastric fermentation in the rumen results in the modification of nutrients before the animal can utilize them. This modification can have positive outcomes such as allowing ruminants to use the complex structural carbohydrates in plants via bacterial fermentation and can have negative outcomes when high-quality nutrients are modified to lower quality nutrients through fermentation. A potential cause of variation in feed efficiency could be a consequence of differences in nutrient utilization by bacteria amongst cattle. One of the difficulties in describing the relationship between the microbiota of the gastrointestinal (GI) tract and feed efficiency is the multiple definitions of feed efficiency. A considerable amount of research conducted in this area has defined feed efficiency by classifying cattle as having less or greater residual feed intake (RFI). Most of the time cattle that are classified as having a less RFI also have less feed intake. A function of lower intakes is often slower passage rates, which may drive differences in the microbiota. Other models have studied extremes in intake and average daily gain (ADG) in a factorial design. Because of the rumen's known contribution to nutrient availability and methane production, many of the studies have concentrated on it and less research has been conducted on the remainder of the GI tract. In beef cattle, results showed that the diversity of bacteria down the digestive tract of ruminants. The jejunum which is a major sight for digestion and absorption had a large number of bacterial operational taxonomic unit (OTUs) that were associated with animal gain, and these associations were nearly equal between the ADG classifications. The cecum had the largest number of bacterial associations with ADG of all the sites evaluated. Approximately 70% of the differentially observed OTUs in the cecum were associated with greater ADG, which might indicate that it has a greater role in animal performance than previously realized. The community of microorganisms inhabiting a given environment is referred to as a microbiota, while the term microbiome is used to indicate microbiota's collective genomes. On the other hand, the concept of metagenomics, first defined as "the direct genetic analysis of genomes contained in an environmental sample", has been elaborated further as the "study of the structure and function of entire nucleotide sequences isolated and analyzed from all the organisms (typically microbes) in a bulk sample". However, the fast-increasing body of research produced in the wake of the above-mentioned compelling socioeconomic reasons has yet to cover much ground. Among the main shortfalls of this kind of study is the almost exclusive focus on cosmopolitan and highly selected breeds, which lacks representativeness both in terms of diversity and functionality, as the most promising knowledge may come from locally adapted native breeds. The role of microorganisms in the resilience and performance of livestock species is of paramount interest for their potential commercial value, especially in a time of rampant global change. Another critical factor is the uneven attention being paid to bacteria, which include taxa that cause significant economic losses in addition to being a serious hazard to public health. On the other hand, the other microorganisms, such as fungi, archaea, protozoa, and viruses, have received far less attention. Yet another weakness is that the classical met barcoding approach is still largely used, as opposed to increasingly feasible and affordable shotgun approaches that are now available (although only for a low number of samples) for a more precise and extensive characterization of microbial communities.



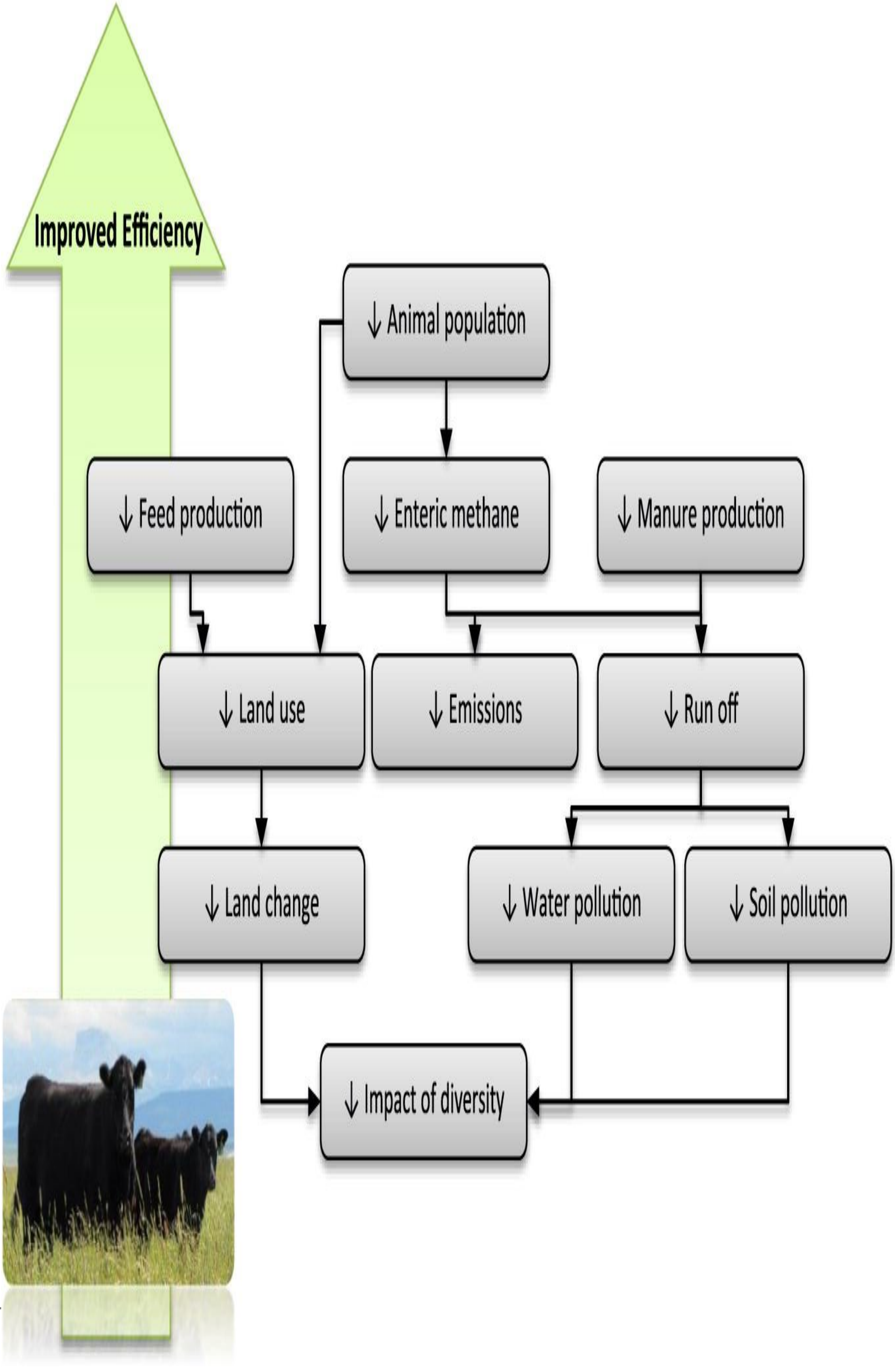
All animals on Earth form associations with microorganisms, including protists, bacteria, archaea, fungi, and viruses. In the ocean, animal–microbial relationships were historically explored in single host–symbiont systems. However, new explorations into the diversity of microorganisms associating with diverse marine animal hosts is moving the field into studies that address interactions between the animal host and a more multi-member microbiome. The potential for microbiomes to influence the health, physiology, behavior, and ecology of animals could alter current understandings of how animals adapt to change, and especially the growing climate-related and anthropogenic-induced changes already impacting the ocean environment. The mammalian gut microbiome has emerged as a key regulator of host physiology, and coevolution between host and microbial lineages has played a key role in the adaptation of mammals to their diverse lifestyles. Diet, especially herbivory, is an important correlate of microbial diversity in mammals. Most mammalian microbiomes are also strongly correlated with host phylogeny, despite profound shifts in diet. This suggests host factors that themselves change across host phylogeny, such as gut physiology, play an important role in structuring the gut microbiomes across mammals. The vertebrate adaptive immune system is even speculated to have evolved as just such a factor for selective maintenance of symbiotic homeostasis. The strong bond between public health and the economy has been propelling the interest in microbiome research, which is deemed to hold a huge applicative potential under the One Health strategy and other similar initiatives. Most of such studies addressing health and animal production have been mostly focused on gut microbiota, which is justified by the crucial role of these microorganisms in nutrition, fitness, and performance traits. It is generally expected that advancing knowledge of the ruminant microbiome, bears a huge potential in terms of boosting animal production and health while lessening environmental pollution. This promise seems of utmost importance when considering forecasts predicting an almost two-fold increase in the current production and consumption of meat in 30 years from now, with changes in dietary habits in developing countries—on top of human population growth—which will boost the demand for dairy products.


SMALL INTESTINE
ESOPHAGUS
RUMEN
OMASUM
RUMEN
RETICULUM
ABOMASUM
1. BACTERIA
2. ARCHAEA
3. FUNGI
4. BACTERIOPHAGES
Metabolic diseases
Bloat
(Excess gas accumulation in rumen)
Ruminal acidosis
(Reduction in ruminal pH)
Hypoglycemia
(Very less glucose uptake)
Diarrhea
(GI microbiome disorder)
Ulcers in GI tract
(Disruption of GI epithelium)
Reticuloperitonitis
(Indiscriminate feeding habits)

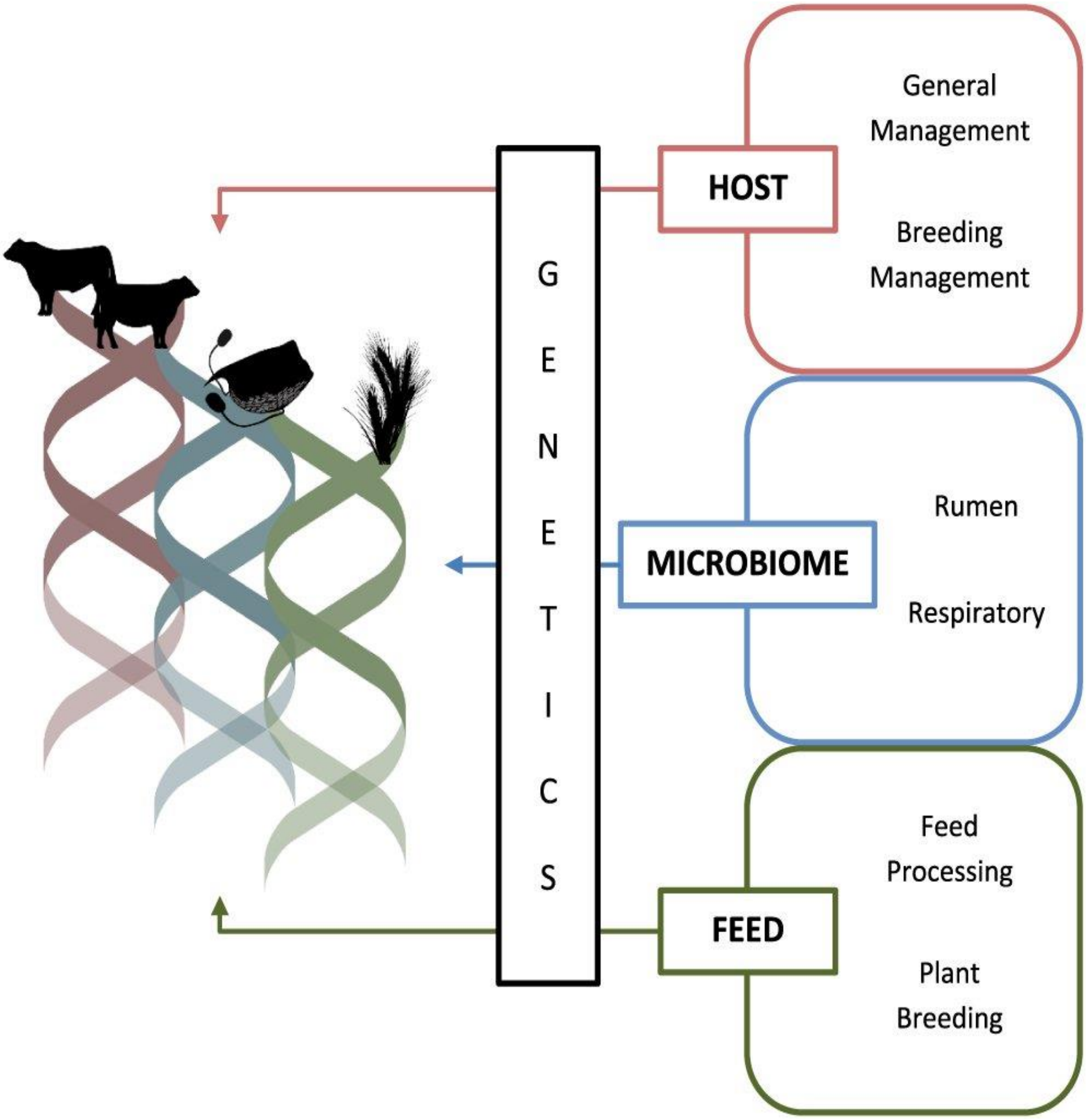


Calf's microbiome.

The major advances in high-throughput sequencing technology have opened a new era in the study of the livestock gut microbiome, the composition and function of which are tightly associated with animal health and productive performance. The information produced has a profound social and economic impact. Previous attempts to take stock of available gut microbiome studies in livestock were mostly focused on cattle and chickens, or on the microbial groups rather than their hosts. In cattle, microbiome composition has been widely investigated in terms of feeding-related changes and their impacts on production strategies or environmental issues associated with ruminal methane emissions. It was expanded this text to other livestock animals, trying to make the point about what has been mostly performed so far and what is still lacking. A first consideration deals with the subjects of the microbiome studies carried out so far, in which priority was given to some species (such as cattle) rather than others (such as goats). Additionally, there is a clear bias in terms of the breeds investigated: expectedly, most studies are focused on a few cosmopolitans and highly selected breeds, while local breeds from rural areas are largely neglected, even though livestock research is a fundamental component to boost development strategies and the socioeconomic level of associated human communities. Characterizing the microbiome composition and its interaction with the host in non-intensive husbandry systems might, for instance, provide useful information on how to optimize livestock productivity through nutrient supplementation. Furthermore, it should be noted that a considerable number of microbiome studies, also on local breeds, have been carried out in China or Europe, while much less attention has been devoted to Africa and the tropical and subtropical regions as a whole.



Improved Efficiency
↓ Animal population
↓ Feed production
↓ Enteric methane
↓ Manure production
↓ Land use
↓ Emissions
↓ Run off
↓ Land change
↓ Water pollution
↓ Soil pollution
↓ Impact of diversity


General
Management
HOST
Breeding
Management
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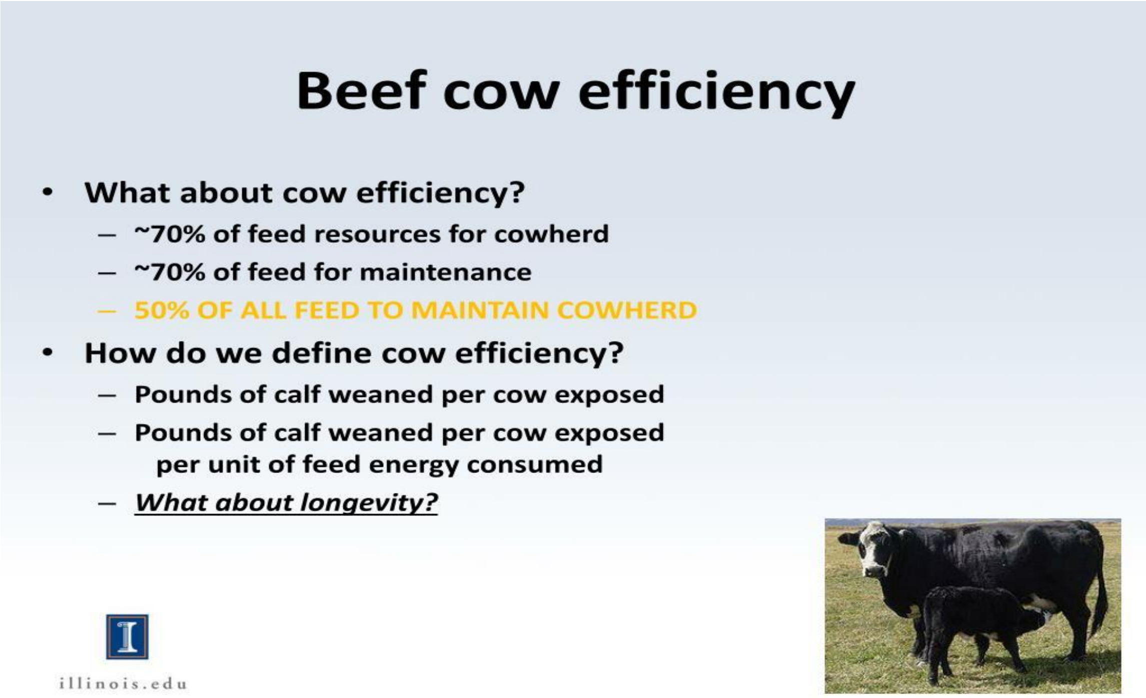
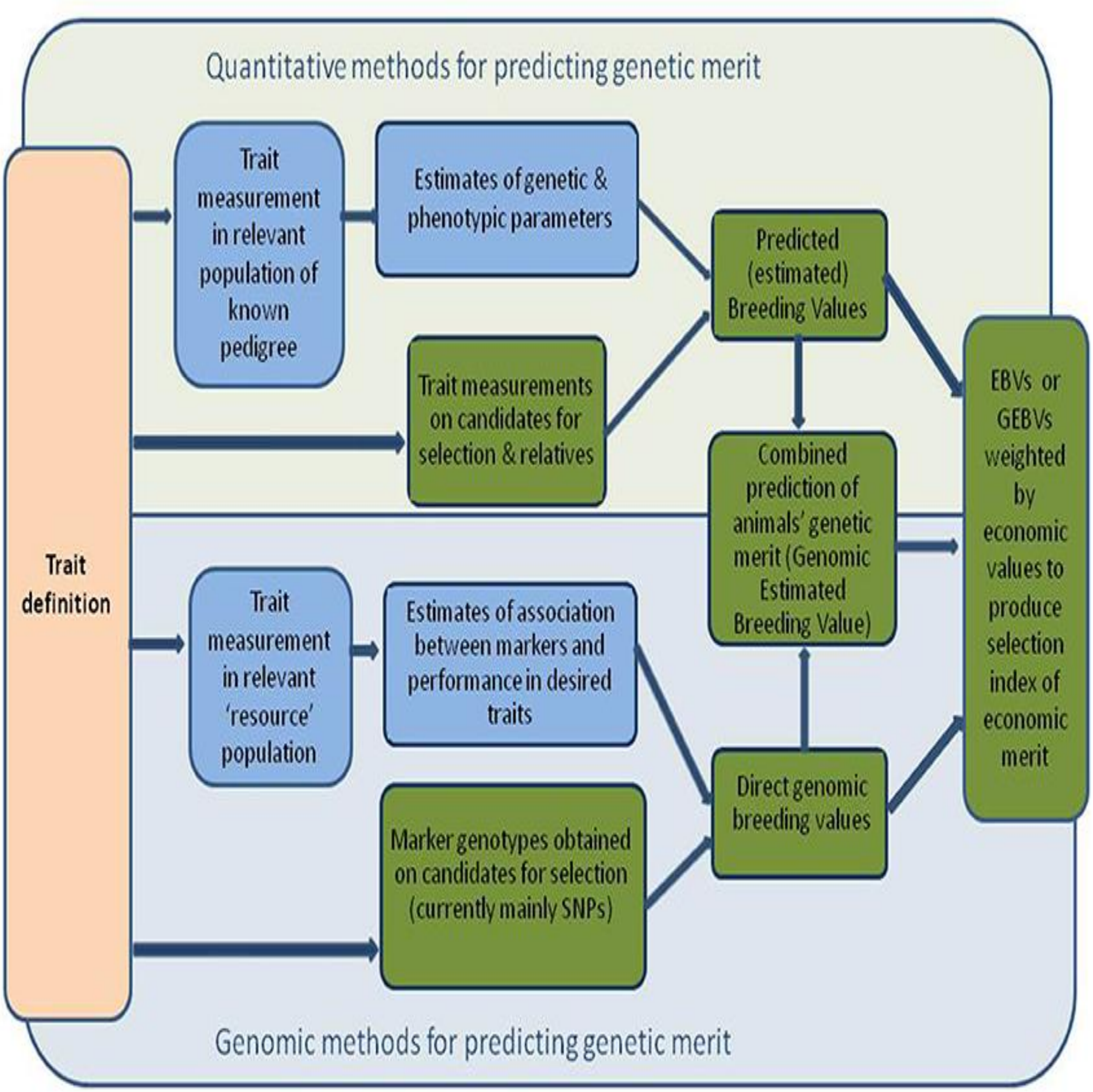
Rumen
MICROBIOME
Respiratory
Feed
Processing
FEED
Plant
Breeding



8-3: Factors Affecting Beef Cattle Efficiency Include

8-3-1: Genetics

Animal breeding and genetics have changed significantly over the past decades. Genetic improvement of beef cattle uses to be largely dependent on visual appraisal. While this remains extremely valuable in selection programs, beef cattle breeding is now based predominately on the use of technology. The development of computer and information technology had a major impact on data collection and genetic evaluation procedures, allowing incorporation of new traits and comparison of breeding values across herds, breeds and countries. Today's consumers are increasingly aware of health, environmental and animal welfare issues. Successful genetic improvement programs for a sustainable beef industry need to balance these issues with price and production efficiency. This text reviews some aspects related to the genetic improvement programs of beef cattle industry. The focus is on challenges, opportunities and innovations related to use of genetics and genomics technologies to address current and future issues facing the beef industry. The use of genotype information to improve the predictability of Expected Progeny Difference was first implemented in American Angus cattle in 2009 and has now grown to where over 50% of all registered calves are genotyped. Animals with only a genotype now have genetic prediction accuracy equivalent to eight or more progeny records across all traits. Reproductive technologies have also been widely adopted with approximately 50% of all calves born being the result of artificial insemination. Non-surgical embryo transfer started increasing in the mid-1990s with just over 10% of calves born being the result of embryo transfer since 2005. The number of embryos created with in vitro technologies has risen sharply since 2015 and now accounts for close to 30% of all ET calves. Genomics has enabled embryo technologies to be more impactful, as females can be selected with greater accuracy and sires can be used at earlier ages with moderate accuracy. Large numbers of females genotyped each year also increases the number of selection candidates, increasing the selection intensity. Genomics, combined with increased recording, also provides more information on females. This increases the spread in the estimated index values of current dams, identifying more elite dams for selection as embryo donors. The greater scope of female selection also contributes to better inbreeding management. Commercial animals genotyped could be targeted for oocyte harvesting at slaughter, creating opportunities for low-cost high value beef embryos to be used in the beef on dairy segment of the industry. Moreover, genomic selection has significantly changed the landscape of genetic improvement in beef cattle breeding. Some herald the technology as the most significant advancement to influence the industry since the introduction of artificial insemination over half a century ago. The genetic evaluation has been described in the past years, and the implementation of genomics, including increases in genetic trends for measured traits since the implementation of genomics, has been recently described by many researchers. Increases in genetic trends since the implementation of genomic selection provides evidence that genomics has changed the way beef cattle are selected and evaluated. Similar to genomics, embryo technologies, are a tool that can be exploited to increase genetic gains by reducing the generation interval and increasing the selection intensity for dams, where more calves are produced from the best dams. Reproduction, fertility and development embryo technologies are not additive but indeed complementary such that genomics provides the opportunity for embryo technologies to be more effective but also embryo technologies provide an opportunity for genomics to be more effective. Genomic selection Genomic selection was first proposed as a technology in early of 20th century. Implementation of genomic selection was made possible through the advent of moderate density genotyping technologies while at relatively low cost. It has resulted in a boon and benefit for breeders as they have made additional genetic progress in all major livestock species, especially dairy cattle. Research predicted a doubling in the rate of genetic gain with the implementation of genomic selection in dairy cattle. This was accomplished primarily through the use of young bulls with moderately accurate proofs instead of traditional progeny proven sires that have more accuracy but greatly increased costs and generation intervals. This prediction of increased genetic gain has proven to be true and has even been surpassed in some instances. The adoption of genotyping by American Angus breeders is a very good indicator of the value of genotyping to their operations and is illustrated by increasing genotyping overtime. Gnomically enhanced expected progeny differences (EPD) were first implemented at the American Angus Association in 2009. The genotyping rates that are presented are the number of genotypes by birth year, which can be different from the number of genotypes in the evaluation each year as animals can always be genotyped later through access to stored semen and other sources of DNA. There are animals born before 2009 with genotypes in the evaluation but these tend to be more historic animals such as artificial insemination (AI) sires. Since then, the number of genotypes has steadily increased and now represents just over half of all calves registered each year. The genotyping rates in males and females is similar to the ratio of males and females registered each year. Although there are more females registered than males each year and there are more males than females genotyped, this discrepancy is not numerically significant. This demonstrates the importance of genotyping both males and females in a beef herd. It is also an indicator that genotyping is actively being used for selection and genetic improvement. If there was a very high percentage of only males being genotyped it could be an indication that genotyping was being used for marketing purposes, as the sale of young bulls can be the breeder's largest source of income. However, this is clearly not the case in the American Angus herd, which is an indication of genotyping being used to select females. This is especially important when considered in the context of embryo technologies, as genomics could be influencing the selection of donor dams, as would be expected, given the increase in selection accuracy with genomics, providing more accurate EPD on all traits.



8-3-2: Feeding Practices

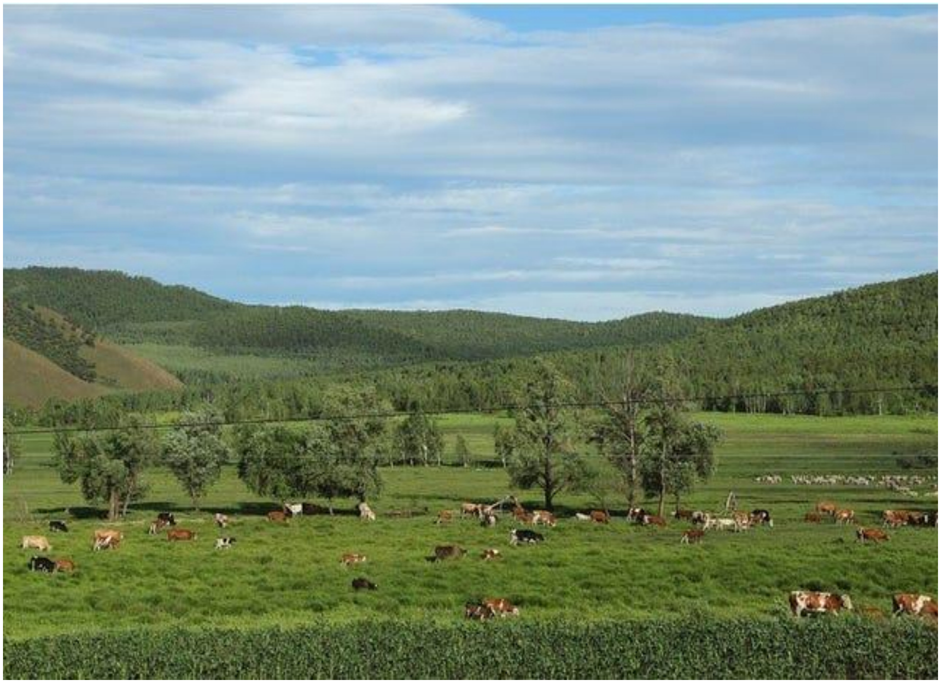
One of the major economic factors influencing the profitability of beef cattle enterprises is the provision of feed, which represents up to three-quarters of total direct costs. In addition, within the context of climate change and more restrictive environmental legislation, beef production is under increased scrutiny.

Consequently, there is considerable interest in improved feed efficiency as a means of augmenting the economic and environmental sustainability of beef production systems. At the animal level, many alternative definitions of feed efficiency exist, each differing in their application. Traditionally, feed conversion ratio (FCR), (i.e. feed: gain) or its mathematical inverse, feed conversion efficiency (i.e. gain: feed), was widely used. More recently, residual feed intake (RFI), defined as the difference between observed feed intake and the expected requirement to support both maintenance of BW and growth, has become the preferred measurement. Because the calculation of the RFI index forces it to be mathematically independent of the level of animal production, it is considered a particularly useful concept to examine the biological mechanisms associated with inter-animal variation in feed efficiency. Globally, beef cattle which are raised in both intensive and extensive production systems. Even in intensive production systems, forage usually accounts for more than 80% of the feed, with calves only receiving high grain diets during a 3–4 month finishing period. The majority of beef cattle are maintained on vast areas of native pastures, where the rumen microbial population converts consumed forages into metabolic products that support the production of protein, mineral and vitamin-rich meat. Production efficiency is higher and the intensity of greenhouse gas emissions lower in intensive than extensive systems. Intensive systems rely more on the use of grains and by-products that are deemed unfit for human consumption, but these feeds can promote digestive disturbances if not properly fed. Intensive systems can also promote disease transmission and the accumulation of nutrients in the form of manure at the site of production. Extensive tame and native pastures harbor vast stores of carbon and promote biodiversity, as these ecosystems are among the most threatened on the planet. Pastures must be managed in a manner that optimizes forage quality while avoiding overgrazing. However, these regions will only produce a reasonable quantity of food for humans if cattle are maintained as an integral component of these ecosystems. If the future demand for beef is to be satisfied, steps need to be taken to adapt beef production systems to climate change. Sustainable intensification of beef production systems is likely the only way to achieve this goal and will require precision feeding, additives that improve efficiency and advanced molecular techniques, like gene editing, to accelerate genetic progress. Humanity needs to accept that sustainable intensification of beef production is a prerequisite to satisfy the future demand for meat. Therefore, improvements in feed efficiency of beef cattle have the potential to increase producer profitability and simultaneously lower the environmental footprint of beef production. Although there are many different approaches to measuring feed efficiency, residual feed intake (RFI) has increasingly become the measure of choice. Defined as the difference between an animal's actual and predicted feed intake (based on weight and growth), RFI is conceptually independent of growth and body size. In addition, other measurable traits related to energy expenditure such as estimates of body composition can be included in the calculation of RFI to also force independence from these traits. Feed efficiency is a multifactorial and complex trait in beef cattle and inter-animal variation stems from the interaction of many biological processes influenced, in turn, by physiological status and management regimen. Insufficient information exists on the relationship between RFI status and productivity-related traits at pasture, a concept critical to the overall lifecycle of beef production systems. The effect of RFI status, suggested that breeding for improved RFI, as part of a multi-trait selection index, is both possible and cumulative, with benefits evident throughout the production cycle. Although the advent of genomic selection, with associated improved prediction accuracy, will expedite the introgression of elite genetics for feed efficiency within beef cattle populations, there are challenges associated with this approach which may, in the long-term, be overcome by increased international collaborative effort but, in the short term, will not obviate the on-going requirement for accurate measurement of the primary phenotype.

Automatic Feeding

8-3-3: Health Status

Beef cattle welfare and health status are influenced by housing and management systems.



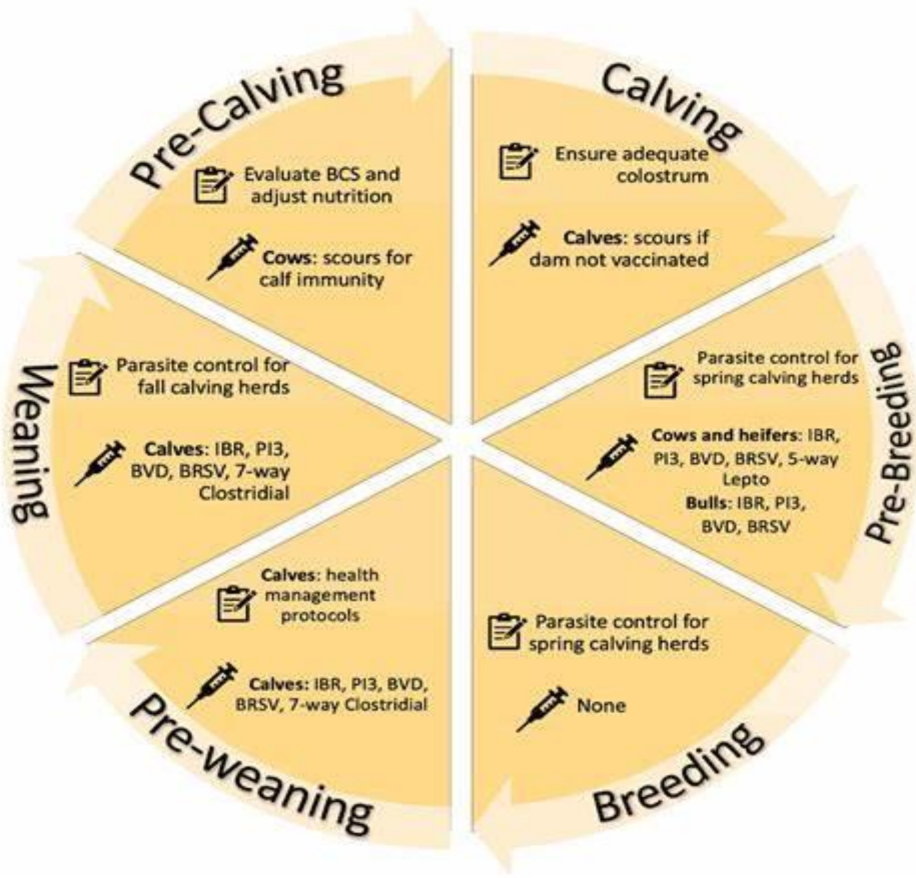
The primary objective of this text is to provide an overview of the interaction between management and health of beef cattle, with a focus on major factors that influence health outcomes and the management practices that promote overall animal health and prevent the development of disease. In the context of this text, "management" is considered to be any procedure or practice that can be adopted by the operation or applied to an individual animal or to groups of animals. Both preventive and responsive herd health management programs are critical to promoting animal health and minimizing the risk of major adverse health events at the individual or herd levels. Having a valid, documented relationship (often referred to as a veterinarian-client-patient relationship, or VCPR) with a veterinarian is a critically important first step toward developing a herd health management program that includes both preventive and responsive components. The veterinarian should be a source of information to determine the components of the herd health management program and the methods that should be used to implement it. The knowledge and experiences of both the producer and the herd veterinarian, as well as perceived health risks to the operation, should be factored in. This should begin with a plan that is established, implemented, and modified over time to meet the evolving needs of the herd. While herd health programs are not one-size-fits-all, there are certain essential components of a herd health management program, regardless of geography, production goals, or cattle type. These include:

- Vaccination programs
- Internal and external parasite control
- Biosecurity
- Disease screening, treatment, and surveillance
- Animal management
- Handling practices
- Facilities design
- Transportation

The old saying is "an ounce of prevention is worth a pound of cure. The livestock industry practices this on a regular basis in order to keep animals healthy. Livestock producers prefer to prevent sickness rather than treat sickness. Treating sick animals is not only expensive, it can be very time consuming. Here are some common techniques producers use to keep their animals healthy and avoid having to treat them. Livestock producers should provide balance rations for their animals to insure a healthy diet. To do this, producers test feeds and then match amounts of nutrients from the feeds to the animals' nutrient requirements. The National Research Council publishes nutrient requirement books for a wide variety of species. Nutrient requirement tables within these books account for different ages of animals and their production status. Requirements differ for various production statuses such as breeding, pregnancy, milk production, animal growth and performance. In addition to the feeds, producers provide trace mineral mixtures formulated with salt to adjust for nutrient deficiencies from the feeds. Why is nutrition so important? Growth rates, reproductive efficiency and especially immune system function all rely on good nutrition for best performance. Good mineral nutrition also boosts an animal's response to vaccinations, a primary method to protect animals from disease. I can't stress enough the importance of a clean and dry environment with good ventilation. Animals are well adapted to handle cold temperatures when they are well fed and have a good hair coat. Good ventilation can result in good air quality. This is why livestock producers keep barns cleaned out and well bedded during the winter months. It is also why animals give birth to their young on pastures. Furthermore, livestock producers carefully choose vaccination products to best meet the needs of their individual operation. They choose vaccines based on prior experience with disease on their farm as well as the likelihood of exposure to diseases. Producers read product labels and handle vaccinations properly. Simple procedures producers follow include proper storage temperature, vaccinating clean and dry animals, injecting with clean needles and injecting with the correct method. Producers also check expiration dates and discard expired products. Only healthy animals get vaccinated so that the immune system best utilizes the vaccine. And, producers vaccinate at least two weeks prior to a stressful event such as weaning, transporting or castrating. One means that animal diseases arrive on a farm is through contact with other animals that may or may not appear sick. Producers who exhibit their animals at various shows will house these animals separate from the main herd or flock once those animals return home from the show. This quarantine period should last three to four weeks before those animals can be mixed with the rest of the herd or flock on the farm. However, animal diseases can also arrive on a farm through indirect contact. This occurs when producers visit other farms, transport animals to a sale barn, or even visit a county fair. Once the producer arrives back at the home farm, they change clothing and shoes to avoid exposing their own animals to bacteria and viruses that could be carried home on their clothing or footwear. Prevention programs are not fool proof: livestock operations can still develop sick animals on occasion. However, the goal is to minimize the risk of animals getting sick so that the need for treatment is less likely. Farmers observe animals on a daily basis so they can identify very quickly when problems arise. Sick animals are moved to a location away from the main herd or flock and treated as necessary. Livestock producers work tirelessly to raise high quality and healthy animals. Several beef cattle management practices are capable of increasing enterprise profitability through increasing animal productivity, enhancing animal value, and/or decreasing cost of production. Animal disease results in economic loss through mortality, treatment expenses, and lost performance or productivity. An understanding of the economic impact of both clinical and subclinical diseases is important to developing a strategic herd health management program. Although the costs associated with death loss, with cattle that are culled or "railed" (marketed prematurely), and with direct treatment expenses are easy to calculate, the hidden or indirect costs of disease, such as decreased performance and productivity or impaired development, are much more difficult to estimate. Management decisions generally impact animal health through influencing susceptibility or resiliency to health challenges, or through influencing the frequency and magnitude of exposure to such challenges.

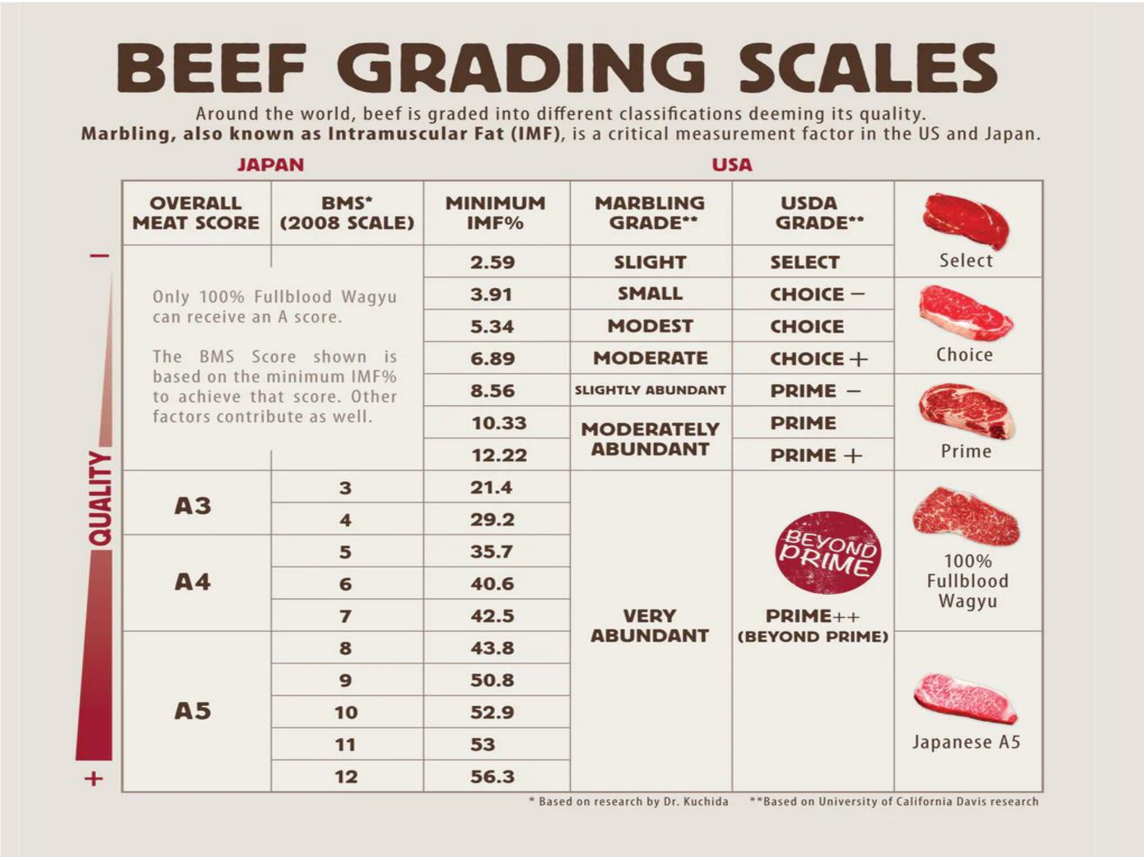
8-3-4: Reproductive Efficiency

A reproductively efficient beef cow herd will be fundamental to meeting the protein and specifically, red meat demand of an ever increasing global population. However, attaining a high level of reproductive efficiency is underpinned by producers being cognizant of and achieving many key targets throughout the production cycle and requires considerable technical competency. The lifetime productivity of the beef-bred female commences from the onset of puberty and will be dictated by subsequent critical events including age at first calving, duration of the postpartum interval after successive calvings, conception and pregnancy rate, and ultimately manifested as length of inter-calving intervals. In calved heifers and mature cows, the onset of ovarian activity, postpartum is a key event dictating the calving interval. Again, this will be the product mainly of prepartum nutrition, manifested through body condition score and the strength of the maternal bond between cow and calf, though there is increasing evidence of a modest genetic influence on this trait. After the initiation of postpartum ovarian cyclicity, conception and subsequent pregnancy rate is generally a function of bull fertility in natural service herds and heat detection and timing of insemination in herds bred through AI. Cows and heifers should be maintained on a steady plane of nutrition during the breeding season, but the contribution of significant excesses or deficiencies of nutrients including protein and trace elements is likely to be minor where adequate pasture is available. Although increased efforts are being made internationally to genetically identify and select for more reproductively efficient beef cows, this is a more long-term strategy and will not replace the need for a high level of technical efficiency and management practice at farm level. Calving Interval In Beef Cattle: Refers to the amount of time between the birth of a calf and the birth of a subsequent calf from the same cow. The target for most commercial herds is to achieve a "live calf every 365 days. Reproductive performance of beef cows affects the profitability of beef production systems. Heritability of fertility traits is generally low, which means that there is a great influence of the non-genetic environmental factors. Selection based on breeding value is an effective way to improve fertility traits, and the knowledge of genetic parameters is necessary for this approach. In this study, the two most common fertility traits—the age at first calving and first calving interval are evaluated. It was found that genetic parameters and genetic correlation between these two traits differ according to population structure (multi-breed population, the population of Aberdeen Angus, and Charolais breed). A breeding strategy should be developed within a breed. Embryo Technologies: The influence that AI has played in the cattle is quite clear. Starting from the early 60s, there has been a steady increase in the proportion of calves born from AI mattings. Proportion of calves from AI mattings has been steady at close to 50% in recent years. The influence of AI on genetic progress is likely considerably higher than this when the proportion of calves whose sire was the result of an AI mating is also considered. The proportion of calves whose sire is the result of an AI mating has been over 80% in recent years. Unlike AI where adoption rates have been increasing steadily from the early 60s, the adoption of embryo transfer (ET) technology did not occur until later. The proportion of calves produced through ET noticeably starting to increase in the mid-90s and has stayed fairly steady at just over 10% of calves registered since 2005. Similar to AI, the proportion of calves where at least one parent was the result of ET is remarkably higher. Going back to the late 80s the proportion of animals who have an ET parent has been steadily increasing and is over 40% in recent time. This is most likely the result of AI sires being ET calves. This highlights the impact ET technologies are having in the most influential category of animals when it comes to genetic progress. The use of in vitro embryo production is more recent and shows that the portion of calves resulting from in vitro embryo production started to increase in 2015 considerably and now represents close to 30% of all ET calves born. One reproductive technology that has intersected with genomics that is also worth mentioning is embryo genotyping. By genotyping an embryo through biopsy, the same selection accuracy, is possible. This allows selection pressure on embryos pre-implantation which can be significant when recipients are a limiting factor. The potential application of embryo genotyping to increase genetic progress was Observed, and challenges with genotyping embryos after a DNA amplification step has been addressed by researchers. The genotyping of embryos is already available to American Angus breeders and results from use of this technology have been recently reported, with gnomically enhanced EPDs calculated and used for selection. The application, in practice, is influenced by a number of factors including the cost of embryo production, the value differential between selected and unselected embryos, along with the cost of raising calves through recipients. The value of embryo genotyping is highest when the cost of embryo production is low and the value differential between selected and unselected embryos is high and when the cost of recipients is high. Although available to Angus breeders, the technology has seen limited application to date. This paper focusses on technologies that are currently available and implemented. A technology that has been discussed for some time but has yet to be put into practice on a commercial scale is in vitro breeding (IVB). New enabling breakthroughs to support this approach were recently observed. The approach leverages genomic selection as an important part of the system. Briefly, embryos from elite parents are used to create multiple embryonic stem cell lines (ESC) which can be genotyped and selected. The selected ESC is used to create gametes to create hundreds of embryos through IVF, which are used to create the next generation of ESC and the cycle repeats. The time to complete one cycle is 3–4 months, which greatly reduces the generation interval. The authors predict that 100 generations would be possible in a 25-year span compared to 10 with regular genomic selection in a dairy cattle breeding program. This greatly reduced generation interval contributes directly to increased genetic progress. Beyond the scope of this paper that is focused on current implemented technologies, it is worth noting these emerging technologies that could provide another step change in the future. Commercial opportunities Genomics could also open up new opportunities in the commercial sector when combined with reproductive technologies. Genotyping of commercial animals through products such as GeneMax Advantage are being used to select and manage commercial animals. This includes the selection of replacement heifers but also the management and marketing of feeder cattle. These genotyped commercial animals essentially have the same level of information regarding genetic prediction accuracy as seedstock animals, as the genomic reference is the same. Genomics has been a significant advancement in selection of American Angus cattle with moderate accuracies available across all measured traits. This provides the opportunity to use younger sires without the need for progeny testing and a trend to have a lower average age of sires in recent years supports this. Genomics supports effective use of embryo technologies as more genetic differences among young females are identified and with close to half of all females being genotyped each year, this large pool of selection candidates increases selection intensity and helps manage inbreeding. Genomics provides further opportunities for embryo technologies in the commercial sector as genotyped females could be targeted at slaughter for oocyte harvesting for use in an in vitro embryo production program. Genomics provides more accurate information for selection, which is complementary to embryo technologies, which capitalize on the identified elite female genetics.



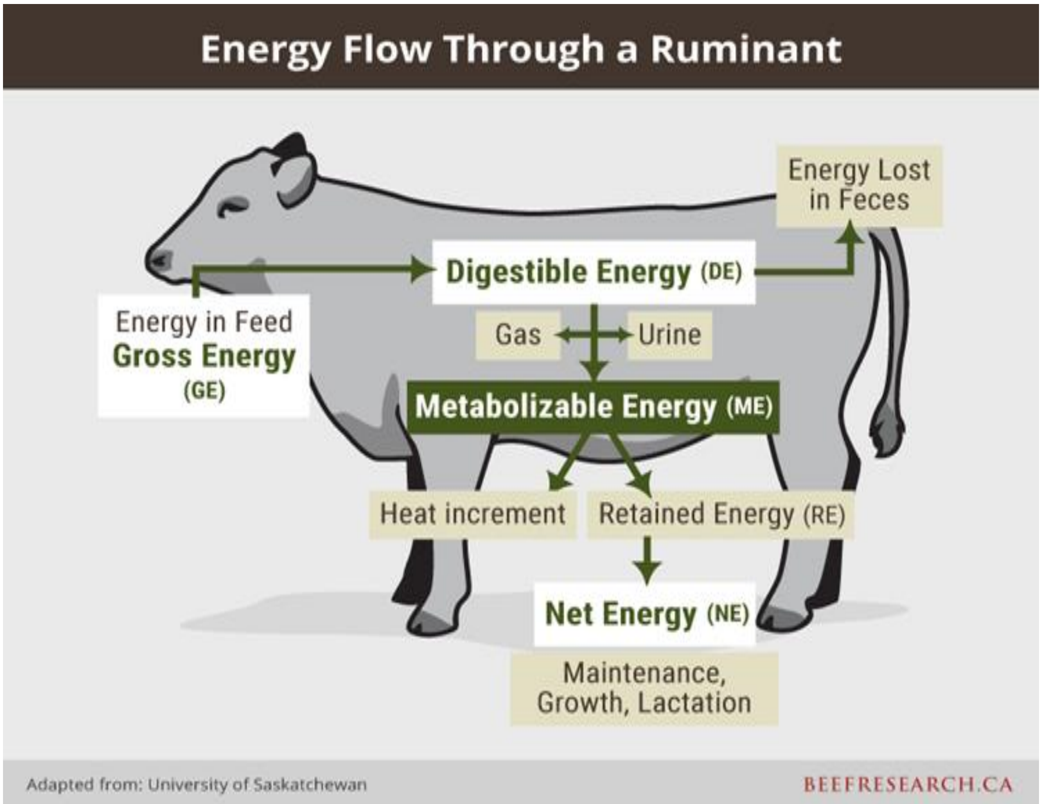
8-4: Relation of Fat Deposition on Beef Efficiency

Cattle in many countries (among them is Iraq) are *Bos indicus* due to their ability to tolerate ticks, heat and poor-quality pasture. However, meat characteristics from these cattle is low due to low marbling. These breeds are crossed with *Bos taurus* to improve growth rate and meat characteristics of several composite breeds. It is irrefutable that genetic make-up plays a significant role in beef fat content and FA profile. Several genes such as *SCD*, *FASN* and *FABP4* are reported to influence carcass fat traits in Korean and Japanese cattle as well as Australian temperate breeds such as Angus and Limousin. In addition, studies are required to determine finishing performance and carcass traits beef crossbred and composite breeds backgrounded on introduced pastures, to enable industry players to exploit them for greater economic gains. Animal fat deposition has a major impact on the meat yield from individual carcasses as well the perceived eating quality for consumers. Understanding the impact of livestock production practices on fat deposition and the molecular mechanisms activated will lead to a better understanding of finishing livestock. This enhanced understanding will also lead to the increased efficiency and improved sustainability of practices for livestock production. The impact of fat storage on physiological functions and health are also important. This review brings together both the production practices and the current understanding of molecular processes associated with fat deposition. Growth is frequently described as weight gain over time. Researchers have used this information in equations to predict carcass composition and estimate fat deposition. Diet, species, breed, and gender all influence fat deposition. Alterations in diets result in changes in fat deposition as well as the fatty acid profile of meat. Additionally, the amount and composition of the fat can affect lipid stability and flavor development upon cooking. Fat functions not only as a storage of energy and contributor of flavor compounds, but also participates in signaling that affects many aspects of the physiological functions of the animal. Transcription factors that are upregulated in response to excess energy to be stored are an important avenue of research to improve the understanding of fat deposition and thus, the efficiency of production. Additionally, further study of the inflammation associated with increased fat depots may lead to a better understanding of finishing animals, production efficiency, and overall health. Furthermore, fat deposition is an important aspect of meat quality. Meat quality can be defined in numerous ways, ranging from product yield to eating satisfaction. These are examples of different qualities identified in unique portions of the production chain. Producers might view meat quality/fat deposition as the appropriate time to harvest an animal or the condition an animal might be in. In contrast, the processor may view fat deposition as either a problem, as it must be removed from a carcass, or essential, as the ingredient in a processed product. Consumers will have an even more different opinion, with some preferring leaner meat, while others may seek out meat cuts that have more fat. These additional requirements of the various industry segments make it important to understand why the targets exist and how fat is deposited throughout an animal's life. Fat accumulates as the animal matures and is deposited in various fat depots. It was reported that fat accumulation occurred after the relative growth of muscle decreased and continued to increase while bone growth decreased. The growth rate of fatty tissues varies widely depending on the location and growth stage.



OVERALL MEAT SCORE	BMS* (2008 SCALE)	MINIMUM IMF%	MARBLING GRADE**	USDA GRADE**	
		2.59	SLIGHT	SELECT	Select
		3.91	SMALL	CHOICE −	
		5.34	MODEST	CHOICE	Choice
		6.89	MODERATE	CHOICE +	
		8.56	SLIGHTLY ABUNDANT	PRIME −	
		10.33	MODERATELY ABUNDANT	PRIME	Prime
		12.22		PRIME +	
A3	3	21.4	VERY ABUNDANT	PRIME++ (BEYOND PRIME)	100% Fullblood Wagyu
	4	29.2			
A4	5	35.7			
	6	40.6			
	7	42.5			
A5	8	43.8			Japanese A5
	9	50.8			
	10	52.9			
	11	53			
	12	56.3			

Furthermore, an animal's growth is often described as a sigmoidal curve indicating the change of weight over time. The body's composition also changes with fat deposition occurring later after muscle and bone growth have slowed. The lipid content of body tissues increases from 25% around birth to 50–75% in adults, while the water and proteins decrease as a percentage of the whole body. Furthermore, the deposition of fat occurs when the energy consumed is greater than the requirements of the animal. When the energy required for bone and muscle growth is reduced as the animal reaches mature size, the energy will be stored as fat. Several factors such as species, genetics, or breed, sex, and environmental factors can influence fat development at various points of an animal's life. Fat deposition happens in specific depots that are common among all mammals. These depots are found in the abdominal cavity, intermuscular (between muscles), subcutaneously, and intramuscularly (within muscles). The internal fat, especially around the internal organs, is the first to deposit, followed by intermuscular fat, subcutaneous fat, and finally, intramuscular fat. There is a difference in the proportion of each fat depot depending on the species and age of the animal, as well as the energy intake. For example, pigs have more subcutaneous fat at about 70% of their total body fat and less abdominal fat than both sheep and cattle. In mature grass-finished beef steers, It was reported that subcutaneous fat makes up about 15% of their total body fat, intermuscular about 23%, and intramuscular about 14%. Fat is made up of triglycerides. The triglyceride has a glycerol backbone, with three fatty acids making up the rest. The triglyceride's fatty acids vary by carbon chain length and the number of saturated or unsaturated bonds within the carbon chain. Fatty acids in meat are predominantly palmitic, stearic, oleic, palmitoleic, linoleic, linolenic, and arachidonic. The fatty acid composition in adipose tissue affects the firmness of the fat. Longer chain fatty acids result in higher melting points, while fatty acids with more unsaturated bonds have lower melting points. Composite fatty acids melt between 25 °C and 50 °C, saturated fats melt at higher temperatures, and polyunsaturated fats (PUFAs) melt at lower temperatures. This translates to different firmness of the fats between species.



Fatty Acid composition of beef Tallow

Acid name	% Composition
Miristic C14:0	2.79
Palmitic C16:0	26.78
Palmitoleic C16:1	2.05
Stearic C18:0	34.85
Oleic C18:1	30.23
Linoleic C18:2	0.74

The differences in fat accumulation and composition between species are partly due to the differences in digestion processes. Fatty acids in non-ruminant fat and muscle reflect the fatty acid composition of their diets. Ruminant fatty acid composition is influenced by biohydrogenation in the rumen. In ruminants, lipids entering the rumen must go through lipolysis, where the lipases hydrolyze the ester bonds in complex lipids and result in the release of fatty acids. The unsaturated fatty acids are converted to saturated fatty acids by an isomerization from *cis* to *trans* fatty acid intermediates, followed by hydrogenation of the double bonds. The rate at which lipolysis and bio hydrogenation occur is dependent on the type and amount of fat delivered to the rumen, as well as the ruminal pH (a measure of the hydrogen-ion activity in water-based solutions, indicating its acidity or alkalinity). Feed intake, as well as the chemical composition of feed, can affect fat deposition in livestock. Feeding non-ruminant livestock dietary oils changes the fatty acid composition of the subcutaneous fat, altering the adipose tissue's melting point and overall firmness, resulting in softer, more unsaturated carcass fat. The supplementation of unsaturated fatty acids to ruminants is a little more difficult due to the bio hydrogenation of the rumen converting the unsaturated fats to more saturated fat, ultimately resulting in harder carcass fat. Fatty acids in ruminants are degraded to monounsaturated and saturated fatty acids, leaving roughly 10% of the dietary fatty acids available for incorporation into adipose tissue. However, if a diet extremely rich in unsaturated fatty acids is fed to ruminants, there is a slight chance that the 10% of fatty acids available to lipid tissue could result in softer fat. This change is concomitant with changes in the rumen microbiota. Specifically, the increased oil content decreases ruminal cellulose degradation and volatile fatty acid concentration. This is mediated by an increase in small cocci and a decrease in small rods within the rumen microbiota. Many researchers have observed fat deposition differences in breeds that selection can also affect. Research compared the carcass composition of seven different beef breeds reared to a specific age, and the breeds differed in the muscle, fat, and bone composition of the carcasses. Furthermore, at a standard carcass weight, larger framed breeds, such as Chiannia and Blonde d'Aquataine, resulted in carcasses with less fat than those from Danish Red and Hereford. These researchers attempted to develop a biologically sound statistical methodology for group comparisons of growth patterns and carcass composition. They suggested that when serial slaughter was incorporated into the statistical methodology, there was an opportunity to examine the growth patterns of individual tissues by using regression and covariance analysis. In general, for beef animals compared at similar carcass weights, heifers will be fatter than castrate males, which are both fatter than intact males. However, it was also stated that comparisons between sexes are probably minor if the comparisons are made at equal fatness. Furthermore, researcher reported muscles from mature cows had more fat compared to muscles from bulls that were reared in confinement or grazed. Environmental factors that influence metabolism can affect fat deposition. Chronic heat stress reduces beta oxidation and positively influences lipid deposition as a method of reducing thermogenesis. Furthermore, it was reported that maternal exposure to heat stress altered the expression of genes associated with lipid metabolism and storage, resulting in the increased fatness of piglets produced from heat-stressed dams. enhanced in one type compared to the other. Cold stress has the opposite effect. Animals increase the oxidation of lipids for energy to maintain body temperature. Also, it was found that exposure to cold stress caused an increase in dietary intake and catabolism of fat reserves to divert energy to the generation of body heat. Intramuscular fat or marbling is located in the perimysium space between the muscle fibers. The storage of fat within the muscle increases the visible marbling, but the fat cells are thought to be in the areas at birth. Marbling can be impacted by selection. However, the greatest impact on fat storage is energy intake above maintenance. When energy requirements for growth are reduced as the animal approaches mature size, the extra energy will be stored as fat both within the muscle and in subcutaneous fat. Fat distribution, subcutaneous and intramuscular (marbling), is believed to contribute to tenderness. Researchers have reported increased marbling as the animal gets older, when fed at a similar level over time, which reflects altered maintenance requirements as the animal matures. Energy intake is still necessary to have the fat stored, including the intramuscular fat. Marbling also affects juiciness and flavor. Small levels of marbling differences result in higher sensory juiciness scores. Similar results have been reported for the juiciness of the beef. Despite marbling having a minor influence on tenderness, it continues to be an accepted indication of meat quality. Marbling is viewed as one of the most important factors influencing beef quality and palatability characteristics. Moreover, adipose tissue is dynamic and is responsive to and responsible for a wide variety of hormonal and metabolic interactions with other tissues and organs, including skeletal muscle. Further research is needed to understand the complex cellular communication between adipose tissue and muscle during growth and development. In addition, the role of adipose tissue immune cells and inflammatory markers may play important roles in regulating adipose tissue deposition and in the alteration of glucose homeostasis and insulin resistance seen in fattening meat animals. An increased understanding of these complex regulatory alterations that occur when the animal body composition is changing may improve our prediction of meat quality and consistency and allow improved selection for animals that will achieve a desirable meat quality endpoint, as well as identifying animals that are better suited for specific dietary and management scenarios. Studies have reported variation in beef fat deposition and FA composition due to genetic differences between cattle. Beef breeds differ from milk breeds and such differences are well documented. Generally, meat type breeds are able to deposit more fat than milk breeds. FA synthesis was reported to be higher in beef cattle subcutaneous and perineal adipose tissues than in same tissues from dairy cattle of similar age and weight. German Holstein bulls had higher SFA and total PUFA compared to

German Simmental bulls on similar diets, but breed had no effect on n-3 FA. Sires may influence the FA content of their offspring.

Factors Affecting Intramuscular Fat Deposition in Beef Cattle

Factors	Description summary
Genetic factors	
Breed differences	IMF content varies with cattle breed
Sex	Sex affects IMF deposition
Heritability	Heritabilities of marbling in Korean cattle and Japanese Wagyu are relatively high
Management factors	
Weaning age	Early weaning age generally increases IMF deposition
Castration	Castration generally increases IMF deposition
Slaughter age	IMF content increases with increasing age in most cattle breeds
Slaughter weight	IMF content increases with increasing slaughter weight in several cattle breeds
Environments	Environmental conditions, such as ambient temperature, can affect IMF deposition
Nutritional factors	

Japanese Black Wagyu cattle sired by different bulls were reported to have significantly different SFA and MUFA contents. Heritability coefficients of FA and other carcass traits were reported to range from 14 to 36% in crossbred cattle. These breed variances are probably due to differences in the activities of enzymes influencing gene expression and/or enzyme function. The activity of Δ9-desaturase enzyme to convert palmitic to palmitoleic acid was observed to be greater in Simmental than

Red Angus lipids. Several genes are reported to be responsible for variation in fat content and FA composition in beef. The genes encode for cocaine- and amphetamine-regulated transcript, leptin, diacylglycerol O-acyltransferase, and growth hormone. Fatty Acid Synthase (FASN) gene is abundantly expressed in the adipose tissue and encodes for fatty acid synthase, an enzyme that regulates the biosynthesis of long chain fatty acids. The enzyme plays a central role in de novo lipogenesis by catalyzing all the reaction steps to convert acetyl-CoA and malonyl-CoA to palmitate. Association of FASN expression or polymorphisms with fat metabolism and obesity traits in cattle has been reported. Analyzing polymorphisms in thioesterase domain of FASN gene, which regulates the termination of FA synthesis, in Hanwoo cattle showed a significant association between g.17924G > A SNP genotypes with palmitic and oleic acid concentrations. For instance, GG genotype had 3.2% and 2.8% higher oleic acid concentration than the AA and AG genotypes, respectively. However, they did not observe any significant association between g.17924A > G genotypes and other examined FA such as meristic, stearic and linoleic acids. GG genotype of g.17924A > G SNP was reported to result in higher UFA and fairly lower amounts of SFA than the AG and AA genotypes in other studies. Another study was carried out to determine exonic SNPs in the gene encoding FASN with FA composition in Korean cattle. It was found that all the SNPs (g.12870 T > C, g.13126 T > C, g.15532 C > A, g.16907 T > C and g.17924 G > A), were associated with varying FA compositions and marbling. Genotypes CC, TT, AA, TT, and GG were associated with higher MUFA and lower SFA. Some studies reported no relationship between FASN gene with fat thickness and marbling score. However, a significant relationship of the fat with DNA-protein kinase, known to play a role in transcriptional activation of FASN. Fatty Acid Binding Protein 4 (FABP4) is a gene highly expressed in the adipose tissue and encodes for fatty acid binding protein 4 that belongs to a group of FABPs. These binding proteins play a significant role in absorption, transport and metabolism of FA, and glucose homeostasis by interacting with peroxisome proliferator-activated receptors. SNP 7516G > C of FABP4 was analyzed for association with IMF profile of upper sirloin cuts in Aberdeen Angus and Blonde d'Aquitaine cattle. CC genotype in Angus cattle was 52% and 64% lower in Myristoleic acid, and 33% and 35% lower in linoleic acid than CG and GG, respectively. Blonde cattle CC genotype had higher arachidonic acid and EPA, but lower oleic acid and total SFA than the CG. The GG genotype was observed in only one bull. g.7516G > C polymorphisms were analyzed for association with marbling score and subcutaneous fat depth in Wagyu x Limousin crosses. A positive relationship between CC genotype and lower marbling and fat depth was observed. GC genotype had the highest scores while GG was in-between. FABP4 SNPs were also reported to have an association with back fat thickness in Korean Native cattle.

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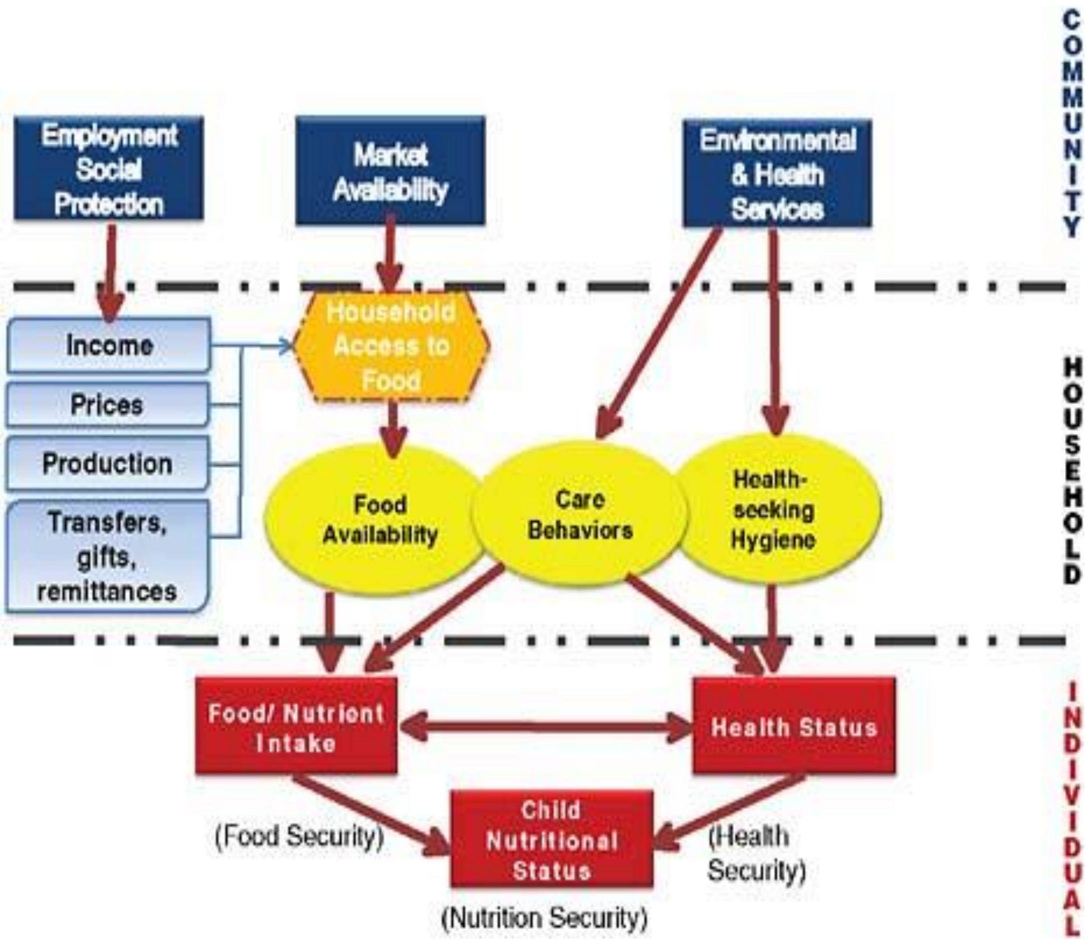
Chapter 9

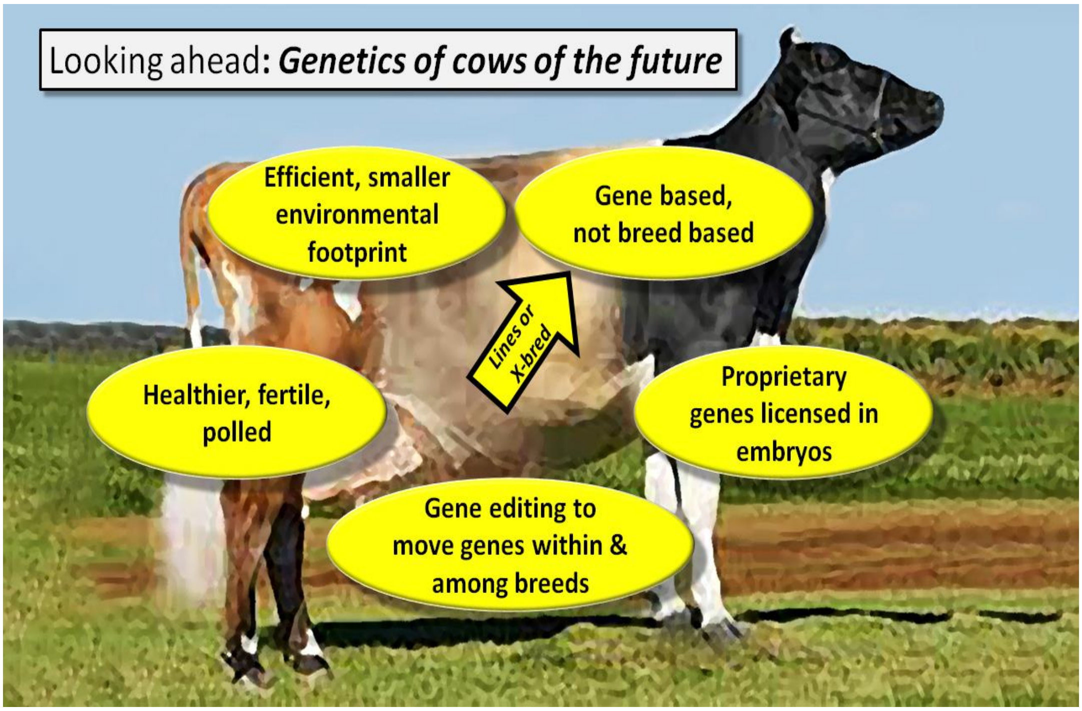
Strategies to Improve Economic Efficiency of the Dairy Cattle

Strategies to Improve Economic Efficiency of the Dairy Cattle

9-1: Snapshots on Dairy Cattle Efficiency

Efficient dairy production must return a profit for the dairy enterprise and produce quality milk for consumers while maintaining optimal cow well-being and practicing environmental stewardship. Economists, nutritionists, and geneticists have attempted to describe dairy cattle efficiency in simple, quantifiable terms. On-farm measures of dairy efficiency include physical feed efficiency, efficiency of nutrient usage, economic feed efficiency, total dairy enterprise efficiency, and lifetime efficiency. Each calculated measure of dairy efficiency has its own advantages and limitations. Each measure has merit for describing a segment of dairy efficiency, yet no one measure can sufficiently describe dairy efficiency or be applicable across all farms. Use of multiple dairy efficiency metrics, each with a moving target specific to the individual dairy enterprise, should be considered. Nutrition and feeding management have major effects on dairy efficiency. Dairy managers and nutritionists need to carefully consider diet digestibility, rumen function, feed analyses, nutrient requirement estimates for various animal groups, forage selection and associated agronomic considerations, forage preservation, as well as TMR preparation, delivery, and intake to define reasonable dairy efficiency targets and production goals for individual farms that will lead to greater economic and environmental sustainability. Livestock have provided crucial contributions for the human wellbeing in social and economic terms since the time of civilization and domestication of animals. Livestock have drastically evolved since then and in light of global challenges such as climate change, population growth and the urgency of ensuring the availability of nutritious and secure food for everybody, the optimization of sustainable livestock production is more important than ever. Efficient livestock production means making livestock systems economically more efficient and striking balance between meeting the growing demand of animal-origin products and reducing to the minimum the negative side effects and externalities from the livestock sector. In order to be optimal, livestock systems need to promote advancements in the technological and infrastructural aspects of the sector and, at the same time, institutions and experts should support the progression of knowledge with policies that define and shape sustainable livestock development from a social, economic and environmental perspective. Furthermore, livestock play a significant role in rural livelihoods and the economies of developing countries. They are providers of income and employment for producers and others working in, sometimes complex, value chains. They are a crucial asset and safety net for the poor, especially for women and pastoralist groups, and they provide an important source of nourishment for billions of rural and urban households. These socio-economic roles and others are increasing in importance as the sector grows because of increasing human populations, incomes and urbanization rates. To provide these benefits, the sector uses a significant amount of land, water, biomass and other resources and emits a considerable quantity of greenhouse gases. There is concern on how to manage the sector's growth, so that these benefits can be attained at a lower environmental cost. Livestock and environment interactions in developing countries can be both positive and negative. On the one hand, manures from ruminant systems can be a valuable source of nutrients for smallholder crops, whereas in more industrial systems, or where there are large concentrations of animals, they can pollute water sources. On the other hand, ruminant systems in developing countries can be considered relatively resource-use inefficient. Because of the high yield gaps in most of these production systems, increasing the efficiency of the livestock sector through sustainable intensification practices presents a real opportunity where research and development can contribute to provide more sustainable solutions. In order to achieve this, it is necessary that production systems become market-orientated, better regulated in cases, and socially acceptable so that the right mix of incentives exists for the systems to intensify. Managing the required intensification and the shifts to new value chains is also essential to avoid a potential increase in zoonotic, food-borne and other diseases. New diversification options and improved safety nets will also be essential when intensification is not the primary avenue for developing the livestock sector. These processes will need to be supported by effective public and private institutions. Nutrition and nutrient management interventions can improve the use of dairy resources, increasing both economic and environmental sustainability. With greater dry matters intake (DMI) and milk yield, a smaller proportion of dietary nutrients are used for maintenance functions, improving productive efficiency and reducing the environmental impact of the dairy cow. Nutritional factors independent of cow genetic merit affect energetic losses in the form of feces, heat of digestion and metabolism, or methane. Improvements in nutrient retention can occur with increases in rate of digestion and decreases in rate of passage of feed ingredients. Forage and grain losses, feed ingredient options, and forage and feed ingredient targeting according to cow potential need to be considered. Consistency of delivery and consumption of the formulated ration without high feed refusal rates typically improves dairy efficiency. Cow grouping affects social behavior, cow well-being, nutrient wastage, milk yield, and expenses, with optimum strategies being farm specific. Feed typically accounts for 60% of the operating expenses on a dairy farm, making it a logical focal point when trying to increase efficiency. Yet, high milk production, which requires proper nutrition, typically generates more profit than low feed cost. The most well-known and used measure of dairy efficiency is the amount of milk produced, expressed as 3.5% FCM, 4% FCM, or energy-corrected milk, per unit of DMI or "physical feed efficiency" (physical FE). This is a measure of gross feeding efficiency calculated as the ratio of total outputs divided by total inputs. Nevertheless, efficiency of use of individual dietary nutrients may not be similar, and calculation of separate nutrient efficiencies such as energetic efficiency and N efficiency can be valuable. Gross nutrient efficiencies, based on the amount of nutrient consumed, are typically calculated. Digestive efficiencies can be informative for comparing genotypes but can also be useful for nutritionists and environmentalists if fecal nutrient losses are separately accounted. Differences in metabolic efficiency suggest divergence in nutrient partitioning between milk production and other nutrient uses such as body tissue accretion. Thus, metabolic efficiency is used more by geneticists rather than by nutritionists or environmentalists. Energy conversion efficiency is calculated as milk energy output divided by ME intake. Unfortunately, as with physical FE, energy conversion efficiency will be improved with greater mobilization of body reserves (early lactation) and reduced during body tissue accretion (late lactation). Because of the negative effects of body reserve loss on reproduction and health, greater energy conversion efficiency is not always desirable. Residual energy intake (REI) is actual ME intake minus the predicted energy requirement of the cow based on production, BW, BW change, and gestational energy needs. Because BW changes are predicted and accounted for, REI is influenced less by body reserve loss and gain. A reduced REI indicates that less energy is wasted after accounting for the energy in milk, maintenance, and growth and that efficiency of energy use is improved. It was noticed that stage of lactation affected REI among Nordic Red cows. This relationship could be due to true energetic efficiency differences during the lactation or to inadequate assessment of changes in body reserves affecting calculated REI. Another measure of dairy efficiency is lifetime Efficiency. This is the percentage of lifetime feed energy (GE) intake converted into milk, conceptus, and body tissues. Obviously, earlier and more efficient calf and heifer growth and greater longevity generally equate to improved lifetime efficiency. It was calculated that a cow producing 9,000 kg of milk/yr at maturity would have a lifetime efficiency of 17% after the first lactation and 20.5% after the third lactation, only increasing to 21.4% after the fifth lactation. Moreover, to accurately describe the efficiency of a dairy enterprise, all nutrient losses and gains need to be accounted for. This includes nutrient losses associated with crops, manure, feeding management and reproductive inefficiency, feed nutrients required for replacement heifers and dry cows, and the value of animals sold for beef or other purposes. Integration of accurate farm data including actual DM and nutrient intakes with advanced nutrition models such as the NRC (2001), or Cornell Net Carbohydrate and Protein System and whole-farm dairy models such as DairyWise and the Integrated Farm Systems Model could help to more accurately calculate actual total dairy enterprise efficiencies. With greater milk yield, a smaller proportion of dietary nutrients are used for maintenance functions. This "dilution of maintenance" has been the primary source of increased productive efficiency on commercial dairies for the last century. For example, a Holstein cow producing 45 kg of milk/d needs 4 times as much energy as that needed for maintenance, whereas a Holstein cow producing 90 kg/d requires 7 times as much. Improved milk production also has been a major contributor to the reduced environmental impact of the dairy industry over the last century. Physiological state, physical and chemical aspects of the diet, psychogenic factors, and environment influence dairy cow meal size and frequency. If cows consume less DM and maintain milk yield, physical FE will improve. However, with greater on-farm DMI, diets can be reformulated so that required nutrients can be provided with reduced diet nutrient density, often promoting rumen health, reducing supplemental fat needs, and increasing economic FE if ration cost per kilogram is reduced. It must be recognized, however, that increased DMI can also promote feed passage, increasing fecal losses and reducing digestive efficiency to some degree. Maximum energetic efficiency in the dairy cow equates to minimal energy loss. Opportunities exist on many dairies for improving dairy efficiency with dietary changes that reduce energy losses. High efficiency of feed usage in the dairy cow requires maximum fiber and starch digestibility and minimal fecal excretion of energetic nutrients. Improved fiber digestibility potentially reduces fecal losses and increases milk yield. Yet, depending on other dietary ingredients, improvements in forage fiber digestibility may increase DMI and rate of passage, negating a portion of the benefits provided by increased digestibility.





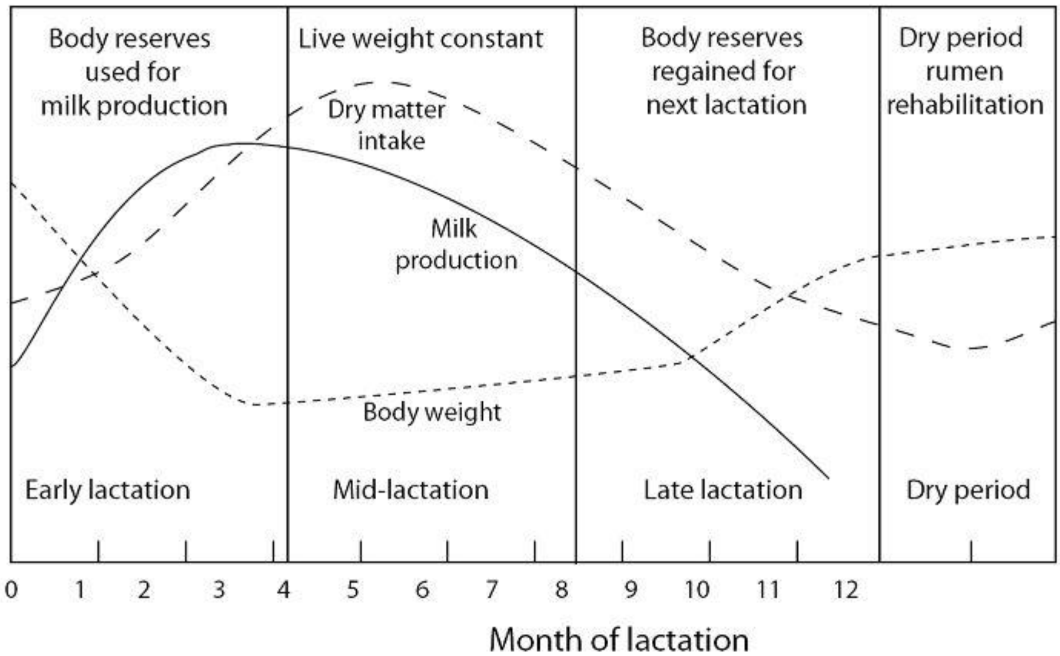
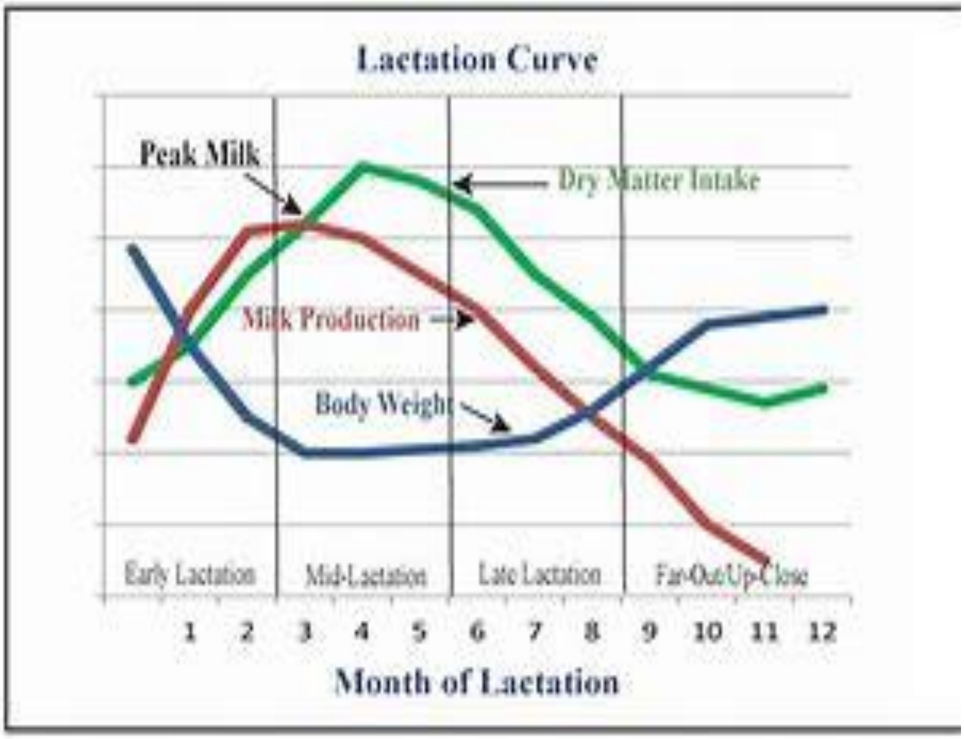
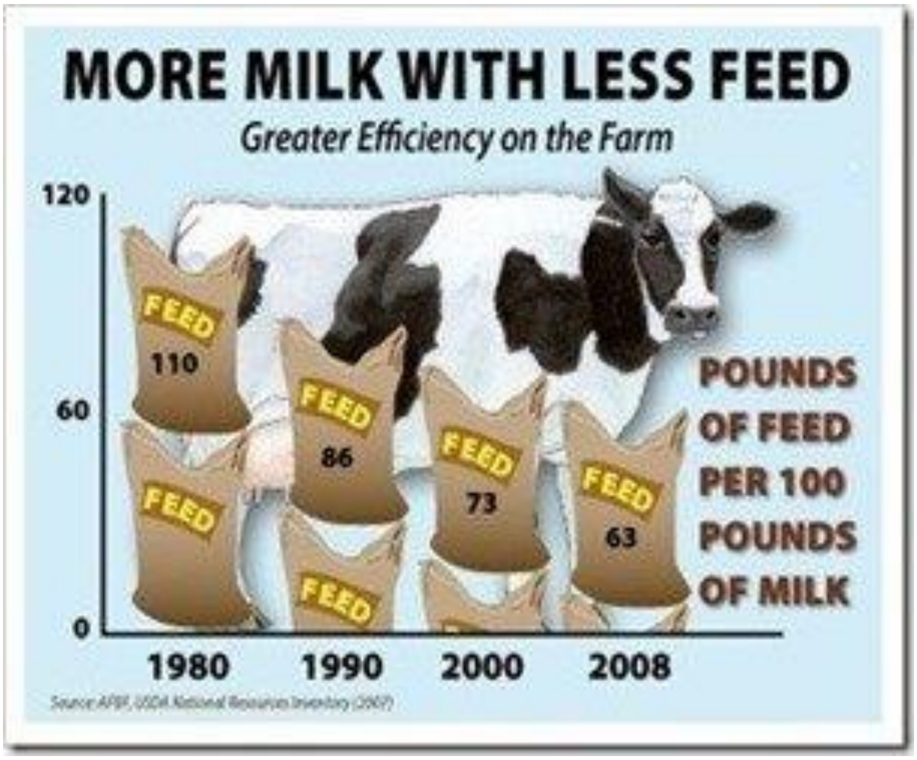


Figure 1. Dry matter intake, milk yield and live weight changes in a cow during her lactation cycle



FACTORS AFFECTING DAIRY FEED EFFICIENCY



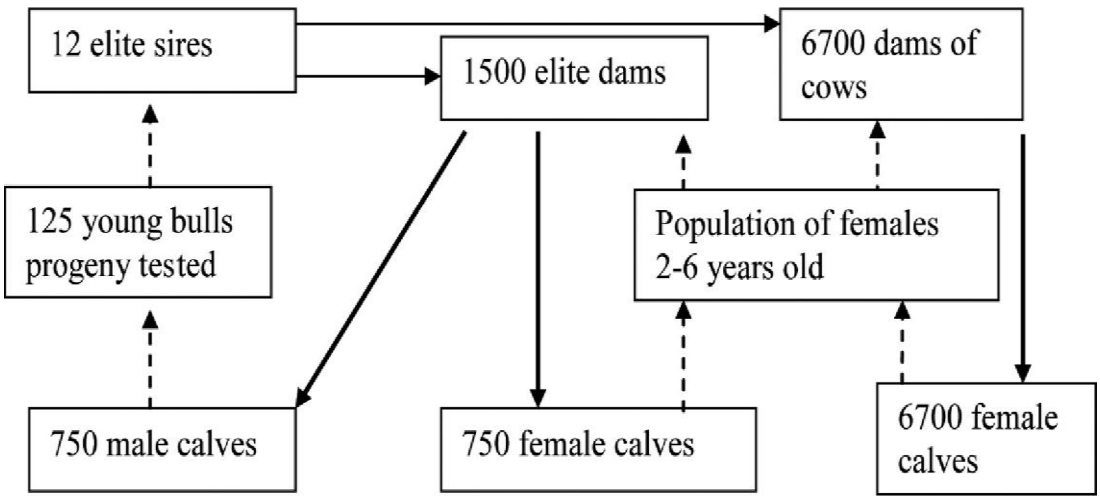
Productive life span in dairy cattle:

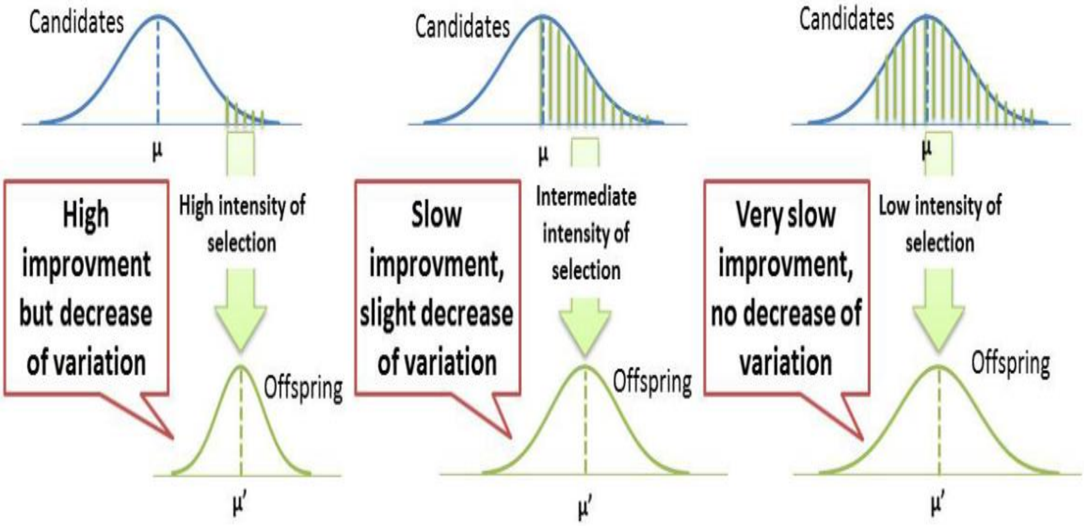
- ❖ Productive life span is another trait of economic importance.
- ❖ The average productive life of dairy cows in a herd is maintained mostly by purchased replacement after entering the herd at a two year of age.
- ❖ The basic reason behind the replacement is low production and reproductive disorders.
- ❖ And the association between the productive life span and breeding efficiency was low and insignificantly.

9-2: Role of Genetic Selection of High-Yielding Dairy Cattle Toward Sustainable Farming Systems

The massive improvement in food production, as a result of effective genetic selection combined with advancements in farming practices, has been one of the greatest achievements of modern agriculture. For instance, the dairy cattle industry has more than doubled milk production over the past five decades, while the total number of cows has been reduced dramatically. This was achieved mainly through the intensification of production systems, direct genetic selection for milk yield and a limited number of related traits, and the use of modern technologies (e.g., artificial insemination and genomic selection). Despite the great betterment in production efficiency, strong drawbacks have occurred along the way. First, across-breed genetic diversity reduced dramatically, with the worldwide use of few common dairy breeds, as well as a substantial reduction in within-breed genetic diversity. Intensive selection for milk yield has also resulted in unfavorable genetic responses for traits related to fertility, health, longevity, and environmental sensitivity. Moving forward, the dairy industry needs to continue refining the current selection indexes and breeding goals to put greater emphasis on traits related to animal welfare, health, longevity, environmental efficiency (e.g., methane emission and feed efficiency), and overall resilience. This needs to be done through the definition of criteria (traits) that (a) represent well the biological mechanisms underlying the respective phenotypes, (b) are heritable, and (c) can be cost-effectively measured in a large number of animals and as early in life as possible. The long-term sustainability of the dairy cattle industry will also require diversification of production systems, with greater investments in the development of genetic resources that are resilient to perturbations occurring in specific farming systems with lesser control over the environment (e.g., organic, agroecological, and pasture-based, mountain-grazing farming systems). The conservation, genetic improvement, and use of local breeds should be integrated into the modern dairy cattle industry and greater care should be taken to avoid further genetic diversity losses in dairy cattle populations. In this review, we acknowledge the genetic progress achieved in high-yielding dairy cattle, closely related to dairy farm intensification, that reaches its limits. We discuss key points that need to be addressed toward the development of a robust and long-term sustainable dairy industry that maximize animal welfare (fundamental needs of individual animals and positive welfare) and productive efficiency, while also minimizing the environmental footprint, inputs required, and sensitivity to external factors. Human diets need to become healthier, more diversified, and better distributed across geographical regions and families with divergent economic incomes, as there are over 690 million undernourished people in the world and obesity is rising in many regions across the globe. In this context, dairy products and ruminant meat provide essential amino-acids, minerals (calcium, zinc, selenium), and vitamins (A, B3, B6, B12, D), highlighting the fundamental importance of dairy farming for human agri-food systems. There are currently more than 270 million dairy (or dual-purpose) cows in the world, with a global average milk yield of around 2 600 kg/cow/year. However, only 33 countries have a national average milk yield greater than 6 000 kg/cow/year, which represents only a small fraction (~13%) of the world dairy cattle population but more than 40% of the total world milk. Yet, the strong focus of the dairy industry on ensuring food security through higher productivity raises concerns on other sustainability dimensions. This requires us questioning continued selection strategies for milk yield in populations (or countries) that have reached very high production levels, but simultaneous selection for productivity and functional traits (e.g. adaptation, welfare, resilience) should be applied in low-producing populations, especially in local breeds and developing-country populations. Since the early stages of cattle domestication (~10 000 years ago), differential selection processes have resulted in the development of about 1 200 cattle breeds with distinct characteristics such as milk yield level, milk composition, environmental adaptation, coat color, body size, fertility, and overall resilience. Currently, ~95%

of the high-yielding dairy cows raised in the main dairy producing regions around the globe are represented by only three breeds: Holstein (or Holstein-Friesian), Jersey, Brown Swiss, and their crosses. The worldwide spread of these few breeds is mainly due to their greater milk production levels and responsiveness to high-input production systems. In these breeds and even for less common ones, both overall and per animal production levels are still rising. The main drivers for this increase in milk productivity are related to the industrialization of dairy production; growing demand from worldwide consumers where large industries with high export and processing capacities (advanced infrastructure to transport and store large amounts of dairy products) urge dairy farmers to be increasingly competitive. As a result, the increase in the overall milk production of many industrialized or developing countries has been accompanied by a reduction in the total number of dairy farms and cows, and consequently, larger herds are becoming more common in these countries (e.g., United States and China; FAOSTAT, 2020).




Candidates
μ
High improvment but decrease of variation
High intensity of selection
Offspring
μ′
Candidates
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Slow improvment, slight decrease of variation
Intermediate intensity of selection
Offspring
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Candidates
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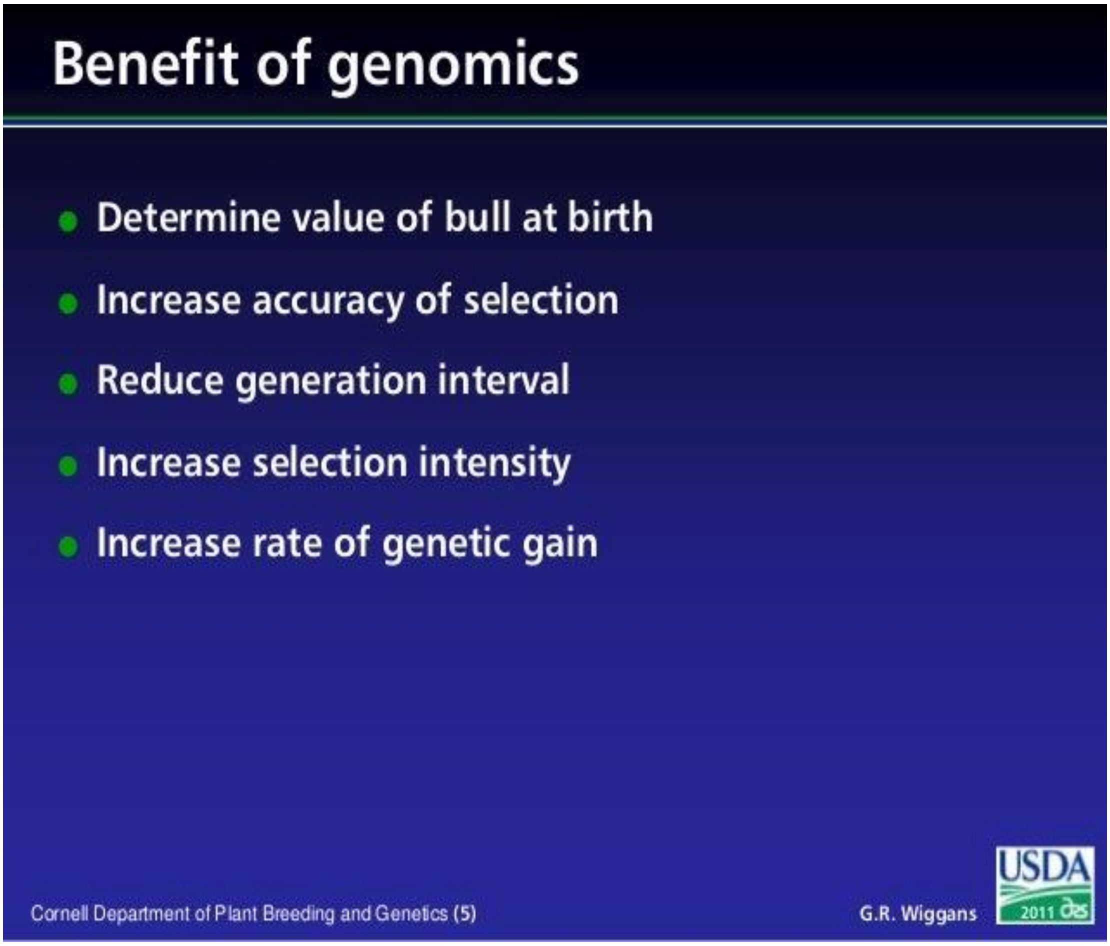
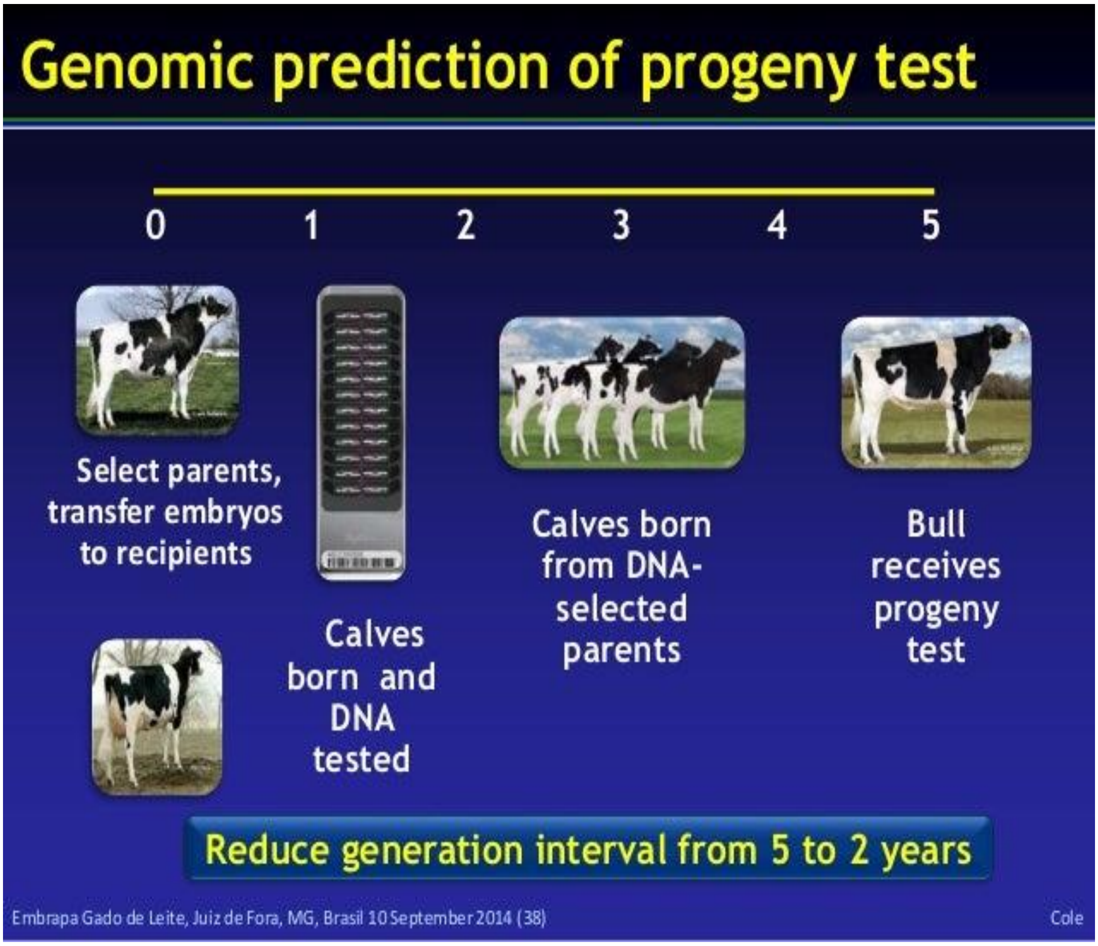
Very slow improvment, no decrease of variation
Low intensity of selection
Offspring
μ′


Benefit of genomics
Determine value of bull at birth
Increase accuracy of selection
Reduce generation interval
Increase selection intensity
Increase rate of genetic gain
Cornell Department of Plant Breeding and Genetics (5)
G.R. Wiggans
USDA
2011


Genomic prediction of progeny test
0
1
2
3
4
5
Select parents, transfer embryos to recipients
Calves born and DNA tested
Calves born from DNA-selected parents
Bull receives progeny test
Reduce generation interval from 5 to 2 years
Embrapa Gado de Leite, Juiz de Fora, MG, Brasil 10 September 2014 (38)
Cole

Dairy Cattle

- 9 million cows in US
- Attempt to have a calf born every year
- Replaced after 2 or 3 years of milking
- Bred via AI
- Bull semen collected several times/week. Diluted and frozen
- Popular bulls have 10,000+ progeny
- Cows can have many progeny though super ovulation and embryo transfer

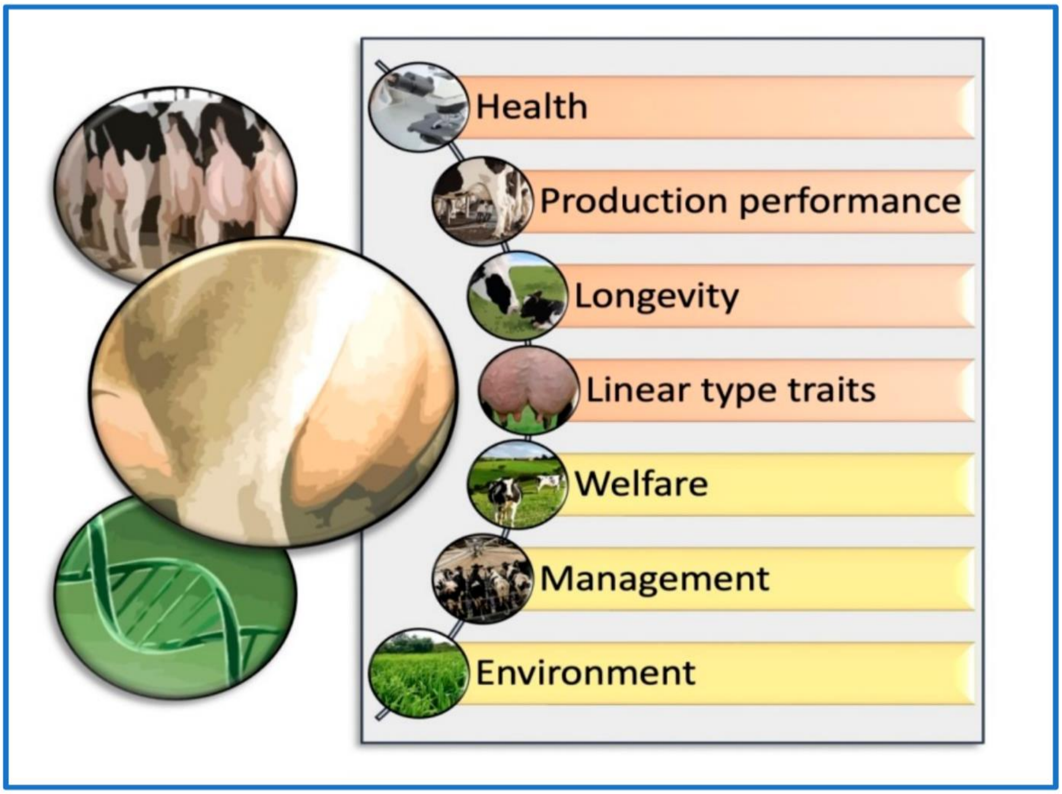
Cornell Department of Plant Breeding and Genetics (2)

G.R. Wiggans

USDA 2011

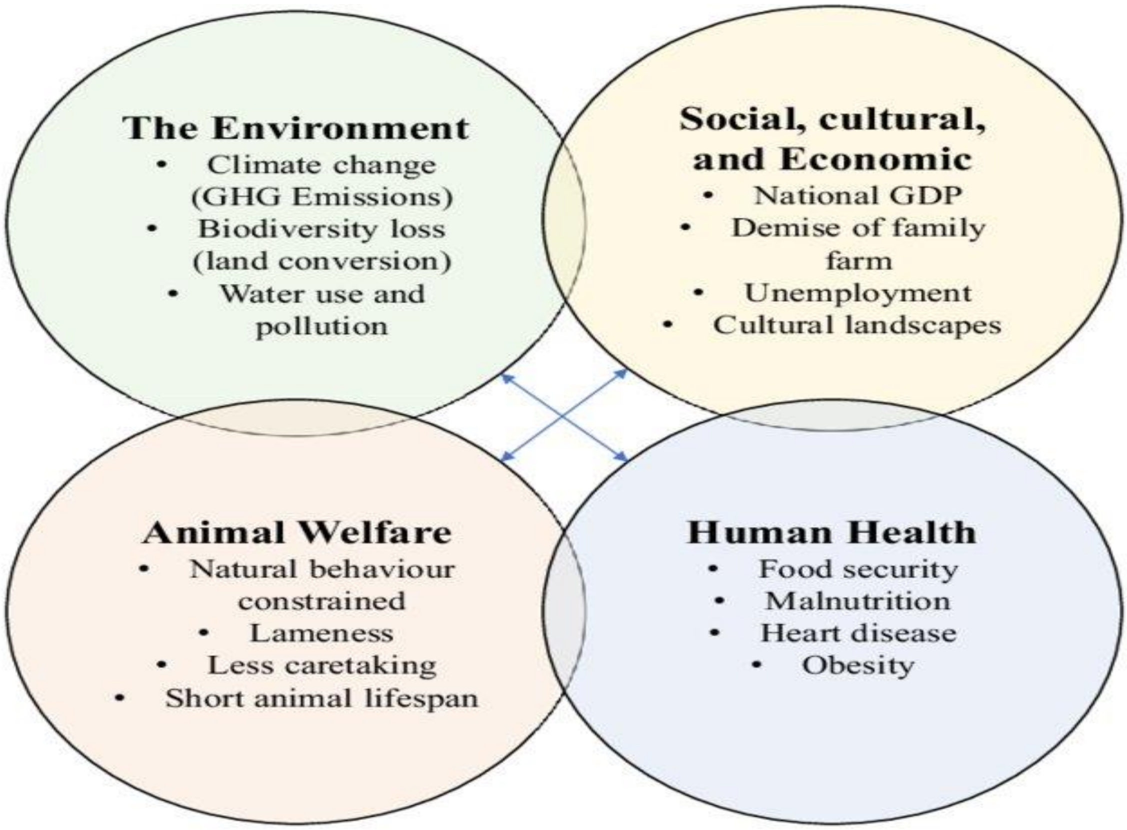
Genomic Selection, What does it bring us?

- Reliable breeding values at young age
  - higher success rate to get top bulls
  - lower costs for test proofs
  - shorter generation-interval



9-3: Intensification of Dairy Production Systems

The development of intensive dairy systems has been fueled by a consistent flow of innovations and technological breakthroughs, among which conventional genetic selection played a major role over the past decades. Animal breeding and genetics has been extensively conceptualized in artificial and standardized environments, where the linear equation: P (observed phenotype/performance) = G (additive genetic merit) + E (environmental effects) proved to be highly efficient, especially under controlled environmental conditions and high-input production systems. However, when not accounting for the interactions between genotype and environment (also termed Genotype-by-environment interactions (GxE)), selection for high-producing animals depends on the availability of high-quality (and usually well-controlled) environments for the expression of the traits of interest. Indeed, together with genetic selection, the dairy industry has also benefited from major advancements in nutritional practices, precision management, wide adoption of reproductive technologies (e.g., artificial insemination, embryo transfer, sexed semen), and precision health and care management. These advancements are not independent from each other and it is clear that many of them have increased the effectiveness of genetic selection for increased productivity. From this perspective, the high-producing dairy cow is thus more than the simple result of high genetic merit for key biological mechanisms and adequate environmental factors; it also reflects complex positive feedback between these two components that took place during the industrialization and intensification of dairy production. Genetic selection for increased milk yield has been a key driver of dairy intensification leading to the development of highly specialized milk production systems, with increasing herd size, and heavily relying on cereals and protein-sources. Locally, the concentration of intensive dairy farms can have a large environmental impact due to the large amounts of waste produced. Thus, there is growing evidence that uncoordinated levels of intensification in high-input dairy production systems are not sustainable. Despite the major signs of progress in productivity, the long-term success of the dairy industry depends on the adoption of more sustainable breeding goals and management practices, especially from an agro-ecological perspective. Current high-producing systems need to be refined with a greater focus on animal health and welfare, environmental efficiency, climatic adaptation, and more preparedness for future challenges through the conservation of a diverse genetic pool. Some breeding programs have recently included several of these traits in the breeding goals, but there is still a need for substantial improvements. For a review of the current worldwide selection indexes, US selection indexes include traits such as health, SCS, livability, productive life, feet and leg traits, and calving ability (CDCB, 2020). The transition toward lower-input (with improved usage of resources) production systems also needs to be favored. This is required to minimize the environmental footprints of the industry, meet the food demands of a steadily growing population in face of rapid scientific and technological innovations, limited resources and land availability, greater environmental and ethical awareness of animal husbandry practices, demand for higher-quality products produced with lower use of antibiotics, and natural challenges (e.g., new pathogens and diseases, climate change). The role of genetic selection in non-economic dimensions of dairy farm sustainability has mainly concerned animal welfare. However, unfavorable genetic relationships among traits of great relevance to the industry (e.g., milk yield and fertility or welfare) have deteriorated some economically important traits, which has consequently motivated the development of more efficient breeding strategies for increased long-term sustainability of the dairy cattle industry. Yet, to contribute to dairy farm sustainability, genetic selection needs to consider its direct and indirect effects on the multiple sustainability dimensions. In our view, the extent to which the dynamics of genetic specialization are interrelated with dairy farm intensification is key to address the contribution of genetic selection to the development of sustainable production systems. In this context, dairy industry stakeholders will continue seeking alternatives to further increase the profitability and sustainability of dairy production. Key players such as breeding companies and national genetic evaluation systems will continue refining the selection indexes used in face of emerging threats and opportunities. However, in some cases, there might be a need for greater governmental involvement to support changes in certain directions, especially toward better animal welfare and environmental footprints, as well exemplified by policies implemented in some European countries.



9-4: High-Yielding Dairy Cows for Sustainable Farming Systems

The main objective of this paper is to discuss the potential contribution of genetic selection in the high-producing dairy cow given the close relationship between genetic specialization and dairy farm intensification. We first highlight the importance of selection for milk yield (and related variables) as the driver of dairy farm intensification and its sustainability from the single perspective of genetics. We then question the ability of the farm environments to keep up with genetic trends. Given the genetic background of sustainability-related traits as well as recent advances in genetic and genomic selection, we discuss how breeding programs and the management of genetic resources could favor the developments of more sustainable dairy systems. Finally, from the description of alternative production systems, we present prospects for future research in the field of genetics of high-producing dairy cows. Over the past centuries, milk production and composition were the main selection goals in dairy cattle breeding programs and, as a consequence, milk yield has increased dramatically. From an economic perspective, the success of selection for increased milk yield or improved feed efficiency in high-producing dairy cows primarily stems at the animal level from the dilution of maintenance requirements with increasing production levels. The economic return from increased milk yield has been the main pillar for continuing genetic selection for higher milk yield. Moreover, greater milk yield is often considered as a key solution to address the global challenges of ensuring food security and reducing greenhouse gas emissions, as the dilution of maintenance results in both better feed efficiency and reduced methane emissions per kg of milk produced. Improvements in efficiency at the animal level alone will not necessarily result in mitigation of global effects (e.g., methane emission) if there is an absolute increased requirement of inputs at the farm scale. Although progress in milk yield depends on the farm environment, there is no evidence that it has been or will be genetically limited. Population genetic diversity is paramount for the long-term success of the dairy industry, as genetic progress depends directly on genetic variability. Furthermore, reduced genetic diversity (e.g., allelic losses and greater inbreeding levels) has strong negative effects on productive and reproductive efficiency, health, survival, and overall resilience. Low-genetic-diversity populations are also less suitable to respond to biological threats in future unforeseen circumstances such as new pathogens or environmental pressures. The main factors that have increased the rates of genetic diversity loss are: intensive selective breeding for a limited number of traits, genetic drift, intensification of production systems (lower animal dependency on external environmental factors), progeny testing of a limited number of bulls (prior to the genomics era), adoption of a small number of breeds worldwide (and limited, if any, investments in genetic selection in local breeds), and globalization of breeding programs (e.g., use of semen from common bulls across the whole world). The rates of inbreeding have increased substantially over time and the implementation of genomic selection in the large majority of dairy cattle breeding programs over the past two decades has also contributed to a much faster rate of inbreeding accumulation per year. As previously indicated, much lower selection intensity has been placed in local breeds, especially because the industry has economically supported a reduced set of production outcomes (e.g., milk yield and fat/protein composition). Consequently, selection for a limited number of traits combined with reduced population size (number of breeding animals; and consequently, effective population size) have further increased inbreeding levels. Selection for a larger number of traits (combined with strategies to minimize inbreeding such as optimal contribution selection, is expected to contribute for minimizing the rates of inbreeding as a greater set of animals could have similar genetic merit based on a more complex selection index in comparison to selection for a reduced number of traits. Therefore, when implementing breeding programs in local breeds, it is important to maintain a large enough breeding population and develop selection indexes that emphasize a broader range of traits. In addition, key industry stakeholders (and potentially governmental agencies) should reinforce the use of techniques to minimize inbreeding such as the use of optimal contribution selection. From a genetic point of view, evidence for selection limits to daily milk production is thought to be limited, especially when genomic selection enables a better assessment of Mendelian sampling and a shorter generation interval in dairy breeding schemes. However, depletion of genetic variation in milk yield seems unlike, but it can happen (as observed in other animal species). This is likely due to the highly polygenic nature of milk yield and other traits of interest. Furthermore, as selection indexes reduce the emphasis on milk yield to simultaneously select for many other important traits, greater genetic variability is expected to be maintained in the long term (i.e., more diverse genetic make-up of individual animals). Intense selection on production traits has led to unfavorable correlated responses on other important traits. These trade-offs between biological functions are commonly interpreted under the “resource allocation theory”: when two (or more) biological processes share the same resources, they are competing in the situation of limited resources. Various cases suggest that antagonistic relationships between production traits and fitness-related traits linked to reproduction (e.g., conception rate) or health (e.g., somatic cell count – SCC) can be dealt with using appropriate multi-trait selection methods. The resource allocation theory modeling can also be applied to select for antagonistic traits. Thus, at first sight, further increasing milk yield of high-producing dairy cows appears both desirable and possible. But situations in which limited resources are more likely to occur in the future because animal production systems are changing to more sustainable ones, might include: less control over the environment (e.g., temperature, relative humidity, wind speed), lower dependence on inputs (producing more cereals, proteins, high-quality forages, and fertilizer on the farm), and the use of more preventive management strategies of health and welfare than ever before. These extensive systems are more exposed to external perturbations such as a shortage of feedstuffs that cannot be produced on the farm (e.g., by-products such as meals), droughts, or disease outbreaks. In this context, high-producing animals tend to be more sensitive to perturbations. Genetics of resource allocation and the dynamics thereof will likely become more important in the future to select animals capable of maintaining different phenotypes of interest (e.g., milk production and resistance to pathogens or parasites) under challenging conditions. Genetic improvement requires sophisticated approaches, as the large majority of relevant traits are quantitative traits and genetically inter correlated in both favorable and unfavorable directions. Therefore, sustainable breeding goals require the measurement and proper weighting of all relevant traits in selection indexes to enable simultaneous genetic progress in the desired direction for all traits of interest.

For instance, reproductive inefficiency results in increased involuntary culling rates, increased calving intervals, increased veterinary costs, decreased milk production, and delayed genetic progress, which leads to significant economic losses for dairy farmers. Production and fertility are negatively correlated and therefore, selection programs that have emphasized milk production and at the same time ignored fertility, have experienced a decline in reproductive performance. Genetic evaluations for reproductive traits were introduced in early 2000 in order to counter the decline in cow fertility. Indeed, the incorporation of female fertility traits into breeding programs, together with the development of reproductive management tools, and improvements in nutrition, health, and cows' comfort have significantly improved cow fertility in the last two decades. Now, despite these advances, the reproductive performance of dairy cows remains suboptimal. Health events result in substantial economic losses, including losses due to on-farm death, increased veterinary and treatment costs, premature culling, and reduced milk production. Production and functional traits are negatively correlated, and the intense selection for milk production in the last decades has compromised health and fitness and increased environmental sensitivity. For instance, intense selection for production has led to modern high-yielding dairy cows often experiencing a state of negative energy balance in early lactation, which in turn leads to an imbalance in metabolic processes giving rise to metabolic diseases. It is not surprising that genetic correlations between milk production and metabolic diseases, such as ketosis and displaced abomasum, are mostly unfavorable. Traditionally, breeding programs have focused on indirect measures of cow health and fitness, such as the length of productive life or SCC as an indicator of udder health. However, given that direct selection is more effective than indirect responses, recently many countries have implemented genetic evaluations for some health traits, including milk fever, retained placenta, metritis, displaced abomasum, ketosis, lameness, and clinical mastitis. Heat stress is another factor negatively impacting dairy cattle performance and welfare, and consequently, causing huge economic losses and welfare issues to the dairy industry. Intense selection for increased production in recent decades has compromised the thermoregulatory competence of dairy cows. Indeed, production and thermotolerance are antagonistic traits because greater milk production leads to higher metabolic heat production, hence an increased susceptibility to heat stress. This is alarming as global temperatures trend upward and heat waves are expected to become more frequent and intense. There is a negative genetic relationship between milk production under thermoneutral conditions and milk production under thermo-stress conditions. This negative genetic correlation suggests that the continued selection for greater milk yield without considering the genetic merit of the animals for thermotolerance will result in increasing, even more, the harmful effects of heat stress on cow performance. Therefore, there is a critical need for breeding for thermotolerance, which is a heritable trait. Recently, the Australian dairy industry introduced a genetic evaluation for thermotolerance which allows selection of animals that are more resistant to the detrimental effects of heat stress.

The modern high-producing dairy cow achieves greater levels of production per unit of digested feed, but higher rates of feed intake have apparently favored a long-term decline in digestive efficiency. The importance of the dilution of maintenance effect decreases with successive increments in milk yield so that the most productive herds are already close to milk production levels beyond which no further gain in efficiency would be expected. It is paramount to consider how the effects of intensification can occur synergistically (e.g., livelihoods and environment can be simultaneously improved or worsened) or as trade-offs (e.g., enhanced economic efficiency may come at the expense of human health. The larger adoption of precision technologies and accumulated knowledge in multiple scientific fields (e.g., nutrition, reproductive management, soil sciences, water management, agroecology, grassland management, ambiance control) also support the development of tools to enable optimal phenotypic expression of the genetic merit of animals raised in different dairy production systems. Since domestication, the key traits under artificial selection (mainly based on phenotypic performance) were temperament (and other behavioral traits), physical and anatomical variables (e.g., coat color, body size), and milk production. With the methodological developments in the area of quantitative genetics, animal breeding, and phenomics, the array of traits targeted for improvement has expanded substantially over the past five to six decades as a response to the dynamic requirements of dairy producers, consumers, and society in general. As multi-trait selection became the norm in dairy breeding programs, the development of selection indexes played a major role in balancing the genetic merit of each individual for each trait under selection, based on their economic value or desired genetic gains. Selection indexes have been refined over time to enable direct breeding emphasis toward specific production systems, market demands, or to address emerging production, environmental, or societal aspects of the dairy industry and society as a whole. Frequently, economic values in the breeding objectives are the key inputs to cost–benefit analysis and optimization of breeding schemes, but in some cases, it is challenging to define economic values for certain traits and therefore, selection indexes tend to be constructed based on desired gains or a blend of economic values and desired gains. There are several national selection indexes that differ based on the emphasis put in each trait category (production, reproduction, health, workability, efficiency, and body conformation). However, it is paramount to have more differentiated indexes to meet niche markets and alternative breeding goals. In general, structured breeding programs have increased the genetic merit of dairy animals and have been accompanied by an improvement in the environmental conditions through management practices, both of which are needed for high productivity. However, there is a wide range of production systems (from extensive and low-input to intensive and precision-technology farms), and the best genotypes selected under certain conditions will not necessarily perform well in other environments or production systems, i.e., GxE (genotype x environment). Briefly, GxE interaction can be defined as a change in the response of genotypes to different environments or changes in the relative merit of genotypes in different environments. Genotype-by-environment between environments leads to lower genetic gain if the selection is performed in a different environment (e.g., a nucleus), than in which the commercial animals are performing. Selection for increased productivity has also led to greater environmental sensitivity and therefore, it is expected that larger GxE effects will be observed when high-yielding dairy cows are raised in different production systems compared to those in which they were selected in (especially low-input systems. Over time, GxE was ignored in many instances, as the environments for intensive production are mainly controlled. However, considering the current challenges (e.g., higher average temperatures) and energy costs, there is a need to genetically select more resilient and robust animals. Several strategies have been sought to overcome these issues. First, breeding schemes can consider GxE in genetic and genomic evaluations to identify the most suitable genotypes for each condition. This can be done through the use of reaction norms using routinely recorded datasets such as milk yield and climatic variables or direct indicators of resilience and welfare. Different tools and approaches can be adopted to collect phenotypes to be used for genetic selection. For instance, precision technologies (e.g., activity sensors, feeding behavior recorders, automated milking robots, computer vision) can generate a wealth of data to maximize genetic progress for traits related to resilience and welfare. Secondly, local breeds can be used for the introgression of desirable alleles, crossbreeding with exotic breeds, and development of new composite breeds. When animals are genetically adapted to specific environmental conditions or production systems, they will tend to be more productive, have better welfare, and production costs will be lower. In addition to environmental conditions, a wide variety of production systems are becoming more common around the globe, including precision-technology-based dairy farms, organic, and agroecological production systems. Thus, different selection indexes need to be developed to select animals that perform well, have a better life (in terms of positive welfare, health, longevity), and are part of an environmentally and economically sustainable production system.

9-5: The Role of Local Breeds Toward Increased Dairy Sustainability

In general, local breeds: (1) are more adapted to less intensive and suboptimal management practices and harsher environmental conditions such as high temperature and relative humidity, endo- and ectoparasites, higher altitudes, or lower-quality feed; (2) have greater fertility and longevity; and, 3) have lower incidence of metabolic diseases, hoof health issues, and reproductive disorders. The large majority of these traits are already under selection (or in research stages) in Holstein (and other cosmopolitan breeds) breeding programs around the world. However, in addition to continue selecting for these traits in cosmopolitan dairy cattle breeding programs, considering the heritability of fitness traits (e.g., health, longevity, fertility), it might be more cost-effective to genetically improve the performance of local breeds while also avoiding deterioration of fitness traits, as already observed in breeds such as Holstein. In other words, the participation of local breeds in dairy production is expected to increase as their production levels are improved and adaptation and fitness are retained. On the other hand, Holstein (and other cosmopolitan dairy breeds) will be selected for increased fitness and adaptation with a reduced focus on milk yield. At the end, both breed groups will be more adapted to play an important role in specific production systems (e.g., precision farming and high-input vs low-input farming). The long-term sustainability of the dairy cattle industry depends on the development of balanced breeding goals to simultaneously improve animal health and welfare, productive efficiency, environmental impact, food quality and safety while minimizing the loss of genetic diversity. Genetic selection for some of these breeding goals have already been implemented around the world and certain countries have placed greater emphasis in these novel traits, especially in Europe. The wide availability of genomic tools provides a great venue to genetically improve traits that are difficult or expensive to measure (e.g., disease resistance, welfare, longevity, methane emissions) as well as to better manage genetic diversity. The refinement of breeding programs to incorporate novel breeding objectives requires the development of high-throughput phenotyping technologies (and structured and continuous data recording streams), investigation of the genetic relationship between novel traits and those routinely recorded (and the potential consequences of selection for every single trait), the performance of large-scale genomic studies, especially genomic predictions and genome-wide association studies, and refinement of selection indexes to reflect improved knowledge of biology, new sources of data, and changing conditions in the environment and economy. It was concluded that remarkable achievements have been accomplished in the dairy cattle industry over the past decades, with a massive increase in milk productivity (in a limited number of breeds). Unfortunately, this progress has been accompanied by strong drawbacks, including loss of genetic diversity and deterioration of key biological mechanisms (e.g., health, resilience, robustness, welfare, longevity) in the most common dairy cattle breeds. Moving forward, the development of a more sustainable dairy cattle industry will require continued innovations in multiple areas, especially in genetics, strong involvement of all stakeholders (e.g., farmers, technical and scientific sectors, consumers, policy-makers), diversification of production systems, and great support from governments and private institutions toward experiencing and developing alternative production systems. There seems to be a consensus on the need to continue refining the current selection indexes and breeding goals to incorporate or give greater emphasis on traits related to animal welfare, health, resilience, longevity, and environmental efficiency. Novel phenotyping technologies, closer-to-biology traits, and genetic and genomic evaluation methods will continue to be developed and should be addressed to specific production systems. Finally, genetic selection of high-yielding dairy cattle will need to be part of more systemic approaches at the farm scale to favor profound transitions toward sustainable farming systems. Breeding strategies for smallholder dairy farming systems in Sub-Saharan Africa (SSA) were simulated and evaluated considering cow traits identified as priorities by farmers in different agro-ecological zones. These traits were related to cow milk yield, fertility, temperament, feed intake and disease resistance. The first breeding strategy was based on continuous importation of genetically superior exotic dairy sire semen to SSA and crossing with local females leading to a gradual upgrade of the indigenous population. The second strategy assumed that semen from elite exotic bulls would be imported to SSA and used on indigenous cows to produce F1 animals. Thereafter, elite animals would be selected from within the F1 and each subsequent generation to establish a new synthetic breed. The third strategy was to improve the indigenous population by genetically selecting the best sires available domestically. Results showed positive genetic progress for all breeding goal traits. After 15 generations of selection, the genetic response of the importation strategy exceeded the corresponding genetic response of the synthetic breed strategy by 20%–60%. The former also exceeded the genetic response of the indigenous breed improvement strategy by 43%–75%. Potentially there is an opportunity for breeders to choose an appropriate breeding strategy that fits a specific need of smallholder dairy farmers.

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Chapter 10

Strategies to Lower Feed Costs and Boost Efficiency of Cattle Production

The Role of the Gut Microbiome in Cattle Production and Health

Strategies to Lower Feed Costs and Boost Efficiency of Cattle Production /

The Role of the Gut Microbiome in Cattle Production and Health

10-1: Highlights on Strategies that Optimize Feed Efficiency and Improving Dairy Farm's Productivity

Enhancing feed efficiency should improve the profitability and sustainability of dairy farming due to reducing of feed cost. The selection of animals that are genetically superior for feed efficiency requires precise measurements of feed energy intake and milk energy output from enough cows to predict genetic merit for feed efficiency with reasonable reliability. The researchers showed that dry matter intake (DMI) and residual feed intake (RFI) had moderate heritability to enhance genetic progress for feed efficiency. Result indicated that the US dairy sector could save $540 million/year with maintained milk production by breeding for more efficient cows. Despite substantial advances in milk production efficiency of dairy cattle over the last 50 years, rising feed costs remain a significant threat to producer profitability. There also is a greater emphasis being placed on reducing the negative impacts of dairy production on the environment. Thus, means to lower greenhouse gas (GHG) emissions and nutrient losses to the environment associated with cattle production are being sought. Improving feed efficiency among dairy cattle herds offers an opportunity to address both of these issues for the dairy industry. However, the best means to assess feed efficiency and make genetic progress in efficiency-related traits among lactating cows without negatively impacting other economically important traits is not entirely obvious.


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Any future feed efficiency project should attain the followings:

1. Increase the reliability of genomic predictions for feed efficiency (Implication of Genomic Selection).

Implications

- Positive return from genomic selection for feed efficiency
- High probability of negative returns (approx. 44%) and high degree of uncertainty about key parameters (feed intake values) and accuracy of genomic technologies – further study needed
- Adoption of both artificial insemination and genotyping of heifers is only optimal under expansion scenarios

2. Develop a feed intake index that uses sensors to predict feed intake on individual cows.

3. Initiate a long-term program for updating genomic predictions of feed efficiency.

4. Determine if genomic predictions of feed efficiency can decrease methane emissions.

5- The project should relate feed intake with milk yield and composition.

6- An indispensable component of feed improvement strategy should be a concrete plan to reduce waste. This can take multiple forms, including reducing spoilage during critical processes such as feed mixing, storage, and delivery.

7- Make a deliberate effort to adjust feeding bunks. It can prevent the common issue of overfeeding. Indeed, dairy farmers would agree that throwing away excellent feed is a cost that no one needs.

8- Dairy farmers should maximize homegrown feeds, ensuring dairy farm thrives.

9- Optimize forage quality and utilization, as a top priority in dairy farming. High-quality forage provides essential nutritional benefits for the livestock and is the cornerstone of affordable dairy rations. The moment of harvest plays a fundamental role in determining the quality and yield of forage. Harvesting forage either too early or too late can negatively impact its digestibility, potentially resulting in lower nutritional value. Thus, timing harvest appropriately is crucial in guaranteeing optimal quality and yield. Once harvested, storing forage correctly is paramount to prevent spoilage. The implementation of correct ensiling methods, use of silage additives, and covering silos or bunkers with high-grade plastic can drastically reduce forage waste. Doing these conserves, the nutritional value of forage longer, thereby maximizing its utility.

10- Regulate nutrient intake and do not overfeed. Every class of animals in the herd, whether calves, heifers, or lactating cows, should receive a diet that precisely matches their nutrient requirements. This may seem like a rudimentary practice, but you would be surprised how often it is overlooked. The effects might initially be subtle but gradually escalate into significant issues such as impaired growth, lowered milk production, or escalated feed costs. Overfeeding doesn't equate to better performance. On the contrary, it could lead to inefficient feed utilization and, more importantly, higher operational costs. Nutrient regulation is critical in balancing animal health and farm profitability. Enhancing feed efficiency is vital to increasing productivity on dairy farm, ensuring that cows can produce more milk from the same or decreased amounts of feed. However, this isn't a one-size-fits-all operation.

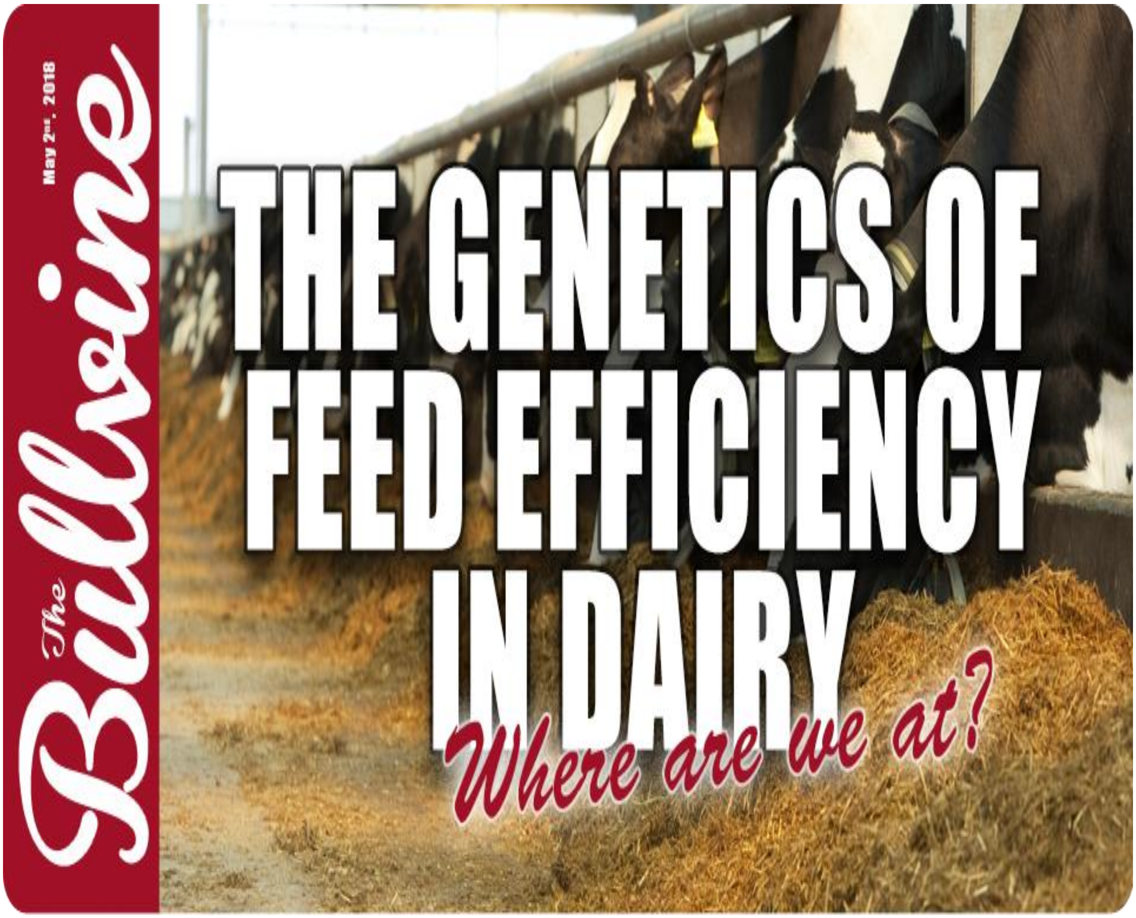
11- Enhance herd health and reproductive efficiency. Healthy cows are more efficient in converting feed into nutrient-rich dairy products. This makes maintaining the health of the herd an integral part of achieving feed efficiency. Prevention is often better than cure, especially when managing dairy herd. Dairy farmers can considerably reduce many common health problems by implementing robust herd health protocols. Regular veterinary check-ups, vaccinations, and strict biosecurity measures can help keep your cows healthier, thus improving their ability to convert feed efficiently. Minimizing stress, as stress can significantly affect a cow's health and overall performance. Heat stress, in particular, can lower herd's feed efficiency. Install proper ventilation and cooling systems to alleviate heat stress and preserve feed conversion rates. Additionally, providing comfortable and ample resting areas will encourage natural cow behaviors, contributing to their overall wellbeing and productivity. Reproductive management, also is another crucial factor in maintaining a high-performing dairy herd. Timely heat detection, synchronization protocols, and regular pregnancy checks can improve reproductive efficiency. The healthier and less stressed cows are, the higher their chances of successful conception are. This not only boosts the productivity of your farm but also contributes to efficient feed utilization.

12- Cull nonproductive cows and heifers. When adopting strategies to boost dairy farm performance and cut feed costs, it is essential to consider the effects on livestock health. It's unfortunate but vital to understand that not all heifers on farm will prove to be profitable or productive. Culling these heifers early if they've had to undergo multiple treatments for conditions like pneumonia can save both escalating feed costs and future disappointment. These savings come from reduced additional feed needed for animals that ultimately may not perform as expected and expensive veterinary treatments.

13- It's worth noting the impact of overpopulation on farm's efficiency. Raising more replacement heifers than necessary can lead to overcrowding and higher feed costs, a scenario dairy farmers would want to avoid. So, aim for a balanced herd that aligns with farm's size and resources. Doing so ensures that each member of herd is productive and contributes positively to dairy farming business.

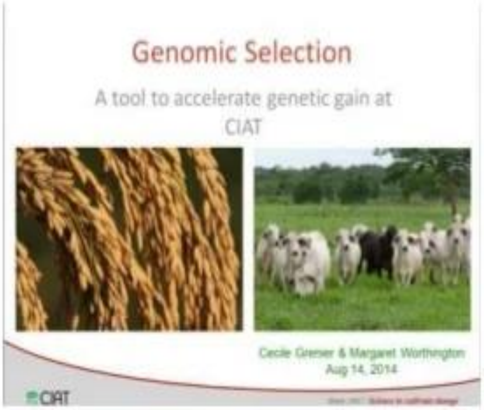
14- Minimize nonproductive days, dairy farmers should give attention to the timeframes in which cows are productive to maximize profitability and efficiency. Any period where cows dry for longer than 60 days or heifers are aged over 22 to 24 months at first calving should be considered nonproductive days. These periods represent additional feed costs without the corresponding milk production, which could significantly impact the overall performance of dairy farm. Therefore, it's essential to try and minimize the number of animals in these categories. Nonproductive days can become a hidden cost on the dairy farm. By pinpointing and addressing this issue, dairy farmers can reduce unnecessary feed costs and help boost overall farm performance. Investing time in proper management and targeted breeding practices can help reduce the length and number of nonproductive days. Here are a few strategies to consider:

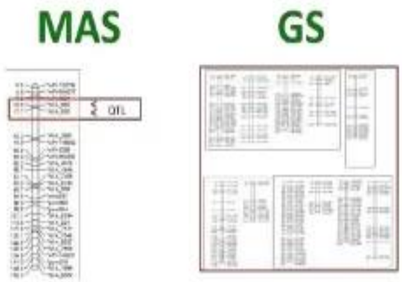
15- Collaborate with industry experts. Collaborating with industry experts is an indispensable strategy for optimizing dairy farm's performance while reducing feed costs. This involves forming robust relationships with a network of professionals in the dairy industry, including feed suppliers, nutritionists, and veterinarians.


The Bullvine
May 2nd, 2018
THE GENETICS OF FEED EFFICIENCY IN DAIRY
Where are we at?

Genomic selection

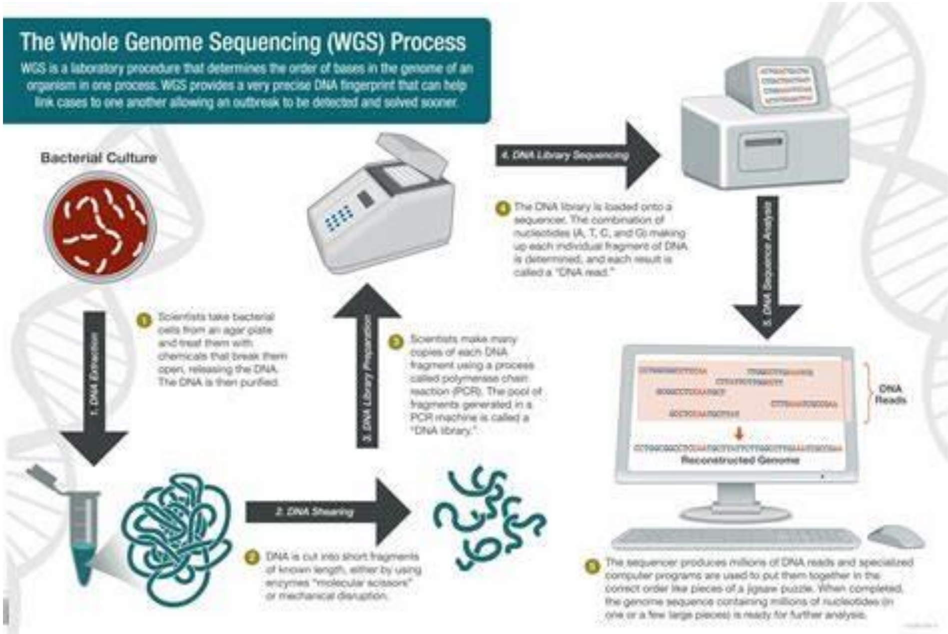
- Decreased genotyping costs and new statistical methods enable simultaneous estimation of all marker effects!
- GS – a new form of MAS that estimates all marker effects across the whole genome to calculate genome estimated breeding values (GEBVs)
- Markers are not tested for significance – all markers are used in selection





CIAT

Since 1967 / Science to cultivate change

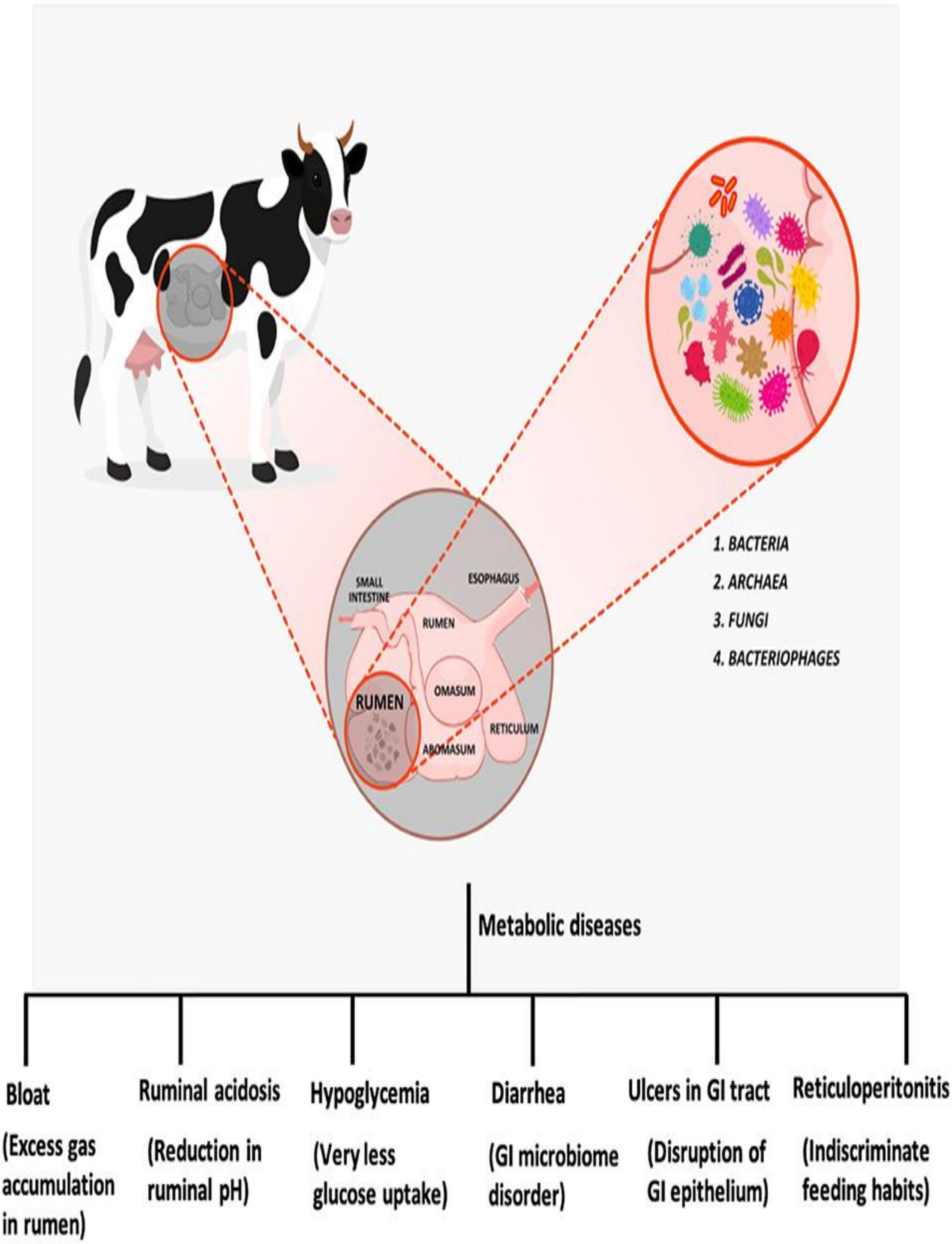

The Whole Genome Sequencing (WGS) Process
WGS is a laboratory procedure that determines the order of bases in the genome of an organism in one process. WGS provides a very precise DNA fingerprint that can help link cases to one another allowing an outbreak to be detected and solved sooner.
Bacterial Culture
1. DNA Extraction
1 Scientists take bacterial cells from an agar plate and treat them with chemicals that break them open, releasing the DNA. The DNA is then purified.
2. DNA Shearing
2 DNA is cut into short fragments of known length, either by using enzymes "molecular scissors" or mechanical disruption.
3. DNA Library Preparation
3 Scientists make many copies of each DNA fragment using a process called polymerase chain reaction (PCR). The pool of fragments generated in a PCR machine is called a "DNA library."
4. DNA Library Sequencing
4 The DNA library is loaded onto a sequencer. The combination of nucleotides (A, T, C, and G) making up each individual fragment of DNA is determined, and each result is called a "DNA read."
5. DNA Sequence Analysis
DNA Reads
Reconstructed Genome
5 The sequencer produces millions of DNA reads and specialized computer programs are used to put them together in the correct order like pieces of a jigsaw puzzle. When completed, the genome sequence containing millions of nucleotides (in one or a few large pieces) is ready for further analysis.


Applying feed intake monitoring systems into producer testing programs
Dr. Daryl R. Strohbehn
Extension Beef Specialist
Iowa Beef Center @ ISU
IBC Iowa Beef Center

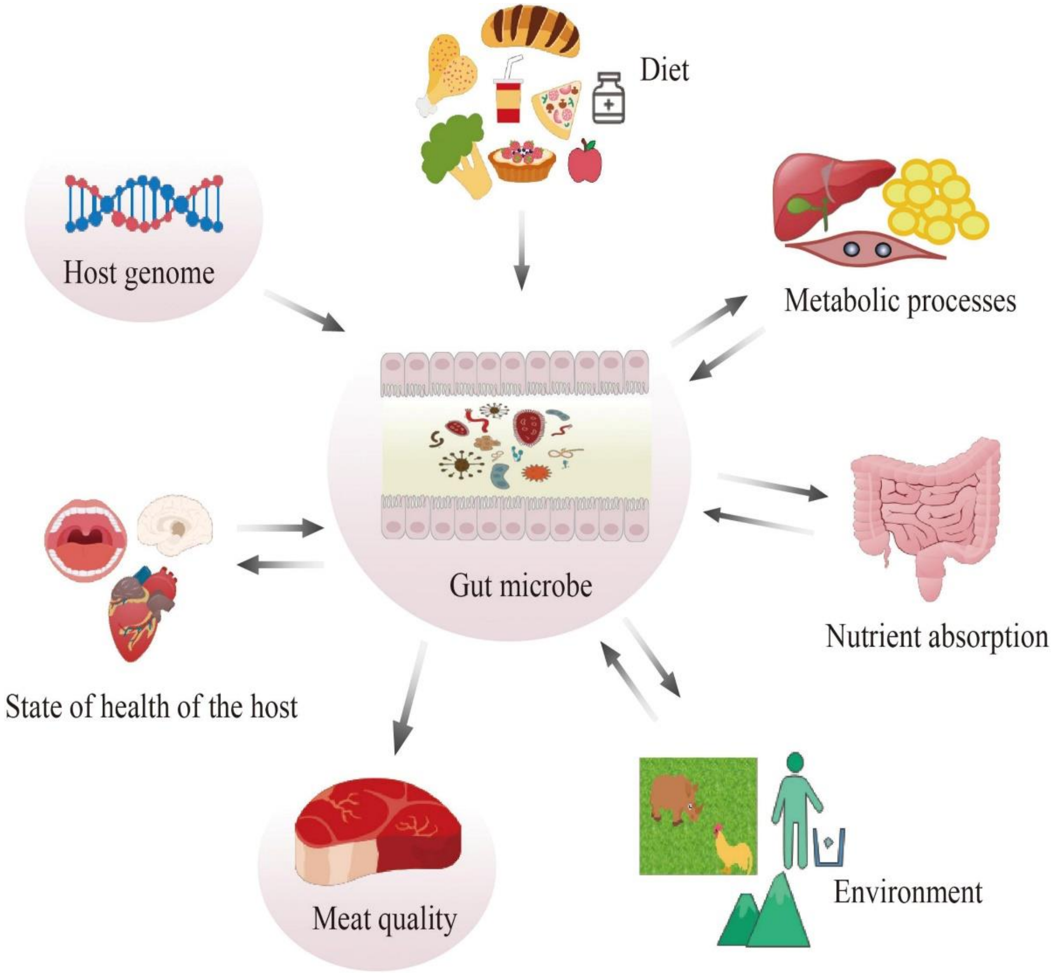
Techniques for Measuring Feed Protein Digestion and Microbial Protein Synthesis

10-2: The Microbiome: The Future Prospect in Cattle Production

Microbiome is a drug-free way to improve cattle health, feed utilization, reproductive efficiency, and environmental impact. Beef and dairy production have made tremendous strides improving the health and productivity of cattle through genetics, nutrition, management practices, immunizations and medications. Now, researchers are focusing on yet another potential area of opportunity: the microbiome, and how it can be influenced even before birth. The microbiome is a collection of tiny organisms – such as bacteria, fungi, viruses and their genes – that live together in a body system. In cattle production, experts tend to focus a lot on the rumen microbiome, because they know how important those rumen microbes are to promoting efficient and healthy digestion that subsequently impacts animal performance in both beef and dairy cattle. Researchers are exploring how the microbiomes of other body systems may also influence cattle performance. Every physical body system has a microbiome, and the researchers note that the microbiota of the respiratory, gastrointestinal, and reproductive tracts have long been recognized as important to cattle health and productivity. More recently, researchers have noted that the liver, hoof, and ocular (eye) microbiota also have significant influence on cattle health. Collectively, microbiomes affect metabolism, immune function, fertility, and nutrient utilization in cattle. The researchers note that microbiomes in adult cattle – particularly in the bovine respiratory and ruminal systems -- tend to be very resilient, meaning they will revert to their original composition after an intervention has ended. That’s a plus when the intervention is a negative one, but not so much when the intervention is intended to alter the microbiome in a beneficial way. If that positive intervention is discontinued, its effects generally do not last long-term. A more effective approach, then, might be to alter the microbiomes of cattle at a foundational level. Ruminants are important in sustainable agricultural practices, as they can render nonarable land useful via grazing, use industrial by-products as a food source, and synthesize energy from low-quality forages for milk and meat production. Ruminant production systems face significant challenges currently, driven by heightened awareness of their negative environmental impact and the rapidly rising global population. Recent findings have underscored how the composition and function of the rumen microbiome are associated with economically valuable traits, including feed efficiency and methane emission. Although omics-based technological advances in the last decade have revolutionized our understanding of host-associated microbial communities, there remains incongruence over the correct approach for analysis of large omic data sets. A global approach that examines host/microbiome interactions in both the rumen and the lower digestive tract is required to harness the full potential of the gastrointestinal microbiome for sustainable ruminant production. The most recent research indicates microbial colonization in calves occurs much earlier than originally thought, and starts in utero. Researchers are exploring ways to influence fetal microbiomes through dam nutrition. In one recent study, researchers examined whether a vitamin and trace mineral (VTM) supplement fed to pregnant dams influenced the microbiomes of the hooves, livers, lungs, nasal cavities, eyes, vaginas, and rumens (tissue and fluid) of their offspring. Compared to the calves of control dams that did not receive the VTM supplement, noticeable differences were observed in the ruminal, vaginal, and ocular microbiota of the calves from supplemented dams. Moreover, the researchers see potential in prenatal microbiome improvement as a natural means to positively influence disease resistance, reproduction, feed efficiency, and environmental impact of beef and dairy production. Among the potential outcomes could be less antibiotic use; improved fertility and reproductive efficiency; lower feed costs; and reduced methane emissions.



1. BACTERIA
2. ARCHAEA
3. FUNGI
4. BACTERIOPHAGES
SMALL INTESTINE
ESOPHAGUS
RUMEN
OMASUM
RETICULUM
ABOMASUM
RUMEN
Metabolic diseases
Bloat
(Excess gas accumulation in rumen)
Ruminal acidosis
(Reduction in ruminal pH)
Hypoglycemia
(Very less glucose uptake)
Diarrhea
(GI microbiome disorder)
Ulcers in GI tract
(Disruption of GI epithelium)
Reticuloperitonitis
(Indiscriminate feeding habits)


Diet
Host genome
Metabolic processes
Gut microbe
Nutrient absorption
State of health of the host
Meat quality
Environment

Bacterial genomes

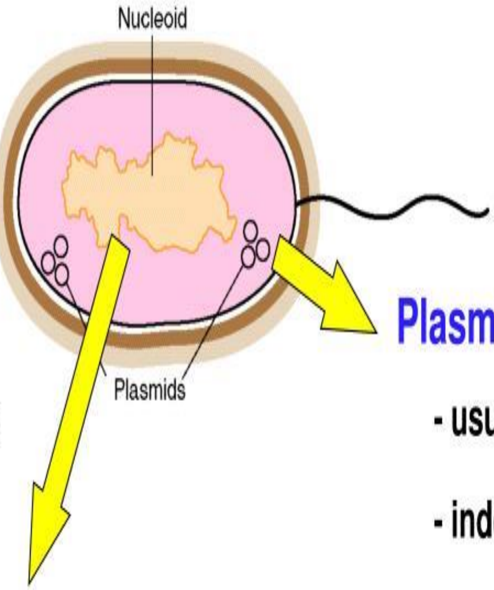


Fig.8.5

Main chromosome
(nucleoid structure)

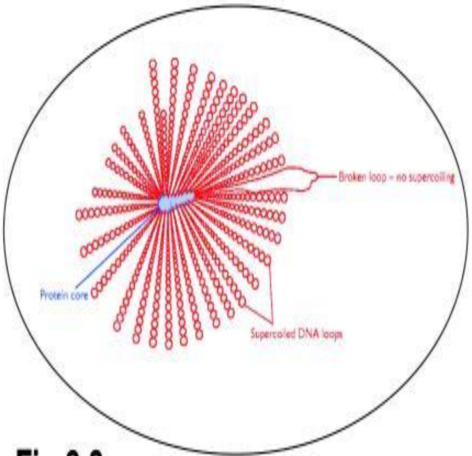


Fig.8.3

Plasmids

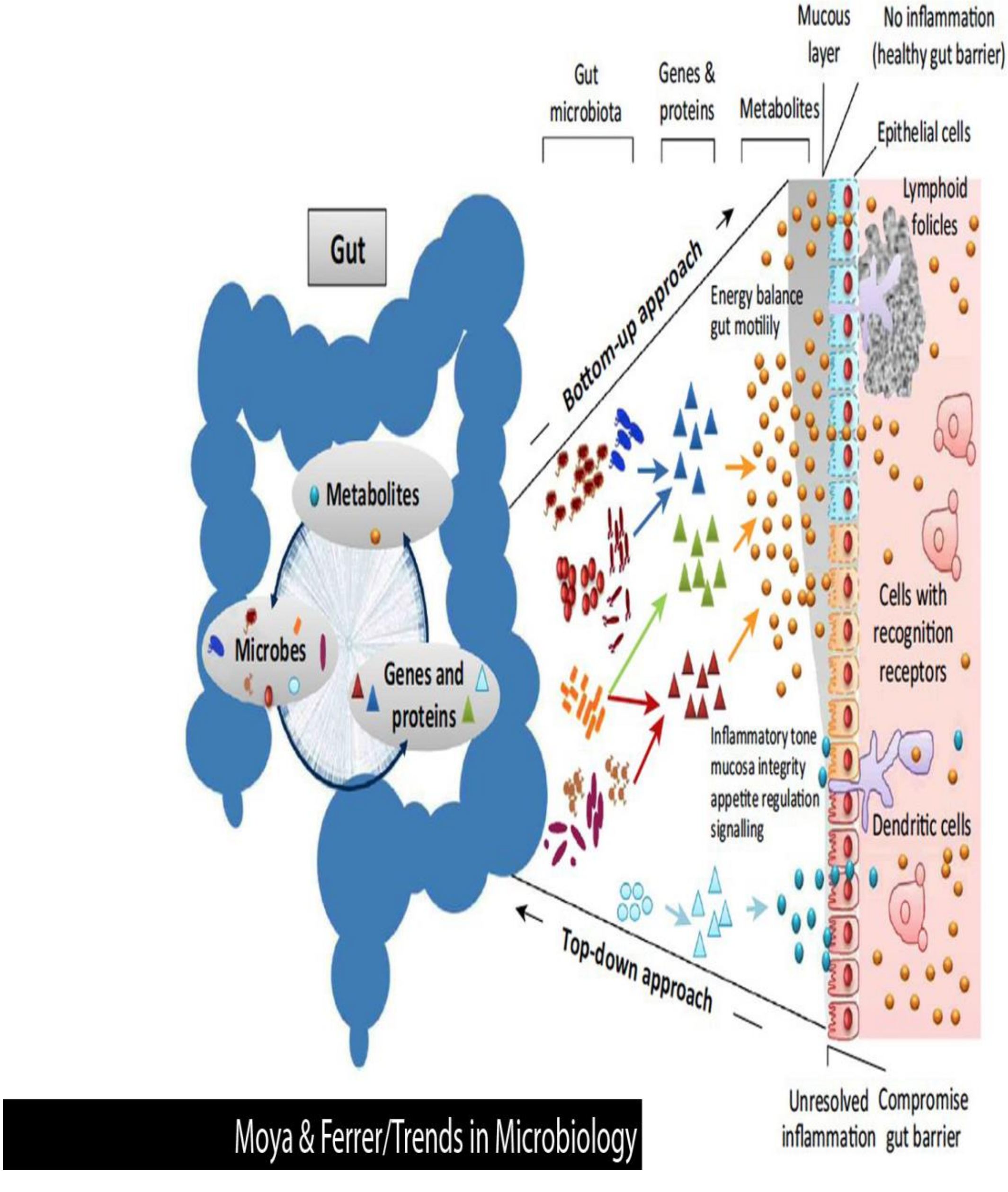
- usually small (<10 kb), circular DNAs
- independent replication
- often present in multiple copies
- carry genes with functions that are non-essential to bacteria

eg. antibiotic resistance
virulence factors
enzymes to synthesize toxins

See Table 8.1

10-3: Importance of the Gut Microbiome to Cattle Production and Health

Gut microbiome is a complex microbial community that resides in the ruminant gastrointestinal tract (GIT), which is now well-recognized as a crucial contributor to the maintenance of intestinal homeostasis, mucosal and lymphoid structure development, and activation of the host immune cell repertoire. Moreover, microbial fermentation of ingested plant biomass in the rumen, a specialized foregut fermentation chamber, allows the animal to harness the nutritional value of host-indigestible plant biomass and so is a critical facet of both beef and dairy systems. Livestock production systems face a myriad of challenges at present. Providing adequate nutrition to the growing global population—estimated to reach 9.15 billion by 2050—will require a 70% increase in food production from 2007 levels in developed countries, and perhaps a doubling of output from developing nations. Compounding this, concerns about the environmental footprint of livestock production are also increasing. Recent estimates based on total life cycle assessment indicate that approximately 14.5% of global anthropogenic greenhouse gas (GHG) emissions are derived from agriculture, but less than 5% of the total is attributable to direct emissions from livestock. A range of GHG are produced throughout beef and dairy production chains, with the livestock themselves generating methane (CH_4) enterically and nitrous oxide (N_2O) from manure. Methane is a particularly prominent GHG associated with ruminant production, synthesized in the rumen and lower gut by methanogenic archaea, and has a global warming potential approximately 28 times greater than that of carbon dioxide. In addition to its negative environmental impact, the loss of gross dietary energy to the animal via enteric methanogenesis is estimated at 2–12% and is therefore a major contributor to reduced host feed efficiency (FE). In light of the intricate relationships between the host animal and its resident gut microbiomes, studies of these microbial communities as a means to improve cattle production efficiency while reducing/removing its environmental impact have been ongoing for many decades. The advent of high-throughput sequencing technologies in recent years has generated a large amount of data on the composition and function of the rumen microbiota across a range of hosts and environments. However, there is increasing evidence that the lower GIT and its resident microbiota also make important contributions to cattle health and production, which has not been extensively studied to date. Understanding the complex interactions between host and microbe throughout the GIT is key to informing strategies to maximize ruminant production efficiency and tackle the challenges outlined above. The rumen microbiome is a phylogenetically diverse consortium of anaerobic bacteria, fungi, methanogenic archaea, ciliate protozoa, and viruses. The microbial cohort contains cellulolytic, hemicellulolytic, amylolytic, proteolytic, and biohydrogenating (lipolytic) species, exhibiting a high level of functional redundancy, and is capable of effectively degrading host-indigestible plant fiber. Volatile fatty acids (VFAs), principally acetate, propionate, and butyrate, are the major products of rumen microbial fermentation and are absorbed and used as energy sources by the host. Ruminal derived VFAs can meet up to 70% of the host's energy needs, and thus their production is essential to animal performance. Metabolism of nitrogen-containing compounds (including peptides, ammonia, and urea) by the rumen microbiota is also vital in the provision of microbial proteins to the host for muscle and milk synthesis. Ingested fiber, carbohydrates, protein, and lipids are first hydrolyzed to shorter chains (or oligomers) and monomers (e.g., glucose, amino acids) by primary members of the microbiota and subsequently used as substrates by various members of the microbial community. Investigation of the temporal colonization of ingested feed by the rumen microbiota showed divergent taxonomic and functional profiles among the primary and secondary colonizers, pointing to variation in their role(s) and/or substrate specificity. Diet, genetics, age, gender, and geography are among the determinants of rumen microbial composition and function; however, influence of diet is the best studied to date.


Mucous layer
No inflammation (healthy gut barrier)
Gut microbiota
Genes & proteins
Metabolites
Epithelial cells
Lymphoid folicles
Gut
Bottom-up approach
Energy balance gut motilily
Metabolites
Microbes
Genes and proteins
Cells with recognition receptors
Inflammatory tone mucosa integrity appetite regulation signalling
Dendritic cells
Top-down approach
Unresolved inflammation
Compromise gut barrier
Moya & Ferrer/Trends in Microbiology

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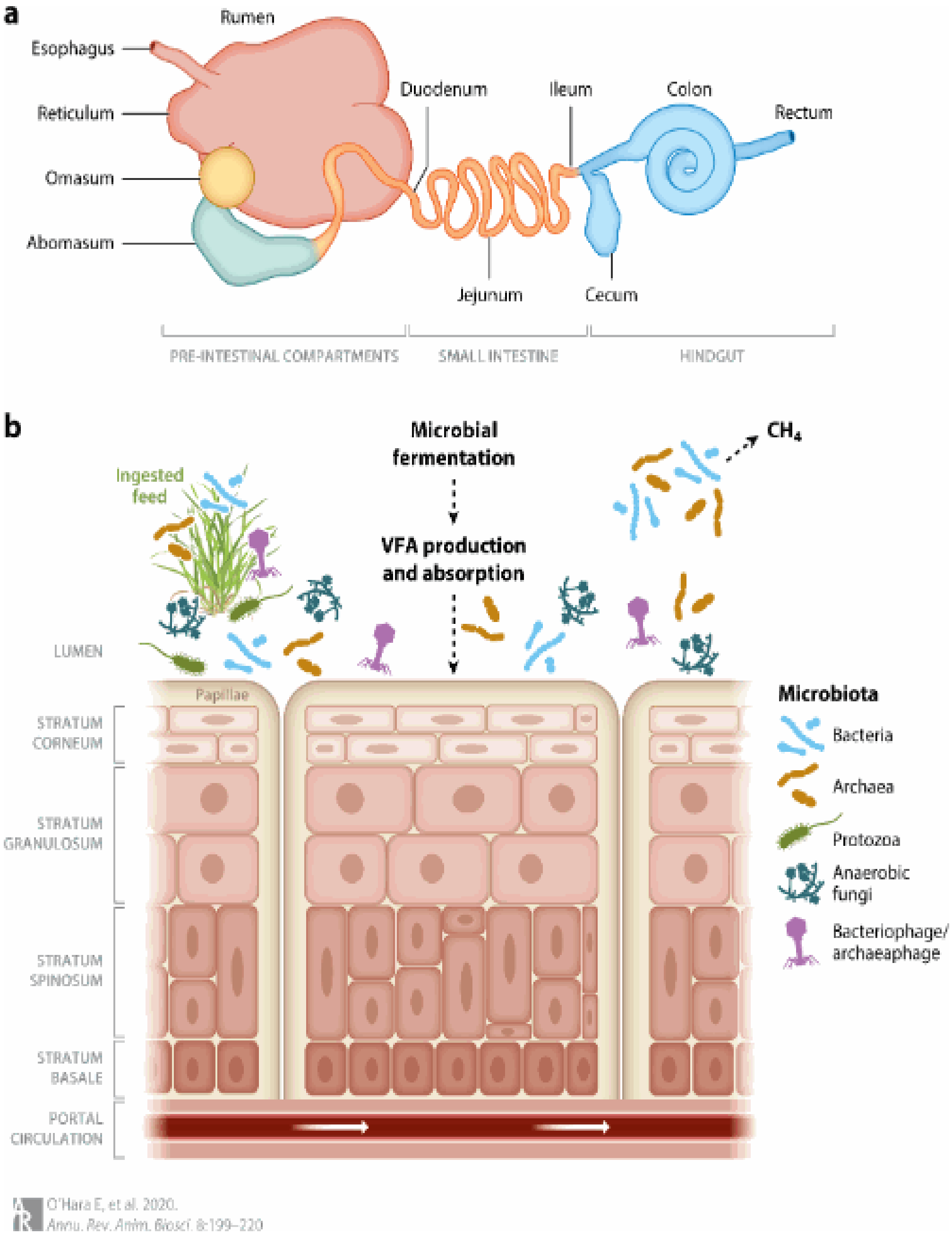


(*a*) Schematic of the bovine gastrointestinal tract and (*b*) depiction of rumen wall structure and microbial diversity and function.

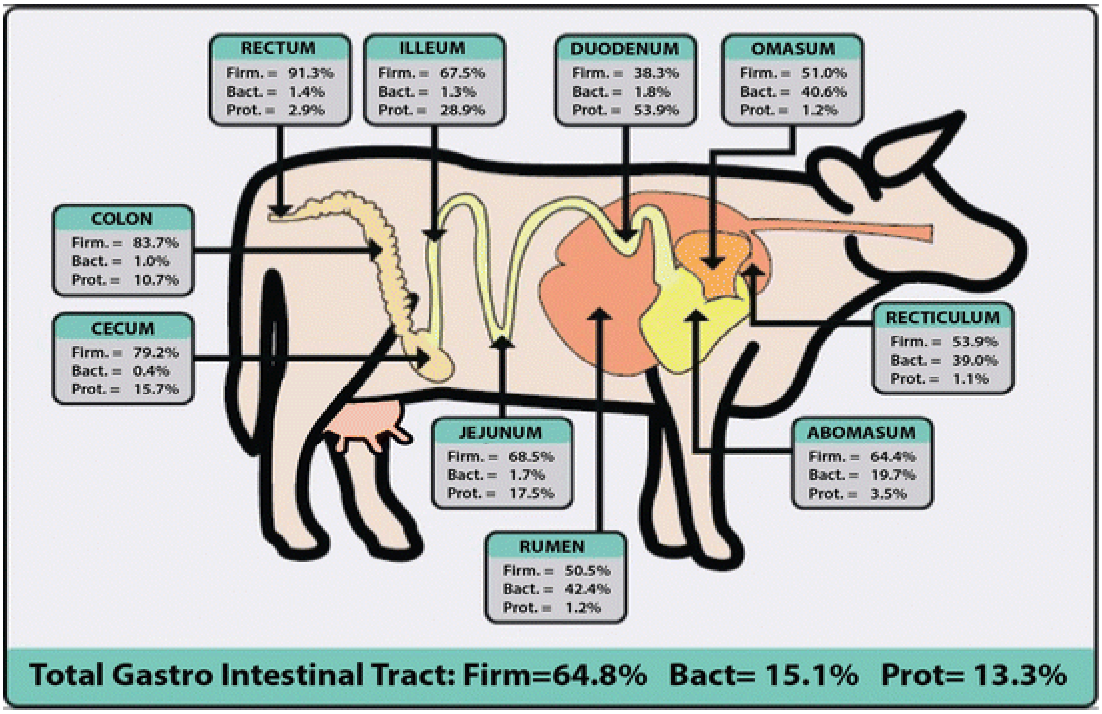
The importance of microbial metabolism in the rumen to the well-being of the host has led to interest in the contribution of the rumen microbiome to animal production. Microbial composition of the rumen is associated with variations in FE, intensity of CH_4 emission, health, and milk composition. More recently, evidence of the heritability of certain groups of rumen bacteria in beef and dairy cattle has emerged, but the extent of the contribution of these microbial species to host traits is not yet clear. If clear relationships between (*a*) the host genome and the rumen microbiome and (*b*) the heritable portion of the microbiome and desirable host traits can be conclusively identified, they could facilitate selective breeding for an optimum rumen microbiome. Finally, extensive efforts have been made to manipulate the rumen microbiome via dietary intervention to improve host performance, particularly in terms of methane abatement

10-4: The Rumen Microbiome and Feed Efficiency

With global food demands projected to rise significantly in the coming decades, the efficiency of food production, both animal and crop derived, must be improved. The term feed efficiency (FE) describes the efficacy at which the conversion of feed to useable product occurs, and it is a moderately heritable trait in cattle. Given that feed inputs account for up to 75% of variable costs in beef operations, and 40–60% of those in dairy systems, improving FE is a means of increasing output while minimizing costs. Several measurements of FE have been used in cattle e.g., feed conversion ratio and partial efficiency of growth, but residual feed intake (RFI) has emerged as the most common measure. First proposed in 1963, RFI is defined as the difference between actual and predicted feed intake of an animal for maintenance of body weight and for weight gain. Genetically independent of growth, animals may be classified as Low-RFI (efficient) or High-RFI (inefficient), with a view to selecting animals that will have the same or greater output value (e.g., meat yield/quality) with lower input costs (i.e., feed). Although a range of physiological processes contribute to divergence in FE within a population, the fact that the conversion of ingested feedstuff to energy substrate (e.g., VFA) is dependent on the rumen microorganisms suggests that the rumen microbiome may play an important role in determining an animal's FE status. Research demonstrated that the rumen microbial ecology of efficient (Low-RFI) cattle differed from that of their inefficient (High-RFI) counterparts, and there was also a greater similarity in microbial profiles among the efficient animals. More recently, the use of high-throughput sequencing demonstrated that efficient cattle (both dairy and beef) had lower rumen microbial diversity and richness, in terms of both microbial species and gene content and metabolic profile. This suggests that the rumen of efficient animals contains fewer non-essential microbes, though it is unclear if this is a cause or a consequence of the efficiency phenotype. Variation in VFA concentration according to RFI classification has also been reported, but these differences appear to be diet dependent.

10-5: The Lower-Gut Microbiome: Unexplored Potential to Improve Animal Health and Performance

In contrast to that of the rumen, the fundamental role(s) of the lower-gut microbiota and its contribution to ruminant health and production are poorly understood. For the purposes of this review, the lower gut is defined as the post-gastric intestinal tract and thus consists of both the small intestine and the hindgut regions. Bacteria are present at levels of 10^{12}–10^{14} cells/ml in the hindgut digesta (cecum, colon, rectum of cattle. Microbial fermentation in the hindgut may be responsible for up to 30% of cellulose and hemicellulose degradation in ruminants, though smaller figures have also been proposed. Lower dietary energy production in the hindgut compartments is likely due to a combination of factors, including reduced retention time of digest in the hindgut compartments versus in the rumen, as well as the fact that substrates entering the cecum and colon already have been partially digested by enzymes in the rumen (microbial) and small intestine (host and microbial). However, dietary energy derived from the hindgut is likely an important contributor to energy availability in cattle throughout all stages of production, and hindgut fermentation could be of elevated importance to the calf during the first days and weeks of life, before the rumen becomes fully developed. The lower-gut microbiota diverges in composition according to intestinal segment, likely reflecting differences in physical, chemical, and biological conditions in each compartment. The jejunum is a major site of post-ruminal protein and carbohydrate digestion and absorption, with *Firmicutes* (up to 90%) being the predominant phyla detected here.



10-6: Sequencing Microbiome and Other Omics Technologies

Nevertheless, development of next-generation sequencing and other omics technologies in the last decade has allowed the study of host-associated microbial communities in ruminants at a depth never before possible. Today, researchers can use a variety of approaches to discern metataxonomic, metagenomic, metatranscriptomic, metabolomic, and metaproteomic profiles of a microbial community and identify patterns or changes related to a biological state of interest. However, high-throughput sequencing efforts are subject to a range of biases, including method of sample collection, method and duration of sample preservation prior to analysis, choice of nucleic acid extraction protocol, and sequencing technology. Furthermore, a large variety of bioinformatic tools have been developed for the analysis of high-throughput sequencing data in recent years but have not been widely compared for their consistency. Finally, although these technologies represent powerful approaches to generate large, high-quality data sets, the best strategy for analysis of these data to draw meaningful and biologically sound conclusions remains a point of debate. In this section, commonly used approaches for analyzing omic data are summarized, and we draw on the literature to propose more robust methods for best-practice statistical analysis of large omics data sets for studies of the ruminant gut microbiome. Data sets generated using omics technologies are inherently compositional and are constrained in a mathematical space known as simplex space, where the features e.g., operational taxonomic units (OTUs) or amplicon sequence variants (ASVs), genes, proteins in each sample are assigned proportions of a unit of measurement, varying between 0 and 1. Unlike the simplex space, the Euclidean space does not exhibit constraints between 0 and 1 but can accept any real number along its dimensions. Thus, the analysis of microbiome data requires statistical methods that account for the simplex structure of compositional data sets, which excludes standard statistical approaches (including Pearson correlations, principal component analysis, and linear regression) that use the assumptions of the Euclidian space. However, these traditional statistical methods are still commonly used by the scientific community to analyze microbiome data sets. Analysis of Composition of Microbiomes. is a statistical procedure that compares the Aitchison's log-ratio of the abundance of each taxon with the abundance of all remaining taxa individually. In this method, differential tests (e.g., Mann–Whitney *U*, ANOVA, ANOVA with Linear Mixed Effect Models, Friedman, Kruskal–Wallis, and Wilcoxon tests) are calculated on each log-ratio to reveal differences in the relative abundance of a taxon between two ecosystems. These differential tests are used to accept or reject the null hypothesis of equality for the abundance of taxa across groups for the condition of interest (e.g., diet). For each taxon, ANCOM computes the number of tests performed and obtains a count random variable W that represents the number of null hypotheses that need to be rejected. The final significance of each test for a taxon is determined using Benjamini–Hochberg algorithms to control the false discovery rate. To deal with the sparsity of the data, ANCOM uses an arbitrary pseudo count value of 0.001 to replace the zero counts and calculate the log-ratios. For drawing inferences regarding taxon abundance in the ecosystem, ANCOM has been suggested as a reliable method to control the identification of false positives and has been incorporated recently into the QIIME 2 pipeline. A recent study evaluating seven statistical methods for differential abundance testing (Wilcoxon rank-sum test, and ANCOM) suggested that the novel methodology implemented in ANCOM based on log-ratio transformations of count data, as defined by Aitchison, was the most effective approach to control false discovery rates.

10-7: Future Perspectives for Studying the Bovine Gut Microbiome

As a result of the technological advances seen in the last decade, the role of the gut microbiome as a critical facet of efficient and regenerative livestock production systems is above reproach. We know the rumen microorganisms are, in terms of both composition and function, associated with economically and environmentally pertinent traits like FE and intensity of methane emission, and there is increasing evidence that the rumen microbiome may be subject to a degree of host genetic control. The intestinal microbiota is also closely associated with host metabolism, health, and immune system development. However, researchers must recognize that these associations are exactly that: only an indicator of a relationship. For all the advances in our knowledge of the mammalian gut organisms over the last 10–20 years, there remains scant evidence of any robust causal relationship between the gut microbes and host production traits, and research concerning the lower-gut microbial functions in ruminants is at an early stage. The vast functional redundancy among gut microorganisms makes it unlikely that the removal of a small number of microbial groups would have any lasting impact on community function or host metabolism. Conversely, to seed a more favorable microbiota, functional niches for these microbial groups to occupy would need to be available, so measuring the effectiveness of manipulation via functional changes rather than taxonomic changes is preferable. Several aspects must be considered if we are to first define the optimal gut microbiota and subsequently apply this knowledge to improve host nutrition and immunity, thereby maximizing the productivity and sustainability of agricultural systems. Taking the next step forward in understanding the total extent to which the gut microbiome contributes to cattle production will likely require a reevaluation of research hypotheses, experimental approaches, and data analysis. The output of future study, be it one using metagenomic, metaproteomic, or meta-metabolomic approaches, is usually a list of biomarker taxa, genes, or metabolites, associated with the phenotype/genotype of interest, but often lacking any clear biological relevance. Moreover, it is impossible to conclusively state whether these changes in microbial composition/function are a driver or a product of host divergence. A shift in thinking from associative to causal relationships between the microbe and host traits will be required for robust contribution of microbiome research to enhanced animal production strategies. The time has come for microbiome research in ruminants to shift focus toward causal, mechanism-based studies, to conclusively identify microbial pathways that actively contribute to a host phenotype, which will in turn allow us to elucidate the optimum gut microbiome under any given condition. Weight is added to such a strategy by evidence that host genetics may also influence some members of the rumen microbiota, though this has not yet been fully confirmed. If strongly defined heritable relationships between the host and the microbiome can be elucidated, it might be possible to target the host (e.g., via genetic selection) to optimize the microbiome, rather than vice versa, as is the current practice.

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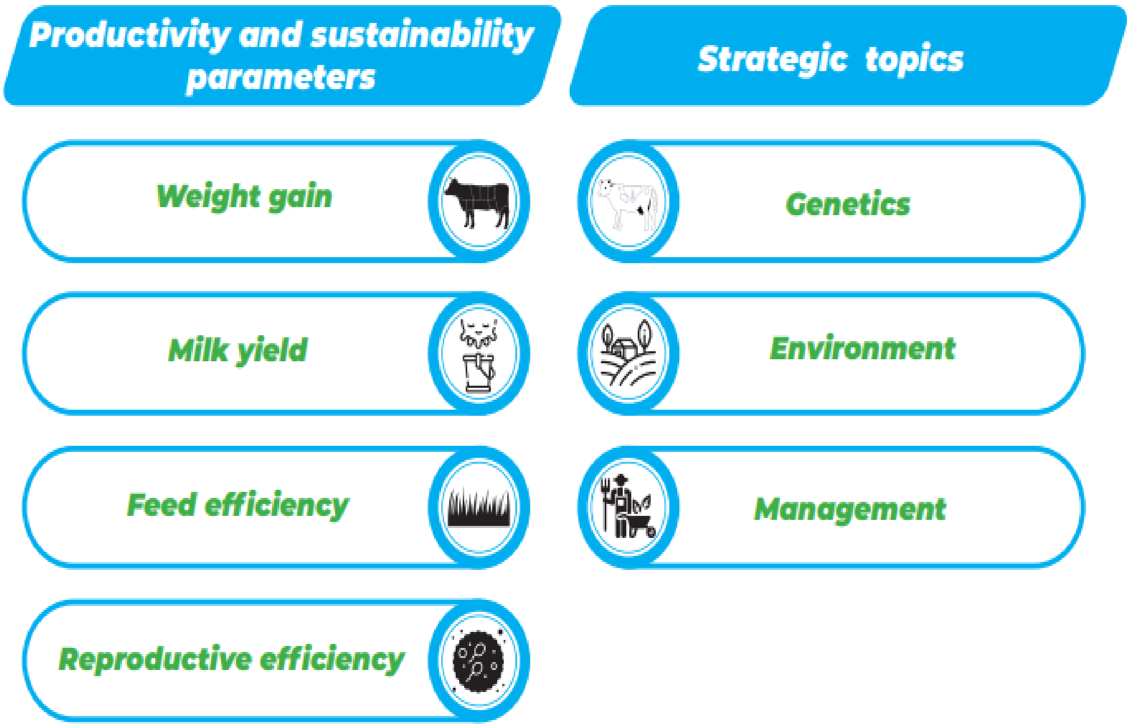
Chapter 11

Factors that Optimize Reproductive Efficiency in Dairy Cattle

Factors that Optimize Reproductive Efficiency in Dairy Cattle

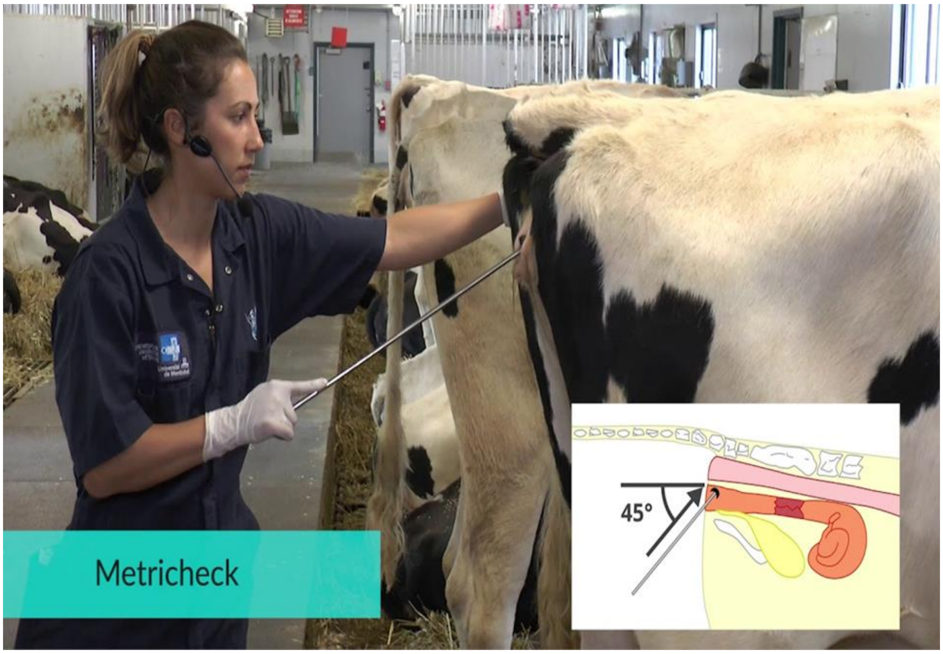
11-1: Implementation of a Systematic Reproductive Management Program

For decades, genetic selection in dairy cattle was primarily focused on milk production. This genetic selection for production, combined with advances in nutrition, management, facilities, and veterinary programs have generated the modern dairy herds with high milk production (9000 to >12,000 kg of milk in a 305-day period). It has been recognized that primary selection for production lead to cows with poorer reproductive efficiency and health traits. Reproductive efficiency is closely tied to the profitability of dairy herds, and therefore successful dairy operations seek to achieve high pregnancy rates in order to reduce the calving interval and days in milk of the herd. There are various factors that impact reproductive performance, including the specific reproductive management program, body condition score loss and nutritional management, genetics of the cows and the cow comfort provided by the facilities and management programs. To achieve high pregnancy rates, pregnancy per artificial insemination (P/AI) should be increased. Currently, there are adjustments in timed artificial insemination (TAI) protocols and use of pre-synchronization programs that can increase P/AI, even to the point that fertility is higher with some TAI programs as compared with AI after standing estrus. Implementation of a systematic reproductive management program that utilizes efficient TAI programs with optimized management strategies can produce high reproductive indexes combined with healthy cows having high milk production termed "the high fertility cycle". The scientific results that underlie these concepts are presented in this manuscript along with how these ideas can be practically implemented to improve reproductive efficiency on commercial dairy operations. Nevertheless, during the last two decades, increased selection for traits linked to reproduction combined with the reliability gains that genomics provided for less heritable traits, such as reproduction, has led to tremendous progress among dairy herds regarding genetic potential for reproduction in the modern dairy cow. Nevertheless, there are so many factors that affect reproductive efficiency in dairy cattle that a multifaceted approach is required to optimize reproductive performance on high production dairy herds. One approach that has been used with great success on many dairy farms across the globe is to have a systematic reproductive management program that includes timed artificial insemination (TAI). Moreover, a longstanding goal of reproductive physiologists during the last seven decades has been the development of programs that allow synchronization of estrus and/or ovulation and result in high-fertility to artificial insemination (AI). Development of these programs has necessarily coincided with increased understanding of ovarian function and hormonal regulation of the bovine estrous cycle brought about by the precise characterization of hormonal and ovarian dynamics, through the use of hormonal assays and ultrasonography, respectively. Availability of these tools was instrumental in the development of physiologically-based approaches to intervene in the cycle. Furthermore, the pathway to this development also involved discovery and approval of different hormonal treatments for synchronization of reproductive function in cattle. The first attempts at synchronization utilized progesterone (P4) injections in oil. This followed the finding that the corpus luteum (CL) was essential for maintaining pregnancy followed by isolation of the steroid hormone, later (in 1935) called progesterone, that was the pregnancy-maintaining factor produced by the CL. Subsequently, the structure and synthesis of P4 from pregnanediol was reported, although the price of P4 in the 1930s was $1000/g making it difficult to utilize it for experiments in cattle. By the mid-1940s, the "Marker degradation" method allowed production of P4 from plant material, reduced prices to $5 to $10 per g. The earliest attempts at synchronization of estrus in cattle were conducted at the University of Wisconsin and Cornell University using daily injections of different doses of P4 in oil. Treatment with P4, generally for 14d, starting late during the estrous cycle (d 15 to d 17) delayed estrus until 4–6 d or 3–9 d after end of P4 treatments, although fertility was low (12.5%; 3/24) after these treatments. Interestingly, both groups reported that P4 administration resulted in the development of large follicles (for example 24.3 mm in heifers treated with 12.5 mg/d). Subsequently, daily P4 administration for 14d followed by treatment with different doses of estradiol benzoate (EB) 2 to 3d later led to improved synchrony of estrus although fertility remained low. Through the 1960s and 1970s, a number of different combinations of oral and injectable progestins were tested and some were approved by the FDA (e.g., Repromix, melengesterol acetate) but each had limitations generally leading to reduced fertility after AI. The next step in the evolution of synchronization protocols required development of drug delivery systems that allowed for sustained release of P4 to better simulate the normal circulating P4 profile. The first system that produced both acceptable synchrony of estrus and fertility was the Syncro-Mate-B (SMB) system consisting of a subcutaneous ear implant of 6 mg of norgestomet for 9 d combined with injection of 3 mg of norgestomet and 5 mg of estradiol valerate (EV) at protocol onset. Administration of both EV and norgestomet were required to induce regression of the CL in cows that were on d 1 to 5 of the estrous cycle at the start of SMB implantation. Results from field trials indicated that between 59% and 88% of heifers expressed estrus between 24 and 48 h after implant removal and fertility was comparable to control heifers bred to spontaneous estrus in three of the trials (54.7 vs. 56.1%; SMB-treated vs. controls) but was 21 and 25% less in SMB-treated heifers than controls in two of the trials. Subsequent research indicated that non-cycling heifers could be induced to have a fertile estrus after SMB, with heifers of ≥250 kg having the largest number of pregnancies per AI (75%). The SMB method could also be combined with 48h calf removal, at the time of implant withdrawal, in postpartum beef cows to increase the percentage of cows that expressed estrus and ovulation. In most of these studies utilizing SMB AI was performed after detection of estrus; however, on some ranches AI was done at a predetermined time after implant removal resulting in comparable fertility. Thus, it seemed possible to develop timed AI (TAI) programs in cattle using hormones that could induce synchronized ovulation; although estrus and fertility were less in thin, anovular cows and heifers. Lack of success in many of the early attempts at synchronization of estrus and TAI were likely related to the length of progestin treatment needed for all cows to have spontaneous CL regression. Extending the length of progestin treatment resulted in some cows developing large, persistent follicles with subsequent low fertility. Conversely, the SMB program was successful due to use of a long-acting estrogen, EV, combined with a high dose of progestin that induced CL regression. Furthermore, it was also later found that EV inhibited circulating gonadotropins resulting in emergence of a new, synchronized follicular wave 3 to 5d later thus effectively controlling lifespan of the ovulatory follicle. Subsequent discovery and approval of other hormonal tools such as prostaglandin F2α (PGF), GnRH, and intravaginal P4 implants led to new programs for synchronization of ovulation and TAI, as detailed below. Use of estradiol (E2) derivatives or, alternatively, GnRH analogs to synchronize follicular development for TAI programs were published independently by two laboratories in the mid-1990s. Estrogen conjugates, such as EB or EV, were administered at the protocol onset, concurrent with progesterone (P4), which was essential to prevent an estradiol-induced GnRH/LH surge and ovulation. Thus, E2 and P4 treatment suppressed LH and FSH secretion and led to initiation of a new follicular wave 3–5 d later. Subsequently E2 treatments were combined with the use of an intravaginal P4, to suppress early estrus/ovulation, PGF to directly regress the CL, and different treatments at the end of the protocol to synchronize the final ovulation with TAI. These treatments allowed development of one of the two major types of TAI program utilized today, termed E2/P4-based TAI protocols. The second major type of TAI protocol that is extensively utilized today was first published by the Milo Wiltbank laboratory using GnRH and PGF with the first iteration of this type of protocol called Ovsynch. The combination of these two hormones in a biologically logical sequence allowed the first reproductive management system using only TAI. The fundamental aspects of this type of program were: 1) synchronization of follicular wave emergence through ovulation of dominant follicles with GnRH; 2) induction of luteolysis using PGF; and 3) synchronization of the time of ovulation with a second GnRH administration prior or at the time of AI. Iterations of GnRH-based programs have been used extensively in both dairy and beef cattle. Since the original development of TAI programs, a large number of studies have been conducted to better understand and optimize the physiological basis for these programs as well as evaluate the resulting fertility. Thus, the purpose of this review is to: (1) summarize the results from TAI fertility studies performed during the last 27 years (1995–2021); (2) evaluate modifications to the protocols that were evaluated in multiple studies including the effect of an intravaginal P4 implant or of a second PGF in Ovsynch-type protocols, and the use of GnRH at the TAI in E2/P4-based protocols; (3) evaluate the impact of using TAI programs on reproductive performance during the breeding season, and (4) provide perspective on the future of TAI programs in beef cattle. Quantification of reproductive efficiency on dairy farms can be accomplished through a variety of measures. In this review, we primarily use the 21-day pregnancy rate (21 d-PR) because of the utility of this measure for making immediate management decisions on a dairy farm. The 21 d-PR is defined as the percentage of eligible cows that become pregnant every 21 d. The 21 d-PR is most efficiently calculated on a computer. First, the number of eligible cows during each 21-day period must be calculated (i.e., cows past the voluntary waiting period (VWP), that are not pregnant, and not designated as "do not breed") including whether a cow should be included that is eligible for only a portion of the 21-day period (usually, if eligible for >11 d in a 21-day period they are included). Thus, it would be better to consider "eligible cows" to be "eligible 21-day periods" because a cow can be eligible during multiple 21-d periods before she becomes pregnant. Next, the number of cows that became pregnant during that 21-d period, either due to AI after estrus or TAI, are determined and divided by the number of eligible cows in that 21-day period. Thus, the 21 d-PR can only be determined after definitive pregnancy diagnosis. Two other key measures determine the 21 d-PR on a dairy and should be calculated when evaluating reproductive efficiency on a dairy farm. The 21-day service rate (21 d-SR) is a calculation of the percentage of eligible cows that are serviced (receive AI) during a 21-day period. The 21 d-SR can be calculated immediately after finishing the 21-day period because it does not include determination of whether a cow became pregnant. The final key measure is the pregnancies per artificial insemination (P/AI), inaccurately called conception rate in some circles. The P/AI should be calculated separately for the first AI (first AI P/AI) and second and later AIs (2nd + AIs). This is because programs that yield differences in fertility are generally used for the first vs. later services. A brief consideration of the link between reproductive efficiency and profitability is appropriate, although this is considered in much greater depth in other manuscripts. One key consideration is that cows in the first third of lactation provide greater income over feed cost as compared with cows in the middle or at the end of lactation. In addition, multiparous cows generally have much greater milk production during the first third of their lactation than primiparous cows. Hence, greater milk production per cow per day and efficiency of milk production can be achieved by increasing the percentage of cows in early lactation and the percentage of cows in later lactations (older cows). Thus, one goal of reproductive management programs is to maximize the number of cows that become pregnant early in lactation in order to increase production efficiency and production per cow per day. For instance, reported that a reduction in calving interval of 60 d increased milk production per day (1.51 and 1.11 kg/d) and during entire lactation (~498 and ~366 kg/lactation) in both high-production (12,500 kg in 305 d of lactation) and moderate-production herds (9000 kg in 305 d of lactation), respectively. An additional key profit generator from efficient reproduction is a reduction in the need for culling high merit cows due to poor reproduction, resulting in either reduced culling or a shift in culling to cows with lower milk production, disease problems such as mastitis, and udder, genetic, or foot and leg issues. Thus, there is an improvement in the overall quality of the herd when reproductive efficiency is improved. Economic benefits may also arise in herds with greater reproductive efficiency due to reduction in reproductive costs, such as costs for semen, reproductive hormones, and veterinary costs such as pregnancy diagnoses, although this will vary with the method used to improve reproductive efficiency. Finally, as discussed in detail later in this review, greater reproductive efficiency will cause a greater percentage of cows to enter "the high fertility cycle" leading to many benefits in terms of improved health, production, and reproduction.


Productivity and sustainability parameters
Strategic topics
Weight gain
Genetics
Milk yield
Environment
Feed efficiency
Management
Reproductive efficiency

Livestock Reproductive Management Practices

- Artificial Insemination- placing sperm in the female reproductive tract using other than natural procedures. Used extensively with swine and dairy cattle.
  - Advantages
    - Wider variety of superior animals can be used.
    - Increases number of females that can be bred to superior males.
    - Reduces the spread of diseases.
  - Disadvantages
    - Requires a trained inseminator.
    - Requires more time and herd supervision.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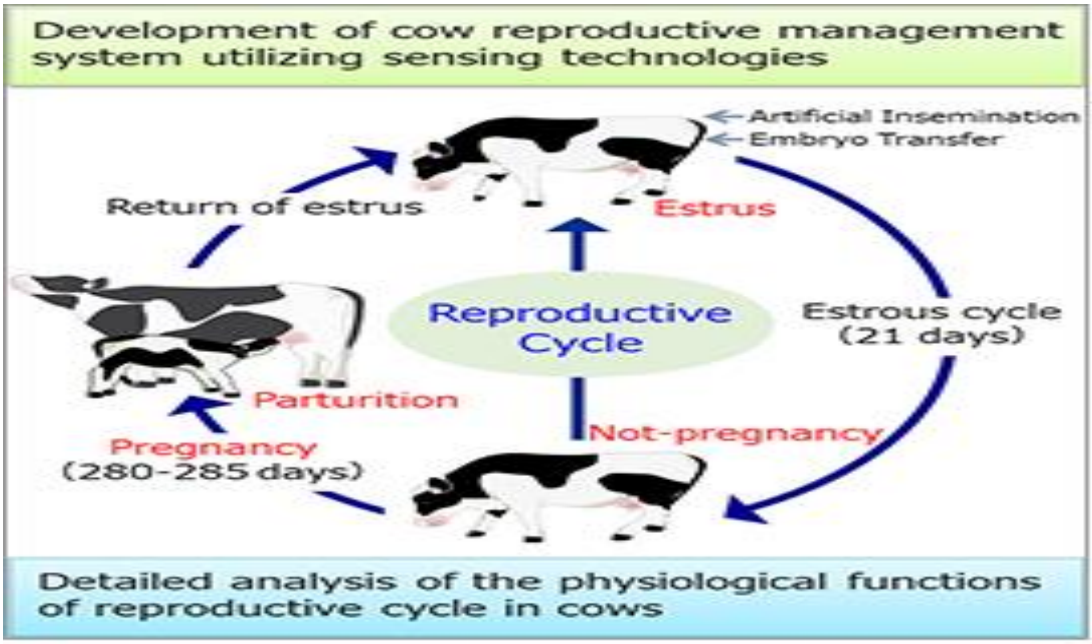
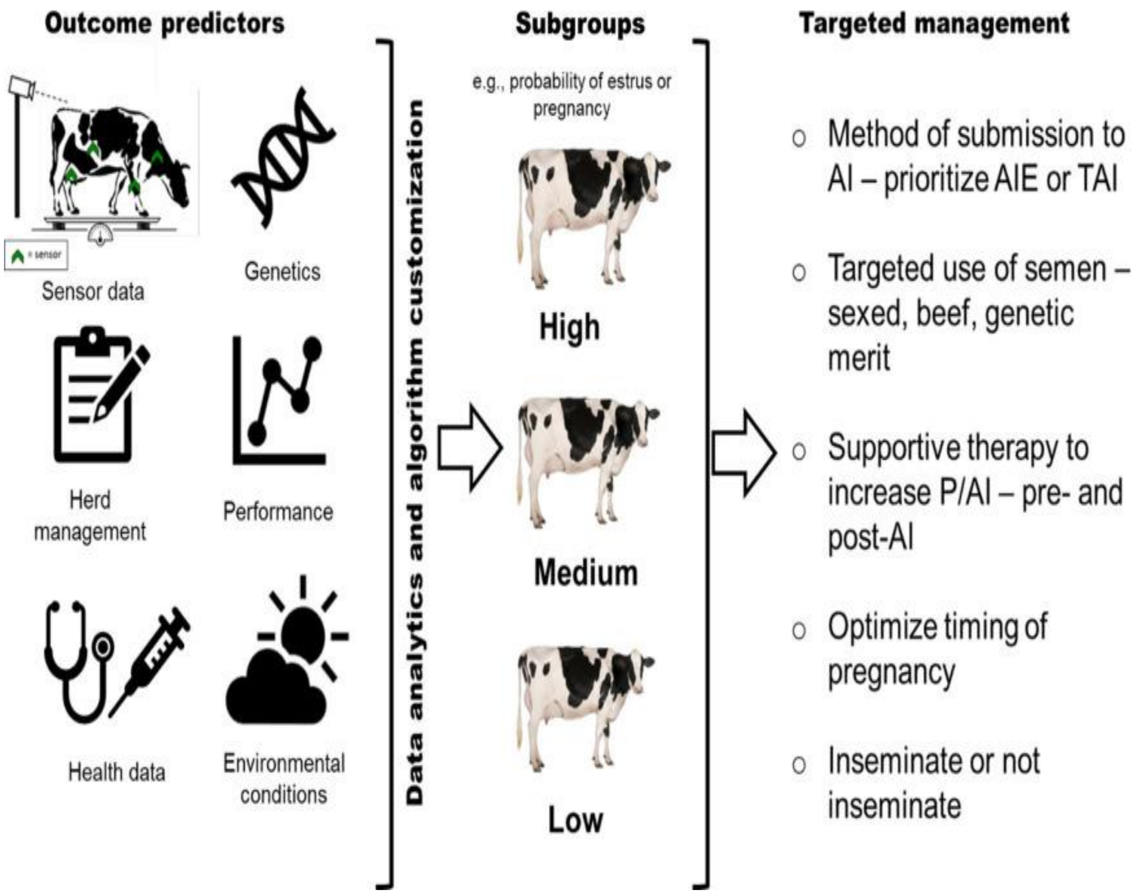
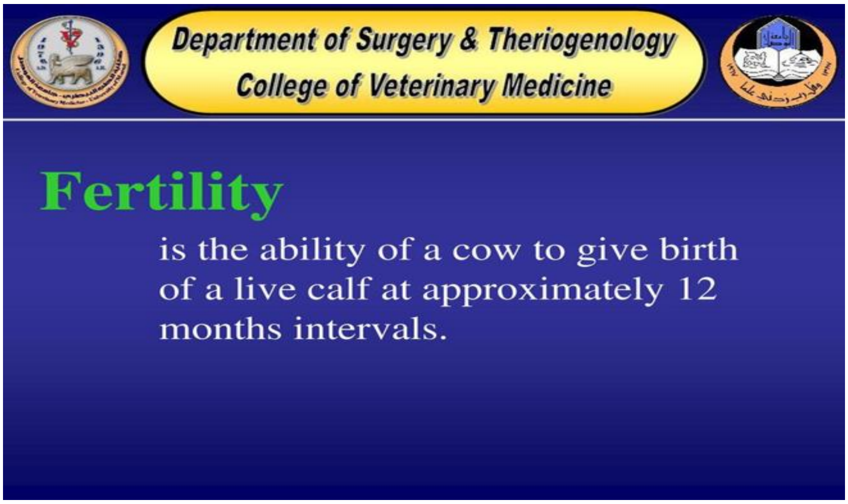

Development of cow reproductive management system utilizing sensing technologies
Artificial Insemination
Embryo Transfer
Return of estrus
Estrus
Reproductive Cycle
Estrous cycle (21 days)
Parturition
Not-pregnancy
Pregnancy (280-285 days)
Detailed analysis of the physiological functions of reproductive cycle in cows

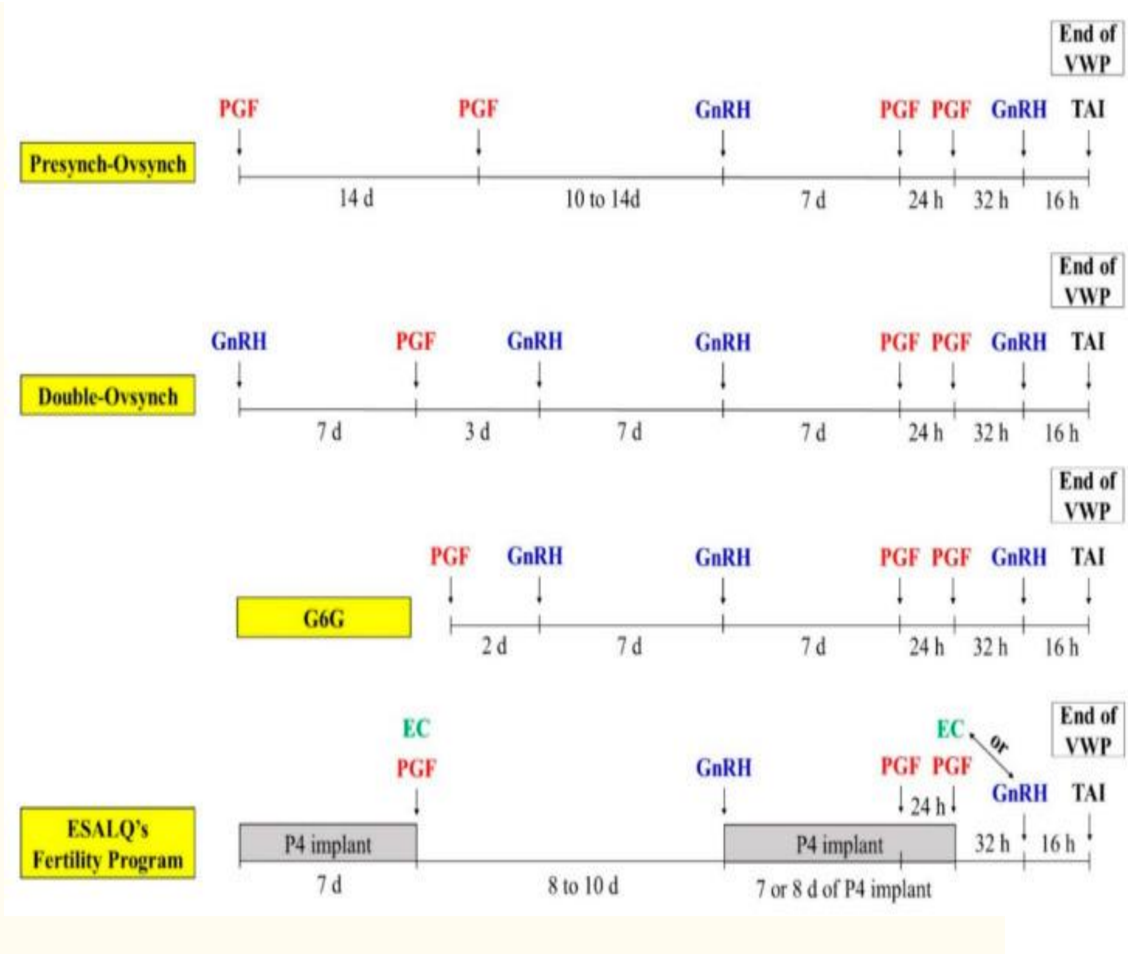


11-2: Fertility Programs

Fertility in dairy cows defined as follows: the ability of the animal to conceive and maintain pregnancy if served at the appropriate time in relation to ovulation. Failure to establish a successful pregnancy could arise from failure to show or detect estrus, failure to ovulate, inappropriate patterns of ovarian cyclicity, embryo or fetal loss. It is becoming increasingly evident that fertility is declining with rising milk yields.



It is well known that one of the greatest benefits of reproductive programs using TAI is the increase in service rate. In addition, optimized TAI protocols can provide extra benefits associated with greater P/AI when compared to programs for AI after estrus synchronization/detection. Thus, those optimized TAI protocols have been termed "fertility programs" and four of these programs presented below:



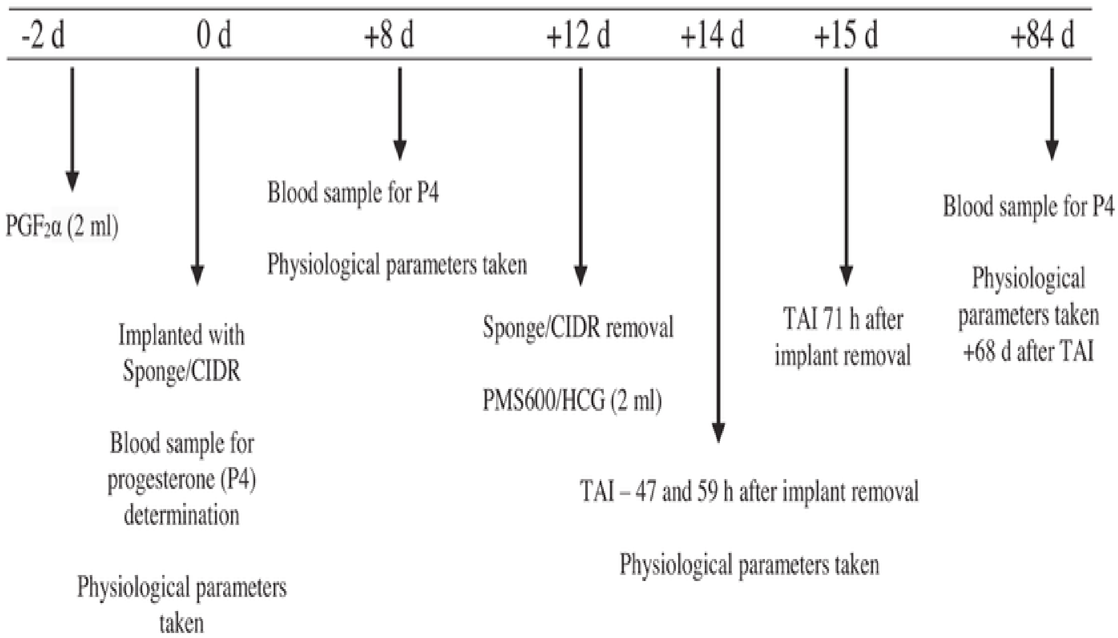
hormonal treatments can be used to achieve 100% service rate and improved pregnancy per artificial insemination compared to the first postpartum timed artificial insemination (TAI) in lactating dairy cows. Voluntary waiting period (VWP), gonadotropin-releasing hormone (GnRH), prostaglandin F2α (PGF), progesterone (P4), and estradiol cypionate (EC). Fertility programs use many of the principles and strategies to optimize synchronization, ovarian dynamics, and hormonal environment during TAI protocols. A critical aspect of these programs is the use of a pre-synchronization strategy in order to ensure that most of the cows initiate the breeding protocol (initiated with GnRH) at an ideal stage of the estrous cycle (6–8 d of the cycle), in which cows have an approximately seven-day-old CL and the first wave dominant follicle that will be responsive to the first GnRH. As previously discussed, increasing ovulation response to the first GnRH will increase the percentage of cows with synchronized emergence of a follicular wave. Causing a new ovulation in the presence of a seven-day-old CL results in cows with two CL throughout the protocol, thus, increasing circulating P4 during the development of the preovulatory follicle. Due to the longer duration of these fertility programs, in general, they are used exclusively for the first postpartum AI, especially because pre-synchronization strategies can be applied before the end of the VWP, resulting in no delay in receiving the first AI. One of the earlier pre-synchronization programs developed was based on PGF administrations, known as the Presynch-Ovsynch protocol (PO). The PO is based on a PGF treatment, followed by a second PGF 14 days later, and initiation of an Ovsynch-type protocol 10 to 14 days after the second PGF. In general, PO increased fertility compared to Ovsynch. In the study, it was noticed that P/AI was 42.8 (113/264) vs. 29.4% (80/272) for PO and Ovsynch, respectively, but it should be mentioned that PO only increased fertility in cyclic cows. Therefore, one disadvantage of the PO is that it is only effective in cyclic cows. Thus, if the percentage of cows that are anovular is high in the herd during early lactation, other strategies that induce ovulation during the pre-synchronization are likely to be more efficient. In addition, PO does not precisely synchronize cows to be in the ideal day of the cycle on d0 of Ovsynch, because it is based on inducing cows to be in estrus with variable timing after PGF treatments. This may produce a less-than-ideal timing for starting the Ovsynch protocol (6–8 d). A final aspect to be considered is whether cows that are observed in estrus during the Presynch-Oyvsynch protocol should receive AI. The percentage of cows detected in estrus after the second PGF can be over 50%, and it is common for dairy operations to inseminate those cows. Although the cows are being inseminated earlier postpartum, fertility is generally lower compared to not breeding cows that show estrus and inseminating all cows at the TAI after PO. Thus, if the herd submits cows to TAI at the end of the PO, this can be considered to be a fertility program, even with the considerations regarding anovulatory condition and accuracy of the pre-synchronization with PGF. The second fertility program presented in this manuscript is the G6G or G7G. Commonly, cows receive a PGF treatment and 2 days later a GnRH treatment, 6 or 7 days before initiating the Ovsynch protocol. Therefore, the G6G/G7G should increase the percentage of cows at the ideal stage of the estrous cycle to initiate Ovsynch. In addition, the inclusion of GnRH during the pre-synchronization may benefit anovular cows. The G6G/G7G is commonly used in commercial dairy herds and several studies have tested this strategy. It was reported greater ovulation to the first GnRH (85 vs. 54%), greater response to PGF (96 vs. 69%), better synchronization rate (92 vs. 69%), and greater P/AI (50 vs. 27%) in cows submitted to G6G compared to Ovsynch initiated at random days of the estrous cycle. The third fertility program is the double-Ovsynch program (DO). The DO was developed to optimize the response to hormonal treatments during the breeding Ovsynch protocol, increasing synchronization and the hormonal milieu during follicle development. Nevertheless, when compared to PO, DO decreased the percentage of cows with P4 < 1.0 ng/mL (9.4 vs. 33.3%) at the time of the first GnRH of the breeding Ovsynch, increased circulating P4 at PGF (4.2 vs. 3.2 ng/mL), and increased P/AI (49.7 vs. 41.7%). In a study, which compared the DO and the PO, in relation to circulating P4 concentrations and ovulation to GnRH treatments, 94% of the cows in the DO had CL at the time of the first GnRH compared to 68% of the cows in the PO. Moreover, ovulation to the first GnRH was greater in the DO (80%) compared to the PO (69.9%), and the percentage of cows with P4 ≥ 1.0 ng/mL at PGF was greater in the DO than the PO (88 vs. 76%). Another study, with ~1700 cows, which compared the DO and the PO, reported a greater uniformity of intermediary P4 concentrations at first GnRH treatment of the breeding Ovsynch protocol in cows submitted to the DO, and only ~6% of the cows had P4 < 0.5 ng/mL at the beginning of the breeding protocol compared to ~25% in the PO program. There was a clear benefit of the DO to anovular cows and greater incidence of ovulation in response to the pre-synchronization treatments. In this study, P/AI was greater with the DO (46.3 vs. 36.8%), with a greater effect in primiparous (52.5 vs. 42.3%, $p = 0.02$) than multiparous (40.3 vs. 34.3%, $p = 0.07$) cows. This increased fertility in cows synchronized with DO has also been described in an elegant study that submitted cows to TAI after the DO compared to a protocol designed to increase expression of estrus, with all cows being inseminated at similar days in milk (DIM) (~77 DIM). Cows in the DO group for first AI had 100% service rate compared to 77.5% in cows bred to estrus. There was also an increase in P/AI from 38.6 to 49.0%, and a 27% relative increase in P/AI when the DO was used. Due to the increase in both service rate and P/AI with DO, there was more than a 50% increase in the 21-day PR. Recent experiments from our laboratory used a novel pre-synchronization strategy prior to breeding protocols that are initiated with GnRH. The pre-synchronization was based on E2 and P4, using an intravaginal P4 implant that was removed after 7 d. At the time of P4 implant withdrawal, cows were treated with PGF and EC to induce estrus and ovulation. Eight to 10 d later, the cows were treated with GnRH to initiate the first postpartum TAI protocol and an intravaginal P4 implant was inserted and kept for 7 or 8 d. One d before and at the time of P4 implant removal, PGF treatments were given. Ovulation at the end of the protocol was synchronized with EC (given at the time of P4 implant withdrawal), GnRH (given 16 h prior to FTAI), or both. The P/AI varied from 32 to 58% among six farms, with an overall P/AI of 43%. Compared to regular TAI protocols that were initiated at random stages of the estrous cycle, the fertility program increased P/AI (59.9 vs. 43.9% [$n = 663$] and 46.4 vs. 30.1% [$n = 416$], for data set 1 and 2, respectively). Therefore, use of TAI protocols can increase SR by allowing AI of all cows without the need for detection of estrus. Use of more optimized TAI protocols have the advantage of increasing P/AI compared to AI to detected estrus and thereby can dramatically increase the percentage of cows that become pregnant during the first week after the end of the VWP.

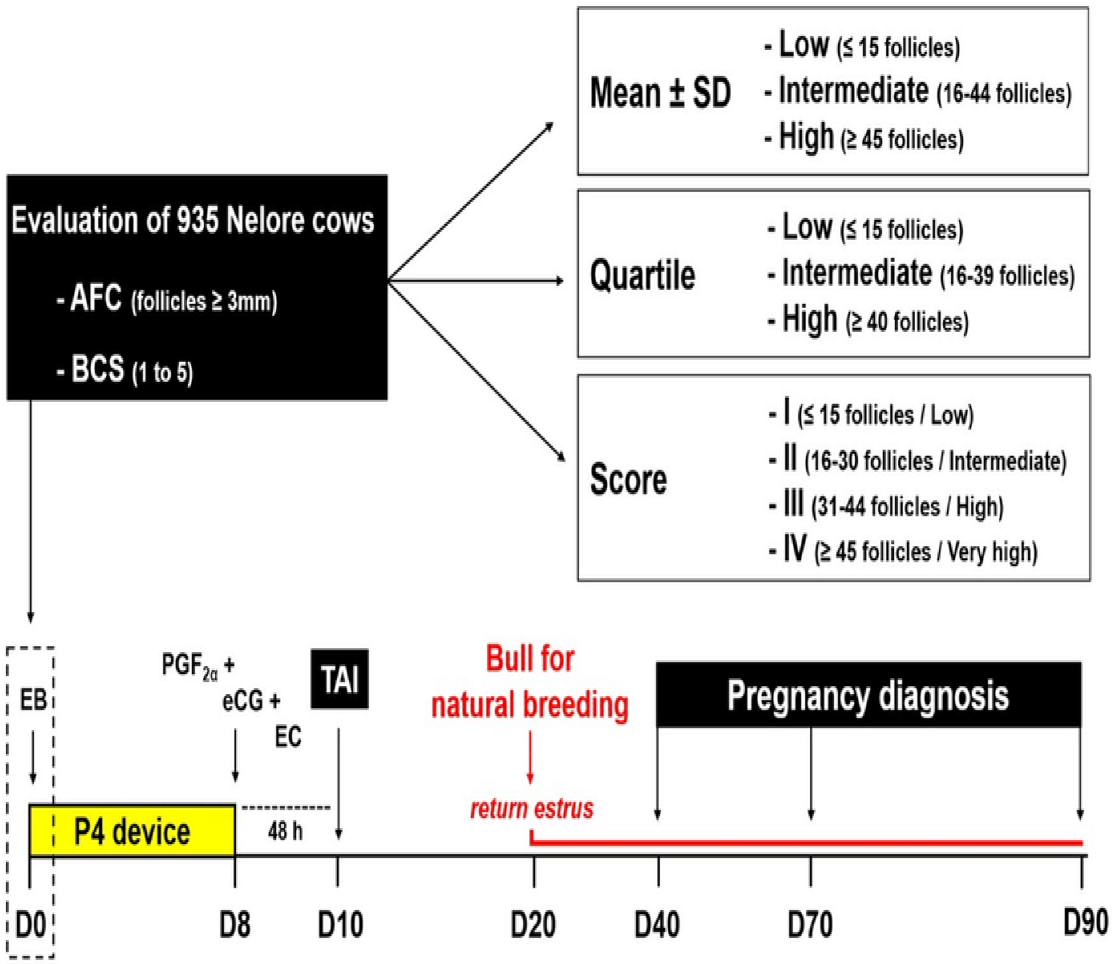
11-3: Factors Influencing Fertility in TAI Protocols

Protocols for TAI can be broadly divided into two the following pharmacological bases: (1) Ovsynch-type protocols using gonadotropin releasing-hormone (GnRH) and (2) protocols that use estradiol (E2) compounds plus treatment with progesterone (E2/P4 protocols). Regardless of the hormonal combinations, the overall physiological objectives are similar. First, the protocol attempts to synchronize emergence of a new follicular wave either by ovulating a dominant follicle after GnRH treatment or by inhibiting gonadotropins after treatment with E2 compounds plus P4 to induce turnover of follicles in the current follicular wave. Second, circulating P4 is maintained at elevated concentrations during development of the new preovulatory follicular wave. Third, efficient regression of the corpus luteum (CL) using prostaglandin F2α (PGF) minimizes P4 and enhances circulating E2 near TAI. Fourth, a follicle with adequate size and age is synchronously ovulated using either GnRH or E2 to correspond with proper scheduling of TAI. Finally, elevated and consistent circulating P4 is maintained from properly functioning CL generated after the final ovulation. Synchronized emergence of a new follicular wave minimizes development of persistent follicles during the protocol. Previous studies have shown that ovulation of follicles that have prolonged periods of follicular dominance can dramatically reduce fertility of lactating dairy cows. Prolonged dominance may reduce fertility by decreasing oocyte quality, possibly by allowing premature meiotic resumption due to high luteinizing hormone (LH) pulse frequency. Although oocytes from these persistent follicles appear to be efficiently fertilized, the embryo stops developing prior to the blastocyst stage. In a study that evaluated ovarian dynamics during an E2/P4 TAI protocol, cows without follicle wave emergence at the beginning of the protocol that subsequently ovulated persistent follicles at the end of the protocol had lower

P/AI compared to cows that had emergence of a new follicular wave (21 vs. 43%). Similarly, in GnRH-based protocols, P/AI was greater in cows that ovulated follicles of intermediary size (15–19 mm, 47%) as compared with those ovulating smaller (<14 mm, 36%) or larger (>20 mm, 38%) follicles. Thus, optimizing the follicle size and oocyte quality near TAI depends on the efficiency of the strategy used to initiate emergence of a new follicular wave at the beginning of the protocol. Secondly, circulating P4 concentrations during preovulatory follicle development have dramatic effects on the subsequent fertility of high-producing lactating dairy cows. Lower circulating P4 during follicular growth, either due to an anovulatory condition or due to the higher catabolism of this hormone in high-producing cows, is associated with greater pulsatility of LH, which can result in premature resumption of oocyte meiosis and germinal vesicle breakdown, decreasing oocyte quality, and consequently fertility. It was reported that cows yielding over 40 kg/d of milk that were superstimulated to produce multiple ovulations during the first follicular wave (low P4 during follicle growth) had a greater percentage of degenerate embryos (23.5%) as compared with cows superovulated during the first follicular wave but with P4 supplementation (7.1%) or those superovulated during the second follicular wave (3.9%). Moreover, the percentage of transferable embryos was much greater after superovulation during the second follicular wave (88.5%) and the first wave with supplementary P4 (78.6%) as compared with superovulation during the first follicular wave (55.9%). An elegant study evaluated the effect of circulating P4 concentration on embryo quality of cows synchronized and with single ovulation, in which the ovulatory follicle developed under a higher or lower circulating P4 milieu. Although fertilization was similar (78% on average), the percentage of grade 1 and 2 embryos (high quality embryos) was greater for cows ovulating follicles that developed under higher P4 (86.5%) than follicles that developed under lower P4 (61.5%). Moreover, cows with higher circulating P4 had fewer degenerate embryos (8.1%) than cows with lower circulating P4 (34.6%).

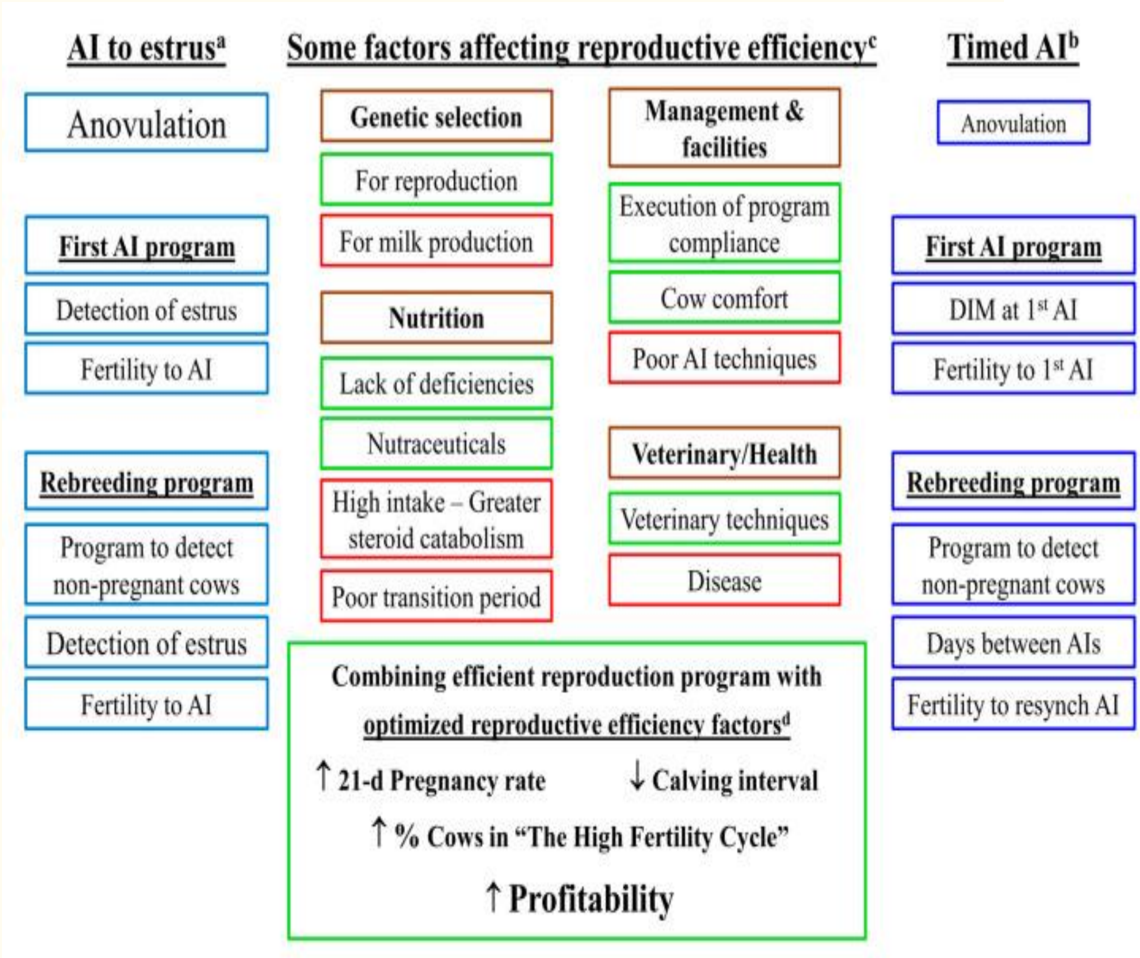
Many studies have reported greater P/AI when cows were submitted to TAI programs in which a CL was present or the P4 milieu during follicle development was high. In a compilation of data from studies of our laboratory using P4-based protocols, that started with estradiol benzoate (EB), GnRH, or both, the presence of CL at the beginning of TAI protocols or at the time of PGF increased P/AI by 15–24%, and the best fertility was achieved when CL was present at both times of the protocol. Another important aspect of circulating P4 concentration during TAI programs is related to double/multiple ovulation and twinning. Double ovulation is more frequent when there is low circulating P4 during the protocol and in cows with higher milk yield. Another factor that influences double ovulation is parity, in which multiple ovulations have been described to be more frequent in multiparous compared to primiparous cows, and this can be explained by the greater milk production in multiparous cows. Double ovulation in dairy cattle is undesirable because it increases the incidence of twin pregnancies, which are associated with calving problems, calf mortality, freemartins, and problems with calf development. Moreover, twinning is associated with greater pregnancy loss after 30 d of pregnancy. Thus, during preovulatory follicle development, increasing circulating P4 optimizes follicle size and oocyte quality and also can decreases development of co-dominant follicles, multiple ovulations, and twins; this effect may decrease pregnancy loss. The third key physiologic outcome to achieve during TAI programs is to efficiently regress the CL, having minimal circulating P4 near TAI. Many studies have reported a relationship between circulating P4 concentrations near TAI and ovulation or fertility with even small concentrations of P4 near TAI producing dramatic decreases in fertility. For example, in a large data set compiled by, there was a 66% relative decrease in P/AI for cows with P4 ≥ 0.4 ng/mL (14%, 161/435) as compared with cows with P4 < 0.4 ng/mL (41%, 1125/2713) at the time of the second GnRH treatment (G2) during the Ovsynch protocol. This outcome is likely to be due to the negative effects of residual P4 on ovulation at the end of a TAI protocol, and on gamete transport, hampering fertilization efficiency. This residual P4 near AI is due to a lack of complete luteolysis after the PGF treatment during the protocols, which may occur in 13 to 44% of cows, and is more problematic when young CL are present at the time of PGF, due to their lower responsiveness to a single treatment with PGF. Therefore, new strategies have been used in TAI programs to overcome the issue of incomplete CL regression at the end of the protocol, and those strategies are discussed later in this manuscript. The fourth key point is related to optimal size and synchronized ovulation of the follicle in relation to TAI. A more optimal size will result in greater E2 concentrations prior to TAI resulting in greater expression of estrus at the end of TAI protocols. In general, cows that express estrus before TAI achieve greater P/AI, in both Ovsynch-type and E2/P4-based protocols. Another positive effect of expression of estrus is a decrease in pregnancy loss, as reported in a study with 5430 cows, in which cows expressing estrus had ~28% lower pregnancy loss than cows not expressing estrus. Cows expressing estrus may also have greater fertility due to greater likelihood of ovulation, although an analysis of only cows that ovulated to an E2/P4 protocol still showed an increase in fertility in cows expressing estrus. Similarly, in cows synchronized with GnRH-based protocols, estrus is related to circulating E2, which is greater for cows ovulating larger follicles at the end of the protocol, and higher circulating E2 before AI is also associated with greater fertility. Adequate circulating E2 prior to AI is associated with a differential expression of genes in the endometrium and conceptus, likely producing conditions that are favorable to pregnancy, and gamete transport. Thus, ovulation of a more optimal size of follicle will result in greater circulating E2 during proestrus and greater expression of estrus. Use of different strategies to induce ovulation can also result in more synchronized ovulation in relation to TAI and this may help fertility. Finally, the absolute requirement for P4 (or the CL hormone) in pregnancy maintenance was demonstrated over 100 years ago.


-2 d
0 d
+8 d
+12 d
+14 d
+15 d
+84 d
PGF2α (2 ml)
Implanted with Sponge/CIDR
Blood sample for progesterone (P4) determination
Physiological parameters taken
Blood sample for P4
Physiological parameters taken
Sponge/CIDR removal
PMS600/HCG (2 ml)
TAI – 47 and 59 h after implant removal
Physiological parameters taken
TAI 71 h after implant removal
Blood sample for P4
Physiological parameters taken +68 d after TAI



11-4: Factors that Alter Reproductive Efficiency in Dairy Cattle

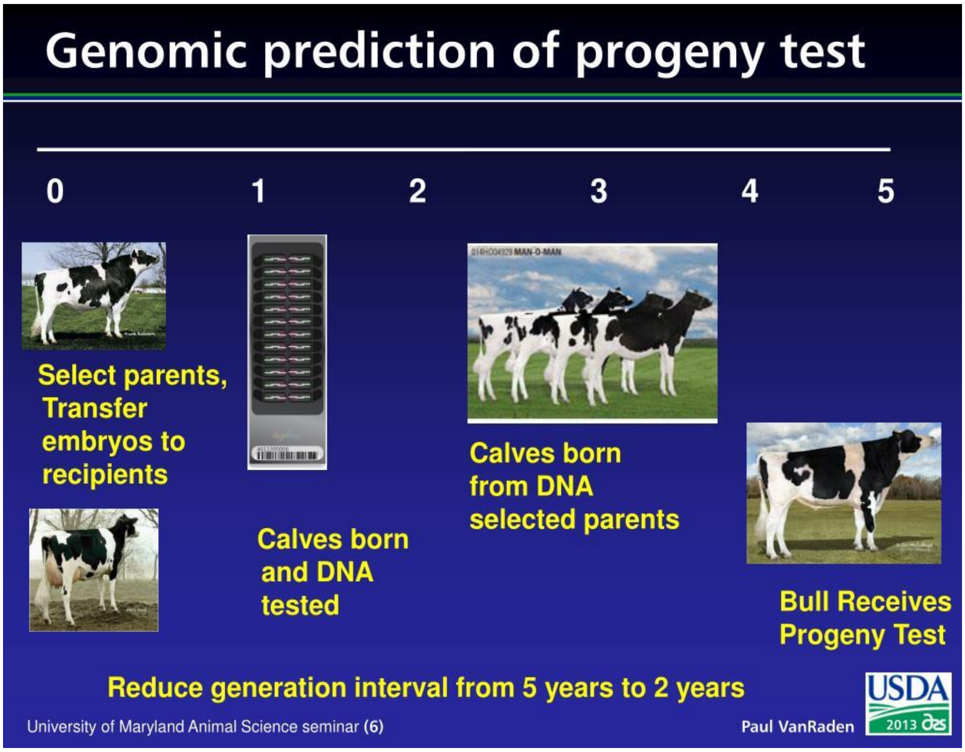
There are multiple factors that determine the success of a reproductive management program. In herds using exclusively TAI programs (right side in purple), anovulation is less of a problem than in herds using exclusively AI to estrus (left side in blue). This is because TAI programs can induce cyclicity leading to AI in all cows, including anovular cows. In herds using TAI, the DIM at first AI can be chosen by the design of the program. In addition, herds using fertility programs such as double-Ovsynch can have high fertility at first TAI. The efficiency of the rebreeding program will depend on the timing of NPD and the design of the Resynch program. In contrast, herds that use AI to estrus are dependent upon cows returning to cyclicity (making anovulation a critical problem) and detection of estrus in these cows with proper timing of AI during all days of the week. Similarly, the rebreeding program is dependent upon detection of estrus. The fertility after AI to estrus may be more controlled by certain factors such as level of milk production than observed in TAI programs that more fully control the follicle size, length of dominance, and hormonal environment.

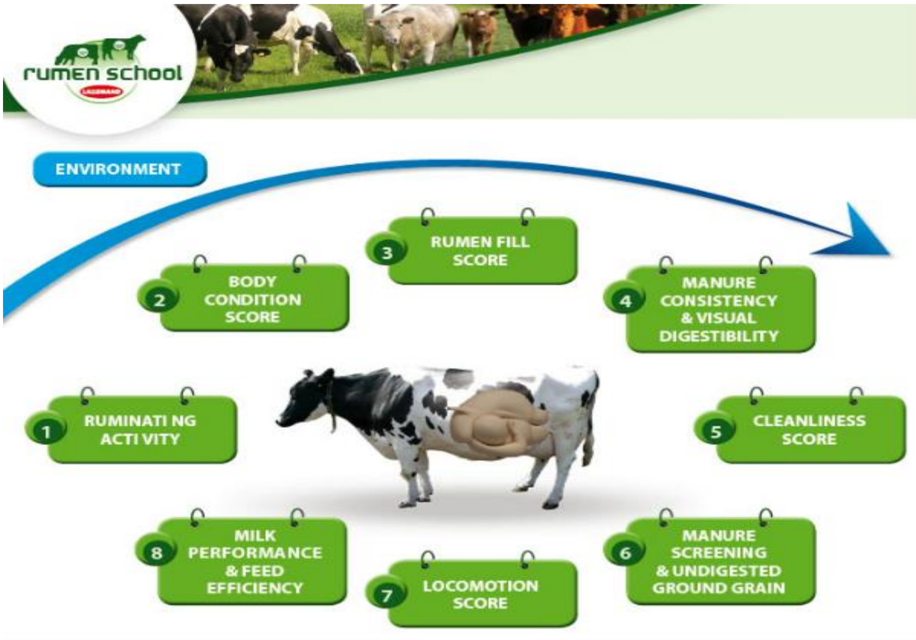


Representation of the key reproductive factors that directly affect a reproductive management program using artificial insemination (AI) to estrus (left column [a]) or timed AI (right column [b]). Some of the key factors that affect reproductive efficiency in either or both types of programs are shown (center column [c]). Factors shown in red squares tend to decrease fertility, whereas factors shown in green rectangles tend to increase fertility. Bottom rectangle [d] Shows that implementation of effective reproductive management programs, combined with optimization of factors that alter reproductive efficiency allows farms to reach the goal of improved reproductive efficiency and profitability on a high-producing dairy farm. Days in milk (DIM). The center section shown four categories (brown rectangles) of factors that can affect reproductive efficiency in herds that use TAI, AI to estrus, or a combination of the two methods in their reproductive management program. Some of these factors are expected to increase reproductive efficiency (shown in green rectangles), while other factors tend to decrease reproductive efficiency (shown in red rectangles).

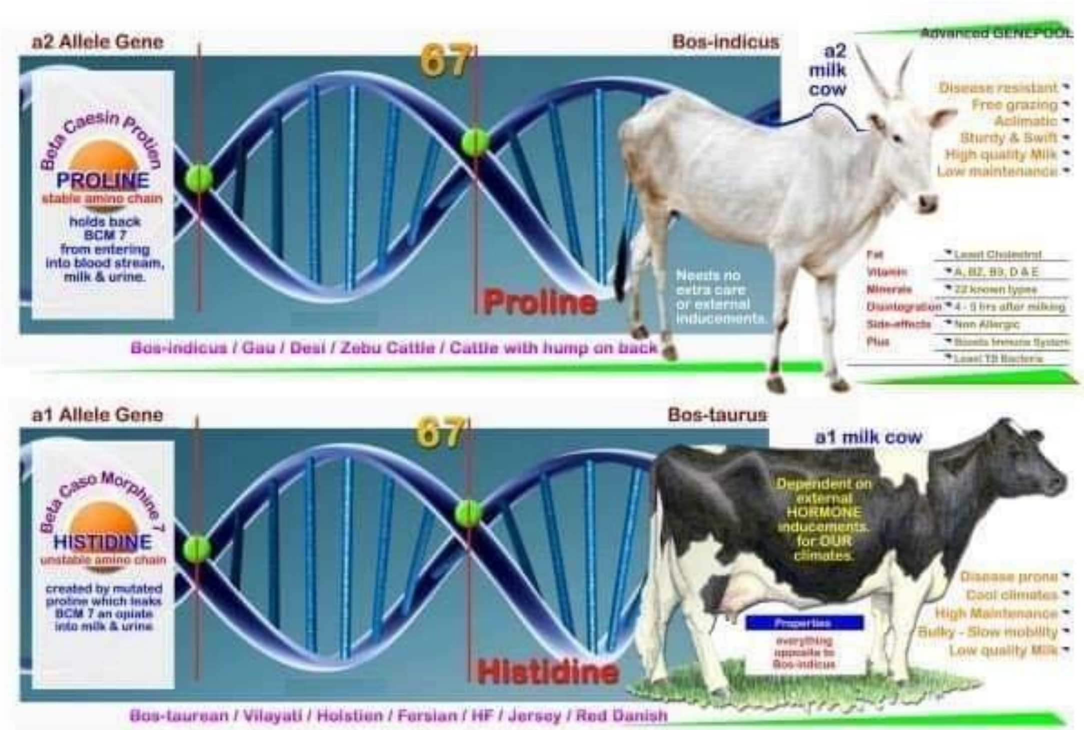
11-5: Genetic Selection for Health and Reproductive Traits

One key change in genetic selection during the last 20 years has been the shift to selection for reproductive and health traits rather than milk production alone. This has been a key factor related to the increase in daughter pregnancy rate (DPR) that has been observed since 2000. The more dramatic increase in phenotypic DPR since 2000 compared to genotypic DPR indicates that management factors, along with selection for high fertility genetics, have played a key role in the improvement in phenotypic DPR, including development of systematic breeding programs using TAI. A recent study reinforced the importance of genetics in reproductive performance by evaluating primiparous and multiparous cows based on their genomic DPR, using quartiles. The herds used the same reproductive management program on all cows but found greatly improved reproductive performance using multiple measures (P/AI at first AI, number of services/pregnancies, percentage of cows pregnant at the end of lactation, and interval between calving and pregnancy) for cows in the top 25% for DPR as compared with the lowest 25%. For example, primiparous cows in the top quartile for DPR became pregnant 30 days earlier (165 vs. 195 d) and multiparous cows became pregnant 36 days earlier (140 vs. 176 d) as compared with cows in the lowest quartile. Another recent study randomized ~2400 primiparous cows by genetic merit for fertility (high, medium, and low) and to reproductive management strategy (TAI vs. primarily AI to estrus). Although fertility was greater for TAI (double-Ovsynch TAI) than for AI to estrus, the cows with the highest genetic merit for fertility had greater P/AI than the cows with lower genetic potential for fertility in either type of reproductive management strategy. Thus, selection of cows with high genetic potential for fertility is a strategy that can and should be utilized by all dairy herds regardless of whether they manage reproduction primarily with TAI or using estrus.





rumen school
ENVIRONMENT
1 RUMINATI NG ACTI VITY
2 BODY CONDITION SCORE
3 RUMEN FILL SCORE
4 MANURE CONSISTENCY & VISUAL DIGESTIBILITY
5 CLEANLINESS SCORE
6 MANURE SCREENING & UNDIGESTED GROUND GRAIN
7 LOCOMOTION SCORE
8 MILK PERFORMANCE & FEED EFFICIENCY



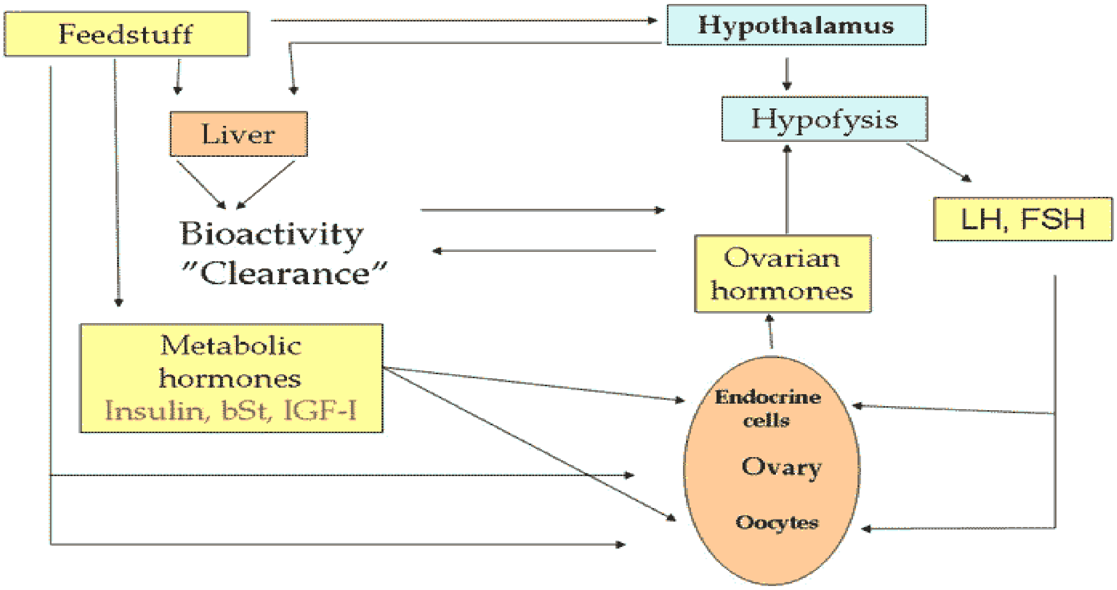
a2 Allele Gene
67
Bos-indicus
Advanced GENEPOOL
a2 milk cow
Beta Caesin Protien
PROLINE
stable amino chain
holds back BCM 7 from entering into blood stream, milk & urine.
Proline
Needs no extra care or external inducements.
Disease resistant
Free grazing
Aclimatic
Sturdy & Swift
High quality Milk
Low maintenance
Fat
Vitamin
Minerals
Disintegration
Side-effects
A, B2, B3, D & E
22 known types
4 - 5 hrs after milking
Non Allergic
Bos-indicus / Gau / Desi / Zebu Cattle / Cattle with hump on back
a1 Allele Gene
67
Bos-taurus
a1 milk cow
Beta Caso Morphine 7
HISTIDINE
unstable amino chain
created by mutated proline which leaks BCM 7 an opiate into milk & urine
Histidine
Dependent on external HORMONE inducements. for OUR climates.
Properties
everything opposite to Bos-indicus
Disease prone
Cool climates
High Maintenance
Bulky - Slow mobility
Low quality Milk
Bos-taurean / Vilayati / Holstien / Fersian / HF / Jersey / Red Danish

11-6: Hormonal Treatment to Improve TAI Protocols

There are two main strategies used to initiate TAI protocols and to promote a new follicular wave emergence. The first one aims to synchronize emergence of a new follicular wave by causing atresia of the follicles present in the ovaries due to negative feedback in follicle stimulating-hormone (FSH) and LH, promoted by a combination of an increase in circulating E2 (from an E2 ester) and P4 (from intravaginal P4 implants, IVP). This is the physiologic basis for initiation of E2/P4-based protocols. The second strategy, which is the basis for Ovsynch-type protocols, stimulates emergence of a new follicular wave by inducing ovulation of a dominant follicle by exogenous GnRH treatment. The most used E2 ester along with P4 implants on Day 0 (d0) of TAI protocols is EB using a dose of 2 mg. However, this strategy did not properly synchronize emergence of a new follicular wave in more than 25% of lactating dairy cows. Another study reported 24.2% of cows ovulating a persistent follicle at the end of a protocol starting with EB, GnRH, and a P4 implant. Therefore, this issue can impair fertility considering that older/persistent follicles may ovulate overstimulated oocytes, and therefore result in poorer embryo development in lactating dairy cows. Studies from our laboratory have focused on strategies to initiate TAI protocols that improve synchronization rates and fertility. In one of those studies, increasing the dose of EB to 3 mg did not improve synchronization of emergence of a new follicle wave as compared with treatment with 2 mg (71.4 vs. 81.6%, respectively). Moreover, initiating the protocol with EB plus P4 implants in the presence of young (3 d after a GnRH treatment) or dominant follicles (7 d after GnRH) produced similar wave emergence efficiency (78.7 vs. 82.3%). The overall synchronization rate (follicular wave emergence at the beginning and ovulation at the end) for these traditional E2/P4-based protocols was 32 to 60% in studies from our lab, and P/AI was much greater for synchronized cows than cows that were not properly synchronized (61.3 vs. 15.7%). Another potential negative factor in P4-based TAI protocols that start with E2 protocols is that treatment with EB at the beginning is associated with a greater incidence of luteolysis between d0 and the time of PGF treatment, decreasing the percentage of cows with CL and the number of CL at PGF, which is related to lower circulating P4 during development of the preovulatory follicle, compromising fertility. About ~40% of the cows that had a CL present on d0 underwent CL regression between d0 and PGF when EB treatment was at the beginning of a TAI protocol. The objective of TAI protocols that begin with GnRH is to induce ovulation, resulting in emergence of a new follicular wave and increasing circulating P4 during preovulatory follicle development. Ovulation to GnRH increased circulating P4 at PGF in multiple studies and increased P/AI. Ovulation to GnRH primarily increases P/AI in cows initiating the protocol without CL or with low circulating P4. Since ovulation after d0 is associated with greater circulating P4 during follicle development and greater P/AI, optimized TAI programs seek to maximize this response. One strategy is to use pre-synchronization strategies. Another approach to increase ovulation after d0 of a FTAI protocol is related to the dose and analogue of GnRH. When increased the dose of gonadorelin acetate from 100 to 200 μg, there was a greater LH peak, and this was particularly important in cows with greater circulating P4, due to an inhibitory effect of P4 on the GnRH-induced LH peak. In fact, in a study using nonlactating Holstein cows, the dose of 100 μg of gonadorelin induced ovulation in only 58.1% of cows with a 7-day-old CL present compared to 95.5% ovulation in cows without a CL. When comparing two analogues of GnRH, studies from our laboratory have shown that 100 μg gonadorelin acetate produced a lower LH peak compared to 10 μg buserelin acetate in Nelore (*Bos indicus*) heifers (5.4 vs. 11.7 ng/mL) and cows (3.4 vs. 6.9 ng/mL) on Day 7 of the estrous cycle. When the dose of these two analogues was doubled, buserelin increased the LH peak in heifers (11.7 vs. 23.2 ng/mL) and cows (6.9 vs. 13.2 ng/mL), whereas the double dose of gonadorelin only increased the LH peak in cows (3.4 vs. 6.3 ng/mL) but not in heifers (5.4 vs. 5.2 ng/mL). Considering the main effects of the study, buserelin induced a greater LH peak and ovulation than gonadorelin. Other studies have reported greater efficiency of buserelin and lecirelin than gonadorelin. Although intravaginal P4 implants may be used to improve fertility during TAI protocols, it should be noted that P4 implants do not increase circulating P4 in lactating dairy cows compared to the concentrations that are achieved in cows with an active CL. For example, in the study by, circulating P4 on d7 and d14 of an estrous cycle in lactating dairy cows was 2.1 and 4.2 ng/mL, respectively. In contrast, in a study from our laboratory, when comparing two commercial P4 devices (1.9 and 2.0 g of P4) in postpartum cows without CL and producing 40.0 kg of milk per day, the peak of circulating P4 was similar between devices (1.6 ng/mL) and the mean P4 during Day 9 of insertion was 0.85 ng/mL (unpublished data). It was reported greater circulating P4 in cows with a CL during the protocol compared to those without CL that were supplemented with two P4 devices (1.38 g), even though P4 supplementation increased circulating P4 to 1.9 ng/mL. Therefore, TAI protocols can be improved by increasing the proportion of cows that initiate the protocol with a CL, either by decreasing anovulatory conditions or by using pre-synchronization programs. Furthermore, a study, with more than 600 cows per group, compared cows initiating the Ovsynch protocol with a CL present on d0 to cows without CL on d0 supplemented or not with two P4 implants with 1.38 g of P4, each. Cows without CL at the beginning of the protocol had the lowest fertility (31.3%), but P/AI on d32 did not differ between cows with CL and those without CL, but supplemented with P4 (38.4 and 42.2%, respectively). In a study with ~160 cows per group, using E2/P4-based TAI protocols and analyzing only cows that ovulated at the end of the TAI protocol, cows treated with two P4 implants tended to have greater P/AI on d60 compared to cows receiving only one implant (48.1 vs. 37.7%). In a meta-analysis, with 25 studies and more than 16,000 cows supplemented or not with one P4 implant, there was a greater risk of pregnancy on d32 and d60 in P4-supplemented cows, but mainly in cows without CL at the beginning of the TAI protocol. Moreover, P4 supplementation tended to reduce pregnancy loss. It is important to mention that in the meta-analysis, cows inseminated in estrus during the TAI program had no benefit from P4 supplementation. Therefore, besides the need for P4 implants in E2/P4-based protocols, Ovsynch-type protocols may also benefit by the addition of P4 implants due to better synchronization of wave emergence, improved oocyte quality, improved luteolysis after single PGF treatments, and reduced double ovulation and twins.

11-7: Nutritional Strategies to Optimize Reproductive Performance

Diets for lactating cows should be balanced to provide the required nutrients for milk production and for the reproductive process. Any deficiencies, whether in required vitamins, minerals, or nutrients, could produce nutritional conditions that might compromise reproduction. Nevertheless, provision of nutritional components in excess of requirements are not likely to lead to increased reproductive efficiency. This was clearly demonstrated by overfeeding of phosphorus (P) in dairy cattle diets during the 1980s and 1990s. On the basis of early studies that suggested cattle maintained on P deficient pastures had decreased calf crop, prolonged periods of anestrus, and poor reproductive performance, many nutritionists recommended feeding P in excess of requirements to improve reproductive performance. However, when researcher we evaluated cows fed two levels of P (0.37%, recommended and 0.57%, excess), we found no differences in any measure of reproduction including return to cyclicity, expression of estrus, length of estrus, P/AI, or time to pregnancy. Thus, although deficiencies of many nutrients may reduce reproductive performance, supplementing nutrients in excess of requirements may be expensive and is unlikely to improve fertility. Nutrition during the dry period can have important implications for subsequent reproductive performance. A retrospective analysis of seven studies that compared higher energy diets and controlled energy diets (higher fiber) found that cows fed higher energy diets during the prepartum period had lower DIM during the postpartum period, greater BCS loss, and increased days open. Thus, higher energy diets during the dry period should not be recommended. In some herds, vitamin E may be limiting during the dry period. In a study from our lab, dry dairy cows were receiving supplementation with less than the dietary recommendation for vitamin E and were randomized to either receive no treatment or to be treated weekly with three injections of 1000 IU each of DL-α-tocopherol administered during the last 3 prepartum weeks. Vitamin E supplementation reduced the incidence of retained placenta (13.5 vs. 20.1%) and stillbirth (6.8 vs. 14.9%). Additionally, after first postpartum AI, for cows receiving vitamin E, pregnancy loss was reduced (12.5 vs. 20.5%) and considering all inseminations up to 200 DIM, Ps/AIs on Day 30 (38.4 vs. 34.5%) and Day 60 (32.8 vs. 26.9%) were greater ($p < 0.05$) and the pregnancy loss was lower (14.5 vs. 21.5%) as compared with cows who did not receive vitamin E. In addition, cows treated with the prepartum vitamin E injections had reduced days open (126 vs. 137 d). Thus, delivery of nutrients during the dry period, including vitamin E, need to meet requirements or there can be fairly severe consequences near calving with increased stillbirth and retained placenta, and subsequent reduction in reproductive performance. In this study, cows supplemented with vitamin E did not have increased milk production suggesting that the requirement for vitamin E, and possibly other nutrients, may differ for reproductive traits compared to production traits. Hypocalcemia is another condition that is tied to the nutritional program during the transition period and can have important consequences for subsequent reproductive performance. In U.S. dairy herds, clinical hypocalcemia (<1.4 mM total calcium concentration) occurs in 5–10% of dairy cows, with subclinical hypocalcemia (1.4–2.0 mM total calcium concentration) occurring in an additional 50% of dairy cows. Hypocalcemia in dairy cows is considered to be a gateway to disorders of the immune system and metabolism, leading to health and metabolic issues in periparturient dairy cows. The focus of recent research has been on the association of hypo/calcemia with neutrophil function and development of metritis. Recent studies have reported that cows developing clinical or subclinical hypocalcemia had decreased dry matter intake, greater negative energy balance, impaired immune function, increased risk of health problems, increased risk of metritis, decreased neutrophil number and activity, and decreased fertility and reproductive performance. Another nutritional strategy that has been evaluated for improving health, production, and reproduction is the inclusion of choline and methionine in the diets of lactating dairy cows. It is reported that increasing rumen-protected choline (RPC) in the prepartum diet increased pre- and postpartum DIM and milk production. Moreover, RPC in the prepartum diet has been reported to decrease inflammation pre and postpartum and improved immune function, as evidenced by a greater proportion of neutrophils undergoing phagocytosis and oxidative burst in the postpartum period. Feeding RPC to cows during pre and postpartum periods reduced the incidence of clinical ketosis, mastitis, and morbidity; however, in primiparous, RPC in the prepartum increased cases of fever and metritis. Another nutrient that has been evaluated for effects on reproduction is feeding rumen-protected methionine (RPM). There is a consistent increase in milk protein percentage and protein yield by feeding RPM. In addition, methionine concentrations appear to be associated with optimal early embryonic development, and modulation of gene expression in early bovine embryos. In addition, feeding polyunsaturated fatty acids (PUFA) has been found to increase fertility in some experiments. For example, a study with more than 700 dairy cows fed marine algae that was rich in PUFA, i.e., docosahexaenoic acid, daily from 27 to 147 DIM, reported increased P/AI in both primiparous and multiparous cows (41.6 vs. 30.7%) and a reduction in days to pregnancy by 22 d (102 vs. 124 d). Thus, RPC, RPM, and PUFAs may be considered to be "nutraceuticals" that can improve reproductive performance when included in diets of lactating dairy cows.



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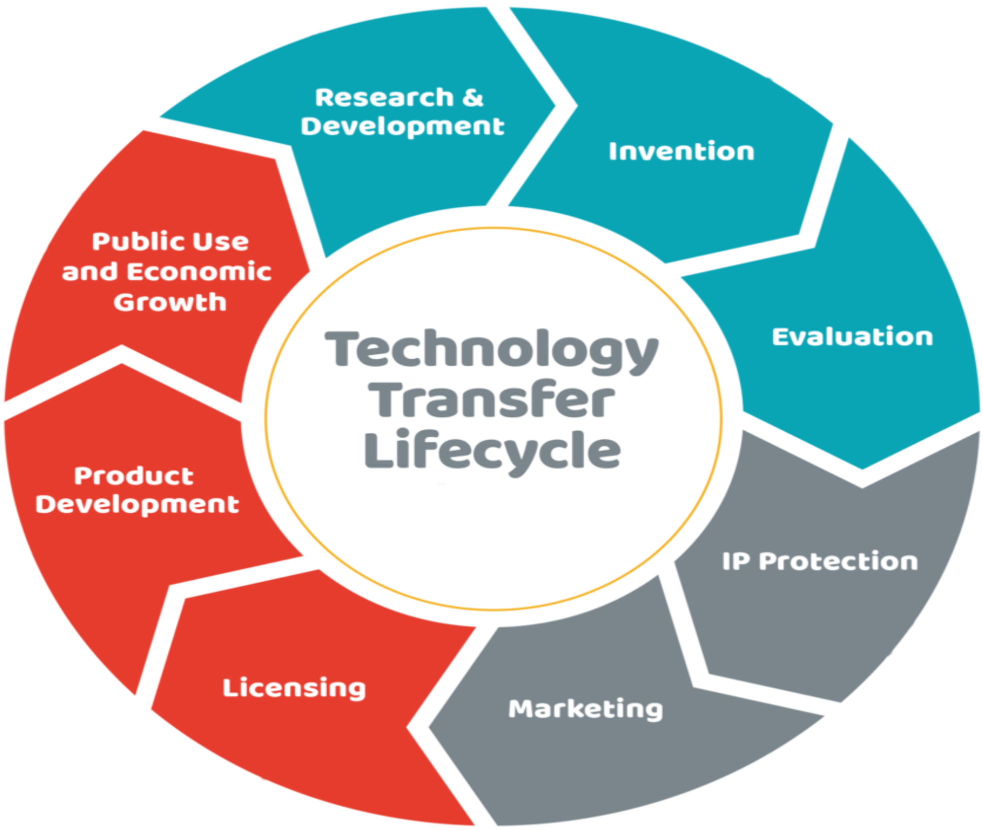
Chapter 12

Exploration of Extension Research to Promote Improvement of Cattle Production

Exploration of Extension Research to Promote Improvement of Cattle Production

12-1: Livestock Technology Transfer

The major challenge for policy makers to increase productivity in the livestock sector is to improve the adoption rate of innovative related livestock technologies for farmers. The current system of technology transfer presents important deficiencies related to the lack of means in the extension institutions. The lack of coordination between the various actors of the technology transfer system, particularly the profession and research, and the lack of a targeted transfer strategy that takes into account the specificity of regions and the sociodemographic and economic characteristics of farmers. The technology transfer model suggests a transfer of critical information from research and development, through extension personnel, to the person on the ground who utilizes such information (the farmers). However, not all farmers are able and willing to adopt new technologies because of the challenges to adoption imposed by various socioeconomic, institutional, and environmental factors. This chapter will contribute to the body of literature highlighting the effectiveness of different methods of information transfer to farmers, such as radio programs and information dissemination from neighboring farmers, SMS messages, field days, and technical, economic, and organizational training. Precision livestock farming (PLF) technologies are becoming increasingly common in modern agriculture. They are frequently integrated with other new technologies in order to improve human–livestock interactions, productivity and economical sustainability of modern farms. Moreover, the goal of technology transfer is to bring university outcomes into the market. The relationships among universities, industries, and the government are essential. These three partners must work effectively to establish a successful process. This relationship must be contextualized because of the significant changes in productive and organizational systems. In developing countries, livestock production intelligence is often prioritized by centralized extension services. National agricultural extension services are primarily designed to spread knowledge on crop production, whereas livestock institutions and sectors are driven by veterinarians who are concerned about animal health. In many developing nations, however, the possibility of raising livestock production through the supply of knowledge is growing. Livestock production is a major part of many country's economy and is essential for guaranteeing food and nutritional security. For centuries, livestock has been known to supply man's animal nutritional needs, as well as give numerous additional benefits to farmers and the national economy. Population in many developing countries is rapidly increasing quicker than the increase of animal protein. Interactions between livestock and the surroundings in developing countries can be both positive and negative. On the one hand, herbivore composted manure can be a valuable resource. In more industrial operations, and where there are huge densities of animals, it is a nutrient for micro crops, but in more industrial systems, or where there are large concentrations of animals, it is a dietary staple for large-scale crops. They have the potential to contaminate waterways. On the other hand, ruminant systems in developing countries can be considered relatively inefficient use of resources. Because most of these production systems have large yield variability, boosting the effectiveness of the process is critical. Through appropriate development strategies, the cattle industry presents a tremendous opportunity for research and innovation can contribute to the development of more long-term solutions Future progress in this field must be based on existing institutions while also aiming to respond flexibly and fairly to the needs of livestock farmers. The demand for livestock production information is increasing, both in terms of producer demands and in terms of the overall development potential for enhancing productivity through the transmission of information. Three interconnected causes are at work: intensification and crop-livestock integration, growing commercialization of livestock production, and the gradual elimination of animal disease as a productivity restriction. The significance of this chapter is that it provides a balanced picture of livestock production's functions. This type of data is required to examine the major concerns in the frequently ill-informed or generalized discussion of livestock's current and future functions. There are many techniques and tools to improve livestock production, and despite efforts to promote their use through agricultural extension, there is still a gap between the creation of these tools and their actual use by livestock owners. Therefore, more research work is needed to understand how to successfully promote the use of these tools in cattle herds. Improvement of genetic as well as non-genetic factors are the key tools in the economic sustainability of cattle production. Genetic improvement tools are used to support the selection of animals with the desired characteristics and facilitate the subsequent transmission to their offspring. Genetic evaluations that incorporate estimated genomic values (GEBV) as a selection tool for traits such as fertility and growth allow selection earlier in the life of the animal when compared with genetic evaluations that use estimating breeding value (EBV) alone. Additionally, these selection tools are more effective than exclusive selection for phenotypic traits in the adult stage of the animal. Therefore, the adoption of genetic tools in cattle has an impact on the direction and speed of genetic progress. The adoption of technology in cattle farming is a broad concept that includes its development, dissemination and use by the end-user (farmers). The adoption of technology is presented as a dynamic process, that demands a holistic vision that pursues the general objective of increasing productivity, efficiency and profitability. The theoretical models and frameworks provide researchers with an ordered way to view and analyze the process of adoption and the factors that drive them. There are a variety of models that consider, for example, acceptance of use, sustained use, intensity of use, economic risk or information management. User acceptance is the first stage in the process of adoption, which is defined by the intention to use a technology. The genetic gain achieved in cattle production systems depends on the intentions first and consequent decisions that farmers make when selecting sires and heifers as replacements. The complexity of decision making in cattle breeding is also influenced by the intrinsic factors of the farmer (e.g., behavior, expectances, preferences) and by external factors such as the quantity, diversity and format in which the genetic information of the animals is provided. To address this complexity, genetic selection tools are promoted that support farmers to make decisions to improve economically important traits. Nevertheless, agricultural as well as livestock extension are defined as public and private sector activities that encourage human resource development, education, attitude change, technology transfer and information gathering and dissemination. Extension activities that aim to encourage the use of technological tools are based on farmers being aware of the importance of the traits to choose in the genetic selection of animals. Consideration of the productive and economic conditions, as well as the social behavior of farmers, is essential for extension services to play an important role in disseminating information and promoting technology use on farms. The effectiveness of agricultural and animal extension activities through the development of trust, in which farmers participate as the main source of innovation, is a strategic approach to improving adoption outcomes, including of genetic tools. Despite the technological advances in genetic selection and the encouragement to adopt through extension services, there is still a gap between the development of new strategies and tools for genetic improvement and their use by cattle farmers. In recent years, there has been increasing interest in understanding the barriers and motivations in the process of adopting new technologies amongst farmers. Educational reforms are also proposed to address the new digital skills and use of technological tools that are required in the workforce. However, some livestock industries, such as the beef sector, when compared with the dairy sector, require more support to adopt technologies such as genetic tools. Incorporating a theoretical framework in extension research allows us to understand the cognitive factors (expectations, efforts and social influences) that affect the adoption process, allowing these to be incorporated into an extension program. The research questions that should addressed are: (1) What are the most used research and extension methodologies to determine the factors that contribute to the adoption by farmers of practices and tools to promote genetic improvement in cattle? (2) What are the factors with the most effect on the adoption of genetic tools? (3) What is the practical impact of the extension activities?



12-2: The Role of Extension Services in Enhancing Livestock Productivity

Livestock farming plays a pivotal role in the agricultural sector of many countries, contributing significantly to their economies. It is not just a source of food but also provides raw materials for industries, employment, and income for millions of people worldwide. However, the productivity of livestock farming often falls below its potential due to various challenges, including diseases, inadequate feeding, and lack of knowledge on modern farming techniques. This is where agricultural extension services come into play, acting as a bridge between research and farming practices to enhance livestock productivity. This article delves into the role of extension services in livestock farming, the challenges faced, and the strategies for improvement. Agricultural extension services are educational and support activities designed to boost the efficiency, productivity, and profitability of farming. These services provide farmers with the necessary knowledge, skills, and technologies to improve their agricultural practices. In the context of livestock farming, extension services play a crucial role in disseminating information on better animal husbandry practices, disease control, feeding, and breeding techniques. The ultimate goal is to enhance the productivity and sustainability of livestock farming, ensuring food security and improving the livelihoods of farmers. Extension services are delivered through various means, including:

- Field demonstrations and farm visits
- Training workshops and seminars
- Use of information and communication technologies (ICTs)

These methods ensure that farmers receive practical and applicable knowledge, tailored to their specific needs and environmental conditions. By fostering a closer relationship between farmers and extension agents, these services facilitate the exchange of information and encourage the adoption of innovative practices. Despite the critical role of extension services in enhancing livestock productivity, several challenges hinder their effectiveness. These include:

- Limited resources: Many extension programs suffer from inadequate funding, which affects their ability to reach out to farmers, especially in remote areas. Limited resources also mean that extension agents are often overburdened, managing more farmers than they can effectively handle.
- Access to information: In some regions, farmers have limited access to extension services due to geographical

isolation or lack of infrastructure. This makes it difficult for them to benefit from the latest knowledge and technologies in livestock farming.

- Knowledge gaps: Extension agents sometimes lack the specialized knowledge required to address the specific challenges of livestock farming. This can lead to the dissemination of outdated or inappropriate information, hindering the adoption of best practices.
- Socio-economic factors: Farmers' willingness and ability to adopt new practices are often influenced by socio-economic factors such as culture, education, and financial resources. These factors can pose significant barriers to the effectiveness of extension services.

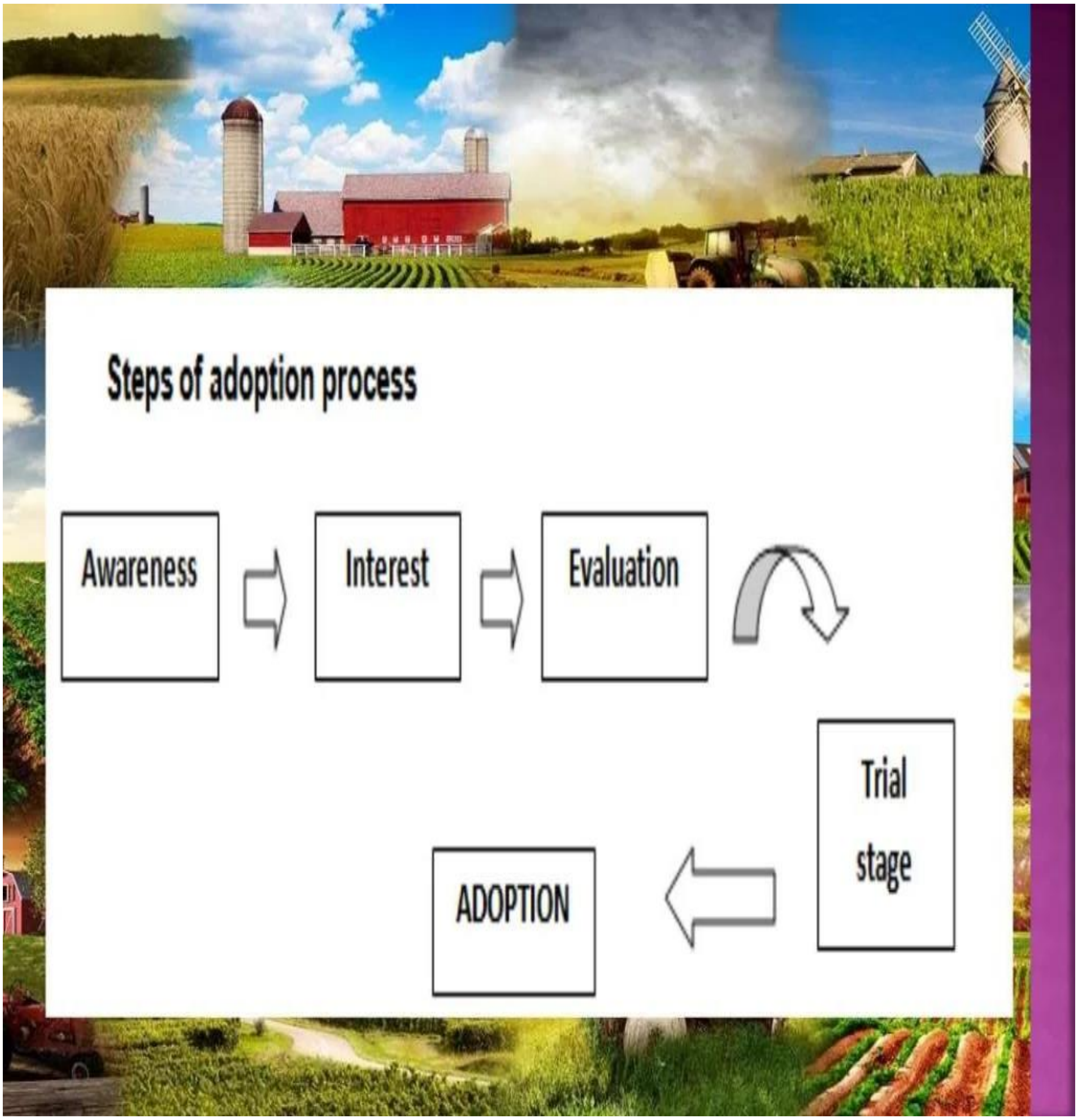
Addressing these challenges requires a multi-faceted approach that involves improving the capacity of extension services, leveraging technology, and fostering partnerships between farmers, governments, and the private sector.

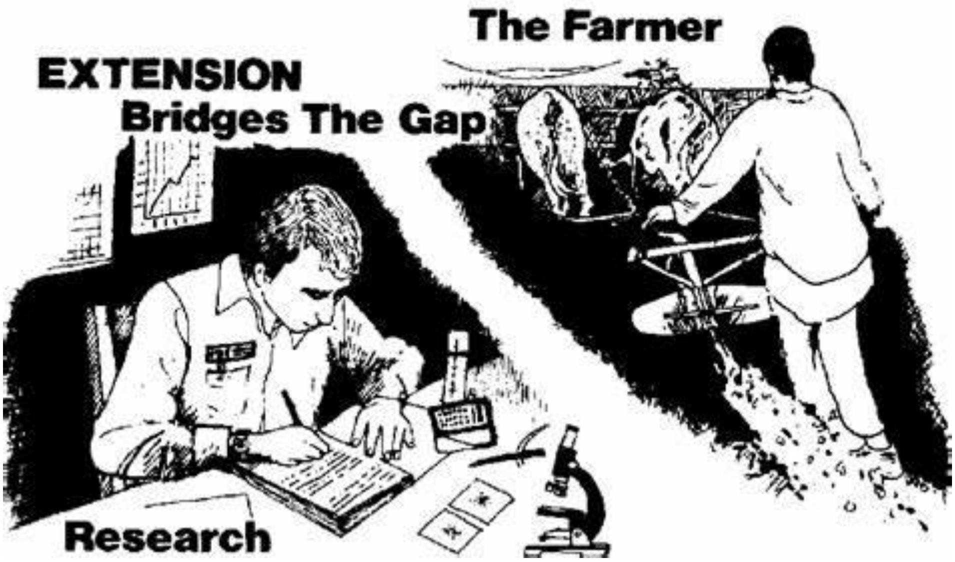
6

What Extension Does?

- ✓**Identify and overcome problems**; farm, production & marketing problems through the exchange of information among farmers, extension staffs, input suppliers, credit agencies and marketing agents.
- ✓**Make better use of existing technology**; through efficient use of feed, fertilizer, irrigation, etc.
- ✓**Introduce new technology**; such as new breeds, new varieties, new crops, new equipment.
- ✓**Address farmers' production constraints to research institutions**; so that appropriate basic, applied or adaptive research can be carried out to address them.
- ✓**Create opportunities to learn and upgrade farmers' skills**; therefore they meet their needs and interest in such a way that leads to self-satisfaction and improve living standards.

9/18/2020 Presented by Md Mahbubul Alam, PhD


Steps of adoption process
Awareness
Interest
Evaluation
Trial stage
ADOPTION


The Farmer
EXTENSION
Bridges The Gap
Research


Elements for an Effective
Agricultural Extension Service
Extension Agent
Good communication skills
Good technical knowledge
Teaching method
Demonstration
Methods
Results
Type
Supporting Funds
Infrastructure

12-3: Strategies for Enhancing Livestock Productivity through Extension Services

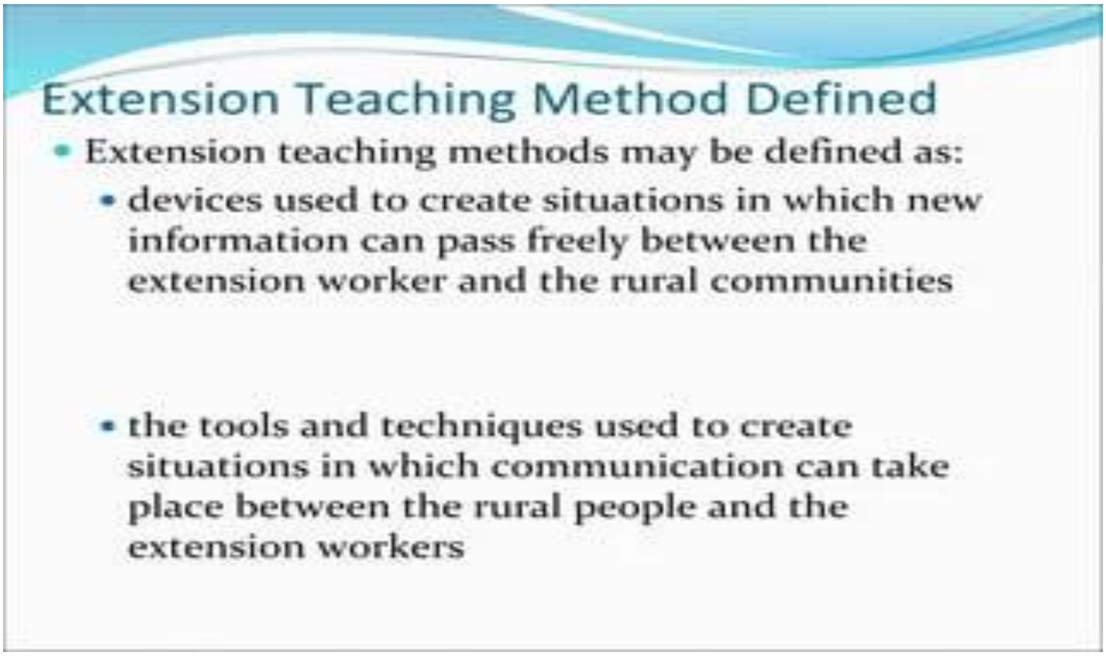
To overcome the challenges and maximize the impact of extension services on livestock productivity, several strategies can be employed:

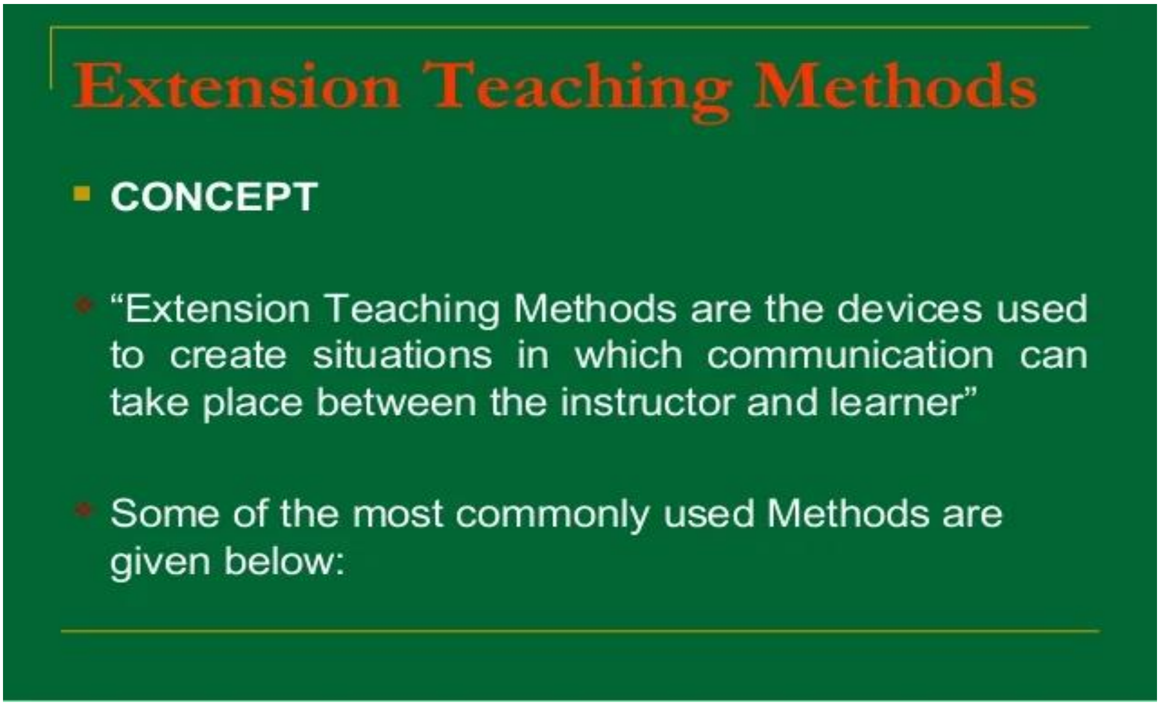
- Strengthening capacity: Investing in the training and development of extension agents to ensure they possess up-to-date knowledge and skills in livestock farming. This includes specialized training in areas such as animal health, nutrition, and breeding.
- Leveraging technology: Utilizing ICTs to extend the reach of extension services. Mobile phones, radio broadcasts, and online platforms can be used to disseminate information and provide support to farmers in remote areas.
- Participatory approaches: Engaging farmers in the development and implementation of extension programs to ensure that their needs and challenges are adequately addressed. This can include farmer field schools and community-based extension models.
- Public-private partnerships: Collaborating with the private sector, NGOs, and research institutions to pool resources and expertise. Such partnerships can enhance the delivery of extension services and facilitate access to improved technologies and inputs.

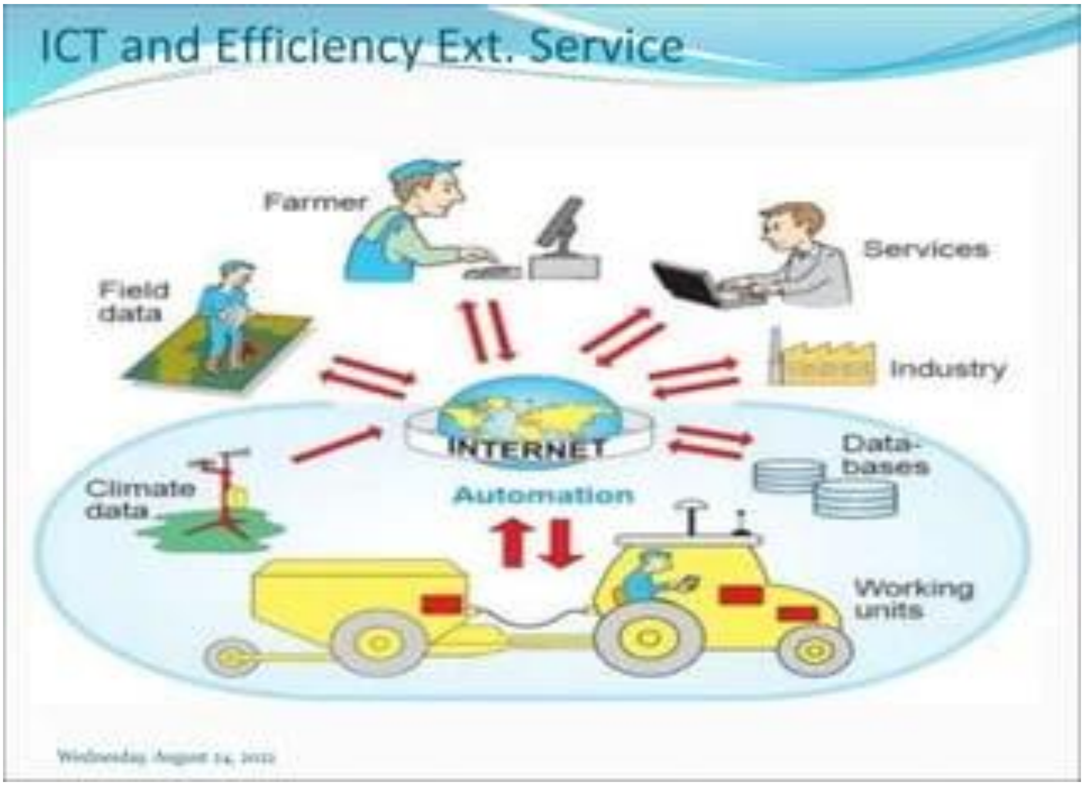
By implementing these strategies, extension services can significantly contribute to enhancing livestock productivity, thereby improving food security, farmers' incomes, and the overall sustainability of the agricultural sector. Furthermore, extension activities seem to be more efficient when they also incorporate other production issues that challenge farmers. It was suggested experimenting with different types of training for farmers with an integrated approach that goes beyond genetic improvement and considers aspects related to animal feeding. Recently, a study was carried out to explore on a global scale the methodology and results of extension research that seeks to promote genetic improvement in cattle. The studies used quantitative and qualitative methods with mixed methods predominating in the research's design. Although social aspects were considered drivers in the adoption processes, the use of theories or frameworks from a social sciences perspective was incipient. The collection of information through surveys and interviews was widely used and accepted. The adoption of practices and technologies related to genetic improvement and preferences regarding traits to be selected in improvement programs vary according to the type of farmer and the production systems. Therefore, knowing the factors that encourage the adoption of technologies or processes is key in designing extension programs that seek to encourage genetic improvement through the application of traditional and new technologies. The participation of stakeholders and the cooperation of farmers in the design of extension services is crucial to know the topics in demand and the preferred strategies to encourage the use of genetic tools in cattle production systems. The data available from the articles selected for this review come from productively and culturally diverse circumstances, which limits generalized conclusions about strategies to motivate the use of genetic tools by beef farmers. Consequently, to carry out successful extension activities that seek to encourage the use of genetic tools in livestock farming for a specific productive region, it is imperative to conduct additional research with a participatory approach incorporating the viewpoints of commercial farmers and stakeholders.

12-4: Extension Methods and Institutions

Despite its growing importance, livestock production extension is a field neglected both by policy-makers and by researchers. The importance of livestock to household welfare, fertility maintenance and production is still under-recognized in many developing countries. But livestock production extension faces the additional institutional problem of being marginal to both agricultural extension and animal health services. Agricultural extension services have developed around crop production, and remain tied largely to the seasonal nature of cropping. Such a system is less useful for livestock production, with a longer time-scale and a lack of synchronization of different animals and herds. Livestock services and the ministries or departments that are responsible for them, are mainly run by vets, and focus on animal health issues: curative treatment of individual animals, preventive health, and health screening of animal products. While many special projects, area-based or sub-sectoral, concentrate on livestock production issues and are run by animal experts, few countries can afford a separate livestock production extension service. Livestock production has often held a marginal status in official circles, between two well-defined sectors with associated interest groups, sometimes neglected by both, sometimes shuffled between them Besides national or regional governments, extension services can be run by NGOs, by cooperatives, by universities or research institutes and by the commercial sector. For example in India, some extension is provided through the system of dairy cooperatives, which reaches from village-level primary societies to a national federation, and has 8 million members. Primary societies are successfully delivering information both on business management and on technical aspects of dairy production such as use of green fodder and concentrates. Individual or group focus Group approaches are preferable where joint action is needed, or where free-rider problems need to be resolved in cost-recovery programs. On the other hand, needs for information will be increasingly individual, as livestock production intensifies and becomes more complex. Information vs. information-with-inputs Extension can either provide pure information or information linked to material inputs. The latter can appeal to the commercial sector involved in input sales or marketed offtake. It has also been used in more remote areas by NGOs to give users a stake in the information system and to promote farmer-to-farmer spread. Some NGO projects link extension to the provision, often on highly subsidized terms, of the animals themselves, sometimes for new sorts of livestock activity, such as sheep fattening by women. Cost-recovery in "pure" extension is difficult because it is difficult to exclude non-payers from receiving agricultural information. There are also equity considerations against charging poor mixed farmers for extension, and environmental considerations where animal production messages are also conservation messages (as with improved conservation and use of manure). Cost recovery can occur where the organization transmitting information benefits from the sale of an input, or where it can levy a charge on marketed output. Specific management plans, e.g. for wealthier peri- urban and intensive livestock producers, are another opportunity for cost-recovery. Participation 'Participatory' or 'farmer-led" extension have received much attention recently. While the need for farmer participation is real, and discussed further below, the strengths of formal systems should not be overlooked: access to a pool of research expertise, systematic procedures for turning research findings into extension messages, and the fact that the organization persists as messages come and go. By contrast, some advisory services, often run by NGOs, are based on predispositions with poor technical grounding. Livestock production is both a highly specialized sub-sector with a strong claim to separate structures, and sufficiently integrated with other forms of agricultural production to warrant inclusion in extension services. One part of the solution lies in decentralization of all extension, and the integration of crop and livestock information delivery under local structures in response to local needs and conditions. Most models for the integration of livestock into national extension systems will require cross-training of crop-specialist staff in livestock production and vice versa. The Kenyan Second National Extension Project has included two weeks of such training for front-line staff, but its availability has been patchy, and the course has been found too short and too classroom-based. Low-cost participatory needs assessment methods are now well established and can assist in the understanding of priority needs. By contrast with crops, livestock extension has to cater for wide inter-household differences in husbandry systems and relative resource endowments, even within small areas. In the African context of resource constraints governing crop-livestock integration, the point at which it becomes worthwhile to invest labor in fodder cultivation, construction of haybarns, and manure pits will arrive at very different times for different households, even within one locality. Similarly, the new opportunities for commercialized livestock production will be taken up unevenly by households. There are thus three linked but distinguishable imperatives for livestock production extension: participatory needs assessment, responsiveness to inter-household variation, and ability to address information needs as they arise, not as determined by a calendar. In meeting these needs, livestock production extension must learn from 'farmer-led extension' initiatives (see Scarborough, 1996), but public sector reform is likely to be essential. Reforms to national systems can be incremental participatory needs assessment methodologies can be introduced, extension calendars compiled at lower levels, and treated more flexibly, and extension workers empowered to present options rather than set messages.


Extension Teaching Method Defined
Extension teaching methods may be defined as:
devices used to create situations in which new information can pass freely between the extension worker and the rural communities
the tools and techniques used to create situations in which communication can take place between the rural people and the extension workers


Extension Teaching Methods
CONCEPT
"Extension Teaching Methods are the devices used to create situations in which communication can take place between the instructor and learner"
Some of the most commonly used Methods are given below:


ICT and Efficiency Ext. Service
Farmer
Services
Field data
Industry
INTERNET
Data-bases
Climate data
Automation
Working units

Classification of Extension Teaching Methods:

1.			**According to use**
	a.		Individual contacts
		i)	Farm and home visits;
		ii)	Office calls
		iii)	Telephone calls;
		iv)	Personal letters
		v)	Result demonstration

Objectives of Extension Teaching Methods

- The Extension Teaching Methods are useful for:
- 1. Approaching village people.
- 2. Working with village people.
- 3. Encouraging village people.
- 4. Influencing village people.
- 5. Attracting their attention towards improved practices.
- 6. Arousing and developing their interest.
- 7. Convincing the people to adopt improved practices.

In conclusion, agricultural extension services are vital for the advancement of livestock farming. They bridge the gap between research and practice, providing farmers with the knowledge and tools needed to improve productivity and sustainability. Despite facing challenges, with targeted strategies and collaborative efforts, extension services can transform the livestock sector, ensuring its contribution to economic development and food security remains robust.

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Chapter 13

Era of Epigenetics and Genomics in Livestock Breeding

Era of Epigenetics and Genomics in Livestock Breeding

13-1: A Brief Introduction to Epigenetics

Epigenetics is the study of heritable changes in gene function that do not change the DNA sequence but provide an “extra” layer of transcriptional control that regulates how genes are expressed. Epigenetics refers to the control of gene expression via mechanisms not directly related to the DNA coding sequence. As a result, all cells in an organism have very different phenotypes despite having the same genome. Epigenetics modulates and regulates gene expression through various epigenomic “marks”, the term given to chemical compounds added to DNA or histone proteins and recognized by enzymes that either lay down or remove the specific mark. These marks change the spatial conformation of chromatin: either compacting it, thereby preventing the binding of transcription factors to the DNA, or opening it, allowing transcription factor binding and usually upregulating cellular processes. For a long time, scientists have tried to describe disorders just by genetic or environmental factors. In the past few decades, many investigations have shown that the epigenetic mechanisms are involved in regulation of all biological process in the body from conception to death. These functional mechanisms are involved in genome reorganization, early embryogenesis and gametogenesis, as well as cell differentiation. The interplay of DNA methylation and histone post-translational alterations, which cause as the result of regulatory proteins and non-coding RNAs, are key epigenetic players to rearrange chromatin into areas such as euchromatin, heterochromatin, and nuclear compartmentalization. However, the role of epigenetics in human diseases has been considered from a half of century ago. Epigenetic changes are responsible for human diseases, including Fragile X syndrome, Angelman’s syndrome, Prader-Willi syndrome, and various cancers. Epigenetic signs may have long-term impressions, for instance, in learning and organizing memory or predispositions to different cancers.

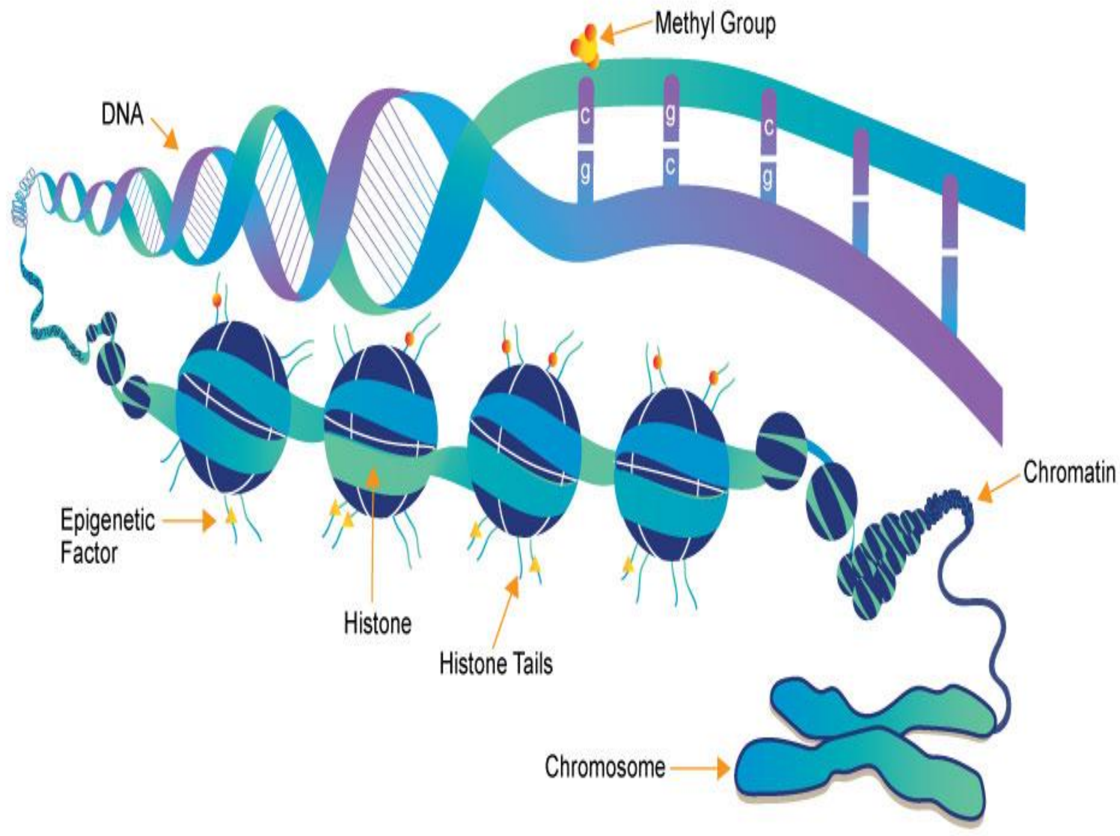
Incorrect epigenetic marks can result in birth defects, childhood diseases, or symptoms of diseases in other interims of life. Epigenetic mechanisms also regulate development and adaptations during the life of an organism, and their alterations may result in various disorders such as cancer. On the other hand, some epigenetic marks can be reversible, and this fact has encouraged many researchers to focus on epigenetic therapy. In recent years, it has been demonstrated that DNA methylation, in some cases, can be irreversible. This trait could be useful in complex features and challenging diseases such as memory function, psychological behaviors and injuries, addiction, cancer, and other diseases that could not be explained just by genetic factors or the environment. In a multicellular organism, the epigenetic changes enable different adult cells to express specific genes that are required for the existence of each cell type and transfer of information to the daughter cells. Epigenetic modifications often happen during an organism's lifetime; however, these changes can be transferred to the next generation if they occur in germ cells. Three major epigenetic modification mechanisms are:

A) DNA methylation. DNA methylation is mediated by DNA methyltransferase enzymes at CpG sites. It can also decrease gene expression by reducing the binding of transcription factors or increasing the binding of methyl-CpG binding proteins.

B) Histone modification. Histone acetylation, particularly in lysine residues of histone tails, is an important histone modification that can accelerate binding transcription factors and then gene expression beside DNA demethylation.

C) miRNA. The formation of miRNA begins in nucleus and continues in cytosol that can perform a mechanism to regulate gene expression in mRNA level. Epigenetic modifications are a dynamic process reflecting a complex interplay between an organism and its environment. For example, the acetylation of lysine residues in histone subunits usually can result in promoting gene transcription, or the methylation of Lys9 or Lys27 of histone

H3 is correlated with gene repression. However, the methylation of Lys4, Lys36, or Lys79 of H3 is ordinarily associated with gene activity. Epigenome generally comprises all epigenetic modifications such as DNA methylation and histone modifications, as well as non-coding RNAs at any given point in time. The cell epigenome is dynamic and can be affected by genetic and environmental factors. Furthermore, epigenetic modifications can be reversible, which makes the genome flexible to respond to environment changes such as nutrition, stress, toxicity, exercise, and drugs. One of the nutritional components in food, which plays a major role in methylation, is folate. Folate can influence methionine production by homocysteine remethylation in the form of 5-methyltetrahydrofolate. It has been reported that folate defect or shortage can enhance colorectal carcinogenesis through hypomethylation of genomic DNA. Stress is an important environmental factor. Recently, some studies have demonstrated that people with post-traumatic stress disorder, who were abused during childhood, exhibit different levels of DNA methylation and gene expressions in comparison to those who were not abused. Methylation is a common and widely used mechanism for epigenetic modifications in cells. In mammals, DNA methylation, which is the best-studied, generally repressive epigenetic signal when located at promoters, occurs predominantly at the carbon-5 position of symmetrical CpG (cytosine and guanine separated by a phosphate) dinucleotides (5mC). The state of DNA methylation is maintained after cell division through the activity of DNA methyltransferase 1 (DNMT1), which methylates hemimethylated CpG dinucleotides in daughter cells. DNA methylation is particularly important in regulating imprinted gene expression, and thus, its modulation has been found to be disease causing for such genomic regions. Epigenetic mechanisms can influence the gene activity at the transcriptional and post-transcriptional levels and/or at the translation level and post-translational modifications. Such epigenetic mechanisms with a potentially vast spectrum of consequences could result in more varieties of cell differentiations, morphogenesis, variability, and adaptability of an organism, which can be affected by both genetic and environmental factors. Therefore, the field of epigenetics covers the modifications of DNA, DNA-binding proteins, and histones, which are important in making changes in chromatin structure without any change in the nucleotide sequence of a given DNA. Also, some of these alterations could be transferred between generations. Moreover, epigenetics involves genetic control by factors other than an individual's DNA sequence. Epigenetic changes can switch genes on or off and determine which proteins are transcribed. Epigenetics is involved in many normal cellular processes. Consider the fact that cells of any organism have the same DNA, but the contain many different types of cells: neurons, liver cells, pancreatic cells, inflammatory cells, and others. How can this be? In short, cells, tissues, and organs differ because they have certain sets of genes that are "turned on" or expressed, as well as other sets that are "turned off" or inhibited. Epigenetic silencing is one way to turn genes off, and it can contribute to differential expression. Silencing might also explain, in part, why genetic twins are not phenotypically identical. In addition, epigenetics is important for X-chromosome inactivation in female mammals, which is necessary so that females do not have twice the number of X-chromosome gene products as males. Thus, the significance of turning genes off via epigenetic changes is readily apparent. Within cells, there are three systems that can interact with each other to silence genes: DNA methylation, histone modifications, and RNA-associated silencing.


Methyl Group
DNA
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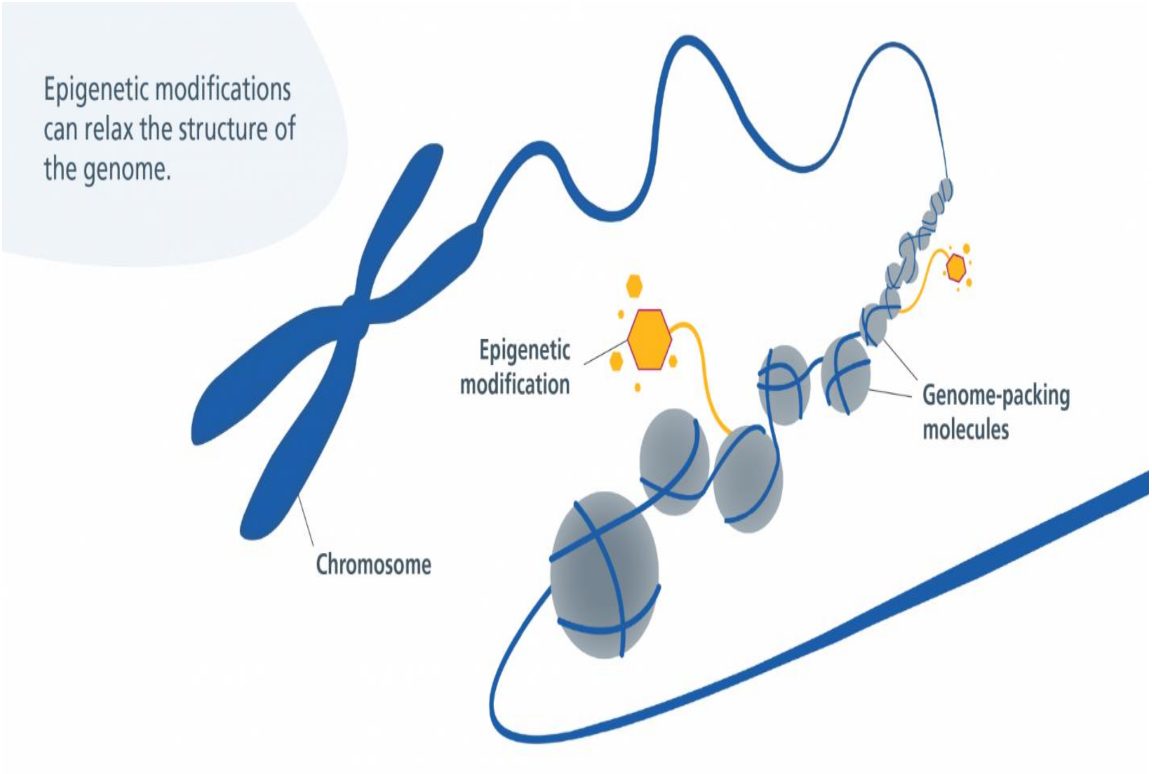
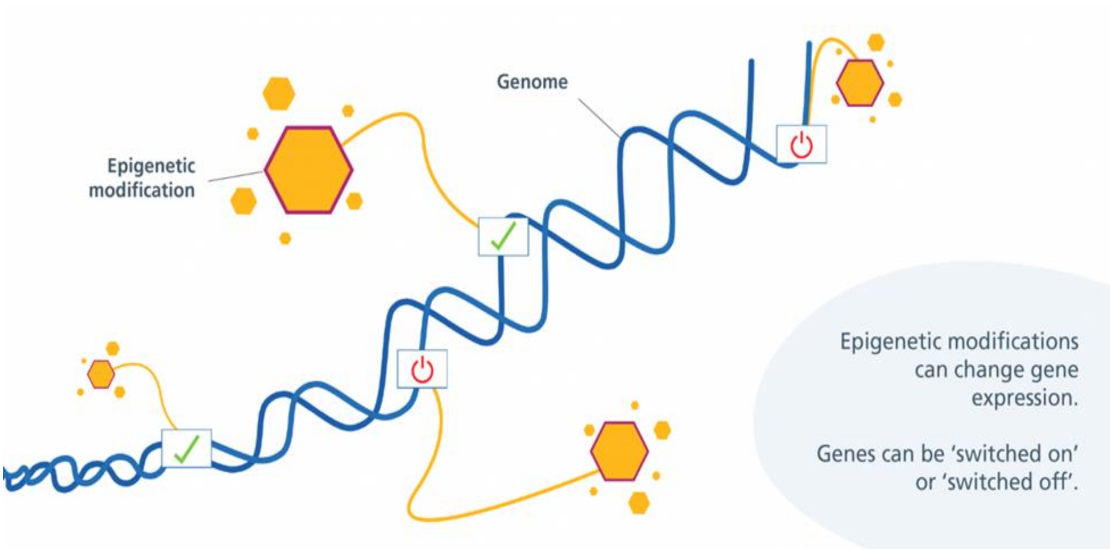
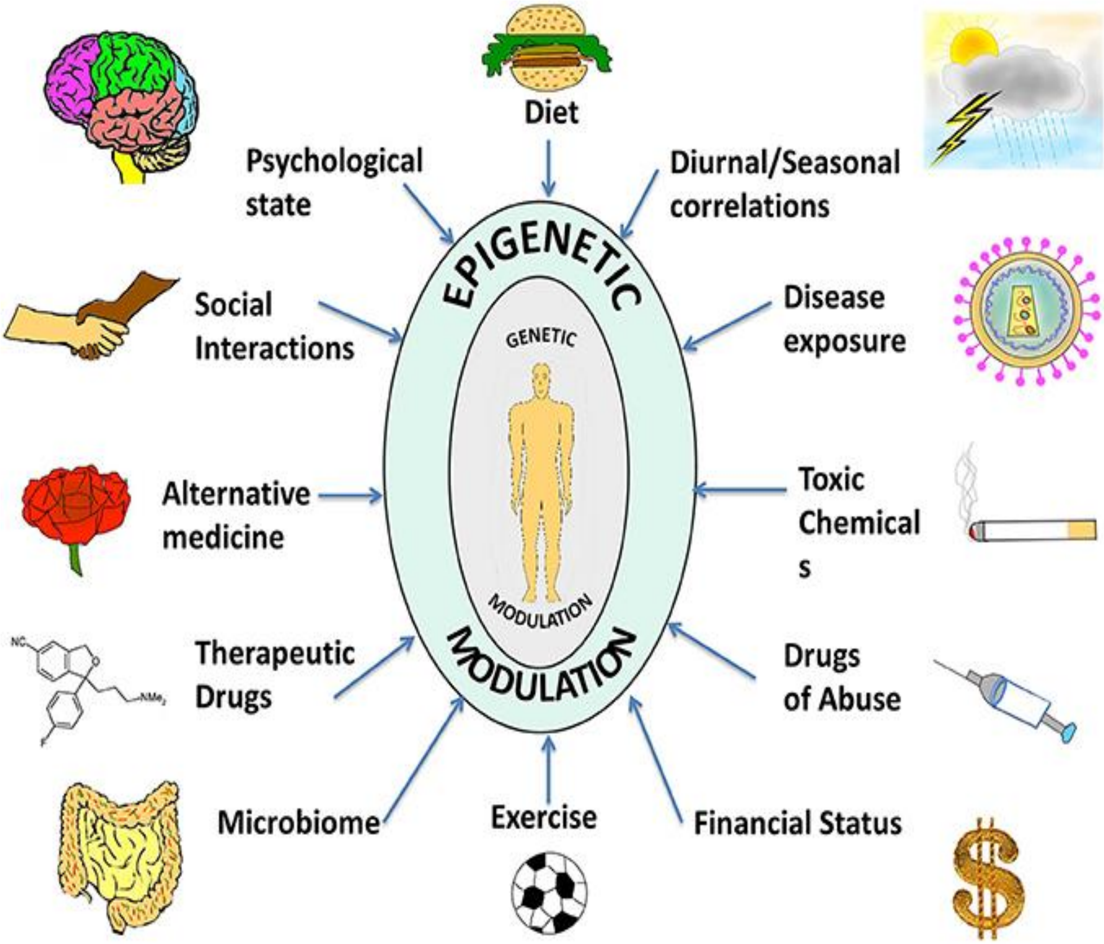
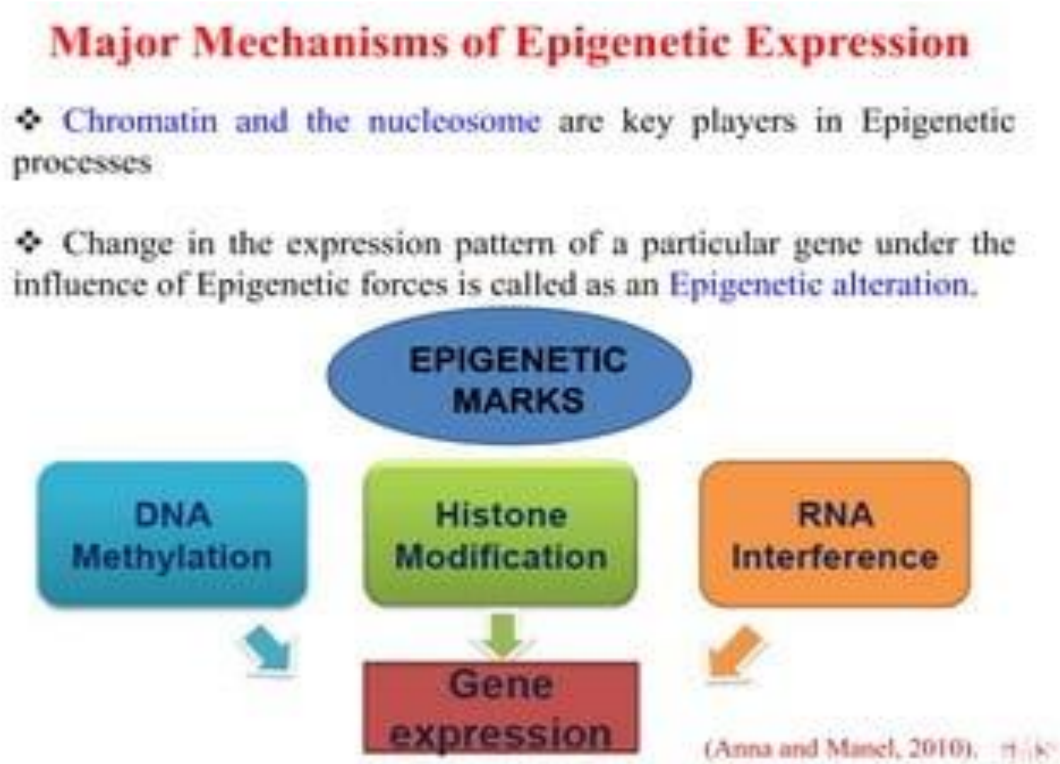

Epigenetic modifications can relax the structure of the genome.
Epigenetic modification
Genome-packing molecules
Chromosome

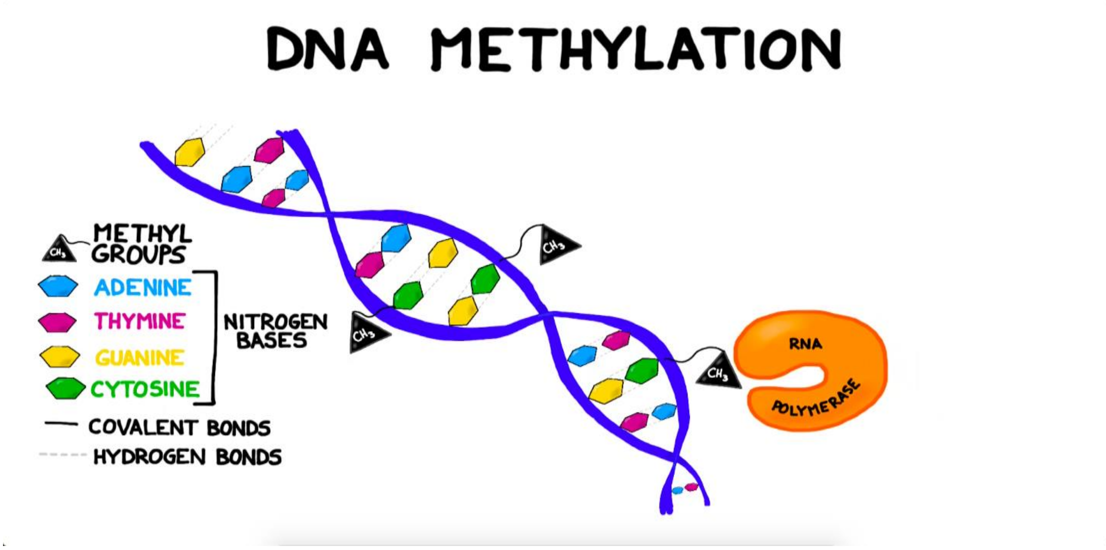

Genome
Epigenetic modification
Epigenetic modifications can change gene expression.
Genes can be 'switched on' or 'switched off'.


Diet
Psychological state
Diurnal/Seasonal correlations
EPIGENETIC
GENETIC
Social Interactions
Disease exposure
Alternative medicine
Toxic Chemical s
MODULATION
MODULATION
Therapeutic Drugs
Drugs of Abuse
Microbiome
Exercise
Financial Status



13-2: DNA Methylation

DNA methylation is a chemical process that adds a methyl group to DNA. It is highly specific and always happens in a region in which a cytosine nucleotide is located next to a guanine nucleotide that is linked by a phosphate; this is called a CpG site. CpG sites are methylated by one of three enzymes called DNA methyltransferases (DNMTs). Inserting methyl groups changes the appearance and structure of DNA, modifying a gene's interactions with the machinery within a cell's nucleus that is needed for transcription. DNA methylation is used in some genes to differentiate which gene copy is inherited from the father and which gene copy is inherited from the mother, a phenomenon known as imprinting.



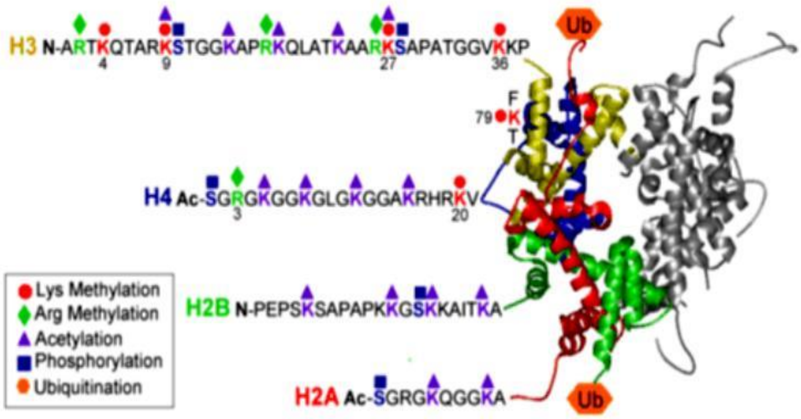
13-3: Histone Modifications

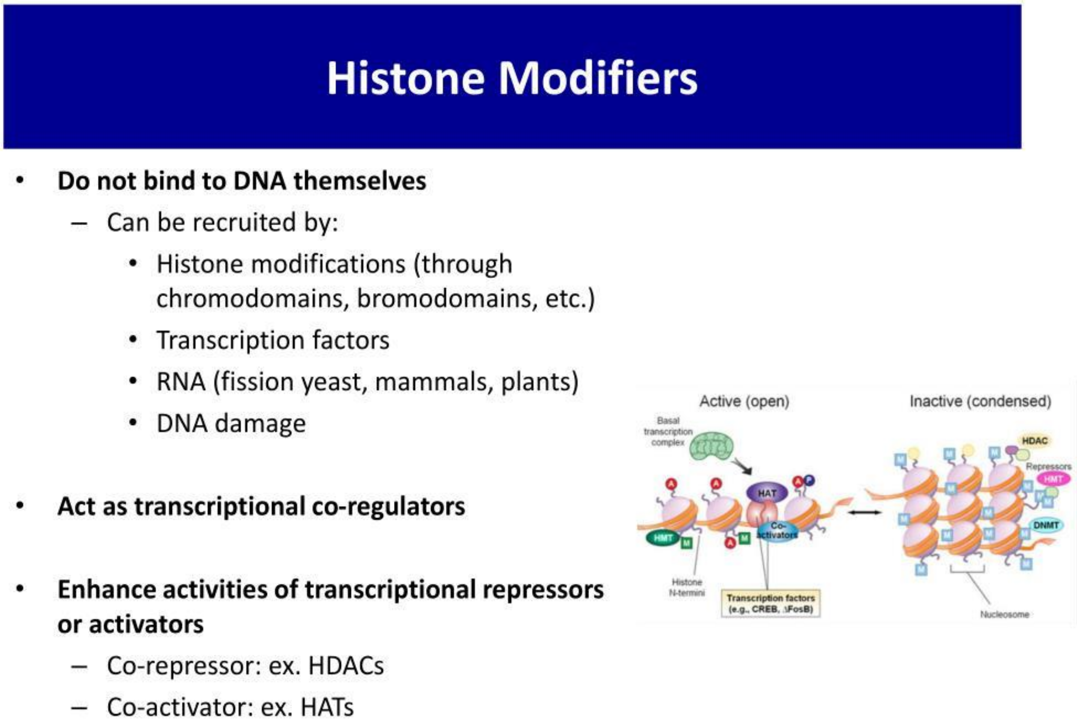
Histones are proteins that are the primary components of chromatin, which is the complex of DNA and proteins that makes up chromosomes. Histones act as a spool around which DNA can wind. When histones are modified after they are translated into protein (i.e., post-translation modification), they can influence how chromatin is arranged, which, in turn, can determine whether the associated chromosomal DNA will be transcribed. If chromatin is not in a compact form, it is active, and the associated DNA can be transcribed. Conversely, if chromatin is condensed (creating a complex called heterochromatin), then it is inactive, and DNA transcription does not occur. There are two main ways histones can be modified: acetylation and methylation. These are chemical processes that add either an acetyl or methyl group, respectively, to the amino acid lysine that is located in the histone. Acetylation is usually associated with active chromatin, while deacetylation is generally associated with heterochromatin. On the other hand, histone methylation can be a marker for both active and inactive regions of chromatin. For example, methylation of a particular lysine (K9) on a specific histone (H3) that marks silent DNA is widely distributed throughout

heterochromatin. This is the type of epigenetic change that is responsible for the inactivated X chromosome of females. In contrast, methylation of a different lysine (K4) on the same histone (H3) is a marker for active genes.
Genes can also be turned off by RNA when it is in the form of antisense transcripts, noncoding RNAs, or RNA interference. RNA might affect gene expression by causing heterochromatin to form, or by triggering histone modifications and DNA methylation. The epigenome consists of nuclear information, heritable during cell division, that controls development, tissue differentiation, and cellular responsiveness. Epigenetic information is controlled by genome sequence, environmental exposure, and stochasticity, or random chance. As such, epigenetics stands at the interface of the genome, development, and environmental exposure. All cells of the body have essentially the same DNA, yet different organs and tissues serve vastly different functions and also retain their identity as their cells divide. This cellular identity is epigenetic information, or information that is added onto the genes themselves. As originally defined in the 1950s by the embryologist Conrad Waddington, epigenetics is the branch of biology that studies the interactions between genes and their products that bring phenotype into being. Waddington's definition was based on a highly deterministic view of the ultimate destiny of tissue development: although it might vary somewhat according to environmental exposure, the end point was inexorably determined by the genes, not the environment. Waddington described an "epigenetic landscape," in which a pluripotent cell acquires differentiated properties as it rolls down "canals" to its eventual fate. A major change in epigenetic thinking came from the realization that the environment has a profound effect on developmental plasticity, particularly with aging and susceptibility to common disease. The modern definition of epigenetics takes this plasticity into account: modifications of DNA or associated factors that have information content, other than the DNA sequence itself, are maintained during cell division, are influenced by the environment, and cause

stable changes in gene expression. Thus, the epigenetic landscape is now viewed more dynamically than it was initially.

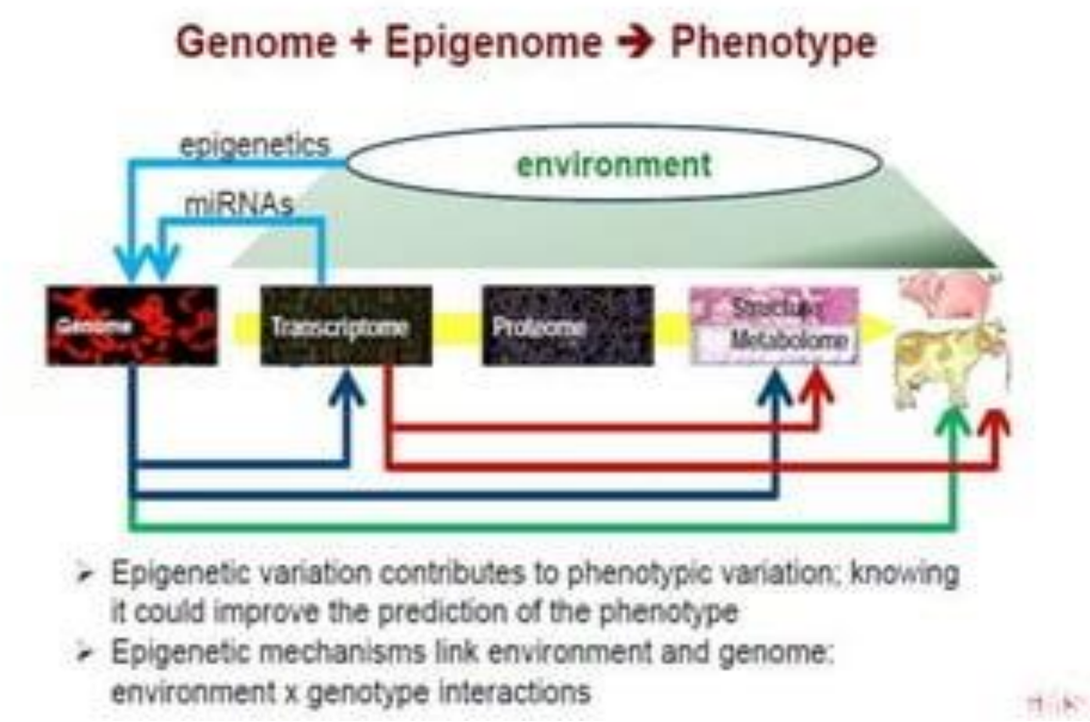
Histone Modifications

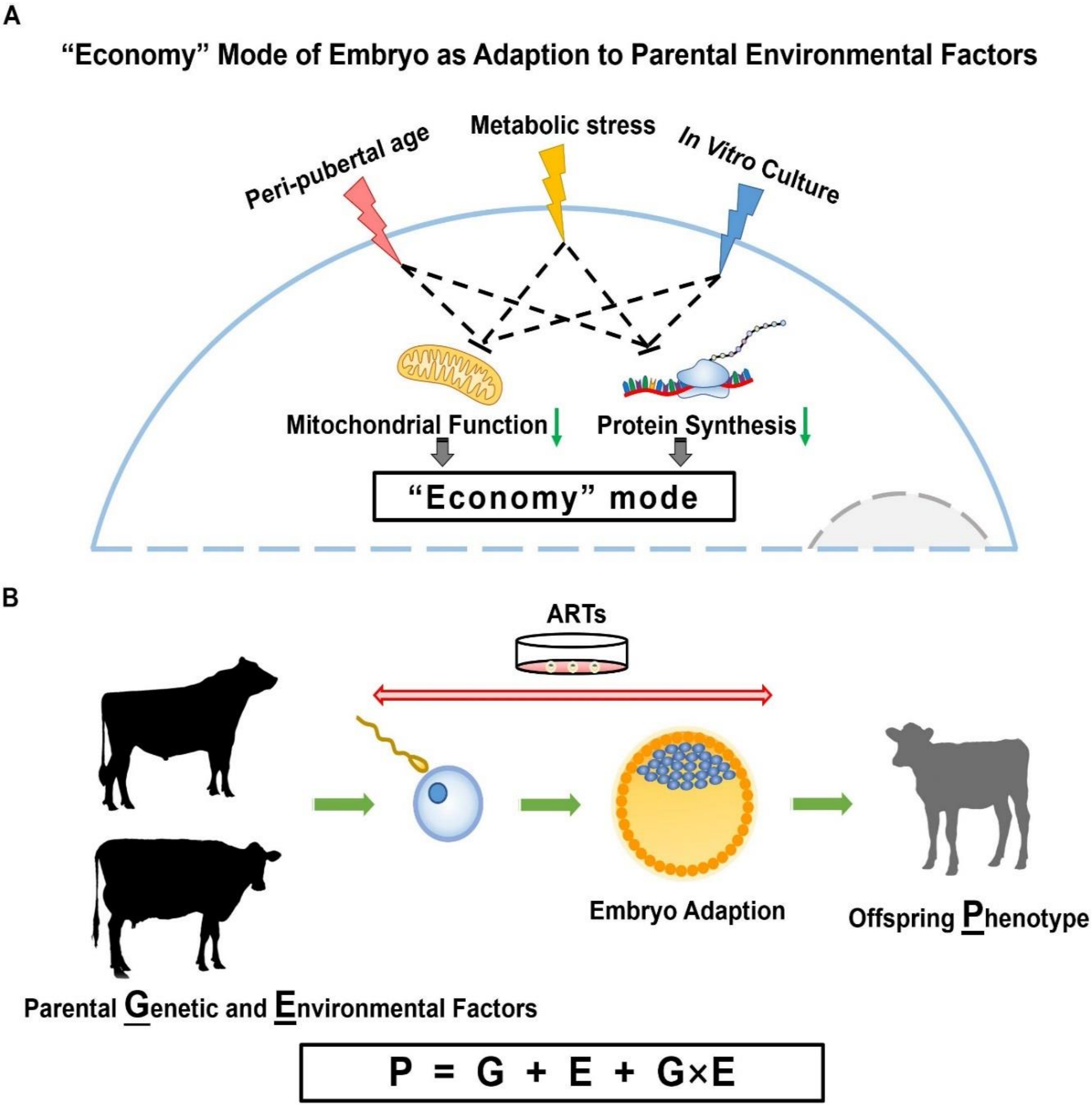




13-4: Future Prospective of Epigenetics in Cattle Breeding

Epigenetics is a recent research field, is not yet used in selection or management strategies in livestock. In light of the state of the art, it is doubtful that a large amount of heritable epigenetic variance exists in cattle populations. Nonetheless, the epigenomic era brings exciting discoveries and challenges that can potentially be included in cattle breeding programs. Firstly, there is a need for a relatively inexpensive technology to sequence the epigenome on a large scale, as a large number of individuals are necessary to accurately estimate small epigenetic effects, and to estimate epigenetic variance at a population level. Secondly, statistical methods need to be developed to incorporate whole methylome information jointly with environment and massive DNA sequence information. Lastly, practical implementation must be carefully evaluated to successfully incorporate epigenetic information in cattle breeding. For instance, mating strategies to increase certain epigenotype frequencies are valid only if epigenetic marks are heritable. However, mate selection in order to obtain genotypes that favor a certain epigenotype could be implemented. Multidisciplinary genetic and management/nutrition practices can promote favorable epigenotypes in the populations, as well. The epigenotype of an individual controls the expression of the genotype. Distinguishing epigenetic effects, whether heritable or not, from heritable genetic effects would result in improved accuracy of prediction of breeding values. There are nonetheless some challenges to face in this implementation: statistical procedures to separate genetic from epigenetic variance must be developed and most convenient tissues to analyze the epigenotype need to be determined for each trait, as epigenotypes differ from one tissue to the other, and even from cell to cell. This increases cost if the traits of interest are tissue-specific, as more than one methylation analysis per animal should be performed. The environment can shape the epigenotype, which jointly with the genotype derive the phenotype. Understanding what external forces can model the epigenotype can help to design management strategies that promote certain epigenotypes. These favorable epigenotypes would promote the expression of productive traits in a more profitable fashion, such as improved disease resistance or increased longevity. Environment is especially important during embryo development, where genetic regulation occurs and can determine the adult life of the individual. Proper nourishment and management of maternal and paternal environments that consider possible effects on the epigenome could produce healthier and more profitable progeny. In addition, if a given epigenetic status is known to have an effect on the phenotype, the epigenetic status itself could be treated as a phenotype for the prediction of future phenotypes. If the epigenetic variance, or that due to imprinted genes, was sufficiently large, selection on male and female lines could be done separately. Mating programs could be designed considering the imprinting status of the progenitors to accommodate the most favorable epigenetic status to complement the breeding value. However, a low-cost procedure for epigenome screening would be necessary to implement these sorts of strategies.





13-5: Nutritional Epigenetics

Nutrients and bioactive food components can therefore reversibly alter the DNA methylation status, histone modifications, and chromatin remodeling, subsequently altering gene expression and having an impact on overall health. Bioactive food components, specific nutrients, and dietary patterns may have beneficial effects and overcome the negative impact of negative life behaviors, such as smoking or exposure to certain chemicals. However, nutritional epigenetics is a quite recent subfield of epigenetics, so current knowledge on the precise effects of bioactive food components on epigenetics and their associations with phenotypes are limited. Deciphering the epigenetic signatures triggered by bioactive food components might pave the way for personalized nutritional interventions and aid our understanding of how our bodies respond to specific diets or nutrients. For example, a recent study showed that fruit and juice epigenetic signatures as measured by DNA methylation marks are associated with independent Nutrition—in particular maternal diet and dietary patterns—and chemical pollutants are two important environmental factors that impact human health.

- These factors have a direct impact on the individual by contributing to the pathogenesis of many diseases, not least cancer.
- Furthermore, these factors probably span generations through epigenetic transmission, making them a major global public health problem not only for the individual but also future generations and society.
- Understanding the molecular mechanisms and signaling pathways involved in environmental epigenetics paves the way for both public health and targeted interventions to reduce their societal impact.

Over the past decade, remarkable breakthroughs in our understanding of epigenetic biology have coincided with an increased public interest in the impact of diet and lifestyle choices on health. It is well established that a balanced diet enhances life expectancy and helps to prevent or treat certain diseases, such as obesity, diabetes, cancer, and mental disorders. However, the biological mechanisms underlying these effects are not yet well understood. In this commentary, we highlight several recent studies that report on a potential link between dietary factors and alterations in epigenetic pathways, providing compelling insight into the possible effects of environmental factors on fundamental biological processes.

13-6: Genomic Techniques

Genomics is the scientific study of the structure and function of the genome of a species with many nucleotide sequences. It is a novel approach toward the genetic improvement of the livestock population. The field of genomics is conceived as the scientific study of a species' genome's structure and function using several nucleotide sequences. Genomic selection is the selection of a population based on estimated genomic breeding values. It has been applied as an invaluable tool for increasing the rate of genetic gain with reduced generation intervals while maintaining a good level of selection accuracy. Moreover, it has been widely used for the selection of superior animals with great accuracy at an early age, resulting in enhanced productivity in dairy cattle populations. Genomic selection is particularly efficient in improving low-heritability traits related to the efficiency of feed conversion, reproduction, adaptation to changing production environments, and resistance to various disease transmitting pathogens and vectors. Genomic selection implementation requires careful model selection, and one of the popular models is best linear unbiased prediction (BLUP). Most studies have shown that pure breeds' genomic evaluation can be utilized to improve productivity, efficiency, and genetics by providing a large reference population for dairy cows with high milk production. Research concentrating on the use of genomic selection on *Bos indicus* cattle is required to assess its effect on the productivity of tropical cattle breeds, as the majority of research studies have been carried out using *Bos taurus* cattle. Genomic selection (GS) was reported as genetic improvement of a population through selection based on the genomic estimated breeding value (GEBV). To compute the GEBV of dairy cattle, one can use single-step genomic best linear unbiased prediction (ssGBLUP). The genomic relationships for genotyped animals and pedigree relationships for other animals are known as ssGBLUP. The ssGBLUP approach has integrated genotypic, pedigree, and phenotypic data into a single evaluation. The associations between the training and validation populations have a greater impact on the accuracy of GEBV. The linkage disequilibrium (LD) between markers and quantitative trait loci (QTL) are the other factors affecting GEBV accuracy. Large training populations are needed for low-heritability traits in order to obtain high GEBV accuracy. Two-step genomic best linear unbiased prediction approach, in which EBVs were combined using various criteria weighted by the heritability of the trait and the accuracy of breeding values. Direct genomic values have been generated based only on genomic and phenotype information. Integrating direct genomic values and EBVs is a crucial stage in the two-step genomic prediction process. The ssGBLUP approach has the potential to produce genomic evaluations that are less biased and more accurate because it includes genotyped and non-genotyped animals in the evaluation at the same time. When implementing a single-step approach, greater GEBV accuracy was achieved compared to a two-step approach. However, it was described that there was no significant bias in GEBV predictions from single- or two-step procedures for the beef cattle population. Also, he described that there were no significant differences in GEBV accuracy. The single-step genomic prediction approach can serve as an effective strategy to estimate the reliability of GEBV on a large scale. To enhance the productivity of dairy cattle, intensive progeny testing of reproductive and production traits based on GEBV has been essential. The GS has shown a dramatic increase in the reliability of breeding values for animals without records or progeny tests, which is a common situation in developing countries. The total genetic value is predicted based on the estimated value of the single nucleotide polymorphism (SNP) effect, which is estimated using reference individuals of genotyped animals. The GS is effective in modern breeding methods for the selection of superior animals. The purpose of GS is to improve production efficiency in a population by using molecular genetic markers. Also, GS is a form of marker-assisted selection, where genetic markers cover the entire genome. The selection can be done at an early age with great accuracy to improve the genetics of farm animals with a reduced generation interval. The GS could play a particular role in improving those traits with low heritability and those that are difficult to measure, such as longevity and health. The SNP markers allow genotyping cattle in a single analysis with thousands of SNPs and providing genomic information explicitly in breeding value estimation. The breeding value prediction in GS is based on the principle of connecting many genetic markers with phenotypic performances. Genomic breeding value is calculated by using the estimated SNP effects in the prediction equation. Genomic information has many new uses, such as pedigree discovery, mating procedures, and guidance in reproductive management. Predictions will use more genetic tests discovered from sequence data and more international genotypes. In addition, GS is used as a tool for an in-depth understanding of the adaptive mechanisms, disease tolerance, and unique traits of indigenous livestock resources. Urbanization is rapidly increasing, as observed in many countries, and it is expected that the demand for dairy products will inevitably expand in the near future. In order to meet the ever-increasing demand for food, the animal husbandry industry must increase production efficiency. This may require a further increase in total output without increasing production costs while maintaining or possibly improving product quality. The increasing global demand for food, due to the continuous growth of the human population, requires improvements in the efficiency and sustainability of animal production systems. Moreover, the demand for the world's population and animal outputs are significantly out of balance. Particularly, developing countries import milk and milk products to satisfy their demand. In dairy cattle, GS is mostly applied in the five global breeds of Holstein, Jersey, Brown Swiss, Guernsey, and Ayrshire, and has not yet been widely adopted in crossbred populations where complex genomic models are required. However, it does not imply that GS is not advantageous to other breeds. Therefore, the aim of this paper is to systematically review the significance of GS in animal breeding in general and its application to the genetic improvement of dairy cattle efficiency in particular.

13-7: Development of Genomic Selection and Its Applications

The chicken genome was the first farm animal that was fully sequenced in 2004, followed by sheep (2007), cattle (2008), and goats (2013). Initially, GS of BovineSNP50 was released in 2008. The first commercially available bovine genomic chip was BovineSNP50. In the absence of molecular knowledge, breeders have effectively used traditional animal breeding methods to produce high-performing animals. In the traditional method, estimated breeding values (EBV) have been predicted. Marker-Assisted Selection (MAS) is a method used for indirect selection of superior breeding animals that depends on identifying genetic markers having strong associations with QTL. The application of molecular genetics to livestock began with the use of DNA markers to identify genes or genomic regions that control traits of interest. Various types of molecular markers have been used to characterize the genetic polymorphism of dairy cows and the application of MAS. Genomic selection can be considered as a modular approach in animal breeding, and its simplicity and effectiveness can bring genetic improvement to the livestock industry within a short period of time. Moreover, due to the effectiveness of its multi-disciplinary approaches to improving livestock production, the application of GS could result in increased productivity, profitability, and sustainability. The GS could further reduce the necessity of progeny testing a bull. It can be concluded that genomic selection is a selection strategy that is based on estimated genomic breeding values. It assumes that all markers might be linked to a gene affecting the trait and concentrates on estimating their effect rather than testing their significance. For effective application of genomic selection, a larger reference population is needed to improve the accuracy of the estimated genomic breeding values. The primary goal of genomic selection is to accelerate genetic trends by reducing generation. Genomic selection has revolutionized the dairy cattle breeding industry, with ripple effects that have greatly impacted dairy herd management. Rate of genetic progress has increased markedly, especially in Holstein and Jersey breeds, for production, health, and fertility traits. Genomic testing of young bulls and heifers provides greater accuracy of selection decisions involving traditional fertility traits, such as daughter pregnancy rate, while creating the opportunity to improve novel traits, such as fetal loss. Cameras, wearable sensors, and other precision livestock farming technologies will allow selection for traits such as estrus duration and intensity that require high frequency phenotyping. At the same time, synergies between genomic testing and advanced reproductive technologies have led to rapid and widespread adoption of sexed semen, coupled with mating of females whose offspring are not needed as herd replacements to beef supply chain, while allowing genetically inferior mature cows that are still producing at a high level to remain in the herd for additional lactations. Furthermore, genomic selection refers to selection decisions based on genomic breeding values (GEBV). The GEBV are calculated as the sum of the effects of dense genetic markers, or haplotypes of these markers, across the entire genome, thereby potentially capturing all the quantitative trait loci (QTL) that contribute to variation in a trait. The QTL effects, inferred from either haplotypes or individual single nucleotide polymorphism markers, are first estimated in a large reference population with phenotypic information. In subsequent generations, only marker information is required to calculate GEBV. The reliability of GEBV predicted in this way has already been evaluated in experiments in the United States, New Zealand, Australia, and the Netherlands. These experiments used reference populations of between 650 and 4,500 progeny-tested Holstein-Friesian bulls, genotyped for approximately 50,000 genome-wide markers. Reliabilities of GEBV for young bulls without progeny test results in the reference population were between 20 and 67%.

The reliability achieved depended on the heritability of the trait evaluated, the number of bulls in the reference population, the statistical method used to estimate the single nucleotide polymorphism effects in the reference population, and the method used to calculate the reliability. A common finding in 3 countries (United States, New Zealand, and Australia) was that a straightforward BLUP method for estimating the marker effects gave reliabilities of GEBV almost as high as more complex methods. The BLUP method is attractive because the only prior information required is the additive genetic variance of the trait. All countries included a polygenic effect (parent average breeding value) in their GEBV calculation. This inclusion is recommended to capture any genetic variance not associated with the markers, and to put some selection pressure on low-frequency QTL that may not be captured by the markers. The reliabilities of GEBV achieved were significantly greater than the reliability of parental average breeding values, the current criteria for selection of bull calves to enter progeny test teams. The increase in reliability is sufficiently high that at least 2 dairy breeding companies are already marketing bull teams for commercial use based on their GEBV only, at 2 yr of age. This strategy should at least double the rate of genetic gain in the dairy industry. Many challenges with genomic selection and its implementation remain, including increasing the accuracy of GEBV, integrating genomic information into national and international genetic evaluations, and managing long-term genetic gain. genetic evaluation, single-nucleotide polymorphism, SNP, reliability, imputation, haplotype, genotype. Nevertheless, genomic selection in dairy cattle builds on a long history of data collection and evaluation methods suitable for reliably ranking selection candidates from very unbalanced field data. The use of artificial insemination (AI) and the possibility of diluting a single ejaculate to create many progenies resulted in a population structure with many very large half-sib families. Data collection is largely from monthly visits by a technician to collect milk weights, milk samples, and management information. This service is provided by farmer-owned cooperatives that are funded by the producers. Bulls are owned primarily by genetics companies, usually with international reach, that work with breeders and dairy farmers to obtain promising bull calves. Prior to genomics, bulls at approximately one year of age typically entered a progeny-test program as a method to determine their breeding value. Bulls were at least five years old when their semen could be marketed based on progeny-test results. The combination of massive historical phenotypic data, breeding organizations able to invest in technology, data processing and evaluation infrastructure, and a long generation interval made dairy cattle an ideal candidate for genomic selection.

13-8: Estimation of Single-Nucleotide Polymorphism

The effect of each SNP on a traditional evaluation is estimated for over 30 traits, these traits are: (Milk (kg), Fat (kg), Protein (kg), Fat (%), Protein (%), Productive life (months), Somatic cell score, Daughter pregnancy rate (%), Sire calving ease, Daughter calving ease, Sire stillbirth rate (%), Daughter stillbirth rate (%), Heifer conception rate (%), Cow conception rate (%), Final score, Stature, Strength, Body depth, Dairy form, Rump angle, Rump width, Rear legs (side view), Rear legs (rear view), Foot angle, Feet and legs composite, Fore udder attachment, Rear udder height, Udder cleft, Udder depth, Front teat placement, Rear teat placement, Teat length). The traditional evaluations are deregressed to make the data more like individual records. Then the deregressed traditional evaluations are regressed on each of the SNP genotypes, where the genotypes are expressed as the count for one of the alleles (0, 1, or 2). The solution is the effect on each trait from replacing one allele in the SNP genotype with the other allele. In addition to individual SNP effects, a polygenic effect is estimated to capture genetic variation not accounted for by SNPs. Most SNPs have small effects that are distributed evenly across all chromosomes but are not necessarily the same for all dairy cattle breeds. The largest effects for milk and fat were found on chromosome 14 for Holsteins and Jerseys (but not for Ayrshires and Brown Swiss); those effects were associated with the DGAT1 (diacylglycerol O-acyltransferase 1) gene. An increased effect for protein was also found on chromosome 14 for Jerseys. Methods to visualize SNP effects have been developed, and Manhattan plots of the effects for all evaluated SNPs are available through CDCB for traits of economic importance depending on breed.

13-9: References

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Chapter 14

Outlook at

Cattle Farming in Iraq

Outlook at *Cattle Farming* in Iraq

14-1: Overview of the Iraq's Livestock Production Systems

The livestock sector has a special importance to the Iraqi economy. It plays a fundamental role in the gross domestic product as well as in supplying foodstuffs for the people, and that livestock contributed to one fifth of the gross domestic product in agriculture. It is estimated that Iraq has a population of 10 million sheep, 1.5 million goats, 1.6 million dairy cattle (70 % indigenous of the Zebu type, 5 % Holstein – Friesian and 20 % of crossbred) and 140 thousand buffaloes as well as few thousands of others livestock. The available animal protein per capita/day is around 18 g, which is below to the figure recommended by WHO. The population estimate of Iraq is 41 million. Average population growth rate is about 2.3%. It is estimated that Iraq currently produces 1.5 million MT of milk, 100 thousand MT of red meat per year. Furthermore, the estimated annual per capita consumption of milk and red meat are around 40 kg and 6 kg, respectively. It can be concluded that although the livestock population is relatively numerous, its production potential is very low. This could be due to severe climatic condition, feed shortage, poor genetic make-up for production and several other factors. Insufficiency in all animal products is a trend accompanied the production in livestock sector. Demand which is always higher than supply of animal products caused importation of some strategic animal products. Moreover, livestock production systems generally lag behind crop production ones in terms of development, standards of management and husbandry and mechanization. Recent report indicated that the share of beef imports to domestic use has increased since 2019 on strong domestic demand and lower production and is projected to rise to a record level in 2024. Traditionally, crop farming and livestock production are carried out as separate activities, proper mixed farming is rare. Livestock feeding generally depends on natural pastures (range land) and crop residues. Forage is produced in only very limited scale. The total area of Iraq is 43.5 million ha in which about 102 thousand ha (0.3 %) covered by water. Total arable land is 12 million ha, in which 50.2 % falls under irrigation and 49.8 % under rain fed area. The permanent pasture estimated to be about 17 million ha. Summary of cattle in Iraq was given in chapter 1 of this book, under subheading 1.7.

14-2: Livestock Production Systems in Iraq

- The Intensive System: This system is characterized by some modern methodologies that allow intensification. It is usually practiced in most of the large- scale projects, especially dairy cattle state-built projects and some other private enterprises. The introduction and usage of new technologies is usually expanding continuously. Exotic breed (manly Holstein Friesian) are reared in such system. Fodder is mostly locally produced and supplemented with bought concentrate according to nutritional requirements. The standards of hygiene, management, pest and disease control are of a quality that allowed better productivity in comparison with other production systems. Moreover, under this system, mixed farming or an integrated crop / livestock production is also practiced on limited scale. This system is characterized by high-capital and high inputs. There is no noticeable change toward an increase in implementation of high-input systems in cattle / livestock sector due to discouraging input-output pricing policy, which is not meet requirements of producers.

- **The Semi-Intensive System:** Farmers usually keep 15-20 crossbred cattle for commercial milk production. Crossbred cattle are mainly ½ or ¾ blood of Holstein Friesian by local breeds) are reared in such system. Fodder is mostly locally produced and may supplemented with concentrates or wheat bran several hundred farmers are practiced mixed farming or integrated crop / livestock production under this system. This system is familiar in central Iraq and around big cities. This system is characterized by low-capital and medium inputs.

- **The Household System:** Under this system, sheep and goats are kept around the houses by most farmers, in all over the country, to produce milk mainly for family use. Cattle are also kept for the same purpose, but in very limited numbers (2-5 heads per family). This system is usually practiced in the villages; it also exists in towns and cities, but on a limited scale. In this system, farmers usually keep 2-5 cows of local or crossbred with Friesian and 10-40 sheep and goat. Moreover, turkey, duck, geese and local chicken may raise in the backyard. Animals are usually kept in enclosures round the family living area; feed is purchased sometimes supplemented by occasional browsing and grazing where available. Productivity of animals under this system is extremely low and the overall standards and measures of management, hygiene, disease and pest control are far below satisfactory. This system is characterized by low-capital and minimum inputs.


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- Fattening System: This covers fattening of lambs and calves for meat production. Lambs of 4-5 months (after weaning), weighing 15-20 kg, that are produced (under traditional system) bought and are fattened for few months to reach a slaughter weight of about 40 kg. In case of fattening local calves, they are usually bought at weaning age of about 6 months from rural farms, are fattened to 200 kg. While calves bought from large-scale farms (under intensive system) usually at their first week of age fattened to about 250 kg. Fattening diets are usually of high energy concentrate based on barley. Fattening usually takes place in feed lots. Most people, practicing this production system, do not possess their own flocks but they rely on getting lambs and calves from the local market. This operation is characterized by low capital and medium inputs.

- Traditional System: The operation of this system takes place under sedentary, transhumant and nomadic system. In the nomadic and transhumant, flocks of sheep and goats, sometimes even few cows, are grazed extensively on natural vegetation. Some transhumant make use of crop residues available in the nearby cropping area. Supplementary feeding is virtually unknown and the animals suffer under nutrition during the dry season. The movement of the majority of flocks in the transhumant system is restricted to closed zones compared to the wide range movement of the nomadic flocks where they cover long distance following the availability of pasture and water according to seasons. In the sedentary system, livestock and crop production is combined but not integrated. The main sources of animal feeds are stubble and crop residues supplemented with roughages of cultivated land where some flocks have an access for forage crops, included in the rotation program. In this system the practice of keeping cattle for milk production is noticeable. The traditional system covers 90 % of sheep and goat production in Iraq. Steppe and grazing areas utilized by this system are very arid or semi-arid where rainfall is unpredictable and scarce and only during winter. Such areas are not suitable for other agricultural purpose. This system is characterized by low-capital and minimum inputs.

14-3: Constraints of livestock development:

Improvement faces many constraints, top of such are:

1- Shortage of feed: Available information indicates that animals rarely get more than 70% of their nutritional requirements specially with the nomadic, sedentary and transhumant systems.

2- Harsh environment: The harsh arid and semi-arid climate with its extreme temperatures, humidity and sandstorms, adversely affect animals. The limited and irregular rainfall limits the availability of fodder as part of the cropping program. The recurrent or persistent draught is a common feature of the area.

3- Health: The instability of flocks and continuous movement made veterinary services difficult. Endemic diseases are the cause of high mortality, morbidity and reduced productivity. This situation was aggravated by the economic sanctions imposed on Iraq since 1991.This was reflected, negatively, relatively on availability and quality of drugs, vaccines and other services.

4- Marketing: Marketing practices are improper and do not offer the producer any protection or incentives. They are not sufficiently flexible to encourage introduction of new technologies and management practices. Such practices, on light of the high inflation rate that appeared for the last 10 years, became very expensive and unaffordable by many producers. Credit facilities, especially those offered by the government, are inadequate and not always available specially for small producers and transhumant.

5- Prices: The current pricing policies for livestock products, though follow the general low of availability of supply and demand, are not geared towards meeting the requirements of producers. The feed / product price ratio should favour the producer, a case which is not existing. Some of the by-products, such as wool, is sold for a minimal price that even does not cause any concern to the producer.

6- Instability of agriculture policies: This situation impedes the implementation of long-term breeding plans and the introduction and use of new technologies that add to the cost and need stability to be fruitful.

7- lack of recording: Proper recording, in the field of animal production, especially on the national level is nearly absent. The bureaucracy in handling or keeping records and their availability hinder timely action and endanger the efficiency of the production process that depends on analyzing related records.

8- Lack of coordination between research activities and production level prevents the implementation of research results by the targeted producers and impede orientation of research toward solving field problems.

9- Extension services and articulation is very weak and improper.

14-4: Livestock Resources

Climate change presents a range of challenges for all animals' species in Iraq as well as in the globe. Livestock production will be affected by changes in temperature and water availability through impacts on pasture and forage crop quantity and quality, feed-grain production, disease and pest distributions. It is worthwhile, to provides an overview on the effect of increasing temperature, changing rainfall patterns, and increased climate variability on livestock health, growth, and reproduction, including through heat stress, and potential adaptation strategies. The rate of adoption of adaptation strategies by livestock producers will depend on perceptions of the uncertainty in projected climate and associated impact and risk. Raising livestock in many areas in the world is a traditional activity contributing to the livelihoods of millions of rural communities. Livestock make use of the scarce feed to convert them into nutritionally and economically valuable products. Iraq has a population of 42 million inhabitants, although the livestock population in Iraq characterize by numerous, its production potential is very low. This could be attributed to severe climatic conditions, feed shortage, poor genetic make-up for production and several other factors, including endemic diseases and management. Most of milk comes from cattle, whereas, 60% of the red meat comes from sheep. Most cattle and buffaloes are found in and around the irrigated areas. Whereas, sheep and goats are found within the range based nomadic and transhumant areas (minimum input practices). Topographically, there are four distinct regions namely: the arid or desert (39.7%), the plains (30.5%), the terrain land (9.7%) and the mountains (21.1%). Rainfall ranges from below 100 mm in the desert to more than 1200 in the mountain's region. Mean temperature is below -10ºc in the mountains during winter to above 50ºc in the desert during summer. The season of the rain generally falls between November and April. Kurdistan displays a great diversity of climate and soil types and caused a variation to the environment and create different zones and habitats. There should be increasing investigations on adaptation of genetic resources to changing environmental conditions and consumer demands. Maintain of genetic diversity and its utilization as well as exchange of genetic material will be importance. The development of global biotechnology system to identify genes responsible for adaptation, acclimatization and behavior stress become important issue for future food security (genes that may be needed in a future of extreme climate change). Such system will for sure will keep animal genetic diversity and conserving genes that could be useful in the future. Simultaneously, it is important to increase animal products. For that, it should comprise between maintaining genetic resources, diversity and improving animal products. The knowledge in animal breeding is needed to integrate current breeding technology. Indeed, the favorable characteristic of local heritage breeds of animal is the thermo-tolerance, diseases resistance and adaptation to prevailing harsh environment. The introduction and usage of new technologies is expanding continuously. European breeds have been improved in many quantitative and economic traits and usually are raised under intensive commercial production system. Speed-up genetic improvement of quantitative trait (such as growth rate and milk yield) will be increasing productivity of cattle. Crossbreeding is one of the tools responsible for high growth as well as milk yield can speed up genetic improvement. New technology, and investment were absent in livestock activities. It was suggested that development project for genetic evaluation and improving of cattle would be appreciated as a new approach to maximize genetic trend of meat yield in Iraq. It is well known that semen of Holstein or Friesian breeds are disseminated to grade-up local breeds since 1950's. Most large-scale commercial farms with Friesian breed nowadays inseminating their breed with Holstein semen. It is worthwhile to mention that no selection was practiced on local cattle as the herder has 2-4 cows (household), which make it unpractical to carry out selection. There is no recording system practiced and consequently no breeding program was applied. It is noticed from above presentation, there is no sustainable long run breeding plan. A breeding project is suggested to produce crossbred animals to sustainable increase of animal products (meat and milk) to satisfy domestic demand and enhance food security. This would be done through improvements of local cattle. The expected outputs are:

1) Increase efforts to create dual purpose type animals.
2) Develop community-based cooperatives for meat and milk production.
3) Develop the traditional livestock sector in areas of animal management and feed production to increased animal production.
4) increased farmer's income.

To achieve this goal, ministry of agriculture, university staffs together with private sector can help in identification, effective and efficient implementation of performance-based projects and to modernize of the livestock system to enhance artificial insemination (besides of dairy breed such Holstein Friesian), dual purpose breeds (such as Tarentaise, Abondance and milking Shorthorn) can be used with local female breeds. As these breeds have excellent fitness, walking ability (due to strong feet and legs) and they are hardiness. Furthermore, the dual-purpose breeds have a good potential for production of milk (5000 – 6000 kg) as well as beef.
Globally, the genetic variations in farm animals are very large, and are available to breeders, these include:

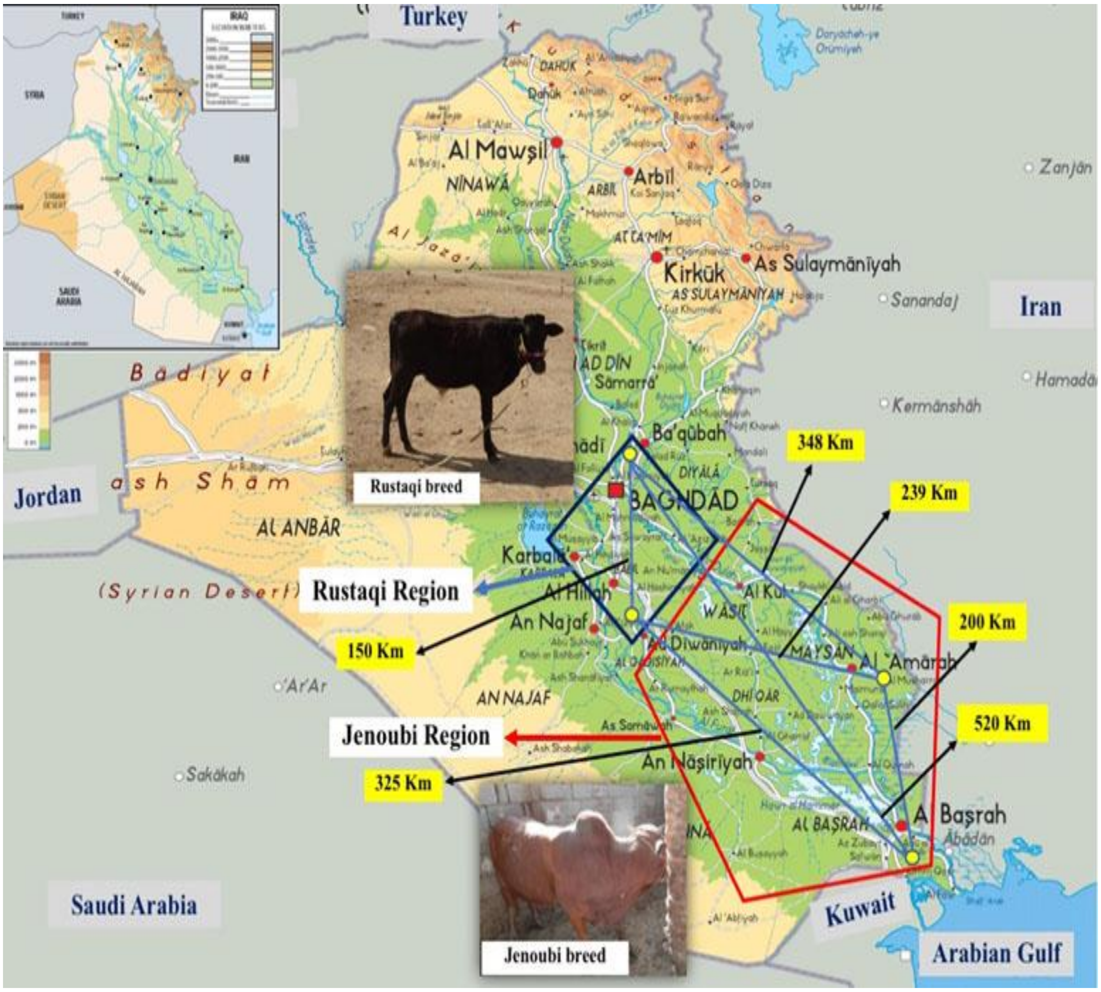
1. Diversity amongst farm animal species: As species evolved over time, they developed unique adaptive and production characteristics, and were domesticated for these genetic qualities.

2. Diversity amongst the breeds of each species: As breeds have developed, they have become highly adapted to their particular production environment, in response to the environment's set of complex selection pressures operating repetitively over many generations of development. These production environments

frequently differ markedly in the overall nature of the set of selection pressures imposed.

3. Diversity amongst the individual animals of each breed with coefficients of variation for input and output characteristics of interest in the breeding livestock populations of developing countries. Consequently, the utilization of this species, breed and individual animal diversity should be an important element in livestock development within and between-human communities. Furthermore, in animal resources, cattle are identified as two main separate species: *Bos taurus*, the European cattle; and *Bos indicus*. Different types and breeds of cattle are suited to different environments. *Bos taurus* cattle such as Holstein, and Angus cattle are more suited to temperate or colder climates. Whereas, *Bos indicus* cattle such as the Brahman breed are suited to subtropical and tropical areas. Most cattle, except those of the *Bos indicus* breeds do not have sweat glands in their skin, but their wet nose is a useful cooling system. Furthermore, differences between adaptation traits of *Bos indicus* and *Bos taurus* are: *Bos indicus* tolerates heat better than *Bos taurus*, and this is reflected in a lower rise of body temperature under hot conditions. This tolerance is due to the high heat resistance of their sleek, dense coat, which prevents heat gain from the environment; low tissue resistance to heat transfer from the body core to the surface; and high sweating competence. Humidity has no adverse effect on *Bos indicus* sweating rate, while water vapor trapped in the air spaces between the hairs of *Bos taurus* impedes evaporation. *Bos indicus* can also store heat during the day and then dissipate it non-evaporative at night, thus reducing the need for watering. Dry matter intake relative to body weight is higher in *Bos indicus* than in *Bos taurus* when coarse forages are fed, but the contrary holds for good-quality forages. The greater ability of *Bos indicus* to recycle urea to the rumen makes it less dependent on feed nitrogen. For *Bos indicus* net energy requirements for maintenance are lower than in *Bos taurus*, but requirements for growth are higher. *Bos indicus* is also highly resistant to parasites.

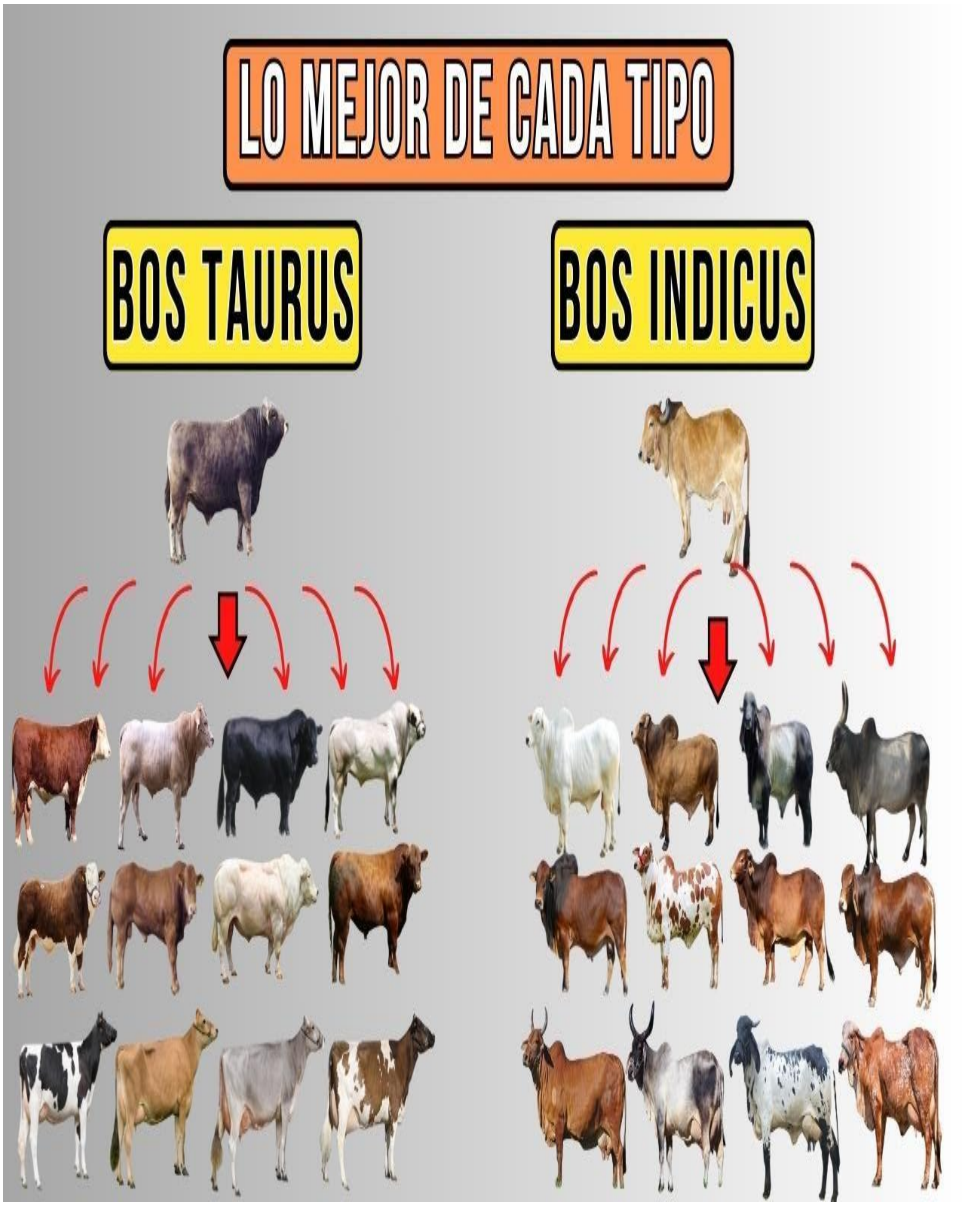
In *Bos taurus* × *Bos indicus* crosses of up to 50% *Bos taurus* gene fraction, resistance to environmental stresses approaches that of *Bos indicus*, but it is much reduced above that level of *Bos Taurus* inheritance. Survival, reproduction and herd-life are generally higher at intermediate gene fractions of both species.



14-5: Crossing *Bos indicus* and *Bos taurus*

Clearly, when *Bos indicus* and *Bos taurus* are brought together in a systematic and orderly breeding program, they are able to contribute effectively to increased milk and meat production from cattle in the tropics. A synthetic population can be formed by inter se mating from any crossbred group. The simplest form of synthetic, with two parental breeds, is formed from the F_1 generation. The performance of the F_2 and subsequent generations can be readily predicted. On average, they contain a 50% gene contribution from each parental breed, and therefore have half of the additive effect. They also, on average, retain 50% of the heterozygosity of the F, generation, and therefore should display half of the heterosis effect. Since a synthetic can be formed by, inter se mating of individuals with any level of gene proportions from the two parental breeds. In many instances, it is clear that less than 50% replacement of the genes of the local cattle by exotic Bos taurus genes is desirable. One crossbreeding strategy in these circumstances which has both operational and genetic advantages is to grade up to 50% exotic bulls. Bulls from the exotic breed (E) are mated to selected cows of the local population (L_1). The F, bulls produced by these mating is then used for general crossing on the main local population (L). The operational advantages of the scheme are as follows. In many local populations, it is difficult to organize any kind of breeding intervention other than the provision of bulls. On the other hand, it may well be possible to organize an effective nucleus herd of selected females from the local population. These females could then be mated with semen imported from the chosen exotic, and the resulting F_1 bulls could be used either in natural service or artificial insemination to breed the local cow population. In addition to achieving a planned exploitation of both heterosis and additive differences, therefore, the structure would also permit exploitation of any selection gains achieved in assembling the nucleus herd. It would also permit continuous exploitation of any genetic improvement in the exotic population. The overall advantages are that the desired intermediate genotype is rapidly achieved; a significant proportion of maximum heterozygosity is retained. Moreover, if a higher degree of exotic genes is required in the crossbred population. As in the preceding structure, exotic bulls are first mated to selected females of the local population to produce an F_1 generation. These are backcrossed to the exotic to produce three-quarter crossbred. A synthetic population could be formed by mating the backcross bulls to females of the same genetic constitution, and this nucleus synthetic group could be a continuing source of three-quarter bred population. The relative performance of populations obtained by grading up to 50% or 75% exotic bulls will depend on the relative sizes of the additive and heterosis effects. Furthermore, it may suggest three-breed rotation crossing (in this case that there is one local population, and that two exotic breeds (E_1 and E_2) are used). Each exotic breed is used in pure form as a sire breed. The rotation begins with the use of the male of the first exotic breed on the local female population, to produce an F_1 population. These are mated to the male of the second exotic breed, to produce a population which has 75% exotic genes. Nevertheless, indigenous cattle of Iraq are low producers compared to European breeds as far as milk and beef are concerned. Many questions remain to be solved regarding the best approach in attempting to increase meat and milk and consequently income from cattle projects, and to alleviate future climatic changes. One approach was suggested to be one of the first steps necessary to achieve acceptable results by crossbreeding local (native or indigenous) cows to beef sires then to cross F1 female to dairy breed sire to combine fitness, growth and dairy traits for meat and milk production specially in developing countries. A work was undertaken to evaluate bulls resulting from crossing Karadi with Hereford and Charolais and to erect a framework of beef industry in Iraq. Three breed groups were evaluated for slaughter weight (SW), average daily gain (DG), hot carcass weight (CW), eye-muscle area (MA), and dressing percentage (DP) of calves resulting from crossing Karadi to Hereford or to Charolais by least-squares procedure. Sire breed significantly affected SW and CW. It was concluded that crossing Karadi cows to Hereford or Charolais sires improved SW by 22.97% and 14.01%, respectively, compared to straightbred Karadi (Al-Rawi, and Farhan. 1990). However, attempt has been made to cross F1

Charolais x Karadi (CK); Hereford x Karadi (HK) and Karadi x Karadi (KK) cows to Holstein sire to produce 3-breed crossbreds. It was observed that the 3-breed crossbreds were superior in both growth rate and milk yield to the 2-breed crossbreds (F1, Holstein x Karadi). Unfortunately, due to second Gulf-war and the economic sanction, trial did not complete (Al-Rawi, 2021). Therefore, it is strongly suggest applying the approach of crossbreeding of native or indigenous cows to beef sires then to cross F1 female to dairy breed sire to combine fitness, growth and dairy traits for better meat and milk production especially in developing countries. Such approach may produce 3-breed crossbreds (50% native, 25% beef breed, and 25% dairy breed), then through inter se mating to form synthetic breed adapted to local environment with acceptable growth and milk potential. The consequences of this breeding pattern for the maintenance of maximum heterozygosity, and heterosis is expected when genes of the two exotic breeds are brought together, Moreover, substantial heterosis is expected whenever exotic genes of either are brought together with genes of the local population.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14-6: Conservation of Iraqi Cattle Diversity

Native breeds of cattle, are one of the main breeding and production of livestock sector in Iraq. Cattle are mainly raised for milk production then meat These native breeds are well adapted to local environment (high ambient temperature up to 50º c during summer and low ambient temperature, down to –10º c during winter, poor farming hygiene and deficient diets). Furthermore, the products of these native breeds are of high quality (good taste and flavor) as compared with products of exotic breeds. The main native (local) cattle breeds are the Jenubi, Karadi, Sharabi and Rustagi. It was reported that local cattle are genetically resistant to endemic diseases (especially theileriosis) and harsh environment (wide range of ambient temperature and low quantity of feed and water). Most cattle and buffaloes are found in and around the irrigated areas. Whereas, sheep, goats and camels are found within the range-based nomadic and transhumant areas. At late forties and later until 1988 many exotic breeds were imported (Friesian, Guernsey, Ayrshire, Jersey, Brown Swiss, Sindi, Simmental or Swiss Fleckvieh, Normandi, Tarentaise, Abundance, Holstein, Herford, Charolais. And Brahman. Traces of genes of these breeds is encountered here and there through crossing with local breeds. Though all these exotic breeds (as purebreds) suffered severely from acclimatization problems. Holstein-Friesian crossbred cattle were more tolerant to local environmental condition and was enjoying a fair rate of demand by breeders in Iraq. The AI service was planned during seventies to produce Holstein-Friesian × local cattle crossbred. Holstein frozen semen was imported from USA and West Europe to upgrade both Holstein-Friesian purebred as well as the Holstein-Friesian × local cattle crossbred. Selection and genetic evaluation using Animal Model technique was applied on Friesian and Holstein breeds, where there is recording system in the large-scale commercial farms. Screening young bulls was practiced in 2001 and 2002. Performance test was conducted on a number of young bulls. Superior young bulls based on the performance test (feed efficiency and growth rate) were selected and dispatched at AI center in Abu-Ghraib for semen collection and evaluation. Semen of Holstein or Friesian breeds are disseminated to grade-up local breeds. Most large-scale commercial farms with Friesian breed nowadays inseminating their breed with Holstein semen. It is worthwhile to mention that no selection was practiced on local cattle as the herder has 2-4 cows (household), which make it unpractical to carry out selection. Although, Iraq has two breeds of buffaloes, but there is no recording system practiced and consequently no breeding program was applied. However, herders select their young bull according to the phenotypic value for milk production of their dams. There is no real breeding strategies, policies or institutional infrastructure. However, there is individual interest in practicing breeding program here and there (by researchers). Therefore, no well-defined plan for recording, identification and evaluation of animals at the national level. The role of responsible offices in the adoption and use of animal breeding techniques is limited to research stations and centers as well as university's research departments. There is little contribution of private sector or breeder's cooperatives or associations to breeding strategies. The reason for those may due to no legislation that supports the development of such breeding strategies. Therefore, there is not sustainable long run breeding plan. However, some tools of breeding program are in operation. AI is mainly used in cattle to produce crossbreds (Friesian or Holstein × local) to improve milk production and growth rate. Recording is practiced in the large scale-commercial dairy farms (about 10 farms, with a total of 20000 cows). No embryo transfer is carried out. Genetic evaluation is recently started using animal model in some large scale-commercial dairy farms and elite cows as young bulb mothers were identified. Hence, breeding policy and legislation assist the scientific researchers, cooperatives and farmers. No funds were allocated for such activities.

- Continuous changes and reorganization of the structures and bodies involved in livestock sector.

- Lack of practical experience needed for breeding program.
- The production system is one of the constraints to carry out breeding program (where there are few cattle-based production systems and the migratory sheep and goat system of productions).
- Prices of livestock products is not geared towards meeting the requirements of breeding program.

Moreover, there is no real genetic conservation program of Animal genetic resources for food and agriculture (AnGR), because no understanding of the role and value of AnGR. Furthermore, no recognition of the role and value of indigenous breeds. Therefore, there is no program to promote awareness of the role of AnGR, and to have a solid conservation strategy like maintaining breed at risk to meet future demands, maintain within breed diversity, for social /cultural/ economic values, research and education and ecological values. The main reasons for not having strategy are: Lack of awareness and lack of financial resources. It is worthwhile to mention that some sort of conservation measures (which are mainly to protect animals against diseases) such as the veterinary vaccination program. Furthermore, there is no genetic material conservation within living animals out of the environment in which it developed (ex situ in vivo) or external to the living animal in an artificial environment. (Cryogenic condition or ex situ in vitro). Furthermore, there in no any incentives and tools for management of ex situ or in situ conservation program. However, occasionally, some measures in drought seasons, vaccination campaign took place to protect heath and production. Such measures are presented by government. Research centers and universities help in studying the state of animal welfare and suggest methods and tools for protection and improvement, but implementation of such suggestion is very rare. Weak extension service is one of the reasons of such lag between research and implementation. Furthermore, the high priority needs is the financial resources followed by use of technology to support conservation program and the needs of training in recording and genetic evaluation. It is suggested that the government should establish AnGR office or department at the ministry of agriculture to plan and implement AnGR especially of local breeds of livestock in coordination with FAO and other NGO.

14-7: Future National Policies and Programs Related to AnGR

Iraq's strategy for the livestock sector is to sustainable increase of cattle products (milk, and meat) to satisfy domestic demand and enhance food security. The country's vision for the livestock sector is set out in the 10-year comprehensive national strategy for agriculture, livestock and natural resources. The livestock strategy aimed at double the size of the national herds and flocks and increasing the animal products by at least 2-fold. This would be done through improvements to the rang land, irrigated fodder

production, integration of livestock with cropping systems, programs for the control or eradication of animal diseases, improve marketing and pricing policies. The strategy set out the following objectives:

- to develop the traditional livestock sector.

- to protect and improve the local livestock breeds.

- to improve and sustain the animal health of the national herd.

- to maximize the production of livestock breeds.

- to increase efforts to integrate livestock into the irrigated crops.

- to build human capacity for the livestock sector.

- to increase the activity of AI.

- control of endemic dangerous diseases such as: brucellosis, TB, theileriosis, FMD and mastitis.

However, the government represented by the ministry of agriculture, offers the essential and basic services to protect and conserve animal resources and improve productivity. The AI service provided by the directorate of animal resources in collaboration with veterinary services and mainly conducted by private veterinary clinics distributed over most rural areas. Holstein or Friesian semen (frozen and cooled) usually distributed to private veterinary clinics who take the responsibility of insemination and pregnancy diagnosis. The semen is produced from locally born Holstein–Friesian bulls. Some sort of genetic evaluation of elite cows (mother bulls) and performance test of the calves were conducted. Progeny testing is done as a start with just two large-scale farms that have recording system. This practice is used mainly to inseminate Holstein-Friesian, local and crossbred cows. No programs or even interest to have any sort of identification or recording or semen collection and freezing of any of the local (indigenous) breeds of livestock. This may due to no incentives to the use and development of AnGR by government agencies or commercial firms and farmers. On the other hand, government made significant investments and undertook initiatives to import and use exotic AnGR especially in dairy cattle. The result of such exotic breeds (Holstein or Friesian) was positive to the milk and meat production. Furthermore, no mechanism or link with other national or international biodiversity objectives (e.g. convention on biological diversity). Furthermore, there is no any capacity building in the management of AnGR (e.g. statistical sampling and survey techniques, breed evaluation and characterization, preservation techniques, geographic information system, management of live population, database management and molecular genetics), except that takes place in the universities by the graduate students as part of their fulfillment of the requirements to the degree. There is legislation concerning sanitary aspects of the AnGR including quarantine, which affects the movement of indigenous and exotic genetic resources. But in many cases illegal (smuggle) movement of both indigenous and exotic livestock breeds took place between Iraq and neighbor countries. Furthermore, no food product standard regulation or legislation exist which affects the use and conservation of AnGR. Consumer preference may indirectly affect the conservation of AnGR e.g. local animal products have more preference, and have higher price than imported meat. No standard or grading for any of the livestock products which could help conserving AnGR. In addition, there is no legislation and policies governing access to AnGR. Even the government policies do not encourage farmers to have animals through loans or providing inputs or services. Moreover, no legislation and policies related to ethical concerns regarding the use and welfare of animals, use and release of genetically modified organisms or that intellectual property right. Iraq has no bilateral or multilateral arrangements with other government, or research institutions, for training, exchange of information and materials and/or conservation of AnGR. This may due to no institution or organizations are involved in AnGR research, education, training and policy development.

The performance of livestock sector in Iraq reached a precarious stage since early eighties then declined noticeably, a result of this drop, and a reflection of it was a shortage of animal products (meat, and milk). The application of new technology in a proper manner can definitely be beneficial to the farmers and consumers. Increasing animal products to meet the rising demand is a designated developmental goal in Iraq. To achieve this goal, the government needs to invest more, both financial and material wise in order to increase animal products. Animal genetic resources in Iraq are among the most valuable and strategically important assets that can be developed and conserved that could contribute to improve animal product availability to the consumers, then they are currently contributing. Therefore, developing policies on AnGR for food is a must. Such policies should develop national capacities and international cooperation to achieve the sustainable intensification of livestock production systems, through the use of locally adapted AnGR. Such policies should decrease the gap between demand and supply of animal products. A number of constraints appear to limit the development of animal production. Top of the list are the shortage of animal feeds and low genetic potentials, in addition to animal and range management practices and lack of records. Attempts to characterize livestock breeds and identify appropriate measures to improve and develop AnGR are essential. In general, livestock breeds (local and adapted exotic) are well adapted to local condition. Genetic evaluation at the national level to select better genetically individual is required. Although, efforts have been exerted to improve animal health, diseases remain important factors contributing to mortality and low production. Improvement of livestock production should start with surveys, preparation of plans and programs, training and conducting research as well as advising animal's owners on better husbandry and means to improve the genetic potential of their animals. Thus, could help in conserving the diversity of AnGR. The strategies in the conservation, use and development of AnGR should be setup to assist farmers, breeders and scientists to better understand, use, develop and conserve livestock breeds and thereby contribute to supply consumers with animal products and to contributed to food security and rural development. As there is no strategies in the conservation, use and development of AnGR in Iraq, so no discussion of alternative strategies could be done. However, it is one of the priorities that ministry of agriculture should setup a strategy for conserving, use and develop AnGR. Special attention could be made if a national committee is formed for implementation of this duty. It was suggested the primary areas and issues that need to be the components of such strategy are:

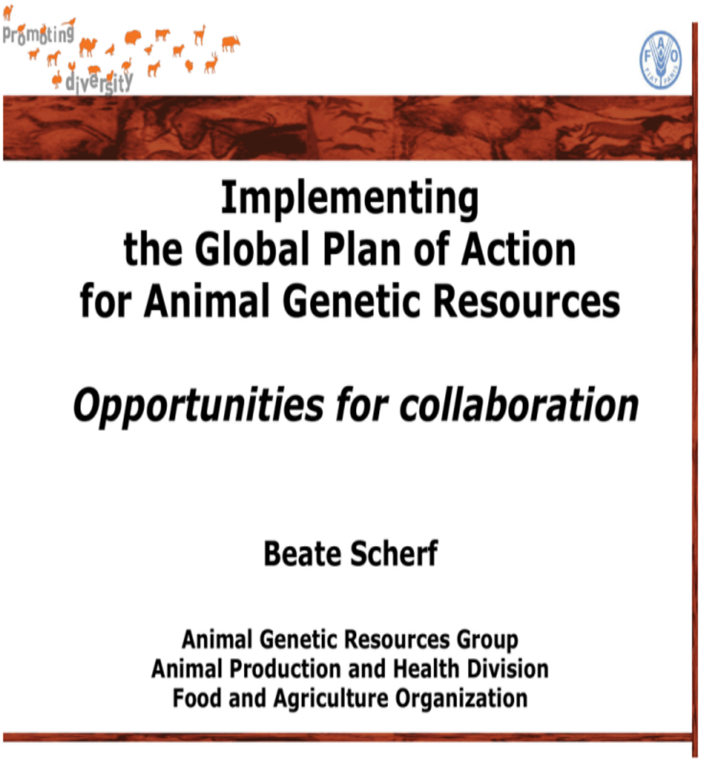
- Organizational structure: which is important to have some scientific structure or institution to be responsible for planning and implementation of the national policy, strategy and management for the conservation, use and development of AnGR. Such institute must have its financial resources and budget.

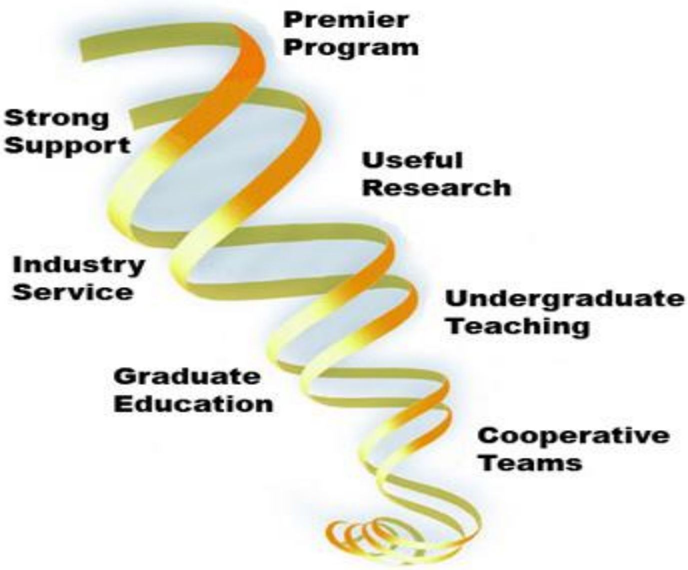
- Capacity building: especially that related to human resources (training, educational and technology transfer).

- Data and information management: baseline information about AnGR of all livestock breeds is required for characterization, identification, genetic evaluation and selection program for improvement of productivity. Such process would lead to better use, utilization and conservation of AnGR.

It has concluded from this chapter that the synergy between the major components of climate (precipitation patterns, floods and droughts, and the geographical redistribution of pests and diseases) influences the physiological, phenotypic, behavioral responses of livestock and productivity. Therefore, breeders of livestock have to do better with their environment by transforming farm systems by adopting better sustainable farming practices in this changing climate. There is a growing global general agreement that the negative effects of climate change will be of a similar nature in both low- and high-input animal production systems and the Earth's climate is expected to change continuously at rates unprecedented in recent human history.

Climate projections indicate a temperature increase of 0.28°C per decade over the next two decades; it predicts the increase in the average surface temperature of the Earth by the year 2100 between 1.88 and 4.08 degrees Celsius. Heat stress can negatively affect reproductive efficiency. Heat stress on animals is expected to increase in the coming decades. Pregnant and milk-producing ruminants are more susceptible to heat stress than non-pregnant and non-milked ruminants. In addition, physical environmental stressors negatively affect metabolism. Heat stress caused by climate change (increased environmental temperature, increased direct and indirect solar radiation, wind speed, and relative humidity). The impact of climate change may lead to changes in the composition of genetic factors (genes) within animals (especially in the stages of embryonic development) which will have changes in the DNA of future disease resistance, and the ability to reproduce and produce, as heat stress is toxic to cells, because it changes molecules biological, disrupts cell functions, perturbs metabolic reactions, leads to cell damage and activates cell death pathways. Climate change, which causes variable climate challenges for all animal breeds, is not only exposed to frequent and severe heat waves and droughts, and as a result, is likely to lead to lack of both feeds and water, which is considered a serious challenge to the homeostasis of sheep, especially in pastoral systems during long periods of drought. The frequency of catastrophic events (drought, floods, change in ambient temperature), as well as potential epidemic diseases and water scarcity, cause an increase in physiological stress and thus a decrease in productivity. The current and projected impacts of climate change vary locally, nationally, regionally and globally. The impacts of negative climate change impacts on livelihoods, food and water security, ecosystems/environmental systems, and infrastructure are different. Located in a water-stressed region with few of its own water resources, many societies in developing countries are facing significant and interconnected political, economic, environmental and security challenges. Accordingly, it is suggested maintaining genetic diversity. Base on the report of the Food and Agriculture Organization, many livestock breeds are extinct and many more will face extinction in the near future. Scientific assessment on the basis of genomic data, may be one of the benefits of upcoming genome techniques, providing a better view of the genetic background of genetic diversity. When tracing the biography of the local animals that lived hundreds of years and perhaps much more than that, whether they were cows, buffaloes, sheep, goats and poultry, they were able to preserve their lives, produce, reproduce and reproduce until we arrived today as if they live in the wild state in which they were raised. The FAO Global Strategy for the Management of Farm Animal Genetic Resources is to help benefit from animal genetic resources important for food security, rural economy, diversification and development. For the purpose of realizing this potential, animal genetics must be planned and developed to utilize these resources effectively to achieve the desired results. Locally adapted breeds are often able to survive and continue to perform and produce in poor environments, scarce forage resources, and weak and variable management. It is worth noting that mixing the genes of these local breeds with those of foreign breeds with high productivity will have a positive effect on collecting the characteristics of adaptation and living with the good productive qualities. The components of the technical infrastructure were also studied, which include saving local breeds through and a particular focus is on locally adapted breeds and low-input systems.


Promoting diversity
Implementing
the Global Plan of Action
for Animal Genetic Resources
Opportunities for collaboration
Beate Scherf
Animal Genetic Resources Group
Animal Production and Health Division
Food and Agriculture Organization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14-8: Cattle Biological Diversity

Native breeds of cattle are well adapted to local environment (high ambient temperature up to 50º c during summer and low ambient temperature, down to –10º c during winter, poor farming hygiene and deficient diets). Furthermore, the products of these native breeds are of high quality (good taste and flavor) as compared with products of exotic breeds. The main native (local) cattle breeds are the Jenubi, Karadi, Sharabi and Rustagi. The general characteristics of livestock breeds. It was reported that local cattle are genetically resistant to endemic diseases (especially theileriosis) and harsh environment (wide range of ambient temperature and low quantity of feed and water). Most cattle and buffaloes are found in and around the irrigated areas. At late forties and later until 1988 many exotic breeds were imported (Friesian, Currency, Ayrshire, Jersey, Brown Swiss, Sindi, Simental, Normandy, Tarentes, Abundance, Holstein, Herford, Charolais. Brahman). Traces of genes of these breeds is encountered here and there through crossing with local breeds. Though all these exotic breeds (as purebreds) suffered severely from acclimatization problems. Holstein-Friesian crossbred cattle were more tolerant to local environmental condition and was enjoying a fair rate of demand by breeders in Iraq. The AI service was planned during seventies to produce Holstein-Friesian × local cattle crossbred. Holstein frozen semen was imported from USA and West Europe to upgrade both Holstein-Friesian purebred as well as the Holstein-Friesian × local cattle crossbred. Selection and genetic evaluation using Animal Model technique was applied on Friesian and Holstein breeds, where there is recording system in the large-scale commercial farms. Screening young bulls was practiced in 2001 and 2002. Performance test was conducted on a number of young bulls. Superior young bulls based on the performance test (feed efficiency and growth rate) were selected and dispatched at AI center in Abu-Ghraib for semen collection and evaluation. Semen of Holstein or Friesian breeds are disseminated to grade-up local breeds. Most large-scale commercial farms with Friesian breed nowadays inseminating their breed with Holstein semen. It is worthwhile to mention that no selection was practiced on local cattle as the herder has 2-4 cows (household), which make it unpractical to carry out selection. In conclusion, there is not sustainable long run breeding plan. However, some tools of breeding program are in operation. AI is mainly used in cattle to produce crossbreds (Friesian or Holstein × local) to improve milk production and growth rate. Recording is practiced in the large scale-commercial dairy farms (about 10 farms, with a total of 20000 cows). No embryo transfer is carried out. Genetic evaluation is recently started using animal model in some large scale-commercial dairy farms and elite cows as young bulb mothers were identified. Therefore. there is no successful sustainable improvement program for some reasons, among these are the following:

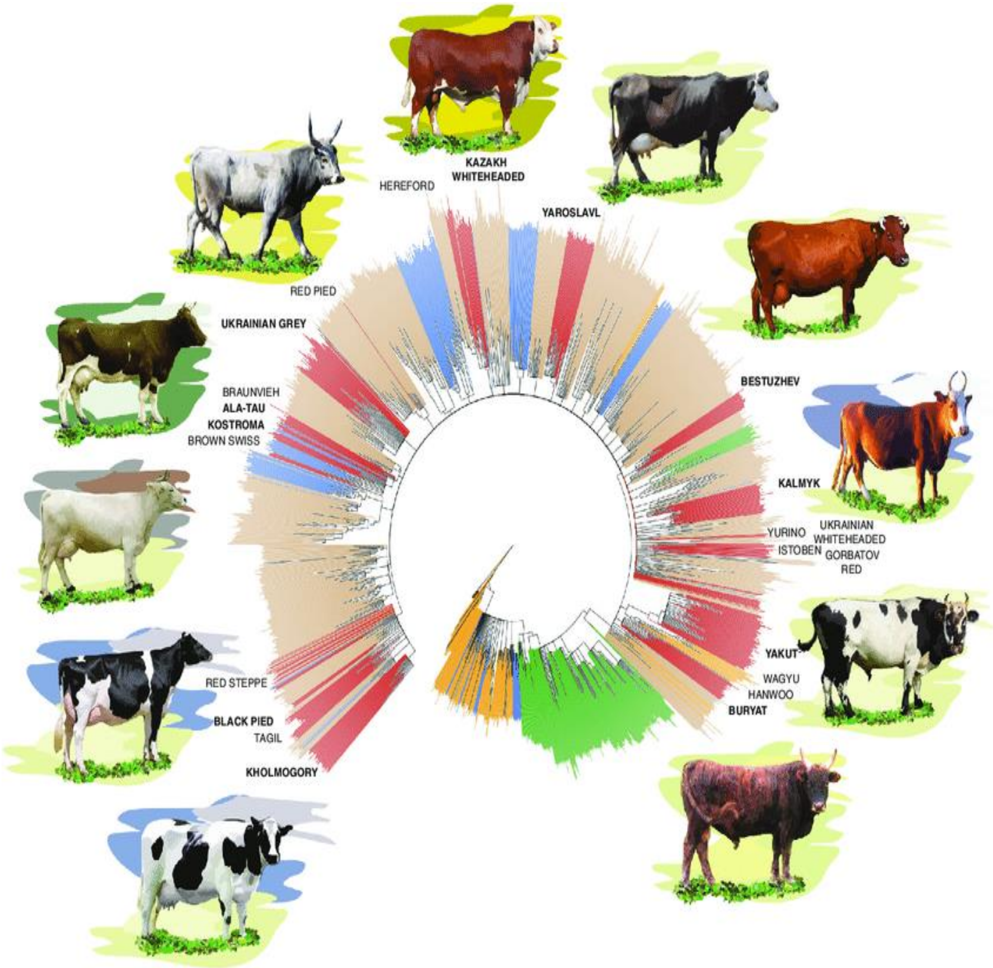
- No breeding policy and legislation assist the scientific researchers, cooperatives and farmers. No funds were allocated for such activities.

- Continuous changes and reorganization of the structures and bodies involved in livestock sector.

- Lack of practical experience needed for breeding program.

-The production system is one of the constraints to carry out breeding program (where there are few cattle-based production systems).

- Prices of livestock products are not geared towards meeting the requirements of breeding program.



14-9: State of Genomic Issues in Iraq

The performance of livestock sector in Iraq reached a precarious stage since early eighties and declined noticeably, a result of this drop, and a reflection of it was a shortage of animal products (meat, milk and eggs). Iraq's strategy for the livestock sector should be sustainable increase of animal products to satisfy domestic demand and enhance food security. Research centers and universities are studying the state of animal welfare and suggested methods and tools for improvement through classical and genomic techniques. There is no recognition and understanding of the role and value of genomic techniques in improving indigenous livestock breeds. Furthermore, there is no program to promote awareness of the role of genetics conservation strategies maintaining indigenous local breeds to meet future animal products demands. The main reasons for not having such strategies are lack of awareness, legislation, and lack of financial resources. It is suggested that the government should establish genomic office or department at the ministry of agriculture to plan and implement genomic especially of local breeds of livestock in coordination with universities staff, and related NGO. It is worthwhile to mention that some sort of genomic technique program is just started in Iraq. Such program for the improvement livestock sector should set out for the next 10-year as a comprehensive national strategy for application of livestock genomic technology to be launched for improving performance. Attempts to characterize livestock breeds and identify appropriate measures to improve and develop genomic are essential. In general, livestock breeds (local and adapted exotic) are well adapted to local condition. Genetic evaluation at the national level to select better genetically individual is required. Although, efforts have been exerted to improve animal health, diseases remain important factors contributing to mortality and low production. The application of new technology in a proper manner can definitely be beneficial to the farmers and consumers. Increasing animal products to meet the rising demand is a designated developmental goal in Iraq. To achieve this goal, the government needs to invest more, both financial and material wise in order to increase animal products. Animal genetic resources in Iraq are among the most valuable and strategically important assets that can be developed and conserved that could contribute to improve animal product availability to the consumers. Therefore, developing policies on genomic for food is necessary. Such policies should develop national capacities and international cooperation to achieve the sustainable intensification of livestock production systems, using locally adapted genomic resources. Such policies should decrease the gap between demand and supply of animal products. It is suggested the primary areas and issues that need to be the components of such program are:

- Organizational structure: which is important to have some scientific structure or institution to be responsible for planning and implementation of the national genomic program? Such institute must have its financial resources and budget.
- Capacity building: especially that related to human resources (training, educational and technology transfer).
- Data and information management: baseline information about genomic of all livestock breeds is required for characterization, identification, genetic evaluation and selection program for improvement of productivity.

As mentioned before that although Iraq has relatively good national capacities represented by numerous and diverse livestock breeds, its production potential is low and consequently animal products gap is noticeable. Future strategy should be planned. This strategy if implemented, future capacity of the national genomic would be contribute to food security and meet human needs of animal products. Care should be taken to both public and private institutions as well as for farmers, and individually and collectively communities to assist them to manage the genomic. Assessing the local and introduced breeds as well as their crosses, also the production systems and their role in genomic should be considered. It is also required to identify emerging issues (e.g. animal health, animal welfare and environment). Communication networking and organization capacity is important issues, which support the genomic program. As there is no regional, inter-regional or international link with Iraq in respect of genomic, it is recommended that bilateral, regional, inter-regional and global co-operation in relation to genomic should established. This because of many livestock breeds that exist in Iraq can be found in other countries e.g. Awassi breed can be found in Iraq, Syria, Jordan, Saudi Arabia, Turkey, Kuwait and Iran. A joint and Co-operation plan can be enhanced the genomic program in these countries.

Buffaloes can be found in Iraq, Syria, Egypt, Italy, India and Pakistan inter- regional genomic plan can enhance the genetic improvement, conservation, development and better utilization. Therefore, regional, inter-regional and global co-operations in characterization and evaluation of genomic resources will benefit all parties. Furthermore, the regional and global strategy would be a key element in country, regional and inter –regional efforts to use genomic resources in a sustainable manner, as well as co-operation in research and assist in communication networks. Global co-operation in genomic profile program could help in-country genomic program, as many decision-makers are not convinced with such activities. In conclusion, financial resources and legislation have the top priorities of needs for utilization of genomic technologies for the improvement of livestock.

Outlook at Biotechnology Programs in Iraq

Biotechnology became a science among all subfields of biology. The benefits of biotechnology have reached many practical fields, whether human health, animal, and/or agricultural. There are several institutes dealing with biotechnology issues in Iraq, among are:

1) Institute of Genetic Engineering and Biotechnology for Postgraduate Studies: The Institute of Genetic Engineering and Biotechnology - University of Baghdad was established in June 1999. Its activities focus on preparing specialized cadres holding postgraduate degrees in the field of genetic engineering and biotechnology, conducting scientific research, holding specialized courses and seminars, and contributing to the transfer of technology in this specialty. The Institute granted Higher Diploma, Masters, PhD in Genetic Engineering and Biotechnology. The most important scientific activities of the Institute are:

1- Issuing a semi-annual scientific journal (Iraqi Journal of Life Technologies), the first issue of which was published in 2002.

2- Organizing specialized courses in the field of PCR technology, isolating DNA from different sources, and separating biological products.
3- Establishing a consulting office to provide scientific services to postgraduate students.
4- Holding annual scientific seminars.
5- Holding scientific conferences, establishing the Institute of Genetic Engineering and Biotechnology for postgraduate studies to achieve leadership and innovation in the field of genetic engineering and biotechnology research, and to be a pioneer in creating a university environment that meets the aspirations of the country's students, enhances student activities and raises the level of students' thinking scientifically.
The Institute is committed to:
1- Preparing a graduate capable of competition and innovation locally and regionally and excels in scientific and applied research to serve society.
2 - The optimal use of the institute's capabilities in the three levels of transfer, represented in education, training, research and application.
3- Gathering research cadres from various scientific and technical disciplines in a multidisciplinary system.
4- Adapting to the changes taking place in the relationship between science and technology in terms of reducing the time period between detection and application and reaching the beneficiaries by conducting research in accordance with the agreements concluded to solve the field problems faced by these parties.
5 - Providing technical consultations, feasibility studies and field participation to solve problems facing the public and private business sectors, in addition to service agencies and research centers in the relevant ministries and agencies.
6 - Providing production models for the optimal use of genetic engineering and biotechnology with an economic goal.
7 - Granting higher degrees, in addition to preparing and training technical cadres capable of assisting in the implementation of

genetic engineering and biotechnology programs and projects at the Institute and other parties, as well as raising the research competence of specialists, provided that these programs are local, external, or joint.

8- Organizing conferences and holding seminars and scientific training courses individually or within specific agreements and courses in cooperation with universities, research institutes and centers and bodies of the public and private business sectors concerned with this activity at home and abroad, as well as issuing a peer-reviewed scientific periodical concerned with publishing research conducted in Iraq and abroad.

2) Al-Nahrain University - College of Biotechnology. The Department of Molecular and Medical Biotechnology was established in 2012 and the department seeks to upgrade the knowledge, skills and scientific research of its students and associates. The department's mission is to supply the society with qualified graduates who are qualified to work in the field Biotechnologies. The department seeks to grant a bachelor's degree in the specialty of molecular and medical biotechnologies by graduating cadres characterized by scientific competence and familiarity with the vocabulary of specialization able to work in medical laboratories and conduct laboratory analyzes and molecular examinations with quality standards and raising the professional skills of this specialization to contribute to building a society and strengthening scientific ties with regional and international universities and research centers. The department offers study programs and advanced research projects that aim to deal with microorganisms in the medical and immunological fields, as well as early investigation of the genes responsible for many genetic diseases by following modern techniques of genetic and immunological engineering and tissue culture of animal cells, thus making the specialty capable of providing society with knowledge.

3) Environmental Biotechnology Program/ University of Duhok: The Environmental Biotechnology challenges are to develop,

understand, and solve of basic and apparent environmental problems of the ecosystems. According to the international society for environmental biotechnology. The environmental biotechnology is defined as an environment that helps to develop, efficiently use and regulate the biological systems, and prevent the environment from pollution, to sustain an environmental friendly society. The interest of the working group in the lab of Environmental biotechnology includes:

1- Evaluate environmental problems and understand the new and emerging dimension of the environmental crisis.

2- Monitoring, analysis and use new technologies such as remediation to clean up some polluted sides in Kurdistan Region and Iraq.

3- To examine the interaction between species of different populations and understand the causal of dominance and exclusion of some species which led to reduce the diversity in the terrestrial and aquatic ecosystems.

4- Use of some local plants residues to produce bio-fuels.

By the way, it is worthwhile to mention that:

A) The Iraqi Journal of Biotechnology is an academic publisher of open access, peer-reviewed journal covering a wide range of academic disciplines. Seeks Review articles, and original contributions from all areas of Biotechnology, Biochemistry, Genetics, Molecular Biology, Environmental Science, Ecology, Immunology, Microbiology, Agricultural and Biological Sciences that are not published or not being considered for publication. *Iraqi Journal of Biotechnology (IJB)* is the official journal of Institution of Genetic Engineering and Biotechnology / University of Baghdad.

B) “Iraqi Biotechnology, Inc.” was founded in 2004 in an effort to provide researchers with high-quality products at low prices, and to be the leading service provider in all areas of laboratory and academic biotechnology in Iraq with a knowledge-based approach and personalized customer service. Iraqi Biotechnology, Inc. is a group of researchers with various specialties in sciences, dedicated to establish a company with scientific goals of serving the Iraqi scientific community and to keep Iraqi researchers and scientists up to date with all recent advancements.

Some of the General Characteristics of Iraqi Livestock Breeds.

- **Characteristics of Jenubi**

General information:	
Main location of breed within country:	South eastern and central Iraq
Main use:	milk
The number of females is:	decreasing
Number of males in AI service:	0
Adult live weight males (average, Kg):	325
Adult live weight females (average, Kg):	309
Adult wither height males (average, cm):	125
Adult wither height females (average, cm):	123
Color: uni coloured: usually red (golden to bright bay) multicoloured: sometimes pied	
Specific visible traits: Zebu, resemble Sahiwal	
Number of horns (male):	2

Number of horns (female):	2
Horn shape:	Moderate sized or quite small horns

Birth weight male (kg):	21.8
Birth weight female (kg):	20.7
Milk yield per lactation (kg):	1400
Lactation length (day):	240
Milk fat (%):	4.1
Daily gain (g):	557
Additional information: - feed conversion ratio 7.6 kg/kg; - mortality rate until weaning 6%;	
In-situ conservation and ex-situ preservation:	
Cryo-preservation semen (number of sires represented:	0
Cryo- preservation embryos:	no

- **Characteristics of Kurdi**

Species:	Cattle
Most common name (language abbreviation in brackets):	Kurdi (Eng.)
Other local names (language abbreviation in brackets):	Karadi (Arabic)
Taxonomic classifications:	Breed

Current domestication status:	domestic
Country:	Iraq
Main use:	meat
Adult live weight males (average, Kg):	300
Adult live weight females (average, Kg):	220
Adult wither height females (average, cm):	106
Color: coloured: black often with light markings	
Number of horns (male):	2
Number of horns (female):	2
Birth weight male (Kg):	14.5
Birth weight female (Kg):	14.5
Milk yield per lactation (Kg):	161
Lactation length (day):	74
Milk fat (%):	4.8
Daily gain (g):	379
Additional information: The lactation period is quite short and was measured from cattle milked by hand (removing all milk from the udder each time). -feed conversion ratio 12.68 kg/kg; - weaning weight 82.8 kg;	
In-situ conservation and ex-situ preservation:	
Cryo-preservation semen (number of sires represented):	0
Cryo-preservation embryos:	no

Birth weight male (Kg):	19.98
Birth weight female (Kg):	18.5
Milk yield per lactation (Kg):	1140
Lactation length (day):	197
Milk fat (%):	4
Daily gain (g):	633
Additional information: service period 82.3 – 130 days; - number of services per conception 1.74-1.83 –feed conversion ratio 8.28 kg/kg; -mortality rate until weaning a 5.3%;	
In-situ conservation and ex-situ preservation	
Cryo-preservation semen (number of sires represented):	
Cryo-preservation embryos:	

- **Characteristics of Rustaqi**

General information:	
Species:	Cattle
Most common name (language abbreviation in brackets):	Rustaqi (Eng.)
Other local names (language abbreviation in brackets):	Restaqi (Arabic)
Taxonomic classifications:	Variety
Current domestication status:	Domestic

Country:	Iraq
Main location of breed within country:	Around Hillah and Bagdad Regions
Risk status:	Not at risk
Population:	
Year of data collection:	1986
The number of females is:	stable
Number of males in AI service:	0
Morphology:	
Adult live weight males (average, Kg):	450
Adult live weight females (average, Kg):	400
Color: uni coloured: brown, light tan	
Number of horns (male):	2
Number of horns (male):	2
Origin of breed:	
Improved variety of Iraq, descended from Jenubi with some influence from Red Sindhi.	
Milk yield per lactation (Kg):	1200
Lactation lengthy (day):	210
Daily gain (g):	688
Additional information: - feed conversion ratio 7.39 - 8.45 kg/kg;	

In-situ conservation and ex-situ preservation:	
Cryo-preservation semen (number of sires represented):	0
Cryo-preservation embryos:	no

- **Characteristics of Sharabi**

General information:	
Species:	Cattle
Most common name (language abbreviation in brackets):	Sharabi
Current domestication status:	domestic
Main location of breed within country:	basin of Tigris river between Fishkhabour and Zummar
Morphology:	
Adult live weight males (average, Kg):	450
Adult live weight females (average, Kg):	400
Color: dark (black) with white line on the back abdomen. the legs are short but the body is full which is similar to beef _cattle breeds	
Number of horns (male):	2
Number of horns (male):	2
Milk yield per lactation (Kg):	1100
Lactation lengthy (day):	200
Daily gain (g):	800

Additional information: feed conversion ratio 7.0 - 8.0 kg/kg;	
In-situ conservation and ex-situ preservation:	
Cryo-preservation semen (number of sires represented):	0
Cryo-preservation embryos:	no

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Chapter 15

The Science Behind Embryo Transfer in Dairy Cattle Improvement

The Science Behind Embryo Transfer in Dairy Cattle Improvement

15-1: Introduction

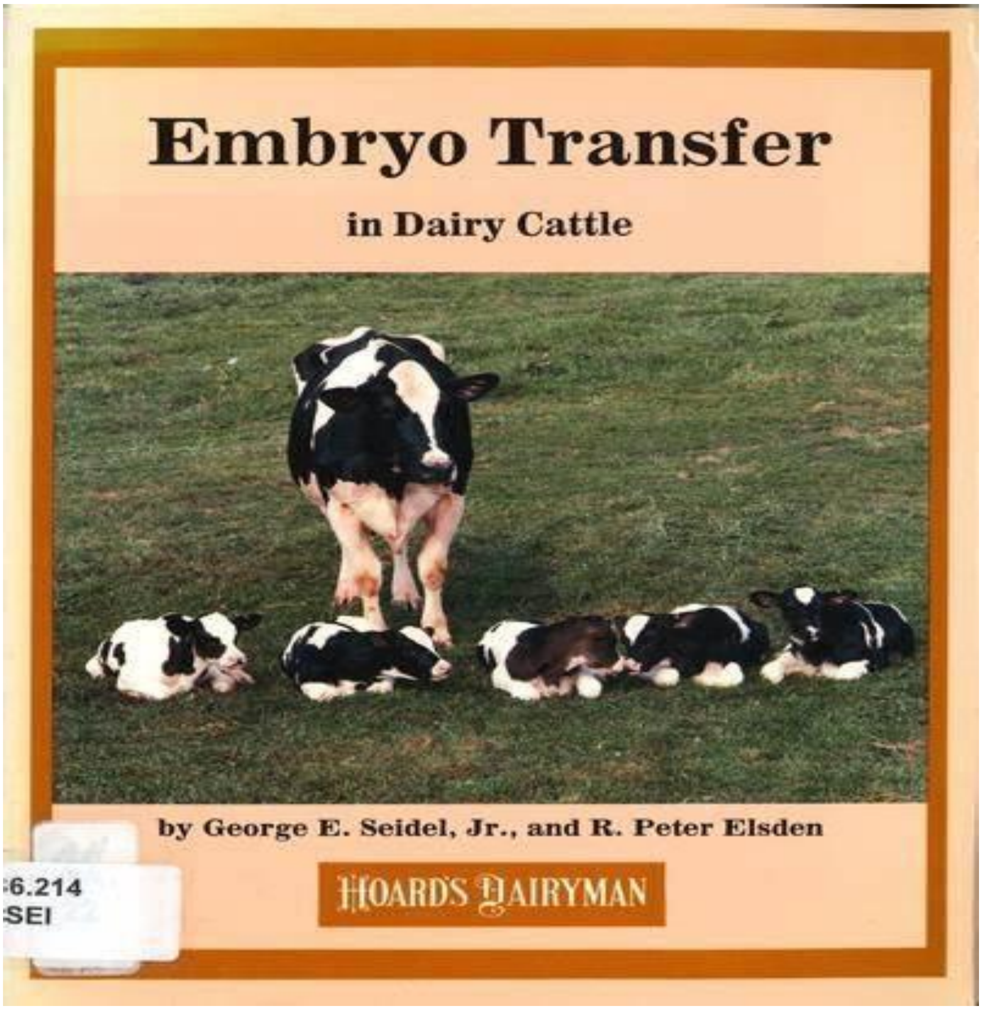
Embryo transfer is one step in the process of removing one or more embryos from the reproductive tract of a donor female and transferring them to one or more recipient females. Embryos also can be produced in the laboratory via techniques such as in vitro fertilization or somatic cell cloning. But the actual transfer of an embryo is only one step in a series of processes that may include some or all of the following: superovulation and insemination of donors, collection of embryos, isolation, evaluation and short-term storage of embryos, micro-manipulation and genetic testing of embryos, freezing of embryos and embryo transfer.

Embryo transfer in cattle has recently gained considerable popularity with seed stock dairy and beef producers. Most of the applicable embryo transfer technology was developed in the 1970s and 1980s; however, the history of the concept goes back much farther. Embryo transfer was first performed and recorded by Walter Heape in 1890. He transferred two Angora rabbit embryos into a gestating Belgian doe. The Belgian doe produced a mixed litter of Belgian and Angora bunnies. Embryo transfer in food animals began in the 1930s with sheep and goats, but it was not until the 1950s that successful embryo transfers were reported in cattle and pigs by Jim Rowson at Cambridge, England. The first commercial embryo transfers in this country were done in the early 1970s. Initially, embryos were recovered from valuable donors and transferred to recipient animals using surgical procedures. It was not until nonsurgical methods were developed in the late 1970s that embryo transfer grew in popularity.

The scientific and technological advances achieved during the past decades in animal reproduction have resulted in the development of a variety of tools commonly referred to as assisted reproductive technologies (**ART**). The primary focus of these tools is to maximize the number of offspring from genetically superior animals and disseminate germplasm worldwide. Furthermore, ART allows for the exploitation of donors with compensable anatomical disabilities and sub-fertile conditions, for safeguarding germplasm from threatened species and domestic breeds and for reducing disease exposure and transmission. While the number of *in vivo*–produced embryos that are collected and transferred worldwide seems to have stabilized in recent years, the transfer of embryos derived and transferred from *in vitro* production (**IVP**) continues to grow at an average annual growth rate of 12% (Figure 1a). In 2016, and for the first time in recorded history, the number of viable IVP embryos surpassed the number of transferable *in vivo*–produced embryos, based on data recorded by the International Embryo Transfer Society (**IETS**). However, this historic event is only based on the declared data submitted to IETS by volunteer participants, and as such it likely does not include the overall number (i.e., declared plus undeclared embryo production) of IVP and *in vivo*–produced embryos worldwide; therefore, it is within the realm of possibility that the actual event could have occurred even earlier.

According to the annual embryo production statistics presented by the IETS in recent years, more than 400 000 bovine IVP embryos were transferred worldwide (Figure 1a). Of the total embryos transferred, around 80% of them were transferred fresh (Figure 2). This reflects the fact that embryos produced *in vitro* have lower cryotolerance than their *in vivo* counterparts. In the late 1990s, the quantity of frozen-thawed embryos (both *in vivo* and IVP) transferred was practically similar to fresh (non-cryopreserved) embryos. Subsequently, the ratio of fresh IVP embryos transferred increased, but in recent years (2014 to 2016) there had been an increase in the number of transfers of frozen-thawed IVP embryos, possibly due to the use of advanced formulated culture media without (or with low) serum content and/or with specific embryo trophic additives promoting embryo quality. Another potential reason behind the increase in frozen-thawed IVP embryo transfers may be due to the improved efficiency linked to the use of co-culture in IVP. The reproductive potential of each normal newborn calf is enormous. There are an estimated 150,000 potentials “eggs” or ova in the cow and billions of sperm produced by each bull. By natural breeding, only a fraction of the reproductive potential of an outstanding individual is realized. The average herd bull will sire 15 to 50 calves per year, and the average cow will have one calf per year. With artificial insemination, it is possible to exploit the vast number of sperm produced by a genetically superior bull; however, the reproductive potential of the female has been largely unutilized. Under normal management programs, a cow produces an average of eight to ten calves in her lifetime. Like artificial insemination has done for the bull, embryo transfer is a technique that can greatly increase the number of offspring a genetically important cow can produce.

Multiple ovulation and embryo transfer (MOET) has been established in cattle breeding since the 1970s. It is an efficient means to increase the number of offspring from genetically superior females. Despite nearly 50 years of development, the average number of transferable embryos recovered in a single embryo collection has remained nearly constant at approximately six embryos per donor. Several factors contribute to the outcome of superovulation and embryo recovery. These comprise animal-related, environmental and management factors. The most prominent factor affecting the success of superovulation is an animal-related attribute: the ovarian follicular population responsive to exogenous gonadotropin stimulation. Environmental factors, such as heat stress or other external factors causing stress, can compromise the embryo yield after superovulation. However, such factors represent a management challenge. The super ovulatory outcome is additionally affected by several factors that can conflict with management decisions, including nutritional management of the donor, gonadotropin treatment protocol and semen and technical performance of donor inseminations.



15-2: History and Perspectives on Bovine Embryo Transfer

For an historical perspective on assisted reproduction, the reader is referred to a comprehensive review of farm animal embryo transfer and its associated technologies (Betteridge, 2003). In brief, the first successful transfer of mammalian embryos was performed by Walter Heape in 1890. Heape transferred two four-cell Angora rabbit embryos into an inseminated Belgian doe, which subsequently gave birth to four Belgian and two Angora young (Betteridge, 2003). There were no reports of further success in mammalian embryo transfer until the 1920s, when several investigators again described embryo transfer in rabbits. Warwick and colleagues did considerable work on embryo transfer in sheep and goats in the 1930s and 1940s, but it was Umbaugh ,1949 who reported on the first successful embryo transfers in cattle. He produced four pregnancies from the transfer of cattle embryos, but all the pregnancies were terminated before full term. In 1951, the first embryo transfer calf was born in Wisconsin following the surgical transfer of an abattoir-derived day-5 embryo.

Embryo transfer organizations: The IETS was founded in 1974, with 82 Charter Members, representing researchers, academics and veterinary practitioners from around the world. The IETS became the main forum for scientific and regulatory exchange and discussion in the field of embryo transfer and associated technologies. The Proceedings of the Annual Meeting of the IETS, which were published as the first issue of Theriogenology each year, served as a yardstick with which to measure changes in emphasis and intensity of activity in embryo transfer. More recently, the IETS Proceedings have been published in the first issue of Reproduction, Fertility and Development. It is noteworthy, that since 1978, the proceedings of the Annual Meeting of the IETS have been published and available to registrants at the time of the meeting.

With the founding of regional embryo transfer organizations, a growing number of commercial embryo transfer practitioners have discontinued membership in the IETS in favor of their regional organizations. A growing number of the IETS members have been basic researchers representing government, industrial or academic institutions, including human medicine. However, the IETS has played an important role in the dissemination of basic and applied information, allowing for the rapid growth of the embryo transfer industry. In particular, the Import/Export Committee of the IETS (now referred to as the Health and Safety Advisory Committee; HASAC) has been instrumental in gathering and disseminating scientific information on the potential for disease control with bovine embryo transfer. The Manual of the International Embryo Transfer Society "A procedural guide and general information for the use of embryo transfer technology emphasizing sanitary procedures" has become the reference source for sanitary procedures used in embryo export protocols.

In 1982, the American Embryo Transfer Association (AETA) was formed to unite and organize the commercial embryo transfer industry in the USA, and in 1984, the Canadian Embryo Transfer Association (CETA) was formed. Objectives included the establishment of standards of performance and conduct, and a liaison with Federal agencies for both domestic and international embryo transfer. These associations also interact directly with breed associations, producer groups and international groups such as the IETS. They established standards of practice to provide confidence within each country, and internationally, for the utilization of embryo transfer technology. In this regard, their Certification Programs are integral in ensuring that Embryo Transfer Practitioners are technically and ethically competent in the handling of embryos used in international trade.

The Brazilian Embryo Technology Society (SBTE) was founded in Brasilia in 1985, as a private, not-for-profit organization of professionals dedicated to embryo transfer technology. Member's interests related primarily to cattle, horses and small ruminants, but also included swine, companion animals, laboratory species and wild and endangered species. Its stated goal is to serve as a forum for the exchange of information among practitioners, scientists, educators, livestock breeders and students as well as suppliers in the area of reproductive biotechnology. SBTE aimed to promote the science of animal embryo technology by encouraging effective research, disseminating scientific and educational information, maintaining high standards of ethics and cooperating with other organizations with similar objectives.

A transfer in the 1970s, its most common use in animal production programs was the proliferation of so-called desirable phenotypes. However, the University of Guelph introduced the concept of MOET (multiple ovulation and embryo transfer) in 1987. They showed that MOET programs could result in increased selection intensity and reduced generation intervals, resulting in increased genetic gains. The establishment of nucleus herds and "Juvenile MOET" in heifer offspring was shown to result in genetic gains that approached twice those achieved with traditional progeny test schemes. It is noteworthy that prior to the Guelph work, most embryo transfer done in Canada was in beef cattle, whereas approximately 84% of the embryo transfer work done in Canada in 2011 involved dairy cattle. On the other hand, approximately 61% of embryo transfer work in the USA continues to involve beef cattle. Embryo transfer is now commonly used to produce AI sires from the top producing cows and proven bulls. In addition, new genomic techniques are being used increasingly to select embryo donors; genomic analysis has become essential for the selection of bull dams to be used in embryo transfer. Although economics would seem to preclude the use of embryo transfer techniques for anything but seed-stock production at this time, the commercial cattle industry has benefited from the use of commercial bulls produced through well designed MOET programs. The success of MOET programs has also led to the use of this technology to genetically test AI sires, bulls were proven by production records from siblings rather than offspring. It was possible to genetically test a bull in 3.5 years as opposed to 5.5 years using traditional progeny testing schemes, which also resulted in shortened generation intervals.

Steps for Embryo Transfer in Cattle: Virtually all commercial embryo transfers use nonsurgical recovery of the embryos rather than surgical techniques. The process involves several steps and considerable time as well as variable expense.

a-Selection of the Donor Cow

The first step is selecting a donor cow. Beef producers will differ in their opinions regarding the criteria for selecting a genetically outstanding cow.

b-Superovulation of the Donor Cow

Superovulation of the donor cow is the next step in the embryo transfer process. Superovulation is the release of multiple eggs at a single estrus. Cows or heifers properly treated can release as many as ten or more viable eggs at one estrus. Approximately 85 percent of all normal fertile donors will respond to superovulation treatment with an average of five transferable embryos. Some cows that are repeatedly super ovulated at 60-day intervals may produce fewer number of eggs over time.

c-Insemination of the Cow

Because of the release of many ova from multiple follicles, there is a greater need for viable sperm cells to reach the oviducts of the super ovulated females. Therefore, many embryos transfer technicians will choose to inseminate the cow several times during and after estrus. One scheme is to inseminate the super ovulated cow at 12, 24 and 36 hours after the onset of standing estrus. Using high-quality semen with a high percentage of normal, motile cells is a very critical step in any embryo transfer program. The correct site for semen placement is in the body of the uterus. This is a small target (1/2 to 1 inch) just in front of the cervix.

d-Flushing the Embryos

To collect the embryos nonsurgical, a small synthetic rubber catheter is inserted through the cervix of the donor cow, and a special medium is flushed into and out of the uterus to collect the embryos seven days after estrus.

e-Evaluation of the Embryos

As the individual embryos are located using a microscope, they are evaluated for their quality and classified numerically as to the potential likelihood of success if transferred to a recipient female. The major criteria for evaluation include:

• Regularity of shape of the embryo

• Compactness of the blastomeres (the dividing cells within the boundaries of the embryo)

• Variation in cell size

• Color and texture of the cytoplasm (the fluid within the cell wall)

• Overall diameter of the embryo

• Presence of extruded cells

• Regularity of the zona pellucida (the protective layer of protein and polysaccharides around the single celled embryo)

• Presence of vesicles (small bubble-likestructures in the cytoplasm)

Embryos are classified according to these subjective criteria as:

Grade 1: Excellent or good

Grade 2: Fair

Grade 3: Poor

Grade 4: Dead or degenerating

Embryos also are evaluated for their stage of development without regard to quality. These stages are also numbered:

Stage 1: Unfertilized

Stage 2: 2 to 12 cell

Stage 3: Early morula

Stage 4: Morula

Stage 5: Early blastocyst

Stage 6: Blastocyst

Stage 7: Expanded blastocyst

Stage 8: Hatched blastocyst

Stage 9: Expanding hatched blastocyst

f-Selection and Preparation of Recipient Females

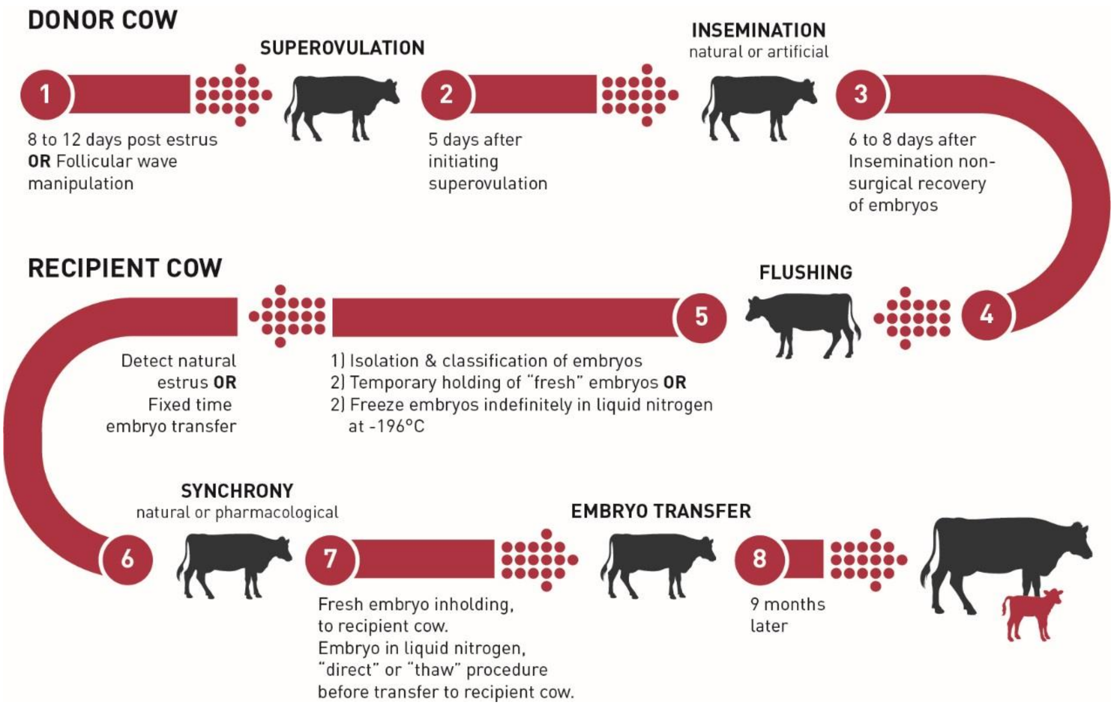
Proper recipient herd management is critical to embryo transfer success. Cows that are reproductively sound, that exhibit calving ease and that have good milking and mothering ability are recipient prospects. They must be on a proper plane of nutrition (body condition score 6 for beef cows and dairy body condition score 3 to 4). These cows also must be on a sound herd health program.

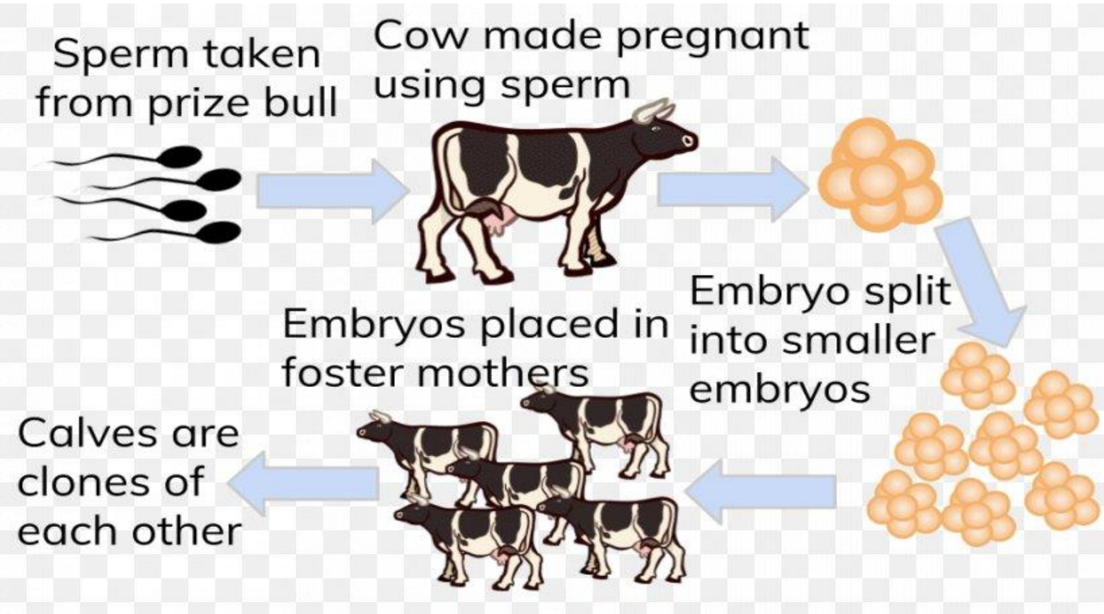
g-Transfer of the Embryos

The transfer of the embryo into the recipient cow first requires "loading" the embryo into a 1/4-mL insemination straw. This is done under microscopic viewing with the aid of a 1-mL syringe and requires considerable practice, patience and dexterity. Degenerated embryos or embryos of very low grade need not be loaded and can be discarded. Just prior to embryo transfer, the ovaries of the recipient are palpated rectally to determine which ovary has ovulated. With the aid of an assistant to hold open the vulva of the recipient cow, the transfer gun or insemination rod is carefully passed through the cervix. The tip of the rod is then allowed to slide into the horn on the same side of the ovary with an active corpus luteum. The embryo is gently expelled in the forward tip of that uterine horn. Great care is taken to not cause damage to the lining of the uterus. Such inflammation and scarring would greatly reduce the probability of the pregnancy being established. Embryo flushing and embryo transfer are both done after an epidural anesthetic has been given to block contractions of the digestive tract and aid in the ease of manipulation of the cervix and the uterine horns. Embryos should be transferred as soon as possible after the flush (within 8 hours at least).

h-Expected Embryo Transplant Results

Embryo production varies greatly from donor to donor and flush to flush. Average production is approximately six freezable (excellent and good) and eight transferable (excellent, good, fair and poor) embryos per superovulation.

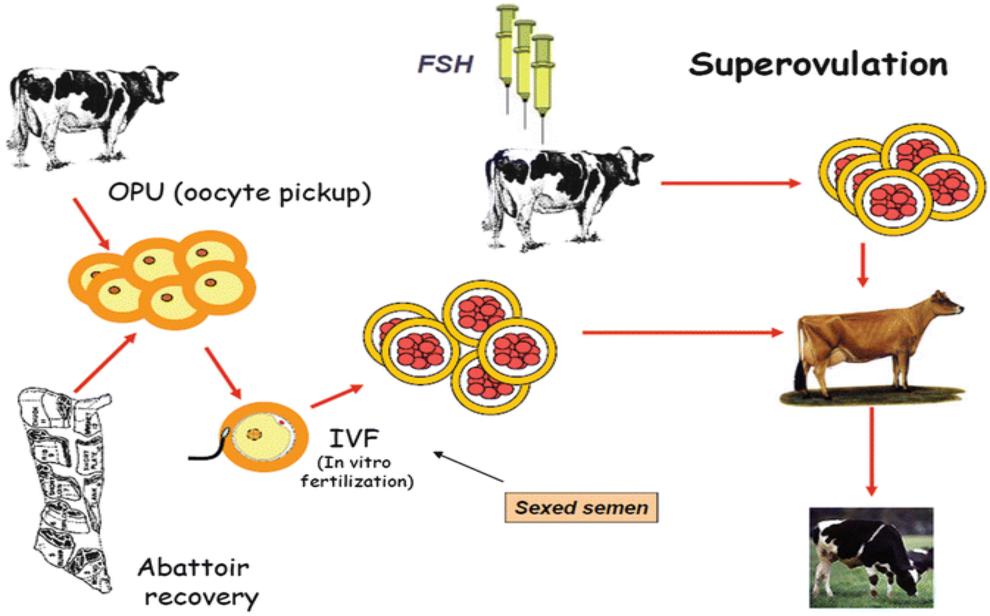

DONOR COW
SUPEROVULATION
INSEMINATION
natural or artificial
1
8 to 12 days post estrus
OR Follicular wave
manipulation
2
5 days after
initiating
superovulation
3
6 to 8 days after
Insemination non-
surgical recovery
of embryos
RECIPIENT COW
FLUSHING
4
5
Detect natural
estrus OR
Fixed time
embryo transfer
1) Isolation & classification of embryos
2) Temporary holding of "fresh" embryos OR
2) Freeze embryos indefinitely in liquid nitrogen
at -196°C
SYNCHRONY
natural or pharmacological
EMBRYO TRANSFER
6
7
8
Fresh embryo inholding,
to recipient cow.
Embryo in liquid nitrogen,
"direct" or "thaw" procedure
before transfer to recipient cow.
9 months
later

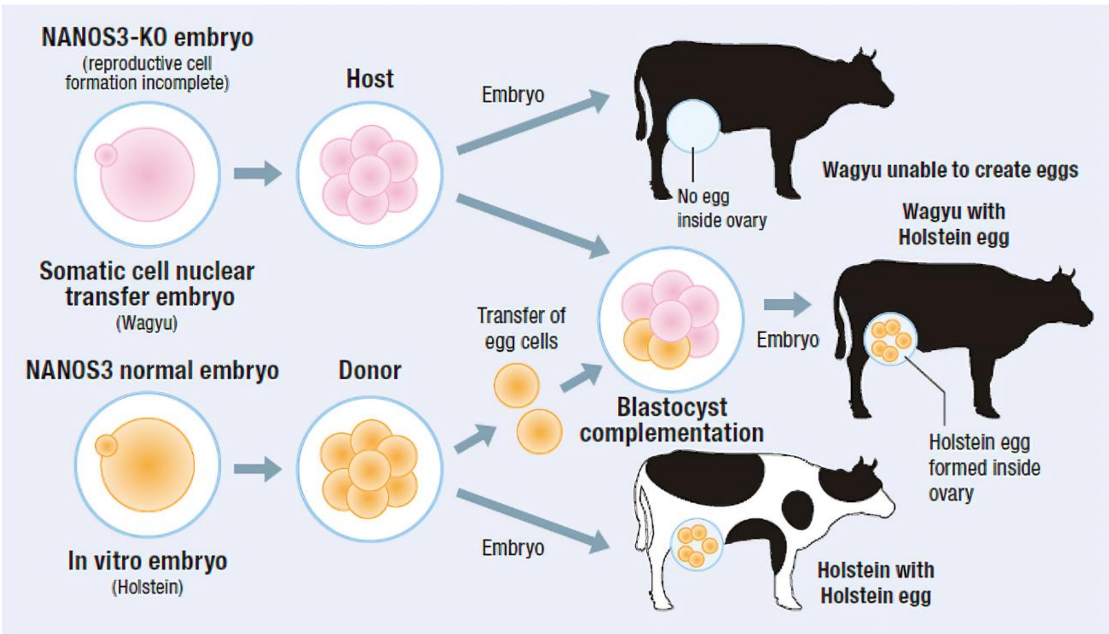

Sperm taken
from prize bull
Cow made pregnant
using sperm
Embryo split
into smaller
embryos
Embryos placed in
foster mothers
Calves are
clones of
each other

15-3: Improving National Fertility Evaluations by Accounting for The Rapid Rise of Embryo Transfer in US Dairy Cattle

Reproductive problems are one of the top reasons for culling in US dairy herds. Cow fertility data have been available from the DHIA for many years but were not routinely evaluated until 2003. At that time, evaluations were administered by the USDA Animal Improvement Program Laboratory (AIPL) researchers who developed format 5 as an avenue to collect reproductive records from US herds. These include information like inseminations for cows, heat detection, breeding's, pregnancy checks, synchronized breeding events, embryo donation, embryo implantation, sire and donor/recipient dams of embryo, and were stored in the AIPL database. Format 5 was developed in 2002 for efficient internet exchange and database storage of up to 20 reproductive events per lactation for millions of cows and heifers each month. For embryo recipient events, the sire and donor dam are stored in 2 separate segments to reduce the maximum format length from 1,047 to 737 bytes, reduce transfer time, and reduce storage required. The AIPL took over the calculation of estimated relative conception rate in May 2006, which characterized fertility by the non-return rate, an indirect measure of fertility estimated by the proportion of cows that are not re-bred during 70 d after first insemination. Around this time, a massive research effort was launched to improve the accuracy of male fertility evaluations and broaden the scope to also include female fertility. In August 2008, sire conception rate (SCR) was implemented, and heifer conception rate (HCR) and cow conception rate (CCR) were similarly developed and released in January 2009. Since 2013, the newly reformulated Council on Dairy Cattle Breeding (CDCB) inherited responsibility for the data stewardship and administration of evaluations, whereas the Animal Genomics and Improvement Laboratory (formerly AIPL) remains as their research partner. Genomic evaluations for HCR and CCR are now provided to producers on a weekly basis by CDCB and SCR 3 times per year to address the high demand for accurate fertility evaluations to guide farm breeding programs.

Reproductive technologies have advanced significantly because these conception rate evaluations were developed and, consequently, dairy herd reproductive management is changing. Commercial embryo transfer (ET) began in the 1970s and today is becoming increasingly popular in herds desiring to increase their rate of genetic progress. Part of the attraction of ET can be explained by substantially reduced generation intervals among habitual ET users. Embryos purchased in high enough volumes could cost as little as $100 per embryo, putting ET at a competitive price level to AI services, which are approximately $15 per conventional service and $30 for sexed semen. Benefits from ET may be more than twice those of AI due to higher conception rates and providing selection gains for breeding value (BV) instead of transmitting ability. With embryo transfer conception is not actually occurring, and so inconsistent reporting of ET calves and breeding events could bias fertility trait evaluations in the population. The United States has previously imposed edits on data that exclude known ET donors and reported recipients in our evaluations, and only 3 Interbull-participating countries account for ET by excluding ET records. This research was motivated by industry member requests to investigate anecdotal reports of bulls with large changes in EBV for conception rate and discussions on the increase in the ET popularity. In April 2022, new edits better accounting for the discrepancies in ET reporting were implemented. In this paper, we detail the research supporting these changes, explore their effect on SCR, HCR, and CCR for 5 common dairy breeds in the context of bull age, bull genetic merit, bull popularity for ET, and overall bull popularity, and discuss the critical need to improve high-quality reproductive management reporting.


FSH
Superovulation
OPU (oocyte pickup)
IVF
(In vitro
fertilization)
Sexed semen
Abattoir
recovery


NANOS3-KO embryo
(reproductive cell
formation incomplete)
Host
Embryo
Wagyu unable to create eggs
No egg
inside ovary
Wagyu with
Holstein egg
Somatic cell nuclear
transfer embryo
(Wagyu)
Transfer of
egg cells
Embryo
NANOS3 normal embryo
Donor
Blastocyst
complementation
Holstein egg
formed inside
ovary
In vitro embryo
(Holstein)
Embryo
Holstein with
Holstein egg

15-4: Effects of Embryo Transfer on Genetic Change in Dairy Cattle

Genetic improvement is a powerful tool for improving animal agriculture sustainability because the results are permanent and cumulative. Unlike nutritional and animal health interventions, which require continuous inputs, genetic improvements made in one generation are passed onto the next. Moreover, genetic solutions for animal health and welfare issues often require less labor and material inputs than chemical or mechanical methods. For example, polled, or hornless, genetics can eliminate the need for physical dehorning of animals, which is undertaken to ensure both worker and animal safety, can save livestock producers both time and money, in addition to addressing an animal welfare concern. Sustainable agriculture and increased production efficiency go hand-in-hand. Efficiency is defend as achieving maximum productivity with minimum waste, or in other words, producing more product with the same or even fewer resources. Livestock genetic improvement programs, beginning with selective breeding using statistical prediction methods, such as estimated breeding values (EBVs), and more recently genomic selection (GS), in combination with assisted reproductive technologies (ART) have enabled more accurate selection and intense utilization of genetically superior parents for the next generation to accelerate rates of genetic gain.

Genetic gain is the amount of increased performance, or the improvement in average genetic value, in a population that is achieved annually through selection. Increased animal performance based on genetic improvement results in more product produced per animal, so fewer animals are required to meet the same amount of demand, which reduces the environmental impact per unit of livestock product. Therefore, increasing rates of genetic gain can improve livestock production efficiency and ultimately the sustainability of animal agriculture.

The power and scale of genetic improvement is well illustrated by the increased efficiency of the United States (U.S.) dairy cattle population from 1944 to today, which now produces over 80% more milk with 65% fewer cows. Is was enabled by a more than four-fold increase in milk production per cow, from 2000 kg/cow in 1944 to 10,000 kg/cow in 2017. It is estimated that approximately 50% of the increased productivity per animal observed can be attributed solely to the increased rate of genetic gain obtained by the widespread use of artificial insemination (AI) over natural service breeding alone. Overall, the dramatic decrease in the number of dairy cows (25.6 million to 9 million) required to meet the demand, due to increased productivity per animal largely from improved genetics, reduced the current environmental impact of a glass of milk to approximately one third of that associated with the same glass of milk in 1944. In livestock breeding programs, the breeder's equation is used to measure the rate of genetic gain (ΔG) towards the breeding objective of a given production system. It consists of four components: G = i×r×σAL, where i is selection intensity (how extensively the most elite animals are used as parents of the next generation); r is selection accuracy (how well the EBV represents the true breeding value of selection candidates); σA is genetic diversity (as measured by the additive genetic standard deviation of the population); and L is the generation interval (interval length calculated as the average age of parents when progeny are born). Strategies to improve rates of genetic gain in a population involve increasing the components of the breeder's equation in the numerator and decreasing the denominator, or generation interval. It is important to note that the foundation of genetic improvement is a well-structure//d breeding program with a clear breeding objective, and routine recording of pedigree and performance information on the population under selection. Genomic information can additionally improve the accuracy of the relationship matrix compared to pedigree information alone. Within a structured breeding program, reproductive and molecular biotechnologies, such as ART and The relatively low reproductive rate of dairy cows has dictated the current breeding structure and has placed an upper limit on selection intensity in females. The low intensity normally possible in cows reduces genetic progress from female selection relative to that of more prolific species. Additionally, accuracy of female selection has been suppressed by reproductive rate. The advent of practical embryo transfer (ET) techniques in recent years has increased potential reproductive rates of females. Consequent improvements in selection intensity and accuracy need to be evaluated for their impact on rate of genetic gain per generation and per unit of time. Our presentation is to evaluate possible effects of ET on genetic progress within and across herds.

Potential improvement in rate of genetic gain ~ through ET techniques exists in many forms. Examination of the impact of ET technology was restricted to the following areas

1) Production of bulls for progeny test through artificial insemination (AI).

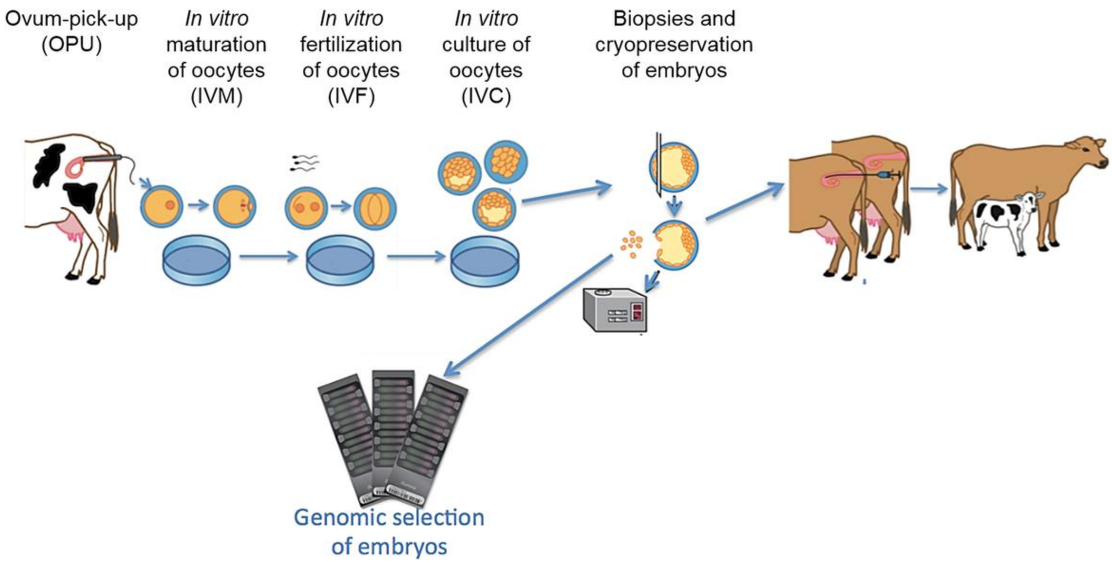
2) Production of replacement females.

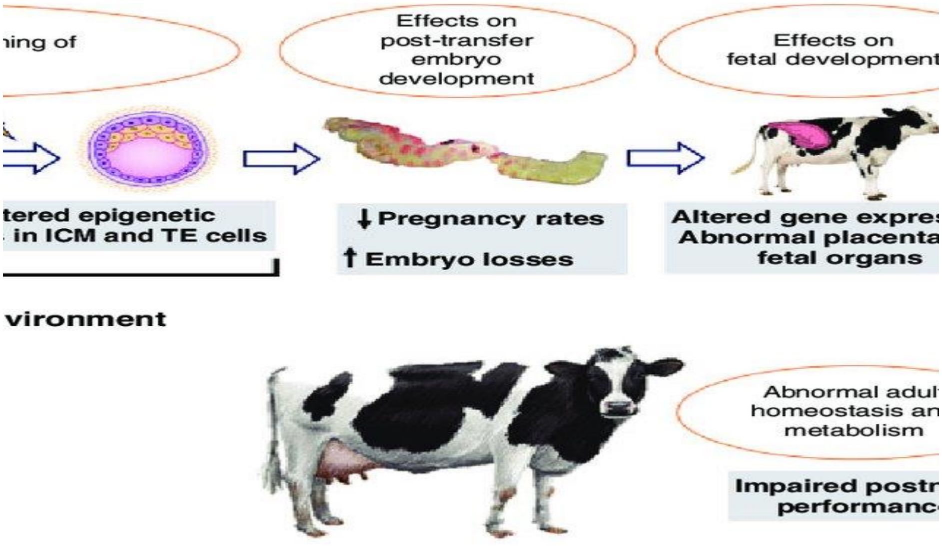
3) Progeny testing dams.

Economic considerations ultimately will determine the extent to which ET techniques are applied. While primary emphasis in this report is on genetic impact of ET, underlying economic issues cannot be ignored entirely. Concluded that economic impact of ET will follow the order listed above. Some of these authors did not consider all three areas in reaching their conclusions, but application of ET to the dam-son path of descent was conclusively the most important examined in each paper. Economic comparisons of the dam daughter path and progeny testing of dams' have produced less clear conclusions but still suggest that ET application ultimately will follow the order listed above.

Embryo transfer has added a new dimension to animal reproduction and breeding. It is now possible to obtain up to 40 offspring from a selected female in I yr. Originally all transfers were done surgically; however, recently, non-surgical embryo recovery has been highly successful. Future developments are required for equal success in non-surgical implantation. The problems in embryo transfer rest with unreliable superovulation, fertilization, embryo and recipient identification. Pregnant mare serum gonadotrophin has shown considerable variation as a super ovulating agent when administered to embryo transfer donors with the use of prostaglandin F2o as a leuteolytic agent. Sources of variation in donor and recipient females are discussed, including egg quality, timing of transfer and the use of surgical and non-surgical transfer procedures. With the use of optimal conditions, it should be possible to obtain an average of approximately eight pregnancies per successful donor. The role of embryo transfers in beef, dual purpose and dairy improvement programs is discussed. Embryo transfer is currently being used for the expansion of limited gene pools whereas in the future such transfers will be for the successful proliferation of offspring from the mating of genetically superior dams and sires. A doubling of response can be obtained in beef improvement programs where defined objectives can be identified. GS, can be applied to further accelerate rates of genetic gain by influencing one or more of the components of the breeder's equation.

To increase selection intensity, ART [e.g., AI and embryo transfer (ET)] have been incorporated into cattle breeding schemes. Concurrently, the development of high-throughput genotyping of single nucleotide polymorphisms (SNPs), has enabled GS to predict the genetic merit of an animal based on its DNA. Using GS has both improved the accuracy of selection and reduced the generation interval. Additionally, GS can provide information on traits that are recorded late in life, or that are difficult or expensive to record. Moreover, the benefits of each of these tools, GS and ART, can be maximized when used synergistically to accurately select young animals, which can markedly reduce the generation interval and ultimately accelerate genetic gain. Genome or gene editing (GnEd) is one of the most recently developed tools for genetic improvement. Tis advanced biotechnology allows animal breeders to very precisely target the addition, deletion, or replacement of base pairs in the genetic code to influence traits of interest. Specifically, GnEd refers to the use of site-directed nucleases (i.e., nucleic acid cleaving enzymes) to precisely introduce double stranded breaks (DSB) in the DNA at a targeted location in the genome. When the cell attempts to repair the DSB, it can result in the disruption (knockout) of a gene, or if a donor repair nucleic acid template is provided, the insertion (knock-in) of an allele or gene from the same species (intraspecies or cisgenic) or possibly a different species (interspecies or transgenic).





15-5: The Role of Embryo Transfer in Cattle Improvement Program

Genetic improvement of cattle can be divided into two steps: (l) the identification of the most productive breed or cross under the management and geography of a particular operation, and (2) subsequently the long-term improvement by selection of the best performing animals in the identified population. In cattle, the progress that can be made in both steps of livestock improvement is limited by the low rate of female reproduction. Therefore, any increase in the reproductive performance of selected females would contribute to the rate of genetic improvement of a population through the proliferation of superior bloodlines and more intense selection. Commercial embryo transfer units have been established on the basis of the economic demand to meet the first step by increasing the numbers of animals of imported breeds which have been limited in numbers by health quarantine facilities. In the long run, however, the success of embryo transfer will be in the successful proliferation of offspring from mattings of genetically superior sires and dams to enhance selection intensity, not simply in the expansion of limited gene pools as at present. Embryo transfer is presently being utilized in cattle breeding programs without much attention being given to the genetics of embryo transfer. Although many technological aspects, such as reliable superovulation, remain to be perfected, commercial application of the Cambridge embryo transfer procedures are in wide use. The successful utilization of both surgical and non-surgical embryos transfer in animal breeding programs represents a significant new approach for animal breeders, since it permits the production of increased numbers of offspring from mating of genetically superior parents. Normally a breeder can only expect four or five daughters, ranging over several years in age, to be produced in a dam's lifetime by natural reproduction. Through the use of embryo transfer, it is possible to produce several daughters from specified mattings, all of the same age, which permits an increased selection intensity. Discussion is currently centered on methods of documenting cows of superior production performance to act as transfer donors. Some of the criteria which might be considered in evaluating prospective cows for embryo transfer to maximize the possible contribution of embryo transfer to cattle improvement programs include:

l. Regular oestrous cycles commencing at a young age.

2. No more than two breeding services per conception.

3. First three calves born within 2 calendar yr.

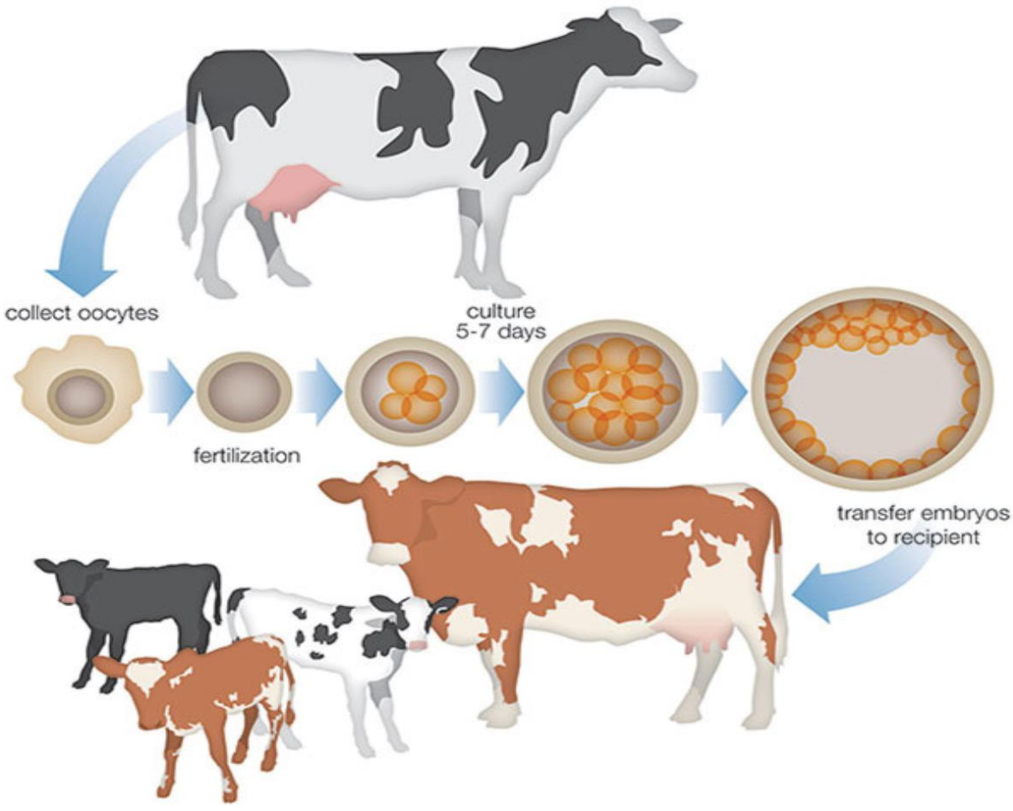
4. Superior individual performance for traits of economic importance.

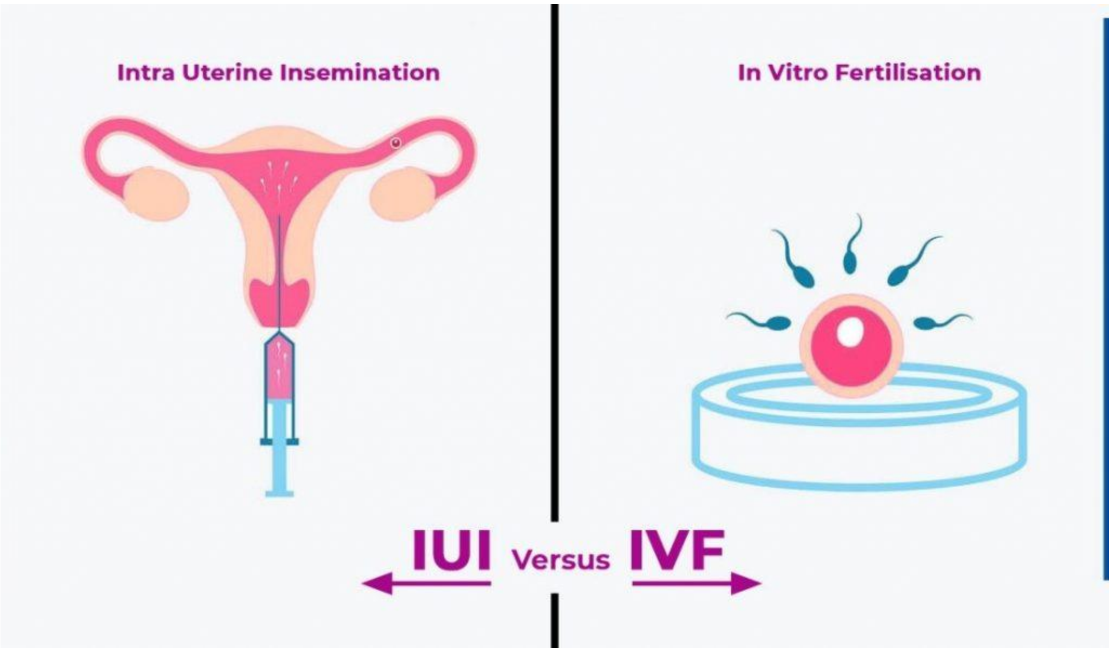
5. Above-average productive performance of offspring from previous ' mattings of the same sire and dam.

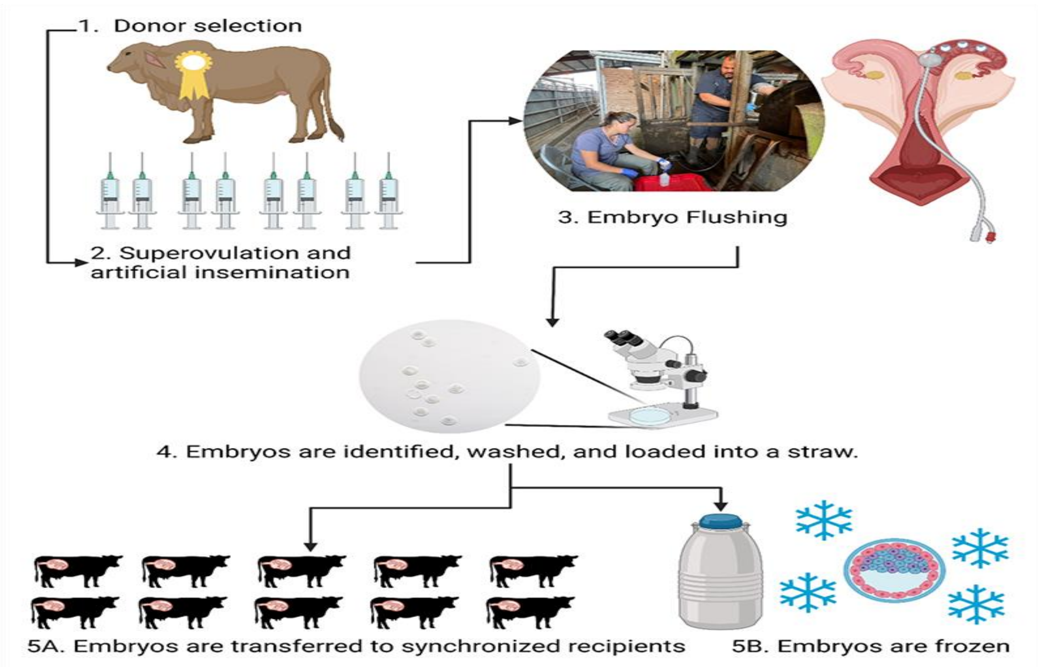
6. No parturition difficulties or reproductive irregularities.

7. No conformational or detectable genetic defects.

A cow with a regular reproductive history whose offspring perform well may be an unsuccessful donor in an embryo transfer program, since her past reproductive per for mince may be a reflection of good reproductive management and veterinary care as opposed to inherent reproductive superiority. Thus, not all reproductively sound females have the ability to respond to present transfer technology. Conversely, an apparent non breeder of considerable genetic potential may well have tubal blockage cleared, or low level infection resolved and subsequently become reproductively sound due to the flushing of the upper tract in surgical embryo transfer.



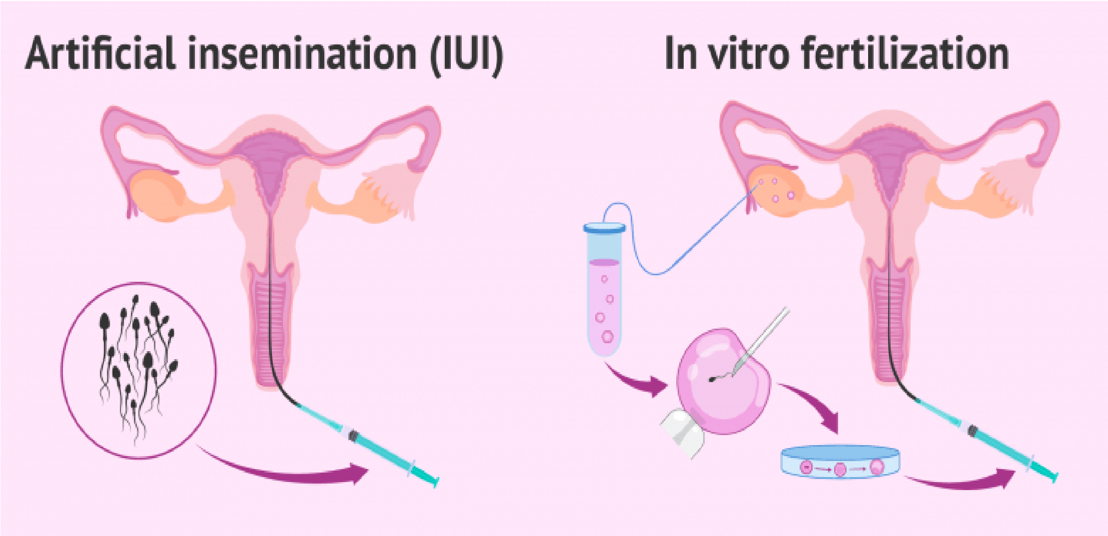

Intra Uterine Insemination
In Vitro Fertilisation
IUI
Versus
IVF

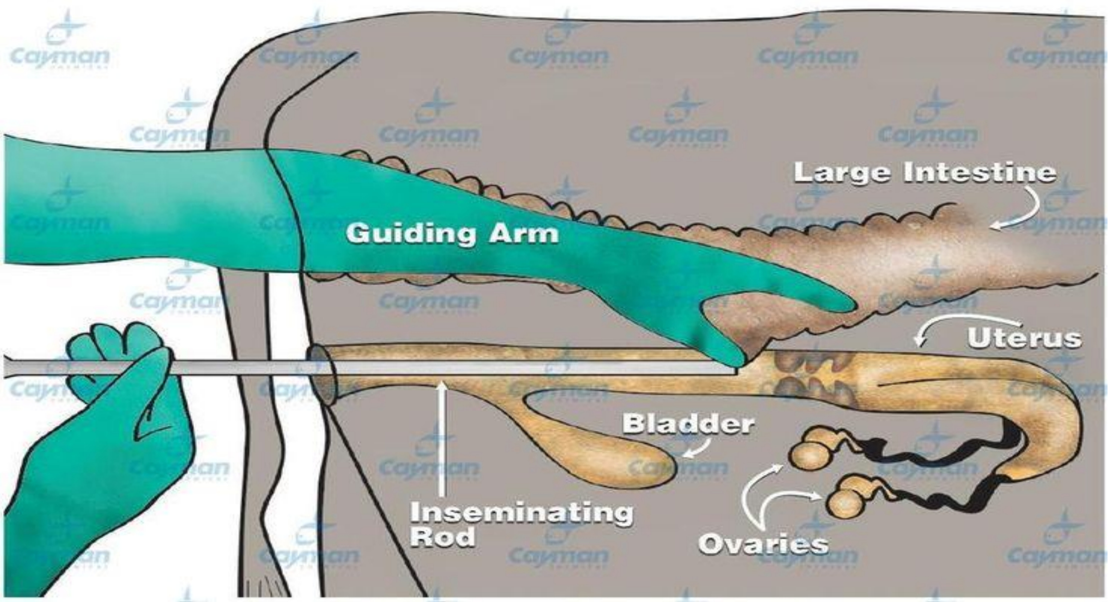

1. Donor selection
2. Superovulation and artificial insemination
3. Embryo Flushing
4. Embryos are identified, washed, and loaded into a straw.
5A. Embryos are transferred to synchronized recipients
5B. Embryos are frozen

15-6: Comparison of Artificial Insemination Versus Embryo Transfer in Lactating Dairy Cows

Several reports have described an association between high milk production and low reproductive efficiency in dairy cows. At least three studies have shown that lactating dairy cows have poor early embryonic development. Reported a very high percentage of non-viable embryos (70% during summer and 50% during winter) by Day 6 after estrus, as compared to heifers during summer (30% non-viable embryos) and non-lactating cows during winter (20% non-viable embryos). Moreover, although fertilization of the oocyte in lactating cows appeared to be decreased by summer heat stress, fertilization rate for lactating cows during winter was very high (90%).

Therefore, low conception rates (CR) in lactating dairy cows appear to be at least partly due to compromised early embryonic development, which can be augmented by fertilization failure and more profoundly impaired early embryonic development during heat stress. A number of studies from Florida compared embryo transfer (ET) to AI in order to improve CR of lactating dairy cows during summer heat stress. In all these studies, CR was greater for ET than AI when fresh or frozen in vivo produced embryos were transferred, or when fresh in vitro produced embryos were used. To the best of our knowledge, there is no published study in which ET was compared to AI in dairy cows during cooler times of the year. Therefore, it is not known whether transfer of an embryo would improve CR and reduce pregnancy loss in lactating dairy cows during non-heat stress times of the year. The present experiment tested the hypothesis that CR can be improved by ET compared with AI, not only during summer (as demonstrated by other studies), but also during other seasons of the year. In addition, we hypothesized that the high pregnancy loss (Day 25 and later) after AI of lactating dairy cows could be overcome by ET, consistent with the idea that events in the oocyte or during early embryonic development are responsible problems in pregnancy.

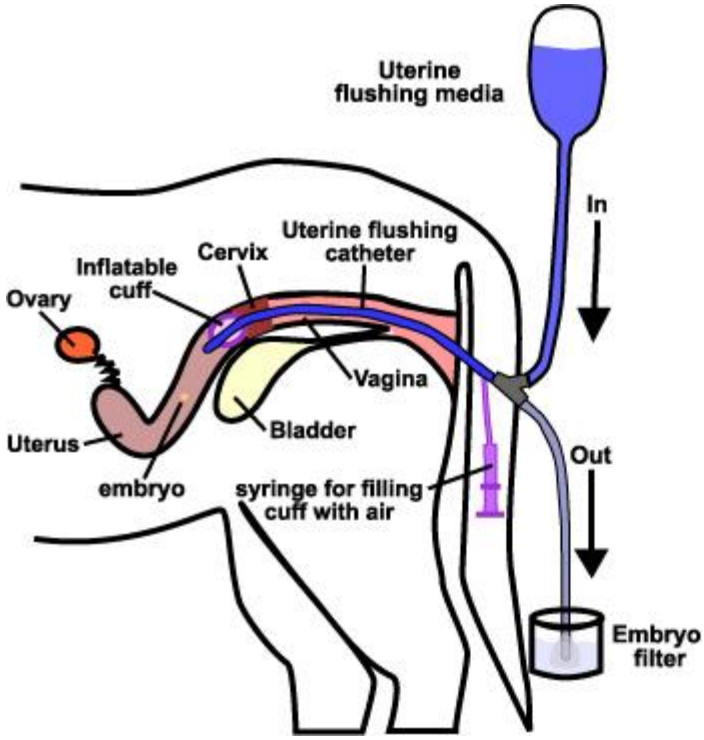


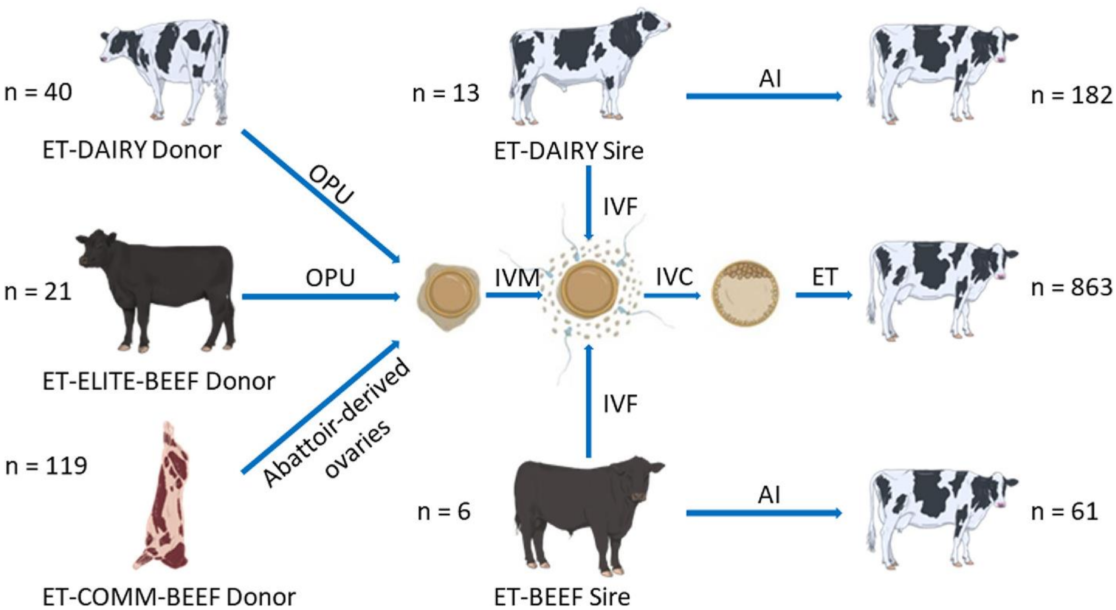


15-7: Biotechnologies of Reproduction Applied to Dairy Cattle

The reproductive biotechnologies discussed in the present paper are related to the embryo. They have been developed in parallel with our acquired knowledge regarding embryo development. Although not as widely used as artificial insemination, they have contributed substantially to the improvement of the dairy cattle industry through the production and reproduction of seed stock animals. Substantial commercial application of embryo transfer started in the early 1980s with the development of super ovulatory regiens and efficient cryopreservation techniques. More recently (1990s), a new generation of embryo technology has developed, based on in vitro embryo production with the use of oocytes collected from live donors. The objectives of the present paper are to discuss the benefits that those embryo technologies have already given to the dairy industry and their potential for the future.

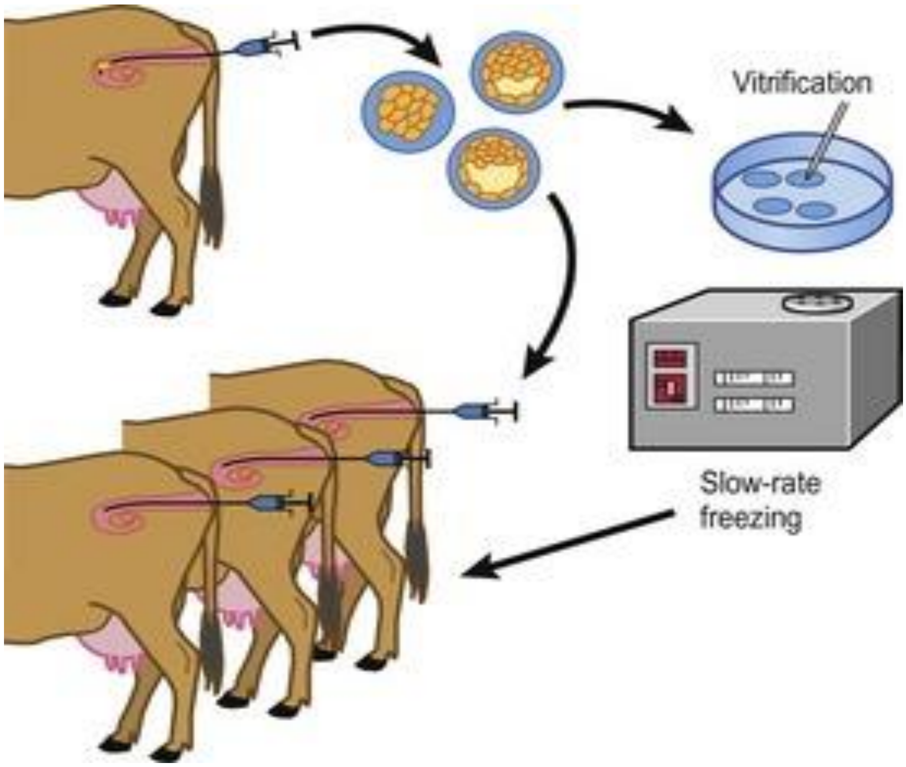
IVF activities. In 2000, throughout the world approximately 530 000 bovines in vivo derived embryos were transferred. Since the early 1990s, annual growth in the number of ET is a little more than 1%. In 2000, >110 000 cows were flushed, with an average of 5.9 transferable embryos per collection. Approximately 53% of the embryos were transferred frozen and the others fresh. In Canada and United States, a total of 224 451 bovines in vivo derived embryos were transferred, with 74 and 37%, respectively, produced from dairy cows. Although the utilization of ET is relatively low compared to the use of AI, more than 95% of dairy bulls in AI centers are produced through ET, clearly demonstrating the importance of this technology to the dairy industry. With the advent of ET, every high-ranking bull dam can contribute one or more sons for progeny testing. This was not the case prior to availability of ET technology.


Uterine
flushing media
In
Uterine flushing
catheter
Cervix
Inflatable
cuff
Ovary
Vagina
Bladder
Uterus
embryo
syringe for filling
cuff with air
Out
Embryo
filter


n = 40
ET-DAIRY Donor
OPU
n = 21
OPU
ET-ELITE-BEEF Donor
n = 119
Abattoir-derived
ovaries
ET-COMM-BEEF Donor
n = 13
ET-DAIRY Sire
AI
n = 182
IVF
IVM
IVC
ET
n = 863
IVF
n = 6
ET-BEEF Sire
AI
n = 61

15-8: Superovulation and Embryo Transfer in Dairy Cattle/ Effect of Management Factors with Emphasis on Sex-Sorted Semen

Multiple ovulation and embryo transfer (MOET) entered into standard use in dairy cattle breeding since commercialization of the industry in the early 1970s, enhancing production of multiple offspring from genetically superior females. However, the efficiency of a superovulation and embryo collection procedure has not improved markedly during four decades of commercial embryo transfer (ET). The efficiency of a superovulation procedure is evaluated in terms of the numbers of viable embryos, pregnancies and live calves. The number of viable embryos recovered from a donor in one embryo collection averages six, but varies considerably among animals, with approximately 15% of embryo collections resulting in no transferable embryos and a small proportion of donors producing 20-50 embryos. Among all donors in the Finnish breeding program, 35% at the embryo collection center produce 70% of the embryos. The unpredictability arising from individual variation in the super ovulatory response is a major limiting factor determining the efficiency of MOET in breeding programs. There are numerous donor-related, environmental and management factors that affect the success of superovulation and embryo recovery in cattle. Investigate management factors that affect the efficacy of MOET. First, the effect of nutritional protein in the form of rapeseed meal on superovulation of dairy heifers was studied. One-year old heifers were fed diets formulated to meet energy requirements for 800 g daily gain and crude protein either at 14% or 18%, which was higher than the feeding recommendations and the common practice on farms. There was no effect of the higher protein level on the ovulation rate, total number of embryos recovered or the number of transferable embryos. Feeding an energy-adequate diet containing moderate or high protein with respect to feeding recommendations resulted in comparable embryo yields. The efficacy of two commercial FSH products was compared in a retrospective study on super ovulations of heifers and cows on Finnish dairy farms and an embryo collection station. A highly purified porcine FSH with a low LH:FSH ratio, Folltropin, was used for 2592 super ovulations, and Pluset, containing equal amounts of LH and FSH, was used for 1398 super ovulations. Pluset-treated donors had a higher ovulation rate, yielding 1.1 recovered structures (embryos and ova) more than those receiving Folltropin. However, the difference was characterized by more unfertilized ova (UFO). For transferable embryos, the number, quality and developmental stage were similar for both preparations. Therefore, it can be concluded that the efficacy of the preparations is comparable. The effect of sex-sorted semen on efficacy of MOET was investigated from a dataset of commercial embryo collections and transfers. A total of 443 embryo collections produced with sex-sorted semen and 1528 produced with conventional semen were analyzed. Sex-sorted semen decreased the number of transferable embryos and increased proportions of UFO and degenerated embryos, compared with non-sorted semen. The decrease was more evident in cows than in heifers. The proportion of poor quality embryos was higher and there was a slight delay in the embryo developmental kinetics for sexed embryos. The risk of recovering no transferable embryos was increased when sex-sorted semen was used. Pregnancy rates after transfer of embryos produced with sex-sorted semen were 12% lower than for embryos originating from conventional semen. It can be concluded from these studies on sexed semen that the use of sex-sorted semen is profitable because more female calves can be produced from a donor heifer, wasting less recipient resources. For super ovulated cows, equal numbers of female calves can be produced per embryo collection, but the need for only half the number of recipients compared with using conventional semen favors the use of sexed semen when female progeny are desired.



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