Dairy Cattle **3**

JEAN MARGERISON

Key concepts

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3.1 Introduction

World milk consumption was approximately 190 million, most (81%) of which was produced by dairy cows, which reached a population of 137 million in 2020. There are approx. 150 million households involved in the production of milk in the world, which are largely small family farms in developing countries, including Thailand, compared with large-scale specialized enterprises in developed countries and China. The vast majority of milk is consumed in the region where it is produced in the form of fresh dairy products, including pasteurized and fermented products, along with ultraheat treated (UHT) milk, while solid processed dairy products, such as especially milk powders, cheese, and butter are exported and the consumption of these are closely related to income growth. This and increases in human population are expected to increase global milk and product consumption by 1.6 percent annually between 2020 and 2029, to reach 997 million tons by 2029. The required increase in milk production is likely to be met by optimization of milk production systems, through improvements in animal health, feeding efficiency and the continued genetic improvement of plants and animals. This will result in an increase in milk yield per cow in most production systems, except for grazing-based systems which are more likely to increase milk yield by increasing the number of cows kept and milk yield per ha. The main challenges faced by the dairy production industry are related to human mortality due to antimicrobial resentence (AMR), climate change and loss of wildlife biodiversity. The industry must lower antibiotic use and be carbon neutral by 2050. This will be achieved by improving animal health and welfare through disease prevention and enhancement of natural microbiome and immunity. While the carbon footprint will be lowered by the adoption of changes in whole farm management practices that lower gas emissions and nutrient leaching, source and selling of products more locally and increase carbon sequestration and wildlife biodiversity on farm.

~~Globally there are over 270 million cows producing milk. India has a large population, using both buffalo and dairy cows for milk production, but yield per animal is relatively low (2000 to 3,000 L/cow/yr) due to inclement weather conditions and feed quality, but they are increasing the productivity of the national herd The European Union (7346 l/cow/y) is one of the largest milk producers and has approx.3 (20.5 ex UK) million dairy cows compared with 10 million cows in the USA (10,62 l/cow/y) and there are 5.92 million dairy cows in New Zealand (4,259 l/cow/y) and 1.5 million cows in Australia (6,170 l/cow/y) In South-East Asia dairy cow numbers and milk production continues to increase, including countries that have not traditionally milked dairy cows, such as China (5,803 l/cow/y), which now have over 12 million cows producing milk (Table 3.1), along with Thailand (3,000 l/cow/y) and other Asian countries.~~

~~< **Table 3.1** Countries with the greatest cow populations (Source Statista 2021) > **near here**~~

~~Most of the milk is produced from specialized dairy cattle breeds, predominantly the Holstein Friesian, followed by a relatively small percentage of Jersey and even fewer~~

~~numbers of Brown Swiss, Guernsey and traditional breeds such as Ayrshire and Dairy Shorthorn. The Holstein Friesian represents over 90% of dairy cattle in North America and the EU, with relatively low levels (5%) of Jersey. The Holstein breed has been actively selected as a specialist, single-purpose milk-producing animal capable of high volumes of milk production and is easily managed in automated milking systems. The milk yield per cow continues to increase, mainly due to improved genetic merit, nutrition, disease control and prevention. However, infertility continues to be one of the main challenges, this related to the high milk yield of early lactation coinciding with the onset of ovarian activity and need for to generate conception at about 80-100 days post-partum to ensure regular, approximately annual, calving which is an essential contributor to efficient milk production. The selection of cattle for dairy production has lead to a competition for partitioning of nutrients, which is prioritized towards milk production, relative to the maintenance of body condition and reproduction. This has been exacerbated by the selection of Holstein dairy cattle and bulls for high milk production, rather than fertility and other important traits consistent with longevity, such as mobility, mammary conformation and heath. In recent years there have been changes in genetic selection of Holstein bulls and breeding policies, to place greater emphasis on fertility and health, along with production and, more recently, feed efficiency. In addition, crossbreeding of Holstein and Jersey remains popular in countries and on farms operating New Zealand style pasture-based systems.~~

~~The other main dynamic of dairy production has been the general continued trend towards fewer larger dairy herds, with many dairy units now including thousands and, in some countries, such as China, many thousands of cows on a single dairy unit. This leads to new challenges in herd and personnel management in the dairy industry and the regular use of standard operating practices (SOPs) by farm personnel. Other advances have been the continued application of on-farm quality assurance schemes, for feed manufacturers and milk producers, that ensure the quality and safety of milk production for human consumption.~~

3.1.1 Milk production for human consumption

The production of milk is monitored through on-farm milk testing and farm assurance schemes, which are based on recording and regular assessment of the production system. The areas assessed include staff training, animal welfare using the five freedoms, food safety using the principles of hazard identification, risk assessment and control, management of animal health through forward planning and disease prevention, the adequacy and appropriateness of animal nutrition and protection of the environment. These are independently assessed by qualified inspectors using accredited systems to monitor dairy farms at regular intervals. These procedures, along with full traceability of the product supply chain, including animals and feeds along with rigorous milk quality testing are essential for consumer confidence. In developed countries, an increasing emphasis has been placed on animal welfare, environmental protection and now the carbon footprint~~limate change~~. The production and supply of milk is dominated by milk buyers, particularly supermarkets, who use individual farm assurance requirements as marketing tools and these standards change more rapidly than~~t~~ and often exceed government legislation. ~~and the national assurance standards.~~ These typically involve additional assessment ~~monitoring~~ and requirements related to ~~of~~ animal health

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and welfare, environmental standards, along with monitoring and recording, which reflect the need to market milk staple food product~~s such as milk~~ in accordance with consumer perceptions of the dairy industry.

3.1.2 Consumption of milks and human health

<Figure 3.1 Composition of whole milk from differing breeds of dairy cattle**.> Near here**

The main constituents of milk are water, fats, proteins and lactose (Figure 3.1). It can be consumed as liquid milk or converted by different processes (traditional or modern) into a variety of dairy products and food ingredients and has some industrial uses. The concept of nutrition of humans in developed countries has progressed from the simple provision of adequate nutrients to include longer-term health benefits and risks. Although obesity and diabetes are major modern concerns in the developed, over-fed world, the high nutritive value of dairy products mean that they can make a valuable contribution to the daily human diet. Increasing wealth has allowed the consumption of dairy products in many countries. The greatest increases in milk production and consumption of milk are occurring in Asia.

Milk from dairy cows plays a significant role in the human diet in developed and developing countries and the consumption of three portions of dairy products daily has been recommended for a well-balanced human diet and weight control. Cow milk and dairy products are known to be an excellent source of fatty and amino acids, along with bioactive minerals and vitamins and a balanced diet contains three portions of dairy products daily. Unfortunately, i~~I~~n developed countries the consumption of soya and nut milks have become increasingly popular. However, these are nutritionally inferior compared with milk from cows, mainly due to the relatively poor amino acid profile and porosity of bioactive minerals, particularly calcium. Some of these alternative milks have a high sugar content. These factors make them nutritionally inferior and unsuitable for children and adolescents, especially females who need to consume enough ~~that require sufficient~~ bioavailable calcium to build and maintain good bone density to avoid post-menopausal osteoporosis and potentially meet the demands of pregnancy and lactation. ~~and avoid post-menopausal depletion of bone strength.~~

The consistent consumption of milk products from cows promotes good bone and tooth health, and is an essential source of minerals and vitamins, along with other functional components that include natural antioxidants and anti-carcinogenic agents. The concentration of certain essential fatty acids such as conjugated linoleic acid (CLA) can be affected by the cow's diet and milk from cows consuming grazed and/or fresh pasture contains higher amount of CLA compared with cows consuming conserved grass.

The consumption of cow's milk is not considered suitable as a direct replacement for breast milk in young infants and currently breast feeding is recommended, where possible, for at least the first 6 months of age. This can be ameliorated and eventually replaced by cow or goat milk in most cases. Naturally existing lactose intolerance, due to a lack of suitable intestinal enzymes, exists in a relatively small proportion of the human population and the consumption of goat milk or de-lactosed cow milk products are potential alternatives. People with continued problems should consult their doctor in the first instance, potentially followed by a qualified dietician for suitable and alternative approaches to achieve a well-balanced diet.

~~<**Figure 3.1** Composition of whole milk from differing breeds of dairy cattle.> **Near here**~~

In developing countries, dairy products make a great contribution to the improvement of human health, but they can be scarce or prohibitively expensive and or of poorer keeping quality. Due to the importance of m~~M~~ilk and dairy products ~~are particularly important~~ in the development of dense bones, strong teeth and mental ability, especially in children, ~~. Milk products are an excellent source of amino acids, essential fatty acids, minerals, particularly bioactive calcium and vitamins. Consequently, the development of da~~dairy production in countries such as China and Thailand has been supported greatly by the government. ~~to improve the health and development of the national population, particularly to improve bone and teeth health.~~ These counties in general consume all home-produced milk and continue to be net dairy product importers, mainly in the form of milk powder. Increasing wealth is~~has~~ resulting ~~ed~~ in greater dairy product consumption per capita and less lactose intolerance as dairy consumption becomes more common place, while bone pain and poor dentition remains a problem in more senior generations, due to the lack of adequate dairy consumption previously.

3.2 The Global Dairy Industry

Globally there are over 270 million cows producing milk. India has a large population, using both buffalo and dairy cows for milk production, but yield per animal is relatively low (2000 to 3,000 L/cow/yr) due to inclement weather conditions and feed quality, but they are increasing the productivity of the national herd using European dairy cows and improving feed resources. The European Union (7346 l/cow/y) is one of the largest milk producers and has approx 3 (20.5 ex UK) million dairy cows compared with 10 million cows in the USA (10,620 l/cow/y) and there are 5.92 million dairy cows in New Zealand (4,259 l/cow/y) and 1.5 million cows in Australia (6,170 l/cow/y). In South-East Asia dairy cow numbers and milk production continues to increase, including countries that have not traditionally milked dairy cows, such as China (5,803 l/cow/y), which now have over 12 million cows producing milk (Table 3.1), along with Thailand (3,000 l/cow/y) and other Asian countries.

< **Table 3.1** Countries with the greatest cow populations (Source Statista 2021) > **near here**

Most of the milk is produced from specialized dairy cattle breeds, predominantly the Holstein Friesian, followed by a relatively small percentage of Jersey and even fewer numbers of Brown Swiss, Guernsey and traditional breeds such as Ayrshire and Dairy Shorthorn. The Holstein Friesian represents over 90% of dairy cattle in North America and the EU, with relatively low levels (5%) of Jersey and other breeds. Tropical countries have adopted European breeds, but they have their own specialized dairy breeds that are too numerous to describe, which are often crossbred with the Holstein and Jersey to increase milk production. European dairy cows, particularly the Holstein Friesian, have actively been selected as a specialist, single-purpose milk-producing animal capable of high volumes of milk production and is easily managed in automated milking systems. The milk yield per cow continues to increase, mainly due to improved genetic merit, nutrition, disease control and prevention. However, infertility of dairy cows continues to be one of the main challenges, this related to the high milk yield of early lactation coinciding with the onset of ovarian activity and need for to generate conception at about 80-100 days post-partum to ensure regular, approximately annual, calving which is an essential contributor to efficient milk production. The selection of cattle for milk production leads to a competition for partitioning of nutrients, which is prioritized towards milk yield, relative to the maintenance of body condition and reproduction. In the past, selection of Holstein dairy cattle and bulls for high milk production, rather than fertility and other important traits consistent with longevity, such as mobility, mammary conformation and heath has been a problem in some countries. More recently there have been changes in genetic selection of dairy bulls and European breeding policies, that place greater emphasis on fertility and health, along with production have been adopted more widely and, most recent has been the addition of feed efficiency traits.

The other main dynamic of dairy production has been the general continued trend towards fewer larger dairy herds, with many dairy units now including thousands and, in some countries, such as China, many thousands of cows on a single dairy unit. This leads to new challenges in herd and personnel management in the dairy industry and the regular use of standard operating practices (SOPs) by farm personnel. Other advances have been the continued application of on-farm quality assurance schemes, for feed manufacturers and milk producers, that ensure the quality, safety and carbon footprint of milk production and for human consumption.

~~Globally the main milk-producing countries, in descending order of milk production are India, USA, China, Russia, Pakistan, Germany, France, Brazil, UK and New Zealand. The EU has been a large contributor to the world trade in milk products, as has New Zealand. The milk production from India differs from most of the other countries, in that more than half of the milk is produced from buffaloes, followed by indigenous cows and crossbred cows, with a small amount coming from goats.~~

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3.2.1 Specialized dairy production

Milk production in the USA is dominated by dairy cows, in particular the Holstein Friesian breed. In New Zealand the domination of the Holstein Friesian is less pronounced, as smaller, lighter 'Kiwi' (Frisian, Jersey) cross breeds are better suited to pasture-based systems. Here, the North American Holstein Friesian represents less than 50% of the dairy cow population, along with an estimated 32% of cows being New Zealand Holstein Friesian cross Jersey and 14% Jersey. This reflects the dominance of pasture-based systems for low-cost milk production, which is facilitated by mild winters, high winter light intensity and sunshine, and relatively consistent rainfall in many areas or irrigation of pastures in others. However, increasing drought frequency and land prices, ~~,~~ especially in the North Island, along with greater access to cost-effective by-products and the increased use of forage maize (especially in times of drought) have led to more farmers offering supplementary feeds to dairy cattle. ~~The milk production is still largely concentrated in the North Island, but the conversion of land previously not used for dairy production into dairy production has continued apace since 2007.~~

The production of milk in countries with established dairy industries has continued to be characterized by declining numbers of milk producers, with larger herd sizes (mean > 350 cows) and increasing milk production per cow. More recently, there has been a decline in dairy cow number in the UK (- 1.5%) and most EU countries, most notably in Germany (-2.2%), except for southern Ireland (+2.1%) (Table 3.2). The improvements made through genetic selection and breeding have increased the genetic potential of the dairy herds; in particular there has been a dominance of the Holstein Friesian dairy breed. Improved genetics, along with improvements in feed resources, conservation techniques, diet formulation and subsequent nutrition of dairy cattle, has led to substantial increases in milk yield per cow in the last 10 years. One of t~~Unfortunately, this increase in milk yield has all too often been concurrent with increases in infertility. Consequently, in recent years, crossbreeding of differing dairy breeds, mainly Holstein Friesian and Jersey, has become more popular, as has the extension of the grazing season, where possible, in order to reduce feed costs. T~~he most recent changes has been the adoption of differing measures of feed efficiency or feed conversion efficiency, ~~as a measure of genetic merit. This has been~~ which has long been a characteristic of the pig and poultry industries that~~y,~~ has been adopted by the dairy industry to lower the impact on the environment, particularly climate change and deforestation related to animal nutrition. ~~and it will be interesting to see the potential for success in the more complicated ruminant nutrition arena.~~

<**Table 3.2** EU countries with largest dairy cow population (Source, Eurostat, 2021)> near here

3.2.2 Developing milk-producing countries

In China and Thailand, the importation of the Holstein Friesian has been central to the development of the dairy industry. However, in countries with more tropical climates, the use of imported dairy cattle genetics has been less successful, mainly due to their lack of heat tolerance and resistance to endemic disease. These genetics are often referred to as European, although they are likely to be American or Canadian Holstein which originated from cows bred in Northern Europe. Holstein Friesian, Jersey and Brown Swiss breeds have been used to crossbreed with the ‘local’ breeds of cattle and this has been a much more successful method of improving milk yield, while retaining some of the desirable characteristics of the local breeds. However, the main problem is the maintenance of the advantages of the crossbreeding and segregation of the phenotype in the following generations. ~~In this crossbreeding the Holstein Friesian tends to dominate as the preferred cross.~~ In the long term, recording and selective breeding within the local population of dairy cattle offers the opportunity to retain the genetic biodiversity as a future resource. However, t~~T~~he extraction of milk for human consumption from many of the ‘local’ breeds and crosses with local breeds often requires the presence of the calf in order to aid milk letdown. These systems may also allow the calf to suckle from the cow on a restricted basis, rather than artificially rear the calf (see section 3.9.3.7). These ‘cow-calf’ systems are currently being assessed and applied within in Europe mainly due to the poor perception that cow-calf separation by consumers. ~~.~~

3.2.3 Main milk product-exporting countries

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The main milk product-exporting countries (% of total world milk exports), where annual milk production exceeds the need of the local population, include New Zealand (21.8 %), the Netherlands (8.4%), USA (6.7%), followed by Belgium, France, Hong Kong, and Australia. The production of milk within the EU, with its expanding number of member states, has been declining, while Australia's milk production has continued to be hampered by drought conditions and water shortages. The size of the New Zealand dairy industry is more or less currently stable, but with its relatively small human pupation, has a large export capacity for milk products, mainly milk powder, cheese and butter. This lowers transport and processing costs by emphasizing the production of milk solids (fat plus protein, measured in kg; 381 kg of milk solids per cow annually).

In general, within countries, dairying is better suited, but by no means limited, to wetter areas that receive regular rainfall particularly during the drier summer period(s), where animals can graze grass or consume a range of fodder crops or conserved forages. However, the dairy cow is a ruminant and is well able to utilize a range of forages, feed, food waste and co-product resources to are non-edible directly by humans. A range of cereals, maize, straw and co-products from the food, beverage and biofuel industries also provide feed for dairy cattle, which provide a valuable biological function upgrading the low-quality feeds into valuable essential nutrients for humans. The availability, cost including any transport, storage requirements, nutrient composition, fibre content and anti-nutritional factors of feeds are used as the basis of formulating a cost-effective diet to fulfil the nutrient requirements of dairy cattle. In many countries dairy cattle are housed for 6 to 8 months of the year, during the winter periods when environmental temperature and pasture growth is low. In warmer regions of temperate countries where winter temperatures and sunlight levels are higher, such as New Zealand, some areas of Ireland, UK, South America and USA, cows can graze pasture or other forage crops for extended periods and even all year around. In other hot climates, such as Saudi Arabia and ~~,~~ areas of the USA ~~and Australia~~ and other countries cows may be cooled using housing, shade, fans and the addition of water as a bath or mist. During periods of low rainfall and drought, when fresh forage growth is limited, the use of conserved forage, fodder crops and/or feed supplements are required to ensure sufficient nutrients are available to maintain an economic level of milk production and body condition or the output of milk ~~output and economic viability~~ would ~~will~~ be much lower.

3.2.4 Milk sale and purchase

3.2.4.1 Milk price, marketing and levy boards

The price of milk is greatly affected by the global production and supply of milk and farmers have little or no control over milk price they receive. Most countries do not protect their national milk markets against imports and low milk price has been one of the main characteristics of the dairy industry, resulting in the need for greater efficiency, specialized dairy breeds and diversity of milk production systems. There are a few exception~~countrie~~s, most notably Canada and Japan, that protect their national milk production using import restrictions to protect dairy farmers from fluctuations in global milk price and low milk prices. This typically leads to an increase in the milk price ~~for farmers~~ and thus cost of ~~the price for~~ liquid milk and dairy products for consumers.

Overall, the production, transport, processing and storage of milk and milk products need to be carefully managed to ensure good milk quality and hygiene. C~~As a con~~onsequently~~ce~~, many countries have or historically have had milk marketing boards run by the government, which regulate ~~the control of~~ milk production, collection, quality testing, processing and marketing, along with knowledge transfer and extension in some cases. In some countries, these have been replaced by ~~a small number of large~~ farmer cooperatives or milk ~~purchaser~~ processors~~groups, often farmer owned~~, some of these ~~. These limit the ability of the farmer to control the price they receive for their milk. Other countries~~ have devolved into farmers having individual contracts with milk buyers. In this case farmer may be able to seek out the best milk price and initiate a contract with a localized milk buyer. These individual contracts ~~will~~ reflect the requirements of the milk buyer and farmers produce ~~a~~ milk ~~fat and protein concentration~~ that facilitates efficient processing into products such as low-fat liquid milk, cream, cheese and so called 'luxury' higher fat dairy products.

Low milk price ~~and individual milk contracts~~ has~~ve~~ led farmers to diversify into the application of differing systems of production, which include calving large numbers of cows in 'blocks', usually spring and/or autumn and calving cows all year round. This either provides large amounts of milk that can be processed into products such as cheddar cheese or provides a relatively consistent level of milk supply that allows processors to control milk supply, maximizing the opportunity to supply the consumer demand, along with use of the processing facilities that minimize the need for investment in expensive processing infrastructure. In all cases, the aim is to produce high-quality milk that is of a suitable composition to achieve the maximum margin between income from milk sales and the cost of producing the milk, according to the payment scheme.

In most countries the differing sectors of the agricultural industry have levy boards, that collect money per litre of milk produced or kg of milk solids processed. This money, that is collected directly from the milk processor from farmers' payments, is used for the development of the industry through marketing, research and knowledge transfer~~extension~~. The government of each country is also involved to a greater or lesser extent in research, development, education and extension of technologies within the dairy industry and facilitating the export and import of dairy products and technologies.

More recent developments have included more direct sales of milk and milk products. In more densely populated countries this has seen the return of doorstep deliveries and farmers installing milk dispensing machines on farm, which allow consumers to collect milk directly from the farm and to visit the farm where the milk is produced. These products often use more recyclable materials such as glass bottles and consumers find this a more attractive than the use of plastic containers. Other striking differences between countries is the consumption of refrigerated fresh liquid milk in some countries, notably the USA, Australia, UK and NZ, while in many other countries the consumption of ultra-heat treated (UHT) milk, which is not required to be refrigerated, is much more common.

3.2.4.2 Milk quotas and co-operative shares

In the EU and UK, quotas had been in place since the mid-1980s, while production quotas have been in place for much longer in other countries such as Canada. These quotas control the amount of milk farmers can produce and are milk fat linked. The EU withdrew milk quotas in March 2015 and milk production has increased subsequently. In New Zealand, while there is no quota system, the majority of farmers sell milk to a farmer-owned dairy cooperative and are required to own shares in order to supply milk to the cooperative, thus controlling the amount of milk supplied for processing. The milk production in New Zealand is highly seasonal, with most of the milk being processed into commodity products such as butter, cheese and milk powder for export. The milk is produced cheaply to meet world market prices and producers block-calve their cows in their spring (July to September) to coincide with the grass-growing season. The lactation length is approx 280 days and therefore many of the processing factories are closed for a period at the end of the season. There is a small pop~~3.3.~~ulation of milk producers that have cows calving in spring and autumn to allow continued 'winter' milk production for the fresh ~~of~~ liquid milk and product market ~~and for processing into dairy products~~ for the relatively small internal human population.

3.3 Animal Breeding

3.3.1 Animal selection and genetic improvement

The selection of dairy cows and sires to increase milk production, animal health and lifetime milk production potential is one of the main tools that has been used to increase ~~milk production and~~ economic efficiency. The selection process is based on the assessment of relatively heritable (25 to 50%) milk production and milk composition traits and body conformation (type) traits (7 to 54%), followed by less heritable but important traits such as longevity (8%), health (somatic cell counts – SCC: 12%) and fertility (4%). The use of computer-based linear production models (e.g. BLUP; best linear unbiased prediction) has allowed the calculation of relatively complicated indexes including economic weighting for milk components and for each sire and cow. The number of factors included in the index varies from country to country and these have changed considerably in the last 10 years. In some countries there are differing indexes according to the milk product to be produced, such as liquid milk or cheese, or overall 'net' genetic merit.

The traits selected can be described as production, durability and health including fertility (Table 3.3). In the past, many indexes gave the highest proportion (%) of weighting to production traits; however, this resulted in a relatively low number of lactations being completed by dairy cattle due to infertility, mastitis and lameness and reduced dairy margins. Consequently, fertility, disease resistance, particularly to mastitis (e.g. low SCC), and traits related to increased herd life/durability of dairy cattle have increased in their importance in the breeding indexes of most countries. The aim is to produce a more robust cow with an improved lifetime performance, reduced replacement cost and greater farm margins. In a breeding index of selection traits that are given weighting (numerical values) and positive values are given to 'desirable' traits, the higher the value the greater the selection intensity of that specific trait; negative weighting can be applied to reduce undesirable traits. The use of negative weightings (– values) on traits such as animal live weight or milk volume (l) would favour the selection of smaller cows or cows that produce a lower volume of milk. Positive weighting can be applied to increase desirable traits such as kg or % of milk fat or protein, fertility or animal conformation characteristics such as mammary system or foot and leg scores (see section

3.8.4.1). Overall, most countries are applying a greater proportion (40 to 50%) of their breeding index (+ and highest numerical values) to durability, health and fertility traits and a lower proportion than previously to production traits (50 to 60%).

<**Table 3.3** Main production, longevity and health traits used in the breeding indexes for dairy cattle.> Near here

The pedigree societies in each country use professional personnel to visually assess dairy heifers to give conformation scores (e.g. legs and feet, udder, dairy type etc.). The use of breeding indexes can be used to compare the 'breed quality' of cows and sires within a herd, across herds and more importantly the reliability of a sire's potential transmitting ability (PTA) of traits in other countries (international sire PTAs).

3.3.2 Improved contemporary comparisons and quantitative trait loci

The use of artificial insemination and the use of high-quality sires is a key factor in increasing the genetic merit of dairy herds. At present the performance of the daughters of sires in differing herds is defined in terms of 'improved contemporary comparisons' (ICC), accompanied by an expression of reliability (REL), which depends on the number of daughters across the number of herds and has been used to assess the potential transmitting ability of the sire. However, this process is inevitably slow, with sires taking approximately 9 months of age to produce semen. There follows 9 months of gestation and a 2-year growing period before the daughter produces milk and can begin to generate milk production data for the ICCs. In recent years genetic technology has identified an increasing array of ~~gene~~ quantitative trait loci (QTLs) on the genome that exert a positive effect on the desirable~~productivity~~ traits and ~~. T~~these have ~~are~~ now largely ~~used to~~ replaced ICC in the short term to increase the speed of genetic selection and improvement. ~~by reducing the interval between generations.~~

3.3.3 Breeding herd replacements and beef from the dairy herd

In practical terms approximately 22 to 25% of the dairy herd requires replacement annually. In ~~a~~ commercial dairy herds, the application of sexed semen has become more common ~~-~~place to avoid the production of male dairy calves and allow more cross bred beef calves to be produced. This sexed semen produces a high proportion of females (well over 90%) that allows ~~and allows approx. 50%~~ the best ~~o~~approx. 25 to 30 % of the dairy herd to be mated to produce heifers, while the rest can be used to produce dairy ~~for herd expansion or~~ heifers or cross bred beef calves for sale to other ~~dairy~~ enterprises. A small selection of sires is generally used (to reduce the risk of inbreeding) at any one time to improve a few specifically selected production and conformation traits in daughters of the better-quality and more productive dairy cattle, based on milk production and conformation records. In this way each herd can increase its genetic merit over time. In pasture-based systems, with the added pressure of seasonal calving, the use of nominated sires for AI may take place at the beginning of the breeding season and this will be followed by the use of beef ~~stock~~ bulls, so that the calving season is limited to a short period to coincide with spring grass growth for the following season. Some pedigree herds with cows of high genetic merit may breed a large~~r~~ proportion or the entire dairy herd to selected dairy sires in order to produce high-quality dairy replacements for sale to other herds.

3.4 Lactation

The mammary gland of the dairy cow is made up of four separate quarters, with a single teat, orifice and streak canal for each of the four quarters. At birth the gland has few developed structures but starts to develop at a faster rate at puberty, which occurs at approximately 40% mature weight and at approx 4 to 6 months of age depending on the early growth rate of the animal. The gland continues to develop, and a final rapid stage of development occurs during pregnancy, during which the milk-secreting epithelial cells within the alveoli develop and colostrum is produced.

Lactation and the secretion of milk are initiated by changes in hormone levels around parturition. The total milk yield per lactation is dependent on the genetic merit of the animal and level of feeding, with yields from 3,500 l being common in pasture/forage-based feeding systems and yields in excess of 10,000 l when cows are offered mixed rations based on concentrated feeds (e.g. cereals) and forage. The level of milk yield and composition of the milk is affected by the stage of lactation, breed and age and nutrition of the cow. The ~~In~~ p~~P~~eak milk yield, in early lactation, is associated with a slight decrease in protein and fat concentration, which recovers as lactation progresses. Protein and fat concentration in milk can be manipulated by diet and genetic selection. Lactose, which acts as an osmotic regulator in the mammary gland, follows the pattern of milk yield (Figure 3.2). The somatic cell count of the milk tends to be highest in early and late lactation and may be greater in older cows that have encountered more incidences of mastitis.

<**Figure 3.2** Lactation curve of dairy cattle including changes in milk yield, milk composition and body condition.> Near here

3.5 Dairy Farm Infrastructure

The housing of dairy cattle is an important factor contributing to animal welfare and is practices during inclement ~~winter~~ weather conditions, both to promote the wellbeing of animals and to protect the pastures. Good levels of housing and hygiene are important in providing cows comfort, preventing disease and ~~to~~ ensuring ~~e~~ the production of high-quality milk for human consumption. The other main important welfare requirements include ~~are~~ the separation of calving cows into deep-bedded calving boxes or in calving paddocks, where they still have the sight and smell of other cattle. It is not good practice to allow cows to calve in free stall cubicles.

3.5.1 Dairy production systems

In pasture-based systems most dairy units calve cows in spring to coincide with maximum pasture growth rates and ~~, T~~these ~~pasture-based~~ systems are commonly ~~practised~~practiced in New Zealand, Australia, areas of South America, Southern Ireland and some areas of Europe and the USA, including a small proportion of the UK dairy herd. These are areas suited to grass growth that allow animals to graze for long periods starting in early spring, often supplemented by fodder crops. The use of housing and amount of concentrate feed offered to the dairy cattle is less than other systems. However, in t~~T~~hese systems may require cattle to walk long distance and t~~s. T~~he provision, design and maintenance of cow tracks (raceways) and, more importantly, the appropriate handling of cattle moving to and from the milking area are of great importance to animal welfare and prevention of lameness. In these pastoral systems, more ~~less~~ animal waste ~~slurry~~ is deposited on the land ~~stored~~ and the leaching of nutrients and fertilizers into ground and surface water can be a considerable problem. These systems may include areas, known as feed pads, often without roofing, that can be used to offer supplementary feeds to dairy cattle and to hold cattle (‘stand offs’) when pasture conditions are too wet to allow cattle to graze efficiently, thus reducing pasture and soil damage (poaching or pugging).

Milk production systems have diversified in response to market forces, climate and resource availability. Many countries, i.e. New Zealand, Australia and more recently the UK, have classified the relative dairy production systems (1 to 5), according to the amount of grazing and feed supplements cows receive (Australia; NZ) and the calving pattern (UK) (Table 3.4). This is because feed is one of the main costs associated with and affecting the amount of milk produced and grazed grass is less costly than ensiled grass. In the UK, prolonged housing of dairy cows is more common, due to climatic conditions. Block calving is often applied to lower feed costs, by coinciding the time of calving and early lactation with the greater volume of spring grass growth. Alternatively, autumn calving takes advantage of greater milk price to offset the greater expense of autumn and winter feeding. All year-round calving systems either use a combination of grazing and winter-feeding diet formulations, while all year-round systems benefit from greater productivity due to ensiled feed and supplements providing a more consistent diet. A recent evaluation of dairy farms across Great Britain (GB) showing that spring block calving with grazing and all year-round calving and housed systems were amongst the most efficient, both in terms of whole farm feed use and financially. Interestingly, system 4 in the Australian, New Zealand and GB dairy system categories is the least efficient: the full rational for this is yet to be fully understood. Clearly, low milk price has limited the opportunity for substantial investment into the dairy business, without substantially increasing the risk, which would ~~. This~~ limit~~s~~ the ability of farmers to invest in housing, allowing them to move from system 4 into system 5.

<, **Table 3.4** Dairy system classification in Great Britain according to calving pattern, season, amount of days grazed annually and feed supplement and partial mixed ration (PMR) use. ~~**Table 3.4** Dairy system classification system for year-round and seasonal calving dairy herds (Amended from AHDB).~~ > **Near here**

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The application of the 5-system approach allows farm to identify with and apply differing performance indicators relevant to each system. It is essential that farmers compare farm performance against relevant key performance indicators (KPIs) to make efficient management decisions (Table 3.5). In terms of genetic merit, ~~addition to this,~~ countries have introduced system-based sire evaluation, allowing farmers to select more suitable sires to enhance the herd efficiency when managed in specific systems such as seasonal / block calving and all year-round calving (Table 3.5), along with once and twice daily milking in New Zealand.

<**Table 3.5** K~~k~~ey performance indicators for all year round and seasonal calving dairy herds (Amended from AHDB).> **Near here**

3.5.2 Types of cow housing

There are some areas of the world where housing is not required or required for very short periods of the year, in which case farms may only have a covered milking unit and few other buildings. These are more typically found in areas such as central and south America, Mexico, New Zealand and some parts of Australia. Housing can be used to protect animals from extreme cold, shade and cooling, or protect the soil and environment from damage.

Most dairy cattle are housed to some extent during winter, while there is an increasing trend towards housing cows throughout the year (or throughout lactation). In these circumstances fresh and grazed grass makes little or no contribution to the overall diet. The systems of housing are generally named after the type of cow confinement (e.g. tethers v. cubicles or free stalls), bed type, bedding used and floor type. The choice of housing will reflect the availability of bedding, which affects the manure stacking and slurry/effluent handing system that need to be installed.

In wet climates that have longer winter periods (approx. ≥ 6 mo.), the buildings are more likely to be an 'umbrella' type that covers the milking shed/parlour and cow housing, so that water pollution and the volume of effluent produced can be minimized. The protection of natural water courses, along with ground and surface water is protected by limitations to the type and quality, season and place where efficiency can be applied. In addition, application of manures and effluent will be subject to limitations that are applied according to the calculation of nutrients, particularly nitrogen, that has been applied or become available from green and artificial fertilizers. These limitations are more stringent in nitrate vulnerable zones, field margins, near water courses and lakes, and in organic production systems. The management and comfort of the cows is of great importance to their health and welfare, with greater cow comfort increasing cow lying time, which increases milk yield and lowers the incidence and prevalence of lameness.

3.5.2.1 Free stall / cubicle systems

The 'free stall' or 'cubicle' system is the most common system in the EU, mid and southern USA, China, UK, Ireland and New Zealand. Cubicles are an efficient use of space and bedding for housing dairy cows but are not suitable for male cattle that urinate in the centre of the cubicle. The main design characteristics of cubicles should be:

- At least 5% more cubicles than animals in the group in the UK, to lower bullying and maximise lying time, but this is often not applied in the USA where larger herds create greater flexibility
- Wide enough to allow animals to lie down and stand up without touching the divisions, with the actual width depend on division design (up to 1.2 m) and animal live weight
- Long enough to accommodate the body and head of the cow and have lunging space at the front (0.7 to 1 m), to allow the cows to move forwards when getting up from a lying position
- Fitted with a brisket board in front of the cow, to help locate the animal so she has space in front of her to get up and lie down. These should be movable to accommodate differing size of cows and stop dunging on the beds
- Made to have a fall of 2 to 3 % from front to back of cubicles, to improve comfort and drainage

- Scraping passage width behind rows of cubicles should be a minimum of 3 m, while feed passages should be at least 4.6 m wide.

The aim should be to maximize cow comfort and welfare, best assessed by lying time, which ideally should be over 10 hours per day. This has been associated with better welfare, disease prevention and improved productivity. There should be at least one cubicle per cow in the UK and the design and size of the cubicle should be in accordance with the live weight and size of the cow (Table 3.6).

The cubicle design, size, ~~design and~~ bedding material and management are some of the main important components of this system. ~~The provision and maintenance of enough space in front of the cow, to allow her to lie down and rise is essential to prevent the cow becoming stuck in the cubicle. It is for this reason that stalls with a blind or 'closed' front need to be longer, to allow space for lunging. This space is protected by the brisket board, which is on the floor in front of the cow and prevents the cow moving too far forwards in the cubicle.~~ The design of the divisions is ~~is also~~ important, with cantilever divisions fixed above ground at the front, that have no leg at the back being more favorable, as these accommodate lying without causing hock damage.

The provision of high levels of comfort and cleanliness are important factors in the management of dairy cows and the use of sand beds, rubber mats or mattresses, with regularly replaced clean bedding materials, is important in the maintenance of low levels of bacterial contamination, ~~and~~ mastitis pathogens and prevent hock damage. Cow comfort and this welfare has increasingly become a subject of cow and system evaluation, using high bed occupation rates, number of cows lying, good lying posture and appropriate animal placement within the bed while standing and lying, along with hock rubbing and knee swelling being and cow cleanliness some of the main 'cow signals' being applied to the success of bed size, ~~e and~~ suitability of bed type, ~~and bedding application~~cleaning out and bedding application. In addition, scoring the cleanness of cow feet, legs and flanks is used to indicate the adequacy of scraping out and bed maintenance, cleanness and bedding material application rates and regularly. This is essential in preventing mastitis and maintaining low milk bacteria scan (Bactoscan) counts.

The proportion / number of cubicles available per cow is subject to differing welfare regulations and farm assurance recommendation being applied in differing countries. The UK welfare regulations and farm assurance schemes state that there must be least 1 cubicle available per animal and there should be 5% additional 'spare' cubicles available for each group of animals. The occurrence of 'overstocking', where there are fewer than 1 cubicle per cow, has been a subject of several surveys in Canada and the USA. In large herds with many 1,000s of cows, it is claimed that milking takes place continually, followed by which cows tend to spend time eating and drinking, so cows can lie for 10 h/day despite such 'overstocking'.

Cubicles and free stalls are not suitable for housing calving cows and animal welfare regulations in many countries stipulate that cows calving indoors should be isolated in a calving pen or placed in suitably open areas with a clean deep liter bed. These requirements relate not only to the health and safety of the cow and calf, but also the need to accommodate natural behavior. Moreover, regular bedding and cleaning of calving facilities is an essential element in lowering the risk of potential contamination of the cow by mastitis causing pathogens and infection of the calf by pathogens that result in enteric ~~and respiratory~~ disorders such as cryptosporidiosis and respiratory disease.

< **Table 3.6** Area allocation for loose-bedded (UK) and free stall/cubicle bed length (UK and USA) for dairy cattle according to live-weight.> Near here

3.5.2.2 Deep litter and 'pack' bedded systems

In areas where cereal crops are grown, deep litter bedding systems may be used to house dairy cattle. These systems can provide a good level of cow welfare comfort and are essential for calving cows. More recently, in dry climates, dried manure has been used as a 'pack' bed for dairy cows. In deep litter bedding systems, it is imperative that adequate amounts and regular provision of clean dry bedding material are applied, along with a separate feeding and watering area that can be cleaned in order to reduce the risk of bacterial contamination and mastitis. The main criterion used to design and assess this system is the allocation of enough space per animal. A separate feed alley and area for water troughs be sited to lower wetting and contamination of the bed. In addition, cows that are on heat should be removed to prevent mastitis due to the bed becoming disturbed.

3.5.2.3 Tie barns

Some countries continue to use tie barns, where cows are tied by the neck. These mostly involve smaller herds both in cooler climates, such as Wisconsin and Canada and warmer climates, such as Thailand. In some units, cows are moved from the stalls to the milking parlour, but mostly they are permanently tethered during the winter and milked in the stalls. In both cases it takes a relatively long time to milk the cows, which limits the system to small herds. Moreover, the extreme restriction of cow movement and exercise can lead to hock swellings and lameness associated with abnormally low levels of hoof wear. These systems do tend to keep the cow and claw horn clean and dry, provided the beds are well bedded, well drained and dung is regularly cleared away.

3.5.2.4 Herd homes

The introduction of herd homes in New Zealand has been increasing in recent years. These are low-cost polythene tunnel-type structures, with fully slatted floors. The impact of the introduction of these on dairy cattle has yet to be determined.

3.5.2.5. Wood chip, concrete feed-pads and 'stand-off' areas

The use of low-cost pads or free draining area is common in pasture-based systems of New Zealand and Australia. These are used to feed cows supplements of silage and/or other feeds following milking, during periods of poor pasture growth, but also to hold cows 'off' pasture when wet soil conditions would cause pasture damage. More recently, these have been replaced by housing and or covered by roof structures, mainly due to increasing regulations regarding nitrate leaching and animal welfare. The opportunity for cows to lay down is limited and number of days cows can continuously be kept on these is limited by welfare regulations.

3.5.2.6. Solid concrete flooring

Flooring should provide comfortable slip free footing, be firm and durable. Floors should have a fall that facilitates drainage, so that they provide a relatively dry walking surface and maintain lower relative humidity levels, to help enhance animal welfare and prevent mastitis and respiratory diseases. Smooth surfaces increase the risk of slippages and injuries, especially dangerous in high-traffic areas and where cows/heifers may exhibit bulling behavior. Concrete flooring wears smooth over time and cattle are less confident walking on smooth floors. Tamping and grooving of concrete flooring successfully improves cow comfort and drainage. The grooves should run in the opposite direction to direction cows travel, because this is much less slippery. The parallel grooves should be 35 mm apart and not exceed 10 mm wide and have smooth edges. Concrete that has a rough finish will increase the rate of claw horn wear, by up to 20%, potentially exasperating negative claw horn accumulation rates, that are associated with negative energy balance during early lactation.

3.5.2.7. ***Slatted floors***

Slatted floors have become more popular in recent years for housing lactating cows mainly to lower bedding material use. The faeces and urine are trodden through or pushed through using a robot, into the tank below. This helps to maintain good animal welfare by preventing lameness by maintain the lower legs, ~~-~~claw horn and digital area in a cleaner ~~r~~ and drier state. The comfort of slats can be enhanced by covering them with rubber. The slats should be wide enough (125 mm) and have a gap that prevents the build-up of faeces on the slats (20 and 40 mm wide), while having a gap that is narrow enough to prevent foot injury and avoid excessive pressure on the sole of the claws (18 to 20% of the total area). The overall accommodation should include some solid-floor area or beds with sand, straw or some other suitable bedding material that makes the cows comfortable, especially their udders.

3.5.2.8. ***Feed face / barriers***

Feed barriers are designed to maximize feed intake, by maintaining a constant supply of clean feed in front of dairy cattle. This is achieved by keeping feed within reach, while minimizing the labour required to pushing feed up and clean out old feed. This is central to minimizing feed wastage. Allocating enough space at the feed face for each animal is a critical component of animal welfare and in maximizing the efficiency of the herd, minimizing bullying, that increases lameness, infertility and herd wastage, while facilitating the opportunity to maximize animal health, growth and milk yield (Table 3.7).

Open horizontal barriers lower feed intake and increase the risk of bullying or animals stealing feed and supplements that are top dressed onto forages. Diagonal barriers reduce these risks, while the expense of head bale gates provide a discrete feeding space for individual animals, which increases feed intake (5 to 7%) and provides a simple way to restrain animals for management purposes. Thus, locking head bale gates have become very popular on dairy units.

The key requirements for a feed face are that the:

- bottom of the feed trough should be no more than 100 mm above the feet of the animal
- surface should be smooth to encourage feeding and make cleaning easier
- trough or brisket boards should be around 500 mm high for adult cattle

- maximum reach is up to 1.0 m for adult cattle, but varies with age and is less for younger animals
- reach is improved by fixing feed rails and diagonal barriers at a forward angle of approx. 20°
- neck rail height should be adjustable, from 1150 to 1250 mm above floor height for adult cattle and 900 to 1100 mm for younger cattle
- neck rails should be high enough so that an animal's neck should rarely touch it while feeding
- signals that indicate the feed barriers are too low and need adjusting include hair being rubbed off or calluses on the back of the neck.

<, **Table 3.7** Feed face / barrier width requirement for different weights of cattle.~~**Table 3.7** Feed barrier width requirement for different weights of cattle~~> Near here

3.5.2.9. *Water troughs*

Milk has a high water content and t~~T~~he supply of fresh clean water is especially important for lactating dairy cattle. Welfare regulations sate that ~~and~~ water must always be available, unless under veterinary advisement. The water supply needs to be well able to cope with peak demands and t~~. T~~he water troughs should be designed and positioned to minimize potential contamination by food and fouling. They should be placed so there is a low risk of freezing in cold weather and where cattle can access them easily and without interference: i.e. not in a dead end. The water trough should be located at the correct height for the animal (850 mm from the floor for adult cattle, lower for younger animals) and the water level should be 50 to 100 mm below the edge of the trough to minimize splashing that increases the humidity and moisture in the building. Water troughs should be cleaned and emptied regularly, and these can be used to clean the floor of crossover passages. It is essential that the water can drain away quickly, avoiding a build-up of moisture ~~either in bedding or by creating a wet floor~~that lowers animal welfare by increasing the risk of disease. In deep litter bed systems, water troughs should be placed away from the bed in a separate scrapable feed alley.

3.5.2.9. *Ventilation*

Good ventilation is essential to achieve good animal welfare by ~~for the~~ preventing ~~ion of~~ pneumonia in younger animals and mastitis in adult animals. Ventilation removes stale air, lowering the relative humidity of the internal environment, mainly due to respiration. ~~and wash water.~~ The placement/aspect of cattle buildings should be used to ensure they take advantage of the prevailing wind direction and opportunity to ventilate naturally. In addition to this, the design of the building should maximize the potential for ventilation even on a still day, without exposing livestock to direct drafts on windy days. It is possible for some, but not all buildings to rely on ventilation on still-air days to be achieved via the stack effect, which is ~~. This~~ natural ventilation that occurs when the design and location of the building allows the heat of the animals to drive the stale air out ~~leaves~~ through a central air outlet in the roof ridge, while wind speeds of more than 1 m/s drive in fresh air at a lower level through gaps in the sidewalls. This can also be used to

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drive air out of the opposite side of buildings. The main reasons that natural ventilation fails are when there is a solid sidewall and/or an adjacent building or structure that prevents adequate air flow or increases air speed creating draughts on the livestock. The sidewalls of building should be designed to provide air diffused inlets along the maximum length of both sides of the building, which should be above animal height to protect them from direct draughts. Alternatively, buildings that feed livestock outside the wall of a building should have internal structures that protect animals from greater air speed at animal height.

3.5.2.10. Lighting

Lighting control and intensity are important for providing good animal welfare along with an efficient and safe working environment. Lighting ~~and it~~ also affects the hormone and production levels of dairy cattle (Table 3.8) and e~~. E~~ach day a period of darkness (less than 30 lux) is essential to ensure optimal endocrine function. Longer day lengths, that provide 16 to 18 hours of light > 170 lux, interspersed with six to eight hours of lower lighting/darkness increase heifer growth rates, advancing the onset of puberty and increase the milk yield from lactating cows.

<**Table 3.8** Lighting requirements for different work and locations.> near here

3.5.3 Milking management

The efficacy of milk practice is essential to mammary gland health and animal welfare, with the majority of dairy cattle are milked in parlours or milking sheds. In large herds these are typically of herringbone or rotary design. Smaller herds in Europe, Canada and developing countries may use abreast or tandem parlours, or even hand milking in some developing countries. Robotic milking continues to become more common due to better technical innovation and lower availability of labour.

The herringbone parlour/shed is the most common type, mainly due to its being one of the most cost-effective ways to ~~of~~ milk~~ing~~ large numbers of cows. The aim should be to ensure the throughput is sufficient to allow all the cows to be milked within about 2 hours. ~~of arriving at the site.~~ Herringbones can be fitted ~~have sufficient~~ with clusters to milk one side at once or both side to milk all of the cows at once ~~time~~ and are described by the number of cows that can be held, followed by the number that can be milked at any one time, e.g. 48:48 or 48:24. Rotary sheds are described by the number of stalls or bales that they contain and the reliability ~~these~~ and less operator walking time has~~ve~~ made these ~~become one of the~~ a ~~most~~ popular choice ~~arrangements~~ for milking larger herds. Tandem milk parlours allow greater access to the cows and allow individual cows to enter and leave the milking parlour or shed, but these have a slower throughput than herring bones and the operator needs to walk much longer distances during milking.

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3.5.4 Milking equipment and practice

Most cows are milked mechanically, by alternating between vacuum (approximately 38 to 50 kPa depending on the equipment) and non-vacuum (atmospheric pressure) phases, referred to as pulsations. The milk is removed from the cows by mimicking the suckling of the calf, where vacuum is used to reduce the pressure outside the teat end to below the pressure within the mammary gland, thus resulting in the milk flowing out through the teat canal. In terms of animal welfare, ~~T~~the maintenance of an appropriate and consistent amount of vacuum is one of the most important factors that ensures the health of the mammary gland. Regular maintenance and checking of milk equipment are essential, along with appropriate staff training in milking practice, machine and equipment maintenance is essential to maintain good animal welfare. In addition, a stock of materials for the replacement of friable materials such as short and long milk and vacuum rubber ware are equally essential. The checks required include:

- annual milking machine maintenance by professionally qualified and equipped contractors~~personnel~~
- appropriate staff training and experience
- daily checking of the vacuum gauge for the correct vacuum
- daily checking of the vacuum regulator allowing air into the system
- daily checking of all rubber wear and the instant replacement of pipes that have slits or cracks, which would allow air to leak into the system.

The correct vacuum level, along with the correct rate and ratio of pulsations, which prevent the build-up of tissue fluid and oedema within the teat, are important in efficient milking and to prevent teat damage. The final important factor is the effective function of the rubber teat cup liners, which should be changed approximately every 2,500 milkings or annually, whichever is the sooner, to ensure the function of these liners in response to the vacuum and/or non-vacuum phases and prevent any cracking or splitting that may cause mastitis and high somatic cell counts.

More recent precision technology has allowed the addition of greater individual animal monitoring ~~that can be added to the~~ during the milking process that can include regularity of –milking visits, milk yield, milk composition and/or conductivity, live weight~~weighing~~, ~~milk composition,~~ camera-based body condition scoring and pressure plate-based mobility scoring as examples.

3.5.5 Milking frequency

3.5.5.1 Twice and thrice daily milking

Most cows are milked mechanically twice daily at relatively evenly spaced (14 and 10 h or 12 and 12 h) intervals. Milk yields can be increased by milking higher-yielding cows (>6,500 L/year) three times daily, which increases milk yield (15 to 25%) mainly through enhancement of the longevity and function of the milk-secreting epithelial cells in the mammary gland. The removal of milk that acts as a feedback inhibitor gives rise to less myoepithelial cell damage from stretch and compaction. Moreover, a greater frequency of oxytocin secretion and its effect on cell signaling increase milk yield both during and following the period of increased milking frequency. The greater milk yield increases nutrient requirements. Greater milking frequency increases labour and fixed costs associated with milking.

3.5.5.2 Robot milking and greater milking frequencies

The application of robots in cow milking has become more common and cows choose to be milked between 3 to 6 times a day in early lactation, thereby increasing milk yield beyond that of twice daily milking. Cows may need to be trained to use the milking robot following parturition and a small proportion of cows may need to be collected and encourages ~~put them~~ to go through the robot daily, especially during late lactation, when their motivation to be milked is reduced due to the lack of pressure from milk within the mammary gland.

The placement of the robot and the greater amount of space available at the entrance and exit to the robot will increase the number of times cows will go into the robot voluntarily and this increases milking frequency and milk yield, provided adequate feed and nutrients are made available. Unlike other systems, each robot typically milks mixed stage of lactation cows, up to 50 in a pen, but fewer early-stage lactation cows because these present themselves for milking more frequently and take a little longer to milk. The robot encourages cows to be milked by offering the cows concentrate at each milking, which provides the opportunity to allocate concentrate feed according to milk yield and offer smaller meals more frequently. Robots allocate concentrate feed according to a set feed plan, starting at a low rate of 2 kg, which can be increased using weekly increments to a max of 12 kg/day, which remains constant during early lactation, before declining according to milk yield in mid and late lactation. Other factors may be built into the system, such as allocating first lactation animals a set ~~greater~~ amount of concentrate. ~~than cows in their later lactations.~~ The main elements of milking robots include individual computerized teat location, laser guided individual teat cleaning, cup application and removal, allowing ~~along with~~ individual ~~teat cleaning, quarter yield,~~ milk flow monitoring and milking, along with accurate post milking teat spray application. In addition, cows can be individually monitored for live weight, activity (heat detection), rumination and rumen pH, and milk conductivity. This allows c~~C~~ows to ~~can~~ be automatically selected out into a management pen for observation, treatment or insemination.

3.5.5.3 Once daily milking

Milking cows once daily has become a more popular option for some farm enterprises in recent years. Lower-yielding cows can be milked once daily, or three times in two days, particularly those producing milk of higher solids such as Jersey and Jersey cross cows in pasture-based systems, with a limited reduction in milk yield. Once daily milking has been used in early lactation to lower peak labour loads in block calving herds. It can be a useful management approach for the maintenance of body condition during drought periods or the management of dairy cattle in marginal areas where feed supplies may be limited. It allows for greater flexibility of working practices, facilitating managers that have second jobs and/or school age children. The lower milk yield associated with long-term once daily milk herds is offset by lower labour, ~~and~~ fixed ~~costs,~~ and supplementary feed costs. ~~requirements.~~ It greatly reduces the distance walked by dairy cattle daily and has a relatively limited effect on somatic cell count (SSC) concentrations, but only provided mastitis is well-managed and the dairy herd has low incidence of mastitis and SSC count initially.

3.5.6 Milk sale, quality and testing on farm and processing facility

Samples of milk are taken from farm milk storage vats prior to collection and from the bulk milk tanker on arrival at the factory. The milk samples from the bulk milk tanker are tested for temperature, fat, protein, ~~and~~ somatic cell and urea composition using near-infrared spectroscopy (NIR) and the presence of antibiotics before the milk enters ~~the~~ factory processing ~~area~~. Milk samples collected from milk producers are subsequently further tested for milk fat, protein, bulk milk cell count, bacterial count and residues such as antibiotics and/or pesticides, along with the existence of unusual taste and smell. There are set standards and grades. Milk that fails any of the tests is unsuitable for producing quality products and the milk will be rejected. Most milk contracts set a milk price that depends on fat, protein (component yield), bacterial count (hygiene), heat resistant bacterial (plant cleaning and silage quality) and somatic cells (mastitis), along with other components that currently have no commercial value such as lactose and urea. It is extremely important that these samples are collected and stored correctly.

3.6 Dairy Cow Nutrition

The nutrition of high yielding dairy cows is typically managed using nutrition consultants, diet formulation packages and analysis of ensiled forage nutrient composition and pasture availability and quality. Lower yielding cows are less challenging and can be managed more easily. The feeding management of dairy cows ~~is~~ typically involves several factors and feeding opportunities, such as feed storage, diet mixing equipment and feed out equipment/opportunities. Dairy cows, with the exception of those milked by robots, are generally allocated into groups according to their physiological stage of lactation; early, mid and late lactation, dry (> 3.5 weeks far off from calving) and 'transition' (3.5 to 2 weeks close up to calving). This facilitates the provision of suitable diets for the efficient use of feed resources to produce milk and to manage the body condition score and health of the cows.

3.6.1 Digestive anatomy and function

Dairy cattle are large ruminants. Their digestive system has evolved to enable the microbial fermentation of cellulose and other fibres in forage-based diets and consists of four main compartments – the rumen, reticulum, omasum and abomasum (Figure 3.3), which are followed by the duodenum, small and large intestine, caecum and colon.

3.6.1.1 The rumen

The rumen is a large organ (capacity 170 to 190 l), which allows large quantities of forages and effective rumen degradable protein (ERDP) to be digested over a period of time. In the rumen there are bacteria, protozoa and fungi that ferment and break down the feeds consumed by the animal. The rumen-based microflora and fauna grow and multiply while the fermentation of carbohydrates from dietary starch and cellulose produces volatile fatty acids (VFA) mainly consisting of acetic, propionic and some butyric acids. The VFA are largely absorbed into the blood through the rumen wall whose surface area is greatly enlarged by tiny finger-like projections, the rumen papillae. The undegraded feed, rumen undegradable protein and m~~M~~icroflora and fauna (Microbiome) pass out of the rumen to be digested in the abomasum, thus providing a ~~a~~ source of protein for the animal. The microbial protein ~~, which~~ is referred to as microbial crude protein (MCP) and these ~~. This process allows~~ provide ruminant animals ~~to produce~~ essential amino acids in addition to those provided by the feeds consumed. There are also bacteria in the rumen that produce B complex vitamins and some vitamin H or biotin, while ~~. of~~ Archaea are the species mainly responsible for methane production.

<**Figure 3.3** The digestive anatomy of the ruminant. > Near here

3.6.1.2 Diet changes

The composition of the rumen microbiome ~~al (flora and fauna) population~~ develops in accordance with the composition of the diet offered to the cows and this occurs over approximately 2 weeks. In consequence, sudden changes in diet should be avoided. The diet should be changed gradually to avoid potential indigestion and diarrhoea. As the proportions of the microflora and -fauna within the rumen are directly affected by the composition of the diet, so too are the proportions of the differing types of VFA produced. Diets high in structural fibre produce higher proportions of acetic acid to propionic acid, while diets lower in structural fibre produce higher proportions of propionic acid to acetic acid. These VFA proportions directly affect milk composition; high proportions of acetic acid result in a greater ~~higher~~ milk fat concentrations~~mposition in milk~~, while higher proportions of propionic acid favour greater ~~higher~~ milk protein concentrations~~levels~~. Moreover, the proportions of VFA affect plasma insulin and growth hormone levels and thus affect milk yield and body condition score. The production of high proportions of propionic acid to acetic acid not only tends to reduce milk fat concentration, it potentially reduces milk yield and increases the potential for live weight and body condition gain.

3.6.1.3 Dietary fibre and rumination

The rumen and the reticulum respond to the longer fibres that tend to accumulate towards the ~~on~~ surface ~~top~~ of the rumen liquor and from here they are propelled up through the oesophagus into the mouth to be chewed and re-swallowed during rumination. The cow adds copious quantities of saliva to the ingesta, both on primary consumption and during rumination. Cows can produce up to 100 l of saliva per day, which contains phosphates and bicarbonates that help to maintain the rumen environment at an optimal pH of 6.0 to 6.5. The monitoring of rumen pH using boluses has become more common place, and these can be added to a selection of cows to lower cost.

Dairy cows spend up to 6 to 8 h/d ruminating and the number of times they chew each cud depends on the amount of fibre and 'functionality' (length of fibre) of the diet. The amount of fibre in feeds is measured by chemical analysis (conventionally defined as neutral- or acid-detergent fibre (NDF or ADF). The functionality of the fibre is affected by the levels of chopping or processing. In recent years the physical assessment of fibre content has been applied to dairy cow diets, mainly due to a higher incidence of displaced abomasum (DA) in dairy cows offered mixed rations lacking longer fibre. This involves a set of sieves with decreasing apertures, which allow the lengths of the fibres of the diet to be assessed. Other practical methods for assessing the adequacy of the diet include inspection of the dung to ensure there are very few loose / sloppy faeces, check that the majority of cows lying down are ruminating and to assess~~ing the number of chews the~~ that the cows are ~~-appl~~applying an adequate number of chews to ~~ies to~~ each cud, approximately between 45 and 70. The total of 45 is fairly low and would be common in a low-fibre, pasture-based system, while 50 to 70 chews would be more appropriate for mixed diets.

3.6.1.4 Water absorption and gastric digestion

The omasum can be identified as a small dark structure, relatively hard in structure, which contains many layers of tissue, which gives it an internal appearance similar to the leaves of a book. This organ is mainly responsible for the absorption of water.

The abomasum is relatively small compared to the rumen and has a relatively smooth texture and pale appearance. This is the equivalent of the simple stomach in the non-fermenting species and as such utilizes gastric juices at a low pH to aid digestion.

3.6.1.5 Dairy cow nutrition and the environment

The potential pollution of groundwater, rivers and lakes due to leaching of both nitrates and phosphates from agricultural practices has come under increasing levels of control in most countries. This includes the effective storage and application of manures, including potential restrictions to manure application to prevent damage to water quality and the environment. Moreover, rumen fermentation can produce~~s~~ large amounts of methane which is a particularly powerful ‘greenhouse’ gas, along with carbon dioxide and nitrogen gasses. The amounts of greenhouse gases produced by ruminants and their global population make them a significant contributor to global emissions. In addition, the transportation of imported of animal feed can increase the carbon footprint of agricultural livestock. These issues may be addressed both at the level of the agricultural system and the individual cow. An example of the former approach is the capture and use of gases from manure using biodigesters. The production of gaseous methane direct from cows can be reduced through manipulation of diet and/or the population of ruminal microbes, mainly to lower archaea numbers in the rumen microbiome and fibre in the diet to increase propionate:acetate ratio in the end-products of fermentation by using maize silage as a partial replacement for grass and pasture. Other products such as garlic, citrus oils and seaweed are useful feed additives that lower methane emissions. In addition, the greater use of home-grown feeds and altering the concentration of dietary nutrient can lower the carbon footprint by lowering overseas import of feeds. Diet formulation and farm practices are evaluated in order to calculate the carbon footprint, compare this with other similar farms and inform mitigation strategies. Finally, the feed efficiency of the dairy industry can be improved by selection and feeding for higher individual yields to offset the feed energy costs of maintenance. Other routes to increased feed efficiency include reduced feed wastage, lowering the number of herd replacements and age at first calving, reducing the number of non-lactating days (50 to 60 d / lactation), increasing longevity and lifetime productivity of dairy cows. All these are key areas where animal management can lower the environmental impact of dairy production.

3.6.2 Feeding the dairy cow

As for any animal, the aim of planned feeding is to match the supply of available nutrients to nutrient requirements. In the special case of the lactating dairy cow, nutrient requirement is high, and supply is limited by the capacity of the animal to ingest and digest fibrous feeds that ferment relatively slowly. Thus, the process of dairy cow nutrition is based on two main elements – estimating the feed intake and nutrient requirements of the animal. In this process it is essential to consider the effects of stage of lactation, feed quality and feeding system when planning to provide nutrients in the diet in an adequate concentration to allow the animal to consume these within the constraints of its feed fresh (FMI) and dry matter intake (DMI) potential. Similarly, when planning a diet, it is important not to overestimate the DMI ~~dry matter intake~~ and to ensure that there is sufficient metabolizable energy (ME) (typically overestimate by 5%) ~~energy~~ in the diet, followed by crude protein (CP) and then minerals and vitamins.

3.6.3 Nutrient requirements

The nutrient requirements of dairy cattle are generally expressed in terms of ME ~~energy~~ (MJ/kg or per day) and CP ~~protein~~(% per kg DMI or g/d), along with minerals and vitamins. However, lowering the CF has led to more precision in the use of CP in dairy cow, calf and growing heifer nutrition is moving towards the division and application lower CP diets assessed according to effective rumen degradable (ERDP) and rumen undegradable protein (RUP) / and digestible undegradable protein (DUP). ~~Lactating animals also require large quantities of water.~~ The dairy cow requires these nutrients for maintenance and production (i.e. milk production, reproduction and pregnancy, growth and live weight gain). In early lactation the dairy cow will prioritize maintenance and milk production before reproduction, growth or live weight gain. This prioritizing of nutrients towards differing purposes is referred to as nutrient partitioning. Lactating animals also require large quantities of water and substantially more in hot weather / conditions.

3.6.3.1 Energy

Energy is usually considered the first limiting factor in production. Dairy cows require energy for both maintenance and production. Energy is also essential for the function of the microbial population in the rumen. In most countries the energy requirements of dairy cattle are expressed as ~~metabolizable energy (~~ME~~)~~. Due to the importance of supplying energy for the rumen microbes, the ME terminology has been refined to include a measurement of the energy that can be fermented by the microbes in the rumen, which is fermentable metabolizable energy (FME) to ensure that these microbes are supplied with adequate amount of FME to function, degrade feed efficiency and maximize DMI. The USA and some other countries use net energy (NE), which is a measure of the energy directly available to the animal for production. The ME and NE are expressed in ruminant production in megajoules (MJ). The energy content can be calculated from the gross energy (GE) content, which is estimated using a bomb calorimeter, and the energy losses associated with the digestion and metabolism of differing feeds (Figure 3.4), indicating clearly that not all the GE is available to be metabolized by the animal.

Figure 3.4 Schematic representation of the relationship between gross energy, metabolizable and net energy, and energy losses during digestion.

3.6.3.2 Protein

The protein requirements of dairy cows ~~for protein~~ are calculated in a similar way as for energy. The most common term presently used to describe proteins for ruminants is CP and metabolizable protein (MP), which is that available for metabolism following digestion and absorption. While ~~The~~ the terminology used to describe the protein content of feeds directly reflects the areas of the digestive system in which it may be digested, this is affected by ~~and~~ the natural proportion ~~rate at which it~~ that may be degraded in the rumen and ~~. That fraction of the protein in the feed that is degraded in the rumen is referred to as effective rumen degradable protein (ERDP), while protein that is digestible but is not degraded in the rumen is digestible undegradable protein (DUP). The ERDP and DUP proportion of any feed is directly affected by the~~ amount of time the feed spends degrading in the rumen. The overall composition of the diet directly affects the rate that feed ~~Feed that~~ passes ~~rapidly~~ through the rumen and a larger proportion of rapidly degradable feed competent increases this rate, which ~~will have a relatively~~ lowers the opportunity for ERDP to be fully degraded, thus lowering the proportion of ERDP and increasing the ~~ed level of~~ proportion of DUP. ~~.~~Moreover, the proportion of DUP can be enhanced by the application of feed processing technology (typically applied to oil seed meals such as rape/canola, cotton seed, sunflower and soya bean) such as heating, extrusion, encapsulation and other treatments that protect the protein from degradation in the rumen and is used to increase the amount of protein and amino acids supplied to the abomasum.

The final amount of protein that is available to be digested by the dairy cow is that which arrives into the abomasum ~~and this comes~~ from two potential sources: ~~microbial crude protein (MCP) and~~ DUP and microbial crude protein (MCP) and ~~. Both of~~ these are digested in the abomasum to provide MP~~metabolizable protein~~. The amount of MCP delivered to the abomasum is a function of a combination of ERDP and fermentable metabolizable energy (FME) available to the microbes in the rumen and this ratio is checked to ensure the diet contains an adequate amount of FME. Finally, milk urea concentration can be used to assess the 'balance' between protein supply and utilization and the need to increase or decrease dietary protein supply to potentially increase milk yield when financially viable. ~~The level of DUP reaching the abomasum is affected by the degradability of the feed and the outflow rate of feed from the rumen.~~

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3.6.4 Feed intake

As a ruminant animal, one of the main factors limiting the performance of the dairy cow is the voluntary feed intake, which is often referred as ~~dry matter intake (~~DMI~~)~~. The factors that affect DMI can be divided into those that are related to the animal or to the feed.

3.6.4.1 Animal factors

The main animal factors that affect DMI include weight or physical size, body condition, physiological state and health. In general, larger individuals or breeds tend to have greater DMI. Within a breed, animals with lower body condition (lower fat reserves) tend to have a higher DMI than those with greater body reserves. This is due to blood metabolites regulating intake, through chemostatic signals, and the physical limitation that abdominal fat places on space available for food within the rumen.

Physiological state is an important factor affecting both DMI and nutrient requirement. The main factor for lactating cows is milk yield, which increases DMI substantially. Conversely, DMI becomes limited during the last trimester of pregnancy, due to the increasing size of the foetus reducing the physical space available for the rumen. This reduction in feed intake ~~may~~ persist, for up to 3 to 5 weeks following parturition. Thus, it is important to take stage of lactation ~~should be taken~~ into consideration when estimating DMI. This ~~e~~ period of lowered nutrient intake in early lactation coincides with high nutrient demands for milk production. This has been termed the ‘energy gap’ and over this period that lactating dairy cows tend to mobilize body fat and some protein to meet the nutrients required for milk production. This live weight and body condition loss should be managed by ensuring optimal body condition score (BCS) at parturition (3 to 3.5 on a scale of 1 to 5, or 5.5 on a scale of 1 to 10; see Table 3.9~~11~~), to allow body reserves to be available, and cows should be offered sufficient nutrients to regain lost live weight prior to mating to optimize reproductive functions, such as regular oestrous cycling, follicle quality, increased oestrous behaviour and detection rates, thus improving conception and pregnancy rates.

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<**Table 3.9** Body condition scoring of dairy cattle.> Near here

3.6.4.2 Feed factors

The main feed factors that affect DMI include feed availability, type and quality. The DMI of the cow can be reduced when feed availability is limited or pasture availability (height) is low. This has the effect of under-utilizing the DMI capacity of the animal and thus reduces milk yield per cow but may increase milk yield per hectare in grazed animals. The type of the feed affects the DMI mainly through the fibre content (conventionally described by NDF and ADF) and energy concentration (ME) or FME which is the major substrate required by the rumen microflora and -fauna. Thus, the fibre content and energy density of the diet directly affect DMI through the degradation rate of feeds in the rumen. Feeds with higher fibre levels and lower energy concentration, which include straw, tall ~~long~~ pasture and late cut silage or hay, tend to degrade more slowly in the rumen, occupy the physical space of the rumen for longer, thus reducing DMI. Conversely feeds that have lower levels of fibre and higher levels of energy concentration, such as young leafy pasture, cereals and some co-products, degrade faster in the rumen and, when offered as an appropriate total diet, result in DMI closer to the animal’s maximum potential. The main aim of feeding dairy cattle is to optimize feed intake by offering an appropriate combination of feeds and nutrients on a regular and unrestricted basis.

Other feed factors that affect DMI include the palatability of the feeds and the feeding system employed. A good example of feeds that are likely to have lower intake potentials are pasture with recently applied manure and poor-quality silages. Dairy cows should be offered high-quality silages, which mainly result from mowing pastures before 50% ear emergence, along with good ensiling and silage storage practices that minimize butyric acid production and microbial deterioration. Pasture silages with higher dry matter (DM) content (29 to 32% DM) tend to have a higher intake potential, compared with wetter silages (<25% DM). The management of animal feeding can affect feed intake, and this includes overstocking at the feed face ~~troughs~~ or at pasture and allowing feed quality to deteriorate due to poor clamp face management, feeding-out management and general hygiene.

3.6.5 Feeding and feeding systems

The main aims of dairy cow feeding are to optimize feed quality and feed intake through good pasture management, ensiling techniques, feed storage and feeding-out practices~~management~~. Most lactating dairy cows rely heavily on the consumption of high-quality forages in order to optimize milk yield potential. Dairy cattle can graze fresh grass or be offered conserved grass as silage or hay. These feeds can be complemented with a range of other feeds such as forage maize silage, cereal silages, cereals, co-products and pelleted compound feeds, along with minerals and vitamins. The cost of diet components and diet cost is a very important factor and least costs formulation of lactating cow diets is applied widely through the feed industry, but may have less of a place in early lactation diets were the main goal is the enhancement of fertility and longer term milk yield. The aim ~~use~~ of a total mixed ration (TMR) to provide both a balanced supply of nutrients and the correct substrates for stable fermentation through the day and night results in a more constant rumen pH, increased feed intake and greater ~~higher~~ milk yields~~, with less health problems associated with low rumen pH (see section 3.8.6.1)~~.

3.6.6 Minerals and vitamins

Dairy cattle require several minerals and vitamins for healthy body function and to prevent deficiency diseases. Macronutrients include calcium (Ca), magnesium (Mg) and phosphorus (P) whose requirement is measured in g/kg feed and Ca in early lactation is added to the diet as low cost Ca carbonate. ~~.~~Micronutrients required in µg/kg include copper (Cu), cobalt (Co), selenium (Se) and zinc (Zn). The levels of macro-minerals will depend on the forage mineral levels, boluses etc. and the requirements of the animal according to ~~and~~ the physiological stage of ~~, usually related to~~ lactation / pregnancy and ~~or~~ season (see section 3.6.6.2).~~.~~

3.6.6.1 Calcium deficiency (milk fever)

The most common problem of dairy cows and the severe form of calcium deficiency is milk fever, which should be prevented to ensure good animal welfare and fertility. This typically presents as extreme muscle weakness in a newly calved cow that can lead to collapse and death within hours, if untreated. Treatment involves administration of calcium salts subcutaneously, or intravenously in advanced cases. However, t~~T~~he ~~risk~~risks of milk fever should be prevented ~~can be greatly reduced~~ by attention to feeding practices during late pregnancy that facilitate early lactation, referred to as the 'transition' period~~and transition from dry to lactating~~. This involves o~~O~~ffering cows diets with low levels of positive ~~calcium and~~ potassium and calcium ions, that includes avoiding grazing pastures that have had effluent applied to it and reducing pasture and grass silage intake. This ~~during the late dry period~~ enables cows to begin mobilizing body reserves of calcium from bone just prior to parturition and thus preventing sudden plasma calcium deficiencies (hypocalcaemia) at and directly following calving~~during early lactation~~. This ~~A more recent~~ strategy is applied to ~~for~~ dry cows that are close to calving (3 to 4 weeks prepartum) and typically ~~may~~ involves the addition of a high fire forage to prevent displaced abomasum and addition of negative ion minerals to ~~manipulating~~manipulate the dietary cation:anion balance (DCAB) to induce a mild metabolic acidosis and thereby encourage the mobilization of calcium and phosphorus buffers during late pregnancy (see section 3.7.4~~8.9~~).

3.6.6.2 *Magnesium deficiency (grass staggers or hypomagnesaemia)*

Magnesium deficiency in dairy cows is primarily associated with low levels of magnesium (Mg) in spring pasture. This can be exacerbated by the application of artificial fertilizers that can reduce magnesium availability. Early clinical signs of acute magnesium deficiency include hyperexcitability and a 'staggering' gait. The conditions can proceed to death within hours, so prevention is critical. Supplementing the diet or water with magnesium is typically used as a preventive for magnesium deficiencies in spring.

3.6.6.3 Copper deficiency (clinical and subclinical) and excess

The supplementation of cow diets with copper (Cu) is often required in areas where copper is deficient or high soil molybdenum, sulphur or iron lead to reduced copper availability. This can be prevented by the implantation of long-acting copper boluses into the rumen. This can enhance oestrous behaviour and improve reproductive performance of dairy cattle. However, it is important to combine all sources to prevent excess Cu being supplied and livestock feed should never be offered to sheep.

3.6.6.4 Other important micronutrients for dairy cattle

The supplementation of zinc and selenium has become more popular, in the belief that these can improve hoof horn quality and immunity and reduce somatic cell count levels (see section 3.8.3). The vitamin H (biotin) has been seen in recent years to improve hoof horn quality, when offered for prolonged periods of up to 8 to 10 months, and reduce lameness (especially white line disease), and has been associated with increased milk yields. Finally, the availability of more complex (e.g. chelated or bioplex) forms of minerals and application of blouses have ~~has~~ become more commonplace on the basis that they may be more bio-available so achieve similar effects on level animal performance at lower levels of inclusion and less risk of environmental pollution. Unfortunately, this may lead to several forms mineral supply, including from diet components, being combined inadvertently and the whole diet mineral supply should be assessed. Unfortunately, ~~The~~ the availability of minerals and micro-minerals can interact to reduce their availability, thus suboptimal levels can be created either by a lack in the diet or reduced availability due to an interaction with another mineral or micronutrient, resulting in suboptimal absorption by the animal. This can lead to a clinical or subclinical deficiency and suboptimal performance. The availability of copper, for example, is profoundly affected by interactions with other elements – sulphur, molybdenum, zinc and iron.

3.6.7 Grazing and pasture management

Grazed pasture is one of the cheapest forms of forage that can be offered to dairy cattle. Good management is essential to limit fibre content, encouraging greater DMI ~~–~~and optimizing ~~e~~ the nutrient concentration of the pasture. This is achieved using pasture measurement techniques to assess pasture height and available for each day and ~~the~~

month, by feed planning (daily, monthly and annually), and by management of grazing frequency, grazing period and stocking rate to control pasture height. Pasture management also includes the incorporation of ensiling during periods of rapid pasture growth. The main aim is to maintain the grass plant in a vegetative stage through regular defoliation. This optimizes the number of tillers and nutrient density by minimizing the opportunity for the plant to enter the reproductive stage, thus limiting the senescent materials and fibre content of the pasture throughout the grazing season.

There are a number of grazing systems available, which allow varying levels of plant management and infrastructure requirements:

- *Paddock grazing*: – the farm is divided into small paddocks according to herd size to allow one, two or three days of grazing. This allows the greatest control of pasture quality, but also has the greatest infrastructure requirements;
- *Set stocking*: – pasture is controlled by the number of animals grazed on a set area;
- *Continuous grazing*: – the area is continually grazed and the stocking rate is adjusted according to pasture availability;
- *Zero grazing*: – pasture is not grazed but cut and carried to the cows;
- *Strip grazing*: – the use of electric fencing to allocate cattle to strips of fresh pasture. This can be used for pasture and forage crops, where there is a high volume of feed.

Finally, ensiling can be used to control plant growth, by cutting down the area to be grazed when pasture growth is rapid during spring, so that silage is available during periods of low pasture growth such as dry summer periods and in winter. More recent precision technology that have been added to pasture management include NIR measurement of pasture height and currently pasture feed quality, including the use of trailed machines and more recently drones. Other developments are location monitoring of cattle and the use of virtual fencing. Greater botanical diversity of pasture species has been introduced recently to support greater wildlife diversity; however, this is are better suited to marginal areas, conservation dairy and beef production systems and specialist dairy product production, rather than intensive dairy production systems.

3.6.7.1 Forage / fodder crops

In climates where grass and white clover can respond to heavier soil types, adequate quantity and frequency of rainfall, grass silage will be a large component of the diet of dairy cows, due to its good level of crude protein (18% CP) and energy (11.5 MJ/kg ME) concentration. ~~,~~ Other forage crops include maize and whole crop cereal silages, which have found to lower methane emissions from ruminants. The most popular of these is forage maize, which is used quite extensively due to the development of faster-maturing varieties that have allowed this crop to be grown in a wider range of environments. Forage maize makes an excellent complement to grass silage, due to its high level of starch, which increases the milk yield of dairy cattle when used at 30 to 75% of the forage in the diet. Other whole-crop cereal silages (e.g. wheat, barley) can be used in combination with grass silage but seem not to be as effective as forage maize in increasing milk yield. In terms of precision technology, the development of portable NIR for more regular assessment of silage quality on farm as an aid to greater precision in monthly diet formulation and precision feeding of dairy cattle. Fodder crops such as fodder beet, turnips and kale can be offered to dairy cattle and are generally strip-grazed to control intake levels to avoid scouring and milk taint. The current need to lower the carbon footprint of dairy systems has led to the use of lower protein diets (from 18 to 15 to 16 % CP), less use of soya and protein resources imported from countries where its growing is related to deforestation and greater ~~the~~ use of more locally grown forages and crops, ~~and protein sources,~~ which may include pasture, white clover, chicory and canola / rape seed meal, red clover, peas and beans and other feed resources suited to the local climatic conditions. In addition, this food security has led to a greater focus on ruminants utilizing non-human edible crops and coproducts, along with the need to enhance the feeding value of co-products though feed processing technology. The efficiency of forage use is evaluated by using the milk from forage and the greater the amount of milk from achieving good forage quality, lowers the amount and costs of supplementary feed required to produce milk.

3.6.7.2 Compound feeds, cereals and co-products

These are classified in the feed resource databases into energy and protein sources according to their chemical composition. A range of cereals and protein-rich oil seeds can be used, following some form of processing, for inclusion into dairy cow diets. The compound feeds are a combination of products including, but not exclusively; cereals, oil seeds, minerals and vitamins that are formulated and processed into a pelleted feed containing a combination of energy and protein, with set levels of fat. The feed can be purchased as 'straights', which are single products that can be purchased in bulk loads that require storage, which ~~and~~ are ~~used to~~ combined with silages using mixer wagons. There are an increasing number and range of co~~by~~products from the food, beverage and ~~more recently the~~ biofuel industry. These include such products as bread and biscuit meal, vegetables, brewer's and distiller's grains, and maize co-products, to mention just a few. ~~The need to lower the carbon footprint of feeds for dairy production systems has led to the assessment of lower protein diets (>14%, rather than 18% CP in early lactation) and for growing herd replacements post weaning, with limited effect on milk yield and growth rate. Other alterations include the use of more locally grown protein resources such as canola/rapeseed meal, peas and beans, rather than soya bean meal. Other~~ T~~t~~echnological developments include the processing of canola/rape-seed meal to increase the proportion of DUP and thus enhance its ability to supply MP~~metabolizable protein~~, and the use of technologies to improve the feeding value of co~~by~~products from bioethanol, beverage and the food processing industry, including the use of naturally occurring feed additives such as enzymes, yeast and essential oil that enhance the gastrointestinal tract microbiome, immunity and animal health and welfare, along with the need to lower farm antimicrobial use, carbon footprint and subsequent climate change. The efficiency of milk production is evaluated by the margin over purchased feed, which is measured from amount of milk income produced after the of costs of purchased feed has been deducted. ~~.~~

3.6.8 Feed storage

Correct and appropriate feed storage is important in ensuring that the quality of the feed is maintained and risks of molding and production of mycotoxins, which negatively affect ~~to~~ animal and human health, are minimized. The addition of mycotoxin binders is expensive, but they are effective when required. It is imperative that feed storage and feeding facilities are designed to ensure that cattle feed and forage cannot be contaminated by bird, pest, rodent, cat or dog urine or faeces and this is an essential part of farm assurance.

3.7 Diet Feeding and Management

3.7.1 Mixed rations

3.7.1.1 Feeder wagons and diet mixers

The use of total mixed rations (TMR) or complete diets (forages mixed with other concentrated feeds and minerals) has become increasingly popular as dairy cow yield potential has increased. The use of mixer ~~feeder~~ wagons to combine and dispense a pre-mixed ~~complete~~ diet has become very popular in both indoor and pasture-based systems~~.~~. This machinery allows the maximum flexibility in the components that can be included in the diet, depending only on the ability of the mixer wagon to render the cow unable to select components from the mixture. These types of diet offer the opportunity to maximize the use of a range of feed resources and the consistency of the type of diet being offered throughout the day and thus optimize DMI and milk yield. This method increases the machinery and labour costs for diet mixing.

A mixed ration is typically formulated to provide enough ~~sufficient~~ nutrients for the maintenance requirement of the cow plus a specific level of milk production. These diets are described as 'maintenance plus'. This allows batches of a mixed ration ~~diet t~~to be made up and offered to groups of dairy cattle according to their milk yield or stage of lactation. The a~~A~~dditional nutrients~~ requirements~~ can be offered through feeding systems that dispense feed to groups in the shed or to individuals in the parlour or via computerized dispensers, this has led to the term partial mixed ration (PMR). These mixed rations ~~mixed rations~~ generally include a combination of forages, protein meals ~~feeds,~~ ~~and~~ cereals and other co-products with calcium carbonate and potentially minerals for lactating cows. They may also contain some straw to ensure that the diet contains enough functional fibre ensure ~~to optimize~~ adequate salivation and rumination occurs ~~en function and~~ to lower ~~reduce~~ the risk of ruminal acidosis and displaced abomasum.

3.7.1.2 Offering forages (silages/cut forages and TMR/PMR)

Silages and mixed rations ~~TMR~~ can be offered from feed bins, ~~or~~ troughs, ~~. Silage can be offered from feed~~ rings or eaten directly ('self-~~–~~feed') from the silage bunker. ~~Straw is typically offered from feed rings. It is important to ensure that cows have sufficient eating space for all to eat at any one time. This should increase feed intake and milk production and reduce lameness.~~ Cows that are required to use self-feed silage bunkers will have a lower DMI compared with cows offered feed freely. It is important to ensure that cows have enough space for all to eat at any one time, which should increase feed intake and milk production and reduce lameness (recommended feed face space is a minimum).

3.7.1.3 Feed pads

These are common in pasture-based systems and are hard-floored areas or standing areas, often concreted, which are occasionally fitted with a roof structure. Here cows are offered feeds to supplement pasture, usually silage forage-based diets with other available cost-effective feeds such as cereals, co-products and plant-based food waste with diet balancers and minerals. Cows are given access to these feeds following milking, during periods of peak yield or when pasture supply is below that required by the animal (dry periods, cool spring, winter) or when high rainfall leads to wet soils and excessive damage to pasture (pugging or poaching) would be caused by cattle treading the ground.

3.7.2 Supplementing ~~the~~ forage diets with concentrated feed or compound feeds

The forage diet of dairy cattle can be supplemented with more concentrated sources of nutrients, thus increasing nutrient intake and subsequent milk yield. Dairy cows respond to a greater extent to these supplements in early lactation and when genetically predisposed to higher milk yields – i.e. when their nutrient demands are greatest. The allocation of concentrated feeds can be achieved on a group or individual cow basis. The feeding rates (kg DM/d) can be managed according to differing approaches:

- lead feeding where cows are fed high rates until peak lactation;
- stepped feeding rates, where differing rates are offered for set periods of the lactation;
- feeding to yield, where cows are offered a feed rate according to the milk yield of the cow, which can be adjusted on a weekly or monthly basis.

The choice of approach will depend on the feeding equipment and resources available. The allocation of concentrated feed to individual cows can be achieved using in-parlour/shed or out-of-parlour/shed automated cow feeders. In more simple systems, cows can be offered feed applied over the top of silage 'top dressed' as a midday supplement or offered liquid feeds from 'lick ball' feeders on an ad *libitum* basis.

3.7.3 Automated feeding systems

The use of automated equipment and electronic tags (or transponders) can be used to operate feeders that distribute feeds to individual cows according to preset levels held on a computer database system. These can be operated in or out of the milking shed/parlour.

3.7.3.1 In-parlour or shed feeding

This system, which can be electronic or manually operated, delivers concentrated feeds, usually pelleted or processed cereals, to cows while being milked. It can be used in addition to pasture or silage feeding and as a complement to mixer wagons. It allows individual cows to be offered feed levels according to their individual milk yield. Its limitation is the amount that can be offered at any one time. This should generally be restricted 3 to 5 kg DM at each milking, to avoid the risk of ruminal acidosis caused by consumption of large quantities of rapidly degradable carbohydrates.

3.7.3.2 Out-of-parlour or shed feeding

These are electronic systems that deliver concentrated feeds, usually pelleted in nature, to cows throughout the day or night. They reduce the amount of compound feed that is required to be offered at one point in time, thus avoiding fluctuations in rumen pH, and thereby permit higher levels of concentrate feeding with consequent increases in milk yield.

3.7.4 Feeding management for dry cows (transition or lead feeding)

The advent of improved feeding management of dry (non-lactating) dairy cattle has been one of the major advances in dairy cow husbandry~~ in recent years~~. The main aim is to prevent metabolic disorders such as milk fever, ketosis and acidosis, and improve fertility in early-lactation cows. This involves the management of calcium mobilization and body condition score and the introduction of a proportion of the lactation diet before calving to allow the rumen microflora and fauna to adapt to the great increase in nutrient demand at the onset of lactation. To achieve this, specific dry cow supplements, limitations of pasture intake and the provision of fibre (i.e. cereal straw) are key components.

The prevention of milk fever requires the management of calcium and magnesium supplementation before calving. Low positive ions of potassium and calcium, along with the addition of ~~-and high~~ magnesium before calving will encourage the cow to mobilize body reserves of calcium. Similarly, the management of dietary cation and anion balance (DCAB or DCAD), using negative (chloride) ions added to the diet, induce a mild metabolic acidosis and stimulate the cow to mobilize body calcium and phosphorus salts, which act as buffers. Grass and silage are high in potassium, especially that that has had effluent applied to it, which will increase plasma pH and thus discouraging ~~e~~ cows from ~~to~~ mobilizinge calcium from bone tissue; the levels of grazed grass, grass pasture silage should be restricted in dry cow diets, e.g. by inclusion of cereal silages and fibre ~~straw~~ into dry cow diets to maintain DMI to satiate the cow ~~intake levels~~ and rumen capacity ~~and to satiate the cow.~~.

3.7.5 Feeding and management of cow body condition (body fat and protein)

The body condition of dairy cattle is evaluated using visual and/or manual palpation to estimate the level of body fat covering the tail head, ribs and spine. This is expressed using either a 5-point (with half points) or 10-point scale, with the lower numbers indicating lower fat reserves (thinner) and the higher numbers indicating greater levels of fat reserves (fatter, Table 3.9~~4~~). The main aim is to allow cows to gain weight in late lactation and the dry period. This will allow dairy cattle to calve in adequate body condition (3.5 on a 5-point scale) to enable them to have sufficient reserves to cope with the energy gap in early lactation. The provision of good quality feed and a nutrition plan in early lactation should then ensure that the dairy cow does not lose too much live weight during early lactation and is on a rising plane of nutrition and increasing body condition during the mating period in order to increase the conception rate and thus herd fertility.

3.8 Health

The main focus ~~of dairy herd~~ should be the enhancement of the welfare and longevity of the dairy herd, through ~~health management should be~~ disease prevention, recording and the use of a herd health plan that is developed with a veterinary surgeon and good feeding plans developed and applied though your nutrition consultant. The majority of diseases of importance for dairy herds are often multifactorial in nature, with a number of factors that interact together to cause disease. In global terms, the three main health issues ~~reasons~~

~~why~~ that cause cows to ~~cows leave (are~~ be culled from~~)~~ the dairy herd are, in decreasing order:

- infertility;
- mastitis;
- lameness.

These diseases are of great importance in both economic and animal welfare terms and they will be discussed in detail because their control and prevention is central to good dairy herd management. Other major potential animal health issues include hypocalcaemia, hypomagnesaemia, acidosis, displaced abomasum, endometritis, acetonaemia (ketosis) and bloat.

3.8.1 Reproduction and fertility

On a global basis, poor reproduction or 'infertility' is the most common reason for dairy cows to be culled from the dairy herd. The loss of cows due to infertility and the subsequent need to provide herd replacements is ~~represents~~ a considerable economic cost, while calving of cows on an approximately annual basis is a key factor in generating high levels of efficient milk production. T~~In consequence, t~~he efficient management of reproduction ~~in the dairy herd~~ is one of the most important factors in dairy herd management. The annual management of reproduction is presented in Figure 3.5. (Further reading can be found in Peters and Ball, 2004, *Reproduction in Cattle*.) and close to annual calving or a calving interval (CI) of 365 days is desirable, with seasonal and lower milk yielding herds needing a CI of 365 days to be efficient, while herds that have cows with greater milk yield per cow (> 9,000 l) allowing longer CI's of 380 to 410 days.

3.8.1.1 Gestation

The gestation length of the dairy cow is a relatively fixed period of approximately 283 days, which ~~but~~ varies slightly with sex of the calf and ~~the~~ breed of the sire. Calves born to sires from the continental beef breeds (e.g. Charolais, Limousin) tend to have longer gestation periods, as do male calves compared to female calves of dairy breeds. In New Zealand the Angus and Angus crossbreeds are favoured as terminal sires compared with the Hereford beef breeds due to the shorter gestation length and ease of calving ~~the~~ needed in ~~for a~~ seasonal calving herds~~pattern~~. ~~The use of hormones to induce calving and thus shorten the gestation period is not commonly used as a management practice for dairy cows, except when required in exceptional circumstances, due to the welfare implications for both the cow and calf.~~

Figure 3.5 An example of the differing components (days) of an annual (365-day calving interval) reproductive cycle of the dairy cow.

3.8.1.2 Puberty and oestrous cycles

Dairy heifers reach puberty at around 40% of mature weight and this can be achieved as early as 4 months of age, where the plane of nutrition has been high in early life. The optimal age for heifers to calve is at approximately 2 years of age, at an estimated 85 ~~to~~

~~90~~% mature weight and, as gestation length is relatively fixed, this can be achieved by heifers conceiving at 13 to 15 months of age at 55 ~~to 60~~% mature weight.

3.8.1.3 Oestrous cycles and conception rate of lactating cows

The dairy cow has a natural period of non-ovulation (anoestrus) following calving, which is approximately 35 days long. This period can be minimized by ensuring adequate body condition at calving and providing adequate nutrition following calving. The aims should be to minimize live weight loss following calving and for the cows to be gaining weight by the time of insemination. First oestrus should occur between 20 to 40 days post-partum and this may be recorded in order to determine the return of 'normal' oestrous cycles in readiness for the next oestrous cycle. Dairy cows that have not shown oestrous behaviour following this period may have cystic ovarian disease (COD) and require treatment by a veterinarian. The uterus requires approximately 40 to 50 days following parturition to return to its normal size and function and, as a consequence, conception rate (CR) to inseminations before 50 days postpartum tends to be low. Due to this and the expense of high-quality semen, dairy cows are typically inseminated following standing heats (oestrus) from 50 days postpartum onwards and this may be delayed to 60 d postpartum in higher milk-yielding herds.

The CR to first insemination completed around 50 to 60 d postpartum tends to be lower compared to second and subsequent inseminations. In the assessment of conception rates, first, second and subsequent inseminations should be calculated and monitored separately. The conception rate of Holstein Friesian cows has tended to decline over the last 10 to 15 years. As a consequence, fertility, despite its low heritability, has been included in the breed assessment index for animal selection and breeding purposes. ~~Similarly, the use and evaluation of differing dairy breeds and the use of crossbreeding of dairy cattle breeds have become increasingly popular within the global dairy industry.~~

3.8.1.4 Oestrous behaviour

The length of the oestrous cycle ranges between 18 and 24 days, averaging around 21 days. The cow is 'on heat' or 'in oestrus' for an average of around 14 hours, but this can vary from ~~as little as~~ 1 hour to ~~as long as~~ 24 hours. Ovulation occurs around 10 to 12 hours following the onset of oestrus, but this timing will clearly be affected by the length of oestrus and the correct animal identification and timing of insemination following oestrus is critical in achieving high conception rates. The amount ~~level~~ and duration of oestrous behaviour can vary according to season, ambient temperature, housing environment, breed, body condition, social interaction and plane of nutrition. Oestrous behaviour tends to be lower in warmer climates or periods, during winter (reduced light), in housed conditions and for cows that have lower social status within the herd. The oestrous behavior is likely to be higher for cows in good body condition, with adequate and appropriate nutrition including mineral supplementation, which are housed or grazed in compliance with the welfare regulations, housing codes of practice and conformance to the relevant farm assurance guidelines.

3.8.2 Factors affecting fertility

3.8.2.1 Oestrus detection

The use of cow observation, ~~by well-trained staff~~which is increasing aided by tail paint or automation, supported by accurate recording and a good communications system are important factors in heat ~~, is the most commonly used approach to oestrus~~ detection. This system relies on observation of cows expressing oestrous activity~~behaviour~~, identification of the correct animal ~~cow a~~and timely insemination ~~at the appropriate time to~~ that follows ~~coincide with~~ ovulation. Manual ~~In an ideal situation the cows could be~~ observation ~~ed continually, but in reality,~~ requires animals to be ~~cows are~~ observed ~~during period of 'natural' behaviour~~ at regular intervals through the day and in the evening and ~~. F~~for this approach to succeed, cows should be observed as many as four times daily for an adequate period time to identify cows that are standing to be mounted or mounting the front of herd mates. In terms of management ~~t i~~it is important to be able ~~be sure that the~~ to correctly identify individual animal~~cow is accurately identified, and recorded. This requires cows to be individually identified~~ potentially from ~~at~~ a distance. The use of freeze branding and electronic tagging are quite common, in addition to the legal requirement for ear tagging ~~and that the cow standing to be mounted is identified as the cow in oestrus.~~. ~~There are some exceptions: a cow in oestrus may mount the front end of another cow, possibly due to frustration at not having been mounted herself. It is important that the cow 'stands' to be mounted. Should she move away she may not yet be in oestrus but may be coming into oestrus. These observation periods should allow adequate time for the activities of the cows to be watched. A team effort from farm staff along with a good communication system is more likely to increase cow observation time and cows seen in oestrus.~~

3.8.2.2 Aids to oestrus detection

The trend to larger herds and to all-year-round calving has led to the development of several aids to the detection of oestrus to ensure timely insemination, high levels of conception and pregnancy rates (PR).

3.8.2.3 Tail paint and pads

Purpose-specific paint or pads of paint can be applied to the 'tail head' on the spine. Cows that have been 'mounted' by other cows can be observed and recorded at milking time and submitted for insemination.

3.8.2.4 Electronic monitors

During the oestrous period the activity level of cows on heat tends to increase beyond the normal levels. Meters that measure the number of steps or activity of the cow can be used to assess cow activity and the possible occurrence of oestrus. Similarly, the body temperature of the cow tends to be higher during oestrus and this can also be monitored and interpreted in a similar way. However, these technologies can give 'false positives' in cows with high activity or body temperature for reasons other than oestrus.

3.8.2.5 Hormone tests

Kits are available to measure milk progesterone levels on-farm. Progesterone is secreted from the corpus luteum. Thus, it is high during the dioestrous period after ovulation and increases further in pregnancy. In a non-pregnant cow, milk progesterone levels fall sharply about 19 days after the previous oestrus and remain low for about 4 days, then start to rise at the time of ovulation. Analysis of milk samples for progesterone on days 7, 19 and 21 after previous oestrus can either predict optimal time for insemination or give a good early indication of the success of a previous insemination.

3.8.2.6 Vasectomized or ‘teaser’ bulls

The intermittent use of vasectomized or ‘teaser’ bulls can also increase oestrous behaviour levels. Undoubtedly the most successful way to achieve high fertility is through natural service. However, this is inconsistent with the need for genetic improvement of the herd that can be gained from the access to nationally and internationally ranked sires using artificial insemination.

3.8.2.7 Target body condition score

The health and productivity of dairy cows has been enhanced by the regular application of body condition scoring and adherence to achieving target body condition for dairy cows (Table 3.10~~12~~). This should maximise fertility and milk yields, and avoid metabolic disorders associated with over condition, such as ketosis. The body condition of the cows is assessed at key points: calving, 60 d pp, 100 d prior to dry off and drying off. The actual body condition of the animal informs us about the success of longer-term animal nutrition, while body condition score change informs us about the adequacy of the shorter-term, current nutrition. In terms of body condition score change, loss of body condition should be limited during the first 60 d of lactation (0.5 on a scale of 1 to 5) to avoid infertility, whole body condition score gain should be avoided entirely during the 60 d dry period, more especially during the 3 week transition period prior to calving to avoid calving difficulty and the risk of ketosis postpartum.

In New Zealand lactation length can be shorter, lengthening the dry period of cows managed in seasonally calving herds. Seasonal spring calving results in cows consuming autumn pasture during late lactation, making it notoriously difficult for cows to gain body condition during late lactation. At this point, depending on the need for cows to achieve optimal body condition, cows will be either supplemented if milk price is higher or dried off to gain body condition during the extended dry period.

<**Table 3.10** Target body condition for dairy cows to maximise milk yield and fertility, by avoiding metabolic disorders.> Near here

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3.8.3 Mastitis

Mastitis is the second most common reason for culling cows from the dairy herd, affecting approximately 35% of cows annually (the range for 95% of herds being between 5 and 60%). It is caused by a bacterial infection of the mammary gland via the teat canal. The bacteria involved are classified as *contagious* (e.g. *Staphylococcus*, *Streptococcus*) because they are typically transmitted between cows through poor hygiene at milking, and *environmental* (e.g. *Escherichia coli*). Clinical mastitis results in inflammation of the affected quarter and can cause considerable pain and discomfort.

Consequently, mastitis represents a considerable challenge to the welfare of the dairy cow. Factors that affect the incidence of mastitis are shown in Figure 3.6.

<**Figure 3.6** Main factors associated with mastitis of dairy cattle. > **near here**

3.8.3.1 Economic effect of mastitis

Mastitis reduces the economic efficiently of the dairy herd by causing losses and increasing costs. The losses associated with mastitis include:

- liquid milk sales (antibiotic milk discarded or offered to calves);
- milk price (lower price for milk with higher somatic cell counts;
- milk component levels (reduced due to mastitis);
- milk production (long-term reduction).

Increasing costs associated with mastitis include:
- treatment (antibiotic or other);
- labour (treatment, dry cow therapy, separation from main herd);
- herd replacements (cows culled due to high SCC or clinical mastitis)
- along with the increased risk of antimicrobial resistance (AMR).

3.8.3.2 Management of mastitis

The level of mastitis in the dairy herd can be monitored using the somatic cell count (SCC) levels in the milk. This is essentially a measure of white blood cells recruited to combat chronic (typically non-clinical) infection with organisms of contagious mastitis (e.g. *Staphylococcus*). The maximum SCC allowed in bulk milk varies considerably in differing countries; within the EU, UK and New Zealand a level of 400,000 (cells/mL) is applied, while in Australia (600 to 700,000 ~~(~~cells/mL) and the USA (750,000 cells/mL) higher levels are applied. Milk that exceeds these levels will not be collected by milk purchasers or will attract demerit points and much reduced milk price (Table 3.11~~2~~). In practice, there are moves in the USA to reduce the maximum levels to 400,000 cells/mL. In all countries the annual mean SCC levels achieved for milk are well below the maximum levels. ~~and in New Zealand, where a demerit system is used, few demerit points are generally applied.~~

<**Table 3.11~~0~~** Examples of bacterial quality and somatic cell count levels used in milk purchase in differing counties (000/mL).> Near here

Milk purchasers use milk quality payment schemes to maintain and increase the quality of milk supplied by milk producers, and in some schemes SCC levels below 50, 100 and 150,000 cells/mL can attract additional payment for good milk quality. The bulk milk SCC levels are monitored by milk purchasers and used to calculate milk price in payment schemes, apply demerit points or refuse to collect milk considered not to be suitable. ~~for human consumption.~~ On the farm the management of mastitis is best described as proactive, where a positive approach is used to prevent, rapidly diagnose and treat mastitis in order to maintain low SCC levels. The main potential for cows to be infected with mastitis is during mechanical milking. A key issue is the need to maintain low levels of SCC throughout the herd in order to minimize the risk of cross-contamination between cows with mastitis (high SCC >250,000) and cows without mastitis (low SCC <250,000).

Milking heifers (with low SCC) before cows with higher SCC can prevent herd SCC from increasing, milking individual cows with high SCC following lower SCC cows and the use of pre-milking teat dip and wearing gloves during milking can reduce the risk of spreading the mastitis bacteria. The application of teat dips following milking is a key point at which mastitis-causing bacteria can be prevented from gaining access into the mammary gland, by protecting the teat canal from contamination while the sphincter muscle, that typically closes the teat canal, remains open following milking. The sooner cows with clinical mastitis are diagnosed ~~and treated the less likely that the cows will have a prolonged infection and~~ that will directly reduce the opportunity for other cows to be contaminated (Table 3.12~~1~~) and lower the potential severity of the disease for the individual animal and whole herd.

3.8.3.3 Mastitis in organic dairy herds

In organic herds, antibiotics are not used as first line of treatment for mastitis, unless withholding this treatment is likely to compromise the welfare of the animal. These greater restrictions to use antibiotics make the prevention of mastitis a key management strategy for organic herds. Organic milk producers emphasize the importance of good milking equipment design and maintenance, and hygienic milking practices, particularly the wearing of gloves for milking. The use of non-antibiotic treatments for the treatment of mastitis is also considered to be important and some of these include vaccination, drenching with vinegar and the use of arnica, peppermint udder creams and cold water applications to minimize mammary inflammation, which is typical to this disease. The efficacy of these is unproven.

<**Table 3.12~~1~~** Prevention and treatment of mastitis. > Near here

3.8.4 Lameness

Lameness is the third most common reason for cows to be culled from the dairy herd, but this it is a serious welfare issue due to the pain involved. The incidence of lameness in dairy cattle is approximately 35% of cows *per annum*, but ranges from as low as 5% to as high as 60% on differing farms. Lameness is a multifactorial disease and the main factors involved in the cause and prevention of lameness include environment, especially housing and cow tracks, animal management and handling, genetic conformation, nutrition, and regular hoof trimming and foot bathing.

The more common forms ~~Nearly all~~ of dairy cows lameness are ~~in dairy cattle is foot lameness~~related to the foot and/or claw horn ~~-~~(Figure 3.7). It can take many forms, but these may broadly be considered within two categories:

- disorders of the sole and hoof horn – these are usually non-infectious in origin and include sole bruising and ulceration, white line disease, toe ulcers and foot rot (as a secondary infection);
- infectious conditions of the skin adjacent to the hoof – e.g. digital and interdigital dermatitis, necrobacillosis (‘foul’).

<**Table 3.13~~3~~** Mobility score and the description of locomotion (mobility) and lameness> Near here

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3.8.4.1 Locomotion and mobility scoring

Mobility scoring (Table 3.13~~2~~) and the identification and accurate recording of claw horn disorders (Figure 3.7) and regular foot trimming are essential to the prevention and treatment of lameness. Mobility scoring involves observing cows walking to assess how evenly cows bear weight in each foot, the evenness of the strides they take, the arch of the back and movement of the head. Table 3.13 ~~3.7~~ describe~~s~~ how these are used to score mobility on a four-point scale and used to record the prevalence (number of cows lame on any one day) and severity of lameness. The main aim of mobility scoring is to identify and diagnose individual lame cows (score 1) as soon as possible, so that appropriate treatment can be applied to lower both the number of animals that progress to severe lameness (scores of 2 and 3) and length of time the cows spend lame. Recent surveys of UK dairy producers showed that farmers did not see the value proposition of this approach. However, some milk purchasers have added regular mobility scoring and the prevalence of lame cows in dairy herds to their farm assurance schemes, with penalties for those who fail to meet their standards.

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The correct identification of lesions (e.g. claw horn haemorrhage, digital dermatitis; Figure 3.7~~9~~) and puncture damage also helps to identify hazards, risks and corrective measures at the herd level. This type of approach reduces the potential for lameness to contribute to other health issues through reduced feed intake, loss of live weight, milk yield and fertility. Early diagnosis also reduces the labour and costs of treating severely affected animals.

Figure 3.7 Areas of the cow's weight-bearing claws and main types of lameness. **About here**

3.8.4.2 Types of lameness

Sole and white line damage account for the majority of lameness in dairy cows. However, the infectious conditions, digital dermatitis (DD) and interdigital dermatitis (IDD), are an increasing problem in the UK, EU and USA and have become endemic on many farms. DD and IDD are not common in New Zealand and other pasture-based systems.

3.8.4.3 Sole bruising and ulceration, and puncture

This is a common problem and is typically at its greatest level at around 120 days following calving. It results from damage that occurs to the corium when it is trapped between the bone tissue within the hoof. Prolonged standing on concrete and walking on hard surfaces such as cow tracks is a major predisposing factor, as is inadequate (or improper) foot trimming. The resilience of the foot structures is also compromised around the time of calving and early lactation. This can be seen by the greater intensity of bruising and potential ulceration in Figure 3.7~~9~~. This condition predisposes animals to sole puncture and handling of cows on tracks and raceways, allowing them to walk that their own pace and avoid rocks and stones is essential in preventing lameness. The maintenance and repair of concrete yards, and to some extent raceways. play an important role in preventing lameness. Animal signals that indicate a lack of adequate space include them raising their head above the shoulder height, while being handled on tracks or pushed up in a collecting yard.

3.8.4.4 White line disease, disorders and toe ulcers

The white line, indicated in Figure 3.7~~9~~, is where the wall horn is cemented to the sole horn. This is weaker than other parts of the claw. In consequence, this area of the claw horn is more subject to physical damage due to wear and damage from twisting and walking, while bruising in this area also occurs. Problems associated with this area of the claw are referred to as white line disease, disorders, erosion and bruising and ulceration. This area is particularly prone to damage in systems where cows walk long distances. The rotation of the distal pharynx (P3) can similarly trap the horn-producing lamellae at the toe and lead to toe bruising and ulceration. Good handling facilities of adequate size to provide the correct amount of space and careful use of 'backing gates' and movement of dairy cattle are essential in the prevention of lameness. Incorrect handling and lack of adequate space creates twisting forces that separate the anatomically weak structure of the white line. Placement of rubber matting at any point were cows make sharp turns, such as backing out of rotary milking bales, will lower white line damage and the potential for secondary infections of the lamellae.

3.8.4.5 Foot rot

This seems to be quite common in New Zealand. It is most frequently a secondary infection and is often associated with ingressions of infectious organism through the white line/sole area (Figure 3.7~~9~~), which is in contrast to infectious lameness seen in other dairy cow systems of management, which usually presents as digital or interdigital dermatitis. It is most apparent during wet conditions and when cows are confined on concrete pads (feed pads) to be offered feed and where cow tracks and lane ways have wet and poorly maintained areas. Feed pads and tracks or lane ways are commonly used in the pasture-based systems of New Zealand and Australia. Good construction and maintenance of tracks and lane ways are imperative in reducing foot rot, and wet conditions in general tend to reduce claw horn strength and resilience to cow housing and management.

3.8.4.6 Digital and interdigital dermatitis

The primary cause of this infectious disease is a spirochete, which is very resilient, survives in manure and as such is more common in housed animals. This infection is spread through manure and can be reduced by attention to floor hygiene (e.g. twice-daily scraping and/or flushing with water). It can however be spread by frequent (inadequate) scraping with automated scrapers. Regular use of clean footbaths becomes essential where the disease is endemic. Some farms incorporate foot bathing as a daily routine. The appropriate use of medications and/or copper sulfate can be used to treat DD when there are lesions. This is not presently a common problem in pasture-based systems.

3.8.5 Environment and lameness

3.8.5.1 Pasture-based systems

In pasture-based systems, which are common to New Zealand, Australia and some areas of Europe and the USA, the cows are managed in large herds, often using paddocks which are grazed in rotation and, as a consequence, cows in these systems walk long distances. In these circumstances the most common types of lameness are white line disease and foot rot, which is a secondary infection that has often resulted from an infection of the white line at the heel area of the outer (lateral) claw, which tends to wear faster than the toe in these systems. The other types of lameness include sole bruising and ulceration, interdigital damage and swelling due to high stocking rates (paddock pressure). There is less infectious skin disease (e.g. DD), but this is increasing with an increasing prevalence of housing.

In pasture-based systems the careful handling of dairy cattle and the infrastructure used to convey cattle to and from pasture are key areas of management in the prevention of lameness. The provision and maintenance of good-quality cow tracks, the steady movement of cattle (at their own speed) along tracks, the prevention of manure build-up and occurrence of wet muddy conditions and the accumulation of small stones or the development of rough surfaces where cows are required to walk, are key areas in the prevention of lameness. On tracks drovers should be more than one fence post distance away from the last cow. Ideally cows should make their own way to being milked, which can be facilitated by automatic time-controlled gate opening devices.

3.8.5.2 Housing and lameness

In many countries, cattle are housed either permanently or, more commonly for 4 to 6 months of the year, when pasture growth is low due to cold wet conditions. Dairy cattle confined in housing or feed areas with concrete flooring may have more feet and leg problems. Due to increasing herd sizes the free stall or cubicle housing systems have become the most common. In these systems sole bruising and ulceration, white line disease and digital and interdigital dermatitis are the most common types of lameness. Provision of at least one stall or cubicle available for each cow, preferably with 5% additional (empty) stalls, will increase lying time and reduce sole and white line-related lameness. These stalls or cubicles should be of an appropriate size (Table 3.6~~3~~) and construction to allow the cow to lie comfortably and have enough 'lunge space' to allow the cows to rise and reduce hock damage. These cubicles/stalls should provide a comfortable bed. Cow mats are common but not ideal. The best material would appear to be sand, which provides comfort when lying at rest and purchase for the feet when the cow is changing position (standing up and lying down).

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Loose housing systems should have a bedding area and separate loafing/feeding area, which can be cleaned regularly to minimize bedding use and incidence of mastitis and milk SCC levels (Table 3.11~~6~~). Tie barn systems, where cows are tethered, are much less common overall, but are still popular in some parts of Europe and Canada, where smaller herds are housed. In these systems, sole bruising along with claw overgrowth and hock swelling are more common types of lameness due to lack of exercise.

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The exact details of housing requirements for dairy cattle, such as space allocation and appropriate cubicle/stall dimensions according to animal live weight, can be found in the building standards of each country along with reference to welfare codes of practice and farm assurance guidance notes.

3.8.6 Nutrition, genetics and lameness

3.8.6.1 Acidosis and subacute rumen acidosis

Laminitis, which should not be confused with sole hemorrhages arising from mechanical damage to the suspensory apparatus of the foot, arises from disturbances to the blood and oxygen supply to the corium, the area of horn production. The condition, which may affect all four feet is extremely painful. The skin above the hooves is hot to the touch though the hooves themselves may feel cold. This lameness is associated with nutritional disorders, especially acute (pH < 5.0), or intermittent or chronic subclinical rumen acidosis (pH < 5.5). A reliable indicator of subclinical acidosis is low milk fat composition. This has become more common in recent years. The use of diets with high levels of rapidly digestible carbohydrates or sugars and potentially low levels of dietary fibre and short forage chopping can result in low pH due to higher rate of fatty acid production in the rumen fluid (especially lactic and propionic acids). A low rumen fluid pH can result in the death of some rumen bacterial populations leading to the release of endotoxins that mediate an inflammatory response and cause the constriction of blood, oxygen and nutrient supply to the corium, where the hoof horn-producing lamellae are located. This causes a disturbance to horn formation, which can be sufficiently severe to result in a break or crack appearing on the outer wall of the hoof wall of the outer (lateral) claw, which typically occurs at the heel of the foot.

3.8.6.2 Vitamins and minerals

The structural integrity of the hoof horn depends on the effectiveness of the keratinization of epidermal cells and this can be affected by diet, e.g. vitamins A, D, E and H (biotin); minerals calcium, phosphorus and magnesium; trace elements zinc and selenium (Table 3.14). Dietary deficiencies of minerals, vitamins and trace elements lead to disturbances in the keratinization process. This can result in decreased horn quality and development of secondary infection. Calcium, phosphorus and manganese are involved in the development and maintenance of bone and collagen formation. The addition of biotin and zinc sulfate have been found to reduce the levels of lameness, especially white line disease, and improve the rate of healing of hoof horn. Copper and cobalt supplementation may also affect hoof and foot health. However, such dietary supplementation will not compensate for poor genetics, environment and/or management.

3.8.6.3 Genetic selection

The selection process favours cows with steeper hoof and mid-~~-~~range leg angles, which allow the cow to wear the toe of the claws and this has also been related to stronger hoof horn quality. This selection of dairy cows and sires for good ‘conformation traits’ such as leg and foot angle has been successfully applied ~~practised~~ to reduce the number of cows with low hoof angles and ‘sickle’ shaped hocks that tend to develop overgrown claws at the toe area. A slight overgrowth is indicated when the outer (lateral) claw is slightly longer than the inner (medial) claw and this should be corrected by hoof trimming before the cow develops an inability to wear the hoof wall at the toe.

3.8.7 Hoof trimming

The routine trimming of cows’ claws is a common practice for the prevention of lameness in countries such as the UK, USA and Canada. This is typically carried out at drying off from lactation This should be carried out by a qualified hoof trimmer, veterinarian or farmer who has completed an accredited hoof-trimming course. While good hoof-trimming is a major contributor to the control of lameness in dairy cattle, poor, overzealous trimming can make matters worse. Therapeutic foot trimming, e.g. in the management of a sole ulcer is normally accompanied by the application of a ‘block’ to the undamaged to one claw to take the weight off the affected claw while it heals. This also brings about an immediate reduction in pain during locomotion.

<**Table 3.14** Preventing and reducing the incidence of lameness of dairy cattle. >Near here

3.8.8. Other potential health problems

3.8.8.1 Hypocalcaemia

Lactating dairy cattle produce large amount of milk, which contains calcium. This requires them to mobilize body reserves of calcium from their bones. However, during early lactation the requirement for calcium for milk production can result in a shortage of calcium in the blood plasma (hypocalcaemia). Acute calcium deficiency can result in lack of muscle function that is enough to cause paralysis and rapid death. Affected cows can be treated with calcium borogluconate injections, but the main aim is to prevent the occurrence of this calcium deficiency in the blood (see Section 3.6.6.1).

3.8.9.2 Hypomagnesaemia (grass staggers)

During periods of rapid pasture growth, typically in spring or following late autumn applications of nitrogen fertilizer, the magnesium levels of pasture can be low and result in a deficiency of magnesium in the plasma. Magnesium is required for muscle function. In acute deficiency, animals will initially show signs of ‘staggers’ and this can rapidly proceed to convulsions and death. Prevention involves giving magnesium supplements, which are typically added to water or included in concentrated diets offered at milking time. Since magnesium is unpalatable the most effective method of supplementation is by addition to water troughs. However, this will not succeed if cows have access to an alternative source of fresh water.

3.8.9.3 Acidosis and subacute rumen acidosis

This disease has become more common in recent years ~~(see section 3.8.4)~~ and is classified as acidosis with a rumen pH <5.0 and subacute rumen acidosis (SARA) with a rumen liquor pH <5.5. These have become common due to the use of high levels of rapidly digestible carbohydrates or sugars and potentially low levels of dietary fibre and forage chopping, which has resulted in low pH due to higher rate of acid production leading to death of protozoa and some bacterial species in the rumen with increased production of lactic acid. The low rumen fluid pH results in low milk fat composition (below 2.9%) and potentially lowered dry matter intake. Attempts to prevent rumen acidosis in cows given diets high in starch and low in NFD and or functional fibre include the dietary inclusion of bicarbonate of soda in the short term, the use of yeast preparations (dead), which utilize lactic acid, in the longer term, or the inclusion of highly digestible fibre (HDF) into the diet, usually as part of the compound feed offered at milking. Other options include the inclusion of some chopped straw in the diet may be an option, since this will stimulate salivation and thus increase the supply of endogenous sodium bicarbonate. However, this may cause an overall reduction in nutrient intake and thus an undesirable reduction in milk yield.

More recently the application of diet separation sieves to check the feed particle length of mixed rations has become more common (Table 3.15~~6~~) to ensure mixing of the diet leave sufficient amounts of functional fibre. In addition, the assessment of dung consistency to check it's not too loose and checking that the rumen is full (rumen fill), that the majority of cows are ruminating while lying down and that they chew cud each cud bolus between 50 and 60 times before swallowing are cow signals that are used to assess the adequacy of functional fibre in the diet.

<**Table 3.15** Maize/ c~~C~~orn silage, haylage, and TMR particle size recommendations for lactating cows.> Near here

3.8.9.4 Bloat

Bloat is caused by the gas from rumen fermentation becoming trapped in a foam of air bubbles. The problem typically arises when cows graze pasture legumes that contain a protein that creates a 'strong' coating on the air bubble, making it resistant to being broken down. This build-up of gas bubbles results in the rumen crushing the lungs and large abdominal blood vessels of the animal, leading to death. This disease can be prevented by treating cows with bloat oil and or piercing of the rumen to let out the froth. However, the use of anti-bloat pasture species is much more practical than dosing animals with oils or other techniques. The main prevention is controlling access by cows to pastures likely to cause bloat, and the use of plant varieties that have low bloat potential.

3.8.9.5 Acetonaemia (ketosis)

Ketone bodies are produced as a result of the excessive mobilization and incomplete oxidation of fat, in cows that are too fat at the time of parturition (Table 3.9~~4~~). The main prevention is to control live weight and condition score through proper nutrition in the transition period and early lactation.

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3.9 Heifer Rearing and Transition into the Dairy Herd

3.9.1 Strategies

The overall replacement rate is typically around 20% to 25% of the dairy herd annually. Truthfully the lower the herd culling rate and replacement rate the lower the carbon footprint and cost of milk production. Conversely, this will lower the rate of genetic improvement of the herd. The main thing is to ensure excellent management of heifers to ensure they come ~~ing~~ into and remain in the herd, so that fewer are lost before first calving and fewer young~~er~~ cows are culled from the herd. Loss of these ~~, because these~~ will be most costly in terms the lack of return on investment and the most damaging to the genetic improvement of the herd. Dairy heifers are typically provided from the dairy herd by selective breeding from the cattle in the herd that are the most productive, fertile and have the desired conformation and mating these to high genetic-merit sires, with desired dairy characteristics. The alternative is to buy heifers, but this introduces increased risk of ~~from~~ disease introduction, ~~and~~ variability in cost and unsuitability to the dairy system~~herd~~.

In herds where non-sexed semen is used, a 25% replacement rate will require mating a minimum of 50% of the highest-merit cows in the herd, using high genetic-merit semen from artificial insemination or possibly natural breeding in order to provide sufficient herd replacements on an annual basis. Recent changes to farm assurance standards require dairy bull calves to be maintained on the dairy unit or reared by allied units. Consequently, many ~~UK dairy~~ herds are using sexed semen, which produces few bull calves and they may inseminate cows to produce cross bed calves for the beef industry. While New Zealand continues to need to concentrate on seasonal calving and has a ‘bobby calf’ processing chain for young male dairy calves, which may include crossbred beef calves when market prices are low.

The optimal economic performance of dairy heifers will be achieved by calving dairy heifers at 22 to 24 months of age. While many countries achieve this, all year calving herds in the UK dairy industry have on average been ~~more~~ consistently ~~calved~~ calving heifers around 4 months older. The incidence of pneumonia due to damp, cold and inclement environment and greater reliance on pasture are two potentially contributory factors, along with feed cost. While seasonal calving herds must ~~will~~ and the USA manages to calve cows for the first time at 24 months of age, which requires heifers to be served at 13 to 15 months of age. While the USA, UK, EU and China ~~, they may not~~ generally reach the optimal 55 ~~to 60~~% mature weight at service and 85 ~~to 90~~% mature weight at first calving, those calving in grazing systems often calve for the first time at lower mature weight. This compromises feed intake and milk yield, but more important fertility and may increase~~s~~ the risk ~~changes~~ of calving difficulty, infertility and premature culling.

Mature weight is highly heritable and thus can be predicted from the parents and breed of dairy heifer, but farmers must be realistic about the true mature weight of the adult animals as genetic improvement and breed will affect adult weight. The application of higher feeding rates, increased protein intake and thus higher growth rates for dairy heifers between 0 and 3 months of age has been found to increase mammary development and subsequent milk yield, while higher growth rates around puberty (40% mature weight) predispose to fat deposition in mammary tissue and this can negatively affect subsequent milk yield potential. Therefore, the rearing and nutrition of dairy heifers differs from that of beef cattle and will have a direct impact on the yield potential of the dairy herd. The effective provision of dairy herd replacements can be achieved through a specific and planned approach using target maturity for age and achieving appropriate growth rates for each phase of development.

3.9.2 Options for the provision of dairy replacements

There is a range of options for the provision of dairy replacements (Table 3.16~~7~~), which include rearing calves from the dairy herd on the home farm, rearing calves to milk weaning and later transferring them to a ‘contract grazier’ or purchasing in calf heifers or freshly calved heifers as replacements. There are advantages and disadvantages to each of these options. If contract rearing is practiced, all contracts should be legally binding documents, drawn up by a suitably qualified and experienced person. These must clearly state targets for growth rates and live weight/maturity according to animal age and penalty clauses if targets are not met. They should include regular monitoring and reporting of heifer development. There should be a health plan and a contingency feeding plan, which should be developed with a veterinarian and nutritionist, documented and monitored.

<**Table 3.16** Optional methods of providing dairy herd replacements and the effect on requirements, cost and risk.> Near here

3.9.3 Dairy heifer rearing programmes

3.9.3.1 Rearing young calves

Most dairy calves are removed from their mothers shortly after birth and many are offered pasteurized colostrum to avoid the potential transfer of Johnes disease, followed by which they are reared artificially. Milk is offered by training calves to drink from a pail or suckle from a teat or from a mechanical calf feeding machine. Suckling systems, where calves are suckled on a cow on a restricted basis or where multiple calves suckle a nurse cow, are less common in developed countries, but are used regularly in developing environments. Calves are offered either whole milk, milk replacer or colostrum. In addition, calves are offered specialized calf starter feeds and forages to encourage rumen development. The main objectives are to achieve low mortality and produce healthy calves that have few disease problems and grow rapidly (750 to 950 g/d) during the first 3 months. The single most important factor in ensuring good calf-rearing practice is the adequate provision of high-quality (high immunoglobulin concentration) colostrum from the first two milkings postpartum This must be offered within the first 6 to 12 h of birth, in enough quantity (10 to 12 % of live weight) to ensure adequate passive immunity transfer.

3.9.3.2 Whole milk feeding

The use of whole milk offered at approx 4 to 5 litres/day (L/d) (or 10% of live weight) is popular in many countries and will achieve growth rates of 630 to 650 g/d, which are below the growth rates recommended for dairy heifers. Whole milk is deficient in nutrients, vitamins D and E and trace elements – iron, manganese, zinc, copper, iodine, cobalt and selenium. To achieve optimal growth rates for dairy calves, whole milk requires the nutrient concentration (fat, lactose and protein) to be increased along with additional vitamin A. These need to be achieved without substantial increase to feeding volume (L), with the addition of high-quality milk replacer, with additional lactose and high protein level (26 to 28%) or preferably with a specifically designed milk supplement. Increasing the feeding level of whole milk above 5 l/d is not recommended; this will reduce solid feed intake, delay rumen development and weaning from milk, which will increase rearing costs and negatively affects mammary development. Milk from cows being treated with antibiotics is not recommended for feeding to dairy heifers.

3.9.3.3 Colostrum feeding systems

Colostrum feeding is more popular in some counties than others, depending on calving pattern and other marketing opportunities for colostrum. Colostrum feeding at 4 to 5 l/d results in high growth rates (700 to 750 g/d) and healthy calves. Continuing to feed colostrum may delay the development of an active immune system in the calf and a period of 'low' immunity, the 'weak' period between passive immunity from colostrum and active immunity in the calf, will occur within 1 to 2 weeks post-weaning or following the removal of colostrum from the diet. Changing the diet to whole milk 3 weeks prior to milk weaning will help avoiding a clash between milk weaning and low immune function.

3.9.3.4 Milk replacers

Milk replacers are typically either skimmed milk or whey-based milk powder. Skim milk powders and whole milk contain caseins, which coagulate in the abomasum and increase retention time, while whey-based milk powders do not form clots. The available comparisons of skim milk versus whey protein concentrate indicate that calves offered skim milk-based milk replacer do not seem to perform better than those offered whey protein concentrate. Heat damage, which can be estimated by testing the lysine content, can severely affect the digestibility of milk replacers and subsequent calf growth rates. The best performance will be achieved from highly digestible milk replacers that contain fractionated milk proteins (skim base) and natural antibodies, which increase disease resistance in the digestive tract and provide good-quality proteins. Milk replacer powders recommended for dairy heifers contain 20 to 21% fat along with additional lactose and 26 to 28% crude protein. The liquid volume of milk and concentration of replacer in the liquid are important factors, while most milk replacers have been reconstituted at 125 g/l, current practice is to offer 150 g/l in general and for this to be increased on a sliding scale up to 175 g/l when ambient temperatures fall below 5 °C. Calves offered milk replacers at 600 g/d they should achieve growth rates around 750 to 900 g/d, depending greatly on management, environment, nutrition and health. The need to lower antimicrobial use has more natural additives being included in milk powder and starter diets. These enhance the microbiome of the intestinal tract and immunity of the animal using prebiotics such as saccharides and yeast cell walls and probiotics such as yeast and lactobacilli spp., along with other natural substances such as essential oils.

3.9.3.5 Ad libitum milk feeding

Ad libitum feeding of milk is not recommended for dairy heifers, due to this practice resulting in slow rumen development and inadequate balance of nutrients in milk.

3.9.3.6 Cow calf systems

Cow calf systems have become increasing popular due to the direct impact of milk purchasers and the poor perception of consumers regarding cow-calf separation. Some farmers have nurse cows and operate multiple suckling systems which involve running a number of calves with one or more 'nurse' cows. This system can be effective provided that calves receive sufficient milk (10 to 13 % birth weight) to achieve adequate growth rates. Farmers sometimes use high somatic cell count cows for this purpose to prevent damage to milk quality supplied to the milk product manufacturer.

3.9.3. Restricted suckling

The use of restricted suckling of dairy calves in developing countries where the infrastructure to ensure hygiene and support factors are limited can be more successful than artificial rearing and feeding calves from buckets, pails or artificial teats. These systems allow the calf to suckle the dairy cow before milking to encourage milk letdown and again after milking (by hand or mechanically) to remove the residual milk remaining. Depending on the milk yield of the cows, the calf may be allowed one or two full quarters or the residual milk of all quarters. The main factor is to ensure that the calf is allowed sufficient milk to ensure adequate growth, health and development. Calves are typically offered milk up until 10 to 12 weeks of age, up to a maximum of 4 to 5 L/d.

The advantages of restricted suckling systems are the lack of potential infection (enteric disorders or scours) of the calf due to poor feeding, utensil hygiene, prolonged passive immunity for the calf and satiation of suckling behaviour. The cow will produce a greater quantity of milk and be less likely to have mastitis. The disadvantages are the potential to prolong the anoestrous period in the dam with twice daily suckling of the calf, which can be alleviated by reducing the suckling frequency to once daily to initiate ovarian activity.

3.9.4 Weaning from milk

Early weaning systems allow calves to be weaned from milk at 5 to 6 weeks of age when intake of the dry, cereal-based starter feed is 1,5 to 2 kg/d for 3 consecutive days prior to weaning. However, this system restricts milk intake to approx. 10% of birth weight, which restricts growth rate to around 450 to 500 g/d. Dairy heifers and larger dairy beef breeds are typically offered milk at around 13% birth weight and weaned around 8 weeks of age. In pasture-based systems calves are typically offered milk for longer, until 8 to 12 weeks of age. In New Zealand calves are generally weaned according to live weight, which is related to breed – approximately 80 kg for Jersey, 85 kg for Friesian Jersey cross and 90 kg for Friesian calves, which is achieved between 8 and 10 weeks of age. This equates to approx. double birth weight plus 5 to 10%. The UK and USA wean dairy heifers at double their birth weight. However, calves are not weighed on many farms, so age and adequacy of growth / health are more typical characteristics. Delaying the weaning of calves that have had health issues and made inadequate development is the better potential approach, rather than weaning strictly according to age.

3.9.5 Organic dairy systems

Organic systems have specific requirements for calf rearing and at present most specify feeding of whole milk until 12 weeks of age. Milk feeding level will be a minimum of 10% birth weight, but maximum milk feeding level will depend on the cost of organic calf starter diets and forage quality and availability. In these cases, individual country and milk company guidelines should be followed.

3.9.6 Solid feeds and feeding

3.9.6.1 Calf 'starter' feeds

Young calves should be offered calf starter and will consume small amounts (200 g per head per day) of palatable cereal-based feeds within the second week of life. These cereal-based feeds are key to the development of the rumen and ruminal papillae, which respond well to volatile fatty acids produced from rumen fermentation. Specialist calf supplement feeds and meals need to be highly palatable, should be offered in small amounts initially and replaced daily, to encourage early and increasing consumption levels. Any leftovers can be collected and given directly to older (weaned) calves.

Good-quality calf supplements for dairy calves should be made from highly digestible components, 22% crude protein (CP) with a good amino acid profile (e.g. soya bean meal). However, due to the need to strive towards carbon neutrality, the importation of soya into the EU and UK is likely to be replaced by locally gown peas, beans and canola (rape seed meal). Dairy heifer growth and mammary development are increased by higher levels of utilizable proteins (amino acids) in the diet. The levels of sugar (50 g/kg and fat (35 g/kg) need to be limited in barley-based diets, as calves have a limited capacity to digest these.

3.9.6.2 Calf starter and feeding levels

Calf starter feeds should be offered *ad libitum* prior to the time of weaning from milk but restricted thereafter according to the availability and quality of pasture or forage. The body condition of heifers can fluctuate, low body condition can be used to indicate the need to increase feeding levels, while short-term increases in body condition should not be a reason to decrease feeding levels.

3.9.6.3 Forages

Ad libitum access to clean, dust-free fibrous feeds, preferably chopped straw, should be offered to satisfy the investigative need of young calves for oral activity from approx. the beginning of the third week of life Insufficient access (level offered or feeding space) to forage will result in calves sucking and chewing other objects in their surroundings, such as each other, buildings, fences and anything they can reach, included string used to fix up gates or fences. Grazing calves will be consuming some pasture but will benefit from being offered straw or hay with a high stem component, which need to be kept dry and covered from rain, to prevent subsequent ~~mould~~mold and aflatoxin development. The consumption of these forages will aid rumen development, although the main contributor to this is the consumption of cereal-based calf starter diets.

3.9.6.4 Water

All livestock should have access to clean fresh water at all times. Calves should be offered good-quality, fresh clean water that should be changed twice daily. The exception is a small proportion of calves that drink water as if it was milk, and these should have their access limited to feeding periods twice daily for the first week or so. Care should be taken to ensure that watering facilities can be cleaned scrupulously, as it can harbor pathogens such as cryptobiosis.

3.9.6.5 Bedding

Housed calves, unless housed on slatted floors, will require bedding materials. Calves will eat bedding and will eat this to a much greater extent when cereal straws or stalk hay is not provided separately. Wood shavings, sawdust, straw, wood chip and sand all make suitable bedding materials and can be used in combination. Calves prefer the softer, more comfortable, bedding types and straw has the added advantage of developing layers, increasing the opportunity for the top layer to remain dry for longer. Bedding choice generally will depend on availability. The cost needs to be considered according to ability to keep the bedding dry and subsequent amount required, and suitability to maintain the relative humidity in the building below 75% (see section 3.9.8.3), however in damp climates this humidly can be greater during winter. Bedding is important in providing physical and thermal conform for calves, along with its role in maintaining air quality in general and at calf height especially.

3.9.7 Calf housing/management systems

3.9.7.1 Pasture-based management

In pasture-based systems, such as found in New Zealand, calves can be housed but are frequently reared at pasture in groups (mobs) of 20 to 40. They are housed briefly and, once they have learned to suck from an artificial teat, are offered milk at pasture from either from a machine or a ‘calfeteria’ (mobile milk vat with many teats, at least one per calf), which delivers colostrum, whole milk or milk replacer at approximately 4 to 5 L per head, each day. Unfortunately, drinking speed varies greatly between calves and unless the system can regulate milk on an individual calf basis this will result in calves drinking very differing levels of milk.

3.9.7.2 Housed calves

The main aims should be to provide a warm clean environment and prevent the development of pneumonia (Table 3.17~~8~~). This can be achieved by the provision of buildings with adequate air space and natural ventilation. Calf buildings should be built to allow the prevailing wind to pass directly through the top portion of the building to remove moist air, while avoiding any direct draught onto the animals. Conditions of high relative humidity in the building can be avoided through attention to good ventilation, regular (daily) addition of bedding and minimizing accumulation of water, through daily cleaning of any water, good drainage and limited addition of water through washing down.

In between groups or batches of calves, the buildings should be cleaned out, washed down thoroughly and rested (1 month) or disinfected between each batch of calves. This includes water troughs and bowls, as these harbour disease organisms. This is referred to as an ‘all in, all out system’ and can be applied to sections of buildings if required, as in pasture-based systems, where multiple groups of calves may use the building for short periods of time.

<**Table 3.17** Minimum space requirements for calves in group housing.> Near here

3.9.7.3 Calf hutches and tethering

Calf hutches, wherein calves can be kept outdoors in physical isolation but in social contact, have become popular in recent years. The main reason is to restrict the spread of respiratory infections. In some countries, calves can be tethered without a hutch (not within the EU). Hutches should be moved onto new areas for each new calf to prevent disease build-up. Hutches should be placed on well-drained areas, cleaned using a similar approach that described above (section 3.9.7.2). These systems are labour intensive.

3.9.7.4 Individual pens and group housing

An individual pen for calves allows individual monitoring of feed intake and is favoured in early weaning systems. The calf should have sight of and contact with other calves. These systems are labour intensive and as a result group rearing has become more popular as herd sizes increase. Cleaning is essential using a similar approach to that described above (section 3.9.7.2).

3.9.7.5 Mechanical feeding

Due to shortages of skilled labour and increased herd sizes, the use of machines for feeding dairy heifer calves is becoming more popular. The level of control and information provided varies greatly between machines. They can be used at pasture or in housing systems. They do require a skilled ~~operator~~operator, but they remove much of the work involved in calf feeding.

3.9.8 Disease prevention and minimizing mortality

One of the main factors in preventing disease and mortality is the adequate provision of good-quality colostrum, soon after calves are born. The main diseases that calves are likely to suffer include enteric disease (scours), clostridial diseases (see sections 3.9.3.3) ~~and 3.9.9.3)~~, joint ill and pneumonia. A disease prevention and treatment plan for dairy calves should be put in place with the advice of a veterinarian.

3.9.8.1 Joint ill

Joint ill is a serious disease that can be fatal. Prevention is the key and as ~~, followed by checking and prompt treatment (antibiotics) of any infected navels (umbilical cords). As~~ soon ~~after birth~~ as possible after birth, the umbilical cord should be treated with a suitable iodine-based solution, in the calving paddock or calving box. Further applications of iodine-based liquid until the cord has dried, and regular checking for a navel swelling, will allow the opportunity to identify and treat any infections quickly using suitable antibiotic therapy as advised by the veterinarian. The regular cleaning and replacement of bedding of calving boxes and calf transport equipment will help prevent infection, in addition to navel treatment. This should be added to the farm's herd health plan.

3.9.8.2 Enteric disease (scours)

Enteric diseases should be prevented through high levels of building management ('all in, all out' system for pens, with resting or disinfection), personnel and equipment cleaning and hygiene. This includes effective biosecurity measures that prevent visitors bringing disease onto the calf unit and into contact with the calves. On units where Rotavirus has been a problem, cows may be vaccinated before calving, so that they provide colostrum with specific antibodies against this organism. The prevention of pathogen challenge is essential, grouping calves of similar ages (less than 3 weeks difference), application of all in-all out approaches, cleaning out and disinfection of all materials, pens and buildings. Twice daily assessment and scoring (1 to 4-point scale) of faeces and the prompt treatment of calves with poor faecal consistency ($\geq$3). The treatment of scouring calves should include the prompt administration of electrolyte solutions to prevent dehydration.

The identification of the pathogen involved, and suitable treatment can be identified through faecal sampling. Scouring calves should be isolated from unaffected calves to prevent disease transfer and kept warm (possibly using heat lamps) and dry to maximize their opportunity for survival. Pens that have held sick calves should be thoroughly cleaned and disinfected before further use. On the reintroduction of food, colostrum can be useful to enhance immunity at the mucosal surface of the gut wall.

A planned approach to calf health management is essential. All calves should be closely observed twice daily for signs of health or incipient disease. The unit should have a store of electrolyte preparations and suitable calf scour treatment products. Colostrum can be stored frozen for emergency use, and should be thawed in hot water, not in the microwave. There should be a herd health plan for the calf unit, which may incorporate (e.g.) a cow vaccination programme when Rotavirus is endemic.

3.9.8.3 ~~Pneumonia~~Bovine respiratory disease, pneumonia and mycoplasma bovis

Bovine respiratory disease (BRD) and p~~P~~neumonia is most likely to occur in housed calves and is best prevented by attention to building design and management (avoid overstocking, provide adequate air space and good ventilation; see section 3.9.7.2). This is more prevalent in damp, cold and changeable winter weather in the UK. Any calves, whether housed or kept at pasture, that develop coughing, which can equally be scored on a 4-pint scale, along with nose and eye discharge, ~~–~~should be examined by the veterinarian, a suitable diagnosis and treatment should be sought immediately, the cause identified, and prevention strategies put in place. These may include improvements to colostrum feeding, building ventilation, bedding strategy and eventually vaccination in addition. Older heifers should not be housed within the same air space as younger calves, to prevent the transfer of pneumonia. Recently, mycoplasma bovis (M. Bovis) has become more common on dairy farms that typically presents itself as pneumonia, but can manifest as a middle ear infection, which can be identified and will need to be treated using antibiotics that are effective against M. Bovis.

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3.9.9 Stock tasks

The main stock tasks will include animal identification, de-horning, supernumerary (extra) teat removal and vaccination.

3.9.9.1 Animal identification

Accurate identification of dairy heifers is essential, not only for traceability, but also for herd improvement and practical management of dairy cattle. Legislation requires the accurate identification of individual animals and this is achieved through ear-tagging with an individual animal and herd number. These tags will be placed into the ears soon after birth. In many countries this is linked to a national animal identification scheme and animal passport system. ~~It is regularly supplemented with electronic tagging soon after birth. Heifers are typically freeze-branded on entry to the dairy herd to present a large, easily visible number on the hindquarters. This facilitates individual management (e.g. feeding, oestrus detection, condition and locomotion scoring).~~

3.9.9.2 De-horning and supernumerary teat removal

Dairy calves will require de-horning and possibly the removal of any supernumerary teats at approximately 5 to 6 weeks of age. It is ~~also~~ important that local anaesthetic be used during the disbudding / dehorning ~~se~~ processes to ensure animal welfare, minimize growth checks and comply with local legislation. It is essential that these tasks are not carried out at the same time as any other changes such as vaccination, weaning, or changes in housing.

3.9.9.3 Vaccination

Vaccination against pneumonia, clostridial infections and/or lungworm may be necessary where dairy calves are likely to be infected by these. An appropriate herd vaccination programme should be applied according to the recommendations of the veterinarian and added to the farm's herd health plan.

3.9.10 Growing dairy heifers

Following the calf rearing point, dairy heifers will be managed at pasture and potentially housed during winter periods in countries where weather conditions are inclement or may be fully housed. During period of grazing ~~and following housing,~~ the control of parasitic infections will be required. In addition the ~~,~~ provision of adequate forage ~~pasture~~ and supplementary feeds, and regular monitoring of heath and growth rate are the main tasks required to ensure that heifers are well grown and ready for service at 13 to 15 ~~16~~ months to create a pregnancy and transfer to the dairy herd (Table 3.18~~9~~).

<**Table 3.18** Energy and protein requirement and targets for live weight gain and wither height in growing Holstein Friesian heifers.> Near here

3.9.10.1 De-worming

At pasture, y~~Y~~oung animals are particularly susceptible to parasitic worms of the intestine and potentially the lungs. Control measures will depend on the age of the animal, access to pasture and the infection that exists on the pasture. Pasture used by older animals may be infected with parasites and necessitate the more frequent control of parasitic infections in younger animals. Parasite infection can be controlled by the use of clean pastures that have not been infected by older animals and reducing the potential infection by mixed grazing with other animal species not susceptible to the same species of parasites. The control of parasites ~~is will usually~~ may need to be backed up with regular use anthelmintic treatments ~~of anthelmintics to control worm infestation levels both~~ while at pasture and ~~during~~ housing to ~~. This programme will typically involve two treatments – the initial~~ eliminate ~~treatment to kill~~ adult worms~~,~~, followed by a ~~and the~~ second treatment following housing to prevent re-infestation from the developing larvae.

3.9.10.2 Service (insemination)

The natural service or insemination of dairy heifer needs to take place at 13 to 15 months of age and the heifer will need to be 55 ~~60 to 65~~% mature weight. This first service should be with a sire that has an 'easy' calving or 'low calving difficulty' rating for first-calving heifers. This rating can be taken from the 'sire' details for bull semen. Alternatively, one can use an easy calving breed such as Jersey or Angus for AI or natural service. Many dairy heifers are synchronized using intrauterine devices and then inseminated to ensure they come into the dairy herd at 22 to 24 months at 85 ~~to 90~~% mature weight. The body condition of heifers should not be a problem, but calving condition scores of 3 to 3.5 (on a 1 to 5 scale) and 5 to 5.5 (on a 1 to 10) New Zealand scale are recommended. There is a range, because breed and genetic merit within breed tends to affect actual condition scores for dairy cattle.

3.9.11 Transition of the heifer into the dairy herd

Increasing the longevity of the dairy cow through careful heifer management will reduce the cost of rearing replacements. This will ~~, and~~ maximize herd genetic merit ~~breeding worth~~ and productivity, thus increasing the profitability of the dairy herd. The i~~I~~ntroduction ~~ing~~ of heifers into the dry cows and the milking shed/parlour or shed before calving will reduce the number of stresses experienced by heifers around calving.

3.9.11.1 Heifer (first lactation cow) ~~in~~ fertility

Infertility can be a major problem for first-lactation dairy cattle. First calving ~~Heifers~~ should be at 85 ~~to 90~~% mature weight ~~at the onset of first lactation~~ to prevent problems such as ~~-~~ competition for feed and aggression from older cows that may lead to weight loss, decreased conception rates rate and potential culling. It should also reduce the risk of a range of postpartum disorders, such as ketosis, ~~- and~~ displaced abomasum and infertility. Alternatively, larger herds have the opportunity to maintaining first lactation cows in a group separate from adult cows, during the initial to mid part of first lactation.

3.9.11.2 Lameness

Heifers are particularly susceptible to developing sole bruising around first parturition, which can ~~and lameness that~~ develop ~~will lead~~ into lameness during first and subsequent lactations. Thus ~~, thus~~ careful ~~heifer~~ transition and management of first lactation cows can reduce the incidence of lameness throughout the whole herd.

3.9.11.3 Mastitis

The management of heifers in separate groups, and milking heifers before adult cows, will reduce the risk of transmission of infectious mastitis from adult cows. Teat sealants may also be carefully administered to dairy heifers before first calving to reduce the risk of mastitis-causing pathogens entering the mammary gland during late pregnancy and causing mastitis during first lactation.

3.10 Precision farming

The development and lower cost of electronic devices, cameras, accelerometers, satellite and localized monitoring of animal location, pH boluses, rumination monitoring, drones, virtual fencing and digital image analysis offer considerable potential for precision management of ~~dairy systems for~~ housed and grazed dairy systems~~animals~~. ~~-~~Some of these technologies are being used as a routine, while others are less ~~well~~ developed. The main constraints on their use are the production and interpretation of the information into a useful format as a basis for decision making, especially the lack of a common platform for managers to be able to access, integrate and interpret data more easily from different systems. The main advantages are greater animal monitoring, which has the potential to enhance animal welfare and productivity.

References and Further Reading

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Field Code Changed