Cattle Behaviour and Welfare

Second Edition

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Preface

This book evolved from an initial publication on cattle behaviour (Phillips, 1993), which was written primarily for farmers and students of farming systems. The intimate relationship between the behaviour of cattle and their welfare encouraged me to develop the original text into one dealing with the welfare of cattle and its relation to their behaviour. The welfare of cattle has been much studied in the last decade, as farm animal welfare has been a prominent topic for debate and research, and this book attempts to review the recent research. Welfare can mean different things to different people and this is discussed as the topic is placed in context. It would be impossible to describe all the possible adverse conditions that could affect the welfare of cattle, so the principal influences are summarised for the different types of production – dairy, beef, calves and draft oxen. Two particularly important influences – humans and transport systems – are given chapters of their own.

In the increasing pressure to intensify cattle production, people often ignore the fact that the unit in the factory production system is a higher mammal, with complex mental and physical needs. An attempt to evaluate the welfare of cattle in a system of production must start with their perception of the system, progress to their choice of components of the system and end with a description of their behavioural reaction to the system. Their physiological response can also be measured and may be related to their metabolism and even production rate, but it usually bears little relationship to behaviour and to the adequacy of the environment. The latter is best indicated by the ability to display normal behaviour patterns and the absence of abnormal, deleterious behaviour. For humans, the behaviour of cattle is a signal about their well-being; for cattle, it is the reaction to the environment as they perceive it, modified by the innate motivation to perform the behaviours.

Studying the behaviour of cattle is probably one of the youngest and also one of the oldest sciences. The first students of cattle behaviour were undoubtedly our primeval ancestors. Many of the physical attributes of cattle rendered them unsuitable for domestication, in particular their large size and the low proportion of muscle tissues in the areas giving desirable meat cuts, such as the loin. However, aspects of cattle behaviour and their ability to thrive on grasses of little value to man led early man to choose cattle as the major domesticated animal. Their limited agility, gregarious social structure, the promiscuity of the male and extravert receptivity display by the female, as well as the precocial development of the young, are probably responsible for the relative ease with which they must have entered into a symbiotic relationship with man. The passion for salt, which they shared with man, provided an easy means of controlling them which is still in use with the relatives of cattle nowadays. Domestication therefore led to significant benefits to both cattle and man and a mutual respect evolved.

Nowadays the study of cattle behaviour is no less important. Cattle are still our major domesticated animal, contributing worldwide almost 18% of man's protein intake and 9% of our energy intake, as well as draft power, hides and dung for fuel. Veterinarians utilise cattle behavioural signals for disease diagnosis, and livestock handlers and farmers can derive useful information on the health of the stock in their charge from their behaviour. As well as discussing the major influences on welfare, this book describes the major behaviour patterns in cattle, their ontogeny and their purpose. It is intended for all involved in the study of animal welfare and ethology, as well as students of animal science, agriculture and veterinary medicine. It is also hoped that it will be of interest to advisers in cattle husbandry and leading farmers.

I acknowledge CAB International for permission to reproduce part of an article already published (Phillips, 1997).

Clive Phillips
Cambridge, UK

Chapter 1
Introduction to Cattle Welfare

Definition and measurement

The welfare of an animal relates primarily to its ability to cope, both with its external environment, including housing, weather and the presence of other animals, and with its internal environment, such as specific pains, fever and nutritional status. An instantaneous assessment of the welfare of cattle would ideally concentrate on their feelings at the time, which would be influenced by their genetic predisposition, by recent experiences, by their environment at the time of assessment and by any anticipation of future events, such as feeding. However, feelings are difficult to measure and the assessment is more likely to concentrate on more easily quantified parameters, such as the strength of their preference for different environments.

A long-term assessment of welfare, for example over the lifetime of an animal, should evaluate the degree to which the animal has been in harmony with its environment, and will include such aspects as whether it could perform behaviours to which it is genetically predisposed, e.g. suckling in infancy, whether the prevalence of disease was unacceptably high, and the extent to which it achieved nutritional and thermal comfort and homeostasis, and adequate rest and exercise (Fig. 1.1).

Fig. 1.1 The different degrees of welfare, assessment and the impact on the animal.

As the animal passes from a good to a worse environment it moves from a state of harmony, or equilibrium, to one where it recognises an environmental deterioration. This can be detected experimentally by preference tests, indicating which environment the animal prefers. These must be treated with caution for several reasons: animals may give an exaggerated or diminished response according to previous experience, they may not be sufficiently experienced to choose the best environment for themselves in the long term and their immediate reaction may differ substantially from their long-term one if they are attracted by the novelty of one or more of the environments. A cognitive imbalance may turn into a physiological imbalance if the environment progressively deteriorates. Later pain may be felt and injuries sustained, both of which will tend to cause abnormal behaviour. Disease may follow and may result ultimately in death of the animal.

We may also evaluate the extent to which an animal is able to perpetuate the bovine species through reproduction. This is related to welfare, because courtship and copulation are natural behaviours that cattle have a strong drive to perform. However, it cannot be claimed that the welfare of a semen-donating bull is necessarily any greater than a bull slaughtered for meat. It is likely to be worse if he becomes lame. It is therefore not a simple relationship between reproductive behaviour and welfare, but man often assumes the management of reproduction as part of their 'domestic contract' with animals. In this contract, we provide basic requirements – food, water, a suitable environment, medical care and companionship – but we take away freedoms that the animal would have in the wild – choice of mate, companion, food, freedom of movement, etc. We also reduce the longevity of cattle kept for the production of beef, because as they get older their growth rate declines and they have increasingly more fat in the carcase. Most dairy cows have a short life, because of the stress of many lactations and the poor conditions that they are often kept in. In intensive dairy systems they only last on average for about three lactations in the milk-producing herd. This will be considered by many to be evidence of inadequate welfare.

The management of the domestic contract, and the issue of whether cattle should be allowed to reproduce naturally, are principally moral issues. In the case of reproduction, the opportunities for highly selective breeding by artificial means not only prevent cows from performing natural copulation, but also may compromise the future of the species by limiting the genotype diversity. Presently cattle are selectively bred to be either high milk producers or fast growing meat animals. In future, their ability to survive on by-products, straw, human food residues, etc., may be of greater importance if increased population pressure dictates that land can no longer be used solely to grow feed for cattle. Also, the efficient use of nutrients such as nitrogen may be of special importance to increase production efficiency and reduce nitrogen pollution in excreta.

The future welfare of the species should be considered in relation to breeding policies, but this is unlikely to be done by individual farmers who cannot be expected to predict or respond to the economic situation in the distant future. A prudent approach would be to maintain sufficient cattle breed diversity for all future eventualities. Maintaining diversity in the cattle genotypes is an important aspect of long-term breeding policy in which central government intervention could be beneficial to the species in the long term.

Modern breeding techniques may also create dilemmas for the welfare of individual animals. For example, if a cow were selected to donate embryos for genetic manipulation, there could be an increase in the welfare of the donor cow, since she would have to be well managed to produce the best embryos. However, there might be a decrease in the welfare of the offspring as a result of the genetic manipulation, if it led, for example, to a large increase in milk production potential. This moral dilemma must be addressed on an individual case basis.

Humans manage both the genotype and phenotype of cattle, and they have perhaps modified the genotype more than in any other species for their own benefit. It should not be forgotten that in modifying cattle to the farm environment, we have improved their welfare. Selection for a suitable temperament, and in particular docility, has enabled cattle to co-exist with humans in an environment where ancient *Bos aurochs* cattle would have found the conditions very difficult to cope with. The ease with which cattle can be managed in dairy and beef farms is in marked contrast to other species that have not been extensively domesticated, such as deer, ostriches, mink and foxes. These species are all difficult to farm and individuals show high levels of aggression to each other and their keepers.

Our modification of the cattle genotype has enabled us to keep them in a large variety of conditions and environments. In environments where many people would consider that cattle are not well adapted, they still produce economic quantities of milk or grow at an economically acceptable rate. Production is largely a function of nutrient supply, and although cattle kept in adverse conditions can have low levels of immunity, and a high incidence of diseases, such as lameness, there is little evidence that any productive function is affected. This does not mean that such systems are morally justified, just because the cattle do not overtly manifest their difficulties in coping with the system. That cattle suffer in silence is partly due to the influence of domestication, and partly due to the evolutionary forces pre-domestication – prey animals grazing in open grassland would not wish to attract attention to themselves by excessive vocalisation or other display if they are having trouble coping with the environment. A survey of cattle vocalisations at abattoirs found that very few cattle (10%) vocalise there, despite the stressful conditions (Grandin, 1998). However, they do emit fear pheromones in their urine that can indicate danger to conspecifics, but not potential predators (Boissy *et al*., 1998).

Determining the optimum welfare for cattle – moral issues

There is no universal guide to the minimum level of conditions that is acceptable for the adequate welfare of cattle. This is a moral decision that people have to take, and it will vary with nationality, gender, previous experiences, age, etc. Usually the moral viewpoint prevailing in any one situation is the majority view. The type of system that is used is largely free for the farmer to choose, but in some regions societal values are taken into account, and legal restrictions are imposed, e.g. on calf accommodation and diet in the European Union. Above any legal limit it would be ideal if animal products were available to a range of international welfare standards, so that consumers could choose according to their moral persuasion and means. However, this is not practical as we do not have international welfare standards yet and consumers want simple choices. Probably the most successful method so far by which consumers can buy products from animals with guaranteed high welfare is when the welfare standards are incorporated into more general environmental control, as in organic produce.

When considering the optimum level of welfare for cattle, there are both altruistic and moral considerations:

(1) Cattle kept in poor conditions are more susceptible to disease, which may reduce the quality of the product. They are more susceptible to zoonoses, such as tuberculosis and paratuberculosis, which may be transmitted in milk to people. Although much progress in controlling zoonoses has been made over the last 50 years, in particular by milk pasteurisation, new pathogens are emerging, e.g. *Escherichia coli* 0157, largely present in faecal contamination of pelts and carcases.

(2) Societal values will be improved if we care for others, animals and humans, in at least as good a manner as we wish to be cared for ourselves. Contact with animals is an important part of a child's emotional development and it positively shapes their future personality. It can also act as a releaser for individual frustrations, and in children violence towards animals is closely linked with violence to people (Miller, 2001). Cattle are an essential part of human society, helping us by providing food, clothing, fuel, traction and companionship, often using resources that would be of little or no value to ourselves. They also act as genetic insurance for the future. Focusing the world's genetic resources into a small number of genotypes dominated by man is dangerous, since future events may favour different genotypes.

    Some farmers may justify low welfare standards for cattle within their care because they are acting for their individual benefit, or that of their families, rather than society as a whole. Because they run businesses, profit is the ultimate objective, not animal welfare, but the approach is not acceptable to societies which have respect for animal welfare. For most of our evolution, humans lived in less complex societies, where self-preservation was more important genetically than acting for the benefit of society. In many cases the two were compatible, as they often are today. However, in an age when society demands conformity to a common purpose, there may be conflict between the inherent desire for self-preservation and the need to support the society. Societal values are portrayed through religious organisations, government, non-government organisations and perhaps most important of all, the media, but they can easily be ignored by individuals in large, loosely configured social groups.

Individuals, and their dependants, may benefit physically if they spend as little as possible on food from animals, which might be best obtained from farming systems that had scant regard for the animals' welfare. However, societal values would also benefit from keeping animals in good conditions. Thus the individual consumer is presented with a moral dilemma, the outcome of which may be determined by the extent of their commitment to society and their disposable income.

(3) Many believe that humans have a God-given duty to care for animals, as prescribed in most of the major religions. However, the Judaeo-Christian religion emphasises man's dominion over nature that is not apparent in older religions, which emphasise careful stewardship of resources. Some argue that the Genesis reference in the King James' version of the Bible to man 'having dominion over the animals' would be more accurately translated from the original text as having 'a duty of care for the animals'. In many Old Testament references the Bible extols the view that animals are worth more than their immediate usefulness to us (Nash, 1990), but this is not reflected in orthodox Jewish society, which places the study of the Mishnah and Talmud over the study of the Bible (Gendin, 1989). Buddhists are strongly encouraged to care for animals, and meditiation is believed to bring affinity to them. The requirement that all adherents to the major religions should care for animals can be used to infer that animals have a *right* to be cared for. Such rights not only are enshrined in religious beliefs but also have been adopted into the legislation of many countries, in terms of prevention of cruelty to animals.

From a moral perspective, it is inconsistent that we adopt different standards for animals according to the benefit that we derive from them. Companion animals usually receive better care than laboratory or farm animals, for whom space is often restricted to maximise output per unit area. Animals in wildlife or safari parks are afforded a similar habitat to the wild, so that the public has the illusion that they are in fact wild. At the bottom end of the care and attention scale, perhaps, are pack and traction animals in developing countries, including cattle for whom work is often excessive. Within the farm animals, different levels of stress may be imposed on the animals according to their type of output. In the case of the dairy cow, which is either lactating or heavily pregnant, or both, for nearly all of its adult life, it is clear that this imposes a metabolic burden that reduces longevity. The average life-span in intensive dairy systems (about five years) is a fraction of the potential of 20 to 25 years, because of the metabolic strain. The high daily output in the early part of lactation, particularly of energy, exploits the cow's ability to catabolise considerable amounts of body fat tissue, which is restored only when milk yield has declined later in the lactation. The constant annual cycle of body fat depletion and restoration stresses the metabolism, and usually the cow succumbs to disease and has to be culled after only two to four lactations. In contrast, cattle for meat production are usually fed a diet that will allow nearly maximum growth, partly because genetic improvement in growth rates has not been as fast as milk production.

Some people believe that the moral right to keep animals on farms depends on the essentiality of the product. Thus it might be more justifiable to farm cattle for the production of food than solely for leather production. It is more difficult to replace cattle food products with other foods than it is to replace leather, since the former are particularly good sources of digestible protein, B vitamins and minerals such as calcium. However, this concept is probably largely derived from a rejection of modern, intensive farming methods rather than a fundamental necessity for the essentiality of animal production. In reality all animal products can be replaced by plant or synthetic products. In some cases this seems entirely justified. The use of large areas of virgin Amazonian forest to produce a beef product for consumption in the USA, which is a country that has its own resources for beef production, is to many people immoral. The global environment is adversely affected by destruction of the rain forest, habitat for endangered forest species is lost and there is extensive debate in the country in question as to whether their natural resources should be used for beef production at the expense of the environment.

In other circumstances cattle production makes a valued and essential contribution to human life. In many developing countries the availability of meat and milk improve the level of human nutrition and they are produced largely from land that is unsuitable for cropping and by-products, that would otherwise be expensive to dispose of, such as straw and agro-industrial wastes. Cattle farming provides useful employment for some of the poorest members of the community and gives them dung, a useful source of fuel, to reduce reliance on wood or fossil fuels. Draft power may also be provided, reducing reliance on tractors and fossil fuel. In these circumstances it is difficult for even the most fervent of animal rights campaigners to advocate the replacement of cattle products with vegetarian options.

Determining the optimum welfare for cattle – evidence from wild cattle

The behaviour of domestic cattle has been extensively studied, but solutions to behavioural problems have been elusive. Excessive licking and sucking behaviour in calves, mounting behaviour in steers, as well as tongue-rolling, prepuce-sucking and other less common stereotypies in steers, persist despite a better understanding of their aetiology than 20 years ago. They contribute to inefficiencies or low-quality production, leading for example in the case of mounting bulls and steers to low-quality meat. Many abnormal behaviours are known to derive from the artificial environment that cattle are kept in, since they are absent in extensively kept cattle. Often they evolve when an animal is thwarted from performing its natural behaviour by deficiencies in its environment. They are particularly common in hot, humid conditions, where the heat stress reduces resistance to environmental deficiencies. Opportunities to modify the environment are always limited, unless productivity is greatly reduced. An understanding of the behavioural repertoire of cattle pre-domestication will indicate which behaviours are innately present in cattle, and allow the environment of domesticated cattle to be most effectively modified to reduce the incidence of problem behaviours.

There are no remaining wild cattle (*Bos aurochs*) that were the progenitors of *Bos taurus* and *indicus* genotypes, the last examples having been slaughtered in Czechoslovakia in the seventeenth century. Detailed information on the behaviour of the progenitors of domestic pig (wild boar), hen (jungle fowl) and sheep (mouflon) is available, as they still exist in the wild. Since such possibilities do not exist with domestic cattle, near relatives are being studied. The Malaysian gaur is well-suited to this task, since cattle evolved in south-east Asia, before spreading across Eurasia until they were domesticated relatively recently in Africa.

The gaur [*Bos* (*Bibos*) *gaurus*] is an endangered species that is a wild ancestor of domestic cattle. There have been few studies of their behaviour, despite their importance to understanding the behaviour of domesticated cattle. Those looking after captive gaur cattle in zoos and wildlife parks report that they are more nervous than domesticated cattle when handled by man, however, they do habituate to the presence of humans in the zoo. The behaviour of the leading animal is of great importance in determining the behaviour of the rest of the herd, possibly more so than in domesticated cattle.

Other behaviours appear to be similar – the bull shows flehman behaviour in response to females in oestrus and, for their part, the cows show homosexual mounting during oestrus. In the wild, some sexually mature bulls are integrated with the herd, probably the dominant ones, others living in bachelor groups. The oestrus of the gaur cattle is shorter than that of domestic cattle, which suggests selection by man for extended oestrus in the latter, and artificial breeding techniques developed for domestic cattle are successful in gaur cattle (Godfrey *et al.*, 1991). In contrast to the gaur, feral cattle in Africa have been reported to live in matriarchal groups, with the bulls being evicted to live in bachelor herds when they are sexually mature (Reinhardt & Reinhardt, 1981). The forest-dwelling gaur cattle would find this strategy of little value, because the oestrus mounting display would be of little value in attracting the bulls from afar. In addition, by integrating with them, the bulls will protect the cows and their calves from attack by predators, in particular tigers. The gaur bull is much more fearsome than its domesticated counterpart, the mithun, and is a match for most tigers.

In common with buffaloes, gaur cattle give birth in the half-standing position. Domestic cattle, however, usually lie down, which may be because parturition is more difficult than in wild cattle, either because the calf is bigger or because genetic selection has changed the angle of the pelvis. Rather than being sloping downwards towards the tail, domestic cattle have a much flatter back, which is known to increase calving difficulties. However, a flat back gives better support to the udder, which is much larger in domestic than wild cattle. It also increases the size of the loins, which produce high-value meat.

Gaur cattle usually live mainly in the forest fringes, where there are shrubs and bushes that can be browsed. They find it more difficult to select food in dense tropical rainforest, where they will venture during the middle of the day. High intake rates are required at the beginning and end of the day, because of the quiescent period at night, but more selective feeding and resting in the forest is possible at midday, often near a waterhole. This will also bring them shade in the heat of the day, but interestingly Gupta *et al*. (1999) report that gaur cattle avoid being in the open sunlight even when the temperature is low. Domesticated cattle start to use physiological mechanisms, such as sweating, to lose heat at temperatures as low as 25 to 27°C, and it is appears likely that gaur cattle also have a weak ability to tolerate hot temperatures. Exposure of cattle to warmer temperatures may have adverse effects on their welfare.

The predominance of activity at the forest fringes would have brought the predecessors of gaur cattle into contact with humans practising shifting cultivation in the earliest days of agriculture. Their diet includes browse species, such as bamboo, and tall tropical grasses. Domesticated cattle are often believed to be maladapted to browsing, but will readily do so on forest fringes even if some pasture is available. They are rarely offered the opportunity to browse in modern production systems, but will readily do so if it is provided. It is likely that some browsing would improve cattle nutrition by varying the diet and would in particular provide a good source of minerals, vitamins and rumen-bypass protein compared with grass monocultures. Browse material, in the form of gorse, broom and other shrubs would commonly have been provided for domesticated cattle until 100 years ago, when its unsuitability for mechanised production reduced its popularity in favour of grass. Many browse plants, although now regarded as weeds, can survive in extreme climates and with little additional nutrient supply owing to their deep-rooting habit.

In South-East Asia, gaur cattle have a strong appetite for salt, as do the local domesticated cattle, the mithun (Gupta *et al.*, 1999). This probably facilitated their domestication, since humans attract the cattle back to their compound at night with salt. Modern farmers use the availability of salt as an aid to controlling the movements of their mithun cattle, and the diet of domesticated dairy cattle is also strongly determined by salt contents of the various foods (Chiy & Phillips, 1991).

The behaviour of other relatives of cattle has been studied, but these are too distant phylogenetically or the studies are of insufficient depth to be of major value. In particular the buffalo (*Bubalis bubalis*) has received considerable attention, but it has been subjected to the influence of domestication. Their behaviour is similar to that of the wild gaur and modern domesticated cattle (Odyuo *et al*., 1995), e.g. they have similar (crepuscular) feeding behaviour patterns (Barrio *et al*., 2000) and the calves engage in both filial and communal suckling (the latter being more common in female calves) (Murphey *et al*., 1995; Paranhos da Costa *et al*., 2000). Some differences in the sexual behaviour of yaks (*Bos grunniens*) are known to exist, when they are compared to cattle, in particular characteristic stomping and tail-swishing behaviours (Sambraus, 1999).

Conclusion

Determining the optimum welfare of cattle first requires that it is accurately measured. This will vary between situations but is connected with their ability to cope with their environment and their feelings over their lifetime. There is a moral imperative to maintain cattle in a high state of welfare, first, to maintain the levels of zoonotic diseases at a minimum, secondly, because moral standards in human society will benefit if animals are kept in good conditions and thirdly, because most modern religions instruct followers to look after their animals well. Evidence from the wild relatives of domesticated cattle is that their behaviour has changed little as a result of human selection, suggesting that intensive housing systems may have deficiencies hitherto largely unrealised.

Chapter 2
The Welfare of Dairy Cows

Introduction

The systems in which dairy cows are kept are diverse, ranging from highly mechanised systems in which the cattle are kept indoors all year, to extensive systems in which the cattle are outdoors permanently. Production levels are highly variable but the level of animal care usually provides at least once or twice daily inspection when the cows are gathered for milk production. The factors influencing welfare depend on the system employed, but inadequate nutrition is often a consequence of the high levels of nutrients required for milk production. This will also influence the disease profile, being orientated towards metabolic diseases. The milking and housing systems utilised can adversely affect the cow's welfare, as will the social influences afforded by the type of housing. Finally, mutilations by man, such as removal of the tail to stop it having to be cleaned regularly, may prevent normal behaviour and reduce welfare.

Hunger and malnutrition

Hunger is a balance between nutrient demands and consumption. Demands are determined by the requirements for maintenance, production and growth, and the efficiencies with which nutrients are absorbed and metabolised. Usually hunger is determined by energy status, although specific hungers for other nutrients commonly in deficit, such as sodium, do exist (Phillips *et al*., 1999). The domesticated dairy cow has considerably increased nutrient requirements as a result of the increase in milk yield potential (Table 2.1). This increases her need for rest (Munksgaard & Herskin, 2001) and contributes indirectly to the short life that most high-yielding cows have in a dairy herd. The risk of contracting mastitis, lameness, fatty liver disease, hypocalcaemia, acidosis, ketosis and many other diseases increases with milk yield. As a result the mean number of lactations is only three or four in most developed countries, compared with more than ten for feral cows. However, it must not be forgotten that starvation during winter months was common in dairy cows until new forage conservation practices allowed food of sufficient quality and quantity to be made available in the twentieth century. As recently as the 1950s there was significant mortality of British

Table 2.1 Comparison of milk production in feral and modern domesticated dairy cows

	Feral	Domesticated
Milk production (litres/day)	8–10	30–50
Number of milkings per day	4–6	2–3
Yield per milking (litres)	1–2.5	10–25
Total lactation yield (litres)	<1000	6000–12 000

Adapted from Webster (1995).

dairy cows during winter months due to undernutrition (Garner, 1989). The hay available for cows was of poor quality and concentrate foods were generally not available, being required for human consumption. However, with the increase in use of artificial fertilisers in the latter half of the twentieth century, forage production could be greatly increased. This, together with the development of mechanised conservation and silage feeding techniques, allowed cows to be adequately sustained through the winter. Feeding cows mainly on fermented herbage is not without health risks, which are principally from undesirable micro-organisms, such as *Listeria*, *Enterobacteria*, *Clostridia* and moulds, undesirable chemicals, such as mycotoxins, and excess acidity (Wilkinson, 1999). Some, such as the mycotoxins, can even potentially affect humans consuming milk or meat products from infected cattle.

Improved ability to feed cows in winter has allowed cows to calve in the autumn, producing peak nutrient demands in winter, when the ration can be more accurately formulated than when the cows are at pasture. During the early lactation period, body reserves of fat, protein and minerals, especially calcium, are used to support high milk yields. Webster (1995) has suggested that cows may be persistently hungry at this time, even though they usually have forage available *ad libitum*. This is possible, since intake is limited not by food availability but by the physical capacity of the gastrointestinal tract, and especially the rumen. The rate of removal of the food particles from the rumen is determined by the speed with which it can be digested by micro-organisms. Preliminary results (Cooper *et al*., 2002) indicate little difference in the extent to which high- and low-yielding cows are prepared to work to obtain extra high-energy food. Theoretically, increasing the nutrient concentration by feeding a ration of high-energy cereals would increase the rate of digestion and allow greater intakes. However, the rumen micro-organisms function at a pH of 6 to 7, and rapid digestion of high-energy foods produces excessive fatty acids as endproducts of digestion. Rumen pH will therefore decline after meals, and the micro-organisms responsible for digestion cannot survive the acidic conditions. The rumen also needs long fibre to support the contractions that mix the contents, and high-energy foods usually have inadequate fibre, resulting in rumen stasis. The primary aim in feeding cattle is to maintain constant and benign conditions in the rumen, which must be considered as a sensitive fermentation vessel, adversely affected by variation in conditions.

Diseases

Production diseases

A failure to provide adequate or suitable nutrients during periods of high milk output leads to a number of common 'production' diseases. Evidently the welfare of cows is adversely affected during clinical disease events, but we have little knowledge of the extent, or impact on welfare, of subclinical disease. For some nutrients, such as calcium, the body has advanced homeostatic mechanisms, and it is likely that there is a sudden failure of these, rather than progressive, prolonged subclinical disease. However, for many other conditions few homeostatic mechanisms exist, usually because there was no need for them predomestication. Such is the case for magnesium deficiency, which is common when cows consume young, rapidly growing pasture that has been fertilised with potassium. Potassium inhibits the absorption of magnesium in the rumen, and young, leafy grass has a low magnesium content anyway. The resulting tetany is usually an acute disorder which the cow cannot survive unless magnesium compounds are injected subcutaneously within a few hours.

Bloat is a painful condition that is common in cows fed rapidly digested pasture legumes or cereals. The production of gases by the rumen exceeds their rate of removal by eructation. This may be due to either the presence of a stable foam in the rumen (pasture bloat) or restricted rumen motility (cereal bloat). It is precipitated by the sudden introduction of bloat-inducing foods, especially after a period of restricted feeding, such as during oestrus in the cow. Affected cattle are restless and find lying uncomfortable. Eventually they die of heart failure, or suffocation as a result of inhaling rumen contents.

Lameness

Lameness is probably the most serious disease affecting the welfare of dairy cows kept in cubicle systems, with a prevalence of up to 20% (Clarkson *et al*., 1996). The annual incidence has been recorded as 35 to 55% in the UK (Clarkson *et al*., 1996; Kossaibati & Esslemont, 2000), but only 7% in Michigan, USA (Kaneene & Hurd, 1990). Because it impairs an essential behaviour, locomotion, the greater the distance that lame cows have to walk in the management system, the greater impact on welfare. The most serious consequences therefore occur for grazing cows, who are unable to keep up with the rest of the herd in finding the best grazing and will remain as close to the farm buildings as possible to minimise locomotion. Speed of locomotion is reduced, so that if a herdsperson hurries the cows back to the farm buildings for milking, there is clearly a big impact on welfare.

About 90% of all lameness is the result of claw horn lesions, and most occur in the lateral digit of the hind feet soon after calving (Thysen, 1987; Leonard *et al*., 1996). A cow responds to the pain by minimising the propulsion of the affected limb, reducing her speed of walking, arching her back and lowering her head. The average duration of an episode of lameness is three months (Phillips, 1990a), including the periods of abnormal locomotion before and after clinical lameness, i.e. the forward thrust from the limb is reduced.

Much of the lameness associated with cubicle housing derives from the cow walking on hard concrete covered in slurry. Cows in tie stalls have far fewer problems (Faye & Lescourret, 1989). Laminitis, or inflammation of the horn-producing laminae that present as sole haemorrhages, is a particularly painful and common condition. It is promoted by both the housing conditions and a high-concentrate diet.

A primary cause of claw horn lesions is the reduction in the supportive capacity of the connective tissue of the hoof wall around the time of calving. This results in the pedal bone sinking and/or rotating, putting great stress on the sole. If there are few external pressures on the hoof, for example when cows are housed in straw yards, hoof connective tissue integrity can recover within 12 weeks of calving (Tarlton *et al*., 2001). However, the shock of regularly stepping on concrete, coupled with the softening of the hoof when the cow stands in slurry, can traumatise the hoof and lead to primary lesions (Tarlton *et al*., 2002). Primiparous cows are particularly at risk, because they are mixed with older cows and may increase locomotion in escape routines. One form of 'escape' is to stand with the front legs in the cubicle and the hind legs in the passageway, which further increases the pressure on the latter. It is important to keep escape routes clear for cows, especially by preventing blind alleys where subordinate cows may be trapped.

One advantage of concrete surfaces is the high wear rate (Vokey *et al*., 2001). The growth rate will also be less in cows in straw yards, but the lack of wear can lead to overgrown hooves, backward rotation of the pedal bone and limited contact between the toe and floor. Although such a condition may not initially be painful, the necessary modification of walking behaviour may lead to inactivity and separation from the herd at pasture.

Bad cubicle design may predispose to lameness, as cows spend less time lying in small cubicles, cubicles with a hard surface or cubicles with divisions that impede movement (Horning & Tost, 2001). Hock damage may occur as the animal lies down, and those lying on soft surfaces or in wide cubicles are less likely to experience this problem (Livesey *et al*., 1998). However, if cubicles are too large cows may attempt to turn around and get stuck, particularly if they are inexperienced at lying in cubicles.

Claw horn lesions may progress to sole ulcers, which are also associated with pedal bone movement, and typically cause severe lameness when they rupture about six weeks after calving. Exploration of the area surrounding the ulcer during treatment may expose the sensitive corium. Claw horn lesions may also damage the 'white line', the name given to the junction between the sole and hoof wall. White line separation can be caused by penetration by stones or fragments of dirt, which may progress even to the sensitive corium. Treatment may involve removal of the hoof wall in extreme cases, with considerable and prolonged pain caused by the injury.

Infectious diseases

Dairy cows do not suffer from many of the traditional range of infectious cattle diseases because they develop immunity when they are youngstock. However, novel pathogens, such as bovine spongiform encephalopathy (BSE), or infectious diseases to which they have not been exposed, such as foot and mouth disease or tuberculosis in the UK, pose a significant threat. The major infectious disease from which cows suffer is mastitis, which may be caused by a variety of pathogens. Some of these are transmitted between cows, but these have been less of a problem in recent years owing to routine use of antibiotics following infection and after the termination of lactation. Non-transmissible environmental pathogens, such as *Escherichia coli*, have become an increasing problem, which is best tackled by improving cleanliness on farms.

The escalating problem of tuberculosis in the UK illustrates the difficulties in permanently controlling infectious diseases in intensive cattle farming. The disease was rampant in the first half of the twentieth century, owing to the lack of control measures and close contact between cattle during housing. Many human deaths followed consumption of infected milk, until pasteurisation began to be widely practised in the 1950s. A compulsory slaughter policy for infected stock and strict control of the badger, the major intermediary host, had almost eradicated the disease by the mid 1970s. However, concern for the welfare of badgers led to a ban on their being culled, and cattle feeding practices that gave badgers access to food, in particular maize, as well as transmission between cattle, have all contrived to allow tuberculosis to increase rapidly in England and Wales. Farmers believe that government should accept responsibility for the control of the disease since it is illegal for them to remove badgers from their farms, but government believes that farmers must accept responsibility for environmental constraints on their farming practices. There are several options for controlling the disease (Table 2.2), which illustrate the difficulty in allocating responsibility for the welfare of intensively farmed cattle between farmers, environmentalists and government officials. No solution is ideal, but government will support only those measures that are ethically acceptable to the public, which excludes wildlife culls, and are not too expensive. Since the number of farmers is decreasing, the government feels responsible to the electorate in these issues and not just to farmers. However, while no solutions can be found that are acceptable to all parties, the welfare of cattle is increasingly threatened by the disease.

Table 2.2 Options for control of tuberculosis in British cattle (Bennett & Cooke, 2001)

Option	Advantages	Disadvantages
Mandatory insurance for farmers against an outbreak	Places responsibility in hands of farmers	High cost to farmers, especially in high-risk areas
Wildlife vaccine	No wildlife cull	High cost of development, seen as invasive by environmentalists
Cattle vaccine	No effect on badgers, gives responsibility to farmers	High cost of development, efficacy may be low, may invalidate herd testing regime
Wildlife elimination measures	Minimise secondary host transmission	Unacceptable to public
Improved biosecurity on farms	Holistic approach, sustainable	Efficacy in doubt while wildlife reservoir exists
More and improved testing on farms, especially at movement	No effect on badgers, responsibility given to farmers	Does not address secondary host transmission, cost
Segregation of cattle and wildlife	Eliminates secondary host transmission	Practicality, high cost
Breeding for resistance in cattle	Acceptable to farmers and public	Efficacy, long time to achieve results, resistant organisms may develop
Create zones with minimal movement between them	Limits spread to low-risk zones, contains the disease	Does not alleviate disease spread in high-risk zones, administration cost

Milking

The development of automatic technology for milk extraction in the twentieth century allowed many more cows to be milked by one herdsperson than when milking was accomplished by hand. *Bos taurus* cows will usually release their milk without a calf, but *Bos indicus* cows need the psychological stimulus of the presence of the calf, suggesting that they may have been subjected to less domestication pressure.

Hand-milking may provide a surrogate stimulus to the cows and the simultaneous provision of a food reward may help them to overcome any reluctance. The removal of milk from heavily lactating cows may offer reward in itself, and they are usually the first to enter the parlour if given the choice. The negative signals to cows that machine milking can provide include being hurried in from pasture by a handler with a dog or motorbike; being controlled in the collecting yard by an electric fence; aggressive treatment from the herdsperson when in the collecting yard or parlour; pain induced by not removing teat cups soon enough; damage to the teat's cardiovascular system by a wrongly set vacuum; danger of slipping on wet concrete floors and close contact with dominant cows. The best parlours allow the cow to enter her stall at will (automated entry parlours), rather than being forced to enter by the herdsperson. Cows develop preferences to enter a specific stall at a specific time and preventing them from doing this can increase their heart rate (Hopster *et al*., 1998), but it will not reduce their milk production or greatly affect their welfare (Paranhos da Costa & Broom, 2001).

Robotic milking

The recent development of technology to enable teat cups to be automatically attached to a cow has led to the commercial production of fully automated milking units, or milking robots. Such units are now being evaluated world-wide, but especially in Europe. To many members of the public, robotic milking of dairy cows will be an anathema when considering their welfare. However, this may not be true when one compares it to the manually operated milking systems in operation on most farms.

Many aspects of robotic milking can affect the welfare of cows, such as the daily frequency of visits by the cows. The vacuum and pulsation characteristics, which are standardised for all cows in conventional milking parlours, can potentially be tailored to the needs of individual cows in robotic milking systems. Given that in some European countries one-third of dairy farmers are predicted to switch to robotic milking between 2000 and 2015, the technique has the potential to have a major impact on cow welfare. At the start of the millennium, there were just over 500 farms using the system, mostly in Europe, and the next ten years will determine whether the technology has universal application or whether it will be restricted to quite specific circumstances. Will all dairy cows eventually be milked by robots?

The technology is expected to be most readily adopted in areas with small family farms and low availability of inexpensive, hired labour. The ageing population of farmers which usually dominate such conditions would find considerable benefit in reducing their labour input. Such conditions exist in much of Europe and North America, where there are strong economies in non-agricultural sectors, and the technology could help to preserve the family farm in these regions. Large industrial operations are unlikely to use the technology widely because a purely economic assessment would not favour its use.

Theoretically, stockpeople employing robots should have extra time to look after their cows, which it is estimated reduce labour requirements for milking by 30%. A person is still required to fetch cows that do not want to be milked, to attach the cluster to cows if the machine malfunctions and to monitor milk storage and cooling. This may involve night attendance in robotic systems. Economic studies have shown that there is only a potential profit margin from adopting robotic milking if surplus labour can be dispensed with (Arendzen &

Scheppingen, 2000). It may be too optimistic to assume that cows will be more closely monitored in dairy systems with robotic milking, since family farmers adopting the system may choose to use the time released for leisure activities. Undoubtedly, the adoption of robotic milking systems will increase the need for stockpeople to be better trained technically.

An indication that there may be adverse effects of robotic milking on welfare comes from the reluctance of most cows to volunteer for milking more than once or twice a day. This may be because the stress associated with being milked by a robot is greater than the reward of emptying a full udder. Some of the stress may relate to automatic udder cleaning and lack of contact with the herdsperson. On the majority of farms there is a good relationship between the stockperson and the cows, and the direct contact during milking may be valued by both. However, in circumstances where the forcing of cows by the herdsperson or an electronic crowding gate to enter the parlour leads to stress, cows entering a robotic milker may suffer *less* emotional stress.

The cows' reluctance to be milked by a robot makes it usual to offer concentrate feed during milking. This could lead to metabolic disorders if the robot is visited frequently and large amounts of concentrates are consumed at each visit. Cows in negative energy balance may be driven to attend regularly for more food, which will increase milking frequency and yield and thereby exacerbate the negative energy balance. The separation of concentrate and forage feeding in this way could make ration-mixing wagons redundant. However, feeding during milking increases oxytocin production and milk letdown and reduces cortisol production, suggesting less stress to the cows.

An alternative to concentrate feeding to entice cows into the robot is to position the milking unit between the cubicles and the cows' food source, and force the cows to be milked when moving between these two. Cows reduce their frequency of passage between the two systems when this is done, indicating some reluctance to visit the milking robot. The loss of freedom associated with this enforced milking almost certainly reduces their welfare, but possibly no more than in conventional milking systems, where they are usually forcibly milked twice a day.

Because of the high cost of robotic units compared with conventional ones, there is usually only one unit provided for every 40 to 60 cows. This may lead to queues of frustrated cows waiting to be milked at preferred times of the day. However, mean queuing time per milking on commercial farms has been recorded as seven minutes, or 34 minutes per day, which is less than in most conventional milking systems. Some farms use electrified 'cattle drivers' in the robotic units to accelerate cow movement through the unit or associated passages. This will reduce motivation to attend and increase stress.

Mastitis, or inflammation of the mammary gland, is a particularly common cause of poor welfare in modern dairy systems. For several reasons, the incidence of mastitis and the milk parameters associated with this disease, such as the somatic cell count, are usually increased by robotic milking, particularly in the first few months of operation. Perhaps the biggest contributing factor is the