EUROPEAN COMMISSION

HEALTH & CONSUMER PROTECTION DIRECTORATE-GENERAL

Directorate C - Scientific Health Opinions

Unit C2- Management of scientific committees

The Welfare of Cattle kept for Beef Production

Scientific Committee on Animal Health and Animal Welfare

Adopted 25 April 2001

The Welfare of Cattle kept for Beef Production

Contents

1. REQUEST FOR OPINION (TERMS OF REFERENCE)

The EU Commission has asked its Scientific Committee on Animal Health and Animal Welfare to prepare a report on the welfare of fattening cattle[1]. As another report has already dealt with the bovine of less than 6 months, including veal calves, these animals are not within the scope of this report. The report does not include cull cows from dairy farms or farms with suckler herds. The report deals with male and female cattle fattened for meat production, older than 6 months if they come from the dairy herd and after weaning for those reared in suckler herds. The Committee is currently preparing a report on the transport of animals and consequently this aspect is not addressed in this report. Since the use of steroid growth promoters is not permitted in the European Union, the implications of the use on animal welfare are not considered.

2. INTRODUCTION

There is no general EU legislation in force concerning the welfare of fattening cattle. However, the Council of Europe Standing Committee of the Convention on the Protection of Animals Kept for Farming Purposes adopted a recommendation on 21 October 1988 concerning cattle, including beef cattle. In addition, a specific regulation (regulation 1804/1999) dealing with organic farming sets out certain welfare requirements for beef cattle in the EU.

The first part of this report introduces definitions of animal welfare. They are used to determine the risks under consideration. Then the different methods of assessment are given. The state of the industry and the different housing systems are described in chapters 3 and 4. This information is essential to identify the sources of risks of poor welfare. The behaviour and physiology of cattle with few constraints on them are described in Chapter 5. This information is used for the hazard and risk characterisations which are developed in Chapters 6 and 7. Conclusions are summarised in Chapter 9 and recommendations are presented in Chapter 10.

---

[1] Cattle managed so to reach carcass characteristics optimum for the market

The report does not contain any socio-economic analysis of the effects of the recommendations made.

2.1. Definitions of welfare

The status of animals has been the object of philosophical concern for a very long time (see review by Ouedraogo and Le Neindre, 1999). Animals are now defined as "sentient creatures" in European law and no longer just as agricultural products (Treaty of Amsterdam, 1997). That change reflects ethical public concern about the quality of life of the animals. Farm animals are reared with human imposed constraints and for a very long time the choice of techniques has been based primarily on the efficiency of production. However it is increasingly claimed that we should protect those animals against mistreatment, or better still, to allow them the maximum of good welfare.

Different ways to define the welfare of animals have been used by various authors. The reports of the scientific veterinary committee on the welfare of calves (1995) and on the welfare of laying hens (1996) give a general view of the literature on that subject. These definitions of welfare, which overlap in meaning, are grouped according to their content into four categories.

1) Descriptive types of definitions (Brambell report, 1965; American Veterinary Medical Association, 1987). Welfare is a broad term that embraces both the physical and mental well-being of the animal. Any attempt to evaluate welfare, therefore, must take into account the scientific evidence available concerning the feelings of animals that can be derived from their structure and function and also from their behaviour (Brambell report, 1965).

2) Definitions referring to an animal being in harmony with its environment (Lorz, 1973; Hughes, 1976). Animal welfare is "A state of complete mental and physical health, where the animal is in harmony with its environment" (Hughes, 1976). The animal has not only physical but also behavioural requirements. The welfare of the animal is basically the way the animal feels about, and is affected by, its environment and not the environment per se. It can result in positive mental states (pleasure) or negative mental states (fear, pain, etc). That definition is very close to the one of human health: "a state of complete physical, mental and social well being, and not merely the absence of disease or infirmity" (WHO, 1992).

3) Definitions referring to adaptation to or control of the environment by the animal (Wiepkema, 1982; Broom, 1986). Broom (1986) defined the welfare of an animal as "its state as regards its attempts to cope with its environment". The author proposes that welfare includes both feelings, which are part of coping systems, and health and that there is a continuum in welfare between very good in ideal conditions to very poor in a detrimental environment (Broom, 1996, 1998). The welfare is measurable using a wide range of indicators and is estimated by measuring the efforts the animal is prepared to make to reach the ideal state. When the adaptation capacities of the animal are overwhelmed the welfare of the animal is poor.

4) Definitions concerned with the subjective experience of the animal (Duncan and Petherick, 1989; Dawkins, 1990). The animal's perception of its environment cannot solely be inferred from our own human perception but needs to be evaluated from the animal's perspective. The definition of welfare that refers only to feelings is narrower than that proposed by Broom. In this report a wide range of coping systems are considered and all aspects of health are taken into account when discussing welfare. The welfare can be measured in particular by studying the physiological disorders provoked by the situation but also by the motivation of an animal to obtain some features of the environment (food, companion, bedding, etc) or to perform some specific behaviours (feeding, social interaction, etc) (Veissier et al., 2000).

2.2. The assessment of welfare

Welfare analysis is multidimensional including health, physiology and behaviour and involves the assessment and weighing of many welfare indicators. These aspects have been extensively described in books (Broom and Johnson, 1993) and previous reports on welfare of this Committee. According to Broom (1996) the following are indicators of poor welfare in animals: decrease in life span, growth and possibilities to breed, body damage and illness, impaired immune system function, physiological attempts to cope with environmental effects, behavioural pathology, increase in behavioural aversion, increase of suppression of normal behaviour, and suppression of normal physiological functioning and anatomical development. A short review of those different methods will be presented below.

Cattle have specific patterns of behaviour and physiological mechanisms that should be possible if their welfare is to be good. The concerns are not only the physiological states but also the ways to reach them, in particular through specific behaviours. Welfare assessment

needs to take into account not only the nutritional status but also the housing and management practices. It also needs to take into account the genetic variability of the animals and the effects of selection on their ability to cope with the environment.

2.2.1. Production and Health

Good **Health** is necessary for good welfare. Since there is general awareness of the effects of infectious diseases, attention in this report is drawn particularly to pathologies relating to the environment.

Production measures are of some use for analysing the welfare of cattle. Any decrease can be an indicate of poor welfare but maximum productivity is not an indicator of a maximum welfare status. That analysis should be done at the individual level and not at the group level. Questions about welfare should be raised if some cattle in a group have a low production, even if the mean production level of the group is high. Genetic modification to increase production could have an effect, either positive or negative, on the welfare of fattening cattle. However, genetically modified animals are not discussed further in this report.

Production related diseases are due to non-specific factors which become pathogenic due to an animal's physiological reactions arising in difficult conditions. The first variables to be seen are **mortality** and **morbidity**, which are affected by a large variety of different diseases. Pathological findings may also be used, and they are part of morbidity. One should also distinguish between clinical and sub-clinical diseases, and between acute and chronic diseases. Epidemiological studies on a large number of animals are necessary to make meaningful estimates, and they only permit assessment of the welfare by comparing different situations. The effects of management on health can be explained, partly at least by the effect of stress on the **immune mechanisms** (Dantzer and Mormède, 1994). Tissue damage related directly to human activity (mutilation, bruising, etc.…) or indirectly to disease is often a cause of **pain** and hence poor welfare. The ability to recognise signs of pain and associated distress is a prerequisite before potentially painful interferences can be avoided or alleviated (Morton and Griffiths, 1985; FELASA REPORT, 1994; OECD, 2000). Adverse states in animals can be measured by observing their behaviour (e.g. loss of appetite and as a consequence bodyweight loss, abnormal body posture or appearance, reduced or abnormal activity, reduced or heightened responsiveness) and by measuring physiological changes (e.g. changed heart rate

and respiratory pattern, increased body temperature). Biochemical signs may also be used (e.g. increases in plasma ACTH, corticosteroids, catecholamines, acute phase proteins).

Adverse effects experienced by animals can cause them to suffer and can be caused by factors in their environment and also from within themselves. Animal suffering is a specific state of mind that might be a consequence of feelings of fear, distress, pain, frustration or boredom depending on their intensity and duration. Where animals are handled and restrained, this will cause varying degrees of fear, depending on the temperament of the animal and its previous contact with humans. Animals may show fear by 'freezing' and not moving or not vocalising, which could be misinterpreted as not feeling pain, but their nervous systems are almost identical to other animals that show pain more overtly. Distress is another form of suffering and can be defined as "an aversive state resulting from maladaption or inability to adapt to stressors" (OECD, 2000) and it may be associated with behavioural changes such as stereotypic behaviour. Pain can be defined as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage" (International Association for the Study of Pain, 1979), and castration, dehorning and docking are mutilations that cause tissue damage and pain. Some diseases are also painful.

In the context of surgical mutilations pain can be divided into three main stages. Firstly, pain perception at the time of surgery, where pain receptors transmit nerve impulses to the brain where they are translated into the actual feeling of pain. Unless the animal has been anaesthetised in some way (e.g. general or local anaesthesia), it will try to escape but it is usually restrained. Secondly, over the next few days, the body normally repairs the damage by mounting an inflammatory response and this too can be painful due to the release of local tissue substances such as prostaglandins (pain at this stage can be alleviated by the use of anti-inflammatory drugs). Moreover, unless the impulses in pain pathways are modulated or blocked at the time of injury, pain becomes exaggerated through a process known as 'wind-up', where not only the injured site but also adjacent sites become more sensitive (hyperalgesia) and even non-painful stimuli can become painful (allodynia). It is important therefore, that some form of pain relief is given at the time of surgery as well as for a few days after to avoid wind-up. Thirdly, while normally, successful healing occurs (unless there is infection) but occasionally pathological changes occur and painful growth at the end of the cut nerves - neuromas – has been recorded in some species (Sunderland, 1978; Simonsen et al., 1991). They do not appear to have been investigated in cattle, but we see no reason why they should not occur in this species as well. Mutilation of cattle is a specific case causing fear, distress, acute and chronic pain, and is discussed later (Chapter 7.1).

2.2.2. Physiology

Physiological measures are useful tools for analysing the welfare of cattle. Among these, neuro-endocrine measuring is often used. In particular, releases of **adrenal hormones** into the blood are important physiological mechanisms indicating that the animal perceives a problem and lead it to adapt to challenging events. The hypothalamic-pituitary-adrenal cortex and the sympathetic systems are involved in most responses. However, other physiological systems can be involved as for example the opioid systems. The analyses are context dependent and the interpretation for assessing welfare should relate to the specific environment. Such analyses are rather difficult to conduct. For example, even if the half life in the blood of the cortisol is rather long the interpretation of the pattern of cortisol levels in the blood is difficult especially in the case of chronic stress when feedback mechanisms are interacting. The analysis of hormones from the sympathetic system, for example adrenaline and noradrenaline is even more difficult, as their rise times and half life in the blood are very short. To analyse these mechanisms, their effects on target tissues are usually studied, in particular their effects on the heart activity and on different metabolic processes. The different enzymes that are involved in hormone synthesis, or their catabolites present in particular in the urine, can also be used. Other biochemical variables can be useful for analysing the welfare of animals, for example those related to the nutritional status of the animals or to the damage or changes of specific tissues (heart, muscle, liver, adrenal glands, etc) (Stoskopf, 1983; Wiepkema et al., 1987; Toates, 1995; Chrousos et al., 1995; Folkow et al., 1997). In several studies it has been found that stressors affecting cattle depress cellular and immune responses (Bleca et al., 1984; Cummins and Brunner, 1991; Pollock et al.,1994; Ferrante et al., 1998).

Another relevant question is at what age animals are able to experience distress and pain, and whether older mature animals feel pain more than young immature animals. The assumption from anecdotal evidence was always that the older the animal, the more pain it felt, but it may simply be that older animals are bigger and therefore are more difficult to restrain, and thus appear to feel pain more. The effect of age has been studied in cattle by comparing the increase in plasma cortisol of animals of different ages and subjected to the same mutilation (King et al., 1991). However, developmental changes in young animals can include changes in the sensitivity of the hypothalamic-pituitary-adrenal axis which would explain the results (Mellor and Murray, 1989). The neurological networks for pain perception and the functioning of those nerve pathways are present before birth, although the exact time varies according to the species. It has always been

recognised that the nervous system continues to mature after birth in that myelination of the larger peripheral nerves (motor) is not completed until a few weeks later. This late development was thought to indicate that young animals could not feel pain, or that it was not so intense as in adults with a fully mature system. This notion has recently been challenged on several grounds and it now looks likely that young animals feel more pain than older ones (for review see Fitzgerald, in Soulsby and Morton, 2001). First, nerve impulses from the pain receptors travel in unmyelinated as well as myelinated nerves and so poor nerve myelination will not stop the perception of pain. The poor myelination may however, impair a young animal's ability to escape the noxious insult e.g. by running away. Secondly, as 'pain impulses' pass along nerves to the higher centres of the brain, they form junctions with other nerves (synapses). Some of these nerves form a chain and impulses pass on up the spinal cord to the brain. Other nerves at the synapse actually originate in the brain and pass down the spinal cord. They are known as descending inhibitory fibres. They act as a sort of gate and impede the passage of impulses up to the brain, and in effect they raise the pain threshold. It has been shown that young animals have lower pain thresholds than adults. The descending fibres develop in the first few weeks after birth in many species but there is no specific information on calves. Finally, young calves may be very frightened at the time of the mutilation and 'freeze' rather than attempt to escape, giving the impression they do not feel pain. In summary, this research suggests that young animals may feel more pain than adults and furthermore, they are less able to take co-ordinated evasive actions.

2.2.3. Behaviour

The **diversity of behaviour** is one important measure of how much cattle are adapting to the environment. It is a major tool for assessing not only the negative impact of constraints but also the positive effects of environmental features. Some cattle show **abnormal behaviours** when they have difficulties or are unable to cope with the constraints. Such abnormal behaviours include the occurrence of stereotypic behaviour, increases in some specific behaviours as for example aggressiveness, changes in movement patterns and rhythms. The activities of the animal in situations with minimal constraints should be known in order to assess the changes in behaviours of the animals when they are under constraints. The usual environment of farm animals has to be defined carefully in order to take into account the effects of the domestication process. Because domestic animals can differ in their genetic and physiological status from the non-domestic populations, they may have problems to cope outside the farming environment.

Preference and motivation methods are sometimes used to answer questions about animal welfare. In preference tests the animals choose between two or more features (food, bedding, social contact, etc) of their environment. Methodological precautions should be observed to identify the animals' true preferences, and this demands that experiments be carefully designed, implemented and interpreted (Fraser and Matthews, 1997). Also, one must establish how strongly an animal prefers an option or avoids another one, or if it is motivated to perform a certain behaviour that is prevented by some environments. This is often studied by using the "elasticity of demand". Commodities for which there is an increase in price which results in a significant decrease in the quantity sold, are said to have an elastic demand and they can be seen as luxuries. Those for which an animal will continually work are said to have 'inelastic' demand - they may be called 'necessities' (Dawkins, 1990). Preferences may not correspond to welfare if the choices fall outside the animals' sensory, cognitive and affective capacities, or if animals are required to choose between short- and long-term benefits (Fraser and Matthews, 1997).

A 'need' is a 'requirement', which is a consequence of the biology of the animal. There is a need for an animal to obtain a particular resource or to respond to a particular environmental or bodily stimulus (Broom and Johnson, 1993). Scientific studies can provide evidence of the consequences for animal health, physiology and behaviour if their needs are not satisfied (see Report of the Scientific Veterinary Committee on the Welfare of Intensively Kept Pigs, 1997).

Conclusions about welfare should always be based on all available evidence, properly weighted, and should not rely only on, for example, preference or other trials in experimental conditions, or epidemiological surveys. When modified practices are used, the relevance of experimental studies where only one or a few factors have been varied, must be carefully considered. On operating farms, effects of such single variables may be exaggerated or compensated by other factors, and the stockman factor is central in the effective functioning of all systems. It is therefore normally desirable that on-farm surveys are carried out before definite recommendations are made.

2.3. Conclusions

1. Cattle welfare can be assessed in a scientific way using a combination of methods. These methods include measurements of health, physiology, performance, and behaviour as well as preference tests, aversion tests, measures of motivation and abnormal behaviour.

2. Welfare in existing systems can range from very good to very poor. The system of husbandry used can have a large impact on the welfare of the animals.

3. Good welfare relates not only to the health of the animals but also to the ability to manage interactions with the environment and the existence of good feelings.

4. The scientific assessment of welfare provides evidence on which to base recommendations for adopting or avoiding particular housing and management methods.

5. Very young animals feel pain and show signs of distress, and may feel more pain than adults.

6. Very young animals may show a freezing response to fear and pain, and so may not show a co-ordinated flight response.

3. STATE OF THE INDUSTRY

3.1. Introduction

Beef production systems in the European Union differ in regard to the age and weight at which animals are slaughtered, the method of feeding and the type of accommodation. Two main categories exist depending on whether the animals come from dairy farms or from suckler herds (Table 1).

A high proportion of the offspring (excluding 6 million used for veal production) of the 21.7 million European dairy cows (Holstein/Friesian and dual purpose cows) are destined for beef fattening units. These offspring are separated from their mothers at 1 to 2 days of age and artificially reared on milk or milk replacer plus solid food for a 6 to 9 week period. They are then weaned off milk or milk replacer and as functional ruminants are thereafter dependent on a diet of solid food i.e. forages (hay, straw, grass, silage) or forages plus concentrates. These animals subsequently enter beef fattening systems. The fattening system will depend on the region, tradition, type of diet available and market outlet.

A large proportion of the offspring of the 11.7 million beef suckler cows in the E.U. is also destined for the beef fattening units. The calves from the beef suckler cow remain with their mother for a 6 to 9 month period before they are weaned. At weaning the calf undergoes a change of diet from a dependence on their mothers' milk to a dependence on a forage diet and a change in environment. Details of weaning are presented in section 7.5. The weaned suckler calf's route from the suckler herd to the beef fattening unit is again influenced by region, tradition, type of diet available and market outlet. The effects of weaning of the suckler calf may be exacerbated by transportation and mixing with unknown animals.

Because of the effects of trade between Member States, the number of fattening bulls as a proportion of the number of cows varies between Member States. For example, France has a low proportion of fattening cattle relative to its cow population. In contrast Italy has a high proportion of fattening cattle relative to its cow population (Table 1) because of the movement of young animals between the two countries.

Table 1 Livestock numbers[1] and fattened cattle[2] in EU countries (thousands).

Country	Total cattle	Total cows	Dairy cows	Other cows	Heifers2	Bulls 2	Steers 2
Austria	2198	891	678	213	82	297	16
UEBL[3]	2977	1144	642	503	50	241	7
Denmark	2026	812	695	117	65	256	6
Finland	1125	415	383	33	43	184	0
France	20041	8530	4453	4077	627	974	304
Germany	15227	5729	5026	703	700	1771	48
Greece	542	278	182	96	33	152	0
Ireland	6992	2406	1268	1137	586	36	1060
Italy	7345	2779	2088	691	644	2063	6
The Netherlands	4287	1754	1674	80	65	203	0
Portugal	1285	651	362	289	47	142	7
Spain	5825	2936	1279	1657	800	1288	0
Sweden	1708	624	462	162	49	218	21
UK	11289	4358	2489	1869	879	290	1048
Total					4760	8114	2523

[1]Dec. 1997   [2]1999   [3]Belgium and Luxembourg

3.2. Production Zones in the European Union

Beef farming practices vary throughout the EU largely because of climatic factors. Allen et al. (1982) described five basic production zones in the EU:

3.2.1. Northern mountain zone

This includes the mountain and moorland areas of Ireland and the United Kingdom (UK), much of Norway, Sweden and Finland. The zone is characterised by high rainfall, high wind speeds, long winters, thin or peat soils and a rapid decline in forage potential at increasing altitude. Much of the area is devoted to forests, but in Ireland and the UK, beef suckler herds and sheep are present as complementary enterprises. Also in fertile valleys and on sheltered coastal plains more intensive agriculture, including dairying and arable crop production, is practised.

There is now little milk production in the northern mountainous areas of Ireland and the UK, except around the coasts. Under upland and hill conditions, suckler herds of beef cattle are kept in a complementary farming system with sheep. Sheep outnumber cattle, but the better the

quality of land the lower the ratio of sheep to cattle. In these areas afforestation is competitive with livestock production.

3.2.2. Northern lowland zone

This zone comprises the western coastal area of temperate maritime climate extending from north-western Spain, through western and northern France, the lowland areas of the UK and Ireland, to the low countries and around the Baltic coast. In this zone of grassland, fodder production predominates.

This is the most important milk production zone of Europe, with the Friesian/Holstein as the main breed. The equable maritime climate, allied to low altitudes and flat or rolling terrain, makes it ideally suited to grassland.

From the 1970's and early 1980's, beef and veal productions in this zone were almost exclusively a by-product of dairying. However, the introduction of milk quota in 1984 resulted in a large increase in the number of beef suckler cows in this region. The 3 million beef suckler cows in Ireland and the United Kingdom now account for approximately 25% of the beef cow population in the EU (Table 1).

3.2.3. Central zone and the Po Valley

This is an area of continental climate, with progressively more severe winters to the east. The Po Valley, the most productive arable cropping area of Europe, has been included within that central zone.

There is a clear distinction between the western and eastern sections of this zone. In the west, farms are predominantly in family ownership and of small size. Indeed in Germany there are many part-time farms with the head of the household earning most of his or her living from a job in industry.

The central zone is varied and includes the main grain-growing areas of Europe. However, it also includes important upland stock-rearing areas such as the Massif Central in France.

In France, breeders have developed specialised high-performance beef breeds of which the best known are Charolais, Limousin and Blonde d'Aquitaine. In marginal areas they have developed rustic breeds such as Salers.

The central zone is not as well suited to grass production compared with the northern lowland zone. However, forage maize has become a most important feed for both milk and beef production.

The Po Valley is a highly fertile area suited to the production of a wide variety of crops. It has been a focal point for the development of beef production from bulls fed maize silage supplemented with maize grain. Most of the cattle are imported either as early weaned dairy calves from Bavaria (Simmental), Poland and the UK (Friesian), or as weaned suckled calves from France (Charolais, Blonde d'Aquitaine, Limousin).

3.2.4. Alpine zone

Included in the alpine zone are the Pyrenees, Alps and Dinaric Alps. It is a high mountainous area with narrow but often fertile valleys.

As in the northern mountains zone, much of the alpine zone is devoted to forest. Also much of the alpine area, under the influence of Mediterranean climate, is barren and sub-marginal for cattle production. In a country such as Austria, milk production is important though there is a tendency for cattle to be removed from mountainous areas.

3.2.5. Mediterranean zone

The zone of Mediterranean climate needs to be subdivided into those areas that can be irrigated and are highly productive, and those areas that cannot be irrigated and where crops suffer considerable moisture stress.

The Mediterranean climate is not well suited to cattle production, and overall, sheep and goats are more important than cattle. Most of the irrigated area that could be used for cattle production is in fact used for crop production though there is sufficient milk production to meet local demands.

3.3. The Industry in the Member States

Beef fattening systems may be divided into two main categories, intensive indoor and grass-based systems involving winter accommodation.

The diversity of beef fattening systems in the EU is influenced by the type of diets (largely related to the climatic environments) and by the different cattle breeds. These breeds may be dairy (primary output milk), dual purpose (producing milk and beef) or beef (primary output beef). The EU dairy herd is dominated by the Friesian/Holstein breed. In contrast the EU beef herd is very diverse with late maturing beef breeds (Charolais, Limousin and Blonde d'Aquitaine) dominating in France. The beef herds in UK and Ireland consist of some pure bred breeds, e.g. Angus, Hereford, French breeds but more cross bred cows (British breeds x dairy breeds) mated to the late maturing beef breeds. The beef breeds in Spain are predominantly local (rustic) breeds. The complexity of the EU beef fattening system is best understood when the industry is presented on a country basis.

Austria: The 0.7 million dairy cows account for 3% of the EU dairy cow total and the 0.2 million suckler cows account for 2% of the EU beef cow total.

Belgium: The 0.6 million dairy cows (Friesian/Holstein) account for 3% of the EU dairy cow and the 0.6 million beef cows (99% Belgian Blue) account for 4% of EU beef cow total. The 0.26 million bulls from the suckler herd are fattened after weaning on a diet of maize silage plus concentrates for a 8 to 10 month period to reach a carcass weight of 485 kg. The 0.06 million heifers from the suckler herd which are fattened are offered a similar diet and slaughtered with a 425 kg carcass (Fiems and Boucqué, 1995).

Denmark: The 0.7 million dairy cows (Danish Red and Danish Holstein) account for 3% of the EU dairy cow total and the 0.12 million beef cows account for less than 1% of the EU beef cow total. The majority of the suckling cows are crossbred from dairy cows mated with various sire breeds (Limousin, Hereford, Charolais, Simmental and Aberdeen Angus). (Hansen and Vigh Larsen, 1995). The tradition in Denmark is to produce young bulls from dairy herd at 12 to 14 months of age with a carcass weight of 250 kg.

Finland: The 0.4 million dairy cows account for 1.75% EU dairy cow total and the 0.03 million beef cows account for 0.25% of the EU beef cow total.

France: The 4.45 million dairy cows account for 20% of the EU dairy cow total and its 4.1 million beef cows account for 35% the EU beef cow total (Kempf, Rouquette and Chotteau, 1995). The male calves from the dairy herd enter veal fattening units (1.76 million animals in

1998) or are fattened as young bulls (470,000 animals in 1998) and slaughtered at 16 to 22 months of age (GEB, 1999). The beef cow herd is composed of 2 million Charolais, 800,000 Limousin, 600,000 Blonde d'Aquitaine and 600,000 animals of local breeds (Salers, Aubrac and Gasconne). Approximately 1.16 million young animals are exported annually to Italy and Spain at ages ranging from 6 to 16 months of age. These animals may be exported either immediately after weaning, or as prefattened store at 12 months of age or as non finished bulls at 16 months of age. Animals finished in France are slaughtered at 18 to 24 months of age (55% from suckler herds and 45% from dairy herds). Charolais and Limousin bulls are slaughtered at 18 to 19 months of age with carcass weights in the range 410kg to 430kg. These animals are fed a diet of maize silage and concentrate in specialised beef fattening units. In addition steers, mainly in the North west of France, are fattened and slaughtered at 2.5 to 3 years of age using Holstein x Charolais and Normand breed (304,000 animals in 1999).

Germany: The 5.0 million dairy cows account for 23% of the EU dairy cow total and the 0.7 million beef cows account for 6% of the beef cow EU total. Ninety percent of the male calves from both the dairy and beef herds are fed on a maize silage concentrate diet and are slaughtered at 15 to 18 months of age with a carcass weight ranging from 330 to 380kg (Munchhausen, 1995) The primary beef breed in Germany is Simmental and the other main breeds in the suckler herd include Angus, Charolais and Limousin. The calves are weaned from the beef cows at 4 to 8 months of age and sold to fattening units.

Greece: The 0.18 million dairy cows (15% Holstein, 69% local x Holstein and 16% local) account for 0.8% of EU dairy cow total and the 0.1 million beef cows account for 0.9% of the EU beef cow total. The beef cow herd consists of crossbreeds, dairy cows crossbred with beef sires (Limousin, Schwyz, Aberdeen Angus and Simmental or local breeds) (Zervas, 1995). Calves are weaned when 5 to 6 months old. In addition Greece import 70,000 calves from Romania and Poland. Cattle are fattened indoors on a diet of straw, hay and concentrates for 10 to 15 months and they are slaughtered at carcass weights of 170kg to 280kg.

Ireland: The 1.3 million dairy cows (Friesian/Holstein) account for 6% of the EU dairy cow total and its 1.1 million beef cows account for 10% of EU beef cow total. More than ninety five percent of the beef cows are crossbred. The majority of them are issuing from the dairy herd (Drennan, Keane and Dunne, 1995). When not being bred for herd replacement, the sire used on mature cows is usually a late maturing breed (Charolais, Limousin, etc.). Both the dairy and beef herds are predominantly spring calving and the majority of animals are finished as heifers or steers. Steers are generally slaughtered from 24 to 33 months of age with heifers slaughtered approximately 6 months earlier. Most animals are slaughtered straight from

pasture (May to November) with the remainder offered grass silage and concentrates prior to slaughter. The mean carcass weight for steers at slaughter is 350 kg, the corresponding value for heifers is 290 kg. In recent years Ireland has annually exported 0.25 million weanlings from the suckler herd to Spain and Italy.

Italy: The 2.1 million dairy cows (1.4 million Friesian Holstein, 0.5 million Brown Swiss and 0.2 million Simmental) account for 10% of the EU dairy cow total and its 0.7 million beef cows account for 6% of the EU beef cow total. The beef cow herd is composed of 420,000 beef cows (Piemontese, 0.27 million, Chianina, 0.06 million and Marchigiana, 0.09 million) and 270,000 of local breeds (Podolica, 60,000, Sarda, 100,000 and Modicana 110,000) (Gigli and Iacurto, 1995) In addition, Italy imports 1.5 million cattle of which 1.3 million enter fattening units and 0.2 million are for immediate slaughter.

In Italy there are many specialised fattening units with a capacity ranging from 200 to 500 heads per unit. They operate on 2 batches of cattle per year, fed a diet of maize silage plus concentrate during a 5 to 6 month fattening period. Some cattle are also finished on their farms of origin. Cattle from the beef breeds are housed indoors and are slaughtered when 18 months old with a mean carcass weight of 350 kg. The animals from the rustic breeds graze part of their time. They are slaughtered when 18 to 20 months with a carcass of 300 to 350 kg. In Italy there is a considerable range of variation of the final carcass weights for both bulls and heifers. The main categories are: - Light i.e. 250 kg for bulls at 14-20 months and 190 kg for heifers at 10-16 months, - Medium i.e. 300 kg for bulls and 250 kg for heifers., - Heavy i.e. heavier than 350 kg.

The Netherlands: The 1.7 million dairy cows (Black and White and Red and White Friesian) account for 7% of the EU dairy cow total and its 0.08 million beef cows account for less than 1% of EU beef cow total. There are approximately 0.2 million young bulls fattened annually (Heeres-van dertol and Plomp, 1993). They are offered a diet of maize silage plus concentrate and co-products from the feedstuff industry. The bulls are slaughtered at 16 to 17 months of age with a 370 kg carcass weight. It is estimated that 75% of bull calves used for fattening are imported.   The small beef cow herd is used for grazing in nature reserves. Artificial insemination (0.25m) is used on poorer producing dairy cows to produce beef crosses (including Piemontese 0.1 million, Belgian Blue 0.04 million, and Blonde d'Aquitaine 0.04 million).

Portugal: The 0.4 million dairy cows (Friesian/Holstein) account for 1.5% of the EU dairy herd and the 0.3 million beef cows account for 2.3% of the EU beef cow herd. The majority of the beef cows are from hardy breeds (Galega, Minhota, Marinhoa, Barrosa, Maronesa,

Arouquesa and Mirandesa) (Alves and Teixeira, 1995). The offspring are weaned at 6 to 8 months of age at approximately 200 kg liveweight. The remainder of the suckler herd includes Salers and Limousin crosses. The beef fattening units and age and weight at slaughter are similar to the ones observed in the Spanish fattening systems.

Sweden: The 0.46 million dairy cows account for 2% of EU dairy cow total. The 0.16 million beef cows account for 1.5% of the EU beef cow total. Main beef breeds are Hereford, Charolais, with some Aberdeen Angus and Simmental.

Spain: The 1.3 million dairy cows (1.1 million Friesian/Holstein and 0.2 million Brown Swiss) account for 6% of the EU dairy cow total and its 1.7 million beef cows account of 14% of the EU beef cow total. The national beef herd are mainly from 24 local breeds. The four main breeds are Rubia Gallega (0.19 million), Avilena (0.08 million), Morucha (0.12 million) and Retinta (0.14 million) (Del Pozo and Osorio, 1995). The management of the calves from all those beef breeds is similar. They are weaned at 6 to 8 months of age, weighing 170 to 300 kg, and are then transferred to fattening units. They are slaughtered at 14 to 15 months of age with a mean carcass weight of 260 kg for bulls and 230 kg for heifers carcass. In Spain 80% of the total beef production is from 7,500 feedlots located near cities. In the feedlots 1 million bulls and 0.7 million heifers are fed a fattening diet of concentrates plus roughage.

United Kingdom The 2.5 million dairy cows account for 11% of the EU dairy cow total and its 1.0 million beef cows account for 16% of the EU beef cow total. The vast majority of cows in the dairy herd are Friesian/Holstein. In local areas the Ayrshire, Jersey and Guernsey are also used for milk production. More than ninety percent of the beef cows are crossbred, the majority being beef crosses born in the dairy herd (Lowman and Wright 1995). However the purebred beef herds e.g. Aberdeen Angus, Hereford, Charolais still make up a significant number of individuals. When not bred to produce replacements, the sire used for mature cows is usually a late maturing breed (Charolais, Limousin, etc.). The majority of animals are finished as heifers or steers. The dairy herd is predominantly an autumn calving herd with the heifers for beef finished at 18 months and the steers finished at 18 to 24 months. A grass or grass silage and concentrate diet is fed in the final 2 to 4 months of fattening. A small proportion of male calves from the dairy herd are fed a diet of cereals and roughage and slaughtered at 12 months of age with a 250 to 280 kg carcass. Similarly a small proportion of animals fed a diet of grass silage and concentrate are slaughtered at 15 months of age with a 280 to 300 kg carcass. The progeny from the beef cow herd (50% sold as yearlings and 50% fattened on farm of birth) is generally finished as heifers at 18 to 20 months or as steers at 24 to

26 months of age. A small proportion is fed a high energy diet and finished as bulls at 15-16 months of age.

3.4. Main Beef Production Systems

3.4.1. 16-month-old Dairy bulls fed Grass Silage and Concentrates

Throughout Europe this system was first developed on a basis of grass silage supplemented with concentrates. In Scandinavia, where maize cannot grow, that system is the most usual. The 16-month old beef system is based exclusively on top quality grass silage. It is supplemented with 2 kg of concentrate (16% crude protein) in the period 3 to 12 months and with 3 to 4 kg of concentrate in the period 13 to 16 months of age. Under Irish conditions one hectare cut 3 times annually provides sufficient silage for finishing 5 animals per year (O'Kiely and Flynn, 1990). Dairy born calves are "conventionally" (as the female calves reared for replacement) reared for the first 3 months. They are then offered grass silage with 74% dry matter digestibility (DMD) *ad libitum* with the following supplementation concentrate schedule (kg/day/head: 3 to 12 months: 2 kg; 13 to 14 months: 3 kg; 15 to 16 months: 4 kg). The animals achieve a daily liveweight gain of 0.95 kg/day from 3 months of age and are slaughtered at a final liveweight of 505 kg (Table 2).

3.4.2. 16-month-old Dairy bulls fed Maize Silage and Concentrate

In continental Europe maize production has spread rapidly northwards with the development of early maturing varieties. European beef producers in Italy, France and Germany have developed maize silage beef systems for both dairy bred and suckler bred cattle (Allen, 1990). Maize silage, while being a good source of energy, is low in protein. As a result maize silage with a 76% DMD is offered *ad libitum* and the diet is supplemented with 2 kg of protein rich concentrate (30% crude protein). Dairy born calves are conventionally reared for first three months and then offered maize silage *ad libitum* to slaughter at 16 months of age. The animals achieve a daily liveweight of 1.15 kg per day from 3 months of age and are slaughtered at a liveweight of 550 kg (Table 2).

3.4.3. 12 month old dairy calf bull beef production system fed a cereal based diet

Particular markets in Spain, Portugal and Italy require a carcass weight of 250 kg from Holstein or Friesian bulls at 11 to 12 months of age. The production targets are very similar to

those outlined for cereal beef production in England by the Meat and Livestock Commission (MLC) which involves feeding concentrates *ad libitum* from 12/14 weeks of age to slaughter with a daily allowance of long roughage such as straw at approximately 5% to 10% of the total diet (Fallon and Drennan, 1998). Other cereals or cereal substitutes can replace all or part of the barley provided that the ration is properly balanced for protein, minerals and vitamins. The animals on this system achieve a liveweight gain of 1.25 kg per day from 3 months of age and are slaughtered at 450 kg liveweight (Table 2).

3.4.4. 16-Month-Old Suckler Beef bulls fed grass silage and concentrate

In the UK a substantial increase in the production of young bulls from the suckler herd occurred in the years prior to 1996. This took place because of the faster growth rate, leaner carcasses and more efficient feed conversion of bulls compared to steers. Provided that fencing is good, leaving the males as entire bulls does not cause any extra management problems during the suckling period at pasture except that they must be grazed separately from the heifers from 6 months of age.

Young crossbred bulls are fed a high quality grass silage (74% DMD) and concentrates from weaning to slaughter. They are slaughtered at 16 months of age with a carcass weight of 350 kg (Drennan, 1993).

Single suckled bulls of late maturing continental crossbreds are weaned at 8 to 9 months of age. They are then offered grass silage (74% DMD) *ad libitum* and 4 to 6 kg of concentrates per head/day for approximately 240 days. The animals achieve a daily liveweight gain of 1.25 kg per day from weaning and are slaughtered at 600 kg liveweight (Table 2).

3.4.5. 16-18 Month Old Suckler Beef bulls fed maize silage and concentrate

The system is widely practised in mainland Europe for the late maturing continental breeds. The animals are weaned at 7 to 9 months of age. Then they are accommodated indoors and offered a diet of maize silage (76% DMD) *ad libitum* and 4 to 6 kg of concentrates per head/day for the duration of the fattening period (Allen, 1990).

In all situations the maize silage concentrate diet is designed to provide adequate protein and the necessary minerals and vitamins. The animals on this system achieve a liveweight gain of 1.40 kg/day from weaning and are slaughtered at 660 kg liveweight (Table 3).

3.4.6. 12 or 15 Month Old bulls from the Suckler herd fed with a cereal based diet

In the EU there is considerable interest in the production of beef from young continental bulls from the suckler herd. This system is for weaned single suckled bulls of the late maturing continental breeds weaned at 7 to 9 months of age (Fallon and Drennan, 1998). The animals are offered concentrate *ad libitum* with daily access to a roughage source (0.5 to 1.0 kg of straw/head/day). The animals are slaughtered at 12 to 15 months of age. The economics of offering an all concentrate diet to continental cross weaned suckler bulls are driven by the price of the weaned bull, the cost of the concentrates and the value of the final carcass. A decrease in grain prices encourages this system. The animals on this system achieve a liveweight gain of 1.55 kg per day from weaning to slaughter at 570 kg liveweight at 12 months of age. The animals slaughtered at 15 months of age achieve a liveweight gain of 1.35 kg per day from weaning to slaughter at 640 kg liveweight (Table 3).

Table 2 Input and Output from different bull beef production systems (from dairy herd).

Systems	Grass silage and concentrate	Maize silage and concentrate	Concentrate *ad libitum*
Initial age (months)	3	3	3
Slaughter age (months)	16	16	12
Inputs (tonnes)			
Silage dry matter	2		-
Concentrate	1	2.2	1.8
Straw	-	0.9	0.15
Output (kg)			
Initial weight	110	110	110
Daily weight gain	0.95	1.15	1.25
Final weight	515	550	450
Carcass weight	280	300	240

Table 3. **Input and Output from different bull beef production systems (from suckler herds).**

Systems	Grass Silage and Concentrate	Maize Silage and Concentrate	Concentrate *ad libitum*	Concentrate *ad libitum*
Initial age (months)	8	8	7/8	7/8
Slaughter age (months)	16	16	12	15
Inputs (tonnes)				
Silage dry matter	1	-	-	-
Concentrate	1	1	1.45	2.25
Straw	-	1	0.11	0.18
Output (kg)				
Initial weight	310	320	320	320
Daily weight gain	1.30	1.40	1.55	1.35
Final weight	620	660	570	640
Carcass weight	360	375	325	370

3.4.7. 2-year-old steers from the dairy herd

The objective is to efficiently use the grass throughout the year either grazed *in situ* or offered as grass silage while maintaining high performance. The male calves are castrated at 2 to 3 months of age. At grass, spring born calves rotationally graze ahead of the yearling animals (leader/follower system). That system is important as it allows the calves to selectively graze and it also facilitates the control of parasites. The stocking rate is approximately 0.50 hectare of grassland in favourable growth conditions per finished animal produced per year (Drennan, Keane and Dunne, 1995).

Finishing animals are housed in mid-October after 210 days at pasture and weanling calves are housed in mid-November after 200 days at pasture, depending on the grass supply (See table12 for a comparison of times spent indoors in the various systems). The silage allowance per animal unit (weanling plus finishing) is 10 tonnes.

In the first winter weanlings are fed 1kg of concentrate per head/day and have *ad libitum* access to silage throughout the 150 day winter period. In the second winter finishing animals are fed 4 kg of concentrates per head/day and have *ad libitum* access to silage throughout the 150 day finishing period.

3.4.8.   2- year- old steer from the suckler herd

The objective is to efficiently use the grass throughout the year either grazed *in situ* or offered as grass silage while maintaining high performance. This is achieved by adjusting the stocking rate during the grazing season. Areas are closed off for silage when grass growth is highest in spring and the entire area is grazed from August to the end of the grazing season. The grass conservation programme is designed to provide adequate silage, with a 72% DMD for all animals in the system from two silage cuts (Drennan, Keane and Dunne, 1995).

The male (castrated at 4 to 6 months of age) and female calves are weaned in the autumn and housed for a 150 day winter period. In the first winter they have *ad libitum* access to grass silage plus 1 kg of concentrate per head per day. The yearling animals are at pasture from April to November where they rotationally graze a number of paddocks. The female animals are supplemented with concentrate from September to November. They are slaughtered at 20 months of age. The male steers are taken indoors in November for a 150-day fattening period. In the fattening period they receive *ad libitum* access to grass silage plus 4 kg of concentrate per head per day.

3.4.9.   2.5 -year- old steers and heifers

Animals from both the dairy and beef cow herds are involved. Animals have two winter periods (5 month duration) indoors offered a grass silage diet and no concentrate. The animals are finished during their 3rd season at pasture. Animal performance is very dependent on compensatory growth with low growth rates during the winter indoor periods and high growth rates at pasture.

3.4.10.   Organic farming

Production of beef by organic methods is clearly defined by the EC-Regulation (No. 1804/1999). This regulation sets out rules for conversion, origin of the animals, feed, disease prevention, veterinary treatment, husbandry management, free range areas and livestock housing.

The minimum net area available to animals indoors must be 5 m^2 per animal for cattle over 350 kg live weight with a minimum of 1 m^2 per 100 kg. In addition, an outdoor area (exercise area, excluding pasture) has to be provided, extending at least 75 % of the indoor area. The housing must be provided with a resting area, consisting of a solid construction which is not slatted and where ample dry bedding strewn with litter material is prescribed. The regulation also states

that at least 60% of the dry matter in daily rations is to consist of roughage, fresh or dried fodder, or silage.

In the case of fattening of bulls, the regulation goes far beyond the level of conventional housing conditions the indoor and relevant benefits for animal welfare are expected (Sundrum, 1999). Rules for organic farming provide certain limitations on veterinary treatments for sick animals. This may have implications for animal welfare, particularly if treatment is delayed or if less effective treatment is administered.

The current number of farms providing livestock production according to the EC-regulation differs widely between countries. An overview is given in table 4.

Table 4: Number of organic farms in different EU-countries (%) (Hamm and Michelsen, 2000)

Country	%	Country	%
Austria	10.1	France	0.6
Switzerland	6.7	Italy	4.0
Sweden	6.5	United Kingdom	0.4
Finland	4.7	Greece	0.2
Denmark	2.4	Spain	0.5
Germany	2.6	Portugal	0.3
Netherlands	0.9		

In some countries beef cattle is the primary production of organic farms whereas dairy cattle is the main production in other countries. In Spain, 50% of the organic livestock production is beef cattle and only 1% dairy cattle (Trujillo, 2000). In Austria, 97% of the organic farms have cattle, consisting of 65% dairy cattle and 35% beef cattle (Graf and Willer, 2000). In Denmark, 33% of the organic farms have cattle, of this 57% are farms with dairy cattle, forming the majority of organic cattle (Anon., 1999a). However, only 26% of the bull calves born on the organic farms in Denmark are slaughtered as organic (Nielsen, 2000), because organic fattening of bull calves is not as profitable as organic milk production is. Lacks of resources such as feed and stall capacity are other reasons for not fattening bull calves.

Although there is an increasing interest in organic beef, the market share of organic beef in most countries is very low - only 2% in Denmark-, whereas other organic products e.g. milk has a market share of more than 20% (Anon., 1999b). Consumer prices for organic beef possibly exceed consumers' willingness to pay, as premiums for organic meat in several

countries in the EU result in a price of nearly 50% above the conventional products (Schmid and Richter, 2000).

3.5. Cattle Fattening Systems In Some Other Regions

3.5.1. North America

The EU has 11.7 million beef suckler cows. In contrast the United States have 43 million beef suckler cows. The number of beef cows in the USA has more than doubled in the last 35 years increasing from 16.4 millions in 1946 to 43 millions in 1993 (USDA, 1995).

The beef cow herd is the primary producers of cattle for feedlots. In the USA they are basically of two types, farmer feeders and commercial feeders with a tendency for fewer but larger feedlots. Farmer feeders operate feedlot with a one time capacity for less than 1000 heads of cattle. These cattle feeders represent over 98% of all feedlots in 1980 and market over one-quarter of the total cattle (Perry, 1992). In 1980 less than 2% of cattle feeders were in the commercial category (> 1000 head capacity) yet nearly half of all fattening cattle were marketed out of 411 feedlots (Perry, 1992). In 1980 there were 69 feedlots with a capacity of more than 32,000 cattle (Perry 1992). The USDA (1995) reported that in 13 selected states that were 79 feedlots with a individual capacity for more than 32,000 animals. The general trend in the USA is for the size of feedlots to increase.

In respect to feedlot design, Perry (1992) considered that fattening cattle did not require shelter as a protection from cold weather as far North as the southern Canadian Provinces. However, in the hotter climate of Southern United States, providing shade from the sun during the summer months results in more rapid and more efficient feedlot gains. Perry (1992) reported that even though fattening cattle are able to cope with rather severe weather conditions outdoors, there is a strong trend towards semi-confinement facilities in order to control waste production.

Feedlot Rations and Feeding System
The composition of rations fed in finishing operations depends largely on types of feed produced locally and on the expected weights and grades of feeder cattle (Perry, 1992). However, cattle types tend to fall into one of a few categories. For instance, cattle purchased for fattening are usually either calves or yearlings, of the type that will fatten to a United States Department of Agriculture (USDA) grade of Choice, Good or Standard and are either steers or

heifers. Similarly, feeding programmes are relatively few in number. In the Corn Belt area feeding programmes are built around various proportions of corn plus corn silage or haylage or other roughages. There is nothing rigid about these limited combinations: if other grains were to compete pricewise with corn, they would be incorporated into the diet.

A cattle feeding system is defined as a feeding enterprise for which the animal's sex, grade, starting weight and finishing weight have been specified (Tables 5 and 6).

The following is an example of the production of Choice grade beef from steers taken from Perry (1992); The steer is generally a product of the beef cow herd with the genetic potential to have high degree of intramuscular fat at slaughter. The animal can produce one of the most popular carcasses for the chainstore trade. The Choice steer calf does not have the time or the capacity to be subjected to a diet containing a high percentage of silage at any time, except for a very short time initially. To take advantage of maximum performance, animals in this system are implanted with growth hormones to improve efficiency and to save feed. This animal should reach a finish weight of 475 kg and should be in the feedlot for 190 days, with an average daily gain of 1.2 kg.

Table 5. **Main feedlot finishing systems in the USA to produce a choice grade carcass**

Age	Sex	Starting Weight (kg)	Finishing Weight (kg)	Daily Gain (kg)	No. Days on feed
Calf	Steer	195-250	475	1.2	190
Calf	Heifer	180-225	410	1.0	180
Yearling	Steer	260-295	520	1.3	150
2-year-old	Steer	340	525	1.3	150

Table 6. **Feeding programmes (kg/head per day) for steer and heifer calves to reach a choice grade.**

Alternative Feedstuffs	Steers[a]			Heifers[b]	
	First 65 days	Second 65 days	Last 60 days	First 80 days	Last 100 days
1. Maize whole plant silage	9.0	8.0	5.5	5.4	5.4
Grain[c]	2.3	3.2	7.3	5.4	7.3
Urea-based supplement	0.5	0.5	0.5	0.5	0.5
2. Ground maize ears[c]	6.4	8.2	11.0	6.4	10.0
Urea-based supplement	0.5	0.5	0.5	0.5	0.5
3. 16 parts shelled corn[c] to 1 part urea *ad libitum*	7.0	8.7	11.5	7.0	10.5

[a]Gain 225 kg in 190 days, or 1.2 kg/day. [b]Gain 200 kg in 180 days, or 1.1 kg/day.
[c]The grain may be maize, milo, wheat or barley.

3.5.2 Eastern Europe

The cattle production systems in Eastern Europe are not very well described, however it is assumed that there is a similarity with those practised in the EU. The main feature in Eastern Europe is the decline in cattle numbers over the last 20 years and more particularly in the last 10 years with many countries experiencing a 50% decline in total cattle numbers (Table 7).

Table 7. Cattle numbers in European eastern countries (millions)

	Year		
Country	1975	1985	1998
Bulgaria	1.5	1.7	0.6
Czech Republic	4.6	5.1	1.7
Slovakia			0.8
Hungary	2.0	1.9	0.9
Poland	12.8	10.9	7.0
Romania	6.0	7.0	3.2

Source WHO, 1999

3.6 Conclusions

1. There is a large variety of climatic and farming conditions throughout the EU. Cattle production systems are partly based on the foodstuffs produced on farms. These foodstuffs are very dependent on the climatic conditions and as a consequence, fattening systems are very diverse.

2. Within the EU there are 21.7 million dairy cows and 11.6 million beef cows. These animals are the source of cattle which will be accommodated in fattening units.

3. In 1999 the number of beef cattle fattened and slaughtered in the EU was 4.8 million heifers, 8.1 million bulls and 2.5 million steers.

4. Large numbers of movements of live animals occur between countries.

5. The diversity of beef fattening systems in the EU is influenced by the different cattle breeds. These breeds may be dairy (primary output milk), dual purpose (produce milk and beef), or beef (primary output beef). The EU dairy herd is dominated by the Friesian/Holstein breed. In contrast, the EU beef herd is very diverse with late maturing beef breeds (e.g. Charolais, Limousin and Blonde d'Aquitane) as the predominant breeds in France. The beef herds in UK and Ireland consist largely of cross bred cows mated to late maturing beef breeds while beef breeds in Spain are predominantly local (rustic) breeds.

6. In mainland Europe the majority of male animals are fattened as young bulls. In the UK and Ireland the majority of male animals are castrated and are fattened as steers.

7. In mainland Europe the majority of young bulls are offered a fattening diet based on maize silage plus concentrate. The duration of the fattening period varies with the type of animal and ranges from 120 to 250 days. The bulls from the dairy herd are slaughtered at 12 to 14 months of age. The bulls from the beef herd (weaned at 6 to 8 months) are slaughtered at 12 to 16 months of age. The demands of the market (carcass weight and conformation) determine the duration of feeding.

8. In Ireland, UK and north western France where the males are fattened as steers, many of the animals are fattened off grass at 20 to 30 months of age and others are fattened indoors for their final 5 months on a grass silage plus concentrate diet. Heifers surplus to breeding requirement can be fattened in intensive units or fattened off pasture at approximately 20 months of age.

9. Beef production in the USA is based mainly on steers and heifers from the suckling herds. Those animals are finished in feedlots with high energy diets. This farming system is very different to systems used in the EU.

10. Cattle production in the eastern European countries has declined in recent years.

4. HOUSING SYSTEMS

4.1. House Types

The type of housing provided for beef fattening will depend on the geographic location, availability of straw, size of the fattening unit and on the traditional methods of fattening. In designing houses for fattening cattle most consideration has been given to labour availability, feeding systems, type of diet, group size, drinking systems, and systems for handling and storage of the manure. The need for housing during the fattening period may be due to land conditions that do not facilitate outdoor fattening or it may be used to protect the animal and the caretaker from adverse weather conditions. In some situation indoor housing is provided to allow for the structured feeding of the animals under controlled management conditions.

A number of housing options are described. Recommendations for stocking density described in the chapter are based on production experiments or on common practice. Apart from regulations dealing with organic production, there are no EU standards dealing with floor space allowances for fattening cattle. These regulations (Council Regulation (EC) No 1804/1999) set a minimum indoor space requirement of 5m² for animals weighing over 350 kg, with a minimum of 1m² per 100 kg for animals over 500 kg.

4.1.1. Permanent tethering in tie-stall

This type of design that facilitates individual feeding is common in small units in Scandinavia and parts of Germany. A survey was conducted in 1994 in France which determined that 21% of the fattening cattle were tethered and most of those animals were on straw bedding (Fraysse, 1994). It is likely that the size of those units is small and concern mainly heifers or steers. Those units are mainly located in the south of France including the Massif Central. The design of the stalls can be very diverse and several parameters which are of importance for the welfare of the animals must be considered. These include the type of floor, the width and length of the stalls, the partitions between stalls, but also the length and the type of the tether. The usual design of such a facility is presented in Figure 1. Littered tie-stalls for fattening beef cattle use a grid at the back half to the stall to facilitate the removal of urine from male cattle. In the absence of a grid the stall platform remains continuously wet from urine leading to dirty animals (Daelemans and Manton, 1987). Slatted floors in the second half to the stall platform solve this problem. The stall length is a critical factor as the animal due to the animals' growth

and part of the design is that the animal defecates in the passageway behind the stall. If the stall is too short for the animal it will tend to lie with its rump in the dunging passageway. This dunging passageway is usually cleaned daily or twice daily with a scraper.

Figure 1. Tie stall design (Haley et al., 2001)
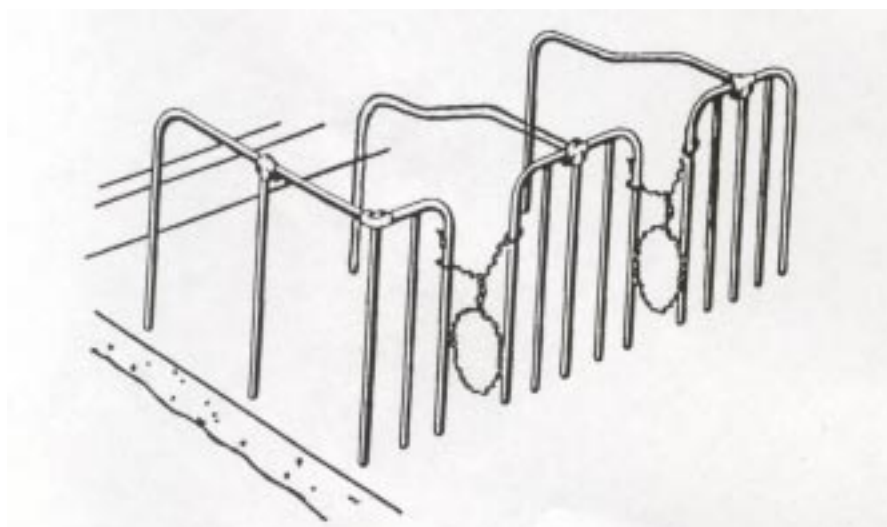
4.1.2.   Littered Loose House

This house type consists of a number of straw bedded pens in one or more rows (Figure 2). Daelemans and Maton (1987) suggested that the pen area depends on the number of animals per pen, the weight of the animals and, if fed individually, on the required frontage as shown in Table 7. The fully littered loose house requires approximately 4 to 6 kg of straw per animal per day (Daeleman and Manton, 1987; Tillé et al., 1996). This equates to 1 tonne of straw per animal every 6 months. The lying area is generally cleaned out only once at the end of the fattening period. Depending on the length of the fattening period the accumulated straw and dung may rise up to 1 m plus above base floor level. It is necessary therefore, that both partition and troughs can be adjusted upwards as the straw and dung accumulate. If an adequate allowance of straw is not provided the animals become dirty as a result of the wet lying conditions.

Figure 2. Fully bedded building with raised central passageway (Hardy and Meadowcroft, 1986)
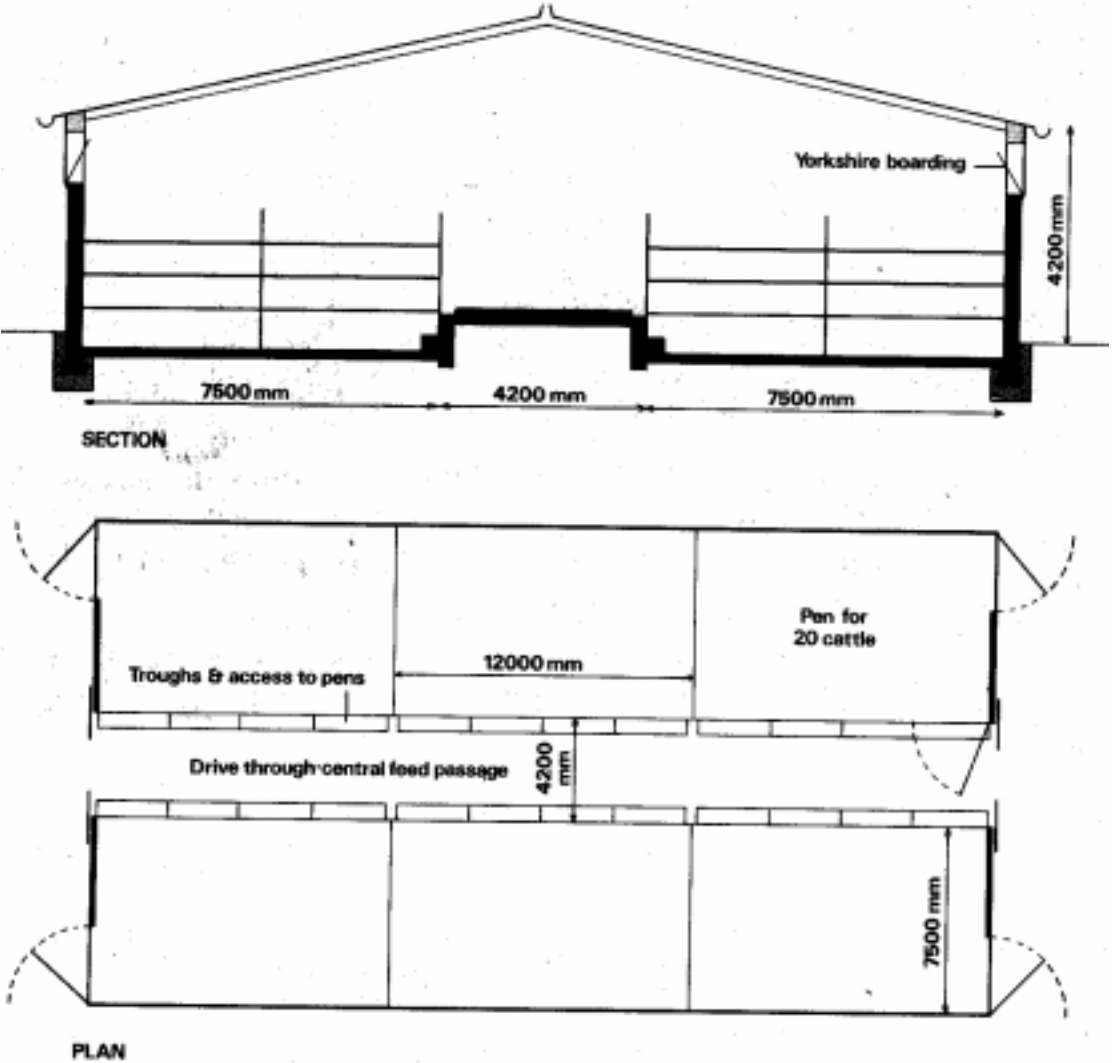
Table 8. The recommended dimensions of littered loose house pens (Daelemans and Manton, 1987).

Animal weight (kg)	200	300	400	500	600	700
Pen area/animal* (m^2)	2	3	4	5	6	7
Frontage/animal** (m)	0.4	0.5	0.6	0.65	0.65	0.7
Pen depth*** (m)	5	6	6.7	7.7	9.2	10

*Rule: 1 m^2 pen area per 100 kg liveweight ; **If every animal needs a place at the trough ;

***Minimum dimensions. They are increased in order to give all pens in one row an equivalent "depth".

4.1.3. Littered loose house with concreted or slatted feeding stand

This house type consists of a number of straw bedded pens in one or more rows with a straw free stand next to the feeding trough (Figure 3). An electric or tractor driven scraper is used daily to clean the feeding stand if the floor in this area is a solid floor. Alternatively if the feeding stand is slatted, the manure is collected in a tank below the floor. With this system the daily straw requirement is 4 kg of straw per animal per day (Daelemans and Manton, 1987). Additional gates are needed to close off the feeding stand from the straw bedded area during cleaning time. The total surface per head proposed by Capdeville and Tillié (1995) is slightly lower than the one proposed in the previous system (for a 700kg animal: 4m² straw bedded surface and 1.8-2m² for the concrete part) and 3 to 5 kg of straw per day and per head are required.

In contrast, Hardy and Meadowcroft (1986) suggested lower area requirements for bedded yards (Table 9).
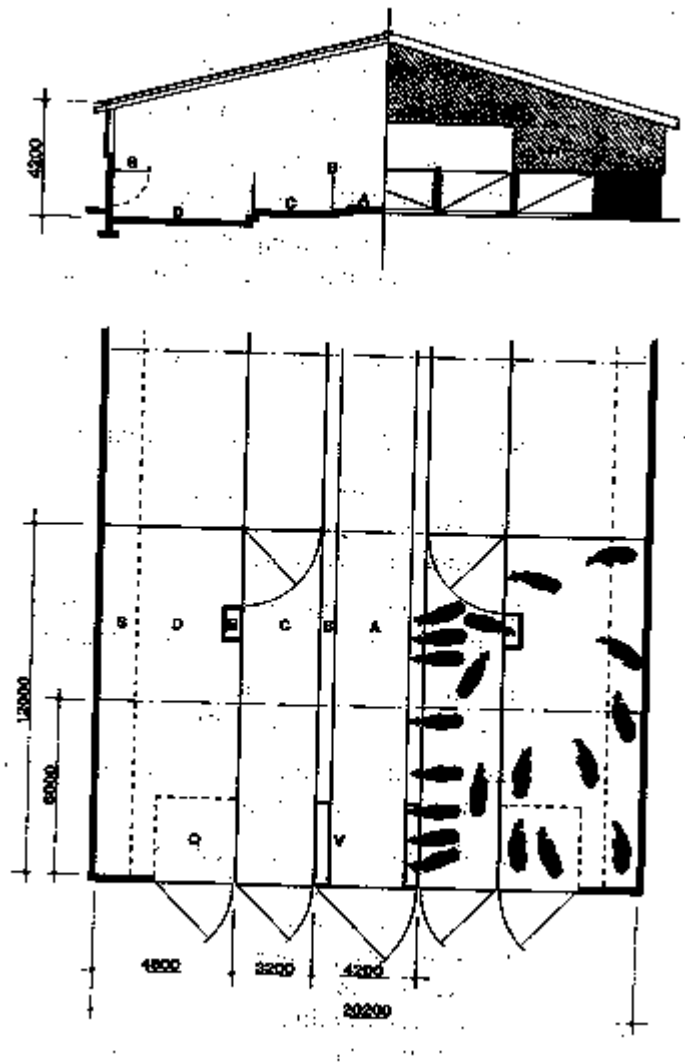
Figure 3. Part bedded/part scraped loose house

Table 9. Recommended space allowance per animal on solid floors (m^2/head) based on production data (Hardy and Meadowcroft, 1986).

Liveweight (kg)	Bedded area* (m²) (excluding troughs)	Loafing/feeding area (m²) (excluding troughs)	Total area* (m²)
200	2.0	1.0	3.0
300	2.4	1.0	3.4
400	2.6	1.2	3.8
500	3.0	1.2	4.2
600	3.4	1.2	4.6

*For fully bedded yards the total area should be used.

The surface of 4.6 m^2 for 600 kg cattle is very similar to that observed by Sundrum and Rubelowski (2000) in a survey of German fattening units.

Swedish legislation requires a minimum surface of 4.5m^2 for head of cattle weighing in excess of 400kg in loose deep litter housing (Jordbruksinformation 2 – 1998).

4.1.4. Litter loose house with sloped floor

This housing system (Figure 4) is based on a slope in the floor of 8 to 10% (Compere and Tillié, 1981; Zeeb, 1986). A small amount of straw (1 to 2 kg/animal/day) is distributed daily on the high side of the floor, next to the trough. The animals gradually thread the straw and manure downwards along the slope. The manure has to be removed daily at the lowest point.

Figure 4. Sloped floor house. (Hardy and Meadowcroft, 1986)
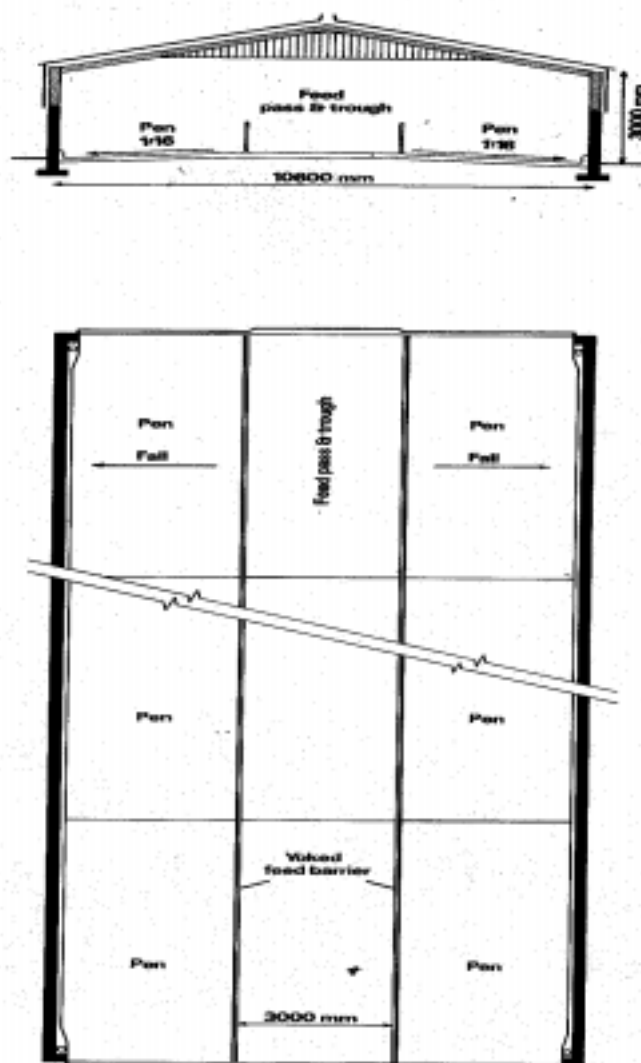
4.1.5. Cubicle house

The cubicle house provides the animal with an individual cubicle in which to lie and the cubicle division may be timber or tubular steel (Figure 5). The size of cubicle will depend on the size of animal which is being fattened. Kollar et al. (1979) suggested the following 1.60m x 0.75m for animal up to 300 kg, 1.75m x 0.85m for animals 300 to 400 kg, 1.90 x 0.95 for animals 400 to 500 kg, 2.00m x 1.05m for animals 500 to 600 kg and 2.3m x 1.2m for adult animals. Kavenagh and Dodd (1976) suggested the following 1.5m x 0.78m for 200 kg animals, 1.82m x 0.91m for 350 kg animals and 1.98m x 1.06m for 510 kg animals (Figure 5). Kavenagh and Dodd (1976) recommended a kerb height of 230 to 250 mm above the passage floor and a passage width of 2.5 to 3m. They also suggested that the cubicle bed could consist of 50 mm of straw, sawdust, sand or 150 mm of compact sub soil base. Kavenagh and Dodd (1976) stated that concrete or crushed limestone was not a suitable bedding material for cubicles. The cubicle house requires a collection and storage facility for the animal manure.
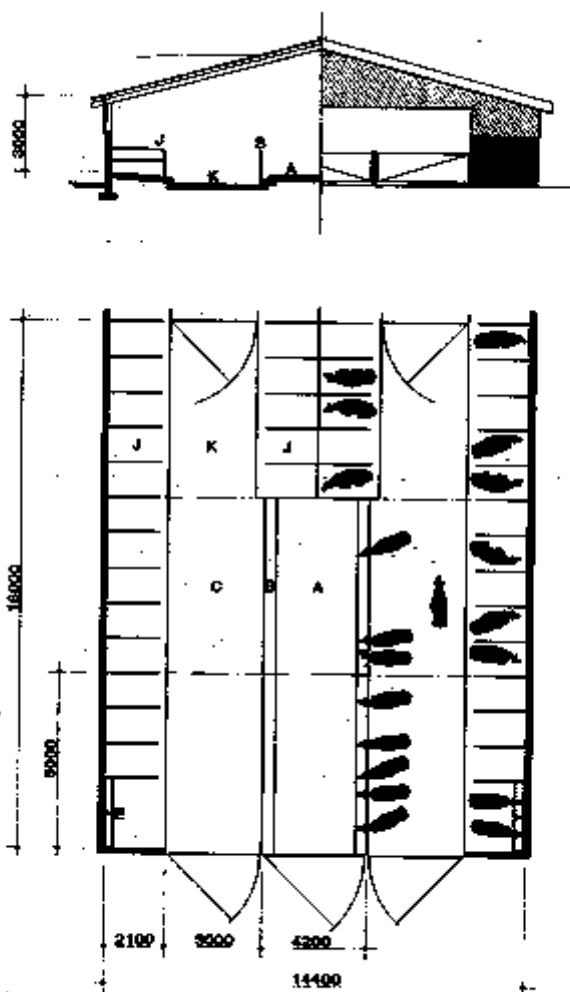
Figure 5. Cubicle house (MAFF, 1985)

Daelemans and Monton (1987) reported that the floor of cubicles contains a wooden or concrete beam with 4 cm wide slots through which urine can be drained when used by male

cattle. These authors also stated that the construction of cubicle is too expensive and they are therefore little used in practice.

4.1.6. Slatted Floor Housing for Fattening Cattle

The development of housing systems utilising liquid manure storage has been promoted in order to overcome the unavailability of straw in many areas (combined with its cost), the need to reduce labour requirements and the necessity to ensure that the manure is efficiently managed to avoid pollution risks. The majority of such systems use concrete slatted floors with the liquid manure or slurry falling through the floor perforations into a below ground concrete tank. The depth of the tank should provide adequate waste storage capacity for the housing period and is typically about 2.5 m. A central covered feeding passage is frequently used with confinement pens on either side. Silage can be fed either independently from concentrates or in combination. Large units often use tractor powered complete diet feeders for mixing and distributing feed along the feeding face. The area and configuration of the pens is designed to ensure adequate access to feed for animals and is typically 0.3 m of feed face per adult animal for silage only or where complete diets are fed or 0.6 m where concentrates are fed separately.
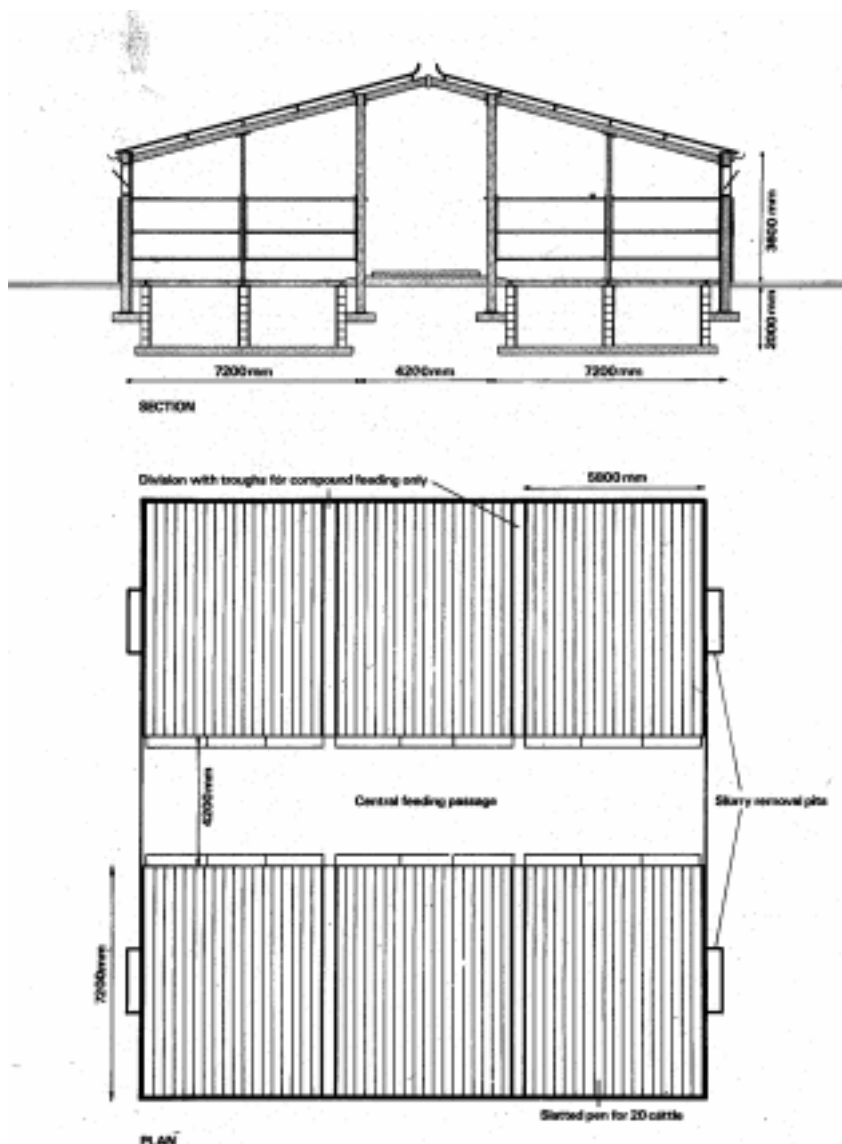
Figure 6. slatted floor house. (Hardy and Meadowcroft, 1986)

The superstructure is typically constructed from steel stanchions, steel trusses and timber purlins. Portal frame configurations are also used. Roof sheeting and cladding are in galvanised steel or fibre sheeting (Figure 6).

Ventilation openings are provided at the sides of the building and at the apex. The size of the openings is dictated by the exposure of the site. More recently spaced roof sheeting has been successfully used in some countries and it has the advantage in that it provides a more uniform removal of stale air from over the animals throughout the buildings.

The system has many practical advantages including low operational costs due to reduced labour and no requirement for bedding material. However, there is a relatively high capital cost associated with such structures and this had led to variations in the design being evolved in some countries (Lenihan pers. comm.). These include a) houses with partially slatted floors, b) houses with "sloped floors" and c) houses with slats over shallow tanks (about 0.9 m) from which the slurry flows by gravity to an adjacent storage facility.

The format of the partially slatted floor house is self–explanatory whereby only some of the occupied area is slatted. This may typically be the feeding area with the remainder of the shed being bedded (see previous section).

In the case of the sloped floor house the floors are predominantly solid concrete slabs laid to slope towards narrow channels covered with slats for slurry collection (Figure 7). Mechanical scrapers or flushing systems have been used to transfer the slurry out of these narrow channels to storage tanks. The configuration of the floor layout is such as to facilitate the movement of slurry towards the collecting channels. A possible problem with such facilities is that the animals tend to be very dirty at the end of the housing season.

The design of houses incorporating fully slatted floors with shallow tanks may be appropriate where ground conditions do not allow the easy construction of deep tanks (e.g. rock, high water table etc.). Slurry flows by gravity from the channels under the slats to an adjacent storage facility which is often an above ground concrete or steel tank.

In many instances, these designs have been incorporated when modifications are being made within existing structures causing practical difficulties for constructing deep storage tanks underneath the total animal accommodation area, as it is usual for the conventional slatted house.

Modification to slat surfaces, e.g. fitting "soft" or rubberised materials to provide more comfort, particularly for younger animals, is a development which has taken place in some countries.

Again, there is considerable variation in the recommended space allocation per animal. Daelemans and Manton (1987) suggested that area allocation should be 0.75 m^2 per 100 kg liveweight. This value is considerably in excess of the values suggested by Hardy and Meadowcroft (1986) and by Capdeville and Tillié (1995). Based on production data, recommendations have been published for the minimum space allowance for beef cattle of various sizes in slatted floored pens (Dodd, 1985, Table 10). Minimum recommended slat width is 125 mm and maximum gap width between the slats 40 mm.
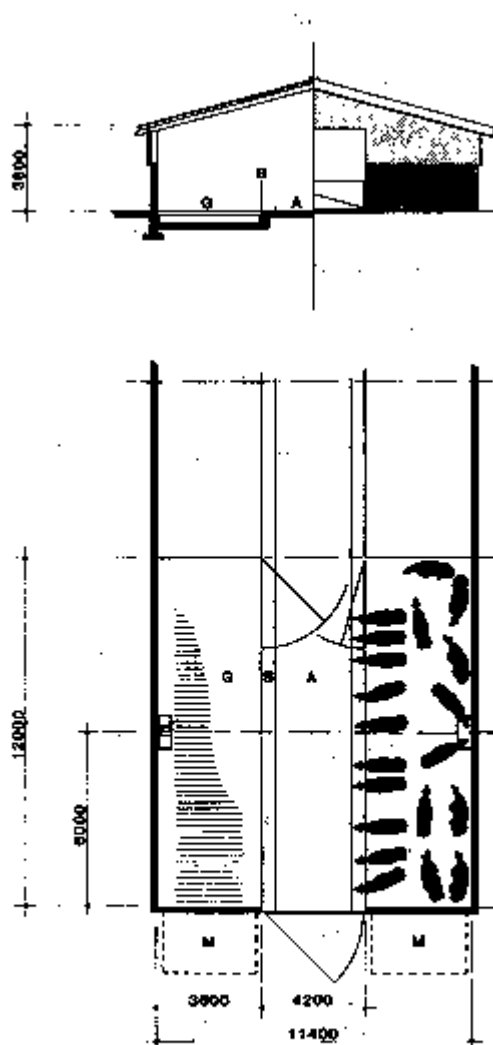
Figure 7. Slatted floor house with shallow tank (MAFF, 1985)

40

Table 10. Recommended minimum space allowance per animal (m^2) excluding troughs on fully slatted floors.

Liveweight (kg)	Hardy and Meadowcroft (1986)	Dodd (1985)	ADAS
200	1.1		1.1
300	1.5	1.4	1.5
400	1.8		1.8
500	2.1	2.0	2.1
600	2.3	2.2	

Sundrum and Rubelowski (2000) reported a mean area allowance of 2.4 m^2 per animal for fattening cattle in a German survey. Swedish legislation (Jordbruhsinformation 2 – 1998) requires a minimum space allowance of 2.3 m^2 in loose slatted floor housing for cattle weighing more than 400 kg.

4.1.7. Synthesis

The housing systems used for cattle fattening in the EU vary a lot between countries of EU. Table 11 gives general estimates of their importance

Table 11. Relative importance of housing types used for fattening cattle in some Member States.

	House type				
	Slatted floor	Deep litter	Litter and concrete or slatted floor	Tie stall	Other
Belgium		********			
Finland	****	*	***	*	*
France		****	***	**	*
Germany	*******	*	**		
Ireland	*********		*		
Spain	*********		*		
Sweden	****	**	***		
United Kingdom	*	******	***	*	

The period of time spent in indoor accommodation is influenced by the beef fattening system and by the category of animal (breed and sex). Table 12 summarises the time spent indoors for the main fattening systems. Some animals are kept outdoors all year.

Table 12: Time spent indoors by animals from different cattle fattening systems (starting with 6 month old dairy calf or post weaning for the suckler calves).

Animal Type	Age when slaughtered (months)	Time spent indoors (months)	
		Period 1	Period 2
dairy	12	9*	-
dairy	16	13*	-
suckler	12	4	-
suckler	14	6	-
suckler	16	8	-
heifer	20	5	-
steer	24	5	5
steer	30	5	5

*starting at 3 months

4.2. Feeding frontage

The frontage allowance will depend on the weight of animal and type of diet. There appears to be general agreement among different authors as to the trough space allowance for loose housed fattening cattle (Table 13).

Table 13. Feeding trough space allowances for loose housed fattening cattle (m/animal) recommended by different authors

Animal weight (kg)	Trough space (m)	Reference
< 400 > 400	0.50 0.60	Jordbruksinformation 2 – 1998
130 – 250 250 – 350 >350	0.3 – 0.45 0.45 – 0.55 0.55 – 0.70	Hardy and Meadowcroft, 1986
500	0.60	Kavenagh and Dodd, 1976

The design of the feeding place is also important as it can have an influence on the feeding time per animal and on the social competition (Tillié et al., 1996). Common designs of feed barrier are presented in Figure 8 (Hardy and Meadowcroft, 1986)
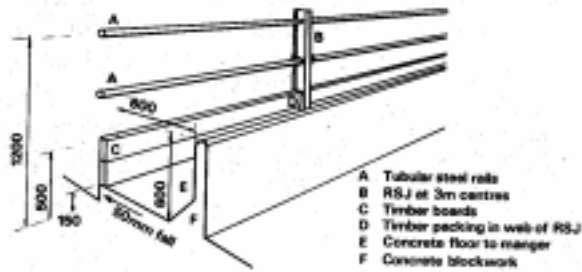
FIG 3.7 : RAIL BARRIER & COMPLETE DIET BUNKER
Source: A.D.A.S. booklet 2612

A Tubular steel rails
B RSJ at 3m centres
C Timber boards
D Timber packing in web of RSJ
E Concrete floor to manger
F Concrete blockwork
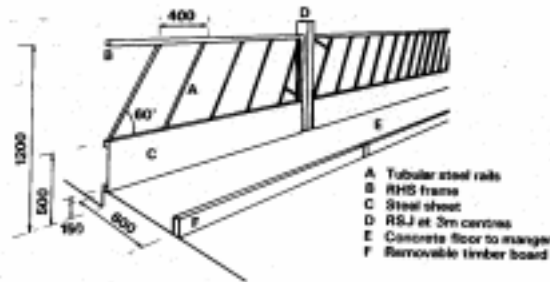
FIG 3.8 : DIAGONAL RAIL BARRIER USED AS AN ACCESS GATE
Source: A.D.A.S. booklet 2612

A Tubular steel rails
B RHS frame
C Steel sheet
D RSJ at 3m centres
E Concrete floor to manger
F Removable timber board

A Shaped timber boards
B Timber boards
C Carriage bolts
D RSJ at 3m centres
E Concrete floor to manger
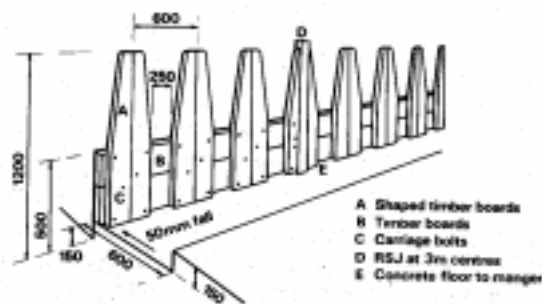
Figure 8. Feed Barrier designs (Hardy and Meadowcroft, 1986)

4.3. Handling Facilities For Fattening Cattle

It is essential to provide adequate on-farm facilities for handling fattening cattle for veterinary investigation, routine examination, treatment, weighing or loading for transport. The handling facility should be friendly to both the animal and the operator. In many areas the scarcity of farm labour means that the handling facility is designed for operation with minimal labour. Handling facilities should be provided either alongside or at the end of the building (MAFF, 1985). Some of the MAFF (1985) recommendations include:

- The layout will depend on the site, e.g. existing gates, roads, access, building layout, and to a certain extent the preferences of the producer.

- A typical layout showing essential elements and space allowances is illustrated in Figure 9.

- A ramp for loading cattle onto transport should be provided in the layout. The maximum slope should be 17% and maximum height for vehicle tailboard 600 mm.

- Provide cover to the cattle weigh/crush with good daylight plus artificial light, a power point and provision for hosing down.

- Handle cattle in groups up to a maximum of 20 in number.

- Long narrow pens (ratio of 2:1, length:breadth) allow better control of cattle.

- Fences and gates should be 1500-1600 mm high, with no protrusions or sharp edges.

- Hardwood, treated softwood and galvanised tubular steel are suitable materials for construction.

- Provide 100 mm thick concrete paving throughout the handling area.

Ease of movement of animals is an important consideration in any cattle handling facility. Grandin (1997) suggests that if animals refuse to move through an alley, chute or race, there may be a very simple solution. Grandin (2001) lists common factors that can cause animals to resist moving through a handling facility and prevent

Figure 9. Layout of cattle handling facility (Hardy and Meadowcroft, 1985)

a properly designed facility from working efficiently. These include strange noises, reflections, objects, draughts, changes in flooring and dark areas.

In Europe handling pens and races tend to have rectangular pens and straight races construction of wood or tubular stall (Hardy and Meadowcroft, 1986). A straight race is shown in Figure 10.

Figure 10. A crush for handling cattle (courtesy www.cashels.net)

The recommended specification for width of working chute in beef cattle handling facilities (Government of Saskatchewan, 2001) are 450 mm for cattle under 270 kg, 550 mm for cattle in the range 270 to 540 kg and 700 mm for cattle over 540 kg liveweight. The above publication recommended a minimum length of 7.2 m. It stated that herd health care is virtually impossible without a headgate and/or squeeze for restraining cattle. There are many headgates on the market and each of the four basic types (Table 14) are specially suited for certain handling procedures.

Table 14. Types of manually operated headgates

	Recommended for	Not recommended for	Warnings
Self Catcher	Hornless cattle, gentle cattle, one-man artificial insemination (A. I.)	Excitable cattle, big feedlots, horned cattle, groups of mixed-size cattle (because the gate has to be readjusted to catch animals of different sizes).	Excitable cattle, big feedlots, horned cattle, groups of mixed-size cattle (because the gate has to be re-adjusted to catch animals of different sizes).
Scissors Stanchion	General purpose, big feedlots, excitable cattle, minimum maintenance. Adjustable for cattle of mixed sizes.	Very large bulls because they may have trouble exiting due to the narrow space between the two bottom pivots.	Be careful not to catch the animal's legs or knees between the two halves of the gate or the animal may be injured.
Positive Control	Dehorning, excitable cattle, big feedlots. Requires less strength to operate than stanchion gates; good head control.	Vet clinics where the animal is held in the headgate for a prolonged time. AI and pregnancy testing are the primary uses of this headgate.	More likely to choke than a self-catcher, scissor, or full-opening stanchion.
Full-opening Stanchion	General purpose, vet clinics, mixed cattle sizes (because the gate seldom needs adjustment). Large bulls can exit easily	Big excitable cattle, big feedlots (because many full-opening stanchion headgates are not sturdy enough to withstand constant heavy usage).	Mechanism requires careful maintenance to prevent jamming. An excited animal may trip over the lower gate track.

Excessive squeeze pressure in a hydraulic chute can cause suffocation. A hydraulic chute is safe if the pressure relief valve is set correctly. Cattle can also be injured when a fast-moving animal is stopped suddenly by clamping the headgate around its neck. A skilful operator can control the squeeze to slow the animal down before it reaches the headgate.

In the US and Canada the general recommendations (Grandin, 2000) for shutes (races) are as follows;

- Solid sides which prevent the cattle from seeing outside the fence should be installed on the shutter (races) and the crowd pen which leads up to the single file shute. Solid sides

prevent cattle from seeing activity outside the fence. Cattle tend to be calmer in a shute with solid sides.

- A curved shute works better than a straight shute because it is thought that cattle think they are going back to where they came from. Cattle move more easily through the curved race system because they cannot see people and other distractions ahead.

However, open sided chutes have handling advantages making it easier to access the animals for examination or treatment, especially where the animals are relatively used to human contact. Such designs are more common in Europe, probably because the animals are generally less wild than in North America.

4.4 Conclusions

1. There are a number of housing type options for fattening cattle including loose housing and tie up stalls. It appears that the vast majority of housed fattening cattle are accommodated in loose houses with slatted floors.
2. Regulations on organic farming set a minimum indoor space requirement of 5m² for animals weighing over 350 kg, with a minimum of 1m² per 100 kg for animals over 500 kg
3. The appropriate size of tie- stalls and cubicles is dependent on the size of animal.
4. The surface recommended for littered loose houses or partially loose house is around 6 m² for 600 kg bulls and slightly lower for littered house with concreted feeding stand (6 to 4.5m²).
5. Various studies have produced recommendations for slatted floor space allowance e.g. 2.2 to 2.5m^2/animal for cattle in the 550 to 650 kg liveweight range. These studies have been largely based on production considerations.
6. Feeding trough space allowances for loose housed fattening cattle are in the range of 0.6 to 0.7 m per animal.
7. Several types of handling equipment are in use depending partly on the type of animals for which they are used. The type of handling facility will depend on the size of the fattening unit and the tameness of the animals.

5. BEHAVIOUR OF CATTLE

5.1. Environmental perception

5.1.1. Vision

Vision is well developed in cattle (Blaschke et al., 1984). Cattle have both cone and rod receptors and can perceive colours (Soffié et al., 1980, Gilbert and Arave, 1986), especially at low wavelengths (red, orange, yellow). However, they may have some difficulty in distinguishing between blue, grey and green (Riol et al., 1989).

Like many other prey species, cattle have their eyes positioned on the side of the head. This results in a restricted amount of binocular vision but at the same time allows a good field of vision of about 330º (Phillips, 1993).

Light is important for cattle. They will work for a light reward (Baldwin and Start, 1981) and the light:dark ratio may affect behaviour, including aggression and locomotion. In calves, Weiguo and Phillips (1991) found that a high light:dark ratio reduced aggression in adverse environments, probably because more unexpected, hostile encounters take place in the dark than in daylight hours.

Research on the effects of day length on growth of beef cattle has given contradictory results. Some authors have found increased growth rates with longer periods of light (Peters et al., 1980; Mossberg and Jönsson, 1986) while others found no effect (Roche and Boland, 1980; Phillips et al., 1997). The variation of the effects of supplementary light on cattle growth rates could be due to the fact that the composition of the growth is often affected. Some researchers have found that supplementary light can reduce body fatness in steers (Phillips et al., 1997) as well as in post-puberal heifers (Petitclerc et al., 1984; Zinn et al., 1984). The balance between protein and fat accretion and the nutrient supply may explain why some cattle have been observed to grow faster with supplementary light in winter and some not, as pointed out by Phillips and colleagues (1997). Studies on the effect of photoperiod on cattle behaviour are also inconclusive. Nicks et al. (1988) and Dechamps et al. (1989) found no effect of supplementary light on the time spent lying by the bulls. Phillips et al. (1997) observed that an increase of the day length significantly increased the time heifers spent lying down, but found no effect in steers.

5.1.2. Hearing

Hearing in cattle has been less studied than vision. Nevertheless, it plays an important role in inter- and intra-species communication. Cattle can hear sounds of much higher frequencies than humans and they are especially sensitive to high-frequency sounds (Heffner and Heffner, 1983; Kilgour and Dalton, 1984; Grandin, 1996; Smith, 1998). Waynert et al., (1999) found that sounds made by people while handling cattle had a greater effect on heart rate and reactivity than equipment sounds such as gates banging. Pajor et al. (1999) reported that shouting at cows was very aversive. High-pitched, intermittent sounds had a greater effect on beef cattle as observed by Lanier et al. (2000).

The suddenness, novelty and unexpected nature of sounds elicit the fear response. In fact noise, such as the sound of a truck horn, was shown to increase the heart rate of free-ranging cattle (Arave et al., 1991), while cattle habituated to the sounds and sights of cars and trucks will graze along highways (Grandin, 1997). Lanier et al. (2000) found that habituation to noises did occur over 5-day trials, but these authors pointed out that it may not occur with infrequent handling as it is typical under normal management procedures. They suggested that reducing noise (shouting or metal clanging) during handling should help to reduce the level of fear experienced by beef cattle.

In a harmonious group of cattle the animals are usually silent. Most of the vocalisations in cattle are related to frustration and distress or extreme pain (animals seeking other animals, anticipations of positive events as milking and food or reactions to painful events). Cattle vocalisations have been described according to syllables, amplitude, pitch, tonality, length and "meaning" (Phillips, 1993). Sonographic analyses of calls from Chillingham bulls have shown that they emit calls and lows, and occasionally rutting grunt sounds (Hall et al., 1988). It is suggested that its ontogeny involves practice and competition with peers in juvenile bulls (Hall et al., 1988). Kiley-Worthington (1982) distinguished 4-5 different types of calls in cattle, but different situations elicited the same calls, and thus no specific meaning could be attributed to them.

5.1.3. Olfaction

Olfactory signals are extremely important in cattle, especially in intra-species communication. Cattle have a well-developed olfactory sensitivity and are able to detect much smaller differences in odour concentration than humans (Bell and Sly, 1983). Unlike humans, cattle have two different sites of odour detection: the nose and the vomeronasal organ (Phillips,

1993). They use flehmen to enhance odour detection in this latter organ, and this can be observed already at an early age (Albright and Arave, 1997). Olfaction is involved in social recognition and cattle can be trained to discriminate between specific individuals (Baldwin, 1977). It is one of the most important senses used by the dam to discriminate between her calf and other calves. Olfaction is also used to communicate their psychological state. Boissy and Le Neindre (1990) have shown that heifers learn a task slower in the presence of stressed animals. Their latency to approach a bucket is higher if it is sprayed with urine from stressed conspecifics than if it is urine from not stressed ones (Boissy et al., 1998).

5.1.4. Pain perception and tactile senses

Neural mechanisms of pain perception seem to be similar in cattle and humans (Iggo, 1985). However response to pain can vary between species as it has been shaped by natural selection (Livingstone, 1986). Although signals of pain may be less conspicuous in cattle and other prey species than in carnivores or primates, this could be due to the former species having evolved a tendency to "hide" pain from predators. Therefore that low response should not be taken as evidence of a lower sensitivity to pain stimuli. However, cattle vocalise more when subjected to painful procedures as branding (Schwartzkopf-Genswein et al., 1998). Tactile perception has not been investigated although it is important in all the relationships with conspecifics, offspring, sexual partners and humans. For example, allogrooming is a main social activity in cattle, and may lead to reduced heart rate (Sato and Kurado, 1993).

5.2. Learning

Learning abilities are well developed in cattle. They perform as well as other domestic mammals in learning tests and better that others such as rodents, cats and horses (Kilgour, 1981). Cattle can learn through stimulus discrimination, generalisation and association (Albright and Arave, 1997). Stewart et al. (1992) found that cattle are able to learn by observation although Veissier et al. (1993) found that observation modified the attention of the animals towards the stimulus but did not improve performance. In addition, cattle will readily explore new areas and this may facilitate some forms of learning (Albright and Arave, 1997). Age seems to have an effect on learning abilities, younger animals being faster -at least in some instances- than older animals, specially in adapting to new housing systems (Albright and Arave, 1997). Cattle learn quickly, and for example, one contact with an electric fence will be remembered for a long time.

5.3. Social behaviour

Cattle are highly social animals. They tend to live in groups interacting agonistically (aggressive acts and response to aggression) and non agonistically (mainly allogrooming and sexual behaviour). Several types of threats can be described depending of the level of ritualisation. Allogrooming between adults mainly consist of licking of the head, neck and shoulder (review by Bouissou et al., 2001).

The social behaviour of cattle living in semi-wild conditions has been studied in several locations (review by Bouissou et al., 2001). On Amsterdam Island, located southwest of Madagascar, a large population running free for a long time has been observed. In that location the basic social structure is a cow associated with one recently born calf and sometime the yearling from the previous year. Three different types of groups are observed: females with some sub-adult males; adults and sub-adult males with a lot of solitary adult males; and mixed groups of males and adult males, mainly seen during the mating season (Daycard, 1990). Males and females occupy different home ranges and the composition of the groups are not constant (Lésel, 1990). In the Camargue, cattle group in polygamous herds without a fixed territory with several adult males in each group (Schloeth, 1961). In England, the Chillingham cattle have a slightly different social structure, with females and young roaming as a group over the entire area available to the animals and bulls living in groups of 2-3 or solitary, each with its own home range (Hall, 1986 and 1989).

Aggression tends to be low between acquainted animals, particularly if they have been long together (Sambraus and Osterkorn, 1974; Bouissou and Hövels, 1976a, b; Reinhardt et al., 1986). Animals within the herd can develop strong bonds, which are usually maintained by allogrooming, i.e. grooming others (Sato, 1984), and grazing in close proximity (Reinhardt and Reinhardt, 1981). It has been suggested that allogrooming may induce 'self-narcotisation' and the fact that it increases in intensive environments gives some support to this idea (Fraser and Broom, 1990). The hormone oxytocin can be released by repeated touch from another animal and could play a role in what appears to be 'self-narcotisation' (Uvnäs-Moberg et al., 2000).

5.3.1. Hierarchy

Groups of cattle have a social hierarchy that determines priority of access to resources. Hierarchies may not be the same for all resources and separate hierarchies may exist for access to feed, space, sexual partners, etc (Phillips, 1993). Access to space is very important in

intensive systems as there is little opportunity for escape for low-ranking animals, and this may cause stress (Arave et al., 1974). In general, aggressive behaviour decreases with increased space allowance (Phillips, 1993; Kondo et al., 1989). Nevertheless, the effect of space allowance on aggression is largely dependent on management factors such as feed supply and location of food and water (Wierenga, 1992).

Once established, a hierarchy tends to be stable and is maintained by threats and avoidance rather than by overt fighting (Kondo and Hurnick, 1987). The rank of an animal seems to be affected by its age, breed, seniority in the group, body weight and horns (Broom and Leaver, 1978; Sambraus and Osterkorn, 1974; Oberostler et al., 1982). Rearing conditions may also be important (Le Neindre and Sourd, 1984). Warnick et al., (1977) and Broom and Leaver (1978) observed that Friesian calves reared in isolation were dominated by others reared in groups. Le Neindre (1989) reached the same conclusions when observing Salers calves. However that effect has not been observed in Friesian calves by Bouissou (1985) and Le Neindre (1989). The discrepancy could be due to the management of the animals when they were grouped (Veissier, 1994). Finally, rank is affected by temperament and this may have an important genetic basis (Purcell and Arave, 1991).

5.3.2.   Group size

Cattle usually retain cohesiveness and although there are situations in which cattle seek isolation, isolation in general is not a natural state for herd animals such as cattle (Phillips, 1993). Small group size contributes to social stability (Albright, 1991) and smaller groups have, in the long term, fewer aggressions than larger groups and the aggressions increased linearly as the group size increased (Kondo et al., 1989). This may be caused by the animals having greater difficulty for individual recognition, as group size increases. Beef cattle herds on rangeland typically break up into groups of 10-12 animals (Phillips, 1993). Fraser and Broom (1990) suggest that the ability of cattle to recognise other individuals may be limited to 50-70 animals.

If space is available, the problem of aggression in larger groups can be overcome by the formation of smaller subgroups (Phillips, 1993). Maximum group size is probably dependent on affiliative relationships between group members. Such relationships are more developed between animals living together from an early age (Bouissou and Hövels, 1976a, b, Bouissou and Andrieu, 1978).

5.3.3. Mother young relationships and weaning of the calves

Mother-young behaviour has been dealt with in a previous report (Report on the Welfare of Calves VI/BII.2, 1995), and therefore only the behaviour of suckled calves weaned from their mother will be briefly described here.

The close relationship between cow and calf can be maintained for more than 14 months if the cow does not calve in that time (Le Neindre, 1989a). Normal weaning age in free-ranging zebu cattle occur between 8 (female calves) and 11 (bull calves) months (Reinhardt and Reinhardt, 1981). However, Lidfors et al. (pers. com.) found that free-ranging dairy cows weaned their calves naturally at least 3 weeks before the birth of the next calf. Natural weaning is usually gradual, where the mother makes it more difficult for the calf to get access to the milk, and the calf gradually change from milk to a grass diet (Lidfors et al., 1994). Reinhardt et al. (1977) reported that the zebu cow may kick, butt and threaten her calf whenever it attempts to reach her teats during natural weaning. Cows suffering from dysfunction of the ovaries continue suckling for more than another 9 months, and it is then the calf who voluntarily stops suckling (Reinhardt et al., 1977). The bond between cow and calf may exist at least until the calf has reached five years of age, and irrespective of the presence of new calves by the mothers side (Reinhardt and Reinhardt, 1980). Cows may even allow a yearling calf to suckle, although they are more aggressive toward the yearling than they were before the birth of the younger calf (Veissier et al., 1990).

After around 10 months of age, the male calves interact more than the females with the other members of the herd while the females interact more with their mothers (Le Neindre, 1984, Kimura and Ihobe, 1985). Young males progressively form bachelor groups (Schloeth, 1956) and females remain with their mothers which is the first step to the matriarchal structure observed in cattle (Review by Bouissou et al., 2001).

5.4. Puberty and reproduction

The area about puberty and reproduction is important because fattening cattle go through this period during their growth, and there might be several problems related to the changes in behaviour caused by sexual maturation. Therefore it is important to have knowledge about the normal behavioural changes during puberty and reproduction.

In bull and female calves mounting occur as a play behaviour already at 1-2 weeks of age, well before sexual maturity (Kiley-Worthington and de la Plain, 1983; Le Neindre, 1984). Mounting activity is high already during the second month of life (Reinhardt, 1983). Free-ranging cross-

bred beef cattle showed no mounting at 1-2 months of age, but from 3-6 months the frequency of mountings and sniffing unfamiliar cows increased (Lidfors and Jensen, 1988). At 5-6 months of age the bull calves were courting and mounting cows in heat (Lidfors, 1987; Lidfors and Jensen, 1988). In early maturing animals there is a risk of having heifer calves being mated by the bull calves. Therefore the latter are either weaned from their dams at about 6 months of age, or else cows with heifer calves are kept in separate groups from cows with bull calves.

In free-ranging conditions young bulls leave the dam's herd from about 1.5 years (Schloeth, 1961) up to 4 years of age (Hall, 1986). As older bulls have the main access to mating with cows, young bulls tend to roam around in bachelor groups (Schloeth, 1961). By 2.5 years of age most bulls are dominant over cows; before that age a dominant cow may prevent a young bull from mounting (Houpt, 1998). A bull's sexual performance is not improved by raising them with females or exposing them to females at the time of puberty (Price and Wallache, 1990; Borg et al., 1993). However, rearing bulls in individual pens compared to group pens does suppress sexual performance (Price et al., 1990). A high frequency of mountings has been observed also in fattening cattle housed in slatted floor pens or deep litter pens (Lidfors, 1992). In large feedlot systems in the USA there are sometimes problems with the "buller steer" syndrome, i.e. specific steers, "buller steers", are repeatedly mounted by other steers in the group (see chapter 7.5.3 for more information).

In heifers, puberty is defined as the time of the first oestrus accompanied by ovulation, and it occurs as a result of endocrine activity (Thomas, 1986). Puberty occurs anywhere from 4 to 24 months of age, usually at 6 to 18 months (Houpt, 1998). The oestrous cycle is 18-24 days long (mean 21 days), but somewhat shorter in heifers (Houpt, 1998). According to Thomas (1986) the following factors influence age and weight at puberty.

– Genetics – larger breeds of cattle are usually older and heavier at puberty than smaller breeds. However, large differences in oestrous age have been observed between heifers from different breeds even if they have the same adult weight. For example Le Neindre (1984) observed that about 50% of the Friesian heifers were in oestrus before 9 months of age when none of the Salers were observed in oestrus at the same age.

– Nutrition – Inadequate nutrition reduces growth rate and therefore delays the onset of puberty.

– Environmental effects – high environmental temperatures delay puberty and produce poor health and sanitation.

5.5. Foraging behaviour

5.5.1. Grazing

Cattle are ruminant herbivores. Although they can browse, cattle are mainly grazers. Normal grazing time is about 8 to 9 hours a day with maximum recorded times of 10-12 hours a day (Phillips and Leaver, 1985). However, on very poor pastures, grazing times of up to 13 hours a day are possible (Smith, 1955). Cattle may be reluctant to increase grazing time at the expense of lying and ruminating (Metz, 1984). It is likely that learning plays a role in shaping grazing behaviour.

Cattle are diurnal feeders and show a distinct grazing pattern with maximum grazing activity around sunrise and sunset (Hafez and Bouissou, 1975). Night feeding also occurs, particularly in hot humid conditions or when days are short (Coulan, 1984).

Cattle can consume coarse grasses that need a large amount of chewing and mastication, as well as rumination. In general, cattle are less selective than other domestic ruminants such as sheep or goats; nevertheless, cattle will still show some degree of selection and will take a greater proportion of leaf material, i.e. the higher parts on grass. In addition, cattle will avoid grazing around faecal deposits (Phillips, 1993).

An important concern for cattle is to stay close together while grazing; maximum inter-animal distances when space is not limited are about 10-12 m (Kondo et al., 1989). That figure is likely to be affected by breed and other factors. Cattle show social facilitation in their feeding behaviour and when an animal eats, another might be stimulated to do so (Curtis and Houpt, 1983). This may result in cattle eating more while in group than when alone (Metz, 1974).

5.5.2. Rumination

Rumination may account for a substantial part of cattle activity (6 to 9 hours) with the most intense period during the night (Phillips, 1993). Rumination is under voluntary control and when the animals are disturbed they cease rumination. Only healthy and unstressed cattle ruminate and thus rumination can be taken as a sign of 'contentment' (Phillips, 1993).

Time spent ruminating depends on the diet, particularly of its fibre content. At pasture cattle ruminate longer compared to eating time when fibre content increases in the vegetation (Hughes and Reid, 1951). Cattle can ruminate either standing or lying, but more often do so while lying down (Phillips, 1993).

5.5.3. Drinking

Cattle originated from humid climates and their water requirements are higher than those of other domestic ruminants such as sheep or goats (Mount, 1979). Although in some rangeland situations cattle may drink only once every 2-4 days, in most systems, they drink several times a day (Phillips, 1993). Water requirements depend on diet, temperature and physiological state. Diets rich in sodium or protein result in higher water intakes (Chiy and Phillips, 1992). When very wet diets are provided, cattle may not drink at all (Phillips, 1993).

5.5.4. Eliminative behaviour

Cattle appear to exercise little control over elimination, which tends to occur randomly throughout their living environment (Albright and Arave, 1997). They usually defecate and urinate when they stand, after recumbency, and rarely while lying (Albright and Arave, 1997). During defecation cows and heifers slightly arch the back, spread the rear legs somewhat and raise the tail. During urination a more extreme arching of the back is seen and the urine is expelled with some force. Bulls assume a normal standing or may walk during urination, and little visible force is exerted during urine expulsion or defecation (Albright and Arave, 1997).

5.6. Locomotion and resting

5.6.1. Locomotion

In wild and semi-wild conditions cattle roam over large areas. Cattle show a diurnal rhythm of locomotion, with greater activity during daylight hours, especially at sunrise and sunset if they have a grazing rhythm as described above (Phillips, 1993). Young animals are more active than adults, particularly when they engage in play activities.

Cattle use the tail to get rid of flies. When harassed by flies or other insects, cattle bunch together and this increases heat load (Wieman et al., 1992).

5.6.2. Lying and sleeping

Lying is important for cattle and they show a strong motivation to do so (Metz, 1985). Lying usually occurs in sternal recumbency although occasionally cattle can lie down in lateral recumbency. Prolonged lateral recumbency is prevented by the need to eructate gases from the rumen. There appears to be social facilitation to lie down (Coe et al., 1991).

Sleep has important functions in animals (Webb, 1979) and sleep deprivation causes severe welfare problems (see Ruckebush, 1974). In ruminating animals, brain activity is similar to that of non-ruminants while sleeping, and it has been suggested that rumination may provide the physiological effects of sleep (Albright and Arave, 1997).

5.6.3. Getting up and lying down

Cattle have an innate movement pattern when lying down and getting up. It has been described in detail by Schnitzer (1971), and a literature review on the subject is available (Lidfors, 1989). When lying down cattle make perpendicular movements with the head over the surface, searching for a suitable place to lie down on. They then bend one fore leg and place the knee on the surface, at the same time as they bend the other leg and place that knee close to the first one. They may stop shortly before descending the hind part of the body slowly downwards, and lastly the front legs are moved forward a bit so that the animal is lying in a comfortable position.

When getting up cattle move to an upright lying position, and place the front legs under the breast region. Then they make a swinging movement forward which helps in raising the hind part of the body. From the kneeling position, cattle first stretch one front leg and then the other. When standing up they often stretch the body, defecate and yawn.

On pasture it is sometimes observed that pregnant cows and heavy bulls have problems to stand up, and they may then perform the swinging movement several times before reaching the kneeling position. They may also get up through a sitting position like a horse or dog (Ref.). This is however quite unlikely to occur in younger fattening cattle if they are healthy.

5.7. Reaction to climatic conditions

Adult cattle seem to be very tolerant to cold but may easily suffer from heat stress. Therefore, in cold climates cattle will need protection at least from wind and rain, whereas in hot conditions methods to alleviate heat load are important and the provision of shade seems to be particularly useful (Silanikove and Gutmen, 1996).

As temperature rises, respiration rate and water intake increase, and at the same time cattle seek shade and reduce food intake. Under hot conditions cattle may prefer to stand rather than to lie and ruminate (Albright and Arave, 1997), however some studies have shown a different response, with animals showing restless behaviour and lying down for long periods of time while stretching out (Lewis and Wenioger, 1976).

5.8. Conclusions

1. Cattle have well developed senses and learning abilities. Although signs of pain may be less obvious in cattle than in other species, cattle have the ability to feel pain and neural mechanisms of pain perception seem to be similar in cattle and other animals, and humans.

2. Cattle are highly social animals. Groups of cattle have a social hierarchy that determines priority of access to resources. Once established, the hierarchy tends to be stable and reduces fighting. Mixing of animals and housing animals in very large groups may disrupt the hierarchy and increase aggression.

3. Cows form long-lasting bonds with their calves when allowed to do so. During natural conditions, weaning is a very slow and gradual process stretching over several months.

4. Age at puberty depends on several factors, breed being important. Mounting may occur as a play behaviour well before puberty.

5. Cattle are ruminant herbivores and although they can browse, cattle are mainly grazers. Cattle usually spend a long time grazing every day and show a distinct grazing pattern with maximum grazing activity around sunrise and sunset.

6. Rumination may account for a substantial part of cattle activity. Rumination is under voluntary control and when animals are disturbed they cease to ruminate.

7. In most situations cattle drink several times a day, more in hot conditions.

8. Cattle roam over extensive areas, and show a strong motivation to move. They also lie down for long periods.

6. EFFECT OF HOUSING ON THE WELFARE OF THE ANIMALS

In the European Community beef production is characterised by a wide range of production systems which were discussed in chapter 3. Regardless the fattening system adopted, some characteristics of the housing such as microclimate, close confinement, space allowance and type of floor seem to have a major impact on cattle welfare and will be discussed in detail. Other housing aspects such as the space allowance at the feeding trough will be considered briefly. In this review an attempt has been made to distinguish the effects of confinement, space availability, type of floor and bedding material on fattening animals. In many studies more than one of these factors vary which makes the analysis difficult.

6.1. Microclimate conditions

Several parameters have to be taken in account when considering the microclimate environment in particular temperature, humidity, air flow and the levels of different gases (SCAHAW, 1999). In that text it has been suggested that acceptable temperatures range from 0 to 30°C when the humidity is lower than 80% and 27°C when the humidity is higher than 80%. These ranges vary depending on breed, growth rate, feed allowance, physiological state and adaptation. Feed intake level, for example, will affect the heat production by the animals. Some acclimatisation process to environment out of those ranges has also been described. It seems that animals can adapt to low temperature but have more trouble to cope when it gets hot.

The efficacy of natural ventilation can be affected by the location of the houses in relation to local topographical features. The location of housing to increase the stack effect will increase the natural ventilation with consequent improvements in the microclimate (Bruce, 1978).

Welfare of the animals is impaired when the levels of some gases are high. For example animals seem to have problems to cope when carbon dioxide and ammonia levels respectively are higher than 0.5% (5000 ppm) and 20 ppm (SCAHAW, 1999). In the case of pigs a maximum level of 10 ppm has been recommended for housing (Scientific Veterinary Committee, 1997)

6.1.1. Housing Insulation

In northern European countries with cold climates, insulated buildings with slatted floor in the pens are a common type of building for fattening bulls. In this type of building the air volume per animal is often low and this fact, as well as the slatted floor, can influence animal health. There is little knowledge of the effect of insulation on production, health and behaviour of growing bulls. However according to current recommendations in Sweden, housed cattle in uninsulated buildings during the winter should be fed to meet a 5-15 % higher maintenance requirement than during warm season (Mossberg et al., 1992). Contradictory results concerning group-fed growing animals in insulated or uninsulated buildings are reported in the literature: Some researchers found a slightly better growth rate and sometimes a better feed conversion in insulated buildings (Harmsen and Smits.,1972; Harmsen and Smits, 1981) while other researchers found no significant difference in growth rate or in feed conversion between bulls and heifers kept on slatted floor buildings with an insulated or uninsulated roof (Hansen and Pedersen, 1980). As pointed out by Mossberg and colleagues (1992) when investigating the influence of environment, there is considerable confusion between different environmental traits and it is difficult to identify the factors causing the various effects. They found that animals kept in uninsulated buildings had a poorer feed conversion per unit of liveweight and they were leaner compared with animals in an insulated building. The former animals had higher energy requirements for maintenance and activity.

6.1.2. Effects of tethering

Several authors have compared animals, either tethered or in loose housing. Tethered animals have restricted movements and cannot walk or take exercise for long periods. It has been found that regular exercise increases muscle and bone growth in tethered growing animals (Melizi, 1985), improves semen quality (Tizol et al., 1987) and prevents limb disorders in bulls kept for semen production (Zaitser, 1985). Jury et al. (1998) have shown that tethered bulls had different patterns of muscle fibres to those housed in free stalls. In summary, exercise has an important influence on the overall physiology of the animals (see also section 6.3.2.).

Tethered bulls had more abnormal getting up movements than those kept in groups on slatted floors (De Vries et al., 1986). Tethering seemed to have a great effect on lying down and getting up movements (De Vries et al., 1986). Resting behaviour is also influenced by tethering. Muller et al., (1989) found that tethered heifers on concrete and partially slatted floors showed a significantly reduction in the number of periods of lying in comparison with

heifers kept free on deep straw. However tethered bulls on slatted floors which had lain down abnormally, lay for a longer period than those which had laid down normally (De Vries et al., 1986). Tethered animals also appear more reluctant to lie down. Ladewig and von Borrell (1988) recorded a time interval of 59 minutes between the first intention behaviour and actual lying in tethered beef bulls compared with only 9 seconds in tethered bulls on deep litter.

There are only few studies in which physiological measurements have been collected in connection with behavioural studies of getting up and lying down (Müller et al., 1989; Ladewig and Smidt, 1989). Müller et al. (1989) compared the heart rate of 18-months old heifers which were tethered for four months on partially slatted floors with heifers kept loose on deep litter. Heart rate increased independently of the floor surface when animals laid down, but in tethered heifers on partially slatted floors the increase in heart rate was higher and it took longer to come back to the starting levels. These animals also showed a great increase in heart rate at first intention to lie down, which occurred up to one hour before the heifers actually lay down whereas there was no change in heart rate in control animals on deep litter (Müller et al., 1989). This study indicated that lying down in tether stanchions was aversive to the heifers and avoided as much as possible. Ladewig and Smidt (1989) compared tethered bulls on concrete and partially slatted floors with bulls kept free on deep straw. As previously reported, the authors found that tethered bulls had a significant lower numbers of periods of lying down and an increased frequency of investigating the area before lying down than those kept on straw. The secretory patterns of cortisol of the bulls in the two housing systems were different during the first four weeks. However after that period the response to ACTH stimulation was still lower in tethered animals. From these data Ladewig and Smidt, (1989) suggested that there was no adaptation at the central nervous level to this housing system, and the return of the basal cortisol secretion was due to intracellular changes at the corticoadrenal level.

Tethered animals have more osteochondrosis than animals kept in loose housing (De Vries et al., 1986). However, loose-housed animals, and more specifically those on slatted floors, have a higher risk of foot problems compared with tethered animals, especially if they are fed concentrates (Ingvartsen and Andersen, 1993). When tethered for a long periods, hoof trimming is often necessary.

The comparisons of performances of loose-housed animals and tethered animals show contradictory results. This is probably because the performance of loose-housed animals often has been severely influenced by different space allowances (Ingvartsen and Andersen, 1993). However, these authors suggested that if loose housed animals are allowed enough space (>4.7m² per animal) they have a tendency to eat more (4%) and have a 4% higher feed

conversion ratio than tethered animals, probably due to an increase in the level of exercise. Consequently they are expected to have at least similar growth rates to tethered animals.

Soft bedding has been shown to be much better for tethered dairy cows than concrete flooring (Haley et al., 2001)

6.2. Space allowance and pen design

The space allowance recommended for fattening cattle varies considerably according to the housing system (permanent tethering in tie-stall, littered or slatted loose housing) as reviewed in chapter 4. Usually the smallest space allowances are used in intensive indoor slatted floor systems (Daelemans and Maton, 1987). The effects of these variables on behaviour, physiology, pathology and production are presented below.

6.2.1. Space allowance, pen design and behaviour

It has been shown that a minimal distance between individuals within a group is important and that a reduction in space allowance increases aggressive behaviour (Lutz et al., 1982; Larson et al., 1984). However, Fischer et al. (1997b) found no increase in aggressive behaviour in heifers with a reduced space allowance and Hicky (pers. comm.) obtained a similar result with steers. A lack of space for lying down may reduce resting time, increase frequency of disturbance of the lying animals while aggressive behaviour may increase (Wierenga, 1987). Abnormal transitions, from lying to standing and vice-versa, also occur more often in smaller pens (Graf, 1979; Wierenga, 1987).

Several studies have been conducted on the effect of space allowance and pen design on various behavioural activities of fattening cattle. The conclusions of these studies can be contradictory. Andreae et al. (1980) did not find any significant differences in lying times of beef bulls kept at stocking densities of 2 m² versus 3 m^2 per animal. Wierenga (1987) recorded only a tendency for a reduction in lying times for bulls at 1.95 m^2 versus 2.60 m^2. Similar conclusions were reached by Kirchner (1986). Ruis-Heutinck et al. (2000) found that a space allowance of 2 m^2 per bull reduced lying duration significantly compared with a space allowance of 4.2 m². Fisher et al. (1997b), comparing finishing heifers kept at 1.5 m^2, 2.0 m², 2.5 m² and 3 m² reached similar conclusions. It seems that finishing cattle housed in groups require more than an individual minimum lying area as suggested by Baxter (1992) in order to maintain a preferred duration of individual lying bouts and resting. However, Fisher et al. (1997a) comparing 1.5 and 3.0 m² space allowances for indoor finishing heifers reported that

restricted space allowance slightly reduced lying behaviour but statistically increased head resting behaviour (leaning upon inanimate structures as well as upon other heifers). Such leaning behaviour can be considered a redirected behavioural substitute for lying down as pointed out by Wiepkema et al. (1983). The results on leaning behaviour are, however, also contradictory. Ladewig et al. (1985) and Muller et al. (1986) reported an increase in this behaviour as space allowance decreases whereas Fisher et al. (1997b) did not report any increase in leaning behaviour. The reason for these different conclusions could be due to differences in the studies other than stocking density such as the types of flooring or housing. Contradictory results have also been reported for aggressive behaviour. Wierenga (1987) and Larsson et al. (1984) detected an increased level of aggression among bulls as space allowance decreases whereas Müller et al. (1986) and Fisher et al. (1997b) did not recorded such effects on heifers suggesting that the effect on aggressive behaviour of high stocking density may be related to the sex of the animals.

Aggressive behaviour increases when there is a reduction in feeding space at manger. It has been reported that when animals could not eat at the same time there was an increase in aggressive and mounting behaviours and a reduction in lying time (Lutz, 1981). Reduced feeding space per animal at the manger may also negatively influence feeding behaviour (Kongaard, 1983). Graf (1984) reported that when trough length was reduced in slatted floor systems there was a significant increase in the frequency and a decrease in the duration of feeding periods.

Several authors observed that social licking was more frequent in the slatted floor systems than in the deep litter system (Lidfors, 1992; Wibran and Akerberg, 1984; Graf, 1984). Wood (1977) suggested that social licking may be important for the social stability within the herd and Lidfors (1992) suggested that the relatively small area per animal provided in slatted floor houses caused tensions leading to more social licking. However Fisher et al. (1997b) found no effect of different space allowance on social activity of cattle housed on a slatted floor.

Buller steer syndrome is a sexual behaviour that is found among confined cattle especially in the north American production systems. Buller behaviour occurs when a steer is repeatedly mounted (buller) and ridden by its penmates resulting in injuries and sometimes death. Factors associated with an increase in the proportion of bullers include: large group size (200- 250 animals per pen), warm weather, and stressful events such as mixing and handling (Blackshaw et al., 1997). The relationship between group size and buller activity is more often reported than is the effect of space per animal on buller activity (Acosta et al., 1981). However, if cattle are given very limited space, buller activity may not be possible. Buller steer syndrome has not

been described in European beef farms suggesting that the mounting activity is not high enough to cause problems. One study reported that some bulls performed a significant amount of mountings (Lidfors, 1992). The different effects of space allowance on behavioural traits are summarised in Table 15.

Table 15 Summary of the results from different studies on the effect of space on behavioural patterns (= no change ; < decrease ; > increase, - not measured)

Studies	m^2/ animal Sex	Abnormal Lying Down Standing up	Time Spent Lying	Disturbance of Lying animals	Aggressive Behaviour	Feeding Behaviour	Ruminating	Sexual behaviour	Oral Stereotypy
Graf, 1984	3 m^2 vs. 2m^2 bulls	>	=	=	=	-	-	>	=
Wierenga, 1987	2.60 vs. 1.95 bulls	=	<	>	>	-	-	=	-
Andreae et al., 1980	3 vs. 2 bulls	=	<	=	=	-	-	=	>
Kirchener, 1986	2.7 vs. 2.3 bulls	=	<	=	=	-	-	=	-
Fisher et al., 1997a	3 vs. 1.5 heifers	<	=	=	<	<	-	-	
Ruis-Heutinck et al., 2000	4 vs. 2 bulls	>	<	=	=	-	-	<	-

6.2.2. Space allowance and pen design and physiological parameters

Several studies examining the effect of restricted space allowance for fattening cattle have reported a reduced cortisol response to ACTH (Beneke et al., 1984; Ladewig and Smidt, 1989; Fisher et al., 1997a). Fisher et al. (1997a) found that chronically restricted movement or overcrowding causes a reduction in adrenal responsiveness to ACTH. They suggest that the effect could be either at the ACTH receptor level, or in the synthesis, release or clearance of cortisol. However, Friend et al. (1977; 1979) detected an increase glucocorticoid response to

ACTH challenge in dairy cows with low space allowance or cubicle: cow ratio. In these two experiments animals were submitted to ACTH challenge one week after the beginning of the trials. It is possible that under those conditions the adrenal response of ATCH in cattle to a chronically stressor such as high density or restricted movements may initially be enhanced and then diminished. This hypothesis is consistent with the result of the study of Munksgaard et al. (1999) who found, in young bulls repeatedly deprived of the opportunity to lie down, that the response of the pituitary adrenocortical axis changed as treatment progressed. These authors suggest that the changes they found may reflect a high priority of an adaptive mechanism serving to minimise peripheral consequences of repeated stress rather than changes in perception of the stressor.

Few experiments have been conducted to evaluate the effect of low space allowance on the immune response of fattening animals. In one study Fisher et al. (1997b) did not find effects of space allowance on the humoral immune response. However thus aspect requires further examination.

6.2.3. Space allowance and pen design and pathology

It has been reported that the number of lame animals increase when trough space is limited (Murphy et al., 1987).

Reduced space allowance on slatted floors increases the occurrences of tail tip lesions as reported by many authors (Konggard et al., 1984; Madsen, 1987; Madsen et al., 1987; Andersen et al., 1997).

In a French survey reported by Béranger (1982), the effects of space allowance and air volume on the mortality related to respiratory diseases of beef bulls on straw bedding were recorded. Most of the animals used for evaluating the effect of air volume were also used for evaluating the effect of space allowance. The mortality of bulls decreased when the air volume (Table 16) and space allowance (Table 17) increased. The mortality curves showed plateaus when the volume per animal was higher than 20 m^3 and the space allowance greater than 3 m^2.

Table 16: Influence of the air volume per beef bull on mortality related to respiratory diseases (Béranger, 1982)

Air volume (m^3/bull)	Number of animals	Mortality (%)
10-15	1014	1.35
15-20	1465	1.29
20-25	663	0.70
>25	1765	0.65

Table 17 Influence of the space allowance per bull on mortality related to respiratory diseases (Béranger, 1982)

Space allowance (m²/bull)	Number of animals	Mortality (%)
<2.5	2124	1.98
2.5-3.0	1717	1.08
3-3.5	1467	0.53
>3.5	1796	0.55

6.2.4. Space allowance and pen design and production

As reviewed by Ingvartsen and Andersen (1993) many studies reported higher voluntary feed intake and daily weight gain with increasing area per animal (Figure 11). In this review the authors found that space allowances of less than 4.7 m^2 per animal on slatted floors, weighing between 250 to 500 kg, reduced average daily weight gain. However, it is not easy to sort out the different risk factors as in most of the study reviewed by Ingvartsen and Andersen (1993) type of floor, space allowance, space at feeding trough and group size were not constant. Other studies have confirmed these data and reported that daily live weight gain and food intake of fattening animals increased when the floor space allowance increased (Mossberg et al., 1992; Pahl, 1997; Fisher et al., 1997b; Andersen et al., 1997; Ruis-Heutinck et al., 1999). The reduction in growth has been explained partly by a decrease of feed intake but mainly by a poor feed conversion ratio. The decrease in feed conversion efficiency at lower space allowance may partly be due to an increased energetic cost associated with longer periods of standing as suggested by Fisher et al. (1997b). No differences in killing out percentage, carcass composition and conformation score have been found when space allowance is reduced (Ingvartsen and Andersen, 1993; Mossberg, 1992; Andersen et al., 1997).
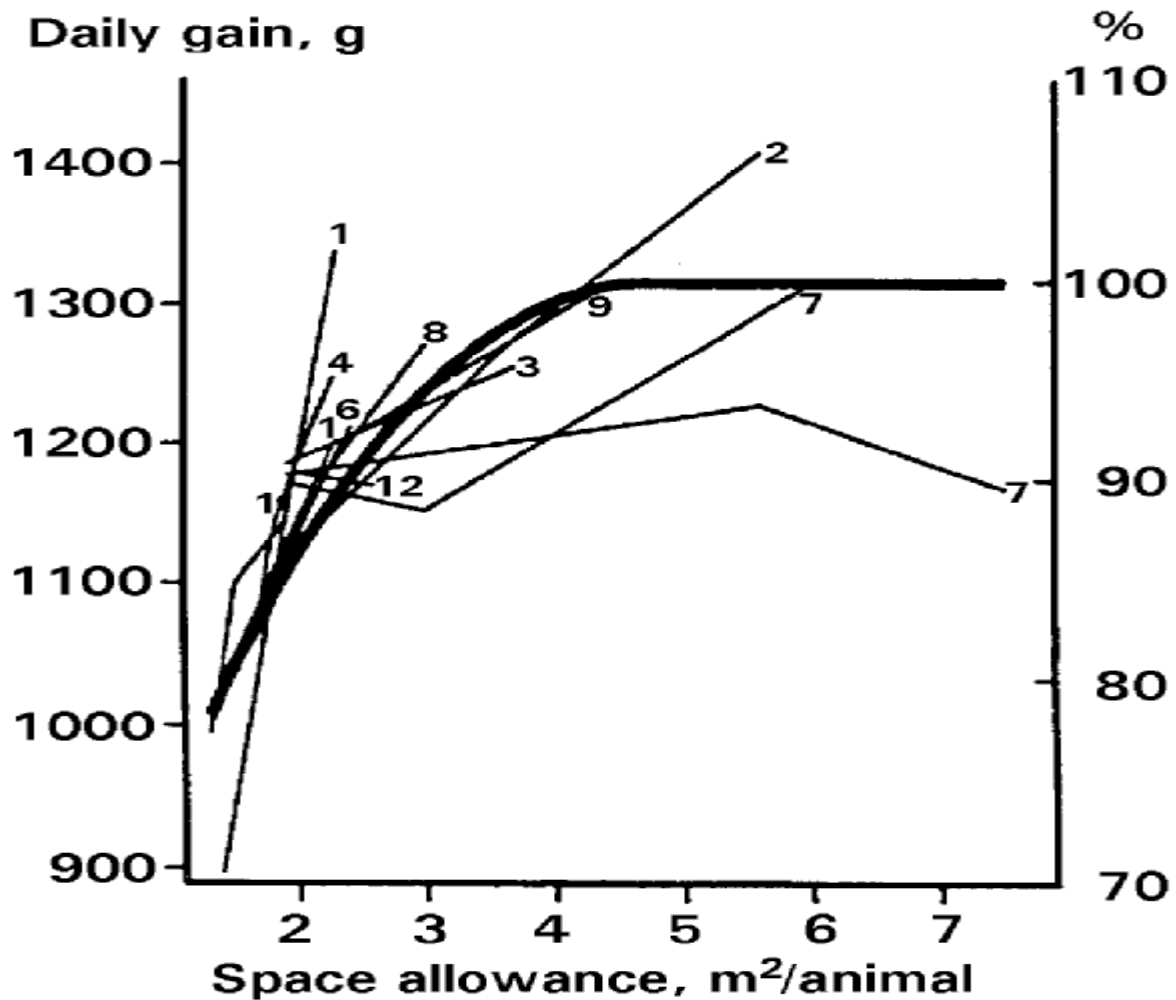
Figure 10 Daily gain of growing cattle at different space allowances on slatted floors after correction for effects of different experiments _____ individual experiments _____ estimated relative daily gain at different allowances. (from Ingvartsen and Andersen, 1993)

The effect of group size, (number of animals per pen) in the range of between 5 and 20 animals, on production parameters seems negligible (Morrison et al., 1981; Hanekamp et al., 1990; Hinddhede et al., 1996).

Reduced feeding space per animal may negatively influence eating behaviour (Kongaard, 1983) and result in a decreased growth rate and an increased feed conversion ratio (Keys et al., 1978; Lutz et al., 1982; Hanekamp et al., 1990). Hanekamp et al. (1990) reported a significantly improved daily gain and feed conversion rate when bulls were allowed 75 cm manger space compared to 55 cm. Reducing feeding space at manger to less than one per animal seems to reduce performance (Ingvartsen and Andersen, 1993). However Andersen et

al. (1997) conclude that the effect of feeding space (1 to 5 animals per eating place) for truly *ad libitum* feed animals seems not to be significant.

It is important to remember that other factors such as the design of the feed manger may also possibly influence performance (Bouissou and Signoret, 1971).

6.3. Type of floor and bedding material

Slatted floors have been used for many years as a convenient floor for intensive housing of beef cattle in group pens or tethered animals, but concerns have been expressed about their effects on animal welfare.

6.3.1. Type of floor and behaviour

Wierenga (1987) has reported how fattening bulls sometimes stand up in an abnormal way (the animals first stretch their forelegs) or lie down abnormally (the animals first sit down on their hind quarters). The proportion of abnormal lying down movements seems to increase with age according to Graf (1979) who recorded 50-60% of the lying down with such a pattern in 13 months old bulls. Andreae (1979) and Graf (1979) found a higher incidence of abnormal transitions in animals kept on slatted floors than in animals kept on straw. Abnormal lying down and getting up has rarely been observed on rubber top-layer slats or on straw (Lidfors, 1992; Smits et al., 1995; Ruis-Heutinck et al., 1999, 2000).

Steers and bulls kept on straw had a higher number of lying periods and more time spent lying (Andreae, 1979; Graf 1984, 1987) than on slatted floors. These data suggest that animals stand up and lie down more easily when they are kept on straw. In bulls, a significantly lower frequency of lying down and getting up on concrete slats than on straw has been reported by other authors (Graf, 1979, Andreae and Smidt, 1982; Sambraus, 1980; Lidfors, 1992; Ruis-Heutinck et al., 2000) indicating that animals may have problems in performing the normal lying down behaviour. According to Graf (1978, 1979) this results from the difficulties that animals have in getting up and lying down on hard and slippery slatted floor. A more frequent occurrence of interrupted lying down intentions and actually lying down in slatted floor has also been reported by many studies (Andreae and Smidt, 1982; Andreae et al., 1982; Lidfors, 1992). These findings seem to indicate that the floor surface was inadequate for allowing a normal movement pattern (Lidfors, 1992). As reviewed by Lidfors (1989) when the bulls are kept on partially slatted floors they not only have a lower frequency of lying down compared to animals kept on deep litter but they also increase the time spent investigating the lying area

before lying down. Ladewig (1987) found that bulls kept on slatted floors were more hesitant to lie down compared to bulls kept on straw. The bulls on slats showed a reduced frequency of lying down periods (6 to 12 times per 24 h) than bulls kept on straw (15 to 25 times per 24 h). Ladewig (1987) reported that despite the fact that the total duration of time spent lying down was the same on straw and slatted floors, the animals on the slatted floors lay without changing body position for longer periods. He suggested that this reduction in the rate of changes in body position on slatted floors may increase the risk of tissue damage.

As previously reported in chapter 3, in some beef fattening systems, animals are changed to a new environment and housing system for the finishing period. Several studies have shown that 6-9 months old calves with no previous experience of slatted floors have more lying down intentions per lying down movement, more interrupted lying down movements and longer times to first lying compared to calves which were raised on slatted floors. However these differences disappeared after about 10 days (Andreae and Smidt, 1982; Pougin et al., 1983). Young cattle kept on slatted floors for 3 to 6 months showed normal lying down movements but approximately 5% of their lying down movements were done via a sitting position (Pougin et al., 1983).

The type of surface not only affected the rising and lying down movements and lying behaviour of the fattening animals but also other behavioural traits (Ladewig, 1987; Ming, 1984; Ruis-Heutick et al., 2000). Ming (1984) reported a higher percentage of cases of slips in fattening bulls kept on slats than on straw during the performance of various behavioural activities such as social interactions, mounting and comfort behaviour. Ruis-Heutick et al. (2000) found that bulls on soft bedding showed more active behaviour than bulls on concrete slatted floors. Several authors pointed out that these changes became more pronounced when the animals were kept under crowded conditions (Ladewig, 1987; Ruis-Heutick et al., 2000).

Several studies have shown that the use of modified "soft" slat surfaces, or partial rubberisation or rubber mats on concrete floor, especially the lying area, reduced abnormal standing up and lying down, and slips (Wee et al., 1989; Koberg et al., 1989; Smits, 1993; Ruis et al., 1999).

6.3.2. Type of floor and physiological parameters

In fattening cattle, little research has been carried out on the effect of type of floor on physiological indicators of stress such as heart rate and pituitary-adrenal axis reactivity (Müller et al., 1989; Ladewig and Smidt, 1989). In these studies the type of floor and rearing condition (loose or tethered animals) were investigated. The results of these studies have already been

discussed in the section on tethered and loose animals. In many cases the study designs have been such that tethering and floor type have been confounded.

6.3.3. Type of floor and pathology

It seems that at the same space allowance bulls on slatted floor have a higher mortality and culling frequencies then than on straw bedding (ITEB, 1983). Bulls on sloped floors have intermediate mortality (Table 18). Lameness is one of most important diseases of beef cattle intensively housed (Hanan and Murphy , 1983; Murphy et al., 1987). The lesions vary from tendon and muscle injuries (Sturén, 1985), to hoof and foot diseases (Dämmrich, 1976; Jensen et al., 1981; Murphy et al., 1987; Davies, 1996).

In a survey, treatments for lameness have been recorded for bulls from beef breeds in different housing systems (ITEB, 1983). The authors found the highest levels in litter housing with a sloped floor and the lowest on deep straw bedding (Table 19).

Table 18: Influence of the type of flooring on the mortality and culling of bulls (ITEB, 1983)

Type of floor	Straw bedding	Slatted floor	Sloped floor
Number of animals	728	1084	276
Mortality (%)	1.25	4.52	2.52
Culling rate (%)	0.70	1.47	1.80
Total (%)	1.95	5.99	4.32

Table 19: Influence of the housing system on the number of fattening beef bulls treated for leg problems (ITEB, 1983)

Type of housing	Number of animals	Lameness occurrences during the fattening period (%)
Cubicle house	160	23
Sloped floor	120	36
Slatted floor	510	26
Straw bedding	230	14

As reported above, fattening bulls housed on full concrete slatted floors have problems with standing up and lying down. This may be caused by lesions in particular of the carpal joint, joint deformities or osteochondrosis (Beukema, 1987). Injuries to the carpus or hock may occur when the animal is getting up or lying down, moreover the gaps between the slats are often large enough to allow a digit to enter and that can cause damage (Dumelow, 1993). Wierenga (1987) reviewed the various ways in which housing systems (loose or tethered animals) and floor properties can affect the incidence of carpal joint lesions. He suggested that animals, which have to lie down on hard surface such as concrete, may try to lie down and stand up more carefully to avoid getting hurt. This could lead to a less optimal loading of their joints resulting in the lesions described by Dämmrich (1986). The same author showed that lesions can also develop when the animals slip or try to avoid slips on a floor which does not allow the animals enough "grip" during movements. Dämmrich (1979) reported that lesions occur more frequently when the housing system does not allow the animals enough possibilities for locomotion. Fully slatted floors caused significantly more severe lesions and a greater proportion of injuries than half slatted floors or quarter-slatted floors (Murphy et al., 1987; Dumelow, 1993). Lesions are less severe on soft bedding (Wierenga 1987; Smits et al., 1995). Bulls on deep litter have less hoof wear and require more frequent hoof trimming (Anderson et al., 1991). The incidence and severity of soft tissue injuries of beef cattle housed on slatted floors seem to be reduced by replacing part of the slatted area with sloped solid concrete floors or by the addition of rubber surfaces to the slats. Many studies have shown that the use of modified "soft" slat surfaces, or partial rubberisation or rubber mats on concrete floors, especially for lying areas, reduced lesion to claws and joints (Wee et al., 1989; Koberg et al., 1989; Smits, 1993; Ruis et al., 1999).

Tail tip necrosis is a multifactorial disease primarily related to the quality of the floor (Metzner et al., 1994). This lesion is caused in most cases by traumatic injuries (tail tramping) which subsequently become infected. The lesion usually begins at the tip of the tail with a typical inflammatory reaction that gradually extends upwards. When the incidence of tail tip inflammation is high this can lead to economic loss due to reduced weight gain, death losses due to pyaemia, and veterinary costs. Tail amputation is used as therapeutic treatment at later stages of the disease or, in some countries, as a preventive measure.

Tail tip inflammation has been reported in intensive fattening bull units with close confinement since the 1970s (Bertocchi et al., 1973; Martig and Leuenberger, 1978; Kunz and Vogel, 1978; Hünermund et al., 1980). The lesion occurs more often in young bulls on slatted floors while a

lower frequency has also been reported in tethered bulls and sporadically in heifers kept in the same housing system as fattening bulls (Bisgaard Madsen, 1987; Kunz and Vogel, 1978; Metzner et al., 1994). Bisgaard Madsen, (1987) showed that concrete slatted floors, high stocking density and high environmental temperature increase the frequency of tail tip lesions in fattening bulls. Mertzner et al. (1994) did not find a seasonal influence on the incidence of the lesions. However, the incidence of the condition also seems to be related to the feeding regime which may relate to the consistency of the faeces.

6.3.4.   Type of floor and production

Irps (1987) observed a higher daily gain when slatted floors were coated with rubber. Koberg et al. (1989) found better performance in fattening bulls kept on rubberised concrete floors. Ruis-Heutinck at al. (1999) compared different types of floors for beef bulls. They found that systems with rubber mats and straw resulted in improved feed conversion. However, in a review, Ingvartsen and Andersen (1993) concluded that the differences in performance of growing cattle housed on slatted floors and on straw bedding were not significant when they are compared at the same space allowance.

6.4. Conclusions

1. Animals can cope successfully only within a range of temperatures and humidity. They are negatively affected when noxious gas levels are high.

2. Insulation of buildings is an option which is used when the animals are housed on slatted floors and the outside temperature is very cold. As the volume allowances in such buildings are often low, a monitoring of the microclimatic environment and efficient ventilation devices are required.

3. Tethered cattle have limited movement possibilities and cannot walk. Their social interaction is limited to their neighbours. Short tethers, low space and concrete floors are among the different factors limiting the comfort of these animals. Tethered animals have more leg problems than those on straw bedding. Hoof trimming is necessary for cattle tethered for long periods or those on excessively soft surfaces.

4. A low space allowance increases aggression between animals especially among males. An increased occurrence of aggressive behaviour is also observed when the trough space is limited.

5. Disturbances in the lying behaviour of animals are observed when the space allowance per animal is low.

6. Diseases such as respiratory diseases are observed when the air volume or space allowance per animal is low.

7. Daily gain seems to be less when the space per animal is lower then 4.7m².

8. The type of floor has important consequences for the welfare of the animals. When they have the opportunity, animals choose straw bedded areas for lying down in preference to slatted floors.

9. Among the different types of bedding, lower mortality is observed in animals with at least some straw bedding and higher mortality in animals on completely slatted floors.

10. Animals on sloped straw bedded areas have a higher incidence of lameness than animals kept on slatted floors.

11. Tail tip necrosis occurs much more often on slatted floors than on other type of housing.

12. The slat surface must not be slippery to avoid animals falling which increases the risk of health problems.

13. Fattening cattle kept on concrete slatted floors have an increased incidence of abnormal postures, lesions to the carpal joint and to the tail, and may show behavioural changes.

14. Increasing floor space allowance for animals on slatted floors improves growth rate and feed conversion ratio.

7. THE EFFECTS OF MANAGEMENT ON CATTLE WELFARE

7.1. Mutilations

7.1.1. Introduction

Several surgical mutilations are carried out in cattle, including castration, spaying, dehorning and tail docking and have been shown to cause fear, pain and distress (Mellor and Stafford, 1999). Pain and distress have been studied using a variety of physiological and behavioural changes, including increased activity in afferent nerves which in humans is associated with painful stimulation, activity of the sympathetic nervous system, activity of the hypothalamic-pituitary-adrenal axis, changes in posture and locomotor activity, changes in other behaviours, and a reduction of all these changes by local anaesthetic or analgesic treatment (reviewed by Molony and Kent, 1997; Mellor et al., 2000). Although, different procedures may cause different changes and so may be difficult to compare (FAWC, 1994; Mellor et al., 2000), if care is taken when interpreting the responses they can be informative about animals' likely noxious experiences. Chronic pain, however, may not be identified by such changes and so may be difficult to study.

The amount of pain and distress caused by a given mutilation will depend on the method used, the skill of the person who carries it out, and what methods are used to alleviate the pain and distress. When providing pain relief no distinction should be made on the basis of age as animals from as early as 4 hours after birth exhibit cortisol responses to mutilations (Mellor and Murray, 1989).

7.1.2. Castration

Castration is carried out in cattle to:

- reduce aggressive and sexual behaviour,
- reduce the incidence of meat quality problems, particularly dark cutting meat,
- encourage fattening (Faulkner et al., 1992).

The necessity for castration depends on the rearing system (see the Report on the Welfare of Calves) and the age at which it is done varies from some weeks to more than one year. The

recommended period of castration in Ireland ranges between 8 and 12 weeks of age (Fallon, 1992). In France, most of the castrations are done when the calves are much older (between 9 and 14 months of age). Micol (1986) describes very late castration at 18 months of age and concludes that the castration later than one year does not improve the economic results.

There are several methods available for castrating cattle, including surgical removal of the testes, Burdizzo clamp and rubber rings. The Burdizzo clamp crushes the spermatic cords, whereas the application of rubber rings to the neck of the scrotum above the testes occludes blood vessels, causing ischaemia and death of all tissues distal to the ring. Immunological and chemical (Cohen et al., 1990) castration has also been reported. The Burdizzo method implies the crushing of large amount of tissue and is difficult to perform on older animals. For those animals the surgical castration is most easy to perform.

The cortisol responses to these different castration methods suggest that surgical castration is more painful than Burdizzo in animals between 5 and 6 months of age (King et al., 1991; Fisher et al., 1996) and that rubber rings were more painful than surgical castration (Chase et al., 1995). In younger calves, Robertson et al. (1994) and K.J. Stafford and D.J. Mellor (personal communication) concluded that the Burdizzo produced less pain than rubber rings or surgical castration, whereas Obritzhauser et al. (1998) found no differences between the Burdizzo and surgical castration. Cohen et al. (1990) found that in Holstein calves surgical castration caused greater distress than chemical castration (injection of alfa-hydroxypropionic acid). There do not seem to have been any study looking at the amount of pain caused by chemical castration as opposed to rubber ring or Burdizzo. Local anaesthesia can reduce the stress caused by castration in calves, but its effectiveness depends on the method of castration used, and in some cases it has little, if any, effect (Faulkner et al., 1992; Fisher et al., 1996; K.J. Stafford and D.J. Mellor, personal communication). As established in lambs (Diniss et al., 1997), in calves local anaesthetic injected into the distal pole of each testis and the distal scrotum virtually abolishes the cortisol stress response to ring castration, but is only marginally beneficial with Burdizzo or surgical castration, whereas local anaesthetic given together with a non-steroidal anti-inflammatory drug (ketoprofen) virtually eliminates the stress response to Burdizzo or surgical castration (K.J. Stafford and D.J. Mellor, personal communication). An alternative, less satisfactory method, also developed in lambs (Kent et al., 1995; Moloney et al., 1993, 1997) may be to combine the burdizzo and rubber ring, but the burdizzo must be applied across the full width of the scrotum and this method is only effective in lambs aged less than one week. After an initial barrage of pain impulses caused by clamping, the Burdizzo

abolishes the afferent pain impulses, and the rubber ring cannot be felt as it is applied below the Burdizzo clamp line, but ensures complete castration. However, this method resulted in a more protracted cortisol response than did clamp castration alone (Robertson et al., 1994; Moloney et al., 1995).

7.1.3.   Spaying **(ovariectomy)**

Spaying of female cattle is an old technique that has been used at least in France and mainly on dairy cows to maintain a lactation, or to improve growth and carcass traits (Chappat, 1993; Neau and Berten, 1993). Some experiments have shown that it does not improve productivity (Berten et al., 1993) and it is probably not very frequently done nowadays. There is a lack of research on the welfare issues related to this procedure.

7.1.4.   **Tail docking**

Tail docking of fattening cattle is performed as a preventive measure to reduce the incidence of necrosis of the tail (Bush and Kramer, 1995). There are two methods commonly available for tail docking of cattle: the application of a rubber ring and the severing the tail with a hot iron that also cauterises the tissues, the former method being preferred because of the absence of subsequent bleeding (Petrie et al., 1996). Both methods apparently cause relatively low-level pain in most animals (Petrie et al., 1996a), leaving the question open regarding the routine use of local anaesthesia for this procedure. As cattle use their tail to get rid of flies, and possibly as a social signaller, tail docking may have detrimental effects on their welfare.

7.1.5.   **Dehorning and disbudding**

Dehorning of fattening cattle is carried out to reduce management problems on the farm and during transport, as well as to decrease carcass bruising (Goonewardene et al., 1999). Several methods are available for dehorning but not all are done with an anaesthetic. A saw, obstetric wire or large shears is used to cut the horn near its base. Sometimes a skin incision around the horn is made and the saw or wire seats in the frontal bone beneath the incision and the horn and the attached skin are removed. In younger animals scoops or hot cup shaped irons or shears are used (disbudding). The available evidence seems to suggest that the distress caused by all these methods is similar (Sylvester et al., 1998a), although this evidence has been obtained only in animals 5 to 6 months old.

Studies of disbudding and dehorning in calves have been carried out using cortisol responses and behavioural measures such as struggling and vocalisation during the surgery (Petrie *et al.,* 1995, 1996; McMeekan *et al.,* 1997, 1998a, b; Sylvester et al., 1998a, b). Practical and other implications of the findings are given below (Stafford and Mellor, 1993, 1997; Mellor and Stafford, 1997, 1999; Mellor *et al.,* 2000 and unpublished observations of Mellor et al.).

Disbudding by cautery

Cautery disbudding caused a significant but short-lived rise in cortisol that was largely complete by 2 hours after surgery and it was less than that caused by amputation dehorning (Petrie et al., 1996b). Prior injection of short-acting local anaesthetic (lignocaine) reduced the acute cortisol distress response (not significantly) but it virtually abolished struggling and other escape behaviours.

Dehorning by amputation

Amputation dehorning caused a marked rise in cortisol that lasted 7-9 hours in calves aged between 6 weeks and six months (Petrie et al., 1996b; McMeekan et al., 1998a; Sylvester et al., 1998a). The magnitude of that response was not influenced by either the amputation method (Sylvester et al., 1998a) or by the depth of the amputation wounds (McMeekan et al., 1997). Dehorning calves and then cauterising the wounds reduced the rise in cortisol (Sylvester et al., 1998b) but struggling was marked (Sylvester et al., 1998b). Prior injection of short-acting (lignocaine) or long-acting (bupivacaine) local anaesthetic prevented both behavioural and cortisol distress responses during the period of nerve blockade, but once the local anaesthetic had worn off, pain-related behaviours occurred and there was a marked rise in cortisol (McMeekan et al., 1998b). These local anaesthetic strategies do not usually reduce the overall cortisol distress response to dehorning, but merely delay it. However, prior injection of the non-steroidal anti-inflammatory drug (NSAID) ketoprofen did not affect the acute cortisol distress response during the first 2 hours after horn amputation, but virtually abolished the last 5-7 hours of it (McMeekan et al., 1998a). When both lignocaine and ketoprofen were given prior to surgery, it virtually abolished the cortisol distress response to horn amputation throughout the first 9 hours after treatment (McMeekan et al., 1998a). Finally, injecting lignocaine before dehorning and then cauterising the amputation wounds virtually abolished the acute cortisol distress response throughout the first 9 hours after treatment (Sylvester et al., 1998b) thought to be due to destroying the pain receptors in the skin.

Comparison of dehorning methods

On the basis that no or less struggling during a procedure and lower overall cortisol distress responses indicated less pain and distress the different procedures could be ranked (see Table 20).

Table 20: Ranking disbudding and dehorning procedures from most to least severe.

Rank	Procedure	Struggling	Acute Cortisol Response
6	Amputation dehorning + wound cautery	During amputation and cautery	Marked (75%)*
5	Amputation dehorning	During amputation only	Marked (100%)*
4	Prior local anaesthetic[#] + amputation dehorning	None/little	Marked (100%)* and delayed
3	Cautery disbudding	During disbudding	Moderate (55%)*
2	Prior local anaesthetic[#] + cautery disbudding	None/little	Moderate (55%)*
2	Prior NSAID + amputation dehorning	During amputation	Mild (35%)*
1	Prior local anaesthetic[#] and NSAID+ amputation dehorning	None/little	Very mild (25%)*
1	Prior local anaesthetic[#] + amputation dehorning + wound cautery	None/little	Very mild (25%)*
1	Prior local anaesthetic[†] + cautery disbudding	None/little	Very mild (?%)
1	Non-treated controls	None/little	Very mild (≈20%)*

*Percentage of the acute cortisol response to amputation dehorning in each study.
[#]Injected near the cornual nerve supplying each horn bud.
[†]Injected near the cornual nerve *and* around the base of each horn bud (Graf and Senn, 1999).
?% Percentage not known.

Mellor et al. 2000 note that the ranking scale is probably not linear. As the procedures ranked 4, 5 and 6 caused different amounts of struggling (very low, marked and very marked, respectively), but evoked similar (i.e. not significantly different) marked overall cortisol responses, the distinction between them was made primarily on the basis of how much struggling was caused. Cautery disbudding without or with local anaesthetic (ranked 3 and 2, respectively) both caused moderate overall cortisol responses, but the latter procedure is ranked lower because other features of the cortisol response it elicits are similar to those of non-treated controls and because struggling is virtually absent during the cautery. Cautery disbudding with prior local anaesthetic and amputation dehorning with prior NSAID treatment are both included in rank 2, despite the overall cortisol response of the former apparently being higher

than with the latter (55% vs. 35%), because the higher cortisol response is offset by a virtual absence of struggling during the cautery and the lower response is offset by the presence of struggling during and immediately after the amputations.   Rank 1 procedures cause little or no struggling and elicit overall cortisol responses which are very similar to those in non-treated controls.

7.1.6.   Branding

Different types of branding methods are used but include hot branding which appears to be more stressful than freeze branding as hot branded animals vocalise much more than cold branded animals (Schwartzkopf-Geswein et al., 1997, Schwartzkopf-Geswein et al., 1998).

7.1.7.   Conclusions

1. Castration causes severe pain and distress. According to some studies surgical castration seems to be less acceptable from a welfare point of view than Burdizzo or rubber rings. However those last two techniques can only be easily be done on young calves. Local anaesthesia or local anaesthetic plus systemic analgesia act to reduce the pain.
2. Spaying is likely to cause severe pain and distress and there is no indication for it.
3. Tail docking is likely to cause pain and interfere with the normal behaviour of the animal.
4. Dehorning by any amputation method causes severe pain and distress. Local anaesthesia and systemic analgesia can reduce, in the short term, the pain caused by dehorning.
5. Disbudding of young calves may be more acceptable than dehorning from a welfare point of view and does not cause as much pain as dehorning older animals.
6. Hot branding causes more pain than freeze branding.

7.2. Genetics

7.2.1. Domestication

Although some evidence may indicate an earlier date for domestication, most authors believe that cattle were domesticated some 8000 years ago in the Middle East (Zeuner, 1963). Domestication involves biological changes (including behavioural changes) resulting from both genetic selection (either conscious or unconscious) and exposure to the domestic environment (Price, 1984). The possibility exists, therefore that some instinctive cattle behaviours may have been modified by domestication. Nevertheless, studies of other domestic animals have shown that the behavioural changes caused by domestication are quantitative rather than qualitative in nature (Wood-Gush, 1983) and that the potentiality to perform most - if not all - "natural" behaviours still exists in domesticated animals.

7.2.2. Genetic variability

Mainly two species of cattle are domesticated, *Bos taurus* and *Bos indicus*. In Europe most of the cattle are from the Bos taurus species. They have been used for several thousands of years in different environments for their work, milk and meat and a lot of different breeds exist. That process has been very efficient and the physiology of the animals has changed considerably in particular concerning the ability to produce muscle and milk. However all these animals have kept their basic behavioural characteristics and a large genetic variability still exists within the breeds even if, probably due to the adaptation to the different those husbandry systems, large differences in some behavioural traits have been observed between some breeds. Physiological traits and resistance to disease that can have an impact on the welfare of the animals can also vary genetically. The absence of horns in polled breeds results from a single gene mutation. However, most of the genetic differences observed are probably have a polygenic origin and the specific genes have not been identified.

Double Muscling

One gene has been identified that has a major impact on the physiology of the animals and on their welfare. Double muscling animals are characterised by hyperplasia and hypertrophy of the muscle fibres. The lean and usually tender meat of such animals fulfils the requirements of the marketplace, at least those of some regions of Europe. The mutation of a gene leading to

the double muscle character has been identified. It is a single major autosomal gene and has been identified as the gene coding for the myostatin protein (Grobet et al., 1997). Double muscled animals found in different European breeds (Belgian blue, Charolais, Piemontese,..) seem to have more trouble coping with their environment (bedding, food,…). The double muscling "condition is a syndrome, implying that it is associated with many physical, physiological and histological characteristics other than muscular hypertrophy" (reviewed by Arthur, 1995).

Double muscled animals show faster signs of fatigue during forced exercise than normal animals. They are also more susceptible to heat stress and to fasting stress. They are usually more excitable and have an increased reaction to stress (Arthur, 1995).

The main feature of the double muscling phenotype is the high frequency of dystocia. The literature reviewed by Arthur (1995) describes difficulties at parturition. That fact is associated with a very high proportion of caesareans. Combining different experiments Arthur et al. (1989) found 2% of caesareans in Friesians whereas Belgian Blue cows have figures of 35 to 48%. In an experiment comparing double muscled and normal cattle, Arthur et al. (1989) found higher percentages of calving difficulties (26.7 vs. 9.9%) and calf mortality (13.4 Vs 4.6%).

Heterozygous animals are characterised only by a higher growth rate than the normal genotype. They do not show any of the detrimental characteristics of the double muscling observed in homozygous animals.

Calving difficulties

Calving difficulties vary between beef breeds. In France, of animals recorded in the herd books in 2000, the highest proportion of caesareans was observed in Belgian Blue cows (Table 19). It was negligible in some other breeds, including a specialised beef breed such as Limousin. The proportion of cows calving after 5.5 years can be used as a indicator of the longevity of the cows. It varies a lot between breeds. The lowest proportion is observed in Belgian blue cows (17%), which may indicate fertility problems and the highest in Salers (53%) (Dodelin, 2000). However it should be kept in mind that this variable is strongly influenced by the culling strategies followed by farmers and not only by the inability of the cows to carry on their productive life.

Table 21: Calving difficulties of the cows registered in herd books of some beef breeds in France in 2000 (Dodelin, 2000).

	Number of cows (X1000)	Calvings of cows older than 5.5 years (%)	Easy calving (%)		Caesarean (%)	
			Primi-parous	All calvings	Primi-parous	All calvings
Belgian Blue	3.8	17	6	11	88	81
Maine Anjou	12.8	34	41	55	15	9
Charolais	234.5	42	41	60	10	4
Limousin	132.3	51	82	92	1	0
Blonde d'Aquitaine	76	46	58	72	3	2
Salers	35	53	95	98	0	0

Social behaviour

Several components of cattle social behaviour seem to be genetically dependent (Grandin, 1998). Individuals from specific breeds seem to dominate over others. For examples, Aberdeen Angus dominate Herefords (Stricklin, 1983) and Salers dominate Friesians (Le Neindre, 1989b). Herens, cattle reared in the Alps, fight to establish a social hierarchy and that tendency is exploited for specific events. Homozygous twins, even not reared together, have the same hierarchical status (Ewbank, 1967). However, the tendency to dominate does not mean that the animals display much more aggressive behaviour when the hierarchy is established. The temperament of animals and fearfulness seems to be important traits involved in the dominance status of animals (Bouissou, 1985).

Some animals also have a tendency to display more non-agonistic behaviour than others. Le Neindre (1989b) observed that Salers cattle, a hardy French breed, had more non-agonistic encounters than Friesians. In fact, the former breed seemed to be more "social", the individuals spent more time interacting with each other and were much more disturbed by short term isolation and when artificially reared without their mothers (Le Neindre, 1989a and b).

Reaction to Human handling

The reactivity to human contact has a clear genetic component (Burrow, 1997; Grandin and Deesing, 1998). Several authors have studied that trait using different methods in dairy cattle and beef cattle (see review of Grandin, 1998). Murphey et al. (1980) observed that dairy cattle breeds have a lower flight distance than beef breeds. Le Neindre et al. (1995) observed the reactions of animals when humans tried to actively drive the animal into a corner of a pen

(docility test). They estimated the heritability to be significant and equal to 0.22. Higher values have been estimated by other authors (Grandin and Deesing, 1998).

Sexual behaviour

Sexual behaviour seems to vary between breeds and in particular it has been said that the bulls from dairy breeds are more sexually active than bulls from beef breeds (Chenoweth, 1986).

Health

Few papers deal with the genetic variability for health traits. However, Dutra et al. (1999) surveyed a performance testing station in Sweden containing 46 12-month old bulls of different breeds. Forty five (97.8%) of the bulls had lesions in the joints and/or growth plates. Prevalence of bulls with at least one lesion was similar between breeds, but the number of lesions per bull was highest in the Charolais, followed by Simmental, Hereford and Limousin. Number of lesions was significantly correlated with daily weight gain, carcass weight and the width of the proximal tibial epiphysis. Bulls with a significantly higher daily weight gain (1629g vs. 1476g/day) showed more thickening of the growth plates than bulls with more usual weight gain. Lesions were statistically independent, indicating that local biomechanical factors within the joints were important in the pathogenesis.

Genetic variations in claw traits and claw disorders are observed between and within breeds (Politiek et al., 1986; Hubert and Distl, 1994). Claw traits in young bulls kept under similar conditions show even higher heritability estimates than claw traits of cows in herds (Politiek et al., 1986).

In Holstein-bulls, liver lesions were about twice as frequent as in Fleckvieh bulls. In the USA, the rate of liver abscesses recorded in 1995 averaged 12.9% for Hereford steers, and 23.5% for Holsteins (Smith, 1998), also indicating a difference due to breed type.

7.2.3. Conclusions

1. A large genetic variability in several traits is observed in cattle.
2. Beef breeds have been selected for a high meat production. These breeds are often associated with a hypermuscularity which can cause leg disorders, increase calving difficulties and decrease cow longevity.

3.   Among hypermuscular animals, the homozygous carriers of myotrophin defective gene, or double muscled animals, need much more care due to their higher susceptibility to stress. A high proportion of caesareans are carried out in these animals.

4.   Health parameters, in particular lameness, are genetically dependent.

5.   Cattle from some breeds have a higher social activity than others.

6.   Reaction to handling is genetically dependent.

7.   Naturally polled breeds exist. The use of naturally polled breeds avoids the need to disbud animals.

7.3. Feeding

7.3.1. Introduction

Improper nutrition can influence the occurrence and severity of several metabolic disorders in beef cattle and can lead to death. Even when the disorder does not have a direct nutritional cause, manipulation of feed composition or supply can help to combat the problem. This is particular true for conditions that are linked to fast growth. Inappropriate feeding regimes and inbalanced feeding rations are causes of various metabolic disorders in beef cattle. In intensive beef production systems (feedlots) 14 - 42% of the mortality are closely related to metabolic disorders (Edwards, 1996; Smith, 1998).

7.3.2. Nutrient Requirements

Nutritional requirements for beef cattle are well described in the literature (ARC, 1980; NRC, 1984; INRA, 1989; GEH, 1995). Energy and protein supplies are the major factors determining growth, feed efficiency and body composition of beef cattle. Additionally, supplies of minerals, trace elements, vitamins and water are important to ensure optimal growth.

ENERGY

Energy is the first demand in the nutrition of all animals. For ruminants fed plant-based diets, fibrous carbohydrates (FC) are the primary source of energy. Within the group of carbohydrates, cellulose is the most abundant organic compound in the world and composes 20 to 50 % of the dry matter of most plants. While no mammalian degradative enzyme is capable of breaking down the ß-1,4-glucosidic linkages found in plant cell walls, microbes inhabiting the rumen have enzymes which cleave these linkages. The major difference between starches, which can be digested by monogastric animals, and cellulose, which cannot, is the spatial configuration about the 1,4-glucosidic bond. The fermentation of ingested feeds by rumen microbes has significant nutritional and metabolic implications for the host animal.

The nutritive value of FC is variable and can be affected by the inherent properties of plant material (e.g. lignification), by processing (grinding and pelleting), and by conditions occurring in the rumen (e.g., pH and particle passage rate). With an increasing portion of crude fibre in the diet, the digestibility of organic matter decreases. The nutritive value of non-fibrous carbohydrates (NFC) is primarily affected by the type of grain and the method of processing.

Main end-products of microbial carbohydrate metabolism in the rumen are short-chain organic acids, referred to as volatile fatty acids (VFA). The VFA provide 50 to 80 % of the total metabolisable energy supply to the host. For grazing ruminants and those maintained on high-forage diets, little NFC passes from the rumen to be absorbed as glucose in the small intestine. Consequently, glucose is derived primarily from the gluconeogenic activity of the liver whereby propionate and other substrates are used to synthesise glucose. Significant amounts of NFC (primarily starch) enter the small intestine in finishing cattle fed high grain diets. However, net absorption of glucose from the gut appears to be low. Consequently, gluconeogenesis still supplies the majority of glucose needed by the animal.

Energy requirements are for maintenance and for weight gain. The energy available for gain is calculated by subtracting feed required for maintenance from total predicted energy intake. The energy requirements for gain is a function of the desired weight gain, which is determined by economic considerations. Maximum attainable gain differs markedly between animals, depending to a high degree on breed, growth period, feeding intensity and sex (Kirchgessner et al., 1994). Physiological restrictions are among others provided by the maximum of dry matter (DM) intake and by the digestibility of the feed in the fore stomachs.

Animal nutritionists have developed different concepts in order to estimate the energy content of feedstuffs in relation to the prediction of expected performance. In European countries, different assessment concepts have been developed, based either on the level of metabolisable energy (ARC, 1980; GEH, 1995) or on net energy (NRC, 1984; INRA, 1989). Net energy concepts provide a more accurate description of energy release from feeds and better predict performance of cattle. However, they are more complicated to handle in ration formulation because each feed has different energy values for maintenance and for productivity functions. In different European Countries, net energy concepts are carried out by the use of different coefficients and levels of performance so that calculations are not directly comparable between countries.

Protein and amino acids
The majority of protein entering the rumen is degraded to ammonia, with protein solubility having a major effect on the extent of degradation. Feed protein solubility varies depending on the foodstuff. Feed sources that are less soluble in the rumen are preferred as they bypass degradation. Such proteins reach the small intestine and are available for absorption. Balancing diets for optimum concentrations of ruminally degradable (RDP) and ruminally undegradable (RUP) protein is important to maximise protein utilisation. In addition to consuming preformed

protein, ruminants also obtain some dietary non-protein nitrogen (NPN). A portion of NPN may be indigestible, but the majority of it is converted to ammonia in the rumen. A goal of ruminant protein feeding systems is to maximise the conversion of ammonia to microbial proteins and to minimise ammonia loss from the rumen by absorption. Ammonia is toxic to the animal when the concentration of ammonia in the rumen is so high which is observed when the rate of absorption into the bloodstream overwhelms the ability of the liver to convert it to urea. The majority of rumen bacteria grow abundantly using ammonia as their sole source of nitrogen.

Growing and finishing beef cattle require minimal levels of essential amino acids for maintenance and tissue deposition, which are a function of live weight and rate of gain. The quantities of essential amino acids arriving at the small intestine level are a function of microbial amino acid flow and undegraded dietary protein flow. Microbial protein generally accounts for 50 to 90 % of total intestinal protein flow and the essential amino acid pattern of microbial protein is quite balanced relative to animal requirements. The constancy in essential amino acid supply to the small intestine imposed by microbial protein flow created conditions whereby no single amino acid clearly limits growth by cattle in most feeding situations.

Estimations concerning the utility of crude protein from different feed for maintenance and gain are difficult to perform due to methodological difficulties. Recommendations show a huge variation between calculation models (ARC, 1984; Geay et al., 1987; GEH, 1995; Schwarz et al., 1995).

Physical structure

Optimum feeding of cattle requires the maintenance of good rumen function. A disturbed rumen fermentation is the main outcome of a shortage of physical structure, which results in depressed feed intake, reduced digestion and can be the beginning of metabolic disorders. Although physical structure is difficult to define, it could be considered as an expression of the "extent to which a feedstuff, through its content and properties of the carbohydrates, contributes to an optimum and stable rumen function" (Brabander et al., 1999). Feed containing physical structure stimulates chewing activity and this in its turn increases saliva secretion. Since saliva buffers the rumen contents, it reduces acidosis and helps to achieve an optimum pH and a ratio of volatile fatty acids. Roughage creates a fibrous layer in the rumen, which is important for frequent and strong rumen contractions. Sauvant et al. (1999) reviewing the literature conclude that the diet should contain more than 40% of particles longer than 2 mm to maintain a sufficient rumen pH. Suggestions have been made that feed contain a

minimum of 1 kg (or 10%) long fibre roughage in order to avoid digestive problems (Journet, 1988). However, due to the great variation in chemical and physical characteristics of roughage, this can only be a crude indication. It has also been pointed out that the long fibre should be ingested with the rich cereal based diet to have a beneficial effect. For example Béranger (1986) reports mortalities in bulls eating a diet based on high concentrate diet. The mortality was much lower when the straw was given in the feeding trough mixed with the concentrate (3%) than when it was given on a special rack (11.2%) or on the floor (10.5%).

Minerals

Calcium, phosphorus, magnesium and sodium are the most important minerals for ruminants. Calcium and phosphorus are essential for good bone formation and bone quality. Beside the quantity, the balance between calcium and phosphorus is also important. Recommended requirements for calcium and phosphorus increase with growth rate. The calcium to phosphorus ratio should remain above 1. Deficiencies or imbalances can have severe effects on the bone quality and welfare of beef cattle.

Magnesium has a role in the bone formation, in neuro-muscular relationships and in the actions of many enzymes. Poor quality roughage may have a low magnesium content but, poor absorption can also occur on leafy grass, favouring the occurrence of grass tetany. Sodium is the 'osmotic skeleton' of the extra cellular fluid. It allows the extracellular fluid to resist the osmotic tensions of the solutes dissolved in intracellular fluid (Michell, 1985). Recommendations for mineral intake are generally calculated taking into account levels of retention and the inevitable losses. For each kg increase in live weight average amounts of 13.5 g Calcium, 7.4 g phosphorus, 0.4 magnesium and 1.2 g sodium are required (GEH, 1995). Requirements for retention differ in relation to feeding intensity. Inevitable losses are primarily a function of dry matter intake. The portion of inevitable losses in relation to the total requirements increase with dry matter intake.

Trace elements

Essential trace elements relevant for beef cattle comprise iron, iodine, cobalt, copper, manganese, molybdenum, selenium and zinc. In practical feeding regimes deficits can occur, so that additional amounts are recommended to prevent decrease in performance or health disorders. As in depth investigations in relation to requirements are largely absent, recommendations have been made both for minimal requirements and for optimal supply levels.

<u>Vitamins</u>

Minimal vitamin requirements, optimal requirements and recommendations for supply must all be taken into consideration (GEH, 1985). While minimal requirements are suited to prevent specific symptoms, optimal requirements are related to secure physiological processes in relation to performance. Recommendations for the supply with vitamins enclose an extra charge for security reasons (Jeroch, 1980).

<u>Water</u>

The exact determination of water requirements and more detailed knowledge about the actual water consumption of each animal is only required if water supply is limited or too expensive to be provided in abundance.

A reduced intake of water provides a risk for animal health. Besides a decrease of urine volume and the accumulation of substances in the blood that are normally excreted with the urine, reduced water intake leads to disturbances in thermoregulation (Kamphues, 2000). One of the first signs of an insufficient water intake is a reduction in the feed intake. On one hand, an increased feed intake promotes water consumption, while on the other hand a sufficient water intake is a precondition for a high feed intake (Langhans et al., 1995). As a general recommendation, cattle should be provided with 4kg of water per kg of dry matter intake (Kamphues, 2000). In case of limited water supply, the water requirement is of special interest in order to prevent negative effects on animal health, performance and welfare.

7.3.3. Metabolic disorders in relation to different feeding regimes

Feeding strategies of beef cattle differ widely in relation to climatic environment, local conditions for fodder growing and in relation to breeds and sex of the animals (see also chapter 3.3). While heifers and steers are mostly fattened on grass and concentrates often including a grazing season in the summer, fattening bulls are primarily kept indoors, fed on corn silage and concentrates, or concentrates and some long roughage. Possible metabolic disorders and diseases are found in relation to grass based feeding regimes, diets rich in energy, deficits in minerals, trace elements and vitamins and in relation to undesirable substances in feedstuffs.

Grass based feeding regimes

Production intensity of grass based feeding regimes ranges from extensive use of low quality grass by steers and heifers without additional supply of concentrate, to high quality grass silage

with high amounts of concentrates by young bulls. Grass based diets usually contain high portions of roughage and are well adapted to the digestive systems in the rumen. Problems provided by grass products are restricted to specific cases. Apart from situations where the quality of silage is poor because of problems during harvesting or conservation, the main metabolic disorders that occur on grass based feeding regimes are bloat and undernutrition.

Bloat

Bloat is a flatulence caused by an excessive gas formation in the rumen and disturbed eructation (Jeroch et al., 1999). Serious cases of bloat are usually caused by a foamy fermentation, which can cause death as a consequence of increasing pressure in the rumen which can obstruct the blood circulation and respiration. Bloat especially occurs when the proportion of legumes (white clover or lucerne) in the diet is high and when cattle are not used to them. Carbohydrates and proteins of the chlorophyll that support emulsion are responsible for bloat. As a consequence a stable and persistent foam generated in the rumen interferes with the eructation of gases arising from digestion (Clarke and Reid, 1974; Majak et al., 1980).

The occurrence of bloat during grazing is infrequent if the pasture contains less than 20% white clover (Carruthers and Henderson, 1994). Late matured plants or slowly degrading plants, such as cocksfoot, reduce the occurrence of bloat in grass-legume pastures. Restricted daily access to legumes can also efficiently prevent bloat. However, bloat is not restricted to the grazing period. Beef cattle fed diets that are rich in grains also show a predisposition for bloat (Perry, 1995). When the portion of crude fibre is low, rumination is diminished and the motility of the rumen is impaired, leading to a deficit in buffering saliva and a reduction in metabolism and fermentation in the rumen (Jeroch et al., 1999**).**

Undernutrition

Grass growth may be very low in dry summer periods and during winter (outdoor/stores) and may result in undernutrition in grazing animals. Restricted nutrient supply retards the daily gain of lean as well as fat and bone, but the fat gain is retarded relatively more than the other tissues, especially in the latter part of the growth period. Cattle are able to reduce metabolism to a high extent without showing clinical signs of disease. For wild ruminants in natural conditions, periods of undernutrition can be considered as normal, but this undernutrition is limited in intensity and duration. Beef cattle can also be exposed to detrimental nutritional deficits for parts of the year. This could occur when they are kept outside during a drought in some southern region of Europe, or in the very late autumn or winter in colder regions, and

when foraging is limited to the grazing of dry and dead grass. Growing cattle are sometimes kept as stores in such situations before the fattening period. Underfed animals are temporary able to reduce their requirements and to use their body reserves before better feeding allow them recover a better body condition (Chilliard et al., 1998). Undernourished stored cattle mobilize their body fat as energy source for maintenance and to some extent continue to develop lean tissues. If the body condition score is less than 1.5 (on a scale of 5 points for very fat to 1 point for very thin) the risk of health problems increases. Undernutrition is often accompanied by other deficiencies of minerals or micronutrients (INRA, 1978). This is the case when cattle are fed poor quality forage (late cut hay or poorly preserved grass silage). In such cases the phosphorus level is often insufficient.

Water shortage

Water supply can be a problem especially for beef cattle grazing on pastures where water cannot be provided *ad libitum*. Intentional water restriction, and reasons for accidentally reduced water intake are quite different e.g. technical problems and freezing of pipes.

Water is regarded as one of the most important distributors for micro-organism, chemical compounds and toxic substances. Presently, in most European Countries there are no specific legal regulations which define the quality of water for animals (Hartung, 2000). Water of drinking quality is not always available. Groundwater as well as surface water generally contains microorganisms of several species with health significance. Sources of bacterial or viral contaminants may be faeces from humans and animals. Drinking water should be free of *Salmonella* and *Campylobacter* (in 100 ml), no *E. coli* (in 10 ml) and a total bacterial count of less than 10,000 colony forming units/ml (Böhm, 2000).

Water is also a key factor in the life cycle of many parasite species. The development of the free living generations (oocysts, cysts, eggs and larvae) and the longevity of the resulting infectious stages are usually dependent on the availability of water (Daugschies, 2000). Infectious stages are often found in pools of water on pasture, in surface water and in dirty watering equipment (Hiepe et al., 1978; Wilkens, 1981; Bridgeman et al., 1995).

Subclinical acidosis

In springtime and autumn, grass with a high protein and water content provides little physical structure within the diet. Low structured crude fibre content increases the risk of metabolic disorders and more specifically of subclinical acidosis. The structure of a diet is not only

dependent on the content of crude fibre, but also on those particles which influence salivary flow and rumination. In early spring, the content of crude fibre in plants is comparatively low and energy content is high. Daccord et al. (1998), in a feeding trial with early cut grass, found that the pH in the rumen decreased rapidly. Supplementing grass with barley led to a further decrease of the pH-value. The authors concluded that early cut grass fed with high amounts of concentrate and not supplemented with roughage increases the risk of subclinical acidosis in cattle.

Diets rich in energy

Energy rich diets are primarily based either on maize silage and concentrate or on concentrate and some long roughage (straw or hay). In central and southern Europe, silage of the whole plant of maize often is the basic feed stuff for fattening cattle. Feeding of concentrate supplemented with some roughage is widely used in feedlot fattening in North America and there is a tendency towards an increasing use of this practice in Europe.

The major source of energy concentrates for cattle is cereal grains, primarily barley, corn, oats and wheat. These grains are high in starch, low in fibre, rich in energy, poor in protein and are generally quite palatable. The major sources of plant protein concentrates include corn legumes, primarily extracted soybean meal, and by-products of cereal grain processing, such as corn gluten meal. Cereal grains are extremely low in calcium but almost adequate in phosphorus relative to the needs of growing cattle. None of the grains contain vitamin D and only yellow corn contains ß-carotene, the precursor of vitamin A. Consequently, diets containing high levels of corn grain must be supplemented with minerals, trace elements and vitamins.

Studies have shown that depriving young bulls of roughage leads to a significantly higher incidence of social licking (Andersen et al., 1991). This is a normal behaviour but, if carried to extremes, can be detrimental or be the expression of disorders.

Due to the high portion of starch, maize silage is a well-suited forage to obtain high weight gains. However, maize silage alone is not a balanced diet. It should be supplemented with protein and minerals such as calcium, phosphorus and sodium, as well as trace elements such as cobalt and possibly zinc.

In the case of very finely chopped maize, the 'roughage effect' is reduced and metabolic disorders and oral stereotypes can occur analogous with those encountered with concentrates or pelleted feeds. Similar effects can be caused by sugar beet-leaves, especially when containing a high portion of beet tops (Scholz, 1984).

Fattening bulls on slatted floors, which receive diets with a low amount of roughage and rich in energy, show a markedly higher incidence of tail tip necrosis than bulls receiving a high percentage of roughage in the diet (Kunz and Vogel, 1978; Hünermund et al., 1980). Although tail tip necrosis is a multi-factorial disease primarily related to the quality of the floor (Metzner et al., 1994), other factors can be involved. These modify the behaviour in rumination, higher readiness to suck the tails of pen mates (Eckert et al., 1989), and metabolic acidosis combined with pathogens in the blood stream (Hünermund et al., 1980).

Metabolic acidosis
A prominent production problem for ruminants fed diets rich in concentrate and therefore rich in readily fermented carbohydrate is metabolic acidosis. According to Perry (1995), it is difficult to feed a high-concentrate diet without experiencing some acidosis. A high intake of easily fermentable carbohydrates first leads to a rapid production of volatile fatty acids (Gäbel, 1990). Since the production of volatile fatty acids (VFA) is not compensated by absorption or buffer inflow with saliva, the intraruminal pH drops. The highest buffer capacity is provided by the bicarbonate in the saliva (Espinasse et al., 1995). Bailey (1961) showed that cattle consuming high-grain diets secreted only 60 to 70% of the saliva secreted by cattle consuming a similar amount of forage.

In acute acidosis, there is an increased growth of lactic acid producing bacteria combined with a reduction in lactic acid fermenting bacteria and protozoa. The imbalance between production and fermentation of lactic acid results in an intraruminal increase of lactic acid concentration. The first clinical signs of acidosis are usually characterised by a loss of appetite, diarrhoea, mucus in faeces, dehydration, and uncoordinated movements (Perry, 1995). The intraruminal accumulation of lactic acid is accompanied by an increase of acidity and osmolarity which leads to damage to the epithelium (Gäbel, 1990). Hyper-parakeratosis has to be regarded as a pathological alteration while an increase of the absorptive surface can be seen as a positive adaptive process. Further consequences in the complex pathogenesis include hyperplastic rumenitis, liver abscesses, increased fat deposition, atypical ketosis, chronic laminitis, cerebrocortical necrosis, and disorders of the acid-base balance (Dirksen, 1985; Gäbel, 1990; Perry, 1995; Owens et al., 1998).

Andersen et al. (1991) found that young bulls of 325 kg and 440 kg live weight fed high amounts of concentrate had a higher incidence of foot rot (52.8% versus 27.8%) and liver abscess (30.6% versus 5.6%) than those fed mainly roughage. In the Ukraine, bulls fed cereals branstraw-pellets had a prevalence of liver lesions of 87% and 55.2% of these lesions were

liver abscesses (Vlizlo and Lewtschenko, 1992). Additionally, the components of the concentrate have an influence on the reduction of the pH-value in the rumen and then on acidosis occurrence. In particular, the starch of wheat, oats and barley are hydrolysed more rapidly than the starch of maize (Daccord, 1994; Sauvant et al., 1994; Philippeau et al., 1999). A chronic acidosis which may continue during the feeding period can often occurs during adaptation to concentrate-rich diets. Daily variation in the feed intake may increase the potential risk of acidosis (Owens et al., 1998).

Skeletal problems

Skeletal and joint lesions are common in intensively fed and managed animals and in animals with heavy muscles, excellent carcass type, and rapid weight gain (Dutra et al., 1999). The incidence of lesions is to a high degree influenced by the housing conditions, but the fast growth of the animals due to the feeding regime is obviously a worsening factor. The skeletal lesions include osteochondrosis in fast growing bulls and feedlots steers (Dämmrich, 1976; Olson et al., 1978; Jensen et al., 1981; Davies, 1996), hip dysplasia in Hereford bulls (Howlett, 1973; Weaver 1978), epiphysis and growth plate changes in bulls fattened on slatted or hard flooring (Murphy et al., 1975; White et al., 1984), Achilles' tendon rupture in fattening bulls (Sturén, 1985), slipped capital femoral epiphysis in heavy-muscled beef cattle (Hamilton et al., 1978), and ulcerative lesions of articular cartilage of tarsal and carpal joints of heavy bulls kept in small pens (Taura et al., 1984).

7.3.4.   Effects of deficiency of minerals, trace elements and vitamins

For optimal health and production, beef cattle require a large number of minerals, trace elements and vitamins. In most cases, it is difficult to exactly identify the requirements and possible deficiencies. As substances in the diet feed cannot be utilised completely for the demand of the animals, the amount of the required substances in the feed is a function of net requirement and utility. Methodological difficulties prevent detailed quantification of both criteria. In the absence of clinical signs, biochemical tests are the only certain ways of defining a deficient state and for assessing its functional and economic significances.

Minerals

According to McCaughan (1992), the main disorders of the metabolism of minerals involve phosphorous (P) and calcium (Ca).

Phosphorous disorders manifest in young cattle as rickets and growth retardation, and in adult cattle as osteomalacia. Furthermore, P is closely related to the development of hypocalcaemia. Phosphorus is required by rumen micro-organisms for cellulose digestion and cell growth. Growing animals that receive adequate or excessive levels of Ca but inadequate P show depressed food intake and low rates of live weight gain (McCaughan, 1992). Cattle fed diets low in both Ca and P may grow normally but have very low serum P values and demineralised bones (Caple and Halpin, 1985).

The flow rate of **Calcium** into the plasma principally depends on the rates of absorption from the gut and resorption from bone. When these two processes fail to balance the rate of loss of Ca to the skeleton, hypocalcaemia develops (McCaughan, 1992). Given adequate dry matter intake, beef cattle receive sufficient Ca from pastures above 3.2 to 4 g Ca/kg DM content (Grace, 1983). However, many grass-dominant and most grain diets contain lower Ca concentrations.

Trace elements

Both a deficiency and an excess of trace elements may result in health risks for the animals. The gap between situations differs from element to element. For example, the gap between requirement and maximal acceptable amount of Selenium (Se) is a factor of three but is a factor of 10-20 in the case of Manganese (Mn) (Schenkel and Flachowsky, 1998).

Copper (Cu) deficiency in cattle is associated with changes in hair coat colour, poor growth rates, reduced appetite, diarrhoea, joint abnormalities, fragile bones, gait disturbances, hemoglobinuria, abomasal ulcers, and anaemia (McCaughan, 1992). Cu deficiency induced by Molybdenium (Mo) or Iron (Fe) leads to impaired phagocytosis and viability of neutrophils in cattle (Boyne and Arthur, 1986). Copper disorders occur in cattle grazing on soils low or deficient in Cu. Furthermore Cu deficiency occurs when cattle have a low dry matter intake or a high Fe intake, or when another disease, such as internal parasitism, causes a loss of Cu. Clinical signs follow depletion of the essential Cu pools within enzyme systems in the tissues (McCaughan, 1992).

Selenium deficiency is associated with a diverse range of beef cattle ailments, including classic white muscle disease, ill thrift or reduced weight gain and diarrhoea (Mills, 1983; Koller and Exon, 1986). Selenium deficiency occurs in cattle consuming food grown on soils lower than 5 mg Se/kg DM or feedstuffs lower than 0.05 mg Se/kg DM. Furthermore Se deficiency arises from soils high in antagonistic elements (eg. Mo), or addition of high sulphate in fertilisers, which impede absorption of Se by plants (McCaughan, 1992).

Vitamins

The microbial degradation of vitamin A in ruminal fluid is influenced to a high degree by the diet. Investigations showed that vitamin A is degraded faster and more extensively when incubated *in vitro* with ruminal fluid from cattle fed high concentrate (C) than in fluid of cattle with hay (H) or straw (S) diets (Rode et al., 1990). Estimated effective ruminal degradations of biologically active vitamin A were 67%, 16% and 19% for cattle fed C, H and S diets, respectively. The results imply that cattle fed high-concentrate diets will have considerably greater vitamin A requirements than those fed high-forage diets.

Vitamin E deficiency in cattle occurs if alpha-tocopherol content is lower than 0.7 mg/kg DM or if diets are supplemented with polyunsaturated fatty acids or rancid fats. Some grain preservatives rapidly destroy vitamin E (McCaughan, 1992). Although Se and vitamin E have separate functions, they are complementary and act synergistically in metabolic processes. Diets low in vitamin E increase the requirements for Se and vice versa. However, there is a limit to the extent to which vitamin E can substitute for Se, following which only supplementary Se is effective (Rickaby, 1980).

Vitamin E supply above the requirements has been reported to increase the antioxidative potential of cattle and contribute to an enhancement of the immune response (Nockels et al., 1993; McDowell et al., 1996). The immune stimulating effect is seen in relation to the metabolism synthesis of arachidonic acid which influences the synthesis of prostaglandin and thereby improves cellular immunity (McDowell et al., 1996).

It is unlikely that changes in fat-soluble vitamin intakes will directly affect production in beef cattle herds. However, vitamins A, D and E, and beta-carotene intakes may influence disease resistance (Herdt and Stowe, 1991).

The requirements of beef cattle for B-vitamins in general are satisfied by a diet rich in fibrous feedstuffs and the development of normal microflora in the rumen. Feeding high-concentrate diets can induce an insufficient supply with vitamin B_1 or niacin (Kolb et al., 1999). A lack of vitamin B_1 with the risk of cerebrocortical necrosis occurs especially when there is a high growth of bacteria rich in thiaminase. All B-vitamins are necessary for the cell regeneration, the rapid multiplication of the immune cells and for the synthesis of antibodies.

7.3.5. Undesirable substances in feedstuffs

Due to the contamination of grass, forage crops and grains with fungi during growth, conservation process, storage or feeding, mycotoxins can be high. The extent of the mycotoxin burden in forage cannot be overseen at the present moment due to the few data available (Oldenburg, 1999). The real burden with mycotoxins in the feeding rations of cattle and the consequences for animal health of cattle are difficult to estimate (Wolff, 1999).

Fusarium belong to the most relevant mould fungi which are found on maize especially in the last 4 to 6 weeks before being ripe for ensiling (Oldenburg, 1993). While *fusarium* cannot survive under the anaerobic conditions during the process of ensiling, the toxins already synthesised remain active (Auerbach and Geissler, 1992). In field investigations, high concentrations of zearalenone in ensiled maize (and maize products) were found in four out of 33 cases (Drochner et al., 1984). A few samples with a considerable value for zearalenone were also detected in hay. Additionally, grass and hay can be contaminated with ergotamine from *Claviceps purpurea* (Landes, 1996).

The occurrences of trichothecene and zearalenone in grains in Europe are listed by Eriksen and Alexander (1998). Contaminated cereals can be easily cleaned and the burden of mycotoxins is markedly reduced. Mycotoxins can impair animal health and performance (Scudamore et al., 1998). However ruminants are less sensitive to mycotoxins as most of them are degraded in the rumen to non-toxic metabolites (Oldenburg, 1995).

Metabolic disorders can occur due to excessive feeding of by products, unhygienic feedstuffs, feedstuffs rich in fat, starch and sugar, leading to disturbances in the fore stomachs when thresholds are ignored (Kamphues, 1998). Silages with obvious deviations in nutrient contents are characterised by high contents of crude ash partly as well by relatively wide ratios between Ca- and P-levels (sugar beet leaves, green rape). Excessive intake of digestible nitrogen compounds such as urea and corn legumes can cause metabolic alkalosis, going along with hyperammonaemia and limited Mg absorption, thus decreasing significantly the Mg content of the blood plasma (Jagos et al., 1985). Hyperammoniemia is also associated with disorders in glucose metabolism (Spires and Clarke, 1979; Fernandez et al., 1988) resulting from an under-utilisation of glucose by insulin-sensitive tissues and leading to a decrease in growth rate. Excess ammonia decreases the capacity of hepatocytes to utilise propionate for oxidation and gluconeogenesis (Overton et al., 1999).

7.3.6.   Conclusions

1. Improper feeding can affect the welfare, including the health, of fattening cattle.

2. Energy and protein supply and the provision of fibre and water are the major nutritional factors determining the growth, feed efficiency and body composition of beef cattle. In addition, the supply of minerals, trace elements and vitamins are important to ensure undisturbed growth. Nutritional requirements for beef cattle are well described in the literature.

3. In roughage based feeding regimes, bloat can occur when the percentage of legumes in the diet is high and when cattle are not adapted to digest those legumes.

4. Shortages in water supply and in feed, as well as poor quality water and feed can be the cause of severe stress for the animals and result in various metabolic disorders.

5. Rumen and metabolic acidosis is a severe stress for beef cattle. The occurrence of acidosis is closely related to feeding regimes that are based on a high proportion of concentrates combined with a low intake of structured crude fibre.

6. The proportion of roughage that is necessary to exclude the incidence of clinical and subclinical acidosis depends on the specific feedstuffs as well as the content and the structure of crude fibre in the diet. There are methodological difficulties in the assessment of the level of minimum requirements for beef cattle in relation to structured crude fibre. However, it seems that a minimum of 10% long fibre roughage dry matter in the diet is required to avoid pathological conditions and poor welfare.

7. Deficits in the supply of minerals and vitamin D to beef cattle undergoing rapid growth due to intensive feeding can cause skeletal lesions, especially when housing conditions are poor.

8. Specific substances in the diet such as mycotoxins can lead to health problems.

7.4. Grouping of Animals

7.4.1. Group size

Small group size contributes to social stability (Albright, 1991) and in the long term in such groups less aggression occurs observed than in large groups (Kondo et al., 1989). This may be caused by the animals having greater difficulty in individual recognition as group size increases. However, if a large space is available this can be overcame by the formation of smaller subgroups (Phillips, 1993). See also section 5.3.2.

7.4.2. Mixing of groups

Mixing leads to an increase in aggression as a new hierarchy has to be established (Bouissou et al., 2001). In bulls, and to a lesser extent in steers, the increased aggression is accompanied by an increase in homosexual mounting (Mohan Raj et al., 1991). Gradually, overt aggression decreases and is replaced by more subtle interaction, such as threats and avoidances (Tennessen et al., 1975). From a health perspective, mixing of animals has disadvantages compared to all-in all-out systems as this may prolong disease outbreaks and increase the exposure to pathogens.

7.4.3. Buller steer syndrome

In the USA and Canada, approximately 2% of feedlot steers are buller steers that are mounted by other steers (Houpt, 1998). This occurred more often in steers that have been implanted with stilbestrol or oestrogen (Houpt, 1998). There is a large component of dominance-related aggression in the buller syndrome. Penile erection and anal intromission rarely occur. The most aggressive animals mount more often than the others, and the rate of mounting increases dramatically when new steers are introduced in the group (Klemm et al., 1983). The syndrome is seen most frequently when groups of animals are mixed, especially in crowded conditions. The economic losses resulting from the syndrome are due to the increased activity of the mounting steers and the harassment of the buller steers as none of the animals will gain weight as they should (Irwin et al., 1979). The usual mean of treating bulling behaviour is to remove the buller steers involved. However, electrified wire placed above the pens, so that a steer that mount would be shocked, is sometimes used to reduce the incidence of the behaviour (Kenny and Tarrant, 1987).

7.4.4. Conclusions

1. High frequencies of social disturbances are observed when the animals are mixed.

2. Steers implanted with oestrogens have a higher social and sexual activity.

3. Electrified grids above the animals are sometimes used for curbing the mounting activities of bulls at high stocking densities but probably cause disturbance to the animals.

7.5. Weaning

7.5.1. Weaning consequences

Without human interference, weaning and in particular the separation from the mother is a very slow process. Weaning as a management routine usually involves an abrupt separation of the calf from its mother. In dairy cattle that separation from the mother is carried out soon after birth or some days later. The calves are then fed with milk for 4 to 12 weeks. In suckling cattle the separation usually occurs when the calves are 6 to 9 months old.

As well as the stress of weaning, this period is difficult for the calves because of other events that often take place around the same time. These include: 1. separation from the mother and the peers, 2. transport/marketing, 3. mixing with new animals, 4. changes in diet (from grass and milk to conserved feed with or without concentrates), 5. change of environment (outdoors to indoors), and 6, in some cases, dehorning and castration.

At weaning it is recommended that calves be removed from the dams and kept out of sight and sound of one another (Thomas, 1986). They should be provided with fresh, clean water. If calves have been creep fed, they should continue receive concentrate during the weaning period.

Calves should be offered either rations to which they are already accustomed or rations that they can rapidly learn to eat (Thomas, 1986). High-quality grass or grass-legume hay, or corn silage, should be offered along with a small portion of grain and supplement. The aim is to nourish them with energy and protein as quickly as possible to reduce nutritional stress. High levels of antibiotics, antibiotic sulpha-drug combinations or commercial stress supplements containing these drugs are available in the USA. However, as there is a major concern in EU about development of bacterial resistance to antibiotics, this type of treatment is under question.

Gradual changes from one feeding programme to another reduce stress and digestive problems (Thomas, 1986). Concentrate should be fed at the rate of 1 kg per 100 kg of body weight. Silage or hay should be fed ad libitum, whereas 0.9 to 1.4 kg of concentrate should be given for the first few days until one is assured that all calves are eating (Thomas, 1986). Silage should be removed within 24 h of provision. Feeding the calves small amounts several times a day is desirable as it keeps the feed fresh and encourages the calves to eat.

After weaning the calves are distressed for some days (Veissier et al., 1989a) as are the cows. The calves also show a different ability, perhaps improved, to cope with new events (Veissier et al., 1989b). They are also more able to develop new relationship with their peers (Veissier and Le Neindre, 1989) and even with humans (Boivin et al., 1992).

7.5.2. Early weaning of suckled calves

In some circumstances farmers running suckler herds practise early weaning at about 2 to 3 months of age, especially in the USA. Thomas (1986) has listed the conditions which make early weaning economically desirable. However, most of these are associated with poor welfare of mothers or calves.

Careful management is needed to rear early-weaned calves.

A weaned calf usually consumes about 2% (Drennan et al 1994; Fallon and Drennan 1998) to 3% (Thomas, 1986) of its body weight in feed each day. By the time the calf weighs 136 kg, it eats approximately 3.6-4.1 kg per day of a ration that is 50% roughage (Thomas, 1986). Calves weaned early are fed in a way that is opposite to that of feedlot cattle. They must first be given high concentrate, then later be switched to higher levels of roughage as their rumen capacity increases with size (Thomas, 1986).

In one study beef calves weaned at 2 or 4 weeks were compared with calves weaned at 7 months (control), and cow-calf pairs or cows with twins were used (Posey and Smart, 1976). Control calves and calves weaned at 4 weeks had similar weights at 205 days (190 kg vs. 188 kg). Twin calves left as singles with the cow and twins weaned at 4 weeks were heavier at 205 days than twins that were both left with the cow (respectively 180, 199 and 135 kg).

In calves weaned at 12 weeks of age, where half of the calves had access to a stand of cow peas and the other half only the pasture, there were no significant differences in weight gain until 30 weeks of age (Poli et al., 1976). Calves weighing at least 90 kg at weaning (12 weeks) gained weight satisfactorily to 30 weeks, whereas those who weighed less did not (Poli et al., 1976).

Early weaned (67 days) Aberdeen-Angus and Polled Hereford calves fed either a concentrate mix on pasture or a complete diet in dry lots until approximately 230 days of age gained faster from the time of early weaning until the time of normal weaning and weighed more than normal-weaned calves (Neville and McCormick, 1981). The average daily gains and weights at the time of normal weaning were higher for early-weaned calves in dry lots than for those calves on pasture, and higher for early-weaned calves on pasture than for normal-weaned calves (Neville and McCormick, 1981).

7.5.3. Preconditioning

The preparation of a calf that has been nursed by its mother and that is destined for the feedlot to withstand the stresses associated with shipping and to adapt to an intensive feeding environment is called preconditioning. This is practised both in the USA and some countries within EU. Preconditioning involves a complete health management program. Thomas (1986) list the following requirements for a preconditioning programme in the USA in order to adapt to the harsh environment of the feed lot.

1) Calves should be weaned at least 30 days prior to sale.

2) All calves must be castrated and dehorned no less than 3-4 weeks prior to sale.

3) All calves must be accustomed to drinking from troughs and eating from feed troughs 30 days prior to sale or shipment, which ensures adaptation to feedlot rations and environment, and results in heavier calves. If calves are to eat all at once, 46-56 cm of trough space should be provided.

4) Most preconditioning programmes require calves to be vaccinated for the following diseases 3 weeks prior to shipping: IBR (Infectious Bovine Rhinotracheitis), PI3 (Parainfluenza-3), BVD (Bovine viral diarrhoea), BRSV (Bovine Respiratory Syncytial Virus), Clostridial infections. Vaccination may sometimes also be demanded for *Hemophilus somnus* infection, pasteurellosis and leptospirosis.

5) Preconditioned calves must receive treatment for ectoparasites and lice. Worming is not mandatory in most preconditioning programmes.

6) All calves must be in the owner´s possession for at least 60 days prior to sale.

7) Most states in the USA require individual identification of each preconditioned calf and written certification of the practices involved in preconditioning. (see Thomas, 1986, p. 169). Within the EU there are specific rules about individual identification of all cattle (Commission Decision 92/102/EEC).

7.5.4. Effect of different post weaning management on weight gain

Several studies have investigated the effect of improved weaning procedures to increase weight gain. In one study male beef calves were weaned at 7-9 months of age and allocated to either 1) yard weaning with hay or silage, 2) yard weaning with hay or silage plus a novel handling procedure to train the cattle to be able to find a grain ration in a trough, or 3) paddock weaning

without supplement or handling, according to common industry practice (Fell et al., 1998). One to two months prior to entry into a large commercial feedlot experimental vaccines against the major bovine respiratory disease (BRD) pathogens were given to half of each group. The yard-weaned and yard-trained cattle had a significantly higher weight gain in the first month and over the 90-day feeding period than the paddock-weaned control groups. Animals from the yard-trained groups were not significantly different from the yard-weaned ones. Vaccination also significantly improved weight gain in the first month and over 90 days. The combination of yard-weaning and vaccination produced the highest weight gains (Fell et al., 1998).

Japanese Black calves weaned at 3 months were given oral doses of granules of rumen-protected tryptophan, and they had a significantly higher average daily weight gain in one of two experiments (Nakanishi et al., 1998). The tryptophan-fed calves spent significantly more time lying down and eating, and performed less agonistic interactions, social investigation, vocalisation, play and mounting (Nakanishi et al., 1998). It was concluded that oral administration of tryptophan appears to have a sedative effect on agonistic behaviour, which may lead to higher feed utilisation. Wood et al. (1973) found that beef calves given a ration containing chlortetracycline and sulphadimidine made a greater weight gain than calves given other treatments during the first 30 days after weaning.

Age at weaning influenced the weight gain. Arguelles and Leiva (1978) found that calves weaned at 6, 7 or 8 months of age had a mean daily post-weaning gain until 18 months of 0.29, 0.29 and 0.32 kg respectively ($p<0.01$).

Richardson et al. (1978) found that differences in weight gain between beef calves of high and low-yielding cows persisted for 5 months after weaning, whereas differences in weight gain due to solid feed increased slightly for 6 weeks after weaning than decreased.

7.5.5.   Effect of different post- weaning management on health

Light calves at weaning were found to have a higher mortality than heavier ones (ITEB, 1983). There was consistently lower morbidity in calves weaned in yards with hay or silage than in calves weaned in paddocks without supplements or handling (Fell et al., 1998). The morbidity in calves weaned in yards with hay or silage and a novel handling procedure to train them to find grain in a trough was variable, but overall it was intermediate compared with the other two. Gibb et al. (2000) and Loerch and Fluharty (2000) found no beneficial health effect of the presence of trainer animals in newly arrived feedlot calves though the latter text reports that trainers improved the eating behaviour of the calves.

The period around weaning is a dangerous time for disease transmission and susceptibility. Wood et al. (1973) showed that the medicated ration of chlortetracycline and sulphadimidine and antibacterial-antiviral serum, either alone or in combination, were effective in preventing acute respiratory tract diseases in beef calves after weaning. In a study on 15 range cow-calf beef herds it was found that most calves (83%) and all herds (100%) had been exposed to *E.coli* O157, and that *E.coli* O157:H7 infection was widespread before weaning and entry into feedlots (Laegreid et al., 1999).

7.5.6.   Effect of weaning on cow-calf attachment

Suckler calves weaned abruptly from their dams were tested for their attraction to its dam, a familiar calf or a familiar cow at different times after weaning (Veissier et al., 1990). Calves showed a preference for its dam to another cow up to day 24, and to a calf up to day 9. From day 20 after weaning, cows rejected their calves when suckling was attempted.

7.5.7.   Conclusions

1.   Beef cattle, both calves and cows, are stressed at weaning because of the many changes to which they are subjected.

2.   Preconditioning is practised to prepare the calf that has been suckling its mother to withstand the stresses associated with shipping and adapting to a feed lot environment.

3.   How weaning is carried out may have an impact on weight gain and health for several months after weaning.

4.   Early weaning demands a more careful management of the calf than late weaning.

7.6. Human-animal interaction

7.6.1. Human-cattle interactions in the modern husbandry system.

The number of animals per stockman has significantly increased in recent decades and consequently the time spent by humans with each animal has decreased. In addition, rapid handling procedures and mechanisation has been encouraged.

Automatic feeding with limited human contact has more and more replaced feeding the young by the farmer. Indeed, human-animal interactions can sometimes be limited to husbandry or veterinary treatments that are at least neutral but also often aversive (Rushen et al., 1999).

Modern husbandry techniques mean that there are less human–animal contacts (Boivin et al., 1998). Moreover change in housing has occurred, especially during wintertime. In the past in Europe, cattle were traditionally tethered and many human contacts were provided. Nowadays more and more animals live free in loose stable or outdoors with limited human contacts.

The changes in husbandry practices described above have acted to decrease the animals' familiarity to humans and to increase their perception of humans as a potential danger. In these situations, antipredatory strategies such flight or fight are typically observed during handling. Moreover, isolation or separation from the herd is often enforced during handling and are strong sources of stress and enhance defensive reactions. When trying to escape, animals can hurt themselves, the other animals and their handlers (Grandin and Deesing, 1998, Le Neindre et al., 1996). Husbandry systems that lead to increased fear, injuries and sometimes death should be avoided.

7.6.2. Factors influencing the stress reaction during handling.

Handling devices are valuable for limiting the stress of the animals (Grandin, 1997) (see section 4.3). Such devices should be thought to reduce the fearfulness of the handling facilities, the isolation stress, and the duration of handling. They should be adapted to the types of animals (calves, adults) and to their temperament (more or less tame). Habituation to such devices in the absence of any negative experience (e.g. painful veterinary treatment) reduces animal stress during handling and is reinforced by providing feed after the handling (Hutson *et*

al., 1985). On the other hand, aversive handling experience can have a very detrimental long lasting effect (Hemsworth and Coleman, 1998).

Human physical cues during handling are key factors stimulating the animal reactions to humans. Cattle are able to discriminate their familiar handler from an unfamiliar one (Boivin et al., 1998). However only visual cues have been examined in detail. Cattle seem able to recognise the familiar caretaker wearing unusual clothes (Boivin et al., 1998) and to discriminate people wearing the same clothes (Taylor and Davis, 1998). They are also able to learn easily the colour of the clothes worn by the caretakers during aversive handling (Rushen et al., 1999). For these authors, it was important to clearly identify the human with special visual cues during aversive handling so as not to generalise the fear induced for the animals during this handling to other more usual handling.

The attitude of the handler towards the animals is an important factor influencing their behaviour. Agitated, nervous or unconfident people are much less efficient with cattle than calm, experienced and confident handlers (Renger, 1975, Seabrook, 1986). According to their attitude towards the animals, people express more or less positive and negative interaction towards the animals (Lensink et al., 2000, Hemsworth et al., 2000). In addition, Lensink (2000) observed a positive relationship not only between a positive attitude towards the animals and a positive behaviour towards them, but also with a positive attitude towards their sanitary state. Both are important for cattle welfare.

There are studies demonstrating the nature of genetic influence on the reaction of cattle to handling (Burrow, 1997; Grandin and Deesing, 1998). Boivin et al. (1994) described also an interaction between genetic and environmental effects. Heifers from different sires were never aggressive towards humans when reared traditionally indoors with many human contacts. In contrast when reared outdoors with little human contact, heifers from some of those sires were often aggressive.

Limited human contact induces fear of humans in cattle (Boissy and Bouissou, 1988; Lensink et al., 2000). Habituation to handling reduces further animal stress during handling and improves docility (Hargreaves and Hutson, 1990; Boivin et al., 1998; Goonewardene et al., 1999).

The type of handling is very important. Gentling and feeding the animals usually have a positive effect on the further relationships with humans (Jago et al., 1999; Lensink et al., 2000). In contrast, negative interaction leads to fear of humans (Rushen et al., 1999). The

balance between positive and negative interactions between humans and cattle is unknown and may depend on the period when the human contact occurs. The period during which the human contacts are given seems critical. In particular, it has been shown that gentle human contact early in life can have a very beneficial effect on the subsequent reactions to humans and handling (Boivin et al., 1992, Krohn et al., 2000). The effect was long lasting and was still observed 18 months after the end of the gentling period (Boivin et al., 1998).

However the maternal environment in early age is probably also a key factor of the development of the human-cattle relationship. Dam reared animals are more fearful than artificially reared animals (Krohn et al., 1999). In addition in beef cattle, the dam often strongly defends her calf. Thus, it is may be necessary to disrupt, at least temporarily, the cow-calf relationship to make human contact more effective (Markowitz et al., 1998, Boivin et al., in press). This separation is used in dairy production with an early and definitive separation between dam and young. This is also traditionally used in beef cattle with twice a day suckling for the calves. However as is described above, the strong tendency at present in cattle husbandry is to leave the dam and the young together or to mechanise feeding, both of which reduce contact during what seems to be a sensitive period for socialisation with humans.

Bateson (1979) proposed that a sensitive period "can represent a time of rapid reorganisation when the developing animal is more easily destabilised by deprivation or environmental insult". Consequently, not only young age but also the time of weaning could be postulated as sensitive periods. In addition such periods involves many contacts between humans and animals. Boivin et al. (1992) observed that human contact during the first few days following weaning appears more efficient and durable than the same procedure performed 6 weeks later. Parturition could also fulfil Bateson's (1979) definition of a sensitive period. Food reinforcement and gentling seems useful in dairy cows to improve the animal reaction towards humans (Hemsworth et al., 1987, 1989). However because of a strong defensive behaviour of the dam during the days often following parturition, such a period may be more difficult to use in beef cows.

However building a positive human-animal relationship does not mean that cattle become so tame that they do not respect humans. Price and Wallach (1990) observed that hand-reared calves in isolation could become aggressive toward humans. In fattening units, it is not recommended to enter the fattening pen because of the risk that a 450 kg bull would "play" with a human. Such behaviours are severe problems for the handler and should be strictly avoided. Lott and Hart (1979) observed Fulani nomads in Africa, living the all day long with

their cattle. They noted that the caretakers not only exchanged positive interaction with their animals but were also very aggressive towards them in cases of animals' threats or attacks, described by the authors as dominance behaviours towards the humans. Lott and Hart (1979) recommended that modern husbandry should be strongly inspired by such traditional methods.

7.6.3.   Conclusions

1. The skill and care of the stockpersons and the way in which they interact with the animals has a considerable influence on the behaviour and welfare of the animals.
2. Correct handling facilities facilitate thorough examination of the animals, improve the welfare of the animals and reduce risks for the handler
3. The tendency in agriculture has been to reduce contact between animals and humans, either by extensive farming or by the use automated systems. This has caused problems for welfare and individual production.
4. The quality of stockmanship has large effects on the welfare of beef cattle in any housing system. A skilful stockperson can compensate for many bad effects of certain housing systems and a poor stockperson causes problems in an otherwise good system.

7.7. Disease management issues

Most beef cattle diseases have a multi-factorial aetiology, meaning that various factors contribute to the occurrence of disease. In addition to pathogens and animal-related conditions, other contributing factors may be considered as stressors in the environment, disturbing homeostasis in the animal (Curtis, 1983; Fisher et al., 1997). Usually there is a dynamic balance between the pathogen burden in the environment and the disease resistance of the animal. Genetic selection over the past decades has focused on the improvement of productivity. Noordhuizen (1999) states that, at the same time, this selection was accompanied by a negative selection in physiological adaptability and immunological responsiveness, which could render the animal more susceptible to stress impact and pathogens. Responses to stressors may be endocrinological, neural, autonomic and behavioural in nature (Moberg, 1985) and may also involve processes relating to health and the immune system (Blecha and Minocha, 1983). The stressors are various, for example ambient temperature (heat stress, cold stress), sun radiation (sun burns), social stress, vaccination, nutritional stressors, housing and climate, conditions, pathogen burden, psychological stress, humans (Curtis, 1983). Stress responses are often detrimental to efficient growth, skeletal integrity and disease resistance (Siegel, 1983). It is not always clear whether the detrimental stress effects on disease resistance are associated with neuroendocrine mediated immune suppression, or with deficiencies and reallocation of nutrients for maintenance processes (Noordhuizen, 1999). Stress conditions may affect food intake and digestibility negatively and change thermoregulatory energy requirements at the expense of energy for growth production (Curtis, 1983). Energy requirements for maintenance sometimes increased by up to 25 % in infected animals indicating that energy was required for processes related to immune function (Kloosterman and Henken, 1987).

At present, it is not possible to assess all aspects of the competence of an animal to adapt to various stressors. Therefore, the main strategy of the stockman to reduce harm for the animal should be to minimise risk factors and to carry out regular checks of animals in order to identify diseased animals at an early stage and to initiate early treatment.

7.7.1. Diagnosis

In beef production the caretaker generally spends only short periods with the animals. Regular man-animal interactions occur mainly during food distribution, which however does not

include a direct contact between stockperson and animals. Observation of the animals is particularly important as problems are likely to be expressed through animal behaviour. Regular, patient and careful observations of the animals are required in order to detect signs of disease at an early stage. The diagnosis of diseases and disorders of fattening cattle can be difficult to carry out for both the farmer and the veterinarian. In order to perform clinical examinations, animals showing disease signs have to be separated from the group and restrained before examination for reasons of thoroughness as well as human safety.

On the other hand, not all disorders show obvious clinical signs. Reduced feed intake and reduced growth of the animals which may indicate disease are difficult to assess without regular weighing, or may only be apparent when the disease process has advanced.

7.7.2. Therapeutic strategies

Drugs used can be divided into those used for prophylactic reasons, for therapeutic reasons and as growth promoters (Blaha, 1996). The prophylactic use of veterinary products usually occurs at stages of the production where there is an increased risk of various diseases, in particular at the beginning of the fattening period. While the prophylactic use of veterinary products may be seen, especially from the farmers' point of view, as a contribution to animal health, it may also serve to conceal deficits in housing conditions and farm management.

With regard to the therapeutic use of veterinary products, misuse occurs, for example, when veterinary products are used in the absence of a specific diagnosis or when all animals are included within a group although only single animals are affected.

Furthermore, products acting as antibiotics[2] have been used as growth promoters and have been fed continuously at low level to control subclinical infections or to decrease the incidence of liver abscesses (Perry, 1995). There is a negative correlation between the level of performance within the herd and the effectiveness of growth promoters indicating that those substances were more efficient in difficult management conditions (Blaha, 1996).

---

[2] see also Opinion of the Scientific Steering Committee on Antimicrobial Resistance - 28 May 1999   http://europa.eu.int/comm/food/fs/sc/ssc/out50_en.html

7.7.3. Conclusion

1. Infectious diseases are important welfare problems. Effective healthcare therefore requires that cattle be kept in appropriate environments. Preventive measures, for example good hygiene and appropriate vaccination regimes, can help avoid infection of herds.

2. Many diseases are multi-factorial. Their development may depend on the husbandry conditions of the cattle. Effective health care therefore requires that cattle are kept in environments which do not cause stress and reduced immunocompetence.

3. Regular inspection by a competent stockperson is important in ensuring good welfare.

4. Additional pens are necessary on farms in order to separate animals and to improve treatment and humane care.

8. FUTURE RESEARCH NEEDS

1. Investigations are needed to develop new methodology for the assessment of structured crude fibre and to determine thresholds for structured crude fibre in feeding rations based on maize silage and on a high portion of concentrate in the diet in order to prevent subclinical and clinical acidosis.

2. There is need for further investigations to assess implications of skeletal lesions in relation to pain and discomfort and to develop assessment systems to evaluate the interactions between fast growth and housing conditions in relation to discomfort.

3. The effect of age on the pain and distress caused by castration and techniques to reduce this suffering should be studied.

4. Epidemiological investigations are needed to study the relationships between risk factors and disease occurrence and to quantify their contribution to disease occurrence.

5. Investigations are needed to assess the time and the facilities necessary for the caretaker for thorough inspection of the animals.

6. Investigations are needed to assess the use of veterinary products for prophylactic and therapeutic reasons.

7. Improved weaning strategies should be developed

8. The optimum group size for beef cattle needs to be determined

9. The minimum light and dark periods for cattle kept in insulated housing or in regions of short daytime needs to be determined.

10. Genetic analysis is needed to determine the traits which can be selected in order to improve welfare.

9. CONCLUSIONS

1. Cattle welfare can be assessed in a scientific way using a combination of methods. These methods include measurements of health, physiology, performance, and behaviour as well as preference tests, aversion tests, measures of motivation and abnormal behaviour.

2. Welfare in existing systems can range from very good to very poor. The system of husbandry used can have a large impact on the welfare of the animals.

3. Good welfare relates not only to the health of the animals but also to the ability to manage interactions with the environment and the existence of good feelings.

4. The scientific assessment of welfare provides evidence on which to base recommendations for adopting or avoiding particular housing and management methods.

5. Very young animals feel pain and show signs of distress, and may feel pain more than adults.

6. Very young animals may show a freezing response to fear and pain, and so may not show a co-ordinated flight response.

7. There is a large variety of climatic and farming conditions throughout the EU Cattle production systems are partly based on the foodstuffs produced on farms. These foodstuffs are very dependent on the climatic conditions and as a consequence, fattening systems are very diverse.

8. Within the EU there are 21.7 million dairy cows and 11.6 million beef cows. These animals are the source of cattle which will be accommodated in fattening units.

9. In 1999 the number of beef cattle fattened and slaughtered in the EU was 4.8 million heifers, 8.1 million bulls and 2.5 million steers.

10. Large numbers of movements of live animals occur between countries.

11. The diversity of beef fattening systems in the EU is influenced by the different cattle breeds. These breeds may be dairy (primary output milk), dual purpose (produce milk and beef), or beef (primary output beef). The EU dairy herd is dominated by the Friesian/Holstein breed. In contrast, the EU beef herd is very diverse with late maturing beef breeds (eg. Charolais, Limousin and Blonde d'Aquitane) as the predominant breeds in France. The beef herds in UK and Ireland largely consist of cross bred cows mated to late maturing beef breeds while beef breeds in Spain are predominantly local (rustic) breeds.

12. In mainland Europe the majority of male animals are fattened as young bulls. In the UK and Ireland the majority of male animals are castrated and are fattened as steers.

13. In mainland Europe the majority of young bulls are offered a fattening diet based on maize silage plus concentrate. The duration of the fattening period varies with the type of

animal and ranges from 120 to 250 days. The bulls from the dairy herd are slaughtered at 12 to 14 months of age. The bulls from the beef herd (weaned at 6 to 8 months) are slaughtered at 12 to 16 months of age. The demands of the market (carcass weight and conformation) determines the duration of feeding.

14. In Ireland, UK and north western France where the males are fattened as steers, many of the animals are fattened off grass at 20 to 30 months of age and others are fattened indoors for their final 5 months on a grass silage plus concentrate diet. Heifers surplus to breeding requirement can be fattened in intensive units or fattened off pasture at approximately 20 months of age.

15. Beef production in the USA is based mainly on steers and heifers from the suckling herds. Those animals are finished in feedlots with high energy diets. This farming system is very different to systems used in the EU.

16. Cattle production in the eastern European countries has declined in recent years.

17. There are a number of housing type options for fattening cattle including loose housing and tie up stalls. It appears that the vast majority of housed fattening cattle are accommodated in loose houses with slatted floors.

18. Regulations on organic farming set a minimum indoor space requirement of 5m² for animals weighing over 350 kg, with a minimum of 1m² per 100 kg for animals over 500 kg.

19. The appropriate size of tie-stalls and cubicles is dependent on the size of animal.

20. The surface recommended for littered loose houses or partially loose house is around 6 m² for 600 kg bulls and slightly lower for littered house with concreted feeding stand (6 to 4.5m²).

21. Various studies have produced recommendations for slatted floor space allowance eg. 2.2 to 2.5m^2/animal for cattle in the 550 to 650 kg liveweight range. These studies have been largely based on production considerations.

22. Feeding trough space allowances for loose housed fattening cattle are in the range of 0.6 to 0.7 m per animal.

23. Several types of handling equipment are in use depending partly on the type of animals for which they are used. The type of handling facility will depend on the size of the fattening unit and the tameness of the animals.

24. Cattle have well developed senses and learning abilities. Although signs of pain may be less obvious in cattle than in other species, cattle have the ability to feel pain and neural mechanisms of pain perception seem to be similar in cattle and other animals, and humans.

25. Cattle are highly social animals. Groups of cattle have a social hierarchy that determines priority of access to resources. Once established, the hierarchy tends to be stable and reduces fighting. Mixing of animals and housing animals in very large groups may disrupt the hierarchy and increase aggression.

26. Cows form long-lasting bonds with their calves when allowed to do so. During natural conditions, weaning is a very slow and gradual process stretching over several months.

27. Age at puberty depends on several factors, breed being important. Mounting may occur as a play behaviour well before puberty.

28. Cattle are ruminant herbivores and although they can browse, cattle are mainly grazers. Cattle usually spend a long time grazing every day and show a distinct grazing pattern with maximum grazing activity around sunrise and sunset.

29. Rumination may account for a substantial part of cattle activity. Rumination is under voluntary control and when animals are disturbed they cease to ruminate.

30. In most situations cattle drink several times a day, more in hot conditions.

31. Cattle roam over extensive areas, and show a strong motivation to move. They also lie down for long periods.

32. Animals can cope successfully only within a range of temperatures and humidity. They are negatively affected when noxious gas levels are high. Insulation of buildings is an option which is used when the animals are housed on slatted floors and the outside temperature is very cold. As the volume allowances in such buildings is often low, a monitoring of the microclimatic environment and efficient ventilation devices are required.

34. Tethered cattle have limited movement possibilities and cannot walk. Their social interaction is limited to their neighbours. Short tethers, low space and concrete floors are among the different factors limiting the comfort of these animals. Tethered animals have more leg problems than those on straw bedding. Hoof trimming is necessary for cattle tethered for long periods or those on excessively soft surfaces.

35. A low space allowance increases aggression between animals especially among males. An increased occurrence of aggressive behaviour is also observed when the trough space is limited.

36. Disturbances in the lying behaviour of animals are observed when the space allowance per animal is low.

37. Diseases such as respiratory diseases are observed when the air volume or space allowance per animal is low.

38. Daily gain seems to be less when the space per animal is lower than 4.7m².

39. The type of floor has important consequences for the welfare of the animals. When they have the opportunity, animals choose straw bedded areas for lying down in preference to slatted floors.

40. Among the different types of bedding, lower mortality is observed in animals with at least some straw bedding and higher mortality in animals on completely slatted floors.

41. Animals on sloped straw bedded areas have a higher incidence of lameness than animals kept on slatted floors.

42. Tail tip necrosis occurs much more often on slatted floors than on other type of housing.

43. The slat surface must not be slippery to avoid falling which increases the risk of health problems.

44. Beef cattle kept on concrete slatted floors have an increased incidence of abnormal postures, lesions to the carpal joint and to the tail, and may show behavioural changes.

45. Increasing floor space allowance for animals on slatted floors improves growth rate and feed conversion ratio.

46. Castration causes severe pain and distress. According to some studies surgical castration seems to be less acceptable from a welfare point of view than Burdizzo or rubber rings. Local anaesthesia or local anaesthetic plus systemic analgesia act to reduce the pain.

47. Castration, where it has to be carried out is probably best done using a combination of Burdizzo and rubber rings, as in lambs

48. Spaying is likely to cause severe pain and distress and there is no indication for it.

49. Tail docking is likely to cause pain and interfere with the normal behaviour of the animal.

50. Dehorning by any amputation method causes severe pain and distress. Local anaesthesia and systemic analgesia can reduce, in the short term, the pain caused by dehorning.

51. Disbudding of young calves may be more acceptable than dehorning from a welfare point of view and does not cause as much pain as dehorning older animals.

52. Hot branding causes more pain than freeze branding.

53. The pain and distress caused by surgical mutilations are likely to be at least as painful in young as in older animals.

54. A large genetic variability in several traits is observed in cattle.

55. Beef breeds have been selected for a high meat production. These breeds are often associated with a hypermuscularity which can cause leg disorders, increase calving difficulties and decrease cow longevity.

56. Among hypermuscular animals, the homozygous carriers of myotrophin defective gene, or double muscled animals, need much more care due to their higher susceptibility to stress. A high proportion of caesareans are carried out in these animals.

57. Health parameters, in particular lameness, are genetically dependent.

58. Cattle from some breeds have a higher social activity than others.

59. Reaction to handling is genetically dependant.

60. Naturally polled breeds exist. The use of naturally polled breeds avoids the need to disbud animals.

61. Improper feeding can affect the welfare, including the health, of fattening cattle.

62. Energy and protein supply and the provision of fibre and water are the major nutritional factors determining the growth, feed efficiency and body composition of beef cattle. In addition, the supply of minerals, trace elements and vitamins are important to ensure undisturbed growth. Nutritional requirements for beef cattle are well described in the literature.

63. In roughage based feeding regimes, bloat can occur when the percentage of legumes in the diet is high and when cattle are not adapted to digest those legumes.

64. Shortages in water supply and in feed, as well as poor quality water and feed can be the cause of severe stress for the animals and result in various metabolic disorders.

65. Rumen and metabolic acidosis is a severe stress for beef cattle. The occurrence of acidosis is closely related to feeding regimes that are based on a high proportion of concentrates combined with a low intake of structured crude fibre.

66. The proportion of roughage that is necessary to exclude the incidence of clinical and subclinical acidosis depends on the specific feedstuffs as well as the content and the structure of crude fibre in the diet. There are methodological difficulties in the assessment of the level of minimum requirements for beef cattle in relation to structured crude fibre. However, it seems that a minimum of 10% long fibre roughage dry matter in the diet is required to avoid pathological conditions and poor welfare.

67. Deficits in the supply of minerals and vitamin D to beef cattle undergoing rapid growth due to intensive feeding can cause skeletal lesions, especially when housing conditions are poor.

68. Specific substances in the diet such as mycotoxins can lead to health problems.

69. Improper feeding can affect the welfare, including the health, of fattening cattle. High frequencies of social disturbances are observed when the animals are mixed.

70. Steers implanted with oestrogens have a higher social and sexual activity.

71. Electrified grids above the animals are sometimes used for curbing the mounting activities of bulls at high stocking densities but probably cause disturbance to the animals.

72. Beef cattle, both calves and cows, are stressed at weaning because of the many changes to which they are subjected.

73. Preconditioning is practised to prepare the calf that has been suckling its mother to withstand the stresses associated with shipping and adapting to a feed lot environment.

74. How weaning is carried out may have an impact on weight gain and health for several months after weaning.

75. Early weaning demands a more careful management of the calf than late weaning.

76. The skill and care of the stockman and the way in which he interacts with the animals has a considerable influence on the behaviour and welfare of the animals.

77. Correct handling facilities facilitate thorough examination of the animals, improve the welfare of the animals and reduce risks for the handler.

78. The tendency in agriculture has been to reduce contact between animals and humans, either by extensive farming or by the use automated systems. This has caused problems for welfare and individual production.

79. The quality of stockmanship has large effects on the welfare of beef cattle in any housing system. A skilful stockman can compensate for many bad effects of certain housing systems and a poor stockman causes problems in an otherwise good system.

80. Stockmen play a critical primary role in promoting the welfare, including health, of cattle in their care and provide essential early disease surveillance.

81. Infectious diseases are important welfare problems. Effective healthcare therefore requires that cattle are kept in appropriate environments. Preventive measures, for example good hygiene and appropriate vaccination regimes, can help avoid infection of herds.

82. Many diseases are multi-factorial. Their development may depend on the husbandry conditions of the cattle. Effective health care therefore requires that cattle are kept in environments which do not cause stress and reduced immunocompetence.

83. Regular inspection by a competent stockperson is important in ensuring good welfare.

84. Additional pens are necessary on farms in order to separate animals and to improve treatment and humane care.

10. RECOMMENDATIONS

Beef production is a major agricultural industry in the European community and is found in all European countries. The production systems are very different between countries. In particular they vary from very intensive indoor fattening systems to extensive outdoor production. However even if all the technical solutions are not possible in every country it is possible to recommend general measures to protect the welfare of the animals. These recommendations can be divided into those dealing with training, housing, feeding management, breeding, mutilations and weaning. The Committee is aware that these recommendations may have far reaching socio-economic consequences. However, these aspects have not been taken into account when drawing up these recommendations.

A. Training

1. Persons responsible for cattle should ensure that the welfare of the animals, including their health, is safeguarded by the use of appropriate techniques. Every person who is in charge of fattening cattle should be licensed for this occupation. Such licensing should follow proper training and certification of competence.

B. Housing

2. Cattle kept for beef production should not be tethered. Tethering increases the risk of health problems in the animals and limits their behavioural activities and social life. Exceptions could include temporary situations such as feeding or veterinary treatment. In this event particular care should be taken in the design and usage of the tethering system and the duration of tethering should be kept to a minimum.

3. Group housing should be used wherever possible.

4. The slope of the floor should not be too steep. The maximum slope should be 10% as steeper slopes may result in increased leg problems.

5. Fully slatted concrete or wooden floors should not be used. Particular attention to the type of slats should be given to avoid slipperiness. The gaps between the slats should not be so wide as to cause foot injuries, for example when claws become trapped. Slatted pens should only be used for animals of the size for which they were designed. A solid lying area with bedding is recommended although the use of rubberised slats may also provide for the animals' needs.

6. Animals should be provided with adequate floor space in order to limit health problems and to ensure that the animals are not disturbed when lying. Increasing available floor space has been shown to improve animal welfare. For 500 kg animals these improvements are significant in the higher density ranges (1.5-3m² per animal) but have been little studied above 4m². The minimum space allowance should be 3m² for an animal expected to reach 500 kg plus or minus 0.5m² for each 100 kg difference expected between 400 kg and 800 kg.

7.   Handling and restraining facilities should be available in each unit. New handling facilities should be tested and approved.

8.   A sufficient number of separate pens should be available to accommodate sick animals.

9.   Insulated buildings should be equipped with an appropriate ventilation system linked to a system for monitoring the microclimatic conditions in the building. Temperatures in such buildings should generally be maintained higher than 0°C but fully acclimatised animals will tolerate much lower temperatures. The maximum temperatures should be lower then 30°C when the relative humidity exceeds 80%. Levels of noxious gases should be kept as low as possible. The maximum ammonia concentration should be 10 ppm.

10.   Animals should not be kept in constant darkness or in constant light. A daily light-dark cycle should be provided sufficient to allow normal activity for the animals and to facilitate proper inspection of the animals.

11.   To minimise competition when *ad libitum* feeding is not practised, each animal should have access to the feeding trough at the same time. Simultaneous access to a feeding area for animals receiving *ad libitum* feeding is not necessary, but is desirable.

12.   When animals are kept outside, they should have appropriate shelter against adverse climatic conditions such as cold, rain, wind and sun.

C.   Feeding

13.   The specific nutritional requirements of the animals should be met to ensure good welfare, including good health. Good quality water should be freely available.

14.   A sufficient daily amount of long fibre should be given to the animals to ensure normal rumen function and to fulfil the need for foraging behaviour. This is especially important where the diet is concentrate based or low fibre maize silage. A minimum of 10% of long fibre foodstuff should be provided.

15.   In order to prevent bloat, high clover content in the diet should be avoided and a sufficient portion of structured roughage should be offered.

16.   Animals should not be underfed so that they lose weight. Particular attention should be paid to the animals kept outdoors which may have increased nutritional need for maintenance.

D.   Management

17.   Mixing of animals during the fattening period should be avoided in order to limit the risk of injuries due to increased fighting.

18. Little specific information is available on maximum group size. However, it appears that the size of the group should be limited to around 40 animals. Above that level, animals may have problems in establishing a stable social structure, making fighting more likely.

19. A good relationship between the handler and the animals should be promoted in order to limit the handling stress for the animal and the risk of injury for the handler.

20. In order to minimise disease in cattle, they should be kept in environments which do not cause stress and reduced immuno-competence.

21. Each animal should be inspected at least once daily. This inspection should be sufficient to detect lameness or other disease conditions. If any abnormality is detected, the animal should receive appropriate treatment as soon as possible.

22. The availability and quality of feed and water supplies should be checked at least daily.

23. Buildings and equipment should be checked regularly to ensure functionality and thereby avoid risk to animals.

E. Breeding

24. When producing animals for the beef herd, the selection index should include as a high priority, qualities which will improve the welfare of animals.

25. Selection for high docility should be promoted.

26. Selection for improved musculo-skeletal factors which can reduce lamenesses should be encouraged. Selection for high body weight or fast growth is acceptable only if welfare is not decreased.

27. Easy calving qualities should be promoted in beef breeds.

28. Animals bearing mutations which lead to welfare problems should not be selected for breeding. Homozygous double muscled animals have a wide range of problems and should not be used in beef production. The use of heterozygous animals bearing the double muscling gene would still entail welfare problems in the stock of parental homozygous animals.

29. The selection of naturally polled animals should be encouraged as this avoids the need for disbudding or dehorning.

F Mutilations

30. As a general rule, mutilations should be avoided and their negative effects minimised as much as possible.

31.   Animals should always be provided with some form of analgesia at the time of surgical mutilations for procedures like docking, dehorning and castration (e.g. local anaesthetic), and for two days or so thereafter (e.g. a non-steroidal anti-inflammatory drug).

32.   If performed, castration should be carried out in animals at as young an age as possible and ideally not in animals aged over six months. Effective techniques to alleviate the pain and distress caused by castration should be used.

33.   Spaying should not be carried out in females of any age.

34.   As a general rule, dehorning should not be performed. If dehorning has to be carried out, however, systemic analgesia and local anaesthesia should be provided by a veterinary surgeon.

36.   Disbudding of young calves is much more acceptable than dehorning from a welfare point of view. The use of caustic substances for this purpose is not acceptable.

37.   Tail docking is not acceptable as a method to prevent tail tip necrosis or for any other non-therapeutic purpose. Tail tip necrosis should be prevented by avoiding overcrowding, by improving bedding and by avoiding slats in the lying area.

38.   Hot branding should not be used.

G.   Weaning

39.   Specific care should be given to the newly weaned suckling calves. They should be kept in groups of familiar animals to avoid fighting and cross-contamination. If some mixing is necessary, and in order to minimise disease, the environment should minimise stress and appropriate treatments should be given. Weaning should be carried out so that stress is minimal in both cows and calves.

40.   Routine early weaning of suckled beef calves (2-3 months) should be avoided, as this can have a negative impact on health of the calves. Weaning at 6 to 9 months is recommended.

41.   Calves should be encouraged to eat some solid feed at an early age and especially in the four-week period prior to weaning at 6 to 9 months of age.

42.   Preconditioning should be carried out on calves before transportation to new environments

11. REFERENCES

Acosta, J. E., Schale, L. M., Brown, G. C., Vermedahl, L. D., (1981). Influence of implants, feed additives and pen size upon incidence of buller steers. *Texas Agric. Expt. Station*, 3758-3830 : 130-133.

Albright, J. L., (1991). To group or not to group. Beef/Dairy Report, Purdue University, West Lafayette, Indiana, pp. 45-50.

Albright, J. L., Arave C. W., (1997). The behaviour of cattle. Cab International Wallingford, UK.

Allen, D., (1990). Planned Beef Production and Marketing. Published by BSP Professional Books, London.

Allen, D.M., Bougler, J., Christensen, L.G., Jongeling, C., Petersen, P.H. Serventi, P., (1982). *Cattle. Livestock Production Science*, 9 P : 89-126.

Alves, V.C., Teixeira A., (1995). Portugese beef and sheep production systems. Extensification of beef and sheep production on grassland. Occasional publication no. 2. Proceedings of a workshop held in Paris on November 22, 23 and 24, 1995, p 220-226.

Andersen, H.R., Krohn, C.C., Foldager, J., Musksgaard, L., Klastrup, S., (1991). Influence of housing and feeding on behaviour, feed intake, growth and carcass and meat quality. Nat. Inst. Anim. Sci. Foulum, Denmark, Report 700, 39 pp.

Andersen, H.R., Jensen, L.R., Munksgaard, L., Ingvartsen, K.L., (1997). Influence of floor space allowance and access to feed trough on the production of calves and young bulls and on carcass and meat quality of young bulls. Acta Agric. Scand., Section A, *Anim. Sci,* 47 : 48-56.

Andræ, U., Pougin, M., Unshelm, J. Smidt, D., (1982). Zur Anpassung von Jungrinden an die Spaltenbodenhaltung aus ethologischer Sicht. *KTBL-Schrift,* 281 : 32-45.

Andræ, U., Unshelm, J., Smidt, D., (1980).Verhalten und anpassungsphysiologische Reaktionen von Mastbullen bei underschiedlicher Belegungsdichte von Spaltenbodenbuchten. *Der Tierzüchter*, 32 : 467-473.

Andreae, U., (1979). Zur Aktivitätenfrequenz von Mastbullen bei Spaltenbodenhaltung. *Landbauforschung Völkenrode Sonderheft*, 48 : 89 - 94.

Andreae, U., Smidt, D., (1982). Behavioural alteration in young cattle on slatted floors. *Hohenheimer Arbeiten*, 121 : 51-60.

Anon., (1999a). Organic Farms 1999. Plant Directorate. Ministry of Foodstuffs, Agriculture and Fisheries, Copenhagen. 12 pp.

Anon., (1999b). Aktionsplan II. Økologi i udvikling. Ministry of Foodstuffs, Agriculture and Fisheries, Copenhagen. 368 pp.

Arave, C. W., Albright, J. L., Sinclair, C. L., (1974). Behavior, milk yield and leucocytes of dairy cows in reduced space and isolation. *J. Dairy Sci.*, 57 : 1497-1501.

Arave, C.W., Bunch, T.D., Callan, R.J., (1991). Measuring stress in cattle via implanted heart rate transmitters. *J. Anim. Sci.,* 69, 236 (Abstr.).

ARC, (1980). Agricultural Research Council : The Nutrient Requirements of Farm Livestock, No. 2. Ruminants. Commonwealth Agricultural Bureaux, Farnham Royal, Slough.

ARC, (1984). Agricultural Research Council : The Nutrient Requirements of Ruminant Livestock, Supplement No. 1, Commonwealth Agricultural Bureaux, Farnham Royal, Slough.

Arguelles, Ch. R. A., Leiva, C.M., (1978). Effect of weaning at three different ages on growth in beef calves. Memoria, Asociacion Latinoamericana de Produccion Animal, 13 : 154-155.

Arieli, A., Schrama, J.W., vander Hel, W., Verstegen, M.W.A., (1995). Development of metabolic partitioning of energy in young calves. *J. Dairy Sci.*, 78 : 1154-1162.

Arthur, P.F., (1995). Double muscling in cattle : a review. Aust. *J. Agric. Res.*, 46 : 1493-1515.

Auerbach, H., Geissler, C., (1992). Mykotoxine in Rauh- und Saftfuttermitteln für Wiederkäuer. *Übersichten zur Tierernährung*, 20 : 167-208.

Axelsen, A., Donnelly, J.R., Freer, M., Dove, H., Neville, J., (1990). Early weaning of winter-born beef calves and the use of nose-rings. Proceedings of the Australian Society of Animal Production, 18 : 451.

Bailey, C.B., (1961). Saliva secretion and its relation to feeding in cattle. 3. The rate of secretion of mixed saliva in the cow during eating, with an estimate of the magnitude of the total daily secretion of mixed saliva. *Br. J. Nutr.*, 15 : 433.

Baldwin, B. A., Start, B., (1981). Sensory reinforcement and illumination preference in sheep and calves. Proceedings of the Royal Society, London, B211 : 513-526.

Baldwin, B.A., (1977). Ability of goats and calves to distinguish between conspecific urine samples using olfaction. *Appl. Anim. Ethology,* 3 : 145-150.

Barnes, K.C., Selk, G.E., Lusby, K.S., (1996). Early weaning fall-born beef calves for improved rebreeding or decreased winter feed. Animal Science Research Report Agricultural Experiment Station, Oklahoma State University, No. P-951, 85.

Bateson, P., (1979). How do sensitive periods arise and what are they for ? *Animal Behaviour*, 27 : 470-486.

Baxter, M.R., (1992). The space requirements of housed livestock. In Phillips, C. and Piggins D. (eds). Farm animals and environment. Cab International, Wallingford, UK, pp. 67-81.

Bell, F. R., Sly, J., (1983). The olfactory detection of sodium and lithium salts by sodium deficient cattle. *Physiology and Behaviour*, 31 : 307-312.

Beneke, B., Ladewig, J., Andræ, U., Smidt, D., (1984). Physiologische und ethologische merkmale bei belastungssituationen von rindern. *KTBL-Schrift,* 299 : 32-45.

Beranger, C., (1986). Pathologie des jeunes bovins à l'engrais. In Production de viande bovine, Ed. D. Micol, 401-416.

Berten, D., Neau, F. X., Nicol, J. M., Florand, (1993). Vaches laitières de réforme : une expérimentation sur la castration. G.T.V.-93-1-B-440, 71.

Bertocchi, D., Franciosi, C., Mondini, S., Zoboli, C., (1973). Necrosi della coda in torelli all'ingrasso. *Rivista di zootecnia e veterinaria,* 6 : 585-592.

Blackshaw, J. K., Blackshaw, A. W., McGlone, J. J., (1997). Bull steer syndrome review. *Appl. Anim. Behav. Sci.*, 54 : 97-108.

Blaha, T., (1996). Gesundheits- und Umweltrisiken nach der Anwendung von Antiinfektiva und Antiparasitika in der Nutztierhaltung - Vermeidungsstrategien und Auswege. *Dtsch. tierärztl. Wschr.*, 103 : 278 - 280.

Blaschke, C. F., Thompson, D. L., Humes, P. E., Godke, R. A., (1984). Olfaction, sight and auditory perception of mature bulls in detecting estrual responses in beef heifers. Proceedings of the 10th International Congress

on Animal Reproduction and Artificial Insemination, 10-14 June 1984. Paper 284, 3pp. University of Illinois, Urbana, USA.

Blecha, F., Minocha, H.C., (1983). Suppressed lymphocyte blastogenic responses and enhanced in vitro growth of infectious bovine rhinotracheitis virus in stressed feeder calves. *Am. J. Vet. Res.,* 44 : 2145-2148.

Blecha, F., Boyless, S.L., Riley., S.L., (1984). Shipping suppresses lymphocyte blastogenic responses in Angus and Brahman x Angus feeder calves. *J. Anim. Sci.,* 59 : 576-583.

Böhm, R., (2000). Microbial contaminants in water for human and animal consumption. *Deutsch. Tierärztl. Wschr.,* 107 : 305-310.

Boissy, A., Bouissou, M. F., (1988). Effects of early handling on heifers'subsequent reactivity to humans and to unfamiliar situations. *Appl. Anim. Behav. Sci.,* 20 : 259-273.

Boissy, A., Le Neindre, P., (1990). Social influences on the reactivity of heifers : implications for learning abilities in operant conditioning. *Appl. Anim.Behav. Sci.,* 25 : 149-165.

Boissy, A., Terlouw, C., Le Neindre, P., (1998). Presence of cues from stressed conspecifics increases reactivity to aversive events in cattle : evidence for the existence of alarm substances in urine. *Physiology and Behavior* 63 : 489-495.

Boivin, X., Boissy, A., Chupin, J. M., Le Neindre, P., (1998a). Herbivores, caretakers and range management. Goddard, P. J. Proceedings of A Workshop 'The Implications of Extensification for the Health and Welfare of Beef Cattle and Sheep'.

Boivin, X., Le Neindre, P., Chupin, J. M., (1992). Establishment of cattle-human relationships. App. *Anim. Behav. Sci.,* 32 : 325-335.

Boivin, X., Le Neindre, P., Garel, J. P., Chupin, J. M., (1994). Influence of breed and rearing management on cattle reactions during human handling. *Appl. Anim. Behav. Sci.,* 39 : 115-122.

Boivin, X., Le Neindre, P., Garel, J. P., Chupin, J. M., (1992). Influence of breed and rearing management on cattle reactions during handling. *App. Anim. Behav. Sci.,* 39 : 115-122.

Bouissou, M. F., Andrieu, S., (1978). Etablissement des relations préférentielles chez les bovins domestiques. *Behaviour,* 64 : 148-157.

Bouissou, M. F., Hövels, J., (1976a). Effet d'un contact précoce sur quelques aspects du comportement social des bovins domestiques. *Biology of Behaviour,* 1 : 17-36.

Bouissou, M. F., Hövels, J. H., (1976b). Effet des conditions d'élevage sur le comportement des génisses dans une situation de compétition alimentaire. *Annales de Zootechnie,* 25 : 213-219.

Bouissou, M. F., Signoret, J. P., (1971). Cattle behaviour under modern management techniques. *Farm Building Assoc.,* 15 : 25-27.

Bouissou, M. F., (1985). Contribution à l'étude des relations interindividuelles chez les Bovins domestiques femelles (Bos taurus L.). Thèse de Doctorat d'Etat, Université Paris VI, France, 366 pp.

Bouissou, M. F., Boissy, A., Le Neindre, P., Veissier, I., (2000). The social behaviour of cattle. (in press).

Bouissou,. M. F., (1970). Role du contact physique dans la manifestation des relations hierarchiques chez les bovins. Consequences practiques. *Annales de Zootechnologie* (Paris)., 19 : 279-285.

Boyne, R., Arthur, J.R. (1986). Effects of molybdenum or iron induced copper deficiency on the viability and function of neutrophils from cattle. *Res. Vet. Sci.,* 41 : 417.

Brambell Committee, (1965). Report of the technical Committee to Enquire into the Welfare of Animals kept under Intensive Livestock Husbandry Systems. Command Report 2836, Her majesty´s Stationery Office, London.

Bridgeman, S. A., Robertson, R. M., Syed, Q., Spped, N., Andrews, N., Hunter, P. R., (1995). Outbreak of cryponsoridiosis associated with a dispefected groundwater supply. *Epidimic infect*, 115 : 555-566.

Broom, D. M., Leaver, J. D., (1978). The effects of group-housing or partial isolation on later social behaviour of calves. *Animal Behaviour*, 26 : 1255-1263.

Broom, D. M., (1986). Indicators of poor welfare. *Brevet. J.*, 142 : 524-526.

Broom, D.M., (1995). Measuring the effects of management methods, systems, high production efficiency and biotechnology on farm animal welfare. In : Mepham, T.B. ; Trucker, G.A. ; Wiseman, J. (Eds.). Issues in Agricultural Biothics. Nottingham University Press, 319 – 334.

Broom, D.M., (1996). Animal welfare defined in terms of attempts to cope with the environment. Acta *Agric. Scand. Sec. A. Anim. Sci.*, Suppl., 27 : 22-28.

Broom, D.M., (1998).Welfare, stress and the evolution of feelings. *Adv. Study Behav.*, 27 : 371-403.

Bruce, J. M., (1978). Natural convection through openings and its application to cattle building ventilation. *Journal of Agricultural Engineering*, 23 : 151-167.

Burrow, H. M., (1997). Measurements of temperament and their relationships with performance traits of beef cattle. *Animal Breeding Abstracts,* 65 : 477-495.

Bush, B., Kramer, S., (1995). (Preventive tail amputation in fattening bulls*). Dtsch. Tierarztl Wochenschr.,* 102 : 127-129.

Capdeville, J., Tillie, M., (1995). Le point sur l'ambiance dans les bâtiments d'élevage bovin, ovin, caprin et équin. Institut de l'élevage, 64pp.

Caple, I.W., Halpin, C.G., (1985). Biochemical assessment of nutritional status. In : Proceedings No 78 Dairy Cattle Production, Post-Graduate Committee in Veterinary Science, The University of Sidney, p 307.

Carruthers, V. R., Hendersen, H. V., (1994). Grazing management and pasture composition on paired farms which differed in the incidence of bloat. *N. Z. J. of Agric. Res.*, 37 : 535-546.

Chappat, P., (1993). La castration de la vache. *G. T. V.*, 1-B-438, 53.

Chase Jr., C. C., Larsen, R. E., Randel, R. D., Hammond, A. C., Adams, E. L., (1995). Plasma cortisol and white blood cell responses in different breeds of bulls : A comparison of two methods of castration. *J. Anim. Sci.*, 73 : 975-980.

Chenoweth, P. J., (1986). Reproductive behavior of bulls. In "Current Therapy in Theriogenology", D.A. Morrow, Ed., 2nd ed., Saunders, Philadelphia.

Chilliard, Y., Bocquier, F., Doreau, M., (1998). Digestive and metabolic adaptations of Ruminants to undernutrition, and consequences on reproduction. *Reprod. Nutr. Dev.*, 38 : 131-152.

Chiy, P. C., Phillips, C. J. C., (1992). The relatioship between salt, bitter and sweet tastes in cattle. Research report to International Additives Ltd.

Chrousos, G. P., McCarty, R., Pacák, K., Cizza, G., Sternberg, E., Gold, P. W., Kvetnanský, R., (1995). Stress – basic mechanisms and clinical implications. Annals of the New York Academy of Sciences, vol. 771, New York, 755 pp.

Clarke, R. T. J., Reid, C.S.W., (1974). Foamy bloat of cattle. A review. *J. Dairy Sci.*, 57 : 753 - 785.

Cohen, R. D. H., King, B. D., Thomas, L. R., Janzen, E. D., (1990). Efficacy and stress of chemical versus surgical castration of cattle. *Can. J. Anim. Sci.*, 70 : 1063-1072.

Commission of the European Communities, (1995). Report on the Welfare of Calves. CEC, Brussels.

Compere, J., Tillie, M., (1981). A modular new design for compact and breathing ear-shaped cattle housing. CIGR Section II Seminar, Aberdeen, Scotland, pp. 117-124.

Coulon, J. B., (1984). Feeding behaviour of crossbred Charolais cattle in a humid tropical environment. *Revue d´Elevage et de Medecine Veterinaire des Pays Tropicaux*, 37 : 185-190.

Council Regulation (EC). No 1804/1999 of 19 July 1999 supplementing Regulation (EEC). No 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs to include livestock production, Official Journal L 222, 24/08/1999 p. 0001 – 0028.

Cummins, K.A., Brunner, C.J., (1991). Effect of calf housing on plasma ascorbate and endocrine and immune function. *J. Dairy Sci.*, 74 : 1582-1588.

Curtis, S.E., (1983). Environmental management in animal agricultural. Iowa State University Press. Amens Iowa.

Curtis, S. E., Houpt, K. A., (1983). Animal ethology : its emergence in animal science. *J. Anim. Sci.*, 57 (Supplement 2). : 234-247.

Daccord, R., (1994). Energieversorgung. In : Fütterungsempfehlungen und Nährwerttabellen für Wiederkäuer. Forschungsanstalt für Viehwirtschaftliche Produktion, Posieux (Hrsg.)., Zollikofen, Landwirtschaftliche Lehrmittelzentrale, 13-22.

Daccord, R., Amrhyn, P., Vlad, J., (1998). Einfluss der Grünfutterqualität auf Pansenfunktion beim Rind. *Agrarforschung,* 5 : 73-76.

Daccord, R., (1998). Effet du mais et de I'orge utilisés comme complément a une ration d'herbe ou d'ensilage d'herbe sur I'activité microbienne dans la panse. Rapport interne. Station fédérale de recherches en production animale, Posieux.

Daelemans, J., Maton, A., (1987). Beef production with special reference to fattening bulls in Agriculture Welfare aspects of housing systems for veal calves and fattening bulls edited by Schlichting M.C. and Smit D, EU seminar held on 16 and 17 September 1996 in Mariensee.

Dämmrich, K., (1976). Adaptationskrankheiten des Bewegungsapparates bei Masttieren. *Fortschr. der Veterinärmed.*, 20 : 69-89.

Dämmrich, K., (1976). Adaptationskrankheiten des Bewegungsapparates bei 12, 15 und 18 Monate alten Mastbullen : Pathologische Histologie und formale Pathogenese der Arthropathia deformans. *Zbl. Vet. Med. A.*, 23 : 617 - 634.

Dämmrich, K., (1979). Befunde am passiven Bewegungsapparat von auf Rost-bzw Spaltenboden gehaltenen Jungridern. *Landbauforshung Völkenrode Sondeheft*, 48 : 166-170.

Dämmrich, K., (1986). The reaction of the legs (bone ; joints). to loading and the consequences for lameness Contr. to Seminar on "the influence of the design of housing systems for cattle on lameness and on behaviour", Brussels, June 3 and 4.

Dämmrich, K., (1987). The reactions of the legs (bone ; joints). to loading and its consequences for lameness. In : Cattle Housing Systems, Lameness and Behaviour, ed. H.K. Wierenga and D.J. Peterse, Curr. Top. vet. Med. Anim. Sci. 40 : 50-55. Dordrecht : Martinus Nijhoff.

Dantzer, R., Mormède, P., (1994). Psychoimmunology of stress. In : Leonard B., Miller, K., eds, Stress, the immune system and psychiatry, Chichester, Wiley, pp 47-67.

Daugschies, A., (2000). Water as a vector for infectious stages of parasites in livestock. *Deutsch. Tierärztl. Wschr.,* 107 : 316-319.

Davies, L. H., (1996). Osteochondritis dissecans in a group of rapidly growing bull beef calves. *Cattle Pract*., 4 : 243 - 245.

Dawkins, M.S., (1990). From an animal's point of view : motivation, fitness and animal welfare. *Behav. Brain Sci*., 13 : 1-61.

Daycard, L., (1990). Structure sociale de la population de bovins sauvages de l'île d'Amsterdam, sud de l'Océan Indien. *Rev. Ecol.* (Terre vie)., 45 : 35-53.

De Vries, F. W. K., Wierenga, H. K., Goedegebuure, S. A., (1986). Een orienterend onderzoek naar het voorkomen van afwijkingen aan het carpaalgewricht bij vleesstieren en naar het verband met de wijze van opstaan en gaan liggen. Instituut voor Veetteeltkungid Onderzoek "Schoonoord", I.V.O. – Report B-278, 50 pp.

Dechamp, P., Nicks, B., Canart, B., Istasse, L., (1989). Influence of supplemental lighting on the resting behaviour of fattening bulls kept in a stanchion barn. *Appl. Anim. Behav. Sci.*, 22 : 303-311.

Del Pozo, M., Osoro, K., (1995). Extensification of beef and sheep production in Spain and improvement of grazing efficiency in Asturias. Extensification of beef and sheep production on grassland. Occasional publication no. 2. Proceedings of a workshop held in Paris on November 22, 23 and 24 : 231-252.

Dodd, V., (1985). Housing for a beef Unit Veterinary Update April 6.

Dodelin, V., (2000). Results of suckler cattle's performance recordings, France, Campagne 1999. Institut de l'élevage, CR n°3003.

Dorval, L., (1989). La race blanc bleu belge. *A la pointe de l'élevage*, 206 : 12-13.

Drennan, M. J., (1993). Planned Suckler Beef Production Beef Series No 4, published by Teagasc, Dublin 4.

Drennan, M. J., Keane, M.,G., Dunne, L., (1995). Outline of beef production in Ireland. Extensification of beef and sheep production on grassland. Occasional publication no. 2. Proceedings of a workshop held in Paris on November 22, 23 and 24, 1995, p 87-94.

Drennan, M. J., Moloney, A. P., Keane, M.G., (1994). Effects of Protein and Energy Supplements on Performance of Young Bulls Offered Grass Silage. *Irish J. Agr. Food Res.,* 33 : 1-10.

Drochner, W., Heckötter, E., Scholz, H., (1984). Actual problems in the veterinary feeding advisement. 4th. Communication : The composition of green forage and silages for ruminates ; investigations on the composition of single feeds in flocks with impaired health or productivity (a report from experience). *Dtsch. Tierärtl. Wschr.*, 91 : 61-66.

Dumelow, J. Unbedded self cleaning sloped floor as alternatives to fully slatted floors for beef. In cattle housing. Fourth International Symposium ASAE, Michigan, USA. 209-216.

Duncan, I. J. H., Petherick, J. C., (1991). The implications for cognitive processes for animal welfare. *J. Anim Sci*., 69 : 5017-5022.

Duncan, I.J.H., Petherick, J.C., (1989). Cognition : the implications for animal welfare. *Appl. Anim. Behav. Sci*., 24 : 81.

Duncan, I. J. H., Rushen, J., Lawrence, A. B., (1993). Conclusions and implications for animal welfare. In Stereotypic animal behaviour (ed. A.B. Lawrence and J. Rushen)., pp. 193-206. CAB International, Wallingford.

Dutra, F, Carlsten, J., Ekman, S., (1999). Hind limb skeletal lesions in 12-month-old bulls of beef breeds. *J. Vet. Med.* A, 46 : 489 - 508.

Eckert, B., Dirksen, G., (1988). Neue Beobachtungen über Vorkommen und Entstehung der Schwanzspitzenentzündung beim Rind. Prak. Tierarzt, collegium veterinarium XIX : 57 - 59.

Edwars, A.J., (1996). Respiratory diseases of feedlot cattle in the central USA. *Bovine Pract*. 30 : 5-7.

Encarnacao, R. de O., Thiago, L. R. L. de S., Valle, E. R. do, (1995). Weaning stress in beef calves. Centro Nacional de Pesquisa de Gado de Corte, Campo Grande, Brazil, 47 pp.

Eriksen, G. S., Alexander, J., (1998). Fusarium toxine in cereals – a risk assessment. TemaNord, 502, Copenhagen, ISBN 92-893-0149-X.

Espinasse, J., Kuiper, R., Schelcher, F., (1995). Physiopartogie du complexe gastrique. In : Nutrition des ruminants domestiques. R. Jarrige et al., Ed. INRA, Paris, 805 - 853.

Ewbank, R., (1967). Behaviour of twin cattle. *J Dairy Sci*., 50 : 1510-1515.

Fallon, R., (1992). Calf rearing. Teagasc, Dublin.

Fallon, R. J., Drennan, M. J., (1998). Production of Red Veal for the EU market. Beef Production Series No. 4, Teagasc Grange Research Centre, Dunsany, Co. Meath.

Fallon, R. J., Drennan, M. J., Keane, M. G., (2000). Bull Beef Production. Teagasc, Grange Research Centre, Dunsany, Co. Meath. P1 – 21.

Faulkner, D. B., Eurell, T., Tranquilli, W. J., Ott, R. S., Ohl, M. W., Cmarik, G. F., Zinn, G., (1992). Performance and health of weanling bulls after butorphanol and xylazine administration at castration. *J. Anim. Sci*., 70 : 2970-2976.

FAWC, (1994). Farm Animal Welfare Council Report on the Welfare of Sheep. MAFF.

FELASA Working Group on Pain and Distress., (1994). Report of the Federation of European Laboratory Animal Science Associations (Baumans, V., Brain, P. F., Brugere, H., Clausing, P., Jeneskog, T. & Perretta, G.). on Pain and distress in laboratory rodents and lagomorphs. *Laboratory Animals,* 28 : 97-112.

Fell, L. R., Walker, K. H., Reddacliff, L. A., Davies, L., Vallance, H. J., House, J. R. and Wilson, S. C., (1998). Effects of yard weaning and pre-feedlot vaccination on feedlot performance of Bos taurus steers. Animal Production in Australia, Proceedings of the Australian Society of Animal Production, 22 : 173-176.

Fernandez, J. M., Croom, W. J., Johnson, A. D., Jaquette, R. D., Edens, F. W., (1988). Subclinical ammonia toxicity in steers : effects on blood metabolite and regulatory hormone concentrations. *J. Anim. Sci*., 66 : 3259-3266.

Ferrante, V., Canali, E., Mattiello, S., Verga, V., Sacerdote, P., Panerai, A.E., (1998). Preliminary study of the effect of size of individual crates on the behavioural and immune reactions of dairy calves. *J. Anim. Feed Sci*., 7 : 29-36.

Fiems, L. O., Boucque, C. V., (1995). Beef and sheep production in Belgium. Extensification of beef and sheep production on grassland. Occasional publication no. 2. Proceedings of a workshop held in Paris on November 22, 23 and 24, 1995, p 151-162.

Fisher, A. D., Crowe, M. A., Alonso de la Varga, M. E., Enright, W. J., (1996). Effect of castration method and the provision of local anesthesia on plasma cortisol, scrotal circumference, growth, and feed intake of bull calves. *J. Anim. Sci,* 74 : 2336-2341.

Fisher, A. D., Crowe, M. A., O'Kiely, P., Enright, W. J., (1997b). Growth, behaviour, adrenal and immune responses of finishing beef heifers housed on slatted floors at 1.5, 2.0, 2.5 or 3.0 m^2 space allowance. *Livestock Prod. Sci.*, 51 : 245-254.

Fisher, A. D., Crowe, M. A., Prendiville, D. J., Enright, W. J. (1997a). Indoor space allowance : effects on growth, behaviour, adrenal and immune responses of finishing beef heifers. *Anim. Sci.*, 64 : 53-62.

Folkow, B., Schmidt, T., Uvnäs-Moberg, K., (1997). Stress, Health and the Social Environment. *Acta Physiologica Scandinavica*, 161 : 1-179.

Fordyce, G., Hodge, P. B., Beaman, N. J., Laing, A. R., Campero, C., Shepherd, R. K., (1989). An evaluation of calf castration by intra-testicular injection of a lactic acid solution. *Austr. Vet. J.,* 66 : 272-276.

Fraser, A. F., Broom, D. M., (1990). Farm animal behaviour and welfare. 3rd edn. Bailliere, Tindall, London, 437pp.

Fraser, D., Matthews, L.R., (1998). Preference and motivation testing. In : Animal welfare, Ed. M.C. Appleby and B.O. Hughes. CAB International, Wallingford, 159-173.

Friend, T. H., Gwazgaudaskas, F. C., Poland, C.E., (1979). Change in adrenal response from free stall competition. *J. Dairy Sci.*, 62 : 768-771.

Friend, T. H., Poland, C. E., Gwazgaudaskas, F.C., Herald, C.W,.(1977). Adrenal glucocorticoid response to exogenous adrenocorticotropin mediated by density and social disruption in lactating cows. *J. Dairy Sci.*, 60 : 1958-1963.

Gäbel, G., (1990). Acidosis : Interrelations between changes in the lumen and the wall of the rumen.

Geay, Y., Micol, D., Robelin, J., Berge, PH., Maltrerre, C., Jailler, R., (1987). Recommandations alimentaires pour les bovines en croissance et a l'engrais. Bull. Tech. C.R.Z.V. Theix, INRA 70 : 173-183.

GEB, (1999). Productions bovines Viande et lait. Supplément à Tendances n°82.

GEH, (1995). Ausschuß für Bedarfsnormen der Gesellschaft für Ernährungsphysiologie der Haustiere, Energie- und Nährstoffbedarf landwirtschaftlicher Nutztiere. Empfehlungen zur Energie – und Nährstoffversorgung der Mastrinder, DLG – Verlag Nr. 6, Frankfurt a.M.

Gibb, D. J., Schwartzkopf-gerswein, K. S., Stookey, J. M., McKinnon, J. J., Godson, D. L., Wiedmeier, R. D., Mcallister, T. A., (2000). Effect of a trainer cow on health, behavior, and performance on newly weaned beef calves. *J. Anim. Sci.,* 78 :1716-1725.

Gigli, S., Iacurto, M., (1995). Present and future cattle and sheep meat production systems in Italy. Extensification of beef and sheep production on grassland. Occasional publication no. 2. Proceedings of a workshop held in Paris on November 22, 23 and 24, 1995, p 253-268.

Gilbert, B. J. Jr., Arave, C. W., (1986). Ability of cattle to distinguish among different wave lengths of light. *J. Dairy Sci.*, 69 : 825-832.

Goonewardene, L. A., Price, M. A., Okine, E., Berg, R. T., (1999). Behavioral responses to handling and restraint in dehorned and polled cattle. *Appl. Anim. Behav. Sci.*, 64 : 159-167.

Grace, N.D., (1983). In : The Mineral Requirements of Grazing Ruminants. Occasional Publication of the New Zealand Society of Animal Production No 9, Palmerston North, Keeling and Mundy Ltd.

Graf, B., (1978). Ethologische Beurteilung der Aufstallungssysteme in der Kälbermast. Proceedings of the 1st World Congress on Ethology applied to Zootechnics, Madrid, 205-213.

Graf, B., (1979). Spaltenbodenhaltung bei Mastochsen. *Landbauforschung Völkenrode Sonderheft*, 48 : 73 - 88.

Graf, B., Senn, M., (1999). Behavioural and physiological responses of calves to dehorning by heat cauterization with or without local anaesthesia. *Appl. Anim. Behav. Sci.*, 62 : 153-171.

Graf, B. P., (1984). Der Einfluss unterschiedlicher Laufstallsysteme auf Verhaltensmerkmale von Mastchsen. Eidgenössichen Technishen Hochschule, Zürich, Thesis, 282 pp.

Graf, S., Willer, H., (2000). Organic Agriculture in Europe - State and Perspectives of Organic Farming in 25 European Countries. SOL. Bad Dürkheim. 400 pp.

Graham, M. J., Kent, J. E., Molony, V., (1997). Effects of four analgesic treatments on the behavioural and cortisol responses of 3-week-old lambs to tail docking. *Vet. J.,* 153 : 87-97.

Grandin, T., (1996). Factors that impede animal movement at slaughter plants. *J. Am. Vet. Med. Assoc.*, 209 : 757-759.

Grandin, T., (1997). Assessment of stress during handling and transport. *J. Anim. Sci.*, 75 : 249-257.

Grandin, T., (1997). The design and construction of facilities for handling cattle. *Livestock Production Science,* 49 : 103-119.

Grandin, T., (1997). Livestock handling and transport. CAB International, Wallingford, Oxon, 320pp.

Grandin, T., (1998). Genetics and the behaviour of domestic animals. Academic press, 356pp.

Grandin, T., Deesing, M. J., (1998). Genetics and behaviour during handling, restraint, and herding. In *Genetics and the behaviour of domestic animals*, Ed T. Grandin, 145-167.

Grimes, J. F., Turner, T. B., (1991). Early weaning of fall-born beef calves : 2. Postweaning performance of early- and normal-weaned calves. *J. Prod. Agr.*, 4 : 468-471.

Grobet, L., Royo, L., Poncelet, D., Pirottin, D., Brouwers, B., Riquet, J., Shoeberlein, A., Dunner, S., Ménissier, F., Masabanda, J., Fries, R., Hanset, R., Georges, M., (1997). A deletion in the bovine myostatine gene causes the double-muscled phenotype in cattle. *Nature Genetique*, 17 : 71-74.

Hafez, E. S. E., Bouissou, M. F., (1975). The behaviour of cattle. In. The Behaviour of Domestic Animals (ed. Hafez, E. S. E.). Williams and Wilkins, Baltimore, pp. 247-296.

Haley, D.B., de Passillé, J., Rushen, J., (2001). Assessing cow comfort : effects of two floor types and two tie stall designs on the behaviour of lactating dairy cows. *Appl. Anim. Behav. Sci.*, 71 : 105-117.

Hall, S. J. G., (1979). Studying the Chillingham wild cattle. *Ark*, 6 : 72-79.

Hall, S. J. G., Vince, M. A., Walser, E., Shillito and Garson, P. J., (1988). Vocalizations of the Chillingham cattle. *Behaviour*, 104 : 78-104.

Hall, S. J. G., (1986). Chillingham cattle : dominance and affinities and access to supplementary food. *Ethology*, 71 : 201-215.

Hamilton, G. F., Turner, A.S., Ferguson, J.C., Pharr, J.W., (1978). Slipped capital epiphysis in calves. *J. AM. Vet. Med. Assoc.*, 172 : 1318 - 1322.

Hamm, U., Michelsen, J., (2000). Analysis of the organic food market in Europe. Proc. 13th Int. ifoam scientific conference, p.507-510.

Hamoud, M., Imrey, P. B., Woods, G. T., Mansfield, M. E., Cmarik, G., (1981). An epidemiologic study of acute respiratory disease in beef cattle after weaning. *Bovine Practice*, 2 : 7-12.

Hanekamp, W. J., Smits, A. C., Wierenga, H., (1990). Huisversting vleesstieren vanaf 6 maanden. Proefstation voor de Rundveehouderij Schpenhouderij en Paardenhouderij, Lelystad, Publication 66 pp.20.

Hannan, J., Murphy, P., (1983). Comparative mortality and morbidity rates for cattle on slatted floors and in straw yards. In Smidt, D (ed). Current topics in Veterinary Medicine and Animal Science, 23, The Hague,

pp251. Fraser, A.F., and Broom, D.M. (1990). Farm animal behaviour and welfare. 3rd edn. Bailliere, Tindall, London, 437pp.

Hansen, K., Pedersen, S., (1980). Isoleret kontra uisolret tag i ungkvaegstald. Beretn. No 3 Statens Jordbrugstekniske Forsøg. Horsens, Dk, 35 pp.

Hansen, M., Larsen Vigh, F., (1995). Beef and sheep production in Denmark. Extensification of beef and sheep production on grassland. Occasional publication no. 2. Proceedings of a workshop held in Paris on November 22, 23 and 24, 1995, p 175-180.

Hardy, R., Meadowcroft, S., (1986). Indoor Beef Production. Published by Farming Press Limited, Wharfedale Road, Ipswich, Suffolk, IPI 4LG, United Kingdom.

Hargreaves, A. L., Hutson, G. D., (1990). Changes in heart rate, plasma cortisol and haematocrite of sheep during a shearing procedure. *Appl. Anim. Behav. Sci.*, 26 : 91-101.

Harmsen, H. E., Smits, A. C., (1972). De invloed van het staltype op de groei van vleesstieren. Proefstation voor de rundveehouderij, Report 8, Lelystad, Nl 18 pp.

Harmsen, H. E., Smits, A. C., (1981). Vleesstieren in geisoleerde en ongeisoleerde stallen. Proefstation voor de rundveehouderij, Report 82, Lelystad, Nl 15 pp.

Hartung, J., (2000). Rules and criteria to control drinking water supply systems in livestock farming. *Deutsch. Tierärztl. Wschr.*, 107 : 302-304.

Heeres-van der Tol, J.J., Plomp, M., (1995). Beef and sheep production systems in the Netherlands and prospects for extensification. Extensification of beef and sheep production on grassland. Occasional publication No. 2. Proceedings of a workshop held in Paris on November 22, 23 and 24, 1995, p 131-150.

Heffner, R. S., Heffner, H. E., (1983). Hearing in large mammals : horses (Equus caballus). and cattle (Bos taurus). *Behav. Neurosci.*, 97 : 299-309.

Hemsworth, P. H., Coleman, G. J., (1998). Human-Livestock interactions : the stockperson and the productivity and welfare of intesively farmed animals. CAB International, Oxon, NewYork.

Hemsworth, P. H., Hansen, C., Barnett, J. L., (1987). The effects of human presence at the time of calving of primiparous cows on their subsequent behavioural response to milking. Appl. *Anim. Behav. Sci.*, 18 : 247-255.

Hemsworth, P. H., Coleman, G. J., Barnett, J. L., Borg, S., (2000). Relationships between human-animal interactions and productivity of commercial dairy cows. *J. Anim. Sci.*, 78 : 2821-2831.

Hemsworth, P.H., Barnett, J. L., Tilbrook, A. J., Hansen, C., (1989). The effects of handling by humans at calving and during milking on the behaviour and milk cortisol concentrations of primiparous dairy cows. *Appl. Anim. Behav. Sci.*, 22 : 313-326.

Hemsworth, P. H., Coleman, G. J., (1998). Human-livestock interactions : The stockperson and the productivity and welfare of intensively farmed animals. New York, USA : CAB International.

Herdt, T.H., Stowe, H.D. (1991). Fat-soluble vitamin nutrition for dairy cattle. *Veterinary Clinics of North Amerika,* 7 : 391 – 415.

Hiepe, T., Buchwalder, R., Gräfner, G., Klemm, M., Meichsner, J., Nickels, S., (1978). Betrachtungen zur Epidemiologie, Diagnostik und Bekämpfung der Rinderzystizerkose aus parasitologischer Sicht. *Mh. Veterinärmed.*, 33 : 888-892.

Hindhede, J., Sørensen, J. T., Jensen, M. B., Krohn, C. C., (1996). Effect of space allowance, access to bedding, and flock size in slatted floor systems on the production and health of dairy heifers. Acta Agric. Scand., Sect. A, *Anim. Sci.*, 46 : 46-53.

Houpt, K. A., (1998). Domestic animal behavior for veterinarians and animal scientists. Manson Publishing/The Veterinary Press, Iowa, 495 pp.

Howlett, C.R., (1973). Pathology of coxofemoral arthropathy in young beef bulls. *Pathology,* 5 : 135-144.

Hughes, B.O., (1976). Behaviour as an index of welfare. In : Proceedings of the fifth European Poultry Conference, Malta, 1005-1018.

Hünermund, G., Romer, H., Wagenseil, F., Albrecht, E., (1980). Schwanzspitzennekrose – Erfahrungsbericht des Rindergesundheitsdienstes Südwürtemberg. *Tierärzt. Umschau,* 4 : 238-245.

Hurnik, J. F., Lewis, N.J., (1991). Use of body surface area to set minimum space allowances for confined pigs and cattle. Can. *J. Anim. Sci*, 71 : 577-580.

Hutson, G. D., (1985). The influence of barley food rewards on sheep movement through a handling system. *Appl. Anim. Behav. Sci.*, 14 : 263-273.

Iggo, A., (1984). Pain in animals. Hume Memorial Lecture, 15 November 1984. Universities Federation for Animal Welfare, London.

Ingvartsen, K.L., Andersen, H.K., (1993). Space allowance and type of housing for growing cattle. Acta Agric. Scand., Section A*, Anim. Sci.,* 43 : 65-80.

INRA, (1978). Alimentation des Ruminants. Institute National de la Recherche Agronomique. INRA Publications, Versailles, S. 151.

INRA, (1989). Institut National de la Recherche Agronomique, Ruminant Nutrition. Jarrige, R. (Ed.)., John Libbey Eurotext, Paris – London – Rome.

International Association for the Study of pain, (1979). Report of subcommittee on taxonomy. *Pain*, 6 : 249-252.

Irps, H., (1987). The influence of the floor on the behaviour and lameness of beef bulls. In Wierenga, H.K. and Peterse, D.J. (eds)., Cattle housing systems, lameness and behaviour. Martinus Nijhoff, Dordrecht, The Netherlands, pp. 73-86.

ITEB, (1983). Le taurillon, I.T.E.B., Paris, 230p.

Jago, J. G., Krohn, C. C., Matthews, L. R., (1999). The influence of feeding and handling on the development of the human-animal interactions in young cattle. *Appl. Anim. Behav. Sci.*, 62 : 137-151.

Jagos, P., Illek, J., Doubek, J., Jurajdova, J., (1985). Metabolic profile in beef under conditions of industrial technologies. *Acta vet. Brno.*, 54 : 41 - 51.

Jensen, R., Park, R. D., Lauerman, I. H., Braddy, P. M., Horton, D. P., Flacj, D.H., et al., (1981). Osteochondrosis in feedlot cattle. *Vet. Pathol.*, 18 : 529-535.

Jeroch, H., (1980). Biostimulation und Futterzusätze, Kapitel 2 (Vitamine)., Gustav Fischer Verlag, Jena.

Jeroch, H., Drochner, W., Simon, O., (2000). Ernährung landwirtschaftlicher Nutztiere. Verlag Eugen Ulmer Stuttgart.

Jordbruksinformation 28, (1999). Djurskyddsbesämmelser mjölkkor och köttdjur, Art.nr : JO28 :99, Jordbruksverket, SE-551 82 Jönköping, Sweden.

Josifovich, J. A., Bertin, O., MacLoughlin, R., Maddaloni, J., (1988). Early weaning and beef calves fattening. *Revista Argentina de Produccion Animal*, 8 : 245-250.

Journet, M., (1988). Optimisation des rations. In Alimentation des bovins, ovins et caprins, Ed. R. Jarrige, 121-133.

Jury, C., Picard, B., Geay, Y., (1998). Influences of the method of housing bulls on their body composition and muscle fiber types. *Meat Sci.*, 4 : 457-469.

Kamphues, J., (1998). Probleme der art- und bedarfsgerechen Fütterung landwirtschaftlicher Nutztiere. *Dtsch. Tierärtzl. Wsch.*, 105 : 117-123.

Kamphues, J., (2000). Water requirement of food producing and companion animals. *Dtsch. Tierärtzl. Wsch.*, 107 : 297-302.

Kempf, M., Rouquette, J.,L., Chotteau P., (1995). Main beef and sheep production systems in France and their adaptation to cap reform. Extensification of beef and sheep production on grassland. Occasional Publication No. 2 Proceedings of a workshop held in Paris on November 22, 23 and 24, 1995, p 1-14.

Kent, J. E., Molony, V., Graham, M. J., (1998). Comparison of methods for the reduction of acute pain produced by rubber ring castration or tail docking of week-old lambs. *Vet. J.*, 155 : 39-51.

Keys, J. E., Pearson, R. E., Thompson, P. D., (1978). Effects of feedbunk stocking density on weight gain and feeding behaviour of yearling Holstein heifers. *J. Dairy Sci.*, 61 : 448-454.

Kiley-Worthington, M., (1982). Animal language ? Vcal communication of some ungulates, canids and felids. 3rd International Theriological Congress, Helsinki.

Kiley-Worthington, M., de la Plain, S., (1983). The behaviour of beef suckler cattle (Bos taurus). Tierhaltung 14. Birkhäuser Verlag, Basel, 195 pp.

Kilgour, R., (1981). Use of the Hebb-Williams closed-field test to study the learning ability of Jersey cows. *Anim. Behav.*, 29 : 850-860.

Kilgour, R., Dalton, C., (1984). Cattle. In : Livestock Behaviour : A practical guide (ed. Kilgour, R.). Westview Press, Boulder.

Kimura, R., Ihobe, H., (1985). Feral cattle (Bos taurus). on Kuchinoshima Island, south-western Japan : their stable ranging and unstable grouping. *J. Ethol.*, 3 : 39-47.

King, B. D., Cohen, R. D. H., Guenther, C. L., Janzen, E. D., (1991). The effect of age and method of castration on plasma cortisol in beef calves. *Can. J. Anim. Sci.*, 71 : 257-263.

Kirchgessner, M., Schwarz, F.J., Reimann, W., Heindl, U., Otto, R., (1994). Untersuchungen zum Energie- und Nährstoffansatz sowie zur Verwertung der Energie für das Wachstum bei Mastrindern der Rasse Deutsches Fleckvieh. *J. Anim. Physiol. a. Anim. Nutr.*, 71 : 208 – 222.

Kirchner, M., (1896). Flächenansprüch von Mastbullen in Vollspaltenbodenbuchten durch Verhaltensstudien. *KTBL-Schrift*, 311 : 107-115.

Kloostermann, A., Henken, A.M., (1987). The effect of gastrointestinal nematodes on metabolism in calves. In : Verstegen & Henken, (eds). Energy Metabolism of Farm Animals Martinus Nijhoff Publ. Dordrecht, The Netherlands, pp. 352-371.

Koberg, J., Hofmann, W., Irps, H., Daenicke, R., (1989). Rindergesundheit bei Betonspaltenbodenhaltung. *Prakt. Tierazt.*, 70 : 12-17.

Kolb, E., Seehawer, J., Steinberg, W., (1999). Bedeutung, Verwertung und Anwendung von B-Vitaminen bei Wiederkäuern. *Prakt. Tierarzt.,* 80 : 1, 44 – 52.

Koller, L. D., Exon, J. H., (1986). The two faces of selenium – deficiency and toxicity – are similar in animals and man. *Can. J. Vet. Res.*, 50 : 297.

Kondo, S., Hurnick, J. F., (1987). Progress of social stabilisation in dairy cows after grouping. *Can. J. Anim. Sci.*, 67 : 1167.

Kondo, S., Sekine, J., Okubo, M., Adahida, Y., (1989). The effect of group size and space allowance on the agonistic and spacing behaviour of cattle. *Appl. Anim. Behav. Sci*., 24 : 127-135.

Konggaard, S. P., (1983). Feeding condition in relation to welfare for dairy cows in loose housing systems. In Baxter, S.H., Baxter, M.R., and MacCornack, J.A.C. (eds). Farm animal housing and welfare. Martinus Nijhoff, The Netherlands, pp. 272-278.

Konggaard, S. P., Larsson, J.G., Madsen, E. B., Nielsen, K., (1984). Halatråd hos ungtyre. I. En epidemiologisk undersøgelse. Meddelelse 558. Statens Husdrybrugsforsøg. Frederiksberg, Denmark, 4 pp.

Krohn, C. C., Foldager, J., Mogensen, L., (1999). Long-term effect of colostrum feeding methods on behaviour in female dairy calves. Acta Agriculturae Scandinavica Section A *Anim. Sci*., 1999 ; 49 : 57-64.

Krohn, C. C., Jago, J. G., Boivin, X., (2001). The effect of early handling on the socialisation of young calves to humans. *Appl. Anim. Behav. Sci.*, (in press).

Kunz, W., Vogel, O., (1978). Schwanzspitzenentzündung – ein neues Gesundheitsproblem in der Rindermast. *Tierärztl. Umschau,* 6 : 344-353.

Ladewig, J, (1987).Physiological results of welfare research in fattening bulls. In Schhlitin, M.C. and Smidt, D. (editors). Welfare aspects of housing systems for vela calves and fattening bulls. CEC Report, Luxembourg 123-129.

Ladewig, J, Borell, (1988). Ethological methods alone are not sufficient to measure the impact of environment on animal health and animal well-being. In Unshelm, J., Van Putten, G., Zeeb, K. and Ekesbo, I (eds). Proceedings of the international congress on applied ethology in farm animals 95-102.

Ladewig, J., Schlichting, M.C., Beneke, B., von Borrel, E., Stuhec, I. and Smidt, D., (1985). Physiological aspects of social space in heifers and pigs. In Zayan, R. (ed). Social space for domestic animals. Martinus Nijhoff, The Netherlands, pp. 151-159.

Ladewig, J., Smidt. D., (1989). Behaviour, episodic secretion of cortisol and adrenocortical reactivity in bulls subjected to tethering. *Horm. Behav*., 23 : 344-360.

Laegreid, W. W., Elder, R. O., Keen, J.E., (1999). Prevalence of Escherichia coli O157 : H7 in range beef calves at weaning. *Epidemiology and Infection*, 123 : 291-298.

Landes, E., (1996). Mutterkorn in Futtermitteln dür Rinder. *Übersichten zur Tiererernährung,* 24/1, 92-101.

Langhans W., Rossi, R., Scharrer, E., (1995). Relationships between feed and water intake in ruminants. Proceed. 8th Internat. Symp. Rum. Physiology, pp. 199-216.

Lanier, J. L., Grandin, T., Green, R. D., Avery, M. K., (2000). The relationship between reaction to sudden, intermittent movements and sounds and temperament. *Departement society of animal sciences*, 78 : 1467-1474.

Larsson, J. G., Konggaard, S. P., Madsen, E. B.and Nielsen, K. (1984). Haletråd hos ungtyre. II. Adfærd i relation til belægningsgrad og staldtype. Meddelelse 559. Statens Husdrybrugsforsøg. Frederiksberg, Denmark, 4 pp.

Le Neindre, P., (1984). La relation mère-jeune chez les bovins : influences de l'environnement social et de la race : Rennes ; Thèse Doc. ès Sci.

Le Neindre, P., Sourd, C., (1984). Influence of rearing conditions on subsequent social behaviour of Friesian and Salers heifers from birth to six months of age. *Appl. Anim. Behav. Sci*., 12 : 43-52.

Le Neindre, P., (1989a). Influence of cattle rearing conditions and breed on social relationships of mother and young. *Appl. Anim. Behav. Sci*., 23 : 117-127.

Le Neindre, P., (1989b). Influence of rearing conditions and breed on social behaviour and activity of cattle in novel environments. *App. Anim. Behav. Sci.,* 23 : 129-140.

Le Neindre, P., Boivin, X., Boissy, A., (1996). Handling of extensively kept animals. *Appl. Anim. Behav. Sci.,* 49 : 73-81.

Lensink, B. J., Boivin, X., Pradel, P., Veissier, I., (2000). Reducing veal calves' reactivity to people by providing additional human contact. *J. Anim. Sci.,* 78 : 1213-1218.

Lensink, B. J., Fernandez, X., Boivin, X., Pradel, P., Le Neindre, P., Veissier, I., (2000). The impact of gentle contacts on ease of handling, welfare and growth of calves and on quality of veal meat. *J. Anim. Sci.,* 78 : 1219-1226.

Lésel, R., (1969). Etude d'un troupeau de bovins sauvages vivant sur l'île d'Amsterdam. *Revue d'Elevage et de Médecine Vétérinaire des Pays Tropicaux*, 22 : 107-125.

Lewis, I., Weninger, J.H., (1986). The behaviour of lactating cows under temperature stress in stallhousing. *Luechtungskundem* 58 : 102-123.

Lidfords, L., Jensen, P., (1988). Behaviour of free-ranging beef cows and calves. *Appl. Anim. Behav. Sci.,* 20 : 237-247.

Lidfors, L., (1989). The use of getting up and lying dawn movements in the evaluation of cattle environments. *Veterinary Research Communications*, 13 : 307-324.

Lidfors, L., (1992). Behaviour of bull calves in two different housing systems : deep litter in an uninsulated building versus slatted floor in an insulated building. Thesis Sveriges Lantbruksuniversitet, Veterinärmedinska Fakultatten, Institut för husdjurshygien.

Lidfors, L., (1987). Moder-unge beteende hos nötkreatur i semi-naturlig miljö – en orienterande undersökning. Swedish University of Agricultural Science, Department of Animal Environment and Health, Report 17, 29 pp.

Lidfors, L., Jensen, P., Algers, B., (1994). Suckling in free-ranging beef cattle – temporal patterning of suckling bouts and effects of age and sex. *Ethology*, 98 : 321-332.

Livingston, A., (1986). Assessing pain by studying physiological responses. In : Pain in Farm Animals, Commission of the Europena Communities, pp. 30-38.

Loerch, S. C., Fluharty, F.L., (2000). Use of trained animals to improve performance and health of newly arrived feedlot calves. *J. Anim. Sci.,* 78 : 539-545.

Lopez, J. W., Woods, G. T., Crandell, R. A., Pickard, J. R., Mansfield, M.E., (1984). A preconditioning program for beef calves. *Agri Practice*, 5 : 7-19.

Lorz, A., (1973). Tierschutzgesetz. C.H. Beck´sche Verlagsbuchhandlung, München.

Lott, D. F., Hart, B. L., (1979). Applied ethology in a nomadic cattle culture. *Appl. Anim. Behav. Sci.,* 5 : 309-319.

Lowman, B.G., Wright, I.A., (1995). Description of the UK beef industry, structure and production systems. Extensification of beef and sheep production on grassland. Occasional publication no. 2. Proceedings of a workshop held in Paris on November 22, 23 and 24, 1995, p 61-68.

Lowman, B. G., Donaldson, E., Edwards, R.A., (1978). The effect of time of weaning on the performance of suckled calves. *Anim. Prod.,* 26 : 381-382.

Lutz, P., (1981). Etologische Untersuchungen zum Tier-Fressplatsverhältnis bei Jungmastbullen. Univers. Wien, Diss.

Lutz, P. V., Bogner, H., Süss, M., Perschke, W., Fusseder, J., (1982). Etologische Untersuchungen zum Tier/Fressplatzverhältnis bei Jungmastbullen in Laufstallungen. Bayer. *Landwirtsch. Wochenbl.*, 59 : 696-717.

MacKenzie, A.M., Drennan, M., Rowan, T.G., Dixon, J.B., Carter, S. D., (1997). Effect of transportation and weaning on humoral immune responses of calves. *Res. Vet. Sci.*, 63 : 227-230.

Madsen, E. B., (1987). Health aspects of welfare research in fattening bulls. In Schhlitin, M.C. and Smidt, D. (editors). Welfare aspects of housing systems for vela calves and fattening bulls. CEC Report, Luxembourg 131-138.

Madsen, E. B., Thysen, I., Ingvartsen, K. L. and Østergaard, V., (1987). Health and production of young bulls at different stocking rates on slatted floors. *Nat. Inst. Anim. Sci. Foulum*, Denmark, Report 628, 209-218.

Majak, W., Howarth, R. E., Fesser, A.C., Goplen, B.P., Pedersen, M. W., (1980). Relationships between ruminant bloat and the composition of Alfalfa Herbage. II Saponins. *Can. J. Anim. Sci.,* 60 : 699-708.

Markowitz, T. M., Dally, M. R., Gursky, K., Price, E. O., (1998). Early handling increases lamb affinity for humans. *Anim. Behav.*, 55 : 573-587.

Martig, J., Leuenberger, W., (1978). Schwanzspitzennekrose in einen Stierenmastebetrieb der Schweiz. *Schweiz. Arch. Tierheilk.*, 120 : 447-453.

McCaughan, J., (1992). Treatment of mineral disorders in cattle. *Veterinary Clinics of North Amerika,* 8 : 107 – 145.

McDowell, L. R., Williams, S. N., Hidiroglou, N., Njeru, C. A., Hill, G. M., Ochoa, L., Wilkinson, N. S., (1996). Vitamin E-supplement for the ruminant. *Anim. Feed Sci. Technol.*, 60 : 273 – 296.

McMeekan, C. M., Mellor, D. J., Stafford, K. J., Bruce, R. A., Ward, R. N. and Gregory, N.G., (1997) Effects of shallow scoop and deep scoop dehorning on plasma cortisol concentrations in calves. *New Zealand Vet. J.*, 45 : 69-71.

McMeekan, C. M., Mellor, D. J., Stafford, K. J., Bruce, R. A., Ward, R. N., Gregory, N. G., (1998b). Effects of local anaesthesia of 4 or 8 hours duration on the acute cortisol response to scoop dehorning in calves. *Austr. Vet. J.*, 76 : 281-285.

McMeekan, C. M., Stafford, K. J., Mellor, D. J., Bruce, R. A., Ward, R. N., Gregory, N. G. (1998a). Effects of regional analgesia and/or a non-steroidal anti-inflammatory analgesic on the acute cortisol response to dehorning in calves. *Res. Vet. Sci.*, 64 : 147-150.

Mellor, D., Stafford, K., (1999). Assessing and minimising the distress caused by painful husbandry procedures in rumiants. *Practice,* 21 : 436-446.

Mellor, D. J., (1998). How can animal-based scientists demonstrate ethical integrity ? In : Ethical Approaches to Animal-Based Science, (Eds. D.J. Mellor, M. Fisher and G. Sutherland)., pp 19-31. ANZCCART, Wellington, New Zealand.

Mellor, D. J., Murray, L., (1989). Changes in the cortisol responses of lambs to tail docking, castration and ACTH injection during the first seven days after birth. *Res. Vet. Sci.*, 46 : 392-395.

Mellor, D. J., Stafford, K. J., (1997). Interpretation of cortisol responses in calf disbudding studies. *New Zealand Vet. J.,* 45 : 126-127.

Mellor, D. J., Stafford, K. J., (1999). Assessing and minimising the distress caused by painful husbandry procedures. *Practice,* 21 : 436-446.

Mellor, D. J, Cook, C. J., Stafford, K. J., (2000). Chapter 9 : Quantifying some responses to pain as a stressor. In : Moberg, G.P. and Mench, J.A. (eds). The Biology of Animal Stress : Basic Principles and Implications for Welfare. CAB International, Wallingford, Oxon, UK, pp 171-198.

Metz, J. H. M., (1984). The reaction of cows to short term deprivation of lying. Applied Animal *Behav. Sci.*, 13 : 301-307.

Metz, J. H. M., (1974). Time patterns of feeding and rumination in domestic cattle. Meded Landbouwhogesch. PhD dissertation, NL 75-12, Wageningen, Netherlands.

Metzner, M., Hofmann, W., Heckert, H.P., Koberg, J., Raue, F., (1994). Zur Epidemiologie der Schwanzspitzenentzündung bei Mastbullen. *Tierärztl. Umschau*, 49 : 348-355.

Michell, A.R., (1985). Sodium in health and disease : A comparative review with emphasis on herbivores. *T. Vet. Rec.*, 116 : 653-657.

Micol, D., (1986). Production de viande de bœufs et de jeunes taureaux. In production de viande bovine, Ed. D. Micol, 169-200.

Mills, C. F., (1983). The physiological and pathological basis of trace element deficiency disease. In : Trace Elements in Animal Production and Veterinary Practice. Edinburgh, Occasional Publication of the British Society of Animal Production No 7, p 1.

Ming, J., (1984). Untersuchungen über die eignung von Loch- und Spaltenboden (betonflächenroste). in der Rindviehmast. Diploarbeit, ETH, Zürich, Switzerland.

Moberg, G.P., (1985). Biological response to stress : key to assessment of animal well-being ? In : Moberg, G.P. (ed.). Animal Stress. Am. Physiol. Soc., Bethesda, 27-49.

Molony, V., (1991). Assessmet of pain in animals. IN : M. C. Appleby, R. I. Horrell, J. C. Petherick and S. M. Rutter (eds.). Applied Animal Behaviour : Past, Present and Future. UFAW : Potters Bar. pp.111-113.

Molony, V., Kent, J. E., (1997). Assessment of acute pain in farm animals using behavioral and physiological measurements. *J. Anim. Sci.*, 75 : 266-272.

Moraes, A. A. S. de, Lobato, J. F. P., Santos de Moraes, A. A., Piva-Lobato, J. F., (1993). Effect of age at weaning on growth in beef calves. *Revista da Sociedade Brasileira de Zootecnia*, 22 : 885-892.

Morrison, S. R., Lofgreen, G. P., Prokop, M., (1981). Effects of floor space allotment and animal group size on beef cattle performance. Transact. ASAE 24 : 450-51.

Morton, D. B., Griffiths, P. H. M., (1985). "Guidelines on the recognition of pain, distress and discomfort in experimental animals and an hypothesis for assessment". *Veterinary Record,* 116 : 431-436.

Mossberg, I., (1992). Environmental influences on growing bulls in two housing systems. Dissertation. Institutionen för husdjurens utfodring och vård. Swedish University of Agricoltural Sciences, Department of Animal Nutrition and Management, Uppsala.

Mossberg, I., Jönsson, H., (1996). The influence of day light and temperature on food intake and growth rate of bulls given concentrate or grass silage ad libitum in two housing systems. *Anim. Sci.,* 62 : 233-240.

Mossberg, I., Lindell L., Johnsson, S., Törnquist, M., Engstrand, U., (1992). Two housing systems for intensively reared bulls slaughtered in two weight ranges. *Acta Agric. Scand., Sect. A, Anim. Sci.*, 42 : 166-176.

Mount, L. E., (1979). Adaptation to thermal environment : man and his productive animals. Edward Arnold, London.

Müller, C., Ladewig, J., Schlichting, M. C., Thielscher, H. H., Smidt, D., (1986). Behavioural and ethological criteria for assessing possoble stress factors arising from flooring and density of heifers in group housing. KTLB- *Schrift,* 311 : 37-47.

Müller, C., Ladewig, J., Thielscher, H. H., Smidt, D., (1989).Behaviour and heart rate of heifers housed in tether stanchions without straw. *Physiol. Behav*., 46 : 751-754.

Munksgaard, L., Ingvartsen, K. L., Pedersen, L. J., Nielsen, V. K. M., (1999). Deprivation of lying down affects behaviour and pituitary-adrenal axis responses in young bulls. Acta Agric. Scand., Section A, *Anim. Sci.,* 49 : 172-178.

Murphey, R. M., Moura-Duarte, F. A., Torres Penedo, M. C., (1980). Approachability of bovine cattle in pastures : Breed comparisons and a breed-treatment analysis*. Behav. Genet*., 10 : 171-181.

Murphy, P.A., Hannan, J., Moneghan, M., (1987). A survey of lameness in beef cattle housed on slatts and on straw. In Wierenga, H.K. and Peterse, D.J. (eds)., Cattle housing systems, lameness and behaviour. Martinus Nijhoff, Dordrecht, The Netherlands, pp. 73-86.

Murphy, P. A., Weavers, E. D., Barret, J.N., (1975). Epiphysitis in beef cattle fattened on slatted floors. *Vet. Rec.* 97 : 445-447.

Nakanishi, Y., Shigemori, K., Yanagita, K., Mieno, M., Manda, M., (1998). Behavioural and growth effect of oral administration of rumen protected tryptophan on weanling beef calves. Memoirs of the Faculty of Agriculture, Kagoshima University, 34 : 89-95.

Neau, F. X., Berten, D., (1993). La castration de la vache, le "stericlip" technique chirurgicale par voie vaginale. G.T.V., 93-1-B-439, 65.

Neville, W.E. Jr., McCormick, W. C., (1981). Performance of early- and normal-weaned beef calves and their dams. *J. Anim. Sci.,* 52 : 715-724.

Nicks, B., Dechamps, P., Canart, B., Istasse, L., (1988). Resting behaviour of Friesian bulls maintained in a tie-stall barn under two patterns of lighting. *Appl. Anim. Behav. Sci.*, 19 : 321-329.

Nielsen, B., (2000). Organic Beef production based on dairy bred bull calves. M.Sc. thesis. The Royal Vet. Agric. University. Copenhagen. 81 pp.

Nockels, C. F., Stanton, T. L., Ellis, R. P., Kibler, D. R., Craig, A. M., (1993). Effect of injectable α-tocopherol on gain, feed efficiency and health of lightweight heifers. Beef Programm Report, Colorado State Univers. Fort Collins, CO, pp 75 – 83.

Noordhuizen, J. P., (1999). Production diseases in dairy cattle ; The veterinarian's role in disease control in the new millennium. In : Wensing, Th. (ed.). Production diseases in farm animals, p. 1-9. Int. Conf. On Production Diseases, Utrecht, Nl.

NRC, (1984). Nutrient Requirement of Beef Cattle. Nat. Acad. Press, Washington D.C.

O'Kiely, P., and Flynn, A.V. (1990). Comparison of unwilted grass silages made using the pick-up wagon and the double-chop harvester systems. *Canadian Agricultural Engineering*., 33 : 119-125.

Oberosler, R., Carenzi, C., Verga, M., (1982). Dominance hierarchies of cows on alpine pastures as related to phenotype. *Appl. Anim. Ethol*., 8 : 67-77.

Obritzhauser, W., Deutz, A., Köfer, J., (1998). (Comparison of two castration methods in cattle : plasma cortisol levels, leukocyte count and behavioral changes). *Tierarztl. Prax. Ausg. G. Grosstiere Nutztiere,* 26 : 119-126.

OECD, (2001). Environmental Health and Safety Publications Series on Testing and Assessment No. 19 Guidance Document on the Recognition, Assessment, and Use of Clinical Signs as Humane Endpoints for Experimental Animals Used in Safety Evaluation. For the complete text of see http://www.oecd.org/ehs/ or contact : OECD Environment Directorate, Environmental Health and Safety Division 2 rue André-Pascal, 75775 Paris Cedex 16 France E-mail : ehscont@oecd.org.

Oldenburg, E., (1993). Occurrence of zearalenone in maize. *Mycotoxin Research*, 9 : 72-78.

Oldenburg, E., (1999). Mykotoxine im Grundfutter und ihre Bedeutung im Carry-over-Geschehen. In : Kreisläufe erwünschter und unerwünschter Stoffe – ihre Bedeutung in der Nahrungskette. Schriftenreihe des Bundesministeriums für Ernährung, Landwirtschft und Forsten, Reihe A : Angewandte Wissenschaft, Heft 483, pp 225 – 235.

Olsson, S.E., Reiland, S., (1978). The nature of osteochondrosis in animals. *Acta Radiol.*, Suppl., 358 : 299 - 306.

Ouedraogo, A., Le Neindre, P., (1999). L'homme et l'animal : un débat de société, INRA Editions, Paris, 218 pp.

Overton, T. R., Drackley, J. K., Ottemann-Abbamonte, C. J., Beaulieu, A. D., Emmert, L. S., Clark, J.,H., (1999). Substrate utilization for hepatic gluconeogenesis is altered by increase glucose demand in ruminants. *J. Anim. Sci.*, 77 : 1940 - 1951.

Owens, F. N. M, Secrist, D. S., Hill, W. J., Gill, D. R., (1998). *J. Anim. Sci.*, 76 : 275 – 286.

Pahl, H., (1997). The effect of different stocking densities on performance and profitability in fattening bulls. 1st communication : the effect on performance. *Zuchtungskunde,* 69 : 181-195.

Pajor, E. A., Rushen, J., de Passille, A.M., (1999). Aversion learning techniques to evaluate dairy cow handling practices. *J. Anim. Sci.,* 77 (suppl. 1) : 149 (abstr.).

Perry, T.W., (1992). Feedlot fattening in North America in Beef cattle production edited by Jarriage R. and Beranger G, World Animal Science C 5, published by *Elsevier*, Amsterdam.

Perry, T.W., (1995). Feedlot disease. In : Perry, T.W. and Cecava, M (eds). Beef cattle feeding and nutrition, 2ed edition, Academic Press, pp. 284-290.

Peters, R. R., Chapin, L. T., Emery, R. S., Tucker, H. A., (1980). Growth and hormonal response of heifers to various photoperiods. *J. Anim. Sci.*, 51 : 1148-1153.

Peterson, E. B., Strohbehn, D. R., Ladd, G. W., Willham, R. L., (1989). Effects of preconditioning on performance of beef calves before and after entering the feedlot. *J. Anim. Sci.*, 67 : 1678-1686.

Peterson, G. A., Turner, T. B., Irvin, K. M., Davis, M. E., Newland, H. W., Harvey, W. R., (1987). Cow and calf performance and economic considerations of early weaning of fall-born beef calves. *J. Anim. Sci.*, 64 : 15-22.

Petitclerc, D., Chapin, L. T, Tucker H. A., (1984). Carcass composition and mammary development responses to photoperiod and phase of nutrition inHolstein heifers. *J. Anim. Sci.*, 58 : 913-919.

Petrie, N., Mellor, D. J., Stafford, K. J., Bruce, R. A., Ward, R. N., (1996a). Cortisol responses of calves to two methods of tail docking used with or without local anaesthetic. *New Zealand Vet. J.,* 44 : 4-8.

Petrie, N., Mellor, D. J., Stafford, K. J., Bruce, R. A., Ward, R. N., (1996b). Cortisol responses of calves to two methods of disbudding used with or without local anaesthetic. *New Zealand Vet. J.,* 44 : 9-14.

Petrie, N., Stafford, K. J., Mellor, D. J., Bruce, R. A., Ward, R. N., (1995). The behaviour of calves tail docked with a rubber ring used with or without local anaesthetic. Proceedings of the New Zealand Society of Animal Production 55 : 58-60.

Philippeau, C., Martin, C., Michalet-Doreau, B. (1999). Influence of grain source on ruminal characteristics and rate, site, and extent of digestion in beef steers. *J. Anim. Sci.,* 77 : 1587 - 1596.

Phillips, C. J. C., Leaver, J. D., (1985). Seasonal and diurnal variation in the grazing behaviour of dairy cows. In : Grazing, BGS Occasional Symposium, No. 19 : 98-104.

Phillips, C. J. C., (1993). Cattle Behaviour. Farming Press Books, Ipswich.

Phillips, C. J. C, Johnson, P.N., Arab, T. M., (1997). The effect of supplementary light during winter on growth, body composition and behaviour of steers and heifers. *Anim. Sci.*, 65 : 173-181.

Phillips, W. A., Juniewicz, P. E., Zavy, M. T., Tungeln, D. L. von, (1987). The effects of the stress of weaning and transit on performance and metabolic profile of beef calves of different genotypes. *Can. J. Anim. Sci*., 67 : 991-999.

Poli, J. L. E. H., Osorio, F. H. S., Becker, A. S., (1976). Weaning beef calves at 12 weeks old (called early). Anuario Tecnico de Instituto de Pesquisas Zootecnicas "Francisco Osorio", 3 : 169-184.

Pollock. J. M., Rowan, T. G., Dixon, J. B., Carter, S. D. (1994). Level of nutrition and age at weaning : effects on humoral immunity in young calves. *Br. J. Nutr*., 71 : 239-248.

Posey, J. T., Smart, L. I., (1976). Early weaning of beef calves. *Louisiana Agriculture*, 19 : 4-5.

Pougin, M., Andræ, U., Unshelm, J., Smidt, D., (1983). Zur Anpassung von Jungrindern an die Spaltenbdehaltung unter Berücksichtigung von Verhaltensmerkmalen, Klauenveränderungen und Blutserumenzymen. *Landbauforschung Völkenrode*, 33 : 158-168.

Price, E. O., 1984. Behavioural aspects of animal domestication. *Quarterly Review of Biology*, 59 : 1-32.

Price, E. O., Wallach, S. J. R. (1990). Physical isolation of hand-reared Hereford bulls increases their aggressiveness toward humans. *Appl. Anim. Behav. Sci*., 27 : 263-267.

Price, E. O., Wallach, S. J. R., Silver, G. V., (1990). The effects of long-term individual vs group housing on the sexual behavior of beef bulls. *Appl. Anim. Behav. Sci.,* 27 : 277-285.

Purcell, D., Arave, C. W., (1991). Isolation vs. group rearing in monozygous twin heifer calves. *Appl. Anim. Behav. Sci.,* 31 : 147-156.

Raj, M. A. B., Moss, B. W., McCaughley, W. J., McLauchlan, W., Kilpatrick, D. J., McGaughey, S. J., (1991). Behavioural response to mixing of entire bulls, vasectomized bulls and steers *Appl. Anim. Behav. Sci.,* 31 : 157-168.

Reiland, S., Strömberg, B., Olsson, S. E., Dreimanis, I., Olsson, I. G., (1978). Osteochondrosis in growing bulls. Pathology, frequency and severity on different feedings. *Acta Radiol*., Suppl. 358 : 179 - 196.

Reinhardt, C., Reinhardt, A., Reinhardt, V., (1986). Social behaviour and reproductive performance in semi-wild scottish highland cattle. *Appl. Anim. Behav. Sci*., 15 : 125-136.

Reinhardt, V., Reinhardt, A., (1981). Cohesive relationships in a cattle herd (Bos indicus). *Behaviour*, 77 : 121-151.

Reinhardt, V., Reinhardt, A., Mutiso, F. M., (1977). Cow-calf relationship in Massai cattle. 28th Annual Meeting of the European Association of Animal Production. Brussels, Paper M/1.04/1-7.

Renger, H., (1975). Agressive Verhalten von Bullen dem Menschen gegenüber.Diss. Med.Vet., München.

Richardson, F. D., Oliver, J., Clarke, G. P. Y., (1978). The pre-weaning and post-weaning growth of beef calves in relation to the amounts of milk and solid food consumed during the suckling period. *Rhodesian J. Agric. Res.*, 16 : 97-108.

Rickaby, C.D., (1980). A note on selenium for ruminants. *ADAS Quarterly Review,* 38 : 129.

Riol, J. A., Sanchez, J. M., Egwen, U. G., Gaudioso, U. R., (1989). Colour perception in fighting cattle. *Appl. Anim. Behav. Sci*., 23 : 199-208.

Robertson, I. S., Kent, J. E., Molony, V., (1994). Effects of different methods of castration on behaviour and plasma cortisol in calves of three ages. *Res. Vet. Sci.,* 56 : 8-17.

Roche, J. F., Boland, M. P., (1980). Effect of extended photoperiod in winter on growth rate of Friesian male cattle. *Irish J. Agric. Res*., 19 : 85-90.

Rode, L. M., Mc Allister, T.A., Cheng, K.-J., (1990). Microbial degradation of vitamin A in rumen fluid from steers fed concentrate, hay or straw diets. *Can. J. Anim. Sci.*, 70 : 227 – 233.

Ruckebush, Y., (1974). Sleep deprivation in cattle. *Brain Research*, 78 : 495-499.

Ruis-Heutinck, L., Heeres-van der Tol, J., Smits, M, Smits, D., (1999a). Meer oppervlak geeft betere groei bij vleesstieren. *Praktijkonderzoek Rundvee, Schapen en Paarden*, 12 : 27-29.

Ruis-Heutinck, L., Heeres-van der Tol, J., Smits, M., Smits, D., (1999b). Zacht ligbed favoriet bij vleesstieren. *Praktijkonderzoek Rundvee, Schapen en Paarden*, 12 : 29-31.

Rushen, J., Taylor, A. A., de Passillé, A. M., (1999). Domestic animals' fear of humans and its effect on their welfare. *Appl. Anim. Behav. Sci.,* 65 : 285-303.

Russell, J. B., Sharp, W. M., Baldwin, R. L., (1979). *J. Anim. Sci.,* 48 : 251 – 255.

Sainsbury, D., Sainsbury, P., (1988). Livestock Health and Housing. Bailliere Tindall, London.

Sambraus, H. H., Osterkorn, K., (1974). The social stability in a herd of cattle. Die soziale stabilitat in einer rinderherde. *Zeitschrift fur Tierpsychologie*, 35 : 418-424.

Sambraus, H. H., (1980). Humane consideration in calf rearing. *Animal Regulation Studies*, 3 : 19-22.

Sato, S., (1984). Social licking pattern and its relationship to social dominance and live weight gain in weaned calves. *Appl. Anim. Behav. Sci.,* 12 : 25-32.

Sato, S., Kuroda, K., (1993). Behavioural characteristics of artificially reared calves. *Anim. Sci. Tech.*, 64 : 593-598.

Sauvant, D., Chapoutot, P., Achime de, H., (1994). La digestion des amidons par les rumints et ses consequences. *INRA Prod. Anim.*, 7 : 115-124.

Sauvant, D, Dulphy, J. P., Michalet-Doreau, B., (1990). Le concept d`indice de fibrosite` des aliments des ruminants. *INRA Prod. Anim.*, 3 : 309-318.

Sauvant, D., Meschy, F., Mertens, D., (1999). Les composantes de l'acidose ruminale et les effets acidogènes des rations. *INRA Prod. Anim.*, 12 : 49-60.

SCAHAW, (1999) Scientific Committee on Animal Health and Animal Welfare Standards for the microclimate inside animal transport road vehicles. 8 December 1999. Sanco/B3/AW/R13/1999. http://europa.eu.int/comm/food/fs/sc/scah/out35_en.html

Schartzkopf-Geswein, K. S., Stookey, J. M., Crowe, T. G., Genswein, B. M. A., (1998). Comparison of image analysis, exertion force, and behaviour measurements for use in the assessment of beef cattle responses to hot-iron and freeze branding. *J. Anim. Sci.*, 76 : 972-979.

Schartzkopf-Geswein, K. S., Stookey, J. M., Welford, R., (1997). Behaviour of cattle during hot-iron and freeze branding and the subsequent handling ease. *J. Anim. Sci.*, 75 : 2064-2072.

Schein, M. W., Hafez, E. S. E., (1969). The physical environment and behaviour. In : The Behaviour of Domestic Animals (ed. Hafez, E. S. E.)., Williams and Wilkins, Baltimore, pp. 65-84.

Schenkel, H., Flachowsky, G., (1998). Bewertung zulässiger Spurenelementhöchstgehalte aus Sicht der Tierernährung. In : Kreisläufe erwünschter und unerwünschter Stoffe – ihre Bedeutung in der Nahrungskette. Schriftenreihe des Bundesministeriums für Ernährung, Landwirtschft und Forsten, Reihe A : Angewandte Wissenschaft, Heft 483 : 67 - 95.

Schloeth, R., (1958). Cycle annuel et comportement social du taureau de Camargue. *Mammalia*, 22 : 121-139.

Schmid, O., Richter, T., (2000). Marketing measures for selling organic food in European retail chains - Key factors of success. Proceedings of the 13th International IFOAM Scientific Conference in Basel. Hochschulverlag. Zürich. 519-522.

Schnitzer, U., (1971). Abliegen, liegestellungen und aufstehen beim rind im hinblick auf die entwicklung von stalleinrichtungen für milchvieh. KTBL – Bauschriften, Heft 10 : 43 pp.

Scholz, H., (1984). Fütterungsbedingte Belastungszustände im Herbst. *Prakt. Tierarzt colleg. vet.*, XV : 72-79.

Schwarz, F. J., Kirchgessner, M., Heindl, U., Augustini, C., (1995). Zum Einfluß unterschiedlicher Rohprotein- und Energiezufuhr auf Mast- und Schlachtleistung von Fleckvieh-Jungbullen. 2. Mitt. Schlachtkörper- und Fleischqualität sowie Auswirkungen auf den Rohproteinbedarf. *Züchtungskunde*, 67 : 62-74.

Scudamore, K. A., Livesey, C. T., (1998). Occurrence and significance of mycotoxine in forage crops and silage : a review. *J. Sci. Food and Agr.*, 77 : 1-17.

Seabrook, M. F., (1986). The relationship between man and animals in managed systems. Cole, D. J. A. and Brander, G. C., Editor. Bioindustrial Ecosystems. Amsterdam (The Netherlands). Elsevier Science Publishers B.V., pp. 211-221.

Siegel, H. S., (1983). Effects of intensive production methods on livestock health. *Agro-Ecosystems,* 8 : 215-230.

Silanikove, N., Gutman, M., (1992). Interrelationship between lack of shading shelter and poultry litter supplementation : food intake, live weight, water metabolism and embryo loss in beef cows grazing dry Mediterranean pasture. *Anim. Prod.*, 55 : 371-376.

Simonsen, H. B., Klinken, L., Bindseil, E., (1991). Histopathology of intact and docked pigtails. *British* Vet. *J.,* 147 : 407-412.

Smith, B., (1998). Moving'em : a guide to low stress animal handling. University of Hawaii, Graziers Hui, Kamuela, HI, USA.

Smith, C. A., (1955). Studies on the Northern Rhodesia Hyporrhemia veld. *J. Agr. Sci.*, Cambridge, 52 : 369-375.

Smith, G. C., Morgan, J. B., Sofos, J. N., Tatum, J. D., (1996). Supplemental vitamin E in beef cattle diets to improve shelf-life of beef. *Anim. Feed Sci. Technol.*, 59 : 207 – 214.

Smith, R. A., (1998). Impact of disease on feedlot performance : a review. *J. Anim. Sci.*, 78 : 272-274.

Smits, A. C., (1993). Vollspaltenboden mit Gummimattenin Vergleichstest. DLZ, 32 : 86-98.

Smits, A. C., Plomp, M., Goedegebuure, S. A., (1995). Comparison of behaviour, performance and health of bulls for beef production housed on concrete and on rubber-topped concrete slatted floors. (Dutch). Wageningen, IMAG-DLO rapport 94-26 pp 48.

Soffié, M., Thinès, G., Falter, U., (1980). Colour discrimination in heifers. *Mammalia,* 44 : 97-121.

Soulsby, L, Morton, D. B., (2001). Eds : FRAME/RSM conference on : Pain : Nature and management in man and animals. London, UK 30/31 March 2000. See chapter by Maria Fitzgerald.

Spires, H. R., Clark, J. H., (1979). Effect of intraruminal ures administration on glucose metabolism in dairy steers. *J. Nutr.,* 109 : 1438 - 1447.

Stafford, K. J., Mellor, D. J., (1997). Calf disbudding : a problem of pain perception by scientists, humans or animals ? *Dairy Cattle Veterinarians Newsletter,* 14 : 5-6.

Stafford, K. J., Mellor, D. J., (1993). Castration, tail docking and dehorning - What are the constraints ? Proceedings of the New Zealand Society of Animal Production 53 : 189-195.

Stewart, P. H., Arave, C. W., Dias, B., (1992). The effect of observation on Holstein heifer´s learning ability in a closed field maze. *J. Anim. Sci.,* 70 (Supplement 1). : 155.

Stoskopf, M.K., (1983). The physiological effects of psychological stress. *Zoo Biology*, 2 : 179-190.

Strickling, W.R., (1983). Matrilinear social dominance and spatial relationships among Angus and Hereford cattle. *J. Anim. Sci.,* 57 : 1397-1405.

Sturén, M., (1985). Serum 25-hydroxyvitamin-D concentration in beef cattle herds in which ruptures of the Achilles tendon had occured. *Acta Vet. Scand.*, 26 : 169-178.

Sunderland, S., (1978). Nerves and Nerve Injuries, 2nd ed. Edinburgh : Churchill Livingstone, p 377.

Sundrum, A., (1999). EEC-Regulation on organic livestock production and their contribution to the animal welfare issue. *KTBL-Schrift*, 270 : 93-102.

Sundrum, A., Rubelowski, I., (2000). Meaningfulness of design criteria in relation to animal health of fattening bulls. *Acta Agriculture Scandinavica Animal Science,* (in press).

Suttle, N. F., Jones, D.G., (1989). Recent developments in trace element metabolism and function : Trace elements, disease resistance and immune responsiveness in ruminants. *J. Nutr.*, 119 : 1055 – 1061.

Sylvester, S. P., Mellor, D. J., Stafford, K. J., Bruce, R. A., Ward, R. N., (1998). Acute cortisol responses of calves to scoop dehorning using local anaesthesia and/or cautery of the wound. *Aust. Vet. J.*, 76 : 118-122.

Sylvester, S. P., Stafford, K. J., Mellor, D. J., Bruce, R. A., Ward, R. N., (1998). Acute cortisol responses of calves to four methods of dehorning by amputation. *Aust. Vet. J.*, 76 : 123-126.

Taura, Y., Sasaki, N., Nishimura, R., Ohaschi F., Takeuchi A., Usui K. (1984). Ulceric lesions of articular cartillages distal to carpal and tarsal joints in Japanese black beef cattle. *Jpn. J. Vet. Sci.,* 46 : 571-576.

Tennessen, T., Price, M. A., Berg, R. T., (1985). The social interactions of young bulls and steers after re-grouping. *Appl. Anim. Behav. Sci.*, 14 : 37-47.

Thomas, V.M., (1986). Beef Cattle production – An integrated approach. Lea & Febiger, Philadelphia, 270 pp.

Thompson, D. L., (2000). Immunization against GnRH in male species (comparative aspects). *Anim. Reprod. Sci.*, 60-61 : 459-469.

Tillie, M., Capdeville, J., Jaubourg, J., Aubert, C., (1996). Bâtiments d'élevage bovin, porcin et avicole : Réglementation et préconisations relatives à l'environnement. Ministère de l'agriculture de la pèche et de l'alimentation, France.

Toates, F., (1995). Stress- conceptual and biological aspects. John Wiley & Sons, Chichester, 339 pp.

Trujillo, G., (2000). Organic livestock production in Spain. In : Diversity of livestock systems and definition of animal welfare. Proceedings of the 2. NAHWOA workshop, Cordoba. The University of Reading. 40-49.

UFAW, (1989). Guidelines for the Recognition and Assessment of Pain in Animals (Editors Association of Veterinary Teachers and Research Workers)., Potters Bar, 24 pp.

USDA, (1999). Cattle-Final Estimates 1994-1998.

USDA Statistical Bulletin SB953.

Uvnäs,-Moberg, K., Johansson, B., Lupoli, B., Svennersten-Sjaunja, K., (2001). Oxytocin facilitates behavioural, metabolic and physiological adaptations during lactation. *Appl. Anim. Behav. Sci.*, 72, (in Press).

Veissier, I., Gesmier, V., Le Neindre, P., Gautier, J. Y., Bertrand, G., (1994). The effects of rearing in individual crates on subsequent social behaviour of veal calves. *Appl. Anim. Behav. Sci.*, 41 : 199-210.

Veissier, I., (1993). Observational learning in cattle. *Appl. Anim. Behav. Sci.*, 35 : 235-243.

Veissier, I., Boissy, A., Capdeville, J., Sarignac, C., (2000). Le bien-être des animaux d'élevage : comment peut-on l'évaluer ? *Le point vétérinaire*, 31 : 25-32.

Veissier, I., Lamy, D., Le Neindre, P., (1990). Social behaviour in domestic beef cattle when yearling calves are left with the cows for the next calving. *Appl. Anim. Behav. Sci.*, 27 : 193-200.

Veissier, I., Le Neindre, P., (1989). Weaning in calves : its effects on social organization. *Appl. Anim. Behav. Sci.,* 24 : 43-54.

Veissier, I., Le Neindre, P., Trillat, G., (1989a). The use of circadian behaviour to measure adaptation of calves to changes in their environment. *Appl. Anim. Behav. Sci.,* 22 : 1-12.

Veissier, I., Le Neindre, P., Trillat, G., (1989b). Adaptability of calves durin weaning. *Biol. Behav.*, 14 : 66-87.

Veissier, I., Le Neindre, P., Garel, J. P., (1990). Decrease in cow-calf attachment after weaning. *Behavioural Processes.*, 21 : 95-105.

Vlizlo, V., Lewtschenko, W., (1992). Contribution to liver affections in fattening bulls. *Dtsch. tierärztl. Wschr.,* 99 : 254 - 257.

Vogel, G. L., Parrott, J. C., (1994). Mortality survey in feedyards : The incidence of death from digestive, respiratory and other causes in feedyards of the Great Plains. *Compend. Contin Educ. Pract. Vet.,* 16 : 227-234.

Waynert, D. F., Stookey, J. M., Schwartzkof-Genswein, K. S., Watts, J. M., Waltz, C.S., (1999). The response of beef cattle to noise during handling. *Appl. Anim. Behav. Sci.*, 62 : 27-42.

Weaver, A.D., (1978). Hip dysplasia in beef cattle. *Vet. Rec.*, 102 : 54-55.

Wee, E., Wierenga, H. K., Smits, A. C. and Smits, M. C. J. (1989). Claw and leg disorders in cattle in relation to the design and constructions of floors. Report Instituut voor Veeteeltkundig Onderzoek " Schoonord", B-345, pp 28.

Weiguo, L., Phillips, C. J. C., (1991). The effects of supplementary light on the behaviour and performance of calves. *Appl. Anim. Behav. Sci.,* 30 : 27-34.

Welch, J. G., (1982). *J. Anim. Sci.*, 54 : 885.

White, S., Rowland, G. N., Whitlock, R.H., (1984). Radiographic, macroscopic and microscopic changes in growth plates of calves raised on hand flooring. *Am. J. Vet. Res.*, 45 : 633-639.

Wibrån, K., Åkerberg, A., (1984). Social slikning hos tjurkalver i varm och kall lösdrift. Sveriges lantbruksuniversitet, Institutionen för husdjurshygien, Skara. Specialrbete 1.

Wieman, G. A., Campbell, J. B., Delshazer, J. A., Berry, I. L., (1992). Effects of stable flies (Diptera : Muscidae). and heat stress on weight gain and feed afficiency of feeder cattle. *J. of Economic Entomology*, 85 : 1835-1842.

Wiepkema, H., (1987). Developmental aspects of motivated behaviour in domestic animals. *J. Anim. Sci.,* 65 : 1220-1227.

Wiepkema, P.R., (1982). On the identity and significance of disturbed behaviour in vertebrates. In : W. Bessei (Ed.)., Disturbed behaviour in farm animals. Hohenheimer Arbeiten 121, 7-17, Verlag Eugen Ulmer, Stuttgart.

Wiepkema, P.R., (1987). Behavioural aspects of stress. In : P.W.M. van Adrichem and P.R. Wiepkema (eds.)., The biology of stress in farm animals : an integrated approach. Martinus Nijhoff, Dordrecht, 113-134.

Wiepkema, P. R., Broom, D. M., Duncan, I. J. H., van Putten, G., (1983). Abnormal behaviours in farm animals. CEC, Brussels, pp.16.

Wiepkema, P. R., van Hellemond, K. K., Roessingh, P. and Romberg, H., (1987). Behaviour and abomasal damage in individual veal calves. *Appl. Anim. Behav. Sci.,* 18 : 257-268.

Wierenga, H., (1983). The influence of space for walking and lying in a cubicle system on the behaviour of dairy cattle. In Baxter, S.H., Baxter, M.R., and MacCornack, J.A.C. (eds). Farm animal housing and welfare. Martinus Nijhoff, The Netherlands, pp. 171-180.

Wierenga, H., (1987). Ethological results of welfare research in fattening bulls. In Schhlitin, M.C. and Smidt, D. (editors). Welfare aspects of housing systems for vela calves and fattening bulls. CEC Report, Luxembourg 105-122.

Wierenga, H.K., (1987). Behavioural problems in fattening bulls. In : Schlichting, M.C. ; Smidt, D. : Welfare aspects of housing systems for veal calves and fattening bulls. Proc. of EC seminar held on 16-17 September 1986 in Mariensee, Germany.

Wilkens, S., (1981). Untersuchungen über die Ansteckungsmöglichkeiten von Rindern mit Taenia saginata uns Sarcocystis spp. Auf Abwasserverregnungsflächen und über das Absetzverhalten von Helmintheneiern in vitro. Tierärztl. Hochschule, Hannover, Diss.

Wolff, J., (1999). Bildung von Mykotoxinen auf Getreide und in Getreideerzeugnissen - Bedeutung im Carry-over-Geschehen. In : Kreisläufe erwünschter und unerwünschter Stoffe – ihre Bedeutung in der Nahrungskette. Schriftenreihe des Bundesministeriums für Ernährung, Landwirtschft und Forsten, Reihe A : Angewandte Wissenschaft, Heft 483, pp 208 – 224.

Wood, J.D., (1984). In Wiseman, J. (ed.)., Fats in Animal Nutrition, Butterworths, London. Pp. 407-435

Wood, M.T., (1977). Social grooming patterns in two herds of monozygotic twin dairy cows. *Anim. Behav.*, 25 : 635-642.

Wood-Gush, D. G. M., (1983). Elements of Ethology. Capman and Hall, London.

Woods, G. T., Mansfield, M. E., Cmarik, G. F., (1973). Effect of certain biologic and antibacterial agents on development of acute respiratory tract disease in weaned beef calves. *J. of the American Veterinary Medical Association*, 162 : 974-978.

Zavy, M. T., Juniewicz, P. E., Phillips, W. A., von Tungeln, D.L., (1992). Effect of initial restraint, weaning and transport stress on baseline and ACTH-stimulated cortisol responses in beef calves of different genotypes. *American Journal of Veterinary Research*, 53 : 551-557.

Zeeb, K., (1986). Design and management of breading litter houses for cattle. Personal communication, to Daelemans and Marton, 2 pp.

Zervas, G., (1995). Beef, sheep and goat production systems and extensification in Greece. Extensification of beef and sheep production on grassland. Occasional publication no. 2. Proceedings of a workshop held in Paris on November 22, 23 and 24, 1995, p 285-304.

Zeuner, F. E., (1963). A History of Domesticated Animals. Harper and Row, New York.

Zinn, S. A, Purchas, R. W., Chapin, L. T.,Petitclerc, D., Merkel, R. A., Bergen, W. G., Tucker, H.A.,(1986). Effects of photoperiod on growth, carcass composition, prolactin, growth hormone and cortisol in prepubertal and postpubertal Holstein heifers. *J. Anim. Sci.*, 63 : 1804-1815.

12. ACKNOWLEDGEMENTS