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Animal welfare and animal health :

Proceedings of Workshop 5 on Sustainable animal Production, organized by the Institute for Animal Science and Animal Behaviour, Federal Agricultural Research Centre (FAL), Mariensee, held September 4-5, 2000

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Animal Welfare and Animal Health

edited by
Franz Ellendorff, Volker Moennig, Jan Ladewig and Lorne Babiuk

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Workshop Series „Sustainable Animal Production", June - October 2000

Foreword to the Proceedings

How can agriculture provide a reliable source of food of animal origin for the world's population without compromising the basis of life of future generations? In view of the rising demand for food of animal origin in industrialized, emerging and developing countries, how can animal production on a global scale become sustainable?

These were among the key issues under scrutiny in a series of international workshops on sustainable animal production conducted during the world exposition EXPO 2000 by a consortium of scientists from four north German research institutions: the School of Veterinary Medicine Hannover (coordination), the Federal Research Institute for Agriculture (FAL), the Institute for Structural Analysis and Planning in Areas of Intensive Agriculture (ISPA) at the University of Vechta, and the Agricultural Faculty of the University of Göttingen.

A broad spectrum of current issues and problems in modern livestock production were covered: animal production and world food supply; globalization, production siting and competetiveness; product safety and quality assurance; the environmental impact of livestock farming; animal welfare and health; biotechnology and gene technology; animal genetic resources; animal nutrition: resources and new challenges; safeguarding animal health in global trade.

The individual workshops were organized by local coordinators and moderated by international discussion leaders. In all 142 scientists from 23 countries worldwide participated as speakers. The workshops produced a differentiated, inclusive and holistic vision of the future of global livestock farming without national bias and free of emotionally-tinged concepts or ideology. The results of the workshops were summarized and presented to the public in a final plenary session including a roundtable discussion with representatives of agricultural policy, public life and the media.

In addition to the publication of proceedings of the workshops as special issues of *Landbauforschung Völkenrode*, abstracts of the papers and summaries of the results are now documented in the Internet at www.agriculture.de, where a preparatory virtual conference was conducted from October 1999 until October 2000.

Volker Moennig
School of Veterinary Medicine Hannover

Workshopserie „Nachhaltige Tierproduktion", Juni – October 2000

Vorwort für die Tagungsbände

Wie kann die Landwirtschaft in Zukunft weltweit Menschen nachhaltig mit Lebensmitteln tierischer Herkunft versorgen, ohne die Lebensgrundlagen künftiger Generationen zu beeinträchtigen? Wie kann eine nachhaltige Tierproduktion global und angesichts wachsenden Bedarfs an Lebensmitteln tierischer Herkunft in Industrie-, Schwellen- und Entwicklungsländern aussehen?

Diese und ähnliche Fragen waren Anlass zur Organisation einer internationalen Workshopserie zum Thema „Nachhaltige Tierproduktion/Sustainable Animal Production" zur EXPO 2000. Veranstalter waren Wissenschaftler aus vier norddeutschen Forschungseinrichtungen: Die Tierärztliche Hochschule Hannover (federführend), die Bundesforschungsanstalt für Landwirtschaft (FAL), das Institut für Strukturforschung und Planungen in agrarischen Intensivgebieten der Hochschule Vechta (ISPA) sowie die Agrarwissenschaftliche Fakultät der Universität Göttingen.

Ein breites Spektrum von Themen, wie Tierproduktion und Welternährung, Globalisierung, Standortorientierung und Wettbewerbsfähigkeit, Umweltverträglichkeit der Tierproduktion, Tierschutz und Tiergesundheit, Produktsicherheit und Herkunftssicherung, Tierzucht und genetische Ressourcen, Sicherung der Tiergesundheit bei globalen Handelsströmen, Tierernährung: Ressourcen und neue Aufgaben, Bio- und Gentechnologie spiegeln die gesamte Bandbreite der modernen Tierhaltung und ihrer Probleme wider.

Die einzelnen Workshops wurden jeweils durch lokale Koordinatoren organisiert und von internationalen Diskussionsleiter moderiert. Insgesamt 142 Wissenschaftler und Wissenschaftlerinnen aus 23 Ländern weltweit haben als Referenten an der Serie teilgenommen. Die Workshops haben ein differenziertes und umfassendes, ganzheitliches Bild von der Tierhaltung der Zukunft ergeben, das frei von nationalen, teils emotional und ideologisch gefärbten Konzepten ist. In einem Abschlussworkshop wurden die Ergebnisse der Workshops mit Vertretern aus Politik, öffentlichem Leben und Presse diskutiert. Die jetzt vorliegenden Proceedings der Workshopserie in der *Landbauforschung Völkenrode* werden ergänzt und weltweit verfügbar gemacht durch die Veröffentlichung im Internet unter der Adresse www.agriculture.de. Unter derselben Internetadresse hatte vor den Workshops eine virtuelle Konferenz als Vorbereitung von Oktober 1999 bis Oktober 2000 stattgefunden.

Volker Moennig
Tierärztliche Hochschule Hannover

Introduction

Franz Ellendorff[1], Volker Moennig[2], Jan Ladewig[3], Lorne Babiuk[4]

The workshop "Animal Welfare and Animal Health" is part of the conference series on "Sustainable Animal Production". Sustainability is the preservation and care of resources for the future of mankind. In agriculture, including animal production sustainability was practised for centuries. In recent decades along with an exploding world population and increasing strain on resources sustainability had lost attention. During the last few years however, sustainability has regained recognition and momentum. A large number of activities evolved nationally and internationally.

The workshop "Animal Welfare and Animal Health" emphasises the close interaction between welfare and health of farm animals; each of the two topics is preceded by a basic paper that outlines major issues of animal welfare and animal health. There is no doubt that domestic animal production and associated high performance of farm animals has its cost and may compromise animal welfare and animal health. Despite considerable knowledge on the complexity of the animal´s function, ignorance still prevails as to the animals needs and coping mechanisms. It is one goal of the workshop to close some gaps and to elaborate new perspectives for a science-based animal welfare. In the second part of the workshop emphasis will be placed on animal health in modern animal production, its maintenance under situations where feed additives and the use of antibiotics is frowned upon by the consumer. Both treatment and prophylaxis will maintain their place in the management of infectious diseases. However, unwanted effects such as development of antibiotic resistance must be considered. New tools for diagnosis and vaccination will assist to fight and control diseases that occur locally or transgress national borders. Along with improvement on farm management of animals health as well as productivity of animals can be improved.

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4 Veterinary Infectious Disease Organization.

Welfare of domestic animals: Is it possible to keep them without exploiting them?

Jan Ladewig [1)]

Domestic animals are kept in order to produce. Livestock provide us with various products such as food, fur, leather and wool. Companion animals provide us with companionship. In addition, dogs may help us in various ways (guard dogs, guide dogs, hunting dogs, etc.), cats keep rodents away from our homes, horses help us perform some kind of sport. In all cases it is possible to breed, raise, and train animals that are capable of performing the various tasks many times better than their wild ancestors would be. Dairy cows selected for a high milk yield and fed according to their production can produce much more milk for much longer periods than nature ever intended. Sows kept in farrowing crates give birth to and raise many more piglets than wild boars. Domestic horses can run much faster over longer distances or jump higher than wild horses. Dogs are able to socialize with people easier and learn more things with less training than wolves.

High performance, however, has its cost. The incidence rate of mastitis increases in high yielding dairy cows with the result that they only last a few lactation periods. The mastitis-metritis-agalactia (MMA) syndrome is the biggest limiting factor in piglet production, and "spent sows" (i.e. sows brought to slaughter at the end of their productive period) are usually a very sad sight. Horses may develop lamenesses or respiratory problems because of inappropriate housing or locomotor pattern. And a large proportion of dogs are killed because of a behavioural problem such as separation anxiety or aggression. When morbidity or mortality rates reach a certain level, this striving for high performance raises an ethical question, namely whether it is acceptable to demand so much of domestic animals that appropriate consideration of their biological needs is severely compromised.

Although we generally know a lot about the biological needs of domestic animals, as far as nutrition, disease prevention, etc. is concerned, our understanding of their behavioural needs is insufficient. The incidence rate of behavioural problems in domestic animals clearly indicate that these needs are far from fulfilled. The rate of occurrence of stereotypic behaviour in many farm animals and horses, as well as more specific behaviour problems in the various species (e.g. aggression in fattening pigs, feather pecking in egg laying hens, anxiety problems in dogs, to name a few) are all clear indications of discrepancies between what we think is "good" for the animals and what the animals think about it.

Over the past two to three decades, research in the behaviour of domestic animals has definitely increased our understanding of their behavioural biology. We are, however, still faced with numerous unanswered questions. We still do not have proper methods with which we can diagnose various states of an animal such as chronic stress, anxiety, or frustration. The result is that it is difficult for us to pinpoint what aspects of the housing and management conditions that need improvement. Objective measures, whether behavioural or physiological, can, at best, give us a hint that something is wrong, but only if many symptoms point in the same direction do we accept them as proof. (Hence the many attempts to develop multifactorial systems to evaluate welfare.)

And if we finally manage to agree upon specific aspects (e.g. that group housing is good for social animals, that straw enables animals to show a more appropriate behaviour pattern than stereotypic behaviour, that diets with more fibre render restrictively fed animals less hungry), we are most often met with great resistance from the various "industries" to change things. Arguments such as 'straw is too expensive to use', 'bulky feed is too labour intensive', or 'group housing causes too much aggression among the animals' slow down any progress. And when legislature is brought in to move things along, loopholes are often found to circumvent specific laws. What good does it do to calf welfare to ban individual pens in Denmark, if the animals are then shipped to Holland and raised in individual pens there? Would the calves not be better off to be raised in individual pens in Denmark and thus avoid a long truck ride to Holland? Why forbid fox farming in Finland, where many attempts are made to improve the housing systems of the animals, if the result is that fur production moves to Russia? Is the welfare of the foxes improved by such a ban?

Modern intensive husbandry conditions have developed solely because they give the highest return with the least input. Any deviation away from present systems towards alternative (e.g. more animal friendly) systems means higher production costs and, consequently, less profit. Who shall pay the extra cost?

As already indicated, evaluation of the welfare of domestic animals obviously must be multifactorial, simply because so many different factors affect this

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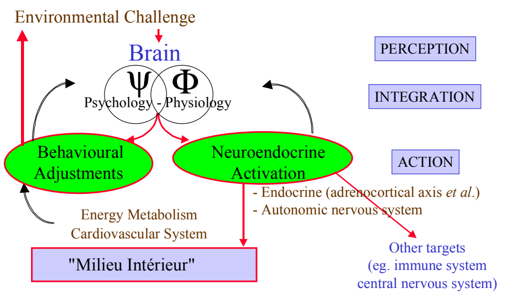
complex phenomenon "welfare". And although we still have a long way to go before we have proper methods by which we can judge how the animals are feeling, some progress has been made and, undoubtedly, will continue to be made in the future. But when it comes to the institution of measures intended to improve the animals' welfare, it is necessary to realize that, also at this point of the process must we be "multifactorial". Unless changes are made in a joint effort, chances are that we will not improve the welfare of the animals, but only the welfare of somebody else.

Stress and welfare, a psychoendocrine perspective

Pierre Mormède[1] and Magali Hay[2]

Animal welfare is usually defined by reference to the adaptation efforts necessary for the animal to cope with its environment. Permanent adjustments to maintain the 'milieu intérieur' (Bernard, 1878) within physiological limits despite variable environmental conditions are permitted by homeostatic mechanisms involving most physiological systems (Cannon, 1935). However, when the pressure from the environment becomes excessive, or in case of psychological threats, new defence mechanisms are initiated, collectively referred to as stress responses (Selye, 1973). All the above-mentioned pioneers of adaptation / stress physiology recognised that part of the stress response was the result of the emotional arousal elicited by environmental stimulations, and this aspect was further given more attention (Mason, 1971), so that the study of stress moved from the field of physiology to psychophysiology. This resulted in the integration of new concepts inherited from

Figure 1. General organization of adaptive responses

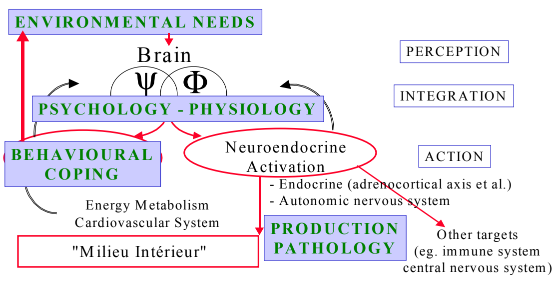


psychology, including coping that refers to the ability for the individual to control its environment and temperament that encompasses the individual variability of emotional processes (Lazarus, 1993). It was therefore recognised that the brain plays a central role in adaptation / stress mechanisms. The central nervous system collects from the external (via sensory organs) and internal environment the information necessary for the maintenance of homeostasis; it gives significance to this information in terms of danger or threat, as related to personal expectations, past experience and opportunities for control; finally, it initiates the adaptive responses, including behavioural adjustments, and neuroendocrine changes to meet the energy requirements for the behavioural response and to maintain homeostasis (Fig.1).

These concepts about adaptation and stress have long been shown to be operative for the analysis of the way farm animals deal with their environment (Dantzer and Mormède, 1983). The 'five freedoms' elaborated by the Brambell Committee of the U.K. Parliament in 1965 and updated by the Farm Animal Welfare Council (1992), that define the obligations of humans to ensure the welfare of farm animals, can be seen as a formal expression of the various components of this integrative psychobiological view of adaptation and stress (Fig.2):

- Freedom from hunger and thirst refers to the physiological requirements,
- Freedom from discomfort refers to the environmental needs,
- Freedom from pain, injury and disease refers to the pathological consequences of an adverse environment,
- Freedom to express normal behaviour refers to the importance of behavioural coping mechanisms for a successful adaptation,
- Freedom from fear and stress refers to the psychological component of adaptation.

Figure 2. Adaptive responses and the five freedoms



Several measures can be used to evaluate the welfare state of the animals, including behaviour, biological functions related to stress physiology, as well as zootechnical and pathological data. These evaluations should be based on multicriteria approaches, since no single measure can unequivocally be related to the level of welfare. Among those, neuroendocrine parameters are probably the most widely used, since corticosteroid hormone secretion by the adrenal cortex has been equated with stress level since the very beginning of the stress concept, and their measurement in plasma is relatively easy. Indeed, circulating levels of corticosteroid hormones are exquisitely sensitive to a

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2) Ethologie - Productions Animales, Ecole Nationale Vétérinaire de Toulouse, France.

wide range of stimuli including low level of emotional activation such as induced by novel environment exposure or social encounter. A large body of experimental data also shows that the hypothalamic-pituitary-adrenocortical (HPA) axis activity is related to the behavioural coping strategy, with active attempts to keep control over the situation being associated with a preferential activation of the sympathetic nervous system (SNS) whereas passive / submissive behaviours are associated with a higher secretion of corticosteroid hormones (Henry and Stephens, 1977).

However, it must be kept in mind that the HPA axis and the SNS are primarily involved in the regulation of numerous homeostatic processes, including energy metabolism, independently of the stress state. For example, the activity of the HPA axis is strongly influenced by the diurnal cycle, with a higher activity at the beginning of the behaviourally active period, at lights on for diurnal animals and at lights off for nocturnal animals. These diurnal changes are the result of the co-ordinated influence of the light cycle *per se* and of metabolic factors. There is also experimental evidence that plasma corticosteroid levels and catecholamines secretion are strongly influenced by the feeding regimen, although this aspect has not been investigated in great detail in farm animals. It is therefore important to be able to sort out the various influences impinging upon the physiological systems under study, since physiological adjustments and psychobiological influences are usually intermingled in the global stress response measured by circulating stress hormone levels.

Another factor to be taken into consideration is the exquisite sensitivity of the neuroendocrine systems to procedural factors such as handling and venous puncture for blood sampling, so that specific approaches have been developed to minimise the influence of the experimenter (e.g. saliva sampling for the assay of corticosteroids, telemetric monitoring of cardiac activity to evaluate SNS function). We are evaluating in pigs and other species the interest of measuring urinary levels of corticosteroids and catecholamines as indices of HPA axis and SNS function respectively. This approach has several potential advantages as compared to other methods of investigation (Hay et al., 2000):

- urine can be collected with minimal disturbance to the animals; therefore it does not introduce an experimental bias and it is convenient for field studies,
- the excretion products in urine sum up over several hours (i.e., since the last urination or collection time) so that hormone concentrations in urine are independent of the rapid variations of hormone release (related either to the pulsatility of neuroendocrine functioning or to procedure-related disturbances) and are therefore more integrative than plasma or saliva concentrations,
- both the HPA axis and SNS activity can be evaluated simultaneously, corticosteroids and catecholamines being measured in the same sample by specific HPLC procedures after solid phase extraction.

It is therefore expected that the monitoring of hormone levels in urine will allow an easier detection of long-term variations in HPA axis and SNS basal activity, as induced by chronic stressful situations or as related to different behavioural reactivity to emotional stimuli.

Recent data obtained in the study of early weaning (6 days) in pigs illustrate the interest of such a psychoendocrine approach for the study of animal welfare. As shown in figure 3, early weaning strongly reduced the growth rate of piglets, mostly because of a low ingestion of dry food during the first days after weaning. Urinary cortisol levels increased the day after weaning and rapidly returned to control levels afterwards (Fig. 4). Indeed, weaning has already been shown to increase cortisol secretion using plasma sampling, even at later ages (Carroll et al., 1998; Dantzer and Mormède, 1981; Kanitz et al., 1998), and from this result, it could be concluded that early weaning induces a short-lasting stress, not much different from classical weaning at 3-5 weeks.

Figure 3. Early weaning in pigs - effect on body growth

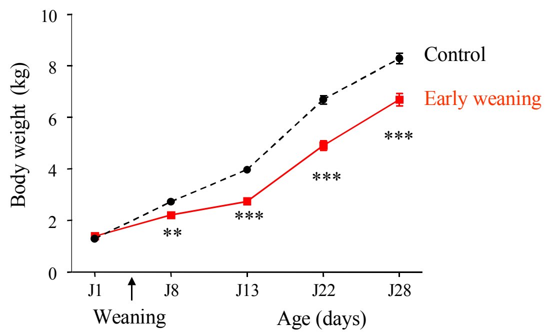
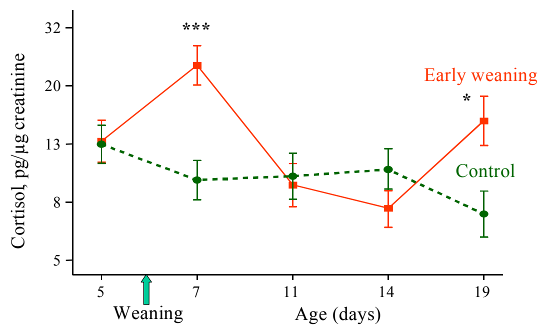
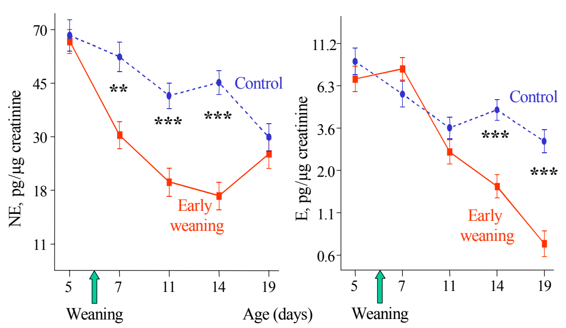


Figure 4. Early weaning in pigs - urinary cortisol



The picture is however different when considering the changes in catecholamine excretion (Fig.5). Noradrenaline concentration in urine showed a sharp and persistent decline and did not return to control levels until day 19, 2 weeks after weaning. Adrenaline concentration in urine remained stable until day 11, but therefore dropped down to very low levels until the end of the experiment. These results can be explained by the role played by catecholamines in energy regulation. Noradrenaline is mainly calorigenic through fat mobilisation and activation of brown adipose tissue metabolism. Thus, the activity of the noradrenergic system is tightly coupled to energy balance. Therefore the drop of noradrenaline likely reflects an energy saving mechanism related to the shortage of energy intake (Young and Landsberg, 1977). Indeed early weaned piglets spent more time under the infrared lamp and huddled together more than control animals, these thermoregulatory behaviours showing the deficit of metabolic thermogenesis.

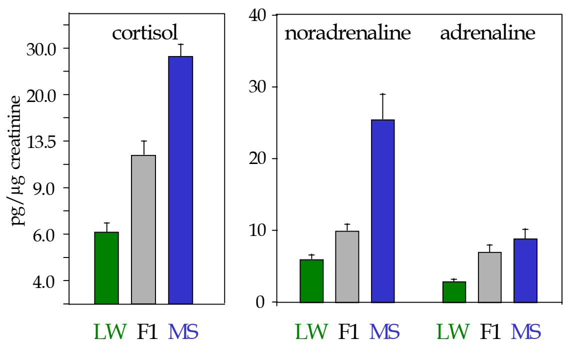
Figure 5. Early weaning in pigs - effect on urinary catecholamines



On the other hand, adrenaline is mainly involved in the maintenance of blood glucose levels via glycolysis and its late drop may be related to the exhaustion of glycogen stores (Young et al., 1984). Therefore, these very large changes in catecholamine excretion show that adaptive mechanisms are considerably taxed by early weaning, although we have no comparative data at the present time for classical weaning. It is worth noting that the intensity of the challenge to homeostatic mechanisms by early weaning was not revealed by the measurement of adrenocortical axis activity. Indeed, the transient increase of cortisol excretion could be related more to the psychological consequences of weaning (rupture of the mother-young link) but does not give a complete picture of the adaptation needs. This strengthens the idea that focusing on a sole physiological system gives an incomplete picture of the challenge imposed to the animals by their environment.

A large invidual variation can be observed in behavioural and neuroendocrine responses to environmental challenges. A large body of experimental evidence obtained mostly in experimental animals shows that these differences arise from the complex interplay of genetic factors, environmental influences during development (gestation and neonatal period), as well as learning processes from past experience. In farm animals, general behavioural reactivity profiles have been described, similar to temperaments in humans and experimental animals (Ramos and Mormède, 1997), as well as specific behavioural reactivity traits, like fear of humans (Lankin, 1997), that are important for their welfare. Large differences can also be found in the neuroendocrine profile (Hay and Mormède, 1998; Fig.6).

Figure 6. Concentration of cortisol and catecholamines in urine from Meishan and Large White lactating sows and their F1 hybrids



The influence of genetic factors in the shaping of these profiles of reactivity is overwhelming and well documented (Désautés et al., 1997, 1999), and a few studies have dealt with the influence of early environmental influences and learning processes. Furthermore, variations in behavioural and neuroendocrine traits are also related to production traits (Désautés et al., 1997). Indeed, as stated previously, neuroendocrine systems reactive to stress are primarily involved in metabolic regulations, and it is well established for example that an hyperactive HPA axis promotes the production of fat (e.g. pigs from the Meishan breed). More recently we also found that meat quality was related to the neuroendocrine profile as measured in urine collected after slaughter (unpublished results). Current molecular genetic studies should give some clues to the biological mechanisms involved in these individual differences of behavioural and neuroendocrine reactivity.

Future improvements of animal welfare should focus on the ways animals react to their environment and not only on changes in the environment, or at least they should take into account the individual diversity of adaptive responses and psychoendocrine reactivity. These reactivity traits can be selected for a better adaptation to environmental constraints, and the shaping of reactivity can also be obtained by early manipulation of the animals or specific training. Available data show that production output and product quality may also be concomitantly increased. Such a goal will be reached by a larger appraisal of animal – environment interactions, combining behavioural and biological approaches, and with the development of new strategies to evaluate more comprehensively the psychoendocrine mechanisms of adaptation.

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Pain in farm animals

Lynne U. Sneddon and Michael J. Gentle

What is pain?

This review will address how we can measure pain in farm animals and discuss the major causes of acute pain and also chronically painful conditions, and finally make suggestions for future improvements. Pain is a relatively difficult concept to define since it comprises both a physiological sensory and a psychological or emotional component. Pain is the subjective interpretation of nerve impulses induced by a stimulus that is actually or potentially damaging to tissues. The sensation of pain is a response to a noxious stimulus and should elicit protective motor (e.g. withdrawal reflex, escape) and vegetative responses (e.g. cardiovascular responses, inflammation). Zimmerman (1986) also suggested that in animals a painful experience should result in learned avoidance and affect the animal's behaviour including social behaviour. Therefore we can use behavioural and physiological criteria to determine whether an experience is painful to an animal. It is easier to assess pain in humans since we can tell each other how we are feeling. Many people are unwilling to accept that animals can feel pain since they believe that animals are not capable of having emotions that are similar to humans. The purpose of this review is not to debate this point but animal pain is possibly different to human pain, and can be defined as an "unpleasant sensory and emotional experience" (Bateson 1991). Pain is associated with suffering and distress and the treatment of animals in farm situations has been subject to increasing public concern. During production, farm animals are exposed to procedures which can lead to injury, disease and other noxious events and this will have negative consequences for the animal and on production (Table 1; Fraser and Duncan 1988; Bath 1998). Therefore it is vital for the animal's wellbeing and for economic reasons that we measure and evaluate potentially painful situations in order to reduce suffering and financial losses. Esslemont (1990) estimated the impact of lameness caused by a sole ulcer to be between £227 and £297 per animal.

Pain assessment in animals

The measurement and evaluation of animal welfare and pain is problematic and ultimately subjective because there is no measurable parameter that is specifically indicative of pain. Molony and Kent (1997) suggested that animal pain is an aversive sensory and emotional experience representing an awareness by the animal of damage or threat to the integrity of its tissues. A painful experience, therefore, should result in changes in physiology and behavioural output designed to minimise or avoid further damage, reduce the likelihood of repeating the experience and to ensure recovery from any damage or injury incurred. Direct measurement of subjective experiences or emotions in animals is not possible therefore physiological and behavioural changes to a potentially painful stimulus must be measured and these indices used to provide indirect evidence of an animal experiencing pain. When analysing information on the normal "pain free" behaviour of an animal, it is essential to compare this to any abnormal behaviour. Abnormal behaviours, such as excessive vocalisation (Weary and Fraser 1995; Weary et al. 1998), posture and locomotor activity (Ley et al. 1991; McGlone et al. 1993; Molony and Kent 1997; Whay 1997; McGeown et al. 1999; Thornton and Waterman – Pearson 1999), as well as reduced performance of "normal" behaviours such as feeding (Hassall et al. 1993; Rushen et al. 1993; Gentle et al. 1997) and stereotypical behaviours (which have no obvious function, Zanella et al. 1996), reflect poor welfare status (Gonyou 1994). Therefore, measuring an animal's behaviour may provide information on the emotional state of an animal and if the behaviour is negatively affected by a noxious experience then this provides some evidence of the aversive nature of the stimulus. However this is not conclusive proof that an animal is in pain as many behavioural experiments are open to a variety of different explanations. Many studies have combined the measurement of physiological changes with behavioural output. Acute pain results in the activation of the sympathetic nervous system changing heart rate, the diameter of the pupils, skin tone and peripheral blood flow and the release of corticosteroids. These changes can be monitored in pain free animals and also those potentially experiencing a painful event such as castration (Molony and Kent 1997). The problem with inter-

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Table 1. The acute and potentially chronic effects of some painful procedures carried out on production animals (Adapted from Bath 1998).

Procedure	Short term	Long term
Dehorning	Pain, bleeding	Infection
Castration	Pain, haemorrhage	Infection, Evisceration
Hoof trimming	Pain, bleeding	Infection
Milking	Pain	Mastitis
Tail docking	Pain, bleeding	Tetanus, Prolapse

preting these parameters is that stress also causes release of cortisol and increased heart rate and it could be argued that the animal is stressed rather than in pain. This argument can be refuted by the use of local anaesthetics during castration that reduced aberrant behaviours and physiological responses thus confirming the peripheral nociceptive basis of acute pain during and after the procedure. Analgesics such as opioids (e.g morphine), α2 agonists (e.g. xylazine) and NSAIDs (Non-steroidal anti-inflammatory drugs e.g. aspirin) have been shown to have a minor impact on many procedures but xylazine was seen to actually reduce the physiological and behavioural effects of tail docking (Molony et al. 1993). A more direct approach to monitoring pain in animals is to record electrical activity directly from the nervous system during a procedure. Cottrell and Molony (1995) recorded a significant increase in neural activity in the nociceptor nerve fibres of the testes and tail during castration and tail-docking in lambs. Beak trimming and shackling of poultry have also been investigated using similar procedures (Gentle 1991; Gentle and Tilston 2000). Recordings of neural activity in response to pain have not been confined to the peripheral nervous system; direct recordings of electroencephalogram (EEG) changes in the brain of sheep that were subject to a painful stimulus demonstrated that the apparatus behaves, is similar to that of humans. However, these methods are confined to laboratory and have little practical use in the farming situation. Although pain cannot be measured directly, by investigating a wide variety of behavioural and physiological parameters in response to a noxious event, we can make an informed judgement as to whether an animal is experiencing pain and attempt to minimise suffering and improve welfare.

Acute Pain

Acute or short term pain lasts a few hours or days and should not outlast the healing process (Molony and Kent 1997). Many procedures, that we subject animals to, result in acutely painful conditions. These procedures include mutilations such as castration, tail docking, disbudding or destruction of the horn bud, dehorning, branding and debeaking and also management procedures such as shackling, transport, milking and housing which can result in acutely painful states.

Castration and Tail Docking

The practice of castration and tail docking are justified on the grounds that they improve an animal's overall welfare and the economic benefits outweigh the welfare costs. Castration is performed to increase meat quality, avoid indiscriminate breeding and maintain general control of stock. There is a risk of injury to animals as a result of sexually related behaviour and dominance amongst males and there is a belief that castration improves conformation of the body thus producing a better quality product (Thornton and Waterman-Pearson 1999). There are three main methods of castration that cattle, sheep and pigs (surgical only) are subjected to:

1) Rubber ring (RR) which causes scrotal necrosis and eventual shedding of the structures including the testes.
2) Emasculator (e.g. Burdizzo clamp or Ritchey Nipper) which crushes the spermatic cord and causes irreversible damage to the vessels supplying the scrotum.
3) Open or surgical method where the scrotums are cut to reveal the testes which are removed by tearing, cutting or twisting.

These procedures have a profound effect on the animal's behaviour indicating possible pain including increased rates of kicking, rolling, restlessness, foot stamping, and abnormal postures (e.g. lambs, Thornton and Waterman-Pearson 1999; calves, Molony et al. 1995; review in Molony and Kent 1997). Cortisol also increases after castration however, surgical methods give a higher and longer elevation of cortisol compared with RR and Burdizzo clamp methods (Thornton and Waterman-Pearson 1999). Weary et al. (1998) recorded vocalisation in piglets when castrated and demonstrated that piglets call at a higher frequency during the procedure especially during the severing of the spermatic cord. Castration has negative effects on behaviour and weight gain. Castration leads to reduced suckling, reduced standing and increased lying times. However if castration occurred at 14 days old, the piglet were heavier at weaning and had a higher weight gain during lactation compared to day 1 castrated piglets (Table 2, McGlone et al. 1993).

Analgesic treatment has had no great influence on visceral or testicular pain (Molony and Kent 1997) however, local anaesthetic does reduce the pain related behaviour and physiology during the castration period (Wood et al. 1991). Studies have, therefore, shown that castration is likely to be painful and that the application of local anaesthetic may reduce the associated suffering.

Tail docking in calves, which is performed in many countries such as Australia, New Zealand and Ireland but is banned in the UK, is justified upon grounds of hygiene. Tail docking is believed to increase udder hygiene and thus improve milk quality and production and animal health (Barnett et al. 1999). In warmer climates, tail docking can have a negative impact since grazing cattle cannot deter flies efficiently and this can lead to grazing and rumination disturbances (Hemsworth et al. 1995). The intense noxious stimulation by tail docking leads to periods of inert lateral lying and the analgesic, xylazine has been shown to reduce the behavioural and physiological consequences of tail docking. Both castration and tail docking can lead to chronic pain due to inflammation and the onset of infection at the lesion after the procedure. Kent et al. (2000) has shown that abnormal behaviours indicative of pain persist for up to 41 days after castration and tail docking.

Disbudding and Dehorning

Disbudding or germinal tissue destruction in juvenile animals or horn amputation in adults is a common practice and is performed with the objective of reducing injury to other animals and to stockpersons and to reduce danger when handling animals in confined areas. Horn buds are destroyed by applying a hot iron or caustic chemicals to the bud and the use of local anaesthetics is rare (Hemsworth et al. 1995). However, in Great Britain local anaesthetic must be used during these procedures except in the case of caustic chemicals. A study on calves using local anaesthetic provided evidence that this is a painful experience for the animal. When the anaesthetic was applied there was no rise in blood cortisol levels (Fig. 1) and less struggling by the animal. In contrast, when this was done without anaesthetic the calves showed an increase in escape and avoidance behaviour and head shaking (Fig. 2; Hemsworth et al. 1995).

Table 2. Castration effects on pig behaviours (min/30 min period for 6h after treatment; McGlone et al. 1993).

		Treatment	
Behaviour	**Control**	**Castrated**	**SE**
Suckling	4.78*	4.33	0.14
Standing under heat	1.35**	0.97	0.08
Standing not under heat	5.06	4.58	0.16
Total standing time	6.41*	5.56	0.19
Total lying time	18.80*	20.05	0.22

*Control vs castrated differ, P<0.05
**Control vs castrated differ, P<0.01

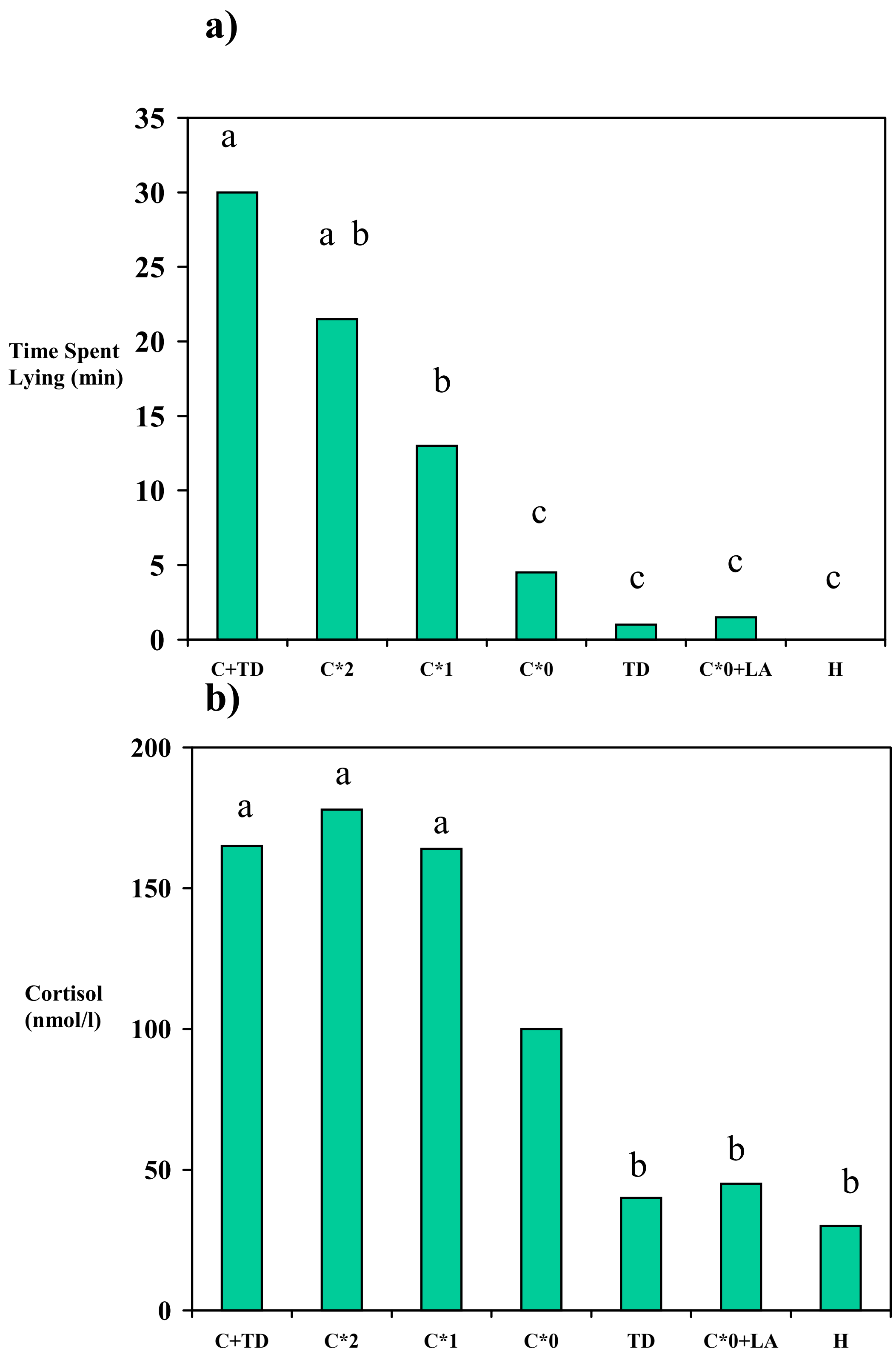

Figure 1. Responses of groups of 5- to 6-d-old crossbred lambs (n=7) to the following treatments of decreasing severity:castration and tail docking (C+TD); bilateral castration (c*2); unilateral castration (C*1); short scrotum castration (C*0); tail docking (TD); short scrotum castration and local anaesthesia (C*0+LA); or handled controls (H). (a) The mean times spent lying abnormally during the 180min after treatment. (b) The mean peak cortisol concentrations (nmol/l) reached during the 180 min after treatment. Mean values for treatment groups labelled with the same letter are not significantly different (P >0.05; Adapted from Molony and Kent 1997).

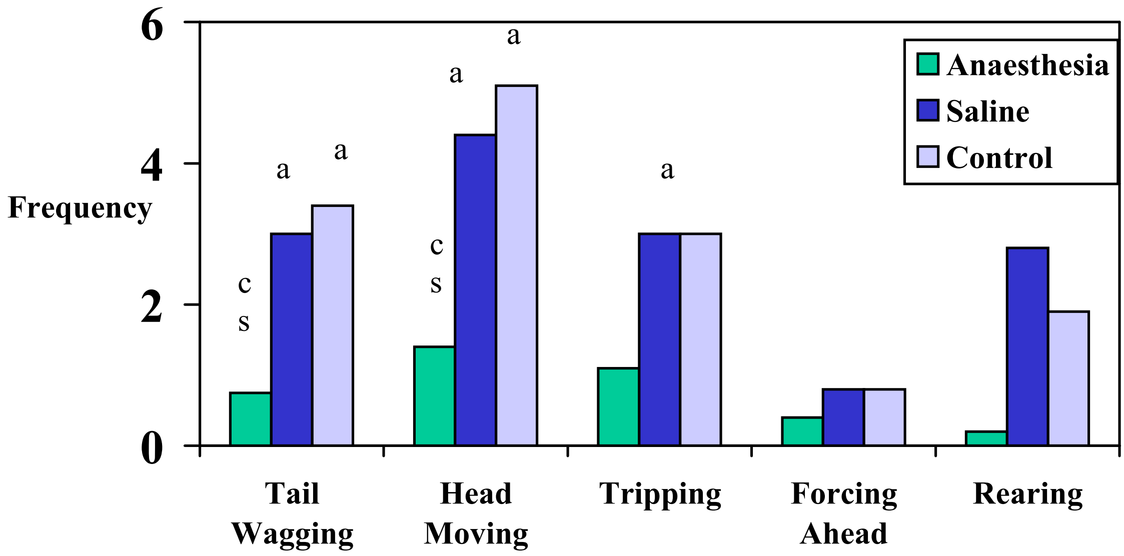

Figure 2. Frequency of behaviours (mean) in calves during dehorning after previous local anaesthesia, saline injection or untreated control. Significance:(a) differ significantly (P <0.05) from anaesthesia group, c) differ significantly from control group (s) differ significantly from saline group (Adapted from Graf and Senn 1999).

Debeaking

Another mutilatory procedure to control feather pecking and cannibalism is carried out on birds and involves the partial removal of the tips of the birds' beak. This is done by cutting through the beak with a red hot blade. The beak has an extensive nerve supply with mechanoreceptors (pressure), thermoreceptors (temperature), and nociceptors (noxious stimuli; Gentle 1989). Amputation results in extensive neuroma formation in the healed stump (Gentle and Breward 1986) and these give rise to abnormal spontaneous nerve activity (Breward and Gentle 1985). Gentle et al. (1991) has found that there is a significant reduction in preening and especially in environmental pecking after amputation. This is thought to be guarding behaviour in response to pain or discomfort where the animal reduces the use of an affected area (Gentle et al. 1997). The painful consequences of beak trimming appear to be age related and if young birds are subjected to this procedure they suffer little or no pain (Gentle et al. 1997) and this has led to a recommendation that debeaking should be performed in birds younger than 10 days of age.

Branding

To aid identification of farm animals, freeze or hot iron branding has been employed in many countries. Concern for the welfare of the animals has led to a number of studies comparing the two methods and determination of how painful the experience of branding is. Measuring the temperature of skin sites as an indicator of inflammation after both freeze and hot branding has shown that the sites are warmer than unbranded sites on the same cow indicating that both methods caused prolonged tissue damage (Schwartzkopf-Genswein and Stookey 1997). Hot branding sites (+1.9^{0}C) were warmer than freeze branded sites (+1.6^{0}C) suggesting that freeze branding is the preferable method (Lay JR. et al. 1992; Schwartzkopf-Genswein and Stookey 1997). Behavioural analysis also confirms this conclusion with animals performing more tail flicks, falls in chute and vocalisation during hot branding than during freeze branding (Fig. 3; Schwartzkopf-Genswein et al. 1998). These behavioural results are also reflected in cortisol concentrations which are higher 40 minutes after branding using a hot iron compared with freeze branding (Fig. 4; Schwartzkopf-Genswein et al. 1998).

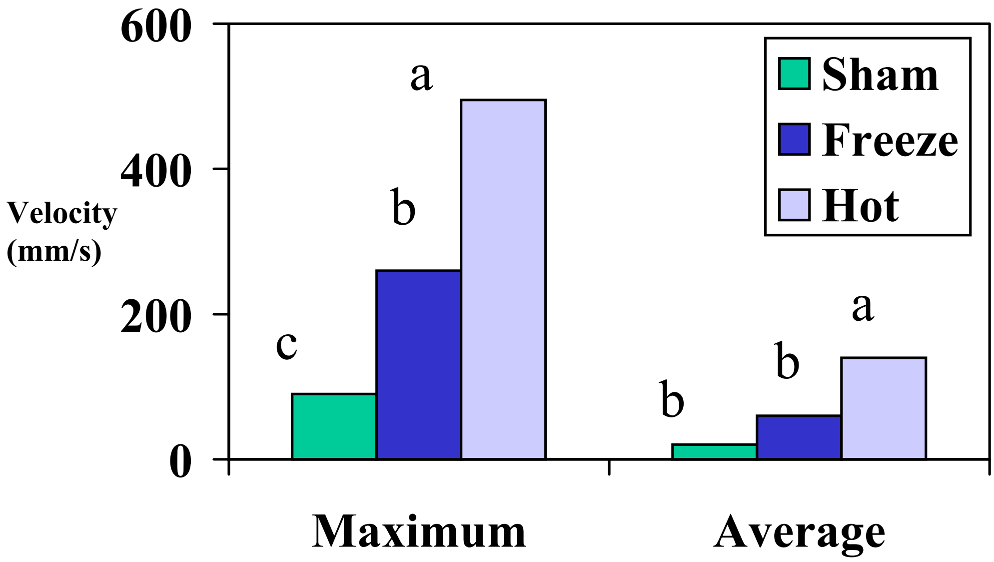

Figure 3. Maximum and average velocities of head movements measured by image analysis for sham, freeze, and hot iron-branded steers (n=11 per treatment). Means with the same letter (a, b, c) are not different (P >0.05; Adapted from Schwartzkopf-Genswein et al. 1998).

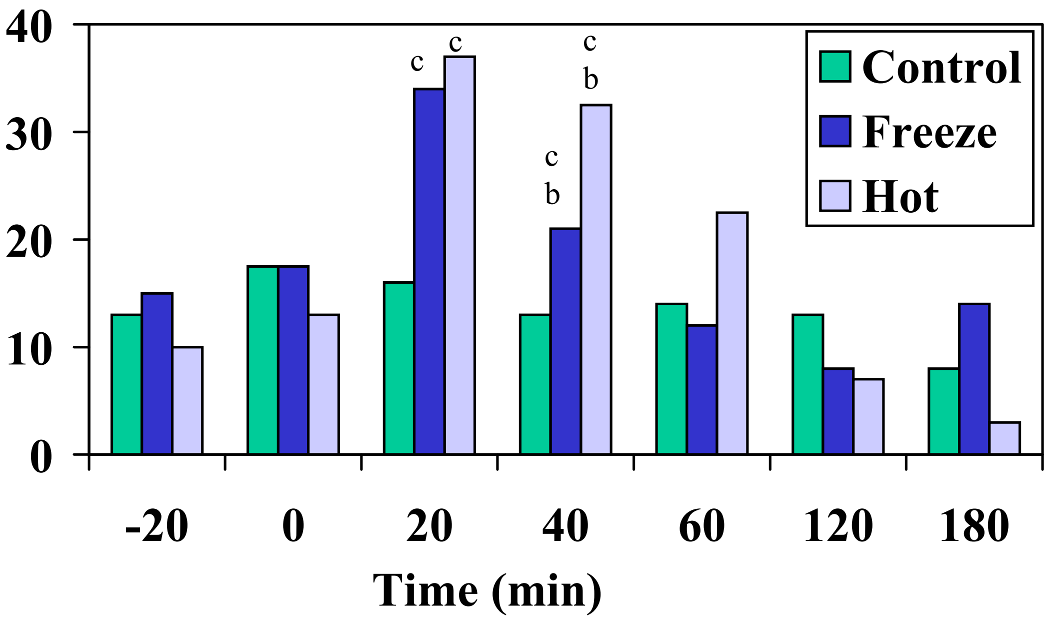

Figure 4. Mean plasma cortisol response of heifers before exposure to freeze or hot iron-branding and after exposure up to 180 min. Control values were obtained from heifers which were not branded. Significance: c) significantly different from control values (P <0.05); b) Significant difference between freeze and hot iron- branding (Adapted from Schwartzkopf-Genswein et al. 1997).

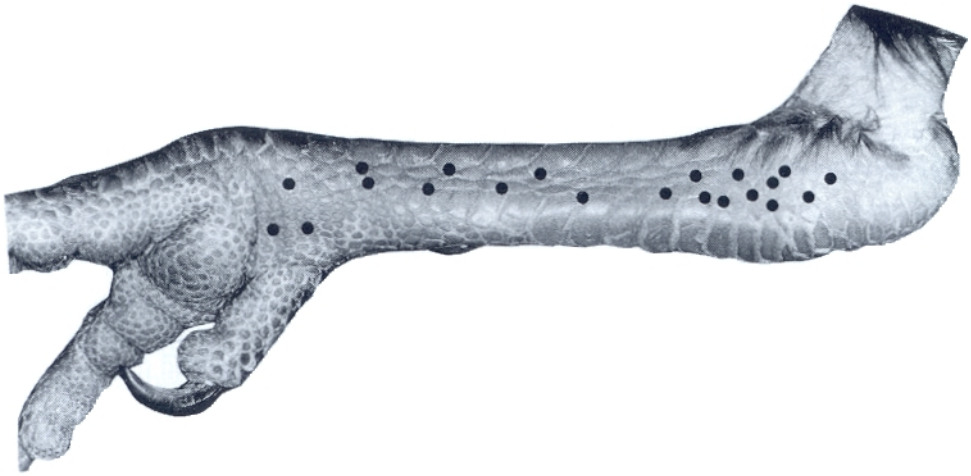

Figure 5. Lateral view of the skin over the tarsometatarsus showing positions of the centres of the receptive fields (1) of each of the nociceptors tested in eight chickens (Taken from Gentle & Tilston 2000).

Production Practices

Many procedures can inflict acute pain to animals. Transportation of animals can result in bruising, increased mortality rates, weight loss and general discomfort if the transport time is long (Hemsworth et al 1995). Malfunctioning milking equipment can also cause discomfort and teat trauma leading to mastitis in dairy cows (Jacobsen 1996). Mastitis is not only a problem in cattle but is also a major concern for the sheep industry since it causes considerable financial loss. The estimated incidence of mastitis is between 1 and 24% in flocks and is an important cause of culling, decreased milk yield and decreased growth for lambs (Calavas et al. 1998). If not treated this acutely painful condition can develop into a chronic illness.

Shackling of chickens and turkeys prior to slaughter has recently been subject to scrutiny. Birds are hung upside down prior to shackling where their legs are forced into much smaller, inappropriately sized shackles. Chickens can be subject to shackling for 3 minutes prior to slaughter and turkeys for 6 minutes (Sparney and Kettlewell 1994). Gentle and Tilston (2000) has recently shown that the legs of chickens possess nociceptors and that shackling is potentially painful. (Fig. 5).

The cramped housing that many production animals are kept in results in discomfort to the animal. Farrowing sows, for example, are kept in cramped, hard crates and develop pressure sores on their shoulders. These sores lead to increased position changing to alleviate the pressure on the sores and as a consequence many piglets are crushed to death (Haussmann et al. 1999). Although application of an analgesic does reduce position changing in sows, it does not reduce the frequency of piglet crushing (Haussmann et al. 1999).

Chronic Pain

Current intensive farming practices have led to increased occurrence of long term painful conditions which last for weeks to months beyond the expected healing time (Molony and Kent 1997). This causes a deterioration in animal welfare and also reduces production and financial gain. Lameness, a common chronic condition affecting dairy cows, chickens and sheep, is the name for a collection of diseases, which cause the clinical symptom of lameness. Lameness in dairy cattle is a major health problem not only because the animal has difficulty walking but also on the basis of problems associated with lameness such as pain, reduced food intake and loss of body condition (Hemsworth et al. 1995). Lameness causes substantial pain of long duration and increases costs to the farmer by increasing labour requirement, treatment costs, reduced milk production, reduced fertility and involuntary culling and decreased slaughter value (Alban et al. 1996). In Denmark, approximately 7% of lactating cows are affected whereas in the UK this can range between 4 and 55% (Alban et al. 1996). Cows suffering in this way enter the milking parlour later, are more restless during milking, lie down in the pasture for longer and grazed for shorter periods (Hassall et al. 1993). The welfare implications of lameness include reduced mobility and detrimental increased effects on physiology and behaviour including increased susceptibility to disease as well as pain and discomfort (Hassall et al.1993). Acutely affected cows are reluctant to get up or move and walk with great tenderness and pain in the digits (Yeruham et al. 1999). Chronically affected cows hobble for the rest of their lives and can appear depressed, anorexic, and suffer weight loss which all compromise the animal's welfare (Whay 1997).

Papillomatous digital dermatitis (PDD) and laminitis are both major causes of pain and lameness. These diseases cause lesions, foul in the foot, separation of the sole at the heel, leakage of exudate, necrotic dermatitis, alopecia and hypekeratosis of the tail. Claw lameness, due to infection, trauma, nutritional deficiency or metabolic disturbances, can be influenced by age, breed, terrain, climate and farm management (Yeruham et al. 1999). This condition leads to decreased milk yield, impaired reproductive output, increased number of culled cows and increased treatment costs. Treatments such as antibiotic and non-antibiotic formulations applied topically or in a footbath can lessen the effects of lameness but recurrence is high (Shearer and Fernandez 2000). Improving management of cows e.g. reduced time spent waiting at the milking parlour and improving terrain and hoof trimming procedures could alleviate some of the problem of lameness amongst cattle. Sheep also suffer from lameness mainly due to foot rot that causes chronic pain and impairment of gait reflected in increased plasma cortisol, which can be elevated for 3 months (Ley et al. 1991; 1994)

Lameness also effects broiler or meat chickens and turkeys. Meat birds are selected for rapid growth and become too heavy for their legs to carry their bodies and their skeleton becomes distorted. This increased weight places unnatural stresses on their joints and results in abnormal gait; impairs the ability to walk and the affected individuals spend less time standing (Duncan et al. 1991; McGeown et al 1999). Studies have shown that a normal chicken takes an average 11 seconds to walk a set distance whereas a lame chicken takes 34 seconds. This time can be reduced to 18 seconds if the drug carprofen, an analgesic, is administered which presumably reduces pain associated with lameness.

Lameness is particularly prevalent in broiler chickens and turkeys and it has been shown that 90% of broilers at 7 weeks of age had detectable gait abnormalities (Kestin et al. 1992). These fast growing birds have more breast muscle and shorter wider legs with immature bones. This leads to a gait which is typified by short steps, feet positioned wide apart and the feet turned out resulting in abnormally large mediolateral forces required to move the bird's centre of gravity over the stance leg (Corr 1999). Affected chickens take shorter steps, walk more slowly and have greater stresses placed upon the musculoskeletal system resulting in an inefficient walking system. Broiler chickens, as a consequence, spend much less time walking and standing (Duncan et al. 1991; McGeown et al. 1999). The possible pain resulting from skeletal disease has been investigated using analgesics with some evidence of pain associated with lameness (McGeown et al. 1999; Danbury et al. 2000).

Arthritis is widespread in humans and is possibly one of the most important diseases resulting in chronic pain. Arthritis is also prevalent in cattle, pigs and poultry. Infectious arthritis and osteomyelitis is common amongst young calves and in chronic infectious arthritis antibodies may not be effective since the infections are difficult to treat. As a last resort amputation of the limb may be the only solution however this leads to problems in the remaining limbs. A study that examined the use of bone grafts to replace damaged tissue and bone worked successfully on a heifer that remained healthy and bore 3 calves subsequently (Riley and Farrow 1998). The problem with this type of major surgical intervention is that it is financially costly to the farmer and so is not easy to put into practice. It would be more effective to prevent the problem or at least treat the animal effectively at an early stage of the disease.

Minimising Pain and Suffering in Farm Animals

We have reviewed the various potentially painful practices and conditions that farm animals endure. Both behavioural and physiological measurements have demonstrated that these painful experiences have a detrimental effect on animal welfare and consequently decrease financial gain. It is perhaps impossible to totally eliminate pain in production animals but suffering should be minimised since it is in the farmer's best interest to ensure his animals' wellbeing. Any measures should take into account the profitability and practical nature of any proposed changes but also should seek to reduce pain and distress. This means prompt diagnosis and effective treatment of damage or disease but in the situation where the problem is a result of selective breeding, the solution will be more complex. For example, broiler chickens, where skeletal disease is prevalent, can be fed a reduced diet thus slowing down their rapid muscle growth. To control pain we must know what pain is and how it arises during farming. Therefore we must invest in sound scientific research to assess pain and find methods of reducing it by using the least painful method available and also the promotion of the use of local anaesthesia and analgesia where appropriate. It is clear that the farmers support is essential to any changes in practice and therefore, awareness of welfare issues should be promoted by a positive interaction between scientists, veterinarians, and farmers. Any changes, of course, have to be economically viable but there is increasing public demand for more welfare and environmentally friendly products and the public must be informed if the products go up in price that this is to pay for the reduction of pain and suffering in farm animals.

Acknowledgements

Table 1 adapted from Applied Animal Behaviour Science, Vol. 59, Bath, Management of pain in production animals. p 147-159., Copyright (1998) with permission from Elsevier Science. Figure 2 adapted from Applied Animal Behaviour Science, Vol. 62, Graf and Senn, Behavioural and physiological responses of calves to dehorning by heat cauterization with or without local anaesthesia. p 153-171., Copyright (1999) with permission from Elsevier Science. Figure 4 adapted from Canadian Journal of Animal Science, Vol. 77, Schwartzkopf-Genswein et al., Comparison of hot-iron and freeze branding on cortisol levels and pain sensitivity in beef cattle. p 369-374., Copyright (1997) with permission from the Agricultural Institute of Canada.

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Immunobiological explanation for the behavior of sick animals

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Reduced feed intake, inactivity, sleep and decreased social interaction are behavioral states observed in animals with an acute bacterial or viral infection. These nonspecific behavioral responses are known collectively as sickness behavior, and in association with other acute-phase responses, are critical for maintaining homeostasis during infection. Because the immune system has the critical responsibility of contending against pathogens and the brain ultimately controls behavior, the presentation of sickness behavior suggests that the immune system and brain communicate. The nature of this communication system has been the subject of intense investigation and it is now evident that the immune system shapes the activity of other systems including the brain by secreting hormone-like molecules called cytokines.

Overwhelming evidence now indicates that pathogens induce sickness behavior by stimulating leukocytes to produce soluble proteins called cytokines (Dantzer and Kelley, 1989; Kent et al., 1992). In essence, the immune system uses cytokines such as interleukin (IL)-1β, IL-6, and tumor necrosis factor α (TNFα), to convey information to the brain about the level of immunological activity. Indeed, it has been shown that if macrophages are unable to produce cytokines when exposed to inflammatory stimuli (e.g., lipopolysaccharide), the immune system cannot communicate with other systems and animals do not behave sick as they would otherwise (Segreti et al., 1997). Thus, when animals are subjected to pathogens, the production of cytokines is the first step towards the induction of sickness behavior.

Our understanding of the interactions between the brain and the immune system has increased dramatically in the ten years since Hart published his treatise describing the biological basis for sickness behavior (Hart, 1988). The important argument made by Hart was that the behavior patterns of sick animals are not maladaptive responses or the effect of debilitation, but rather organized evolved strategies that facilitate recovery. A clever set of experiments conducted in the 1970's that investigated fever in the lizard *Dipsosaurus doralis* provides an excellent example of the importance of "behaving sick" (Vaughn et al., 1974). Like all ectotherms, lizards regulate body temperature by behavioral thermoregulation. Thus, when placed in an experimental chamber where one end was kept at 50^o C (a lethal temperature) and the other end at 30^{o}C, lizards regulated body temperature by shuttling from one end to the other. The body temperature at which lizards moved from the hot end to the cooler end represented the high set-point, and the body temperature at which lizards moved from the cooler end to the hot end represented the low set-point. Interestingly, lizards challenged with killed bacteria had a higher high set-point temperature and a higher low set-point temperature than controls. Thus, immune-challenged lizards "chose" to develop a fever, which was behaviorally mediated. The importance of the behavioral response was later revealed when lizards were inoculated with live bacteria, but kept at a constant 34, 36, 38, 40, or 42^o C so as to prevent behavioral thermoregulation. The results showed a high positive correlation between body temperature (i.e., environmental temperature) and survival (Kluger et al., 1975).

There also is some evidence that the loss of appetite in sick animals is an adaptive response. Murray and Murray (1979) experimentally infected mice with *Listeria monocytogenes* (LD_{50}) and let some consume food *ad libitum*, while others were intubated and force fed to the level of free-feeding, non-infected controls. Mice allowed to consume food *ad libitum* ate 58% of the controls and were much more likely to survive than those force-fed. Furthermore, there was a positive relationship between weight loss and survival for the infected mice with *ad libitum* access to food. Therefore, survival appears to be positively related to anorexia and weight loss, at least in the short term. Of course, when anorexia and weight loss caused by degradation of body protein and fat persists, a condition known as cachexia or wasting develops. A positive relationship between loss of lean body mass and mortality in a number of diseases has been reported.

Evidence indicating that decreased feed intake in response to disease challenge is adaptive in growing domestic food animals is indirect, but important nonetheless. Pigs kept under management schemes that limit host-pathogen interactions consume more

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feed, grow faster and retain more nitrogen for proteineous tissue growth, compared to those maintained in a dirty, less hygienic environment (Williams et al., 1997a,b,c). Under the latter circumstance, a common practice is to increase dietary lysine to account for the decreased intake caused by disease challenge. The idea is that lysine intake may limit protein accretion in immune challenged pigs. The evidence is mounting, however, that stress-related decreases in feed intake are associated with a lower lean growth potential (Baker, 1996; Webel et al., 1997). Results in pigs and chicks indicate that stimulation of the immune system reduces the capacity for lean tissue accretion (Williams et al., 1997a,b,c; Webel et al., 1998). Therefore, the practice of increasing lysine to account for lower feed intake in sick or immune challenged animals appears to be invalid (see Baker, 1996). In retrospect, it is logical for an animal to adjust its feed intake according to the balance between anabolic and catabolic processes.

These examples underscore the importance of understanding the complex behavioral and metabolic responses triggered by immune cells in response to pathogens. Animals have always lived surrounded by pathogenic microorganisms and will continue to do so regardless of the animal housing system. Therefore, effective disease management will continue to be one of the most important aspects of animal production. Management practices that enhance the host response, and not thwart it are needed. Clearly, disease reduces animal well being, and increased incidence of disease may indicate other problems in the environment that threaten good well-being. It is important to improve animal well being by minimizing the incidence of disease, reducing the severity of disease, and/or enhancing recovery from disease. Because behavior is an important part of the host response to infection, a better understanding of sickness behavior should help improve animal well-being in the face of disease.

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Communication of the welfare status by the animal: Clinical ethology

Jan Ladewig [1]

Introduction

For the last 25 years the welfare of domestic animals has been an important aspect of applied ethology, i.e. that part of behavior biology that studies domestic animals. Consequently, scientists have searched for objective ways to evaluate welfare. As part of this evaluation, various ways to measure stress have been proposed, in that the demonstration of stress indicators could provide an objective information about how well farm animals kept under production conditions have adapted to their environment (e.g. Ladewig, 1994; 2000). Over the years many such potential indicators have been suggested, both behavioral and physiological stress indicators, as well as production, fertility, and disease related indicators. The main result of this research is that we have realized that we cannot answer these complex questions with the information provided by a single or a few stress indicators. In behavior science two separate disciplines focus on the behavior of domestic animals. Apart from applied ethology, i.e. the discipline that works primarily with the behavior of farm animals (cattle, pigs, and chickens), another discipline, usually referred to as behavior therapy of companion animals, works with the treatment of behavior problems in dogs and cats. Although the two disciplines use somewhat different approaches, they both attempt the same, to identify behavior problems in domestic animals, to search for the reason for them, and to correct them in various ways. In applied ethology the behavior problems are related to the way farm animals are housed and managed. Apart from fear related problems, the most common problems are aggression because of high stocking density, large group size, and competition over limited resources and stereotypies due to housing in a restricted and sterile environment. In companion animals behavior problems are also related to the way the animals are housed and managed, although cat and dog owners use different terms than housing and management. The most common problems are separation anxiety and aggression towards humans in dogs and urination problems in cats, all problems that, to a large extent, are related to fear. In applied ethology the approach to solve the problems is mostly experimental, i.e. scientific studies are first conducted in an experimental setting before they are transferred to practice. The approach in behavior therapy is primarily clinical, i.e. based on case stories and only to a limited extent on scientific experimentation.

To date the two disciplines have had surprisingly little contact with one another. This lack of collaboration is, however, unfortunate, because many of the problems that exist in the two areas are quite similar. A dog's fear of being left home alone is principally not much different from a fattening pig's fear of being attacked in its social group. A horse's anxiety of being ridden in traffic is in principle not much different from a dairy cow's hesitation to enter a milk robot. The problems we face when trying to diagnose these states are similar. Moreover, the way these states can be treated or prevented undoubtedly has much in common, too.

In fact, the problems that these two behavior disciplines face are not much different from the problems that veterinary medicine face in general. To identify a problem, whether a behavior problem or a health problem, is a process that in veterinary medicine is called to make a diagnosis. This diagnosis is based on a clinical examination and on various diagnostic tests. Correction of the problem once the diagnosis has been made is called therapy and procedures that reduce the probability that it occurs sometime in the future are called preventive medicine.

Comparison between animal health and animal welfare

The search for symptoms and the conduction of diagnostic tests to reach a diagnosis, plus therapy and prevention of the problem is the procedure used in medicine. It is also the way behavioral problems are handled in the behavior clinic. There are many reasons why we should use a similar procedure when we tackle welfare problems in farm animals.

Health is a condition characterized by the absence of disease. To be healthy, an individual must be free of bacterial and viral infections, of parasite infestations, it must live on a balanced diet, not be exposed to noxious agents plus many other conditions. Consequently, in order to guarantee the health of an animal (e.g. in order to issue a health certificate), a veterinarian looks for symptoms of a disease, such as changed behavior, fever, pale or reddened mucus membranes etc. plus conducts various diagnostic tests (such as serological tests, x-ray

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examination, etc.). If no symptoms of diseases are found in general or in specific, a limited warrantee can be given that the animal is healthy.

In the same way that health is characterized by the absence of disease, welfare is characterized by the absence of a number of aversive states such as pain, suffering, frustration, boredom etc. Consequently, to guarantee the welfare of an animal, we must search for symptoms (or stress indicators) such as changed behavior, altered secretion of stress hormones, altered heart rate, reduced fertility and many more. In addition, we may conduct various behavior tests (open field test, elevated plus maze test, human approach test, tonic immobility test and many more). If no symptoms of reduced welfare are found, we can give a limited warrantee concerning the welfare status of the animal.

In our search for symptoms of reduced welfare it is important to realize that just like „disease" cannot be diagnose by one or a few signs common for all types of sicknesses, so it is not possible to diagnose reduced welfare by a few symptoms either.

Instead of searching for common signs of stress that can indicate the presence of a wide variety of aversive conditions, we must reverse the process and use the approach that is common in medicine. When a health problem occurs, the search for the cause begins. In addition, specific signs or symptoms of the disease are defined and, if necessary, specific diagnostic tests are developed to help diagnosis of the disease. The next step in the process is to develop an effective therapy of the disease and finally the effect of preventive measures are tested out.

When a similar approach is used to solve behavior problems, we search for the cause of the problem. Usually behavior scientists agree that this step is an important one. But when it comes to defining specific signs of the problem or to develop specific behavior tests that could help identification of the problem, we are often less specific and less goal oriented.

Epidemiology, health, and welfare

One thing that behavior scientists can agree upon is that the cause of most problems is multifactorial. Unfortunately, it is an extremely rare situation where we are able to pinpoint one or a few reasons for a problem. On the contrary, in most cases we have to consider a multitude of factors as well as the interaction between them, when we analyze the reasons for a problem. Needless to say that more than once have we lost our way in the chaos towards the solution of the problem. But also in this aspect it can be helpful to turn towards the health profession to look for ways to analyze problems of a complex nature.

Many health problems nowadays are not caused by a single agent, the presence of which means that the animal is sick, and the absence of which means that the animal is healthy. Instead, more and more diseases are caused by two or more states that must be „just right" in order for the disease to manifest itself. The analysis of the interaction between involved factors is one of the subject areas of epidemiology.

Since most behavior problems are of a multifactorial nature, the use of multivariate techniques, such as factor analysis, is an important addition to behavioral research. As a consequence, more and more behavior studies include such methods, at least as far as the causation of a behavior problem is concerned (e.g. Alban et al., 2000; Moinard et al., 2000). There is little doubt that the inclusion of such methods is an absolute necessity in our future work.

Diagnostic tests or behavior tests

In clinical work it is often the case that symptoms revealed by a general examination (e.g. body temperature, pulse, blood pressure etc) are not specific enough to justify an exact diagnosis. Principally, this situation is similar when it comes to a behavior problem. Most behavior problems in cats and dogs are not seen in the behavior clinic. Similarly, many behavior problems in the barn are only performed when the stock person is not present, or the symptoms of the problem are so subtle that the animal must be put in a special situation to reveal their existence.

Just like the health profession has developed specific diagnostic tests (serological tests, x-ray examination etc), so have behavior scientists over the last decades developed various behavior tests, the aim of which it is to support a diagnosis. Thus, many fear tests have been developed (e.g. the human approach test in different species, tonic immobility in chickens, the glove test in mink), or tests for general activity (e.g. the open field test). Only a few of these tests, however, have been sufficiently evaluated according to the methods used for evaluation of diagnostic tests. Obviously, before a diagnostic test can be used in connection with the eradication of a disease, it is necessary to know to what extent the test can be trusted. In other words, the sensitivity, the specificity, and the prevalence of the test must be calculated.

As far as behavior tests are concerned, the same evaluation must be done before we can trust our tests. Obviously, before we use a test to say something about the level of fear in a herd, we must know how good our test is to indicate both fearful and calm individuals. Again, the tools used in epidemiology can be applied for such an evaluation.

Therapy: Solutions here and now

One of the goals of our study of the behavior of domestic animals is to improve welfare. An important aspect of this effort is to reduce the frequency of behavior problems. In principle this reduction can be achieved either by treating animals in some way after the problem has developed or by somehow changing aspects of the environment so that the problem does not develop. The first approach is similar to therapy in the clinic, the second is similar to prevention.

In applied ethology we have seen many instances where the therapy of a behavior problem has been done by others that the behavior scientists. Thus, producers are often quite effective in developing methods by which a problem is solved. Tail biting in fattening pigs is reduced by cutting part of the tail off. Feather pecking in laying hens is avoided by amputating part of the beak in chickens. Crushing of the piglets is avoided by putting rails around the lactating sows, to name a few examples. Crib biting in horses is suppressed by placing a tight collar around the throat of the horse. Aggression between group members of many different species is avoided by keeping animals in individual housing.

Probably all behavior scientists can agree that these „treatments" are symptomatic, i.e. they are aimed at reducing the animal's possibility to perform the unwanted behavior, but do nothing to alter the animal's motivation to perform the behavior. However, as long as the result of an untreated behavior problem (e.g. infection, infliction of severe pain) is worse than the symptomatic treatment, it seems meaningless not to allow such treatment, provided that sufficient effort is made to find and institute more appropriate methods. We have to be more aware that, just like it is not acceptable simply to restrain an animal that is motivated to perform some unwanted behavior, so it is not acceptable either to „restrain" the producers in their activity, before acceptable alternatives are available.

Prevention: Lasting solutions

Whereas treatment of a behavior problem in many cases means reducing the animals possibility to perform the behavior and, thus, is symptomatic, a far better and ethically more accepted way to proceed is to reduce an animal's motivation to perform the unwanted behavior. Needless to say that this realization is not new in applied ethology. A growing body of evidence indicates, however, that many behavior problems can be truly prevented, if a certain exposure of the animal occurs at a specific period of its life. In the behavior clinic it has been known for years that in order for cats and dogs to become good pets, they must be socialized towards conspecifics and humans during a so-called sensitive period while they are puppies or kittens (e.g. Scott & Fuller, 1965. But more and more studies on farm animals indicate that a similar phenomenon is at work in farm animals.

In a recent study on laying hens it was shown that hens that had been exposed to perches during the first four weeks of life used elevated nest boxes significantly more for egg laying than hens that had not been exposed to perches early in life. The result of the more frequent use of nest boxes was that fewer eggs were laid on the floor and that cloacal cannibalism occurred less frequently (Gunnarsson et al., 1999). Similarly, in this host institute it was shown many years ago that exposure of calves to slatted floor during a time when they had less of a problem lying down on the hard surface resulted in faster adaptation to this floor type later when the animals were adult (Pougin, 1982).

Preventive medicine means, among other things, inoculating an animal to alter its immune system with the specific aim to prevent the outbreak of a specific disease later on. In principle, this approach is no different from exposing an animal to certain stimuli (e.g. perches) to alter the central nervous system (e.g. the right synaptic connections in the brain to develop spatial orientation) with the specific aim to prevent floor laying and cloacal cannibalism later on. Whether we shall call this preventive ethology, as I am suggesting elsewhere (Ladewig, 2000), or something different is less important. What is important is that in our attempt to search for the true cause of a behavior problem, we need to be much more goal oriented.

Conclusion

In present day welfare research more and more studies are done which use multivariate techniques to identify important factors and correlations between them. Similarly, many new behavior tests are being developed that give much more specific information about the various states of the animals. There is no doubt that these attempts are important and necessary additions to behavior research. But if we think a little more clinically and maybe call this way of thinking clinical ethology, and if we think a little more preventively and maybe call this way of thinking preventive ethology, chances are that we will be more efficient in reducing the frequency of behavior problems, that producers will be a little bit more interested in and positive towards our results, and that the welfare of the domestic animals may end up being a little bit better.

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Table 1. Examples of behavior problems in domestic animals

Swine	Pregnant sows, gilts	Aggression Stereotypies Inactivity Anestrus, silent heat
	Lactating sows	Crushing of piglets Cannibalism Lack of nest building behavior Aggression towards people
	Fattening pigs	Aggression Tail biting
Cattle	Calves	Mutual sucking
	Heifers	Stereotypies
	Fattening bulls	Tail necrosis Aggression towards people
	Beef cattle	Aggression towards people
	Dairy cows	Disturbed lying behavior
Hens	Laying hens	Feather pecking Cloacal cannibalism Floor laying
	Broilers	Lameness, tibial dyschondroplasia Starvation of breeding cocks
Horses		Stereotypies Uneasiness during riding Fear Head shaking
Dogs		Separation anxiety Aggression towards people Fear Attention getting behavior
Cats		Urination problems, spraying Aggression Psychogenic alopechia

Table 2. Example of the behavior problem aggression in pregnant sows

Problem Aggression

Causality	Under natural conditions sows live in a home range in groups of 2 - 6 sows with offspring. An adult boar visits the group at intervals to search for estrous sows. The sows know each other (they are often related), and a stable social hierarchy exists among them. Strange sows are antagonized. All group members spend the major part of their active period (early morning, late afternoon, early evening) searching for food. Food searching, mostly performed as rooting behavior, is [illegible] Under production conditions, sows are generally kept in considerably larger groups (20 – 40 sows, in extreme cases up to 400 sows). They are kept on a relatively small area with limited possibility to avoid higher ranking animals. The social groups are often unstable, because highly pregnant sows are moved to the farrowing barn and newly inseminated sows are brought into the group. The feeding is restrictive, which can cause hunger and competition over the food. In some systems the sows are fed simultaneously. In others they are fed sequentially (e.g. in feeding automats) which can lead to aggression due to frustration among waiting animals. In some systems straw is used in the lying area which enables the animals to perform rooting behavior in the straw.
Diagnostics	Restlessness or overt aggression in the group, particularly when sows are active (during and after feeding). Some animals may have wounds on the neck or thighs. Single individuals may be extremely lean. Fertility may be reduced in the herd.
Therapy	Several of the following conditions should be changed. - Feeding less nutritional but more fibrous feed (e.g. silage) on a larger area can satiate the sows better and reduce the attention on the concentrated feed. - Structure (e.g. partitions) in the pen particularly around the feeding area can make it easier for low ranking animals to avoid higher ranking animals. - A smaller group size, more space, preferably with outdoor access.
Prevention	Generally: smaller groups, more space, fewer changes in the social structure, more natural activity (e.g. rooting behavior in litter material and silage) can reduce the risk of aggression.

Table 3 Example of the behavior problem crushing of piglets in lactating sows

Problem	Crushing of piglets
Causality	Under natural conditions the sow lays down in a nest by first entering the nest, pushing piglets away with her snout as she enters. Thereafter she lowers her front part and slowly he back part. If she lies down on a piglet, its screams will cause her to stand up again. Under production conditions the natural lying down behavior is disturbed in various ways. - Often the sow is unable to walk into the nest and thus remove the piglets from the lying area. - Because of a high body weight possibly combined with a weak leg and back constitution she often has problems lying down in a controlled fashion, but rather falls down. If the floor is slippery this may add to the problem. - Many generations of selection for weakened maternal behavior has resulted in sows that do not react sufficiently to the screams of crushed piglets.
Diagnostics	High piglet mortality. In outdoor herds dead piglets may be removed by foxes, mink, or ravens.
Differential diagnostics	Metritis, mastitis or agalactia can cause reduced milk uptake in piglets that then are too weak to get out of the way when the sow lies down.
Therapy	In traditional farrowing crates the sow is restrained so that she cannot lie down against a wall, or bars are placed along the walls to prevent crushing. In addition, piglets are encouraged to lie away from the sow by providing alternative heating. In alternative systems the nest should have dimensions that allow the sow to walk into the nest area.
Prevention	The better the physical condition of the sow, the bigger the chance that she is able to lie down in a controlled fashion. This means, among other things, the possibility of locomotion during pregnancy. A slippery floor should be avoided.

Table 4 Example of the behavior problem tail biting in fattening pigs

Problem	Tail biting
Causality	Tail biting is primarily caused by explorative behavior in that the tail of other pigs are taken into the mouth and chewed upon. The less opportunity the pigs have to investigate and chew on other objects (straw, sticks, stones etc.), the higher the risk. Because the distal one third of a pig tail has only few pain receptors, the recipient reacts too late to damage of the tail. Wounds and blood on the tail invites other pigs to chew it. Actual tail biting (i.e. cannibalism where parts of or the whole tail is eaten away) can be caused by many additional factors. Actual tail biting is a multifactorial behavioral problem. Such factors can be group size, stocking density, floor type, ventilation, room temperature, air quality, feeding system and feed quality, age at weaning, lack of rooting material, and tail position.
Productions conditions	The more sterile (i.e. boring) the environment, the higher the risk for outbreaks of tail biting. In addition, poor ventilation, high ammonia concentration, flies, heat, etc. can increase the risk.
Diagnostics	Damaged or missing tails, abscesses in the body.
Therapy	Symptomatic therapy can be obtained by amputating the distal one third of the tail. The treatment results in the recipient reacting when the tail is chewed on before serious damage is reached. The treatment is considered ethically unacceptable. Actual therapy is difficult. Provision of straw can reduce outbreaks of tail biting, partly because it can serve as rooting material and something to chew on, partly because it can improve air conditions in the stable.
Prevention	Prevention should be aimed at correction of involved factors, such as reduced group size, stocking density, improved ventilation, etc.

Table 5. Example of the behavior problem cloacal canibalism and floor laying in laying hens

Problem	Cloacal cannibalism and egg laying on the floor
Causality	When a hen lays an egg the cloaca is momentarily exposed. If the laying occurs near other hens, the exposed cloaca can induce pecking behavior in neighboring hens, causing serious or lethal damage to the recipient.
Production conditions	Eggs laid on the floor as opposed to in a nest box are undesired, partly because of increased risk of contamination, partly due to the extra labor involved in collecting the eggs.
Diagnostics	Lesions possibly increased mortality among hens. Five percent or more of the eggs are laid on the floor.
Therapy	An effective therapy is not possible.
Prevention	Both cloacal cannibalism and egg laying on the floor can be prevented by imprinting chicks on perches within the first four weeks of their life. During this period spatial orientation is developed in the central nervous system. It is important that chicks are not only exposed to perches but also stimulated to using them, e.g. by placing food or water troughs up on the perches.
Supplementary literature	Gunnarsson et al., 1999.

Table 6. Example of the behavior problem crib biting in horses

Problem Stereotypies

Causality
Housing in a sterile environment, i.e. without possibility to perform species specific behavior (locomotion, social contact) causes understimulation. The horses attempt to cope by developing stereotypic behaviors.

Stable conditions
Individual housing in a box, possibly without visual contact to neighboring horses. Inadequate locomotion (outdoor access or riding) can increase the risk of development of stereotypic behavior.

Diagnostics
Possibly the stereotypic behavior is only shown when the horse is alone. The most common type of stereotypic behavior is crib biting. The horse places the front teeth on the edge of the crib and contract various neck muscles. Often a gurgling sound is heard. In rare cases the behavior is performed freely in the air. It was earlier thought that the horse swallowed air during crib biting, causing cases of colic. Newer investigations have shown that the amount of air swallowed is negliable. Other stereotypies are weaving or stable walking, tongue rolling or tongue sucking.

Therapy
Crib biting can be treated symptomatically either by placing a tight metal clamp around the neck of the horse preventing contraction of the neck muscles or by removing surgically the frontal part of the sternohyoid, the sternothyreoid, the omohyoid, and the sternomandibular muscles.

When a stereotypy has developed (i.e. become emancipated), it is virtually impossible to get rid of again. Considering that the performance of a stereotypy can reduce the heart rate, indicating having a calming effect, allowing the horse to perform the behavior probably increases its welfare.

Many horse owners are hesitant to have their horses stabled next to a crib biting horse, fearing that their own horse will start the stereotypy. If the conditions mentioned earlier are absent, however, the risk of other horses learning the habit is minimal.

Prevention
The cause of a stereotypy is probably developed early in life. Prevention therefore consists of allowing the young horse adequate locomotion outdoors and social contact.

Supplementary literature
Lebelt et al., 1998.

Natural behaviour and behavioural needs of farm animals

Per Jensen [1)]

Evolution of natural behaviour

Evolution has selected animals for increased fitness in their natural environments over thousands of generations. Fitness in this context can roughly be defined as reproductive success (often measured at allelic level), and is not necessarily related to welfare; an animal with high fitness may have a poorer state of welfare than one with low fitness. One of the major achievements of behavioural research over the last decades is the realisation that animals are equipped with flexible behavioural programs, usually referred to as strategies (Krebs and Davies, 1991). A strategy involves a number of different possible behavioural outputs and a decision mechanism that helps the animal in selecting the best behaviour under different conditions. The best strategy in this context is the strategy that gives the largest possible fitness for the animal. For example, one specific social situation may require that the animal avoids conflict and assumes a subdominant role, while in a different situation, the same animal may be better off seeking conflict and attempting to become dominant. The best strategy will be the one that allows the animal to make the choice which will render the largest fitness in any group. Within a population of animals, different individuals may therefore show different behaviour in a similar situation, even though they use the same strategy. The trait that is selected by evolution is net benefit (in fitness units, but often approximated by, for example, energy), so animals are expected to assess the costs and benefits of each possible behaviour and then select the one that provides the largest net benefit under prevailing conditions.

Effects of domestication

During domestication, animals have been genetically changed in relation to their ancestors, which has affected various aspects of their adaptive traits, including behaviour (Price, 1997). However, as is obvious from many comparisons between domestic animals and their ancestors, behaviour is usually affected in a very limited manner. Generally, no new behaviours have developed and none have completely disappeared from the gene pool. The changes are usually referred to as altered release thresholds (Price, 1997), but a better description may be to say that the strategies have been modified. Since domestication provides animals with food and protection, and involves selection for specific traits, the optimal behaviour is likely to be different compared to when food is scarce and predation pressure high. Other strategies than in the wild may therefore give the highest fitness. We have found that domestic pigs and poultry use slightly different strategies than their wild counterparts, wild boars and jungle fowl, during food search, and the differences appear to reflect an adaptation of strategies to the conditions offered during domestication (Schütz and Jensen, 1999; Gustafsson et al., 1999a; Andersson et al., 2000). However, when comparing maternal behaviour betwen domestic pigs and wild boars, almost no differences were detected, which indicates that some fundamental behaviour patterns are virtually unaffected by domestication (Gustafsson et al., 1999b).

It is therefore clear that domestic animals still possess natural behaviour and motivational systems that are inherited from the ancestors, and have been little changed by domestication. Any understanding of how these systems function needs to be based on the assumption that they were developed to work in a completely different environment, the environment of evolutionary adaptation (EEA). Animals will therefore perceive stimuli and attempt to react on those in accordance the best strategy in the EEA, or sometimes with a slightly modified strategy.

Motivation

Whereas motivation is a common concept in ethology and psychology, there is no universally accepted definition. A recent text-book describes the concept as follows: ”The internal state of the animal, which is the net result of stimuli arising from both inside and outside its body, constitutes its ’motivation’” (Manning and Dawkins, 1998). As pointed out by Jensen and Toates (1997), the interesting aspects of motivation go on in the brain, and what we really seek to understand in motivational research are the processes by which an animal integrates information from different stimulus sources, both from inside and outside the

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body, and translates that into behaviour. So motivation is concerned with the state of the nervous system.

Different models of motivation have different merits. Elements of homeostatic motivational models and "drive"-based models both have to be taken into account in any analysis of a specific behaviour. Based on that, Jensen and Toates (1997) offered a simple model which outlines the possible pathways whereby motivational states (tendencies to engage in particular behaviour) could be affected in the brain, and which therefore have to be considered in any analysis of a specific behaviour pattern (Fig 1). Unlike many other models, this one does not claim that every motivational system works in this way; rather, it offers an account of the different pathways according to which any motivational system could work. It is therefore a conceptual model, offering a tool for specific analyses, and not a predictive model.

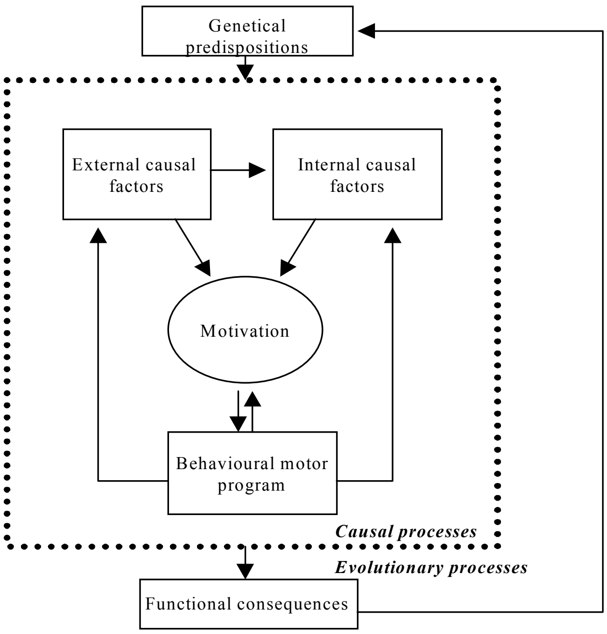

Figure 1. A conceptual motivational model showing the different causal and feedback pathways that need to be considered in a motivational analysis. The evolutionary processes are not necessarily accessible to the animals and the functional significance of a behaviour therefore has no immediate effect on the causal events. However, the whole causal system is shaped by evolution.

Behavioural needs

The model offers some insights into the needs of animals with respect to their behaviour. In particular, the following two aspects of the model may be of interest: (1) There is no qualitative difference to an animal whether a particular motivational state is evoked by external or internal stimuli. In fact, both will usually be the case (Toates and Jensen, 1991), and the state of the nervous system is likely to be the same in both cases. (2) Sometimes, the animal may be programmed to perform a specific motor program before it can detect any feedback effect on the stimuli which have aroused the motivation. An animal feeling hunger may be programmed to forage, ingest, chew and swallow before it can detect that the gut is filling up; attempts to shortcut such pathways by tubular feeding has sometimes proven unsuccessful in reducing the feeding motivation (see Toates and Jensen, 1991)

The concept of behavioural needs is often used to describe a behaviour which is normally released predominantly by the action of internal stimuli (see Jensen and Toates, 1993 for an overview). However, since the motivational state of an animal is not affected whether it has been aroused by internal or external factors, the needs of the animal are consequently not related to the source of stimuli. It is therefore difficult to split the behavioural repertoire of an animal into some that constitute needs, and others that do not. However, a close understanding of the motivational system governing a particular behaviour will be helpful in specifying the needs of the animal with respect to that behaviour.

Nest building in sows

As an example, consider a case which has been in the focus of the debate regarding the needs of farrowing sows. Under free-range conditions, sows build farrowing nests during the last day before giving birth (Jensen et al., 1993). This is partly triggered by a preparturient rise in prolactin (Lawrence et al., 1994), and sows in all housing conditions attempt to carry out nest building activities during this period (Jensen, 1993). It has been argued that sows will not be motivated to nest build if they are not stimulated by external stimuli, and that they may be unmotivated if they have a sufficiently comfortable lying place or a ready-made nest (i e are exposed to stimuli associated with the goal). This has been strongly refuted by experimental evidence (Haskell and Hutson, 1994; Hutson and Haskell, 1990; Jensen, 1993). It has also been suggested that it may be sufficient for the sows to carry out the motor patterns of nest building, even if this does not result in a nest. This would be possible for sows that are tethered or confined in stalls, and they may therefore not experience any stress in this situation. However, sows in tethered conditions have considerably highercortisol levels prior to farrowing than loose sows with straw (Lawrence et al., 1994), which strongly suggests that carrying out the motions is in itself not sufficient to reduce the nest building motivation.

In this particular case, the behavioural needs of sows during the last day before farrowing appear to consist of a combination of being able to carry out the motion patterns involved in nest building, but also to receive feedback from the activities. The importance of feedback is also evident from the fact that under free-ranging conditions, sows will adjust their behaviour to the prevailing condition, for example collect more nest material in harsher climate (Jensen, 1989).

Why do animals perform ”unnecessary” behaviour?

The example of the nestbuilding sow strikes some people as unlogical. If a sow is provided with a protected, thermally optimal farrowing site, such as a farrowing pen, the evolutionary appropriate action would appear to be to save energy and refrain from activity. However, in the EEA, sows were unlikely to ever encounter such conditions, and the motivational system is designed to work in that context. In addition, pre-farrowing nest building is an essential behaviour which is only performed a few times in the total life-time of a sow, which may explain why the behaviour is largely hard-wired. Whereas behaviour like this may appear ”unnecessary” under farming conditions, it certainly is easy to understand from the perspective of the EEA.

A second source of apparently ”unnecessary” behaviour is ignorance of the function of a particular behaviour. This may be the case for a type of behaviour termed ”contrafreeloading”. It was discovered already in the 1960:s that animals offered a choice between eating free food and working for food by pressing levers would often consume the highest proportion of its food from the source which required effort (Jensen, 1963). Again, this was surprising, since it would appear most evolutionary logical to save energy when free food is available. It was therefore interpreted as a sign of a behavioural need in the sense that foraging and working for food was hard-wired behaviour which an animal would always attempt to express (Gardner and Gardner, 1988). However, studies of free living wild starlings feeding from food sources requiring different amount of work, led to another, more plausible explanation: Animals work for food in order to obtain information about possible alternative food sources (Inglis and Ferguson, 1986). This has rendered experimental support in studies of gerbils (Forkman, 1993).

We studied the behaviour of semi-naturally kept jungle fowl and White Leghorn laying hens in enclosures where they could feed freely available food or food that was mixed with sawdust, and therefore required that the hens worked for it. Whereas jungle fowl followed the contrafreeloading pattern and obtained most of its food from the source requiring work, the laying hens did the opposite (Schütz and Jensen, 1999). We interpreted this as a domestication induced change in the foraging strategy of the birds. Whereas it may pay off to a wild omnivore like a jungle fowl to use energy to gather information about alternative food sources, laying hens have been selected to use their energy mainly for growth and egg production, and this selection has occurred under conditions where food has been abundant. This may have caused the strategy of the laying hens to be modified towards relying more on safe food supply.

Implications

The two examples above show that we need to be careful in interpreting the behavioural needs of domestic animals. Whereas the behaviour may sometimes be hard-wired and the animal therefore motivated to perform the motion patterns regardless of environment, it could also be that the animals are searching for specific goals which we are not aware of. Any conclusions about the needs of animals with respect to their behaviour therefore has to be based on a thorough functional and motivational analysis.

The major source of information about the needs of animals is therefore their natural behaviour. Although it is not certain that animals have a need to perform every behaviour they show in a natural surrounding, their behaviour under such conditions will always reflect some sort of need. By careful studies, we can examine the relevant stimuli and feedback pathways associated with each behaviour and thereby assess the needs of the animals.

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The welfare of the high producing animal

Jeffrey Rushen

Discussions of animal welfare often stress the disagreements that exist between scientists and farmers or industry groups or between different scientists. In contrast, I suggest that there exists considerable agreement as to what does constitute poor welfare particularly when we focus on welfare problems that result from health problems. With the research emphasis that has been placed on the behavioural aspects of good welfare, we risk overlooking the fact that for many high producing animals health problems represent one of the major threats to their welfare. It is on these that I will focus my attention.

The High Producing Animal

As an example of a high producing animal, I shall take the dairy cow. Fig 1. shows data from a number of countries that illustrate some of the changes that have occurred over the last few decades in the production and husbandry of dairy cows.

First, and most striking, is the large increase in average milk production for each individual cow. Based on figures from North Carolina (NC Dept of Agriculture and Consumer Services 1999), each cow produces nearly four times as much milk as she did in the 1950's. Milk production per cow in the US in 1910 was reported to be 1320 kg per year (Peterson 1950), suggesting that relatively little change occurred before 1950. Data from the US as a whole (USDA, National Agricultural Statistics Service 2000) shows that milk production per cow has increased by 20% over the last ten years alone. Similar increases have also been reported in most developed countries (USDA, Foreign Agriculture Service 2000).

A second trend is the apparent reduction in genetic diversity within the dairy herds. At the most obvious level, this trend is apparent in the enormous dominance in many countries of Holstein cows, which now account for over 95% of dairy cows in the US (USDA, Animal and Plant Health Inspection Service 1996). By contrast, in 1948, according to figures in Peterson (1950), Holstein cows accounted for no more than 48% of all registered milk cows in the US. Even within the Holstein breed, there appears to have been a reduction in the genetic diversity. For example, Thompson et al. (2000) reports a fourfold increase in the inbreeding coefficient of dairy cows in the US from 1970 to 1998 (Fig. 1). Unfortunately, there is little data to judge whether a similar situation exists in other countries.

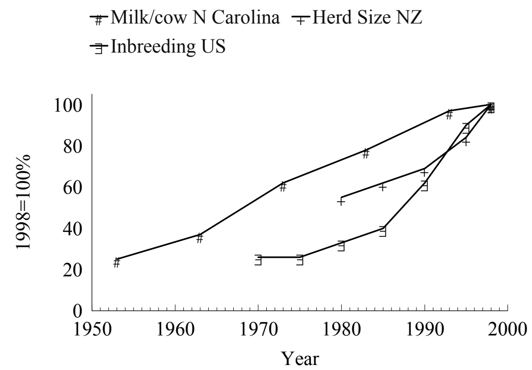

Figure 1. Historical trends in mean milk production per cow (NC Department of Agriculture and Consumer Affairs 1999), coefficient of inbreeding (Thompson et al., 2000) and herd size (NZ Dairy Board 1999). Data expressed as a percent of 1998 values.

Third, is a change in the way animals are housed. There has been a marked increase in the number of cows on each farm. For example, the data from New Zealand shows that average herd size nearly doubled in 20 years (Fig 1; NZ Dairy Board 1999). Similar increases in herd size are likely to be widespread in developed countries. In some countries, particularly the US and Canada, this increase in herd size has occurred alongside a change in the type of housing used for dairy cows. In particular, the development of free-stall housing (cubicles) has resulted in a reduction in the number of cows having access to pasture. For example, in the US 50% of cows now have no access to pasture, while 12% have no access at all to an outside area (USDA, Animal and Plant Health Inspection Service 1996).

As well as these changes in the production and management of dairy cattle, there has been an increase in the incidence of production related diseases. This is most obvious in the reported incidence of lameness in dairy herds of the UK. Surveys done before 1980 report the incidence of less than 10% (e.g. Russell et al. 1982), whereas surveys done since 1980 report the mean incidence of more than 20% (Whitaker et al. 1983; Clarkson et al. 1996; Kossaibati and Esslemeont 1999; Whitaker et al., 2000). A high incidence of lameness is now reported in dairy cattle in many countries (Harris et al. 1988; Wells et al 1993, Philipot et al. 1994; Barkema

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et al 1994). Data from the milk recording program in Quebec, suggests that the incidence of other production diseases has also increased (Dürr et al. 1997). For example, in 1980 over 16% of cows culled were the result of "voluntary" culling for low milk production. However, in 1994 the number of cows culled "voluntarily" was reduced to only 4.5%, mainly because of a large increase in involuntary culling for problems with reproduction (8%), mastitis (5%), lameness (4%) or because of an unspecified illness (4.5%). Similar rates of culling for these production diseases have been reported from countries as diverse as the UK (Whitaker et al 2000), the US(Ruegg et al. 1998), Finland (Rajala-Schultz and Gröhn 1999), France (Seegers et al. 1998) and Australia (Stevenson and Lean 1998), again suggesting a widespread trend. These production disease are now considered to be the most important welfare problems facing dairy cattle (Farm Animal Welfare Council 1997), and represent a major financial loss (Enting et al. 1997; Kossaibati et al. 1997; Bennett et al. 1999).

Is intensification the problem?

An obvious question is whether the trends shown in Fig 1 i.e. an increase in milk produced per cow, larger herds with less access to pasture and reduced genetic diversity are the cause of the production diseases. Critics of modern animal agriculture often point to these aspects of intensification as a cause of reduced animal welfare of dairy cattle (e.g.Adcock and Finelli 1995). Certainly the incidence of lameness appears higher in countries such as the UK (Whitaker et al., 2000), the US (Wells et al. 1993 1995) and the Netherlands (Barkema et al. 1994) with more intensive dairy production (that is: higher production per cow, larger farms, more indoor housing) than in Switzerland (Frei et al. 1997) which has much smaller farms or Australia (Harris et al. 1988) which has much lower production and much less use of indoor housing. In a number of European countries there has been a great increase in the sales of "organic" milk which try to meet the growing consumer demand for milk from less intensive agricultural systems, and which claim to pay greater attention to animal welfare issues. However, surveys to date show that such organic dairy farms do no better than the conventional ones in terms of the incidence of these production diseases (Vaarst et al. 1998; Weller and Bowling 2000)

Farm surveys of the incidence of such maladies always document considerable variation between farms. For example, Whitaker et al (2000) reported that the incidence of culling for reproductive problems, mastitis and lameness in the highest quartile of UK dairy farms was 26 % but was less than 2% in the lowest quartile. Such differences may reflect differences between farms in various factors related to the genetics and housing of the animals. In the following sections, I look at the evidence that relates the incidence of various production disease, with a particular emphasis on lameness, to levels of production per se, genetics, herd size and type of housing. Although both management and nutrition factors are important, I do not discuss these.

Effects of increased production and genetic contributions.

A number of studies have investigated whether or not the occurrence of such maladies among dairy cows is associated with a high level of milk production. Unfortunately, such results are not easy to interpret: the occurrence of these maladies can themselves result in lower milk production (Deluyker et al. 1991) or a correlation between high production and a high treatment rate of diseases may reflect a higher level of vigilance and concern for disease among better herd managers (Emanuelson and Oltenacu 1998). High levels of milk production are widely associated with high levels of mastitis (Faye et al. 1997; Emanuelson and Oltenacu 1998; Waage et al. 1998). However, such a relationship is not as obvious for lameness. Early studies did report higher levels of lameness in herds with higher levels of milk production (Deluyker et al. 1991; Enevildsen and Gröhn 1991a,b), but more recent studies have not reported such a relationship (Vaarst et al 1998; Whitaker et al 2000).

To understand the correlation between levels of milk production and lameness (or indeed of all production diseases) it is necessary to separate the effects of genetics and the effects of management in bringing about the level of production. Rauw et al (1998) reviewed a number of studies that separately calculated the genetic correlations and the environmental correlations between milk production levels and the incidence of various diseases. Environmental correlations were generally absent. In contrast, there were small but important positive genetic correlations between the level of milk production and the incidence of ketosis, mastitis and lameness. This has been confirmed in more recent studies for lameness (Van Dorp et al. 1998). These results suggest that management differences between farms that result in differing levels of production need not necessarily result in changes in the incidence of mastitis or lameness. In contrast, continued breeding and selection of animals purely on the basis of high milk production could likely result in an increased incidence of such production diseases. Rauw et al. (1998) suggeste that strong artificial selection for a trait such as milk production leads to the animal using its biological resources to the maximum leaving few resources left to respond to other demands or to various stressors.

The finding that many of these maladies are heritable (even if heritabilities are relatively low) has renewed interest in including such health parameters in selection indices for dairy cattle (Boettcher et al. 1998). However, it remains to be seen whether the genetic correlations between high production and health problems can be uncoupled, or whether they are inevitable, as Rauw et al.'s (1998) argument suggests.

The role of genetic factors in production diseases is emphasised by the fact that Holstein cattle suffer from a higher incidence of both mastitis (Washburn et al. 1998) and lameness (Harris et al. 1988; Alban 1995) than Jersey cattle. In conventional and organic dairy herds in Denmark, a higher incidence of acute sole haemorrhages were found among Danish Holsteins than among other dual purpose breeds (Vaarst et al. 1998). The increasing incidence of inbreeding that has been noted on US farms seems likely to have lead to reduced survival of dairy cattle (Thompson et al., 2000) but there is no evidence available to judge whether or not inbreeding leads to an increased incidence of mastitis or lameness. However, there are increasing calls for the practice of cross breeding in dairy cattle (Hansen 1999).

Concerning the effect of breeding on animal welfare, the UK Farm Animal Welfare Council recommends that: "Achievement of good welfare should be of paramount importance in breeding programmes. Breeding companies should devote their efforts primarily to selection for health traits so as to reduce current levels of lameness, mastitis and infertility; selection for higher milk yield should follow only once these health issues have been addressed" (1997 p66).

Effect of housing and environment.

Considerable research supports the idea that the housing can affect the incidence of lameness and other production diseases. Removing or limiting access to pasture has been found to increase incidence of mastitis (Washburn et al. 1998; Waage et al. 1998; Barkema et al. 1999) and digital dermatitis (Wells et al., 2000). Although free stalls may seem preferable to tie stalls in terms of greater freedom of movement, the use of free stalls has been found to be associated with a higher incidence of lameness (Rowlands et al 1983; Ingvartsen and Anderson 1993; Whitaker et al., 2000). Although loose housing on deep straw has been found to reduce the incidence of lameness compared to free stalls (Whitaker et al, 2000), the reverse relationship has been found with mastitis (Faye et al. 1997; Whitaker et al, 2000). Even considering hoof problems alone, the effects of housing can be complex. For example, compared to straw yards, free stalls have been found to increase sole haemorrhages but decrease heel horn erosion (Livesey et al. 1998), while housing heifers indoors compared to giving them access to dry lots increases haemorrhaging on some parts of the horn but decreases it on other parts of the horn (Vermunt and Greenough 1996). The fact that different housing systems affect different welfare problems in different ways is a common finding in research on animal welfare (Rushen and de Passillé 1993) and makes it difficult to make generalizations regarding the effect of housing on animal welfare.

The effect of type of housing on welfare can depend to a great extent upon the details of the particular system. For example, cows housed in tie-stalls with concrete floors had a higher incidence of sole haemorrhages than cows housed in tie-stalls with rubber mats (Bergsten and Frank 1996). Stalls that are too small or are designed in a way that make it difficult for the cow to get up and lie down have also been found to be associated with an increased incidence

Most commentators believe that the main walking surfaces for cows play a major role in affecting the incidence of lameness, with concrete surfaces being seen as a particular problem. Philipot et al. (1994) assessed risk factors for chronic and subacute laminitis as well as heel horn erosion and found that conditions such as high steps were risk factors linked to subacute laminitis. Inappropriate flooring can increase the incidence of lameness by causing excessive and uneven wear of the hoof, by direct damage as a result of uneven surfaces or protrusions, or by causing skin breaks which increase the risk of infectious diseases such as footrot. An epidemiological survey of farms concluded that lameness was prevalent where walking surfaces were smooth concrete (Faull et al. 1996). Cow walking surface has also been related to the incidence of apparently infectious foot diseases: the incidence of papillomatous digital dermatitis (foot warts) was found to be substantially higher on farms where cows walked on grooved concrete compared to farms where cows walked on dirt, pasture or smooth concrete (Wells et al. 1999) perhaps because the abrasive properties of the flooring caused damage to the hooves.

There is not strong evidence that herd size per se increases the incidence of various production disorders. A survey of a large number of farms in the US found no evidence that culling rates for lameness, mastitis or reproductive problems (USDA, Animal and Plant Health Inspection Service 1996) were higher on larger farms . However, in other studies large herd size has been found associated with an increased risk of digital dermatitis (Wells et al. 1999), lameness (Alban 1995) and mastitis in heifers (Waage et al. 1998). It is understandable that larger herds, leading to increased contact between a larger number of animals, would increase the risk for infectious diseases. However, it is clear that large herd size alone should not be assumed to be associated with poorer levels of welfare in general. In contrast, crowding does clearly lead to a higher incidence of production diseases. A reduced number of feeding spaces per cow has been found associated with an increased incidence of mastitis (Barkema et al. 1999) while too few cubicles per cow leads to higher incidence of hoof lesions (Leonard et al. 1996).

The role of behaviour

Although I have concentrated on health related welfare problems, the behaviour of the cattle can be an important mediating factor in influencing how housing systems lead to lameness.

In early research, Colam-Ainsworth et al (1989) found that the incidence of lameness was high in one group of heifers that showed reduced time lying down, presumably because the stalls were uncomfortable. In more systematic research, Leonard et al (1994; 1996) found that when cows were kept either in uncomfortable stalls, or with too few stalls per cow, both the time spent lying down was reduced and the incidence of hoof lesions increased. Furthermore, there were significant negative correlations across individual cows between lying time and the incidence of hoof lesions. This correlation was likely due to reduced lying time leading to increased hoof problems, rather than the reverse, because at pasture lame cows lie down longer than healthy cows (Hassall et al. 1993). This correlation between reduced lying time and increased hoof problems has recently been confirmed (Chaplin et al., 2000).

Rest is clearly an important behaviour for dairy cattle (e.g. Munksgaard and Løvendahl 1993) but can be greatly affected by the design of stalls (e.g. Haley et al., 2000). In a survey of UK dairy herds, Faull et al (1996) noted a widespread use of stalls that were either too small or poorly designed. It seems possible that by reducing resting time in cattle the use of such stalls is a contributing factor to the high incidence of lameness.

Conclusions

Although this review has focussed on the dairy cow, many of the factors leading to the welfare problems discussed are typical of other high producing animals such as pigs and poultry (Rauw et al. 1998). Production diseases such as lameness and mastitis represent the most serious welfare problems for dairy cattle. The incidence of these are clearly affected by a combination of genetics and housing, which is perhaps no surprise. The mounting evidence of genetic correlations between high milk production and the incidence of these maladies, combined with the worrying trend to higher levels of inbreeding in dairy cattle herds, suggest that some thought be given to selecting animals primarily on the basis of health related traits and considering greater use of breeds other than the Holstein. However, the housing environment is clearly important, and the fact the cattle genetically selected for high milk production are more susceptible to these maladies, emphasises the importance of ensuring good housing conditions for high producing animals. However, the relationship between housing and the incidence of these maladies is not a simple one, and few generalizations can be made regarding types of housing such as tie-stalls, cubicles etc. Much depends upon the particular details of each type of housing, such as the number of stalls available and their size and design.

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An evaluation of "indexing welfare in farm animals

Eberhard von Borell [1)]

Welfare assessment and of on-farm animal welfare index systems

The welfare, health and management of farm animals are relevant issues that have an impact on the success of the producer in the market and need to be considered in order to increase consumer acceptance of animal production in the near future. Criteria for the assessment of farm animal housing have been proposed by several groups and minimal standards for animal welfare are already implemented in the legislation of most European countries (as reviewed by von Borell, 1996). These minimal requirements implemented by legislation do not relate to all farm animal species or production stages. For example, there is no specific EU council directive on the minimal housing requirements for dairy and beef cattle.

In order to assess animal welfare on the farm in a variety of production systems, different assessment systems have been developed in Europe, considering the advantages and disadvantages of specific housing and management features for the welfare of farm animals. The idea for creating an index system for welfare assessment goes back to a concept of Bartussek (1985), proposing a Tier-Gerechtheits-Index (TGI, translated as animal needs index) in context with a state directive for intensive animal housing legislation in Austria. The concept has been further developed leading to the current version which is called TGI 35 L, with an index system for cattle, laying hens and fattening pigs (Bartussek, 1995 a,b,c). On-farm evaluation is based on an assessment sheet on which a range of scores is assigned to a variety of housing features, technical prerequisites and management measures for different functional areas in the housing environment that have an impact on the health and welfare of farm animals. The TGI 35 L is mainly based on technical requirements in the housing system (i.e. space allowance and floor quality), considering 30-40 criteria. Initially, one to seven points were assigned to each of 5 functional areas of the housing environment summing up to 35 points as the highest score. More recent versions are allowing a more differentiated scoring, including a negative score or higher scores than initially proposed (see Tab. 1). It also considers that animals can compensate for negative influences in one aspect by positive in another.

Based on the TGI concept of BARTUSSEK, another assessment system was developed by Sundrum et al. (1994) as a contribution for a state competition, providing a guideline for animal welfare friendly housing of laying hens, calves and pigs. This concept includes 60-70 criteria that are assessed for 7 functional classes with emphasis on prerequisites for the performance of goal directed behaviours and factors that have an impact on animal health. A maximum of 200 points can be assigned, ranging from 0 to 200 (see Tab. 1). This concept allows a repeated scoring of special housing features in multiple categories, which partly explains the relative high scores. Intensive housing systems such as housing of fattening pigs in indoor pens on slatted floors can therefore never exceed a certain score (in this example about 120 points), even when aspects like health and care are optimal.

Tab. 1: Defferences between TGI 35 L and TGI 200

	TGI 35L (BARTUSSEDK, 1995)	TGI 200 (SUNDRUM et al., 1994)
Score Range	max. 46.5 - 9 t0 46.5	max. 200 0 to 200
Function classes	- movement - social contacts with other animals - floor design - climatic conditions in the hausing - intensity of care by the farmer	- Locomotion - Fedding behaviour - Socia behaviour - Resting behaviour - Comfort behaviour (elimination [pigs] & nest building [hen] - Hygiene - Care
Criteria	30 – 40	60 – 70
Emphasis	Housing technique; allowing compensation	a) Prerequisites for performing goal directed behaviours b) Animal health
Inrerpretation of index	assesment according to scores "bad welfare" "good welfare"	- enables comparisons between housings - documentation of deficits - emphasizing advantages
Application/ User	State laws in Austria Consulting Organic farming organisations Control institution > 20.000 farms	Training of consultants Consulting Organic farming organisation

modified after Andersson, 1998

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Evaluation of on-farm animal welfare index systems

This evaluation is intended to summarise some of the major advantages and disadvantages of on-farm index systems in general rather than comparing the two index systems TGI 35 L and TGI 200 in terms of reliability and practicability. The latter would require a very detailed comparison within functional classes of each system, which has been already done by Van den Weghe (1998) and others (Ofner et al., 2000; Hörning, 2000).

Advantages:

1. On-farm animal welfare indexing constitutes a practical method to assess major deficits in a housing system within a relatively short period of time (approx. one hour).
2. The TGI evaluates welfare relevant criteria for different functional aspects of the housing environment and on the animal itself in a very systematic way.
3. The assessment requires a relative short training of the assessors, although this training is very critical for reliability of the assessment.
4. Repeatability of scores between different assessors and for multiple visits on the same farm is relatively high for objectively measured criteria (i.e., for pen dimensions).

Disadvantages:

1. The on-farm indexing system contains subjectively scored criteria such as cleanliness and the quality of flooring (i.e., decision whether floor is slippery or non-slippery).
2. The time point of the farm visit for assessment is critical. The situation during summer might be different from that during winter. Outdoor systems are significantly influenced by the actual climatic condition.
3. The evaluation sheet contains some uncertainties concerning some of the definitions, interpretations and explanations. For example, the welfare relevance of dehorned versus horned cattle in mixed herds with both types of cattle.
4. A conclusive statement for a particular housing system such as “good” or “bad” in terms of welfare is not appropriate as this method of assessment is not based on scientific grounds. Especially the weighting of the different criteria for welfare relevance is critical.

Testing of serious produced farm animal housing equipment or systems

Pre-testing of housing equipment or systems has been discussed within Europe for a long time. Switzerland, Sweden and Norway have already implemented mandatory systems for approval of new technology. Switzerland is most advanced in that regard, as new technology has to be tested mainly on a specific federal testing station or on reference farms by means of ethological studies and veterinary assessment (Troxler, 1998). The Scandinavian approach (Sweden and Norway) is to assess animal housing mainly based on epidemiological field studies using clinical, subclinical and behavioural records (Ekesbo, 1992). The Animal Welfare Committee of the German Agricultural Society (DLG) has now established a procedure of voluntary assessment and certification of housing and handling equipment according to welfare criteria within the utility value testing system (Hesse et al.., 1999). A legal frame for such a testing is given by the German Animal Welfare Act of 1998 (Knierim et al., 2000a). Welfare assessment is mainly based on functional classes of behaviours which are relevant for the specific equipment being tested (see example for functional classes and criteria on pig welfare assessment in Tab. 2; Knierim et al., 2000b). If relevant, other criteria such as physiological, pathological, performance and hygiene are added to the testing procedure. Testing is conducted on research stations or reference farms under the control of testing engineers being advised on the welfare assessment protocol by experts of the Welfare Committee. A certificate (DLG tested) is only provided if the new technology complies with the existing welfare standards.

Tab. 2: Specific welfare assessment criteria for pigs (Knierim et al., 2000)

Functional class	Assessment criteria
Resting behaviour	- Individual lying times (eg overall duration, duration of lying periods) - Lying down and standing up behaviour (eg frequency of abnormal sequences of movement, extent of circumscribed pressure on limbs) - Lying positions (eg proportion on side or belly) - Synchrony of lying behaviour - Quality of lying area (eg dimensions, heat conductivity, slipperiness, dryness, hygiene) – Risk of injury and damage
Eliminative behaviour	- Functional separation of dunging area from lying and feeding areas - Floor slipperiness – Hygiene (eg self-cleaning and cleaning properties of perforated floors, cleanliness of animals)
Feeding behaviour	- Individual feeding and drinking times, diurnal rhythm - Design of drinking and feeding place (eg dimensions, accessibility, animal/feeding or drinking place ratio, protection from competition, fail-safety of automated devices, speed of water flow) - Synchrony of feeding behaviour - Abnormal behaviour (eg vacuum chewing, bar biting) - Hygiene at drinkers and feeding places - Functioning of medication devices (eg accuracy of doses) – Risk of injury and damage
Reproductive behaviour	- Size and floor quality of the service area (eg slipperiness, cleanliness) - Opportunities for contact between sow and boar - Possibility of nest-building in the farrowing area - Course of farrowing (eg overall duration and interval between emergence of individual piglets) - Protection devices for piglets (eg provision and functioning) – Risk of injury and damage
Comfort behaviour	- Possibility and frequency of performance (eg availability of scratching devices, space allowance, slipperiness of floor) - Possibilities for thermoregulation - Hygiene (eg risk of transmission of disease) - Integument Condition – Risk of injury and damage
Locomotion	- Possibility of performance (eg space allowance, structuring of space) - Floor quality (eg slipperiness, step safety, dryness, cleanliness) - Risk of injury and damage (eg foot health)
Social behaviour	- Social interactions (eg possibility of performance, number of agonistic interactions, social grooming) - Social structure (group size and composition, range concerning weight and age) - Possibility of retreat and avoidance of contact - Synchrony of behaviour – Risk of injury and damage
Exploration	- Possibility and frequency of performance (eg available stimuli, space allowance, floor quality, structuring of space) - Risk of injury and damage
Play behaviour	- Possibility and frequency of performance (social, locomotion and object play) - Risk of injury and damage

Evaluation of testing concepts for serious produced farm animal housing equipment

The following general evaluation summarises the advantages and disadvantages of housing equipment testing, although there might be some distinct differences in some aspects between the existing testing concepts.

Advantages:

1. Data collection and documentation is based on scientific principles in terms of numbers of animals and replications.
2. Unsuitable housing features are excluded from certification or being improved during the procedure to meet the standards.
3. Inclusion of welfare assessment criteria in the testing of animal housing will stimulate the development of new welfare friendly technology.
4. The certificate (i.e., DLG tested) will help the producer to gain acceptance and to be able to compete on the market.

Disadvantages:

1. The testing procedure is relatively time consuming and expensive.
2. The level of bureaucracy is relatively high, especially for federally supervised compulsory testing.
3. Compulsory testing requirements in some countries might hamper free trade in the European Union.
4. The testing results (if mainly collected from research stations) might not entirely reflect the on-farm situation, as deficiencies in management and complex interactions between animals, technology and the whole housing system are usually excluded from assessment.

Hazard Analysis and Critical Control Point (HACCP) system

HACCP was originally developed as a microbiological safety system to ensure the safety of food.. It was based on the engineering system, Failure, Mode and Effect Analysis (FMEA), which looks at what could potentially go wrong at each stage in an operation together with possible causes and the likely effect (Mortimore and Wallace, 1998). Effective control mechanisms are then put in place to ensure that the potential failures are prevented from occurring. HACCP looks for hazards in the product-safety sense and became eventually a legislative requirement for food safety and food hygiene in many countries. The principles of the HACCP concept have been extended to animal health management strategies by various groups, demonstrating that process control (expressed in terms of controlling both general and specific disease risk factors) and product control (expressed in terms of testing animals or animal products for specific disease agents) could form the basis for improving animal health. More recently, this concept has been adopted by welfare scientists in order to safeguard the welfare of farm animals (Grandin, 2000a,b). An animal welfare index is currently developed in The Netherlands that might become an integrated part of the Dutch Integrated Quality Control (IKB) program which is based on elements of the quality assurance system ISO-9000 (Vesseur and Den Hartog, 2000). A major component of the HACCP system is to describe potential hazards and to establish Critical Control Points (CCP) to assuring the safety of the product (or in relation to welfare assessment: to safeguard the welfare of the animal in the production process). The critical limits for each identified CCP must involve a measurable parameter. The working group "Animal Husbandry and Animal Welfare" of the German Association for Animal Production (DGfZ) is currently establishing assessment criteria for housing and management practices being mainly based on sound scientific knowledge from the literature, ensuring that the necessary parameters can be objectively measured and verified (von Borell, 2000). A number of prerequisites or minimal requirements are already given by existing technical standards, legislation or are simply based on Good Farming Practice. The actual critical limits are not necessarily based on scientific principles as there are no clear cut thresholds between "good" and "bad" welfare. Grandin (2000a) recently developed an animal welfare audit for cattle and pig slaughterhouses that includes control points such as stunning efficacy, animal vocalisation scores and electric prod usage. A large food company (McDonald's Corporation) has now added animal handling and stunning audits to their existing food safety audits being assessed by a third party HACCP team. Currently, this company has established an animal welfare committee that sets minimum housing and management requirements for egg suppliers (i.e., for minimal space allowance in cages). There are numerous other programs driven by supermarkets, consumer and welfare organisations, having all set up their own welfare standards to satisfy the specific demand for niches in the marketplace.

Evaluation of the HACCP concept for welfare, health and management criteria

The following evaluation strictly relates to the advantages and disadvantages of the HACCP concept applied to criteria and critical limits for farm animal welfare, health and management:

Advantages:

1. The assessment/auditing is under third party control with independent inspectors/auditors being member of the HACCP team
2. A high repeatability between assessors is guaranteed
3. The critical limits for each of the Critical Control Points are generated by objective measurements on a regular basis.
4. The critical limits are clearly defined within the specific program.

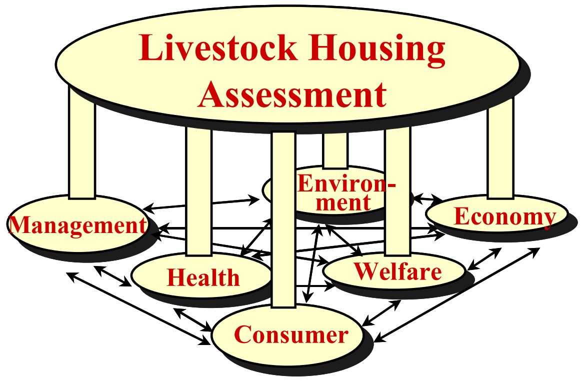
Disadvantages:

1. Only few criteria might fulfill HACCP requirements. Others with relevance for animal welfare, health and management may not be accessible by the HACCP protocol (i.e., incidence of behavioural deviations).
2. The specific time point of assessment is critical (the same as for TGI assessment).
3. The certification might suggest a uniform internationally accepted standard for welfare, health and management assessment. In reality, the critical limits and certification process might vary considerably between the specific programs.
4. The critical limits might not be based on scientific knowledge.

Conclusions and future outlook

Low investment costs and high production efficiency are vital criteria for future competitiveness in animal production. However, in contrast to the past decades, issues such as animal welfare and health, environmental care, product safety and consumer acceptance are becoming increasingly important and need to be strongly considered in future livestock housing assessment. All concepts of animal welfare indexing may eventually improve the welfare of farm animals in the long run, considering that all programs have their advantages and disadvantages and depending on the specific goals for which they were introduced. On-farm assessment of welfare has to be combined with the current scientific knowledge on how animals perceive their social and technical environment. Fundamental studies from different scientific disciplines (i.e., psychophysiology, pathology and stress physiology) can help to create better assessment parameters and to improve the interpretation of what we can observe on the farm. Animal welfare has become now an integrated part of quality assurance programs for sustainable animal production, considering that welfare, health, management, economy, consumer acceptance and environmental impact are depending on each other (see Fig. 1). For this purpose, welfare assessment via objectively measured indicators provide the knowledge needed to further improve this approach in the future.

Fig. 1: Factors influencing livestock housing assessment



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Animal welfare during transport and slaughter

Temple Grandin[1)]

Intruduction

Good management combined with well-designed equipment must be used together to insure adequate animal welfare during transport and slaughter. In this paper, I will discuss some of the major factors which affect welfare during transport and slaughter. The first section will cover transport and the second section will cover welfare in slaughter plants up to the point of stunning. Stunning methods have been well researched and validated, but there needs to be more emphasis on how the animals are handled. Large restaurant and supermarket companies have been instrumental in enforcing welfare standards in both the U.S. and Europe and the effects of these programs in the U.S. will be discussed.

The U.S. is a huge country which is larger than Western Europe. There are no Federal (country wide) regulations on the transport of cattle, pigs or sheep. Animals used in bio-medical research are covered by Federal regulations, but the transport of agricultural animals with the exception of slaughter horses is unregulated. Animals on the premises of a Federally inspected slaughter plant are covered by the 1978 Humane Slaughter Act, which is similar to European regulations.

Rest Stops

Rest stops during transport is an area of great controversy. One must be careful not to turn rest stops into stress stops. In the U.S., practical experience has shown that the health of 250 kg weaner calves from rangeland will be better if they travel non-stop for up to 32 hours (Grandin, 1997a). The stress of loading and unloading of wild cattle not accustomed to close contact with people increases stress. If the trip is longer than 32 hours, the animals will stay in better condition if they are unloaded and rested.

In other situations, rest stops will be beneficial. One area that needs to be researched is the use of different stocking densities for long and short trips. Pigs stocked loosely enough so that they can all lie down would benefit from a rest stop where they could remain on the vehicle. However, in the southern U.S., this might not be practical due to extremely hot summer weather. Heat builds up rapidly in a stationary vehicle, unless the rest stop had fans to cool the animals.

Fit Animals for Transport

The single most important transportation issue is having a physically fit animal for transport. The author has observed that the greatest welfare problems during transport were caused by death losses in stress susceptible pigs, and downers in old cows and sows which have been allowed to deteriorate into a skinny, weak condition prior to transport. Genetic selection for ever increasing productivity has resulted in weaker pigs and dairy cattle which may be less fit for long distance transport.

For old dairy and beef cows, timely marketing is the single biggest issue. The author estimates that 10% of the dairies are responsible for 90% of the problems with cows that go down in the truck during transport. These unethical people allow their cows to deteriorate to a weak condition.

The National Market Cow and Bull Quality Audit in the U.S. indicated that the percentage of dairy cows arriving at a slaughter plant with a poor body score of 1 or 2 increased from 4.8% in 1994 to 5.4% in 1999 (Smith et al., 1994, 2000). Cows with a body condition score of 1 or 2 are emaciated and their ribs are sticking out.

The most alarming finding was that the percentage of dairy cows arriving with arthritic leg joints has tripled. In 1993, 4.7% of cull dairy cows had arthritic joints and in 1999 the percentage increased to 14.5%. This increase in lameness may have contributed to the increased incidence of downers. There is a need for producers to put more emphasis on breeding good feet and legs and a little less emphasis on production.

Old Breeding Sows

A slaughter plant manager wrote to me complaining about the deteriorating condition of old sows (Grandin, 1997b) found that 16% of the sows that arrived at a large Midwestern slaughter plant were lame. A major indicator that sow condition is declining is increasing sow mortality on large farms. Koketsu (2000) collected data from 825 U.S. and 240 Canadian farms. One clear result was that the largest farms had the highest mortality (Koketsu, 2000). The cause of the increase appears to be a combination of genetic selection for leanness and poor management. Average mortality increased from 4.3% to 5.8% from 1993 to 1997.

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Koketsu (2000) reports that the sows died from a combination of acute and chronic conditions. Lameness was one of the conditions listed. Some of these lame sows would have ended up in the transportation system.

Market Pigs and Baby Calves

Pigs which have been selected for huge muscle growth and the stress susceptibility gene will have the greatest death losses during transport. The author has observed death losses of 0.5% in these pigs during transport. It is my opinion that these pigs are simply not fit for transport. Murray and Johnson (1998) report that 9.2% of pigs that were homozygous for the stress gene died during transport. The death loss percentages were 0.27% for heterozygote carriers and 0.05% for pigs which were stress gene free. Many integrated producers in the U.S. have eliminated the stress gene. The only producers that still breed pigs with the stress gene are producers whose payment is based on the size of the loin. The integrated companies eliminated the stress gene to improve pork quality. Payment systems should be changed to reward quality instead of quantity. Changing the payment system would improve animal welfare because the producer would be rewarded for quality instead of quantity.

Another problem area in the U.S. is transport of day-old baby Holstein dairy calves. In some instances, 10 to 20% die either during or shortly after transport. Some of these calves have not received colostrum A few unethical dairy producers treat calves like rubbish that they have to get rid of.

Improving the Fitness of Animals for Transport

1. Breed good, strong feet and legs.
2. Grow dairy heifers and gilts more slowly to provide time for the skeleton to develop.
3. Weak, sick or emaciated animals should be euthanized on the farm.
4. Use calm, quiet handling practices.
5. Develop audit systems for monitoring the body condition of dairy and breeding sows. People manage the things that they measure.
6. Do not overload trucks.
7. Avoid sudden braking and acceleration.
8. In the U.S., many animals cannot be traced back to their origin. Accountability for losses provides an incentive to maintain breeding stock in better condition.
9. Market old breeding animals when they are still fit to travel.
10. Producers will be more motivated to take care of old breeding animals and baby Holstein calves if they have more economic value. Develop markets for these animals. Many baby Holstein calves are raised by calf raising companies and then fed in feedlots to produce grain fed beef.

Continuous Measurement and Monitoring

People who handle and stun hundreds or even thousands of animals in slaughter plants often become numb and desensitized to animal suffering (Grandin, 1994). The author has observed that handling transport and stunning procedures have a tendency to become rough and careless unless they are continuously monitored. A one-time meeting of showing a handling video to employees is not sufficient to maintain good animal welfare. The manager who is most effective in maintaining high standards of animal welfare must be involved enough to care, but not so involved in day-to-day operations that he/she becomes desensitized.

The author strongly recommends using a HACCP-type approach to measuring the efficacy of stunning and the performance of animal handlers. HACCP stands for Hazard Analysis Critical Control Points and it is used around the world to maintain food safety standards. An objective scoring system is described fully in Grandin (1997b, 1998a). The five major critical control points of stunning and animal handling are briefly outlined here. Each item is scored on a *yes/no* basis for each animal. An auditing system has to be simple so that it is easy to use under commercial conditions. Therefore, each animal is scored for each variable on a yes/no basis. For example, prodded with an electric goad or not prodded. Score a minimum of 100 pigs and in cattle plants with line speeds of under 100 per hour score 50 animals.

1. Stunning Efficacy – Percentage of animals rendered insensible on the first attempt.
2. Insensibility – Percentage of animals that remain insensible after stunning.
3. Vocalization – Percentage of cattle or pigs that vocalize (bellow, moo or squeal). Each animal is scored on either being a vocalizer or a non-vocalizer.

Vocalization is highly correlated with physiological stress measurements and adverse events such as missed stuns, excessive electric prod use, excessive pressure from a restraint device, slipping or falling, surgery and isolation of a single animal (Dunn, 1990; Grandin, 1998b; Warriss et al., 1994; White et al., 1995). Do not use on sheep. Each pig or bovine is scored as either a vocalizer or non-vocalizer during handling and stunning. Vocalization is not scored while animals are standing in the holding pens because animals standing undisturbed often vocalize to each other. Data collected in beef slaughter plants clearly shows that vocalization scoring can be used to document improvements in handling. When the shock intensity on an electric goad was reduced, the percentage of cattle that vocalized decreased from 7% to 2.5% (Grandin, 2000a). In two other plants, vocalization percentages of 8 and 9% were reduced to 0% after simple equipment modifications were made. These modifications reduced cattle balking and refusing to move which reduced electric goad usage. In a fourth plant, reducing the pressure applied by a head restraint device reduced the percentage of cattle that vocalized from 23% to 0%.

In large plants where counting of individual squeals is difficult, a sound level meter can be used. Another simple way to monitor the amount of pig squealing is to determine the percentage of time that pigs are squealing. As each pig is stunned, the auditor marks down "yes heard a squeal" or "no room quiet." The entire stunning area is scored. If an animal is immobilized with electricity it may still be conscious, but unable to vocalize. This is extremely distressful for animals and must not be used as a method to keep animals still (Pascoe, 1986; Grandin et al., 1986; Rushen, 1986; Lambooy, 1985). Electro immobilization must not be confused with electrical stunning where a high amperage current is passed through the brain. Vocalization scoring should not be used on sheep.

4. Slipping and Falling – Percentage of animals that slip or fall during handling and stunning.
5. Electric Goads – Percentage prodded (poked) with an electric prod (goad). Reducing the percentage of animals shocked with an electric goad reduces stress and improves welfare.

Audits of these critical control points must be done on a regular basis, the same way microbiological audits are conducted. Bacteria counts would increase and sanitation procedures would become sloppy unless continuous monitoring was done. Handling and stunning must be audited the same way in order to maintain high standards. One factor that contributes to a deterioration of handling and stunning practices is an emphasis only on speed and efficiency. Abuse is more likely to occur if employees are evaluated only on speed and efficiency.

The critical control point welfare auditing system can be used in plants around the world from the most sophisticated to the most primitive. The standards of performance which would be considered acceptable are debatable. The auditing system can be used to continually improve handling and stunning.

Meat Quality Correlations

Measurements of meat quality and bruises are important. Progressive plant managers have found that quiet handling in the stunning area will reduce PSE (pale, soft, exudative) in pork. In four different plants, the author has found that reducing electric prod use and quiet handling of pigs resulted in 10% more pork which was suitable for high quality export to discriminating customers in Japan. Reduced levels of squealing are correlated with improved meat quality (Warriss, 1994). Cattle that become agitated during handling have lower weight gains and tougher meat (Voisinet et al., 1997; P. Niendre, personal communication). An over emphasis on preventing gaps in the production line may result in more animal stress and poorer meat quality. Handling must be measured on a regular basis to maintain high standards. Animal welfare is also part of quality.

Effect of Customer Audits

Two of the major hamburger chains are using HACCP-type audits of animal handling and stunning. They are done in the same manner as microbiological audits. Audits by McDonald's Corporation in the U.S. have resulted in great improvements (Grandin, 2000). Major meat buying customers are in a position to require their suppliers to maintain high standards. In the U.S., the meat industry started to take animal welfare seriously after a major slaughter plant was removed from the McDonald's supplier list after they failed an audit.

How Stressful is Slaughter?

People often wonder "are animals afraid of slaughter." I have observed that cattle and pig behavior during handling and stunning is the same both on the farm and at the plant. Extensively raised cattle in the U.S. often become highly agitated and vocal when they are restrained for vaccinations. Often they are calmer at the slaughter plant because being restrained and held for ear tagging and vaccination takes longer than stunning.

Animal handling both on the farm and in the slaughter plant will cause physiological measures of stress to increase. When animals become agitated during handling it is most likely to be motivated by fear. The fear circuits in the animal's brain have been completely mapped (LeDoux, 1996; Rogan and LeDoux, 1996). Grandin (1997a) reviewed numerous studies of cortisol (stress hormone) levels during handling both on the farm and at slaughter. The range of values for cattle were similar for both on-farm restraint in a squeeze chute and slaughter. The range was 24 ng/ml to over 63 ng/ml (Crookshank et al., 1979; Mitchell et al., 1988; Tume and Shaw, 1992; Zavy et al., 1992; Lay et al., 1992; Ewbank et al., 1992 and Dunn et al., 1990). Rough handling, slipping on the floor and electric prod use resulted in higher cortisol levels. The highest levels recorded in a slaughter plant was 93 ng/ml (Dunn, 1990). Cattle were inverted on their backs for 103 seconds prior to slaughter. Properly performed cattle slaughter seems to be no more stressful than on-farm restraint for vaccination and eartagging. One must remember that cortisol is a time dependent measure. Twenty measures is required to reach peak value (Lay et al., 1992).

Causes of Poor Welfare Audit Scores

When an audit reveals poor performance, management must determine the exact cause of the problem. The correct diagnosis of problems can help avoid costly purchases of new equipment. Many managers have a tendency to assume that equipment may have to be replaced when a problem could be easily fixed without a major expense. The major causes of poor stunning and high percentages of vocalizing animals are listed below.

1. People using improper handling procedures. This is usually the number one problem. The author has observed that the two most common animal handling mistakes are overloading the crowd (forcing) pens and over use of electric prods. Pigs and cattle need room to turn. Crowd pens should be filled only half full. Moving small groups of pigs and cattle will facilitate handling. Sheep can be moved in larger groups because this species has more intense following behavior.
2. Distractions that cause balking and backing up – This is the second most common problem. All species of animals may balk and refuse to move when they see things in the race that scare them such as sparkling reflections, dangling chains, moving people or equipment, shadows or water dripping (Grandin 1996, 1998c). A calm animal will stop and look right at the distractions that scare it. You should crouch down and look up the race to see what the animals are seeing. It is important to get right down at the animal's eye level. Shields can be installed to prevent animals from seeing moving people or moving objects up ahead. One of the worst causes of balking is air blowing down the race into the faces of approaching animals. Animals also balk and may refuse to enter a dark place. They have a tendency to move from a darker place to a brighter place (Van Putton and Elshof, 1978; Grandin, 1982). Adding a light to illuminate a race entrance or moving a lamp to eliminate a sparkling reflection will often improve animal movement (Grandin, 1998e). Sometimes moving a ceiling light off the center line of a race will eliminate a sparkling reflection. If air is blowing towards the animals, the plant ventilation should be changed. Simple inexpensive changes can often greatly improve animal movement. People who are working to remove the distractions that impede animal movement must be very observant of small details that may be insignificant to them. A person may not notice a sparkling reflection, but the animal does. Animals should move through the system easily. If they balk or refuse to move forward, you should find the distraction that is causing balking instead of increasing electric goad usage. In the very best systems, 95% of the cattle could be moved through a slaughter line which processed over 200 cattle per hour without an electric prod. There will be more information on facilitating animal movement in the behavior and equipment design sections.
3. Equipment maintenance – Poor maintenance of captive bolt guns was the main cause of poor stunning (Grandin 1998a). Employees will become frustrated and will be more likely to handle animals in a rough manner if they have use broken or malfunctioning equipment.
4. Equipment design - Will be discussed in the equipment section (Grandin, 1991, 1990, 1984, 1992; Grandin 2000 www.grandin.com).
5. Excitable genetics or excessively wild animals – There are some animals which

have a very excitable temperament and are difficult to drive. Some lean pigs and cattle are very excitable (Grandin, 1991a; 2000). These animals will often have high vocalization scores. Hunter et al., (1994) have also observed that animals from certain farms are more difficult to drive. Plant management should work with producers to solve this problem. Pigs with excitable genetics will be easier to handle at the meat slaughter plant if producers have walked through the pens every day during the finishing period. Only 10 to 15 seconds per 50 pigs is needed. Such interaction trains excitable pigs to be more comfortable with human handling. Pigs which had been walked in the alley during finishing were less excitable and easier to handle (Grandin et al., 1991a; 1998c and Geverink et al., 1998). Producers should be encouraged to produce animals which will be reasonably easy to handle.

Another problem the author has observed are extremely wild cattle which become highly agitated and difficult to handle at a slaughter plant (Grandin and Deesing, 1998). This problem is caused by both genetics and previous experience with handling. Cattle with an excitable temperament which are raised on large pastures where they seldom see people should be exposed to people on foot, months before they arrive at a slaughter plant. The author has observed that cattle which have never seen a person on foot can be difficult and dangerous to handle at the slaughter plant. Ranchers should be encouraged to get their animals accustomed to people on foot.

Animal Vision, Hearing and Smell

Vision

Ruminant animals can discriminate between different colors (Arave, 1996). The latest research shows that sheep, goats and cattle are dicromats which means they may be partially color blind. The cones in the ruminant eye are most sensitive to yellowish green light (552 to 555 nm wavelength) and blue (444 to 455 nm)(Jacobs, et al., 1998). They lack cones which are maximally sensitive to the color red. Practical experience has shown that cattle and pigs are very sensitive to anything that has high contrast. This causes them to balk at drain grates or a change from a concrete to metal floor (Grandin, 2000, 1980, 1982). Lighting should be even and diffuse and harsh contrasts of light and dark should be avoided. Cattle and other grazing animals have wide angle vision and they can see in excess of 300 degrees (Prince, 1970). To prevent the animals from becoming scared of distractions outside the race, stunning boxes, races and crowd pens should have solid fences (Grandin, 2000). The crowd gate should also be solid.

Hearing

Cattle and sheep have very sensitive hearing. They are more sensitive to high frequency noise than people and they are especially sensitive to high frequency sound around 7000 to 8000 Hz (Ames, 1974). Cattle can easily hear up to 21,000 Hz (Algers, 1984) and there is also evidence that cattle have a lower hearing threshold than people (Heffner and Heffner, 1983). This could mean that sounds that may not bother people may hurt the animals ears. Intermittent noise is very aversive to pigs (Talling et al., 1998).

Reducing noise will improve animal movement. High-pitched noise is worse than low-pitched noise. Employees should not yell, whistle or make loud noises; clanging and banging equipment should be silenced by installing rubber stops and noisy air exhausts should be piped outside or silenced with inexpensive mufflers (muffling devices wear out and should be replaced every 6 months to keep noise levels low). Hissing air is one of the worse noises, but it is also the easiest to eliminate.

Yelling, screaming and whistling is aversive to livestock. Waynert et al. (1999) reported that the sound of people yelling was more stressful to cattle than the sound of a gate slamming. Pajor et al. (2000) also found that yelling is aversive to cattle. People handling animals should be quiet. Cattle that have an excitable temperament are more likely to flinch and react to sudden movements and intermittent high pitched noise than animals that have a calmer temperament (Lanier et al., 2000).

A high-pitched whine from a hydraulic pump or undersized plumbing is disturbing to animals and can make them balk. At one plant, installing larger-diameter plumbing to eliminate a high-pitched whine from a hydraulic system resulted in calmer, easier to move animals. In another plant, excessive noise from ventilation fans made pigs balk. Noise from the fans increased as the pigs approached the restrainer.

Noise increases physiological stress levels. Slaughter in a quiet research abattoir resulted in lower cortisol levels compared to slaughter in a large noisy commercial plant (Pearson et al., 1977).

When new systems are built, there needs to be more emphasis on noise reduction. Recently, the author visited an up-to-date pork slaughter plant. Over 800 pigs per hour were quietly moved through the plant with very little balking or backing up. The race system, overhead conveyors and restrainer system were engineered to reduce noise greatly. Gates on the race had rubber pads to prevent clanging and banging; motors and conveyors were designed to reduce high-pitched noise. Well trained handlers quietly moved the pigs up the race with very little squealing.

The type of building used in the animal handling area will also influence sound levels. Buildings constructed from pre-cast concrete with a high ceiling will have higher sound levels due to echoes than a building constructed from cooler board panels which have foam insulation sandwiches between two pieces of metal. Lowering the ceiling can sometimes help reduce sound levels. Hanging baffles from the ceiling may also help.

Smell

Many people interested in the welfare of livestock are concerned about animals seeing or smelling blood. Cattle will balk and sniff spots of blood on the floor (Grandin, 1980); washing blood off facilitates movement. Balking may be a reaction to novelty. A piece of paper thrown in the race or stunning box elicits a similar response. Cattle will balk and sometimes refuse to enter a stunning box or restrainer if the ventilation system blows blood smells into their faces at the stunning box entrance. They will enter more easily of an exhaust fan is used to create a localized zone of negative air pressure. This will suck smells away from cattle as they approach the stunning box entrance.

Observations in Kosher slaughter plants indicate that cattle will readily walk into a restraining box which is covered with blood. In Jewish ritual (Kosher) slaughter, the throat of a fully conscious animal is cut with a razor sharp knife. The cattle will calmly place their heads into the head restraint device and some animals will lick blood or drink it. Kosher slaughter can proceed very calmly with a few signs of behavioural agitation if the restraining box is operated gently (Grandin, 1992). However, if an animal becomes very agitated and frenzied during restraint, subsequent animals often become agitated. An entire slaughter day can turn into a continuous chain reaction of excited animals. The next day after the equipment has been washed, the animals will be calm. The excited animals may be smelling an alarm pheromone from the blood of severely stressed cattle. Blood from relatively low-stressed cattle may have little effect. However, blood from severely stressed animals, which have shown signs of behavioural agitation for several minutes, may elicit a fear response. Eibl-Eibesfeldt (1970) observed that if a rat is killed instantly in a trap, the trap can be used again. The trap will be ineffective if it injures and fails to kill instantly.

Research with rats support this idea. Rats showed a fear response to the blood of rats and mice that had been killed with carbon dioxide (Steven and Gerzog-Thomas, 1977; Stevens and Sapiloski, 1973).

Recent research with pigs and cattle indicates that stress pheromones are secreted in the saliva and urine. Vieville-Thomas and Signoret (1992) and Boissey et. Al. (1998) both report that pigs and cattle tend to avoid objects or places which have urine on them from a stressed animal. This stress response is not instantaneous. The stressor was applied for 15 to 20 minutes to induce the effect. In the cattle experiment, cattle were given repeated shocks during a 15 minute period.

Basic Handling Principles

The first principle of animal handling is to avoid getting the animal excited. It takes up to 30 minutes for an animal to calm down and have its heart rate return to normal after it has been handled roughly (Stermer et al., 1981). Calm animals move more easily and they are less likely to bunch together and be difficult to remove from a pen (Grandin, 1998e). Handlers should move with slow deliberate movement and refrain from yelling.

All species become agitated when they are isolated form other animals. In sheep and cattle, isolation can cause cortisol levels to rise (Boissy and Boissou, 1995). Cattle, elk, bison and other large animals can be become agitated and very dangerous when isolated. If an isolated animal becomes agitated, other animals should be put in with it. Electric goads should be replaced as much as possible with other driving aids such as flags, panels and plastic bags. A piece of plastic fabric which is stiffened on the top with a rod makes a good tool for moving pigs down an alley. Electric goads should not be constantly carried around. A flag or other aid should be used as the primary driving tool. If an animal refuses to enter the stun box, the electric goad can be used. After use, it should be immediately put back down. I have observed that employee attitudes and behavior become more caring towards the animals when they were not allowed to constantly hold an electric goad.

Handlers also need to learn how to use the following behavior. The crowd pen should not be filled until there is room in the single file race for the animals to enter. If the single file race is full, animals in the crowd pen will turn around. Good handling requires paying attention to many small details of exactly how to do a procedure. The crowd pen and the alley that leads to it from the yard should be filled only half full.

Handlers must also be careful not to force animals with crowd gates. This is especially a problem with power crowd gates. If a system is designed and operated correctly, animals should walk up the race without being forcibly pushed. When animals are pushed up too tightly with a power crowd gate, handling becomes more difficult. Tightly packed animals are unable to turn around to enter the race.

Handler Movement Patterns

People who handle animals need to understand the principles of the flight zone and point of balance (Grandin 1987, 1998c). Handlers should work on the edge of the animal's flight zone. Flight zone size depends upon the wildness or tameness of the animal. A completely tame animal has no flight zone and may be difficult to drive. To make an animal move forward the handler must be behind the point of balance at the shoulder. To back it up he/she stands in front of the point of balance. Cattle, pigs or sheep will move forward in a race when a handler walks quickly past the animal in the opposite direction of desired movement. The handler must move quickly past the point of balance at the shoulder to induce the animal to move forward. The animal will not move forward until the handler passes the shoulder and reaches the hips.

Design of Handling Facilities

Non-Slip Flooring – A minimum essential for all species is non-slip flooring. Careful, quiet handling is impossible if animals slip or fall. Slipping in a cattle stunning box will cause animals to become agitated and difficult to stun. A grating constructed from 2 cm steel bars welded in a 30 cm x 30 cm grid will prevent slipping in high traffic areas where floors have become worn.

Pen Space – Stockyard or ante mortem pens must provide enough space. The American Meat Institute (1991a) has guidelines for minimum pen space requirements (Grandin, 1991a). Many countries have Codes of Practice which stipulate the amount of pen space required. A good rule of thumb is that there should be sufficient space for all the animals to lie down at once. In the United States, the Humane Slaughter Act of 1978 requires that all holding pens be equipped with water troughs or some other watering devices. In hot weather, pigs require additional space to prevent death losses due to heat stress.

Design of Races and Crowd Pens

Detailed information of race and crowd pen designs can be obtained in Grandin (1990, 1991a, 2000c, www.grandin.com). There are three major design mistakes which can make quiet, calm handling extremely difficult: a single-file race that is too wide, a race which appears as a dead end and a crowding pen on a ramp. Single-file races and stunning boxes must be narrow enough to prevent animals from turning around or becoming wedged beside each other. A cattle race should be 76 cm wide and races for pigs should have only 3 cm of clearance on each side of the largest pigs. For cattle, a curved race is more efficient (Grandin, 1991-2000c). Curved races work well because cattle entering the race cannot see people or other activity up ahead. However, a curved race must be laid out correctly. If it is bent too sharply at the junction between the single file race and the crowding pen, the animals may refuse to enter because the race entrance appears to be a dead end. Curved races must be laid out so that animals standing in the crowding-pen can see a minimum of three body lengths up the race before it turns. Grandin (1984, 1990, 1991a, 200b) illustrated correctly curved race layouts.

Another serious design mistake is to build a crowding pen on a ramp. In facilities where a ramp is required to reach the stunning box or restrainer, it should be located in the single-file race. Groups of animals in a crowding pen will tend to pile up on the back gate if the crowding pen is located on a ramp. Cattle and sheep will readily move up a ramp but pigs will move easier in a level system with no ramps. New pig handling facilities should be level.

Design and operation of restraint devices

If animals vocalize during handling, restraint or stunning they are being subjected to something that is aversive, vocalization scoring is one of the most important measures of animal distress.

In small plants with line speeds of under 240 pigs per hour, it was less stressful to electrically stun pigs with hand held tongs while they were standing in groups on the floor compared to moving them through a single file or double file race (Warriss et al., 1994). At higher speeds floor stunning with tongs tends to become rough and sloppy and a system which uses single file or double file races would be preferable for moving pigs to an electric stunner. Whereas cattle and sheep move easily through a single file race, pigs tend to be more difficult to drive. This is a species difference, cattle and sheep naturally move in single file whereas pigs do not. Cattle and sheep will move very easily and quietly through a well designed single file race. A new Danish system for CO_2 stunning has eliminated lining pigs up a single file race. Pigs are moved in small groups into the stunner. Pigs can be moved without electric goads in the system.

Design of animal restraint (holding) devices for both conventional slaughter where the animal in stunned and ritual slaughter are covered in detail in Grandin (1988, 1991ac, 1992, 1995, 2000d). The behavioral principles of low stress restraint are:

1. Animals should never be left in a stunning box or restraint device. Stun or ritually slaughter immediately after the animal enters.
2. Animals should enter the device easily. If they balk or back up, check for distractions discussed previously. A lamp can be used to illuminate the entrance. It must provide indirect lighting. Devices that are above the floor should have a false floor to prevent the entering animal from perceiving the visual cliff effect (Grandin 1991c). Ruminants can perceive depth (Lemon and Patterson, 1964).
3. Block the animal's vision so that they do not see people or suddenly moving objects. Install metal shields around the animal's head on box type restrainers. This is not necessary on conveyor restrainers. Block the animal's vision of an escape route until it is fully held in a restraint device (Grandin 1991d). This is especially important on restrainer conveyors. Cattle often become agitated in conveyor restrainers if they can see out from under the solid metal hold down cover before their back feet are off the entrance ramp. Extending the solid hold down cover which is over the animal's back on a conveyor restrainer will usually have a calming effect. Most cattle will ride quietly. Solid hold downs over the animal's back can also be beneficial for pigs on conveyor restrainers. The solid hold down should not touch the animal's back. It's purpose is to block vision and control what the animal sees.
4. Provide non-slip flooring in box-type retrainers and a non-slip cleated entrance ramp on conveyor restrainers. Animals tend to panic when they lose their footing.
5. Parts of a restraint device that press against the animal's body should move with slow steady motion. Sudden jerking motion excites animals. On existing equipment, install flow controls to provide smooth, steady movement of moving parts which press against the animal.
6. Use the concept of optimum pressure. The restraint device must apply sufficient pressure to provide the feeling of being held but excessive pressure that causes pain should be avoided. Install a pressure regular to reduce the maximum pressure that can be applied. Very little pressure is required to hold an animal if it is fully supposed by the device. If an animal bellows or squeals in direct response to the application of pressure, the pressure should be reduced.
7. A restraint device must either fully support an animal or have non-slip footing. Animals panic if they feel like they may fall. Restraint devices should hold fully sensible animals in a comfortable, upright position.
8. Equip restraint devices with controls that enable the operator to control the amount of pressure that is applied. Different sized animals may require differing amounts of pressure. Hydraulic or pneumatic systems should have controls which unable a cylinder on the device to be stopped in mid stroke.
9. Restraint devices should not have sharp edges that dig into an animal. Parts that contact the animal should have smooth, rounded surfaces and be designed so that uncomfortable pressure points are avoided.
10. The operator must be adequately trained and supervised. One big problem in many slaughter plants is that the people who handle and stun animals are the lowest paid in the plant. In England, their pay has been raised and people who stun animals must be licensed.
11. If a restrainer conveyor is mounted above the floor level, it must have a false floor to prevent the incoming animal from seeing the visual cliff effect (Grandin, 2000, 1991). Ruminants can perceive depth (Lemman and Patterson, 1964).

Conclusions

To maintain an adequate level of animal welfare requires constant auditing of handling and stunning to prevent people from becoming careless and sloppy. We manage what we measure. Economic incentives and accountability for losses such as bruises and PSE will also improve welfare. Grandin (1981) found that cattle sold liveweight where the slaughter plant paid for the bruises, had twice as many bruises as cattle sold in the carcass where the producer paid for bruises. Large supermarket and restaurant companies such as McDonald's have greatly improved welfare by requiring their suppliers to maintain high standards.

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Biotechnology of reproduction and farm animals welfare

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Introduction

Based on the progress in scientific knowledge of endocrinology, reproductive physiology, cell biology and embryology during the last fifty years new biotechniques have been developed for and introduced into animal breeding and husbandry. Among them are oestrussynchronisation/induction, artificial insemination, multiple ovulation induction and embryo transfer (MOET), in vitro embryo production (IVP) and cloning by nuclear transfer (NT). The aims of these reproductive technologies were initially to speed up the genetic improvements of farm animals by the increase of offspring of selected males and females and the reduction of the generation intervals. The technique of cloning by nuclear transfer is mainly applied for experimental purposes, with the prospect of a more practical implementation in the near future, with the aims of the enhancement of the uniformity of herds for an easier management or for the multiplication of transgenic animals after gene-targeting.

Parallel to these developments public concern about new biotechnologies has grown, and call now, anno 2000, scientists to account. Although concerns of the general public may be related to a variety of reasons (i.e.: fear for food quality, the aversion for the attidude of playing God, or the feeling that something happens which cannot be controlled and will lead to an unwanted society), an important part of societal concerns seems to involve questions about the welfare of the animals, even though solid information on the consequences of new biotechnologies for animal welfare is generally lacking. Also scientists directly involved in the development of new biotechnologies have recognized the importance of animal welfare, but, perhaps understandably, their prime concern is technological progress. Thus, animal welfare is often treated as an ethical or public perception issue rather than as a biological one, and, so far, scientist in the field of farm animal biotechnology generally fail to specify concrete steps to monitor and prevent possibly adverse effects of the treatments imposed.

In this paper we evaluate the subsequent technologies and judge them on their effects on animal welfare by use of biologically measurable parameters. We argue that the welfare of farm animals requires special attention. We would like to suggest that the introduction of new biotechniques into farm animal husbandry should be accompanied by a study of health and welfare with the help of a comprehensive welfare protocol for the benefit of a sustainable animal production.

In this paper, we provide evidence demonstrating that new biotechnologies may have profound and negative effects on essential biological functions and systems in the animals involved, and, hence, may detrimentally affect animal welfare. Therefore, we argue that within the context of farm animal biotechnologies, animal welfare should receive special attention. We would like to suggest that the introduction of new biotechnologies into farm animal husbandry should be accompanied by systematic and scientifically valid studies into the effects on animal welfare, with the help of a comprehensive welfare protocol.

Sustainable production

Incompatible with sustainable production is in our opinion each situation in which the animal cannot reproduce anymore without help of one of the modern techniques. Since the new techniques are aimed to accelerate the selection for some traits, the results of a particular breeding programme can be incompatible with sustainable production. For example, the selection of turkeys for meet production has lead to large and overweighted cocks in such a way that fertilisation of the hens can only be done by A.I.. The double muscled belgium blue cows cannot reproduce without the help of the caesarian section. Transfer of embryos of meat cows into dairy cows may lead to more dystocia, etc. Not the techniques themselves are by definition incompatible with animal welfare but the goals for what these techniques are used.

Incompatible with sustainable production is also the situation in which the public concerns about animal welfare in connection with the modern reproductive biotechnologies leads to abjuration of the farm products.

Artificial insemination

The most universally adopted (zoo)technique in cattle seems to trigger little concerns. Nobody has thought that A.I. may already be deviated from the natural situation. However, palpation of the genital tract per rectum as well as the artificial insemination into the uterine cavity cause an increase in plasma cortisol levels as demonstrated by Nakao et al.,

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(1994). When genetically valuable bulls will not mount on a dummy or on living animals (lack of libido) they often are subjected to electrostimulation to induce an ejaculation. This procedure leads to a strong release of ACTH, followed by a rise in cortisol levels (Colenbrander et al., personal communication). The question can be raised whether a rising cortisol level is an indication of stress and seriously affected welfare. But in many other species of small farm animals including sheep, there is a trend towards the use of more invasive insemination procedures, like intrauterine insemination via laparoscopy or laparotomy with minimal anaesthesia. It is argued by breeder organisations that with experienced operators the stress is minimal. They found little evidence that a single laparoscopic procedure affects stress sensitive physiological events like the timing of ovulation (Walker et al., 1986). Notwithstanding these opinions, objective measurements have to be developed to judge the degree of stress.

Oestrussynchronisation and oestrusinduction

Oestrussynchronisation has been developed in the early sixties of the last century. It started with methods based on the artificial replacement of a corpus luteum by progestagens. Withdrawal of the progestagen device, either a sponge (sheep), a PRID or ear implant (cattle) at one moment for the whole herd resulted in the synchronous oestrus. The techniques were aimed to help a large scaled introduction of A.I. in the sheep industry and in the extensive beef industry. The fertility of the herd in the synchronized oestrus was compromised and lowered by 10 to 15%. Research to understand what was going on revealed that synchronisation of the oestrus does not mean a concurrently synchronisation of the genital tract (Kruip 1972; 1973). The results lead to the assumption that 15% reduction of the fertility is due to low fertilisation during the synchronised oestrus and/or early embryonic death. Whether this is compatible with animal welfare and sustainable production has to be discussed. Till the moment that cryopreservation of embryos was introduced, the oestrus synchronisation was used in embryo transfer for the synchronisation of donors and recipients. Oestrusinduction is based mainly on the same treatments with the same drugs. In many cases it will be used as a medication of animals suffering of sub- or even anoestrus. But even then one should asked whether that treatment is more or less a symptom contest.

Multiple ovulation and embryo transfer

Both multiple ovulation induction and embryo transfer are generally accepted technologies. However, the transfer of embryos after multiple ovulation has given increase in embryonic death, larger calves with longer gestation times, and more dystocia (van Wagtendonk-de Leeuw et al. 2000).

Although, at present, the mechanisms underlying these effects are unknown, multiple ovulation induction has been found to be associated with a number of disturbances which might be linked to these abnormalities. Firstly, multiple ovulation induction can lead to an asynchrony in the development of the preovulatory follicle and the meiotic process of the oocyte (deLoos 1992; Hyttel et al. 1986). Secondly, the growth of a cohort follicles results in abnormally high oestradiol-17b (E2) before and in high progesterone (P4) levels after ovulation, respectively. It has been demonstrated that high levels of E2 affect the microtubular organisation, meiosis and extrusion of polar bodies (Kruip et al. 1988). Earlier and higher P4 levels may affect the uterine environment and result in asynchrony between the developmental stage of the embryo and the uterine environment at the moment of transfer. P4 treatment during the first 3 days of pregnancy has been shown to promote the development of advanced embryos in the uterus (Wilmut et al. 1981; Klemann et al.1994). Transfer of advanced embryos, i.e. longer embryos with more cells, increases the rate of abnormalities in resulting calves (Lazzari et al., personal communication). Moreover, in a study of Dorland et al. (1993), a high percentages of mixoploid embryos was detected, as well as one totally haploid and one completely triploid embryo, after superovulation. These abnormal configurations of nuclear chromosomes cannot be detected by examining the morphology of the embryos. The embryos look good and will be transfered. According to Karwasky et al. (1996), 27- 45% of the embryos after multiple ovulation induction have an abnormal karyogram and are expected to die shortly before or after attachment.

The welfare of oocyte/embryo donors and recipients

In addition to well-documented and clearly undesirable side-effects on the offspring, it is conceivable that MOET, IVP and NT, may also negatively affect the welfare of the oocyte donor or the recipients of embryos. An obvious source for reduced welfare of the recipients of transfered embryos is the enhanced probability of dystocia after MOET, IVP and NT.

It might be speculated that, because of a considerable increase of the size of the ovaries, multiple ovulation induction in cattle is associated with pain, especially during manual palpation. Although the needle puncture through the vaginal wall of the oocyte donor is invasive, repeated puncture for OPU was not accompanied by adhesions or any pathological changes in the tissue (Kruip et al.1994).

An other question is whether the flushing of the uterus is always without any measurable negative effect? For the large species like cattle and horse the flushing can be done non-surgically, but for other species like sheep and goats, the collection of embryos has to be done surgically. In the pig, embryo collection can only be performed after surgical shortening of the uterus. Those animals can not reproduce anymore naturally. In the face of these facts, published data on negative effects on animal welfare in this particular situations are currently lacking.

Ovum Pick-up & Embryo production in vitro

A very good alternative for superovulation induction and embryo flushing is the recently developed series of technologies like non-surgical transvaginal ultrasound guided ovum pick-up (OPU) followed by in vitro maturation (IVM) and fertilisation (IVF) and embryo culture (IVC) up to the blastocyst stage (Pieterse et al. 1988; Kruip et al. 1991; Kruip et al. 1994).

There is a large body of evidence demonstrating that, in comparison with in vivo produced controls, the size and weight of IVP calves is higher (30% over 50 kg), the gestation time of IVP calves longer, the % dystocia and the incidence of caesarean sections is much higher as well as the % abortions and perinatal death (Behboodi et al., 1995; Kruip and DenDaas 1997; Van Wagtendonk-de Leeuw et al.1998; 2000). In general the calves are less active and vital (Reinders et al. 1995). In addition, the % of hydroallantois and congenital malformations, including abnormal limbs and spinal cords, is increased in IVP calves and lambs. Taken together, these problems are defined as the large offspring syndrome (LOS)(Young et al., 1998). Farin & Farin (1995) and Sinclair et al. (1997) found a differential growth of different organs (liver, heart, kidneys and adrenal gland) after IVP. Postnatally some IVP calves have obvious anomalies (deRoos et al. 2000).

Epidemiological studies in humans provided evidence for the association between prenatal life and adult diseases or susceptibility to diseases (Barker 1995). Why should that be different in animals. Birth weight is one of the first parameters to pay attention to for the judgement of normal development. Although an embryo/fetus will develop according to its genome, the activity of the genome can be influenced epigenetically by environmental factors. Along that way the lifetime, the health of organs, malformations and anomalies, abnormal karyograms, gestation length, birth weight and neonatal problems can be introduced. Most of them by inproper differentiation of the mesoderm, ectoderm and entoderm. One can suggest that these differentiation, driven by the expression of developmentally important genes, should have been programmed already in the ovary in the oocyte or in the genital tract or in culture in the embryo. This programming occurs on special critical periods of embryogenesis (Wilson et al. 1995). Changes in the timing of the expression of these genes induce malformations later in development and might explain some birth defects. Good examples of these are the HOX genes. Many data are available to support the relevance of this statement (Boerjan et al. 2000). Compaction and blastulation are affected by culture conditions. The same can be said about the differentiation of the inner cell mass. Differentiation means onset of gene expression. Recent studies have collected good data to support this concept (Wrenzicky et al. 2000; Young et al. 2000) of disturbed gene expressions. Special genes that are affected by culture conditions are the imprinted genes (Young 2000). Demethylation of the IGF2rec gene in in vitro produced mice embryos lead to abnormalities like oversized offspring (Lau et al. 1997).

The most important question is now: how can the IVP culture protocol or transfer protocols affect the molecular and morphogenetic processes govering the phylotypic period? The hypothesis and possible answer is: “Just by inadequate conditions either in the culture or later in the uterine environment” as pronounced by many speakers during the IETS satellite symposium “Embryonic origin of animal health and welfare” (Dieleman et al. 2000). IVP embryos misses in their first cleavages obviously the interaction with the mother or comparable environment. Serum seems to be one factor that has this effect on the genome or on the mitochondria, changing the intra cellular metabolism.

The use of immature oocytes coming from atretic follicles might be an other reason for the problems observed sofar. It has been speculate (Kruip et al. 2000) that the imprinting is lost due to atresia of the follicle or during the maturation in vitro. If true, the selection of COCs is for that reason very important to avoid or to reduce the % problems. In fact, the selection of the COC is the first act that should and can be controlled much better in order to prevent problems as LOS.

Cloning by nuclear transfer

Similar to MOET and IVP, NT has also been shown to induce LOS symptoms in resulting offspring, including high rates of peri- and postnatal death (Willadsen 1991; Garry et al. 1996; Kato et al. 1998; Chavatte-Palmer et al. 2000; McCreath et al. 2000). The occurrence of LOS symptoms after NT may be related to in vitro embryo manipulations also used in MOET and IVP, for example IVC or embryo transfer, but also to factors specifically associated with NT. Firstly, donor nuclei transferred to enucleated oocytes have to go through the process of genetic reprogramming, which is the transformation from the pattern of gene expression that is characteristic of the donor cell to one that is appropriate for early embryonic development. This process may be incomplete and result in inappropriate patterns of gene expression. Secondly, NT involves the exposure of reconstructed oocytes to various environmental stimuli intended to facilitate fusion between nucleus and recipient cytoplasm, for example electric shock or treatment with protein inhibitors (Brower 1998; Campbell 1999; Colman 1998; 2000). Such stimuli may disrupt epigenetic modifications of imprinted genes. The relative contributions of in vitro embryo culture or nuclear transfer to the induction of abnormality remain to be determined (Wilmut et al. 1998; Hill et al. 1999; Young and Fairburn 2000). Theoretically, any procedure at any stage of the sequential process of in vitro embryo production and manipulation (e.g., in vitro maturation of oocytes or in vitro fertilization) may influence embryo development and characteristics of offspring (Van Wagtendonk-de Leeuw et al. 2000).

Welfare protocol

We conclude that there are convincing arguments to support the idea that treatments, applied in farm animal biotechnology, in their effects on animal welfare are by no means biologically neutral. On the contrary, several treatments appear to directly threaten the animal's pre- and postnatal survival. Therefore, we believe that within the context of farm animal biotechnologies, animal welfare should receive special attention.

We propose to systematically monitor welfare of animals involved in, or produced by, new biotechnologies, and to evaluate potential risks of these technologies, on the basis of a comprehensive welfare protocol. This protocol would have to specify: 1) which treatment groups to compare, and the number of subjects needed, 2) which parameters to monitor, and 3) at which stages of farm animal's life. Although a (limited) number of studies specifically addressing side-effects of in vitro reproductive technologies or transgenesis have been reported (Walker et al. 1996; Van Reenen and Blokhuis 1997; De Sousa et al. 2000), currently such a welfare protocol does not exist. Some initial ideas are considered below.

Ad 1) One of the main goals of the implementation of a welfare protocol would be the accurate and unbiased estimation of the essential treatment effects, i.e. of MOET, IVP or NT. An essential condition in this respect would be the inclusion of adequate control groups, in sufficient numbers, e.g.: in vivo produced offspring with the same genetic background as the in vitro produced treatment group. With respect to the evaluation of effects of NT, the experimental design should allow for separating effects of inadequate reprogramming of the transferred nucleus/genome as much as possible from effects of reproductive technologies used in the process of generating cloned animals. This will require specific breeding steps (Smith et al. 1987; Gibson 1998).

The sensitivity of a welfare protocol in terms of the ability to detect relevant effects if they do exist, is greatly influenced by the number of animals investigated. It will be easy to reliably identify in vitro embryo manipulations with extremely unfavourable effects, but large numbers of animals will be needed to detect smaller, but still biologically relevant, harmful effects of nuclear transfer.

Ad 2) Relevant parameters and biological functions that are clearly associated with welfare are: clinical symptoms of health or disease, measures of growth and fertility, measures of immunoresistance and behavioural measures. Parameters for a welfare protocol could also be provided by immunotoxicological (Luster et al. 1994; Van Loveren et al. 1995, 1998) or pharmacological disciplines (Martinod 1995).

We propose to formulate, for each of the important livestock species involved infarm animal biotechnology, a basic set of welfare parameters, encompassing a cross-section of the most essential parameters and biological functions, the scope of which could then be adjusted, either extended or reduced, according to the specific properties of the treatment under observation. For example, in a study on the welfare of offspring of a transgenic bull carrying a human lactoferrin transgene designed to express in udder tissue of lactating transgenic females, next to parameters concerning growth, general health, behaviour, reproduction and immunocompetence, specific measures on milk production, characteristics of milk and udder health were included in the protocol (Van Reenen and Blokhuis, 1973;1997). Protocols used for the evaluation of in vitro reproductive technologies should involve observations appropriate for detecting LOS symptoms, such as specific measures of neonatal vitality and viability, or ultrasound measurements to investigate disproportionate organ development (Garry et al. 1996; Van Wagtendonk-de Leeuw et al. 2000). In addition to these parameters some molecular biological indices should be incorporated in the protocol, especially those that would enable to assess and reduce the risks of impaired welfare. A promising concept considers gene expression profiles in preimplantation embryos of imprinted genes (Niemann and Wrenzycki 2000).

3) Stages of life. The stages of life of a farm animal at which to monitor welfare aspects should, in our view, at least include: (a) gestation and birth, (b) the developmental phase from birth to puberty, and (c) a representative period of adult life, including the stage of (re)productive performance. Investigations up to senescence could have scientific value, but need not necessarily be relevant for all farm animals since their productive lives usually represent only part of the entire possible life-span.

Conclusion

MOET, including synchronisation and induction of oestrus and AI, as well as IVP, NT may have undesirable and sometimes serious consequences for farm animal welfare. We suggest that (potential) risks of biotechnologies for farm animal welfare should be comprehensively and systematically assessed. This type of research should be multidisciplinary, should be logically integrated into ongoing research programmes, and and should make use of appropriate and scientifically valid experimental designs and protocols. Results obtained accordingly allow for developing and using the safest biotechnological methods and procedures, and, thereby, enable technological progress which is ethically justified, and beneficial for socieity in general as well as the scientific and agricultural community.

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Does present legislation help animal welfare?

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1. Sustainability, welfare and health

There are several possible reasons why an animal production system might not be sustainable. It could be because it involves so much depletion of a resource that this will become unavailable to the system. It could be because a product of the system accumulates to a degree which prevents the functioning of the system. However, in each of these cases, and in the case of some other aspects of systems, the earliest effect which renders the system unsustainable is one which impinges upon the general public's values in a way which the members of the public find unacceptable. Where there is depletion of a resource or accumulation of a product, the level at which this is unacceptable, and hence the point at which the system is unsustainable, is usually considerably lower than that at which the production system itself fails. Unacceptability is often due to effects on other systems.

One major reason why animal production systems may be regarded by the public as unacceptable and hence become unsustainable without some modification, is that the product adversely affects human health, whilst another reason is their effect on the welfare of animals which are used in the production system. There is a point at which the welfare of the animals is so poor that the majority of the public consider the system to be unacceptable. Hence animal welfare and public attitudes to it must be considered wherever the sustainability of an animal production system is evaluated.

The terms "health" and "welfare" overlap in that health is an important part of welfare. The welfare of an animal is its state as regards its attempts to cope with its environment (Broom, 1986). Hence welfare is a characteristic of an individual animal and includes extent of success in coping with all aspects of its environment, failure to cope which may lead to disease, injury and death, and extent of difficulty in coping. The mechanisms for trying to cope include behaviour, physiological systems, immunological systems, a range of feelings such as pain, fear and various forms of pleasure, etc. Health is that part of welfare which concerns coping with pathogens and pathology. Welfare varies on a scale from very good to very poor and can be assessed scientifically, an adequate range of measures being needed (Broom 1991, 1996, 1998, Fraser and Broom 1990, Broom and Johnson 1993). Health also varies from good to poor. Good health involves absence of pathological effects whilst good welfare involves absence of indications of poor welfare, including those of pathology and disease, and indications of contentment, pleasure and happiness. Animal welfare science has developed rapidly in recent years.

Both poor health and other aspects of poor welfare can have economic aspects. Farm animal disease can cause great economic problems and a few farm animal diseases pose a risk for human health. Poor welfare which does not involve poor health can result in reduced survival of young animals, failure to conceive or successfully give birth, impaired growth or impaired production of milk or eggs. Farm animal welfare is therefore a matter of public concern (a) for its own sake, in that people consider that they have moral obligations to animals, (b) because of effects on costs of food and other animal products and (c) because of effects on human welfare. The animal health component of welfare contributes to each of these. The very substantial effects of farm animal health on economics of production and the recent increase in concern about moral obligations to animals have been reasons why animal health has been thought of as a separate subject from animal welfare but it is logically and scientifically incorrect to speak of health as distinct from welfare.

2. Factors which affect the welfare of farm animals

Legislation has effects on how people house and manage animals but several other factors also affect this. Codes of practice produced by governments, the animal production industry, or companies which purchase the products from farmers and sell them to the public have an effect. So too do other factors which help to form the attitudes of the people who construct animal accommodation, own animals, manage units, care for animals on a day to day basis, transport animals, handle animals in markets, or slaughter animals. Each of these kinds of influence on the treatment of animals, and hence on their welfare, will be considered together with the consequences of efforts to make animal production more economically efficient and the impact of international trade agreements.

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2.1 Legislation and the extent to which it is enforced

Legislation is generally initiated by pressure from voters on elected politicians. The politicians would usually seek advice from civil servants before formulating new legislation. In recent years, whenever any legislation on animal welfare is proposed, advice is sought from committees or working groups of scientists. The non-government organisations who lobby the politicians, whether they are producers' organisations or animal protection organisations, will have some access to scientific advice so it is important for the legislators to know the latest state of scientific knowledge on the subject. As a consequence, the European Union has set up, via the European Commission, scientific committees on a range of subjects.

Table 1. Some E.U. Directives and Regulations relevant to animal welfare: 1. farm animals

•	98/58 (20/7/98)	Concerning the protection of animals kept for farming purposes
•	74/577	Stunning before slaughter
	93/119 (22/12/93)	On the protection of animals at the time of slaughter or killing
•	86/113 88/166 (7/3/88)	Laying down minimum standards for the protection of laying hens kept in battery cages
	99/74 (16/7/99)	Laying down minimum standards for the protection of laying hens
	Regulation 1906/90 (22/6/90) 1907/90 (26/6/90) 1538/91 (5/6/91)	Marketing standards for eggs
•	91/629 (19/11/91) (24/2/97 annex amended) 97/2 (2/1/97)	Laying down minimum standards for the protection of calves
•	91/630 (19/11/91)	Laying down minimum standards for the protection of pigs
•	90/425 91/496 91/628 (19/11/91) 95/29 (29/6/95)	Concerning the protection of animals during transport
	Regulation 1255/97 (25/6/97)	Concerning staging points and amending the route plan
	Regulation 411/98 (16/2/98)	On additional animal protection standards applicable to road vehicles used for the carriage of livestock on journeys exceeding eight hours

Table 2. Some E.U. Directives and Regulations relevant to animal welfare: 2. animals other than farm animals

•	78/1027	Veterinary training
•	79/409 (2/4/79) 97/49 (29/7/97)	On the conservation of wild birds
	Regulation 3626/82	Wild animals
	83/129	Seal skins
	Regulation 3254/91 (4/11/91)	Prohibiting the use of leghold traps (imports: humane trapping standards)
	Regulation 338/97 (9/12/96)	On the protection of species of wild fauna and flora by regulating trade therein
•	86/609 (24/11/86)	The protection of animals used for experimental and other scientific purposes
	88/320 (9/6/88) 99/12 (8/3/99)	Inspection and verification of good laboratory practice
•	99/22 (29/3/99)	Relating to the keeping of wild animals in zoos

The former committee was the Scientific Veterinary Committee, Animal Welfare Section. The present committee is the Scientific Committee on Animal Health and Animal Welfare. There are also various national scientific, or scientific and ethical committees. Indeed the subject matter of much of the possible legislation on farm animal welfare is so complex that it would be most unwise to proceed with it without expert advice. Some E.U. Directives and Regulations are listed in Tables 1 and 2.

Legislation within European countries and E.U. Directives and Regulations have usually been preceded by Recommendations from Council of Europe committees. The committees have representatives from all European countries and observers from non-european countries, the European Confederation of Agriculture, animal protection societies and the International Society for Applied Ethology which provides scientific advice. In addition to ad hoc committees on Conventions on slaughter, transport, laboratory animals and companion animals there has been for 25 years the Standing Committee of the European Convention on the Protection of Animals Kept for Farming Purposes. This last Committee has produced Recommendations on: poultry kept for egg production, pigs, cattle, fur animals, sheep, goats, chickens kept for meat production and ducks. The information in the Convention and Recommendations has formed the basis for legislation and codes of practice in many countries.

The actual effect of legislation on the welfare of animals depends upon the responses of those owning and managing the animals. This response, in turn, depends upon the nature of any enforcement. Some systems for farm animal production will not continue if they are made illegal because they depend upon large manufacturers who are easily forced to change to a legal system. Other aspects of legislation can be enforced only by checks on farm, transport vehicles, markets, slaughterhouses etc. and the extent of law-breaking will be significantly affected by the frequency and quality of the checks. For many transgressions, unannounced inspections are necessary if transgressors are to be discovered. There are regional and national differences in the extent to which legislation is viewed seriously by those involved in the animal production business. The general direction of movement within the European Union in this respect is towards better enforcement in all member states because it is manifestly unfair for there to be significant differences in the extent of compliance with the laws.

2.2. Government-produced codes of practice

Guides to how particular farm animals should be housed, and managed and guides to procedures during transport, in slaughter houses or in relation to particular farm emergencies such as fire or to diseases are produced by some governments. These have a considerable educational value provided that they are made available to people carrying out the relevant work and that they are read. In some countries such codes of practice have a legal status in that they can be referred to in situations where there is a question as to whether a generally-worded law is being broken. However, aspects of codes of practice are sometimes widely ignored by the animal production industry. For example, a statement about maximum stocking density in the production of turkeys or chickens reared for meat may be ignored by the majority of producers during the latter stages of rearing. If there is no enforcement of the statements in the code of practice, or if there is ambiguity about the legal status of the code, its value is greatly diminished. The effect on the welfare of animals may then be very little. The public opinion about the value of a code of practice will be greatly affected by information about its effectiveness. The government department itself is devalued in the eyes of the public if it is perceived that a code is ineffectual in important respects.

2.3. Production-industry-derived codes of practice

There can be important improvements in the welfare of farm animals if good codes of practice are devised by the industry and implemented by the majority of farmers, transporters, slaughterhouses, etc. The public image of the industry can be substantially improved and the sales of products maintained or increased if it is perceived by the public that standards are good and are observed. However, in most countries, at present the public has insufficient trust in the animal production industry to take the word of producers that standards are observed. Some independent checking is needed.

2.4. Retailer-produced codes of practice

Farmers often sell animals or their production of milk, eggs etc. to single purchasers who represent large retail chains or wholesale distribution companies. The increase in direct selling to supermarket chains has led to considerable power being placed in the hands of these supermarket companies. It is possible for these purchasers to lay down conditions for animal production and to enforce these by inspection. The standards set by the supermarket chains are determined by what people will buy and by their reputation with the public.

The public image of large companies which retail food, including supermarket chains and fast-food companies, is of great importance to them. Bad publicity because of a risk to public health, a risk to the environment or the occurrence of poor welfare at any stage of the production process can be very damaging. Hence it is in the interest of such food companies to avoid any scandal which might threaten their good image. When these companies receive many letters from consumers complaining about a product which they sell, they have to take notice of the points which are being made.

As a consequence of consumer pressure, food retail companies are adopting standards which they impose on their suppliers. In some cases, these standards are quite simple, for example Albert Hein in the Netherlands and elsewhere limited their sales of eggs to "scharreleie" which meant that the hens were reared in conditions where they could scratch in litter. Marks and Spencer in the U.K. and elsewhere stopped selling eggs from battery cages. In other cases, elaborate standards have been described in detail and sent to suppliers. One of the first systematic attempts to provide comprehensive information about the conditions under which animals were kept in the course of food production was the "Freedom Foods" scheme run by the R.S.P.C.A. in the U.K. In this scheme, the standards for housing and management have been set by a widely respected animal protection society and farms are inspected by Freedom Foods staff. Retailers who subscribe to the scheme are allowed to use the Freedom Foods logo which is accepted as honest by the purchasing public. Acceptance, by the public, of products which are produced in such a way that the welfare of the animals is good, depends upon trust in the organisation which is carrying out the labelling and inspection. Some large supermarket chains and other food retailers are trusted because it is thought that they could not afford to be found out if they were not labelling and policing adequately. Animal protection groups are trusted in this respect and their label is a valuable asset for some retail companies. A recent development in this area is the announcement by MacDonalds fast-food chain in the U.S.A. of standards for the welfare of hens which produce their eggs, including increased space allowance and the banning of forced moulting.

The enforcement of standards by food retailers has led to substantial changes in the welfare of animals on farms because every producer has to conform to the standards in order to sell their products. The rapid development of such schemes in several countries has, in general, been based on scientific evidence about animal welfare. The retail food chains started to seek the advice of independent scientists in order to be able to reply to customers' questions. They subsequently sought such advice, or employed scientists or veterinary surgeons with extra qualifications in animal welfare, when setting up their animal welfare standards. Since the standards themselves are open to public scrutiny and those scrutinising can have expert scientific advice, most of the standards are soundly based.

2.5. Effects of builders and designers of animal facilities and equipment

It is the people who design and build farm animal facilities and the people who own, manage and work on farms, transport operations and slaughterhouses who have the principal effects on animal welfare. The actions of these people may depend to some extent on expert advice, for example that of veterinary surgeons.

The architects, builders and equipment companies who provide accommodation and other facilities for those in the food animal production industry, depend upon their customers in the sense that their products would not be bought if they were not economically viable but they also have freedom to be innovative and they are perceived by the public and the farmers to have moral obligations to animals similar to those of the farmers themselves. Some of these moral pressures are not as immediate, however, so these companies are not always ready to acknowledge their responsibilities.

Table 3 - Evidence for increased concern about animal welfare.

1.	Letters from the public, media coverage.
2.	References in parliamentary discussions and government statements.
3.	Requests for scientific evidence concerning animal welfare.
4.	Activity of scientific and other advisory committees.
5.	Funding of scientific research on animal welfare.
6.	Increased teaching and conferences.
7.	More legislation.

(from Broom 1999)

2.6. Attitudes of farmers, transporters, slaughterhouse staff etc.

Public concern about animal welfare has increased in many countries during the last thirty years and especially in the last ten years. Evidence of this is summarised in Table 3.

People who run or work on farms are influenced by a variety of factors when they are deciding on their housing and management policies and when they are executing these policies. They are involved in a commercial enterprise and will be endeavouring to make a profit so the monetary costs which they incur and the potential financial returns which they are likely to get for their product will be factors of major importance to them. Some other costs to the industry exist, for example, consumers who do not like some aspect of production may refuse to buy the product (Broom 1994). These costs are often ignored by individual farmers.

Attitudes of animal users depend upon early training, traditional practices, acquisition of knowledge from others subsequent to any training, personal experience and general beliefs and philosophy. Training did not, until recently, include much information about animal welfare except where it impinged on profitability. Even diseases were often mentioned in agriculture training only in relation to effects on growth, offspring production or product quantity and quality. Recent training courses are more likely to have included information about the welfare of the animals and most agricultural trade journals nowadays do cover animal welfare issues. Traditional practices are often deemed by farmers to be right for the sole reason that "this is the way that we have always done it". Some of these methods are the best ones for good welfare but in a time of changing attitudes to animals, such arguments are untenable.

Farmers and other animal users have to live with their families, friends and neighbours. If these people are critical of the effects on the welfare of animals of the methods used, the farmer may change these methods. In some cases, the animals are very obvious to all who pass by the farm. If a sheep or cattle farmer has many animals which are noticeably lame, there will be a considerable likelihood that someone will comment on this to the farmer. Farmers do not like to be thought incompetent or uncaring, so they may respond to such comments by giving the animals veterinary treatment or changing the management system so as to avoid lameness. If the animals are inside a building or otherwise hidden from public view, the number of people who might comment on poor welfare will be smaller and there is a greater chance that the farmer can persuade himself or herself that there are no significant welfare problems.

Meetings with others in the same business and trade magazines will tend to help farmers and others to arrive at common views about their various problems. A farmer who has to reconcile himself or herself to poor welfare in some animals will find it easier to do so with the support of others. Such influences will tend to slow down change towards better welfare in the animals if economic factors mitigate against such change.

The views of the general public are largely made known to farmers and others involved in animal production via the media. There is frequent coverage of animal welfare issues in newspapers, on radio and on the television and this, by bringing scientific knowledge about animal complexity to the attention of most people, affects the attitudes of people and then comes to represent it. Farmers see themselves portrayed as uncaring in some respects. They are unfairly portrayed on some occasions but other portrayals are correct and the farmer cannot hide from them by retreating physically into buildings and socially into a farming only society. When public demonstrations about animal welfare issues occur, farmers cannot ignore these. The demonstrations by great numbers of largely orderly and apparently normal people against the shipping of calves to conditions which were illegal within the United Kingdom, had a big influence on farmers and politicians alike. It is not the most vociferous people, who are sometimes rather extreme in their views, who have the greatest influence on animal users or politicians but the moderate people who represent a groundswell of public opinion. In many recent surveys in Europe, animal welfare has been shown to be an important issue for the general public. For example about three quarters of people questioned in France regarded animal welfare as a problem affecting their purchasing of veal or eggs (Ouedraogo 1998) and 34% of 420 schoolgirls questioned in Dublin stated that they avoided eating meat, principally (53%) for animal welfare rather than nutrition (29%) reasons (Ryan 1997)

2.7. Consequences of efforts to make animal production economically efficient

The improved nutrition of animals and the genetic selection of animals in order to increase rates of growth and to improve feed conversion efficiency have resulted in cheaper and more readily available animal products for consumers. This has been a great success story but continuing efforts in these directions have often not involved sufficient consideration of the adverse consequences for the animals. As has been pointed out (Broom 1994, Phillips 1997) continuing efforts to achieve earlier and faster growth, greater production per individual, efficient feed conversion and partitioning, and increased prolificacy are the causes of some of the worst animal welfare problems. To prevent these, in addition to housing systems and management methods, feeding systems and genetic selection need to be changed. The breeding companies have a very great effect on animal welfare. Especially in relation to broiler chickens, turkeys, pigs and dairy cattle, there are major problems such as lameness, ascites, inability to mate, other cardio-vascular disorders, mastitis and reproductive problems which are a direct consequence of breeding for high production. The direction of selection needs to be reversed, or at least causes of poor welfare need to be taken into account during selection, if animal welfare is not to get poorer and poorer.

Legislation against genetic selection of farm animals which frequently results in poor welfare exists in a few countries but should be passed in all countries. To some extent the standards set by retail companies can deal with the problem. These companies can insist on slower growth, less bodily distortion and eradication of undesirable, if profitable, traits. Farmers can also insist on more appropriate strains of animals when they buy from breeding companies.

2.8 International trade agreements

The European Union started as a trade agreement but now encompasses legislation which is in force in all member states. Some of this legislation has a moral basis, for example it prevents unreasonable exploitation of people, such as child labour, or it prevents poor welfare in farm animals. Although there is a general effort, within E.U. legislation, to prevent trade barriers within the E.U., for example in the for sale of animal products, this legislation has effects which are regarded as morally right by most citizens of E.U. member states.

Future improvements in farm animal welfare depend to some extent on world trade agreements. Poor welfare in animals must be regarded, in any such agreement, as a moral issue in relation to imports. It is intolerable to most civilised people that all countries must drop their standards to that of the lowest when a moral issue is at stake so all European countries should endeavour to insure that the next World Trade Organisation agreement, or the interpretation of the present one, is changed to include poor welfare in animals as a criterion for legislation which allows refusal of imports.

3. Conclusions

Animal welfare is one of the criteria which is used by the public when deciding whether an animal production system is acceptable, so it is a necessary consideration for sustainability. Animal welfare, of which animal health is an important part, can be scientifically assessed and is the subject of much public concern. The actions of farmers and other people involved in animal production in relation to animal welfare must be considered when asking how animal production is regulated. These actions are most affected by regulations imposed by those who purchase their products. The standards set by food retailers are having a considerable effect on the welfare of animals on farms. Secondly, animal welfare during animal production is affected by legislation but the extent of this effect depends upon the efficacy of enforcement and the general attitude to legislation. Thirdly, the knowledge of the individuals concerned in animal production and their philosophy in relation to animals will affect animal welfare. The actions of the farmers, transporters or slaughterhouse staff will also be affected by the attitudes of their family, friends, visitors, and colleagues and of the farming press and general media or other sources of information about public views. The breeding of animals, which causes significant and serious welfare problems, should be prevented by means of legislation although pressure from the purchasers of products may bring about some changes. There is an urgent need to change the present World Trade Organisation agreement so that animal welfare standards are allowed criteria for refusing imports.

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Farm animal welfare in an economic context

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1 Introduction

Consumers show a growing interest in the quality of agricultural products and the manner of production and distribution, including issues such as animal welfare, food safety and environmental pollution. Demands of this type refer to a large extent to the upstream farm stages of the so-called supply chain, requiring that those consumer preferences be incorporated in all stages involved. To anticipate this development, the potential structural and economic effects on the stages of the supply chain should be explored. Regarding product development policies, trade-offs have to be made between preferences and profitability. This paper elaborates on animal welfare in the pork chain, including the evaluation of its perception and economics.

To anticipate the concerns that are important regarding pig welfare and to evaluate the level of importance, one can consult scientific literature and pig welfare experts. However, product development strategies can only be successful if producers adopt a consumer-oriented approach, as the consumer ultimately decides what food products are bought (Steenkamp, 1987). Moreover, consumers may evaluate product attributes differently from experts (Kramer, 1990). While the mood of the general public is difficult to gauge, one indication is a proliferation of pressure groups dedicated to improving animal welfare. As some of these groups are known to carry on successful campaigns, they are assumed to both represent and influence the perception of various consumer groups. For this reason they may serve as indicators of public concerns. In this paper, conjoint analysis was used to study the evaluations of pig welfare experts and consumer-related respondents with respect to pig welfare (Green and Srinivasan, 1978).

To evaluate the economic impact of the pig welfare concerns, an economic pork chain simulation model was developed. The model includes a farrowing stage producing feeder pigs, a fattening stage producing fattened pigs, and a slaughtering stage. Also transportation between the stages was considered. Pig welfare evaluations and economic calculations, therefore, concerned sows, young piglets and pigs during the growing to finishing phase, during transportation and in the lairage room prior to slaughter. In using the pork chain model instead of models simulating the separate stages of the chain, interstage relations could also be taken into account.

However, in designing products differentiated on the basis of pig welfare, the pork product that satisfies the highest level of pig welfare is not the only point of interest, because that product concept may also be the most expensive one. Consumers may prefer a product with less additional pig welfare guarantee at a more favourable price. Therefore, it is important to explore how pig welfare perceptions and economics are balanced. Effects of requirements of pig welfare on structure, economics and stability of pork production-marketing chain concepts will reveal useful information on establishing pig welfare policies for both government and businesses. In this paper a dynamic linear programming model is presented which deals with these issues. The optimization model is used to evaluate the development of pork production-marketing chain concepts, in which additional costs to realize increasing levels of extra pig welfare in the pork chain are minimized.

2 Material and Methods

Based on scientific literature (e.g. Van Putten and Elshof, 1978; Sybesma, 1981; Gloor, 1988, Fraser and Broom, 1990), popular press papers, material published by animal welfare pressure groups (Anonymous, 1994), characteristics of pork products available in the marketplace (e.g. Anonymous, 1991), and consultation of experts, the pig welfare concept was subdivided into various underlying attributes along the pork supply chain. Consequently, attributes were subdivided into two or three levels. The values of attribute levels were based on literature or variation in characteristics of pork products in the marketplace. Regarding some attributes, however, quantified levels were lacking or vague.

The attributes selected were subdivided into two major groups, without the intention to base these categories on ethological grounds. One group concerned attributes related to social contacts with conspecifics or human beings, and the other involved attributes related to the surroundings of the pigs. Attributes in the ‘social contacts’ group included the mixing of socially unfamiliar animals, the weaning age of piglets and the way in which pigs are handled during transportation and in the slaughterhouse. Surroundings-related attributes involved the type of housing, the stock density in pens, lorries and lairage rooms, the availability of straw, roughage and outdoor space, illumination and ventilation devices, the slope of the (un)loading bridge and the use of water sprays in

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lairage. Providing more concrete floor space, straw as distraction, day-night rhythm of illumination and outdoor space are considered beneficial to the pig's welfare (e.g. Bäckström, 1973; Grandin, 1980; Sybesma, 1981; Vellenga et al., 1983; Fraser and Broom, 1990).

Conjoint analysis pursues to quantify and predict the respondent's overall judgement (e.g. on pig welfare) on the basis of the concept attributes. We used a fractional factorial designs, so only 8 orthogonal alternative combinations of these 7 uncorrelated attributes have to be evaluated to estimate main effects (Steenkamp, 1985). Ordinary least-squares (OLS) regression analysis is used to break down the respondent's overall judgements on the set of concept alternatives into the contribution of each attribute level. The contributions of the various attribute levels to the overall judgement are called part-worths, and are directly compatible with each other. The difference between the part-worths of the various levels of an attribute is equal to the regression coefficient. Besides such additive models, it is also possible to take potential interactions between attributes into account. In general, conjoint analysis offers the advantages of allowing for quantitative evaluation of subjective and differently-scaled attributes using only a limited number of alternative profiles, consideration of interactions and testing for consistency in the answers of the respondents (Hair et al., 1990, Green and Srinivasan, 1978). Compared to compositional methods such as direct questioning, conjoint analysis provides the advantage of higher realism because attributes are evaluated in combination with one another, as in the 'real world', instead of separately (Huber et al., 1993). Other advantages may refer to the absence of groups effects, reducing the likelihood of socially desired answers and probably being less time-consuming than repeated rounds of group- or individual elicitation procedures.

Per case, each profile had to be judged on an interval scale ranging from 0 to 100. Respectively 8 and 16 profiles per case were used to estimate the part-worths of the attribute levels, while the remaining 3 so-called 'hold-out' profiles served to test the predictive validity of the estimated models. The predictive validity indicates the fit of the estimated part-worths to the respondent's real values of the hold-out profiles and is assessed in terms of Pearson's product moment correlation coefficient (interval scaled data) and Kendall's rank correlation coefficient (hierarchically ranked data) (Siegel, 1956). Both coefficients also served as indicators of the internal validity of the models, i.e. the conformity between the input values of the 'non hold-out' profiles and the estimated values based on the assessed part-worths.

The economic effects of the pig welfare related attributes were calculated, using an economic pork-chain simulation model (for details see Den Ouden, 1996). The model was developed to simulate technical and economic performances in both individual stages and pork production-marketing chains as a whole, taking into account interstage relations between the various stages. Interstage relations are defined as the way in which the performance of a stage is influenced by the activities performed or affected in other stages of the chain. Examples of interstage relations include the relation between farm size and transportation efficiency and between the distribution of fattened pigs over live weight classes at the end of the fattening period and carcass quality and value in the slaughterhouse. Besides variables representing interstage relations, input and output variables are distinguished. They represent biological, technical and economic parameters.

3 Results

3.1 Estimated pig welfare contributions

Questionnaires were completed by 7 of the 11 respondents. The non-respondents involved one expert and three members of the consumer-related group. At the individual level, attribute importance weights were calculated to indicate the relative importance of each attribute per case (Cattin and Wittink, 1982). In Table 1 the three attributes with the highest average importance weights per case are presented.

The respondents showed a fairly high concordance with respect to the attributes they regarded as most important in each case. For example, in the farrowing case, the attribute 'individual or group housing of sows' was valued at the highest importance score by 6 out of 7 respondents. In general, social contacts related attributes, including the way of handling the pigs and whether or not unfamiliar pigs were mixed, were considered particularly important during transportation and prior to slaughtering. In the farrowing and especially in the fattening stage, the surroundings related attributes were considered most important.

The attributes presented in Table 2 are in order of decreasing chain pig welfare coefficients of the consumer-related respondent. The values of attribute levels that were quantified in open-end questions are also shown. In correspondence to the general perception (Table 1), both the consumer-related respondent and the expert regarded the fattening stage as most important with respect to the overall welfare of the pigs.

Both respondents favored especially the surroundings related attributes in this stage. On a scale from 0 to 100, the absolute total scores varied considerably, however (55.3 versus 35 respectively (Table 2)).

Individual differences concerned particularly the access to outdoor space. The consumer-related respondent appreciated this attribute more than the expert, who assigned, moreover, a lower pig welfare coefficient to a bigger amount of outdoor space per animal. The same contrast was shown for outdoor space in the farrowing case. Additionally, the consumer-related respondent considered an increase of the resting period from 2 to 4 hours non-beneficial to the welfare of the pigs, as can be seen from the negative coefficient in Table 2. Similar to the general perception, both the consumer-related respondent and the expert considered the social contacts related attributes the most important pig welfare ones in the transportation and slaughtering stages.

3.2 Static linear programming approach

The least-cost chain concepts of the static linear programming approach for different desirable levels of additional pig welfare are presented in Table 3 (placed at the end of the paper). Results are shown for additional pig welfare (Wtot) levels of 10, 20, 30, 50, 70 and the maximum level of 100 points. The total additional costs incurred are expressed per pig from farrowing to slaughtering. When an improvement in additional pig welfare (Wtot) of at least 10 points was the consumer-related respondent versus a level of 70 in the case of the expert.

Table 1 The three pig welfare related attributes per case with the highest average importance weights.

Farrowing	Importance weight	Fattening	Importance weight
1. Housing non-lactating sows	31.6	1. Supply of straw	24.2
2. Mixing of unfamiliar pigs	17.1	2. Total:concrete space	21.0
3. Weaning age	12.2	3. Illumination	19.1
Transportation	**Importance weight**	**Slaughtering**	**Importance weight**
1. Handling	30.2	1. Handling	26.9
2. Mixing of unfamiliar pigs	19.9	2. Mixing unfamiliar pigs	21.2
3. Stock density	17.4	3. Water spraying lairage	13.7

3.3 Dynamic linear programming approach

When comparing the values of the attributes of the optimal chain concepts at the various Wtot levels in Table 3, it can be seen that some attributes decreased or were excluded from the chain concept at a higher Wtot required, the coefficients of the consumer-related respondent resulted in an optimal chain concept incurring Dfl. 0.19 higher costs per pig (Table 3) than in the default situation, i.e. Dfl. 357 per pig from the farrowing to the slaughtering stage. Seven attributes were incorporated into this optimal concept ranging from ‘not keeping pigs at the slaughterhouse overnight’, ‘reducing the stock density in the slaughterhouse lairage rooms from 300 to 235 kilograms of live weight per m^2’ to ‘increasing concrete floor space in nursery pens by 1.35 m^2’ (Table 3). Increasing the Wtot constraint to higher levels, both values of some already included attributes were enhanced and new attributes were added.

The relatively low additional pig welfare levels were satisfied at lower additional costs per pig (Table 3) when using the coefficients of the expert. At a Wtot-level of 10 even a net benefit of Dfl 0.05 per pig was found. The money saved from not having to pay the compensation for pigs that stay at the slaughterhouse overnight, was the main reason for this net benefit. In the case of the expert, higher pig welfare coefficients were attached to attributes with relatively lower cost coefficients. Examples involve the attributes ‘stock density’ in the slaughterhouse and ‘handling’ during transportation. As a result, it can be seen from Table 3 that when using the coefficients of the expert fewer attributes were needed to achieve the same level of additional pig welfare. However, the attributes that were incorporated were almost identical. Until a Wtot level of 30, the optimal chain concepts based on the expert only differ with respect to the length of the resting period prior to slaughter. As the consumer-related respondent considered an increase in this attribute not beneficial to the pigs’ welfare (Table 2), this attribute was not included in the corresponding least-cost chain concepts at all (Table 3). The same holds for the increase in total floor space of non-lactating sows with respect to the expert. From a Wtot level of 50 points and higher, the difference in attributes included in the optimal chain concepts increased. Compared with the consumer-related respondent, particularly attributes related to the farrowing stage were included earlier. Examples involve ‘not mixing unfamiliar pigs at weaning’, ‘not moving piglets at weaning’ and ‘supply of straw to sows’. On the other hand, attributes such as ‘access to outdoor space’ and ‘increasing total and concrete floor space’ were added later. The consumer-related respondent attached more value to an increase in (concrete) floor space for improving the pigs’ welfare

Table 2: The estimated pig welfare coefficients based on the data of a consumer-related respondent, denoted W_c, and an expert, denoted W_e. The levels of each attribute are denoted Δ_C and Δ_E.

			consumer-rel. resp.	expert	Cost coefficient
	Default	Δ	W_C	W_E	
Farrowing					
social contacts					
- mixing socially unfamiliar pigs at weaning	Yes	No	1.29	8.34	1.39[1]
- weaning age (weeks)	4	6	1.00	4.53	8.76[1,4]
surroundings					
- outdoor space (m^2/sow)	0	5/15[2]	5.69	2.04	1.98/4.70
- group housing	No[3]	Yes[a]	3.92	8.88	2.78
- total floor space nursery (m^2)	3.75	6.5	3.18	0.54	2.39
- concrete floor space nursery (m^2)	0	4			0.34
- housing in cubicles	No[3]	Yes[a']	3.15*	2.57*	2.16
- supply of straw (kg/pig/week)	0	1.4/7[2]	3.05	2.66	3.20/5.89
- total floor space non-lactating (m^2)					
. tethered housing or in cubicles	1.1	1.4	2.35	-2.13	0.25
. group housing	2.0	3.0			0.84
- illumination standards (lux/12 h./day)	No[5]	20	2.54	1.69	0.42
- moving at weaning	Yes	No	<u>2.15</u>	<u>1.33</u>	2.09
Maximum welfare points			25.2	30.0	
[4] 2 feeder pig suppliers instead of 1					3.89[1]
Fattening					
social contacts					
- mixing socially unfamiliar pigs start cycle	Yes	No	3.21	1.67	3.63[1]
surroundings					
- outdoor space (m^2/pig)	0	1.1/2.5[2]	16.31	7.22	8.12/13.51
. longitudinal vs. cross-sectional					4.26
- total floor space longitudinal (m^2/place)	0.57	0.9	12.96	1.67	8.08
- total floor space cross-sectional (m^2/place)	0.57	0.9			5.29
- concrete floor space (m^2/place)	0	0.4			1.95
- supply of straw (kg/pig/week)	0	0.1/1[2]	10.18	11.67	5.88/28.25
- illumination standards (lux/12 hours/day)	No[5]	20	6.55	8.33	0.79
- supply of roughage (kg/pig/day)	0	(1/10)[6]/0.5[2]	5.16	3.89	9.39/12.59
- ventilation automated	No	Yes	<u>0.98</u>	<u>0.56</u>	1.57
Maximum welfare points			55.3	35.0	

[1] The additional costs per pig were partly incurred in a subsequent stage.
[2] Representing the highest attribute levels of the consumer-related respondent and the expert respectively.
[3] In the default situation, non-lactating sows were tethered.
[4] Additional costs incurred when feeder pigs were supplied by 2 instead of 1 supplier.
[5] In the default situation it was assumed that (artificial) lights were used for about 2 hours and 1 hour per day in the farrowing and fattening stage respectively. An average illumination of 31, 48, 44 and 36 lux per m^2 was provided in farrowing, gestation, breeding and fattening rooms respectively.
[6] The amount of roughage fed to hogs was quantified at one tenth of the daily amount of concentrates.
[a-a'] Mutually exclusive attributes; sows can be housed in either cubicles or groups.

Table 2 Continued.

			consumer-rel. resp.	expert	
					Cost coeffi-cient
	Default	Δ	W_C	W_E	
Transportation					
social contacts					
- handling	rough	Quiet	6.10	6.48	0.08
- mixing socially unfamiliar pigs at loading	Yes	No[a']	0.82	5.35	1.18*
- loading on various farms	Yes	No[a]	0.82	2.54	3.21
surroundings					
- stock density (kg/m^2)	300	235[a']	0.99	2.25	0.69*
- ventilation automated	No	Yes	0.33	0.56	0.06
- interaction loading density x ventilation	-	-	0.99	2.82	
Maximum welfare points			10.05	20.0	
Slaughtering					
social contacts					
- handling	rough	Quiet	5.30	3.29	1.3
- mixing socially unfamiliar pigs during lairage	Yes	No[b]	1.56	3.29	0.016
surroundings					
- stock density (kg/m^2)	300	235[b']	1.25	2.46	0.004*
- automated lifting platforms	No	Yes	0.93	2.63	0.04
- water spraying during lairage	No	Yes	0.93	1.63	0.036
- keep overnight	Yes	No	0.09	0.08	-0.14
- resting period (hours)	2	4	-1.25	1.63	0.016
Maximum welfare points			10.05	15.0	
Interaction mixing unfamiliar pigs:		-			
- farrowing x fattening		-	-0.3	-1.7	
- farrowing x transportation/slaughtering		-	-0.6	-1.7	
- farrowing x fattening x transport/slaughtering			0.3	3.4	
Total maximum welfare points			100	100	

[a,b] Mutually exclusive cost coefficients. The cost coefficient that is excluded in denoted *.

than the expert did. As a result, the attribute 'increasing total floor space in the nursery pen', for example, was added to the optimal level. Examples are the concrete floor space of the nursery pen (Wtot level of 10 versus 20 points) in the case of the consumer-related respondent (Table 3), and the increase of the resting period (10 versus 20 and 30 versus 50 points), water spraying prior to slaughter and raising the illumination standards in the farrowing stage (30 versus 50 points) in the case of the expert (Table 3). As mentioned before, this was the main reason for switching from the static to the dynamic linear programming approach.

Results of the dynamic linear programming approach are shown for a three-step improvement in additional pig welfare (Wtot) (Table 4; placed at the end of the paper). Included are the Wtot levels at which attributes were excluded or decreased in value when using the static approach. For reasons of comparison, the total additional costs per pig rather than the discounted costs are presented.

When comparing the results of the dynamic approach (Table 4) with those of the static linear programming one (Table 3) it can be seen that indeed no attributes were excluded or decreased in value at increasing levels of Wtot. In the case of the consumer-related respondent's results, the concrete floor space in the nursery pen increased at a Wtot level of 10 as well as at 20 points. As a result of the smaller increase in concrete floor space at a Wtot level of 10 points, the attributes 'water spraying', 'automated lifting platforms' and 'automated ventilation' were no longer sufficient to satisfy the constraint of a Wtot level of 10 points. Instead, these attributes entered the optimal chain concept only at a Wtot level of 20 points. On the other hand, the illumination standards at the farrowing stage had already been raised at a Wtot level of 10 points. The attributes incorporated at the Wtot level desired in the final period influenced the optimal solutions at lower Wtot levels. As a result, as expected, the additional costs incurred at lower Wtot levels were higher in the dynamic approach than in the static one.

In the case of the expert's results, the attributes 'water spraying' and 'automated lifting platforms' at the slaughterhouse changed places as to their position at the Wtot level of 20 points. This resulted from the longer resting period which was also present at a Wtot of 20 points (dynamic approach). Moreover, the length of the resting period was reduced at the Wtot level of 30 and increased at the Wtot level of 50 in order to realize a gradual improvement (dynamic approach). Because the length of the resting period decreased and illumination standards were no longer raised at a Wtot level of 30, a further decrease of the stock density during transportation and not mixing unfamiliar pigs during transportation and resting, resulted in the least-cost additional welfare points required.

4 Discussion and conclusions

Using a chain model instead of separate stage simulation models offers the advantage of taking interstage relations into account. Interstage relations were quantified for both economic effects and pig welfare concerns. The contributions of the various concerns on the welfare of pigs along the stages of the pork chain were quantified, using a questionnaire developed and analysed by conjoint analysis of multi-attribute parameters.

Conjoint analysis is especially suitable for handling variables that are qualitatively specified or evaluated on different scales. This was especially suitable as the pig welfare predictor variables included both nominal and ratio scaled attributes and, as pig welfare, as a response variable, seems a qualitative notion itself. Moreover, with respect to product development it is the consumer's perception of pig welfare that is also (i.e. more) important (Sybesma, 1981), being a nonmetric and personal notion in itself. Potentially, consumer's perception could even be in conflict with scientific indicator criteria or expert perceptions based on these criteria (Kramer, 1990). Based on the valid and useful results obtained, this method seems to be a promising tool for broader application in livestock farming research. Examples may range from evaluation of exterior characteristics of livestock to the assessment of the relative importance of qualitative factors e.g. in disease control or animal replacement decisions.

In general, the predictive validity of the estimated models was good, indicating that the respondents were quite capable of a consistent evaluation of the pig welfare attributes. On average, Pearson's and Kendall's correlation coefficients equalled 0.92 and 0.78 respectively. Differences in validity observed between respondents could partly have resulted from different perceptions of attribute interactions. The expected attribute interactions that were incorporated in the questionnaire were not always mentioned in the open-end questions on potential interactions. Moreover, respondents mentioned interactions not included in the questionnaire or interactions with attributes that were not included either. Although the attributes and attribute levels incorporated in the models have been carefully selected, there will be attributes excluded that affect both the welfare of the pigs and the behaviour of people in response thereof in the marketplace (Cattin and Wittink, 1982).

Static and dynamic linear programming models were developed in order to explore the potential effects of incorporating various pig welfare-related attributes into the structure and economics of the production and transportation stages of the pork chain. Although the pig welfare coefficients of the consumer-related respondent and the expert were not similar, and can only be perceived as individual perceptions, the sequence in which the various attributes entered into the chain concepts showed great resemblance. Until a Wtot level of 20 points (consumer-related respondent) and 30 points (expert), the same 9 out of 10 attributes were included in the least-cost chain concepts. These attributes involved transportation- and slaughterhouse-related attributes in particular, including 'reducing stock densities', 'water spraying in lairage rooms', 'using automated lifting platforms for unloading pigs at the slaughterhouse', and 'handling the pigs quietly without the use of electric prodders'. Moreover, illumination standards were raised in both the farrowing and the fattening stage. These attributes also proved to be quite stable in sensitivity analyses. The additional costs incurred varied between Dfl. 0.56 and Dfl. 1.20 per pig depending on the pig welfare perceptions of the respondent that were used as input.

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Table 3 Results static linear programming approach: least-cost (Dfl./head) pork chain concepts at different desirable additional pig welfare levels, using the coefficients of a consumer-related respondent and an expert.

Overall Pig Welfare (Wtot)			consumer-related respondent						expert					
			10	20	30	50	70	100	10	20	30	50	70	100
Total extra costs (Dfl/head)			0.19	1.20	4.01	14.52	28.73	77.17	-0.05	0.56	1.48	5.98	26.11	114.02
Pig welfare attributes	default	stage												
stay overnight	Y	S	N	N	N	N	N	N	N	N	N	N	N	N
stock density (kg/m2/pig)	300	S	235	235	235	235	235	235	235	235	235	235	235	235
resting period (hours)	2	S	-	-	-	-	-	-	3.2	-	4	2.3	4	4
handling	rough	T	quiet	quiet	quiet	quiet	quiet	quiet	quiet	quiet	quiet	quiet	quiet	quiet
water spraying during resting	N	S	Y	Y	Y	Y	Y	Y	-	-	Y	-	Y	Y
automated loading platforms	N	S	Y	Y	Y	Y	Y	Y	-	Y	Y	Y	Y	Y
automated ventilation	N	T	Y	Y	Y	Y	Y	Y	-	-	Y	Y	Y	Y
concrete floor nursery (m2)	0	F	1.35	-	2.31	2.31	2.33	4.0	-	-	-	-	2.31	4
illumination (lux/12 hours/m2)	N	H	-	20	20	20	20	20	-	20	20	20	20	20
illumination (lux/12 hours/m2)	N	F	-	20	20	20	20	20	-	-	20	-	20	20
stock density (kg/m2/pig)	300	T	-	275	235	235	235	235	-	-	250	235	235	235
handling	rough	S	-	-	quiet	quiet	quiet	quiet	-	-	-	-	quiet	quiet
tot. floor non-lactating (m2)	1.1	F	-	-	1.4	1.4	3	1.4	-	-	-	-	-	-
mixing during transportation	Y	T	-	-	N	N	N	N	-	-	-	N	N	N
mixing during resting	Y	S	-	-	N	N	N	N	-	-	-	N	N	N
concrete floor (m2/place)	0	H	-	-	0.03	0.2	0.2	0.4	-	-	-	-	-	0.4
outdoor space (m2/sow)	0	F	-	-	-	5	5	5	-	-	-	-	15	15
housing non-lactating sows	teth.	F	-	-	-	cubi.	group	group	-	-	-	group	group	group
straw supplied (kg/pig/week)	0	H	-	-	-	0.64	0.70	0.7	-	-	-	-	-	7
total floor space (m2/place)	0.57	H	-	-	-	-	0.58	0.9	-	-	-	-	-	0.9
outdoor space (m2/pig)	0	H	-	-	-	-	1.1	1.1	-	-	-	-	-	2.5
tot. floor space nursery (m2)	3.75	F	-	-	-	-	-	6.5	-	-	-	-	-	6.5
straw supplied (kg/sow/week)	0	F	-	-	-	-	-	1.4	-	-	-	-	7	7
mixing start fattening cycle	Y	H	-	-	-	-	-	N	-	-	-	-	N	N
automated ventilation	N	H	-	-	-	-	-	Y	-	-	-	-	-	Y
moving piglets at weaning	N	F	-	-	-	-	-	N	-	-	-	-	N	N
mixing at weaning	Y	F	-	-	-	-	-	N	-	-	-	N	N	N
roughage supplied (kg/pig/day)	0	H	-	-	-	-	-	(1/10)	-	-	-	-	-	3.5
loading on various farms	Y	T	-	-	-	-	-	N	-	-	-	-	N	N
weaning age (weeks)	4	F	-	-	-	-	-	6	-	-	-	-	-	6

Y = Yes, N = No, F = Farrowing, H = Hog fattening, T = Transportation, S = Slaughtering

Table 4 Results of the dynamic linear programming approach: least-cost (Dfl./head) pork chain concepts for a desirable additional pig welfare level of 50 points in three successive steps of 10, 20 and 30 points, using the coefficients of the consumer-related respondent and the expert.

			consumer-related respondent				expert			
Overall Pig Welfare level chain (Wtot)			10	20	30	50	10	20	30	50
Total additional costs/period (Dfl/head)			0.23	0.97	2.81	10.51	-0.05	0.61	1.19	4.23
Tot. cumulative additional costs (Dfl./head)			0.23	1.20	4.01	14.52	-0.05	0.56	1.75	5.98
Pig welfare attributes	default	stage								
stay overnight	Y	S	N	N	N	N	N	N	N	N
stock density (kg/m^2/pig)	300	S	235	235	235	235	235	235	235	235
resting period (hours)	2	S	-	-	-	-	3.2	3.25	3.25	3.5
handling	rough	T	quiet	quiet	quiet	quiet	quiet	quiet	quiet	quiet
concrete floor nursery pen (m^2)	0	F	0.07	0.07	2.31	2.31	-	-	-	-
illumination (lux/12 hours/day)	N	F	20	20	20	20	-	-	-	-
water spraying during resting	N	S	-	Y	Y	Y	-	Y	Y	Y
automated lifting platforms	N	S	-	Y	Y	Y	-	-	-	-
automated ventilation	N	T	-	Y	Y	Y	-	-	-	Y
illumination (lux/12 hours/day)	N	H	-	20	20	20	-	20	20	20
stock density (kg/m^2/pig)	300	T	-	275	235	235	-	-	235	235
handling	rough	S	-	-	quiet	quiet	-	-	-	-
tot. floor non-lactating (m^2)	1.1	F	-	-	1.4	1.4	-	-	-	-
mixing during transportation	Y	T	-	-	N	N	-	-	N	N
mixing during resting	Y	S	-	-	N	N	-	-	N	N
concrete floor space (m^2/place)	0	H	-	-	0.03	0.20	-	-	-	-
outdoor space (m^2/sow)	0	F	-	-	-	5	-	-	-	-
housing non-lactating sows	teth.	F	-	-	-	cubi.	-	-	-	group
straw supplied (kg/hog/week)	0	H	-	-	-	0.64	-	-	-	-
mixing at weaning	Y	F	-	-	-	-	-	-	-	N

Y = Yes, N = No, F = Farrowing stage, H = Hog fattening stage, T = Transportation stage, S = Slaughtering stage

Summary and outlook towards a science based animal welfare

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Ever since man has left the status of hunting and gathering he has domesticated animals for food production. At the same time husbandry systems have developed and selection procedures were employed. Demographic changes, urbanisation and the resulting demand for food have led to increased specialisation and performance of farm animals, have intensified highly efficient husbandry systems and resulted in regional concentrations of animal production. Well to do societies more and more object to such developments. Public acceptance of animal production is closely linked to care for the environment, quality of products and animal welfare. Animal welfare is the animals ability to cope with its environment. So far, complex and individual relations in response to the environment have not received sufficient scientific attention and lag behind legal and public demands. Environmental stimuli results in a cascade of adaptation mechanisms within the organism and activate endogenous regulatory systems including the immune system. Some reactions are reflected in behavioural expressions. Even though domesticated animals preserve basic elements of behaviour throughout evolution, environmentally dependent genetic changes in adaptive mechanisms must be taken into account. It become increasingly evident, that interpretations of the animals state of welfare can no longer be based solely on behavioural observations. Conclusions must be based on thorough functional and motivational analysis. Damage, suffering and pain must be avoided. Pain is a concept involving noxious stimuli that evoke protective motor, behavioural, emotional and physiological reactions. Pain adversely affects both welfare and productivity of farm animals. Clinical ethology may assist to analyse at least grave problems of the animals welfare and uncover underlying causes. Production diseases are frequently responsible. They often result from a combination of deficits related to genetics, husbandry and management. To reduce potentially adverse effects of husbandry systems welfare indicators have been advanced in recent years. They need critical appraisal. New technologies (e.g. biotechnology) may also compromise the animals welfare. They should be accompanied by multidisciplinary research to detect and consider deleterious side effects and welfare problems.

For the producer animal production serves to obtain income. Implementation of the societies demands for animal welfare will largely depend on incentives to the producer and on international acceptance of welfare codes to avoid export of welfare problems into countries with no welfare standards. Legal constraints must be based on sufficient scien tific evidence and on established practical experience to meet the animals biological demands and to account for the animals adaptability . Most of all, the consumer needs to be prepared to bear the cost of welfare for the animal. Finally, a sense of responsibility for all parties involved will improve animal welfare. The workshop addresses these issues and hopefully contributes to a science based improvement of animal welfare.

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Animal health

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One of the most crucial parameters in modern animal husbandry and production is animal health. Animal welfare, consumer protection and economic success are directly linked to the health status of farm animals. Major factors influencing animal health, i.e. housing, breeding and feeding are subject of other forums. This forum deals with treatment of health problems of farm animals and prophylaxis.

There is a fundamental difference between health care of companion animals and farm animals: The former experience - at least in industrialised countries - an extensive and expensive health care almost resembling human health care. The latter face some constraints that are given by economical facts and consumer expectations. The use of feed additives for the maintenance of animal health is largely rejected by the public, and the use of therapeutic drugs is subject to controversial discussions. However, in this context the fact is often overlooked that even under optimal conditions animals may fall ill; thus the use drugs for metaphylactic and therapeutic purposes should be an animal rights and ethical issue, respectively.

In order to illustrate this conflict it is helpful to distinguish between positive and negative animal health (Sainsbury, 1986).

It is in the best interest of managers of modern animal farms to keep their animals healthy. However, many of them still dwell too much on the prophylactic and metaphylactic use of feed additives and drugs instead of improving living conditions, hygiene and system management. The labile health status that may be achieved using these methods is defined as negative animal health. This kind of health management has disadvantages for the animal and is considered to be potentially hazardous for human health. The relatively untargeted and unprofessional use of drugs promotes the emergence of multiresistant pathogens, that may even have zoonotic potential. In addition drug-contaminated excretions of treated animals may give rise to environmental problems.

In general animals that are kept under optimal conditions stay healthy. This state is defined as positive animal health. However, good management practices alone cannot protect farm animals from pathogenic microorganisms. These will always pose a threat to animal health, and one of the major challenges for biomedical research is to combat infectious diseases of farm animals.

The most important tasks for research and development in the field of animal infectious diseases will be:

- Definition of requirements for the professional use of antiinfective drugs in all fields of human and veterinary medicine. Ideally farmers, legislators and scientists should agree on internationally accepted guidelines. The development of multiresistant microorganisms should be carefully monitored and appropriate actions taken in order to avoid negative influences on human and animal health, respectively.
- Research and development of novel antiinfective drugs should be encouraged, e.g. antimicrobial peptides of plant and animal origin (e.g., defensins and cecropins). This is an urgent issue and at present it is not clear whether the development of new substances is keeping/will keep pace with the rapid emergence of multiresistant microorganisms.
- Research and development of novel vaccines. The availability of DNA recombinant techniques offers the long-term perspective of developing prophylactic vaccines with properties superior to our present vaccines: Marker vaccines will allow the distinction between vaccinated and infected animals, an important prerequisite for an efficient control of many infectious diseases; precise selection of immunogens and their targeted application will enhance the efficacy of vaccines; nucleic acid vaccines will overcome the potential hazards of live vaccines without having the disadvantages of poorly efficient inactivated vaccines.
- Improvement of the diagnosis of infectious diseases: A crucial prerequisite for the control of infectious diseases is the availability of sensitive and specific diagnostic tools. Progress in this field has been dramatic during the last 15 years, and these developments may be expected to continue, thanks to a multitude of techniques that may be utilised for diagnostic purposes, e.g. immunoenzymatic tools, nucleic acid amplification and identification techniques, and the emerging field of biosensor development.

  We hope that this forum will highlight present developments and contribute to the long-term improvement of animal health.

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Major health problems in the livestock production sector caused by infectious agents

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Introduction

There is a large variation in animal health status between the different EU member states. This variation refers to both highly contagious diseases and endemic infections. Moreover, certain infections in livestock appear to be of increasing public health concern. Many factors appear to be involved in the phenomenon of prevalence differences. In-depth insight into such factors may help in designing appropriate disease combat or eradication programmes. In this presentation emphasis will be on the various factors contributing to the major health problems in the livestock sector.

Highly contagious infections

Such infections refer to e.g. foot-and-mouth disease (cattle; swine); classical swine fever; New Castle disease (poultry); avian influenza (poultry); brucellosis and tuberculosis (cattle). Factors contributing to the repeatedly occurring outbreaks of highly contagious diseases are animal population densities; introduction of agents through wildlife; the EU non-vaccination strategy; the open internal EU borders; the intensive live animal transportation network over the EU; increased mobility of man, animals and feed commodities; on-going genetic selection for productivity traits; increased disease susceptibility of animals.

In certain areas of the EU the animal population, e.g. pigs, is so high that once an agent is introduced it spreads so rapidly that large populations are affected and losses are tremendous. Area examples (e.g. pigs) are Po-river area (Italy), Brittany (France), West Flandres (Belgium), Holland and Nordrhein Westfalen (Germany). Areas to which the aforenamed conditions apply need to develop new tactics to be safeguarded from most disease disasters. Tactical manoeuvres in such areas may refer to clustering of herds within that area coupled to the creation of buffer zones between clusters. And to restriction of transportation separated from external transportation. Uniform health status within clusters, standardised hygiene procedures within clusters, fixed relationship between breeder multiplies and fattener. A cluster might thus be considered a closed participatory business unit. Once an infection is introduced in an area, a few affected clusters are closed and stamped out, while other clusters can take preventive or protection measures (e.g. ring vaccination) and again other clusters are safeguarded. The question that remains to be solved at the local level is whether this industrial type of approach is politically, socially and economically acceptable and feasible.

Endemic diseases

Endemic disease prevalence differences between countries, regions and farms are even larger than in the case of highly contagious diseases. Factors contributing to this phenomenon are the prevailing differences in husbandry systems, marked differences in management quality levels, the highly intensified production and the physiologically marginal potential of food animals to cope with all kind of stresses including infectious agents, the largely monotrait focussed genetic selection programmes. Special attention may be given to food animals affected by metabolic stress. This is a relative problem, largely provoked by one-sided genetic selection on productivity mainly. One to this metabolic stress (e.g. after calving or around piglet weaning), endocrinological, neurological and immunological functions are impaired. This impairment may ultimately result in increased disease susceptibility and or reduced reproductive performance. It is obvious that particularly exporting countries need to focus on this kind of infectious diseases too in order to retain market access for live animals or their products. Emphasis may be a disease eradication e.g.IBR; Aujeszky disease) and or on disease risk management (e.g. after eradication to prevent (re-) introduction of agents; or to safeguard herds from becoming infected). Disease risk management is an underestimated instrument in disease combat programmes while emphasis has been on vaccination and medication. Disease risk management requires a qualitative and quantitative approach. The latter not in the least to set priorities in a more justified manner.

Public health issues

The most commonly known zoonoses such as brucellosis and tuberculosis are largely eradicated from the EU but have not disappeared. They still pose

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a threat. One should rather be aware of the fact that modern livestock production carries implicitly the risk of presence of carriers or infected animals, representing a potential risk for man, sometimes even without causing overt disease in animals. Examples of such infections are salmonellosis, vtec, Str. suis II. Various voluntary and compulsory disease combat programmes are operational. These programmes aim at eradication of the agent from the food animal herds and or reduction of prevalence. It would be worthwhile to apply quality risk control programmes at farm level in order to control the prevalence of such disease, or rather the risks of such disease to be introduced and spread. An example of such an approach is the HACCP concept which focuses on hazard identification, risk assessment and definition of critical control points, as well as of critical management points, the latter as elements of a Good Farming Practice code.

Concluding remark

Sustainable animal production can be enhanced when more emphasis is put on better managerial qualities, and on disease risk management instead of on disease control alone.

Emerging and re-emerging viral diseases

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A new political and economic paradigm is emerging with the turn of the century, which is affecting the prevention, control, and eradication of animal and zoonotic diseases. We live in an era when ever more complex and intertwined

- global political systems evolve, as exemplified by e.g. the European Union,
- trading systems develop, as exemplified by e.g. the North American Free Trade Agreement,
- food production, processing and distribution systems unfold, brought about by international trade in meat and poultry, dairy products and seafood and shellfish
- information storage, retrieval, processing and dispersion systems become accessible through the internet.

These trends have lead to increased public awareness of disease risks and to the expectation that the veterinary profession should become the global steward of animal health, environmental quality, food safety, animal welfare and zoonotic disease control. All these responsibilities will require the application of the principles of preventive medicine: surveillance - increasingly based on international collaboration - and disease prevention and control.

Prevention and control strategies chosen must be in keeping with the characteristics of the virus, its transmission patterns and environmental stability, its pathogenesis and threat to animal health, productivity and profitability, zoonotic risk, etc. When available and legally permitted, the most valuable preventive measure is vaccination, not merely for the protection of the individual animal, but to build up a level of population immunity sufficient to break chains of transmission. Hygiene and sanitation measures are important methods of controlling fecal-oral infections in kennels and catteries, on farms and in commercial aquaculture facilities. Test-and-removal programs continue to be used on regional and country-wide bases to eradicate several viral diseases of livestock and poultry. The importation of exotic diseases (the term *foreign animal diseases* is used officially in some countries) into countries or regions is prevented by surveillance and quarantine programs. Finally, following the lead taken in human medicine to globally eradicate smallpox (accomplished in 1977) and polio (expected to be accomplished in 2002) the global eradication of rinderpest is now considered attainable.

Irrespective of all these concerted efforts, there is no chance that all pathogenic viruses will be definitely eliminated, ever. New diseases will strike time and again, and their causative viruses will be identified ever more quickly, either as being well-known agents that have undergone subtle genetic changes, or as recombinants with other viral or cellular genes. They may also turn out to be really new, hitherto undiscovered agents. Especially viruses possessing RNA genomes (which are replicated by error-prone replicases without proof-reading) will contribute to epidemics. As our knowledge increases, virus persistence in a host organism will turn out to be rather the rule than the exception; during this prolonged presence, changes in the viral genome take place, but most of them will pass unnoticed, as they have no pathogenetic corollary, or they only lead to lethal mutations. Every now and then, however, a ‘killer’ virus will emerge and wreak havoc – either to be controlled by veterinary efforts or peter out in virulence to become a harmless commensal.

The mutation rate in RNA viruses has been estimated at about 10-4, i.e. 1 out of 10,000 nucleotides is changed in any round of replication; since e.g. a coronaviral RNA holds about 30,000 nucleotides, any genome in a population would differ from the next in at least one site. In other words: no two particles are genomically identical - a notion that has led to the 'quasispecies' concept for viruses. They possess the machinery to evolve more than a million times faster than cellular microorganisms, and one wonders how they can maintain their identities as pathogens over any evolutionarily significant period of time.

The answer is surprisingly simple: not individual viruses count biologically but a cloud of genetic variants centered around a consensus sequence. Like the cloud's unknown center also the consensus sequence is inscrutable; any published nucleotide sequence determined in the laboratory therefore is a random choice and may be more or less representative of the virus ‘species’. New mutants appear at the periphery of the quasispecies distribution where they are produced by the erroneous copying of mutants. If these mutants have acquired new transmission, host spectrum, or virulence properties, they may start an epidemic, an emerging infection.

The term emerging diseases was used as a book title by the Food and Agricultural Organization (FAO) in 1966 to describe several viral diseases of

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veterinary importance, such as African swine fever, that appeared to have the potential to spread beyond their known geographical boundaries. In 1992, the Institute of Medicine, a branch of the National Academy of Sciences of the United States, in response to the recognition of the emergence of AIDS and nosocomial virus diseases such as Ebola hemorrhagic fever, but also to the re-emergence of e.g. tuberculosis, issued a report in which emerging infectious diseases were defined as diseases whose incidence has increased within the past two decades or threatens to increase in the near future. It was this 1992 report that drew the public's attention to the infectious diseases and the concept of emergence. Viral diseases, because of their rapidity of spread, feature prominently in any listing of emerging disease. Their prominence has been further highlighted by recognition of epidemics throughout the 1990s of Ebola hemorrhagic fever in central Africa, by an outbreak in 1994 of a new paramyxovirus disease in horses and humans in Australia and by identification in 1997 of a zoonotic outbreak of H5N1 avian influenza in Hong Kong. The infamous Bovine Spongiform Encephalopathy, though not caused by a virus, is another man-made emerging epidemic disease with a zoonotic potential.

Antimicrobial resistance

Stefan Schwarz [1)], Corinna Kehrenberg [1)], Gabriele Frech [1)]

Most of the antibiotics currently used in human and veterinary medicine originate from substances which were produced by fungi or soil bacteria and provided the antimicrobial producer a selective advantage in the fight for resources and the colonization of ecological niches. Thus, bacteria came in contact with antimicrobial substances and consequently began to explore ways to avoid being killed or inhibited by those substances a long time before the first antimicrobial agents were introduced into clinical use. There are mainly three ways by which bacteria have gained resistance to antimicrobial agents: (a) bacteria acquired resistance genes of the antibiotic producers and modified them with regard to an optimized functionality in the new host, (b) bacteria developed resistance genes by stepwise mutation of genes whose products play a role in physiological cell metabolism, and (c) bacteria modified the target structures of the antimicrobials by either single-step or multi-step mutations and thus rendered them resistant to the inhibitory effects of the antimicrobials (Anon, 1998; Bennett, 1995; Quintilliani and Courvalin, 1995; Schwarz and Kehrenberg, 2000; Schwarz and Noble, 1999).

As a result of the exposure of bacteria to antimicrobial agents, a large number of genes and mutations associated with antimicrobial resistance has been developed. The observation that the introduction of an antimicrobial agent into clinical use has been either accompanied or followed shortly by the occurrence of resistant bacteria underlines the extraordinary capacity of bacteria to quickly and efficiently respond to the selective pressure imposed by the use of antimicrobials. In recent years, bacteria have also shown to be able to develop resistance to completely synthetic substances (Anon, 1998; Bennett, 1995).

The exchange of resistance genes between members of a mixed bacterial population has distinctly accelerated the spread of certain resistance genes to a large number of pathogenic bacteria, but also to harmless commensals. Resistance genes were usually first present in the bacteria in which they had evolved and were initially only transmitted vertically. However when integrated into mobile genetic elements, such as plasmids, transposons or integrons/gene cassettes, the resistance genes were spread horizontally among bacteria of the same, but also different species and genera by transduction, conjugation, mobilization or transformation. Thus, the driving forces of emerging antimicrobial resistance are repeated exposure of the bacteria to antibiotics and the access of the bacteria to a large resistance gene pool in a polymicrobial environment as it is seen on the mucosal surfaces in the respiratory or alimentary tract as well as on the skin of humans and animals (Anon, 1998, Bennett, 1995; Schwarz et al., 2000).

The selective pressure imposed by the use of antimicrobial agents plays a key role in the emergence of resistant bacteria. Whenever a mixed bacterial population is exposed to antimicrobial agents, it is likely that there will be bacteria that are resistant to the respective drugs at the concentrations applied. Under selective pressure, the numbers of these will increase and some may pass their resistance genes to other members of the population (Schwarz et al., 2000). Consequently, the transfer of resistance gene(s) between harmless commensal bacteria to pathogens is likely to occur and must be considered. The application of a single antibiotic may not only incur resistance to that particular drug, but can also result in resistance to other structurally related antibiotics or even unrelated antibiotics which, however, share the same target site. In addition, co-transfer of multiple resistance genes associated with a single mobile element is often ignored when considering the population dynamics of antibiotic resistance. Numerous plasmids have been identified which carry several antimicrobial resistance genes as well as genes whose products confer resistance to disinfectants, heavy metals or nucleic acid binding substances. When such a multiresistance plasmid is transferred under the selective pressure imposed by the use of a single antimicrobial agent or disinfectant, the recipient cell will gain all resistance properties mediated by this plasmid (Neu, 1992; Schwarz et al., 2000).

Food producing animals as well as pets can act as a reservoir of resistant bacteria, as can humans (Neu, 1992; Schwarz et al., 2000). Antimicrobial resistance can develop in bacteria residing in animals and humans exposed to antimicrobial agents. Subsequent spread of the resistant bacteria between different hosts can occur directly by skin to skin contact, contact with bacteria containing material (saliva, faeces, etc.) or by the uptake of contaminated food, feed, air or water (Schwarz et al., 2000). When reaching the new host, resistant bacteria can either colonize and infect, or remain in the new environment for only a very short period of time. During this period, the resistant bacteria can spread their resistance genes to bacteria the new host (commensals or pathogens), but can also accept resistance genes from these bacteria. Long-term residency may provide greater opportunities for transferring or receiving resistance genes than a brief co-habitation (Schwarz et al., 2000). Among the antibiotic resistant bacteria causing infections in humans, *Salmonella enterica* subsp. *enterica* (*S.*) serovars, *Campylobacter* spp. as well as *Enterococcus* spp. are considered the only ones which can be traced to animal sources with a high degree of certainty (Goossens, 1999; Neu, 1992; Witte, 1998). Their predominant way of reaching humans is via the food chain. However, once established in a human population (not always associated with disease), such pathogens can also be spread by various ways between humans (Molbak et al., 1999). Therefore, it is important to consider that infections with the afore mentioned zoonotic bacteria isolated from a human source may not necessarily have originated directly from animals shedding the bacteria or from contaminated animal products (Molbak et al., 1999). The transfer of (multi)resistant zoonotic bacteria from animals to humans is often difficult to prove, even by using sophisticated molecular methods. This is mainly due to (a) the clonal structure of the pathogens as proven for *S.* Typhimurium DT104 (Baggesen et al., 2000) and *S.* Enteritidis PT4 isolates (Weide-Botjes et al., 1998) from different geographical and animal sources, but also to (b) a highly diverse genomic arrangement as observed in *Campylobacter jejuni* or *Enterococcus* spp. (Van den Braak et al., 1998; Van den Boogard et al., 1997). The proof of the direction of transfer of resistance plasmids or transposons/integrons between bacteria residing in animals and humans is even more difficult to achieve. Since antibiotics of the same classes, such as tetracyclines, aminoglycosides, macrolides, and ß-lactams, have been used for decades in both humans and animals, resistance to these antibiotics has also been selected for and transferred, probably *vice versa,* in both groups of hosts. Studies which confirmed the presence of identical resistance genes located on indistinguishable plasmids/transposons in bacteria from humans and animals (Greene and Schwarz, 1992; Schwarz et al., 1990; Schwarz and Noble, 1994) produced strong evidence for their transfer between human and animal bacteria, but in most cases it is impossible to trace back where and when the original resistance gene/plasmid/transposon had developed and which transfer events have taken place since. The spread of resistant bacteria from animals to humans is, in principle, possible and there is evidence in the literature that such transfer events have not only occurred, but occurred bilaterally (Levy et al., 1976; Seguin et al., 1999). The frequency with which resistance properties are transferred between animals and humans is difficult to quantify. Since the efficiency of such transfer is, in part, dependant upon the type of antibiotic used, the colonisation of bacteria, the transfer of the resistance gene(s), host pharmacokinetics, immune status, or other ongoing infections, a risk assessment must be carefully performed in every single case (Schwarz et al., 2000). The excessive attention drawn by the media to the use of antimicrobials in animals as the cause of all or at least most resistance problems in human medicine is a distraction (Bywater, 1999; Phillips, 1999). Based on the present evidence, antimicrobial use in animals mainly causes resistance problems in animals while antimicrobial use in humans mainly accounts for the resistance problems encountered in human medicine. With the exception of the afore mentioned resistant zoonotic pathogens, both disciplines are mainly responsible for their own "home-made" resistance problems (Bywater and Casewell, 2000).

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List a diseases: Threat and control

Jorgen Westergaard [1)]

List A diseases are defined by the World organisation for animal health (Office International des Epizooties, OIE, located in Paris) as transmissible diseases which:

– have the potential for very serious and rapid spread, irrespective of national borders;
– are of serious socio-economic or public health consequence;
– are of major importance in the international trade of animals and animal products.

The List A comprises at present (2000) of 14 viral diseases and one Mycoplasma disease, Contagious bovine pleuropneumonia. The domestic animals affected by List A diseases belong to species referred to below:

Animals affected (by species)	Disease
Avian	Avian Influenza, Newcastle Disease.
Bovine	Contagious bovine pleuropneumonia, Lumpy Skin Disease, Rinderpest.
Equine	African Horse Sickness.
Ovine/caprine	Sheep pox and goat pox, Peste des petits ruminants.
Porcine	African Swine Fever, Classical Swine Fever, Swine Vesicular Disease.
Multispecies	Bluetongue, Foot and Mouth Disease, Rift Valley Fever, Vesicular Stomatitis.

Since the present List A of diseases was established the significance of certain diseases has changed, diagnostic techniques and control procedures have improved and the international movements of animals and animal products have greatly increased. The list has for years helped animal health authorities to set priorities for their research and control programmes. In the light of recently added responsibilities for OIE under the WTO SPS Agreement, however, it appears appropriate to examine the justification of the list and of the diseases included in the list.

The reservoir of List A disease agents in wildlife and in domestic animal populations, the route and the mode of disease transmission play a major role, when evaluating disease threat and deciding on control measures to be applied.

Disease threat

The threat or risk of a List A disease entering a susceptible domestic animal population can arise from several possible sources. Most of the risk factors for a primary outbreak originate from outside the region where the primary outbreak is confirmed. The transmission of the infection can take place via animals incubating disease, diseased animals, infected or contaminated products of animal origin, inadequately cleaned and disinfected means of transport, people and, for certain diseases, air currents or vectors. Primary outbreaks, however, may also be caused by a source present within the affected area such as infected wildlife, laboratories handling List A disease virus and vaccines which have been inadequately inactivated/attenuated or contaminated.

Until recently disease threat or risk were evaluated on rather subjective assessments. Whenever possible this type of assessment should be replaced by a quantitative risk-analysis, which gives a transparent, objective and defensible estimate of the risk posed by a particular action.

Disease control

In the context of controlling List A diseases the term "control" in this paper shall refer to prevention (measures to exclude infection from an unaffected area), control (measures to reduce the frequency of existing disease) and eradication (measures to eliminate pathogens from a defined area). All countries with a developed animal production have adopted legislation concerning the control of List A diseases. Within the EU this legislation includes rules governing trade and rules to be applied in the event of an outbreak. The later rules require stamping-out of infected holdings, restrictions on movement within and from an infected area and the potential use of vaccination in emergency situations. Difficulties encountered in recent years concerning the control of List A diseases have primarily been related to outbreaks in densely populated livestock areas and in areas where a disease has been endemic in the wildlife population. Information on List A diseases which have occurred during 1990-1999 is shown in table 1.

1) Animal Health and Welfare, Zootechnics, European Commission

Table 1 - Reported outbreaks of List A diseases, 1990-1999, in the EU

Diseases	Outbreaks Total number	Year(s) Outbreaks/ source*	Number of reporting Member States
Foot and mouth disease	191	93, 94, 96/a	2
African swine fever	1.410	90 – 99/b	3
Classical swine fever	1.377	90 – 99/a+b	7
Swine Vesicular Disease	164	91 – 99/b	5
Sheep pox	195	94 – 98/a	1
Bluetongue	1.438	98, 99/a	1
Avian Influenza	40	92, 94, 97 – 99/b	3
Newcastle Disease	669	90 – 99/b	14

* Source of primary outbreaks a - outside EU
b - inside the EU.

Epilogue

A precondition for success in the control of a List A disease outbreak includes a comprehensive and well-rehearsed contingency plan. The plan must clearly describe: the legal power held as regards disease notification, stamping-out, payment of compensation, movement controls, vaccination and use of penalties. Other aspects of the plan refer to the chain of command; the establishment and operation of disease control centres; the use of diagnostic laboratories; training of staff and publicity. In the long-term measures of importance for better disease control include: increased disease surveillance; better protection measures at farm level and protection measures relating to movement of animals.

Progress in the diagnosis of infectious diseases

Ruth E. Lysons [1)]

Introduction

There is a huge variety of veterinary diagnostic tests available, and technological advances mean that new tests are emerging all the time. The selection of a laboratory test should be dependent upon the purpose for which it is being used. There is increasingly a requirement for tests to be rapid and of low cost. At the same time, the test must be adequately validated and quality assured to ensure consistent results.

The main reasons for use of diagnostic tests in farm animals are for individual animal diagnosis, herd investigations, disease control or disease surveillance. In Great Britain the requirement for farm animals is increasingly for large-scale surveillance programmes. These are usually designed with a mathematical basis to answer specific epidemiological questions. In Britain there is currently a particular emphasis on surveillance of livestock for prevalence of specified food borne zoonoses such as salmonella, *E. coli* O157. Large-scale testing requires cheap and robust tests.

Test costs can be influenced considerably by careful selection of sample type, sample handling methodology, and by the available test technology.

Quality assurance of testing is essential and should comprise suitable within-test quality control and external quality assurance. Independent accreditation e.g. ISO9000 or UKAS/ISO 17025 adds an additional level of quality assurance.

PrP Genotyping

The TaqMan PCR technique can be used to demonstrate single base differences in a gene. In sheep, polymorphisms exists in the amino acids encoded at codon 136, 154 and 171 of the PrP gene. The significance of different polymorphisms varies with different breeds of sheep, but certain genotypes are always associated with scrapie resistance.

Cryptosporidium

Cryptosporidium parvum is believed to be associated with human illness. A new multi allele specific PCR has been developed which can differentiate the two main genotypes of *C. parvum*. Although still in a developmental phase, this is an example of a PCR on several genes which can be carried out in a single tube.

Brucella ELISA

Although Britain, in common with many European countries, is free from brucella, our national brucella monitoring programme means that a conventional brucella ELISA is our highest throughput test. This is an instance where false positive results can be tolerated in the primary screening test, as the vast majority of samples are negative. Any samples proving positive on ELISA can be re-tested by confirmatory assays.

Rabies

The Pet Travel Scheme (PETS) was launched in Britain this year. Britain is rabies-free and has previously required incoming dogs and cats to spend six months in quarantine. The PETS enables eligible animals to enter Great Britain without quarantine provided they are identified by microchip, vaccinated against rabies, blood tested for evidence of sero-conversion following vaccination, and that they carry appropriate veterinary certification. The official test used under this scheme is the rabies fluorescent antibody virus neutralisation assay. Increasing the throughput of this test presents logistical difficulties due to the requirement for high level laboratory containment facilities.

Tuberculosis

Unlike many other European countries, bovine tuberculosis remains problematical in Great Britain due to a persistent reservoir of infection in wildlife. A blood test is needed to replace the comparative intradermal tuberculin test currently used. A conventional antibody-based assay is not appropriate because *M. bovis* generates a cellular (T-cell) response. Detection of cytokines expressed by antigen-stimulated white blood cells is the basis of a test which is about to be used in a field trial involving British cattle.

1) Veterinary Laboratories Agency, New Haw,
Weybridge, Surrey, KT15 3NB, United Kingdom

(mucosal route), thus inducing not only systemic immunity, but also mucosal immunity. By developing mucosal immunity, one can prevent the initiation of infection as well as preventing disease.

It is also possible to introduce genes coding for protective antigens into viral or bacterial vectors, thereby immunize animals against both the vector and the pathogen from which the foreign gene was derived. These live vectored vaccines are being used to not only control infectious diseases of domestic animals, but of wildlife as well. This approach has resulted in a dramatic reduction in transmission of rabies from wildlife to domestic animals and humans. This would not have been possible by conventional methods.

Polynucleotide Vaccination

The most recent development in vaccinology is immunization with polynucleotides. This technology has been referred to as genetic immunization or DNA immunization. The basis for this approach to immunization is that cells can take-up plasmid DNA and express the genes within the transfected cells. Thus, the animal acts as a bioreactor to produce the vaccine. This makes the vaccine relatively inexpensive to produce. Some of the advantages of polynucleotide immunization is that it is extremely safe, induces a broad range of immune responses (cellular and humoral responses), long-lived immunity, and, most importantly, can induce immune responses in the presence of maternal antibodies. Most recently, it has also been used for immunizing fetuses. Thus, animals are born immune to the pathogens and at no time in the animal's life are they susceptible to these infectious agents. Although this is one of the most attractive developments in vaccinology, there is a great need to develop better delivery systems to improve the transfection efficiency *in vivo*.

Modern Vaccines

Lorne A. Babiuk [1)]

Successful vaccination against infectious diseases has been practiced for over 200 years. Indeed, it has been stated that vaccination is the most cost-effective method of reducing animal suffering and economic losses due to infectious diseases in animals. However, even with these successes, infectious diseases continue to be of economic significance to society in reduced productivity and animal death. The advent of genomics, proteomics, and biotechnology, combined with our understanding of pathogenesis and immune responses to various pathogens provides us with an unprecedented opportunity to develop safer and more effective vaccines for many pathogens. In addition to using vaccines to cure infectious diseases of animals, it is also possible to immunize animals against various hormones and cellular proteins to improve growth and alter reproductive efficiency. The present review will focus on the different types of genetically engineered vaccines that are presently at different stages of development, clinical trials, or licensing. These include: 1) live vaccines, 2) live chimeric vaccines, 3) live replication-defective vaccines, 4) subunit vaccines, 5) peptide vaccines in various modifications of monovalent, multivalent, or chimeric subunit vaccines delivered as individual components or incorporated into virus-like particles for improved immunogenicity, and 6) polynucleotide vaccines.

Subunit Vaccines

Subunit vaccines are defined as those containing one or more pure or semi-pure antigens. In order to develop subunit vaccines, it is critical to identify the individual components out of a myriad of proteins and glycoproteins of the pathogen that are involved in inducing protection. Indeed, some proteins, if included in the vaccine, may be immunosuppressive, whereas in other cases immune responses to some proteins may actually enhance disease. Thus, it is critical to identify those proteins that are important for inducing protection and eliminate the others. Combining genomics with our understanding of pathogenesis, it is possible to identify specific proteins from most pathogens that are critical in inducing the immune responses. The potential advantages of using subunits as vaccines are the increased safety, less antigenic competition, since only a few components are included in the vaccine, ability to target the vaccines to the site where immunity is required, and the ability to differentiate vaccinated animals from infected animals (marker vaccines). One of the disadvantages of subunit vaccines is that they generally require strong adjuvants and these adjuvants often induce tissue reactions. Secondly, duration of immunity is generally shorter than with live vaccines. In addition to using a whole protein as a vaccine, it is possible to identify individual epitopes within these protective proteins and develop peptide vaccines. The major disadvantage of peptide vaccines is that they often need to be linked to carriers to enhance their immunogenicity and, secondly, a pathogen can escape immune responses to a single epitope versus multiple epitope vaccines. To overcome some of these disadvantages, chimeric peptides can be made to broaden the immune response to different epitopes.

Live Genetically Engineered Vaccines

Live vaccines are generally believed to give excellent immune responses because they simulate a natural infection. However, conventional attenuation is generally unreliable, therefore, novel approaches to attenuation are being developed. Using molecular approaches, it is possible to identify specific virulence genes from a variety of different pathogens and to induce multiple mutations or even delete the entire gene in question – depending on the pathogen. By introducing these multiple mutations or deletions, it is possible to develop a safer vaccine than using conventional attenuation technologies. For example, the degree of attenuation can be controlled by deleting or mutating the appropriate gene or groups of genes. By deleting an entire gene or portion of a gene, the chances of reversion to virulence is dramatically reduced. The probability of reversion to virulence can further be reduced if two different spacially-separated genes are deleted or mutated. Based on these factors, these newly engineered vaccines should be much safer than conventionally-produced live vaccines. In addition, to being safer, these gene-deleted vaccines can also be used as ‘marker vaccines’. By deleting an essential gene, one can develop replication incompetent vaccines which are extremely safe since they cannot be transmitted in the environment. A further advantage of live vaccines is that they can often be delivered via the natural route of infection

1) Veterinary Infectious Disease Organization,
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(mucosal route), thus inducing not only systemic immunity, but also mucosal immunity. By developing mucosal immunity, one can prevent the initiation of infection as well as preventing disease.

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New antiinfective drugs

P. Schmid 1)

Introduction

The ability to treat bacterial infections with chemotherapeutic agents represents one of the most important medical achievements of the twentieth century. The modern era of chemotherapy began with the clinical use of sulphanilamide in humans in 1936. Antiinfective therapy began with the industrial production of penicillin in 1941 and was followed by the discovery and development of streptomycin in 1944, chloramphenicol in 1947, chlortetracycline in 1948, the macrolides in 1952, semi-synthetic penicillins, cephalosporins and glycopeptides from 1958 onwards, streptogramins and quinolones in 1962, fluoroquinolones in the 1980s and, finally, oxazolidinones and cationic peptides in the 1990s.

From the 1950s onward and parallel to the increasing use of antimicrobial agents to control disease in man, veterinary use has provided similar control in both livestock and companion animals. Their application in veterinary practice has contributed to significant improvements in animal health and welfare and assisted in enabling the production of meat and milk products which thereby became unlikely to present disease problems for the customer. The most recent developments in the field of veterinary medicine are the third and fourth generation cephalosporins, fluoroquinolones, tilmicosin and florfenicol.

However, even from the very earliest period of the antiinfective era the potential for the emergence of drug resistant bacteria has been recognized. In 1998 some 19766 tonnes of antiinfectives were used in human medicine and some 9920 tonnes in veterinary medicine. It seems reasonable to suppose that there is a connection between the amount of drug substances used and the extent and speed of resistance development. Based on this assumption numerous organisations, from the WHO to national bodies and pressure groups, have elaborated *prudent use guidelines*. A key message of these guidelines is the sentence: Antiinfectives should only be used when it is known or suspected that an infectious agent is present which will be susceptible to therapy.

There is no doubt that sensible measures to limit the therapeutic use of antiinfectives to valid indications and to ensure the susceptibility of the causative agent prior to any treatment will be of value in limiting the emergence of resistant organisms. However, the resistance problem already existing especially in human medicine requires renewed efforts by the pharmaceutical industry to discover and develop new products.

New antiinfective drugs

The driving force in the search for new drugs is the human health sector. We can therefore realistically expect that in the medium term this is where new antiinfectives for animals will come from. In the medium term, as in the past, the animal health industry will therefore rely primarily on spin-offs from the human sector.

Four principal drug discovery approaches are employed in the search for new antiinfectives, namely, (i) the expansion of known drug classes to cover organisms resistant to earlier members of the class, (ii) the reevaluation of un(der)explored molecules, (iii) the classical screening of synthetic compounds and natural compounds isolated from fermentation broths of microorganisms, plants or other organisms and (iiii) the identification of novel agents active against previously not-exploited or even unknown (novel) targets within the pathogen.

(i) Variations on an old theme

So far industrial approaches have been dominated by this first approach. This is obvious within the ß-lactam class of antiinfectives, e.g. the cephalosporins. Spectrum and activity of these compounds have been improved over the years and lead recently to the introduction of the fourth cephalosporin generation. Several companies are working on the development of ß-lactam antibiotics with an improved Gram-negative and Gram-positive spectrum and of novel inhibitors of ß-lactamases. Examples are the carbapenems, which are being developed by Zeneca and others, and the trinems (e.g. sanfetrinem, GV143253) which are being investigated by Glaxo/Smithkline. New generations of fluoroquinolones are also under development. These substances are characterised mainly by improved activity in the Gram-positive range and a more favourable pharmacokinetic profile. The first example, grepafloxacin (Glaxo/Smithkline), has since been withdrawn from the market (severe

1) Intervet International GmbH, Frankfurt am Main, Germany

cardiovascular side effects). Substances that remain promising are gatifloxacin (Kyorin/BMS), moxifloxacin (Bayer) and gemifloxacin (Glaxo/Smithkline).Macrolides are also being investigated. Here, too, improvements are made to the activity spectrum and the pharmacokinetic profile, i.e. primarily the duration of action. The ketolides are an example. The most advanced of these is telithromycin (HMR 3647) by Aventis, but Abbott, Kosan and Pfizer are also researching this class of substances.Another example is the introduction of Synercid® by Aventis. Synercid® is a combination of quinupristin and dalfopristin, two streptogramin antibiotics. This activity class was discovered way back in 1962, and today synercid is a key weapon in the fight against multiresistant Gram-positive pathogens.The glycylcyclines, a core research focus of AHP, should also be mentioned in this context. They are true broad-spectrum antiinfectives.

The main advantages of this approach for the industry are obvious: the resistance mechanisms are known, realistic assumptions regarding the possible product profile and commercial attractiveness can be made and the risks of unexpected efficacy and safety issues are quite low. However, a great disadvantage of this strategy is cross resistance. Unfortunately, the existence of resistance mechanisms to earlier members of the drug class often provides the organisms with a head-start for mutational adaptation by which expression of resistance to the newest member of the class also rapidly emerges. Thus, this approach can only be considered at best a temporary solution to the problem of resistance.

(ii) Recollection of the unexplored

A variety of peptides with pronounced antimicrobial properties were discovered back in the 1960s. These drugs were abandoned by the pharmaceutical industry for a variety of reasons: Their large scale production and purification was considered difficult or non-viable, there were concerns about the therapeutic utilisation of proteins and, finally, the medical need was not recognised (pre-MDR). Today biotech companies in particular are active in this area. A typical example is AMBI, who is carrying out intensive research on Nisin and Lysostaphin. Nisin is considered to have potential mainly in the treatment of clostridial and enterococcal infections. Lysostaphin is highly effective against staphylococci. Resistance development seems highly unlikely, especially in combination with ß-lactam antibiotics.

Another class of agents attracting considerable interest is the cationic peptides. They are ubiquitous in nature (>300 peptides known), evolving as a first-line defense mechanism in all higher organisms. It is particularly interesting that these substances damage the bacterial cell membrane via a novel mechanism. Most of the cationic peptides have broad-spectrum activity. Two examples of clinical candidates are Protegrin IB-367 (Intrabiotics) and pexiganan acetate (Magainin). An example of a substance with a narrower activity spectrum is BPI (human bactericidal permeability increasing protein), which XOMA is investigating. This peptide has the advantage of not only killing multiresistant Gram-negative organisms, but also of binding lipopolysaccharide. This leads to a significant reduction of the toxic effects of Gram-negative bacteria.

The reevaluation of unexplored or under-explored molecules has some obvious advantages. The discovery project starts with a defined molecule, thus enabling the sponsor to define a likely product profile. Furthermore, there is a distinct chance to establish a new class of antiinfectives with a new mode of action lacking any cross resistance to established compounds and ensuring intellectual property rights to the sponsor. However, the main shortcoming of this approach is the lack of clinical experience with the respective compound and the risk of unexpected efficacy and safety findings during development.

(iii) The classical approach

The classical screening approach determined by testing the inhibitory effect of synthetic and natural compounds or extracts in in vitro cultures has generated decreasing amounts of interesting structures. But pharmaceutical companies are adopting this approach in growing numbers. One reason is almost certainly the discovery of the oxazolidinones and daptomycin through using this very strategy. The oxacolidinones are being investigated by Pharmacia & Upjohn. Linezolid is the first representative of this class. The characteristic features of this class of compounds are: synthetically manufactured, unique mode of action, spectrum includes multiply resistant Gram-positive bacteria. Linezolid binds specifically to the 50S ribosomal subunit and inhibits the formation of a functional initiation complex. Laboratory and clinical experiments to date have shown that it is very difficult to induce resistance in bacteria to these drugs. There is no cross-resistance with known antiinfectives. Daptomycin is being investigated by Cubist. Daptomycin is a fermentation product of *Streptomyces roseosporus*. Chemically it is a lipopeptide. It, too, is characterised by a broad activity against Gram-positive pathogens, including resistant staphylococci and enterococci. Daptomycin has rapid bactericidal activity, a novel mode of action without cross-resistance to known antiinfectives and is mostly excreted actively via the kidneys. As a special side effect it confers protection against the nephrotoxic action of aminoglycoside antibiotics. In terms of effectiveness and safety Daptomycin could therefore be an ideal combination partner for this traditional group of compounds.

(iv) Target based high throughput screening

The discovery of novel agents active against existing targets or novel targets is based on the following paradigms: The genomic paradigm: genomics can identify targets on the basis of sequence comparisons and select the best targets with regard to spectrum of activity and selectivity. The target based paradigm: high throughput screening can identify molecules that bind to and inhibit a target protein, medicinal chemistry can solve problems of spectrum, cell permeability and potency of the so identified compounds. In principle, this approach allows for the identification and differentiation of in vitro and in vivo expressed genes, thus, enabling the identification of housekeeping and virulence targets and the discovery of compounds active against the respective targets. Overall, this strategy might offer the best chance to establish new classes of antiinfectives with completely new modes of action lacking any cross resistance to established compounds and ensuring intellectual property rights to the sponsor. However, the risk to fail is also significant. So far, there is no indication in the scientific literature that targets related to genes of unknown function would be more productive than known targets. Furthermore, sequence homology of a target is not necessarily predictive for the spectrum and selectivity of its inhibitors. A key success factor and thus a severe limitation of this approach will be the diversity of the chemical library used in high throughput screening.

Conclusion

With prudent use it will be possible to control the spread of the resistance problem also in the long term. The therapeutic arsenal will grow in the short and medium term by traditional approaches (i-iii). In the long term, leading edge biochemical and molecular biological methods together with bioinformatics provide a good chance of controlling bacterial infections in entirely new ways. It should even be possible to conquer bacterial infections with bacteria-friendly substances. To quote Joshua Lederberg:

"The most important change we can make is to supersede the 20th century metaphor of war for describing the relationship between people and infectious agents. A more ecologically informed metaphor which includes the germs´ eye view of infection might be more fruitful."

Strategies for avoiding health problems of farmed animals

Martin Wierup

Introduction

Sick animals should be given the best possible treatment in order to prevent suffering, death and economic losses. However, in the animal production it is too late to undertake actions first when clinical signs of disease have developed. Therefore, a health control should be established that continuously focus on disease prevention in order to avoid health problems. This summary describes elements involved in the prevention and control of infectious diseases and the strategy for their use.

Diagnose

All actions for the control of infectious diseases should be based on a proper diagnose. Access to qualified diagnostic laboratory is therefore essential. As disease preventing health control is a specialised work deep insight in the epidemiology, pathogenesis and possible ways to control occurring diseases is also needed.

Recording of disease occurrence

Control and prevention of animal diseases also require insight in disease occurrence. Suitable ways of recording occurrence of diseases should therefore be established. Especially for the health control at herd level, many valuable disease- recording systems can be based on observational results like the recording of lesions at slaughter or production data such as weight gain, pregnancy and farrowing rate. These data are often of non- etiological type but are good tools for further evaluation of possible involvement of specific infectious diseases.

Strategies for control

The causative agent to be controlled should be focused .The following model for factors influencing the occurence of infections can be used as a base for an analysis of the concepts used for prevention of infectious diseases :
MICROBIAL EXPOSURE/ INFECTIVE DOSE ------HOST DEFENCE / IMMUNITY

Microbial exposure

Prevention of infections can simply be done by the exclusion of the target animal from exposure to infectious doses of the pathogenic microbe. This can be done by:

1. Total exclusion

The most extreme and safest way to prevent an infectious disease is by eradication of the pathogenic microbe. The concept is to reach a status where exposure of the microbe can be totally excluded. An eradication procedure needs the access to an organisational capacity and technical resources necessary to stop the spread of the infection and to combat its source. This method is best exemplified by the control of the epizootic diseases (separately discussed at this work shop). From scientific and economic points of view it is also possible and justified to control also other diseases with the aim of eradication. Examples of such diseases are Aujeszky´s disease in swine and IBR in cattle and also diseases with a more complicated epidemiology like BVDV in cattle. In addition today we have the knowledge and it is economically justified to maintain an already disease- free status in an area or a herd also for other than the epizootic diseases. This can be done by preventing the introduction e.g. by control of imported animals or animal products.

If an eradication status cannot be achieved on a country basis it can be achieved on a herd basis. As part of an organized health control scheme or quality control programme, individual and specified types of herds can reach and maintain a disease- free status for certain diseases. This is usually also officially regulated for herds of special importance like boar – and bull stations as well as for hatcheries.The SPF production in swine is a special form of production where total freedom from certain infections exists.

Measures aiming at controlling and eradicating diseases are in conflict with the idea of free international trade as being continuously discussed within the EU and WTO. If these problems are not solved, the free international trade tends to result in a situation where ambitions to improve animal health are discouraged and instead we may end up in a situation where the lowest disease status of a

1) Swedish Animal Health Service,12186 Johanneshov, Sweden

participating country will be considered as the standard.

2. Partial exclusion

The methods used for total prevention of microbial exposure are needed also for actions aiming at decreasing the intensity of animal exposure to pathogenic microbes. In the latter case, additional health supporting actions are also needed.
All the measures, as exemplified below, needed to control infections by microbes being prevalent in animal production also have to be continuously implemented and improved in contrast to measures in an eradication programme. The latter can largely be withdrawn when the eradication status has been achieved.

The theoretical concept for the disease preventing method is to obtain a microbial exposure that is below the infective dose, or decreased to such an extent that immunity is induced but no clinical disease occurs in exposed animals. Doing so, a possible further spread of the infectious agent from the primarily exposed animals is limited to such an extent that secondary clinical outbreaks in contact animals are prevented. Some methods empirically and/ or scientifically found to work along this concept are: optimize hygiene, isolation of sick animals, do not introduce sick animals in a herd and the replacement of live breeding animals by semen and embryos.

Antibiotics

Antibimicrobials can decrease or eliminate pathogens, so far primarily only bacteria and parasites. Due to the emergence of antibiotic- resistant strains control of bacterial infections can not uncritically be based only upon the use of antibiotics. The use of antibiotics in animals is also a real and potential threat to human health. The implementation of disease prevention measures in animal production as a means to decrease the need for the use of antimicrobials is therefore strongly recommended. This recommendation is further supported because of the limited acess or possible ban to use antibiotics for growth promoting purposes. The use of antibiotics should thus be considered as an integrated and usually the last part of the other disease- preventive methods, and should be used until the others have failed, and not as a replacement for them.

Host resistance

An optimal physiological general resistance of healthy animals should be full filled by correct feeding housing and other environmental factors. In addition natural defence mechanisms are enhanced by the use of vaccination. Immunodeficient diseases like Bovine Virus Diarrhoea, Bovine leucosis in bovines as Aujeszky´s disease in pigs decrease the resistance. Control and erradication of such diseases thus have a significant health supporting effects beyond the direct losses due the absence of clinical disease caused by those diseases.

Combinations

The production systems of animal husbandry usually combine several of the above principles in order to optimize the disease- preventing effect. Examples are the all- in all- out system is to prevent the spread of infections between consecutive groups of animals raised in the same unit. In contrast to the continuous production the all in all out system facilitates the cleaning and disinfection between batches, which is a further step to minimize the spread of pathogens from older growing animals to new ones.

A further development of this concept is age-segregated batch production In the multi- site production of swine the concepts of age- segregated production and all- in all- out system are combined, and when the piglets being weaned at 2-3 weeks, segregated early weaning (SEW), also with the use of the protection given by the maternal immunity. As movement of pigs (and most likely also of other animal species) has a negative impact on growth rate the FTS (farrow- to finish) – production offers a stress reduced alternative system to multi- site production. In the FTS- system the pigs are placed in the same pen from birth to slaughter.

The significance of the measures exemplified above can be better understood when considering that most infectious diseases caused by one specific microbe usually primarily have a multifactorial course. All factors thus decreasing the risk of an infection becoming established will contribute to an improved health situation in individual animal and on a herd basis.

Implementation

The intelligent use of the wide panorama of available disease preventive measures, as exemplified above, easily contributes to a good health situation and improved economy of animal production. The implementation on both herd and national level needs close co-operation between producer, stakeholders, vets and responsible authorities and sometimes also consumers. Economic incitements are usually a driving force. Ideally a disease preventing health control should be driven from the producer. At herd level basic hygienic routines should first be implemented and an initial focus on prevention of one disease complex usually has a positive impact also on the general health situation and leads to increased ambitions. Disease preventing health controls is a continuously ongoing process with the object to maintain and improve animal health.

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Summary animal health

Lorne Babiuk, Marian C. Horzinek, Ruth Lysons, Volker Moennig, Jos. P. Noordhuizen, Peter Schmid, Stefan Schwarz, Jorgen M. Westergaard and Martin Wierup

One of the most crucial parameters in modern animal husbandry and production is animal health. Animal welfare, consumer protection and economic success are directly linked to the health status of farm animals. In addition poor animal health seriously damages the public image of animal production. Major factors influencing animal health, i.e. housing, breeding and feeding were subject of other workshops in the series "Sustainable Animal Production". This workshop dealt with treatment and prophylaxis of health problems of farm animals due to infectious diseases. For this purpose the field was subdivided in several areas:

- Major health problems of farmed animals caused by infectious agents
- Emerging and reemerging diseases
- List A diseases: Threat and control
- Antibiotic resistance
- Progress in the diagnoses of infectious diseases
- Modern vaccines
- New antiinfective drugs
- Strategies to avoiding health problems of farmed animals

Major health problems of farmed animals caused be infectious agents

Endemic infectious have a considerable negative impact on the profit of animal production and there are large variations in animal health status between the different EU member states, countries, regions and even farms. Factors contributing to this phenomenon are the prevailing differences in husbandry systems, marked differences in management quality levels, the highly intensified production, the physiologically marginal potential of food animals to cope with all kind of stresses including infectious agents and the largely monotrait focussed genetic selection programmes. Special attention should be given to food animals affected by metabolic stress. This is a relative problem, largely provoked by one-sided genetic selection on productivity mainly. As a result of this metabolic stress (e.g. after calving or around piglet weaning), endocrinological, neurological and immunological functions are impaired. This may ultimately result in increased disease susceptibility paving the way for a number of facultatively pathogenic micro organisms causing disease. Apart from these multi-factorial infectious diseases several endemic mono-causal infectious agents, e.g. Aujeszky's disease, influenza, paratuberculosis and IBR/IPV give rise to serious
economic losses. A serious public health issue is the fact that modern livestock production carries implicitly the risk of presence of carriers of zoonotic agents, e.g. salmonella and Streptococcus suis II, representing a potential risk for man, sometimes even without causing overt disease in animals.

Emerging and reemerging diseases

Outbreaks of so far unknown diseases, e.g. BSE, paramyxovirus infections in horses and pigs in Australia, zoonotic H5N1 influenza in Hong Kong and AIDS in man, have drawn our attention to the subject of emerging diseases. Today we know that new diseases will strike time and again, and their causative agents will be identified ever more quickly, either as being well-known agents that have undergone subtle genetic changes, or as recombinants with other viral or cellular genes. They may also turn out to be really new, hitherto undiscovered agents. Every now and then, one of the emerging agents might turn out to be a 'killer' virus wreaking havoc – either to be controlled by veterinary efforts or peter out in virulence to become a harmless commensal. It is save to assume that high animal population densities combined with the close proximity of different species could play a favourable role in the emergence of new diseases. One classical example of a re-emerging disease is tuberculoses, once though to be well under control.

List A diseases: Threat and control

List A disease are defined by the World organisation for animal health (Office International des Epizooties, OIE, located in Paris) as transmissible diseases which:

- have the potential for very serious and rapid spread, irrespective of national borders;
- are of serious socio-economic or public health consequence,

- are of major importance in the international trade of animals and animal products.

The List A comprises at present (2000) 14 predominantly viral diseases. The reservoir of List A disease agents in wildlife and in domestic animal populations, the route and the mode of disease transmission play a major role, when evaluating disease threat and deciding on control measures to be applied. The threat or risk of a List A disease entering a suspectible domestic animal population can arise from several possible sources and it is imperative to assess the risk. Whenever possible this type of assessment should be based on a quantitative risk-analysis, which gives a transparent, objective and defensible estimate of the risk posed by a particular action. A precondition for success in the control of a List A disease outbreak includes a comprehensive and well-rehearsed contingency plan. The plan must clearly describe: the legal power held as regards disease notification, stamping-out, payment of compensation, movement controls, vaccination and use of penalties. Other aspects of the plan refer to the chain command; the establishment and operation of disease control centres; the use of diagnostic laboratories; training of staff and publicity. In the long-term measures of importance for better disease control include: increased disease surveillance; better protection measures at farm level and protection measures relating to movement of animals.

Antibiotic resistance

The ability to treat bacterial infections in animals and man with chemotherapeutic agents represents one of the most important medical achievements of the twentieth century. However, as a result of the exposure of bacteria to antimicrobial agents, a large number of genes and mutations associated with antimicrobial resistance has been developed and the introduction of an antimicrobial agent into clinical use in both humans and animals has been either accompanied or followed shortly by the occurence of resistant bacteria underlining the extraordinary capacity of bacteria to quickly and efficiently respond to the selective pressure imposed by the use of antimicrobials. In recent years, bacteria have also shown to be able to develop resistance to completely synthetic substance and resistance to several antimicrobial agents as well as against disinfectants, heavy metals or nucleic acid binding substances, respectively. As a consequence of he widespread use o antimicrobial agents in all fields of medicine food producing animals as well as pets and humans can act as a reservoir of resistant bacteria. Of particular interest if not concern is the ability of a few multiresistant bacteria with pathogenic potential for humans to cross from their animal hosts to humans via the food chain. Among them subspecies of Salmonella enterica, Campylobacter spp. as well as Enterococcus spp. are suspected as human pathogens. However, in the public perception this problem is largely overestimated. Based on the present evidence, antimicrobial use in animals mainly causes resistance problems in animals while antimicrobial use in humans mainly accounts for the resistance problems encountered in human medicine. With the exception of the afore mentioned resistant zoonotic pathogens, both disciplines are mainly responsible for their own "home-made" resistance problems. The real problems of veterinary medicine are the increase in number of resistant bacteria in animals and the banning of some antiinective drugs. New antiinfective drugs are reserved for human medicine only.

Progress in the diagnoses of infectious diseases

A prerequisite for the control of infectious disease in animals is the availability of suitable, i.e. reliable, sensitive and inexpensive diagnostic tests. The main reasons for use of diagnostic tests in farm animals are for individual animal diagnoses, herd investigations, disease control or disease surveillance. In countries with a highly developed agriculture the requirement for farm animals is increasingly for large-scale surveillance programmes. These are usually designed with a mathematical basis to answer specific epidemiological questions. In several European countries there is currently a particular emphasis on surveillance of livestock for prevalence of specified food borne zoonoses such as salmonella, E. coli O157. Large-scale testing requires cheap and robust tests. The enormous progress in biomedical technology during the last two decades made the development of novel tests possible, including sensitive genetic analyses for different purposes, e.g. the selection of sheep resistant to Scrapie or the rapid identification of dangerous pathogens, respectively. Internal and external quality assurance of testing is essential and will increasingly be implemented using independent accreditation, e.g. ISO 9000 or ISO 17025.

Modern vaccines

Successful vaccination against infectious diseases has been practised for over 200 years, and it is safe to assume that vaccination is the most cost-effective method of reducing animal suffering and economic losses due to infectious diseases in animals. However, even with these successes, infectious diseases continue to be of economic significance to society in reduced productivity and animal death. The advent of genomics, proteomics, and biotechnology, combined with our understanding of pathogenesis and immune responses to various pathogens provides us with an unprecedented opportunity to develop safer and more effective vaccines for many pathogens. In addition to using vaccines to cure infectious diseases of animals, it is also possible to immunise animals against various hormones and cellular proteins to improve growth and alter reproductive efficiency. Different types of genetically engineered vaccines are presently at different stages of development, clinical trials, or licensing. They include: 1) live vaccines, 2) live chimeric vaccines, 3) live replication-defective vaccines, 4) subunit vaccines, 5) peptide vaccines in various modifications of monovalent, multivalent, or chimeric subunit vaccines delivered as individual components or incorporated into virus-like particles for improved immunogenicity, and 6) polynucleotide vaccines. However, despite alle promising developments the common knowledge that "However smart we are, microorganisms are smarter than us" might still be true in the future.

New antiinfective drugs

The driving force in the search for new drugs is the human health sector. We can therefore realistically expect that in the medium term this is where new antiinfectives for animals will come from. In the medium term, as in the past, the animal health industry will therefore rely primarily on spin-offs from the human sector.

Four principal drug discovery approaches are employed in the search for new antiinfectives, namely,

- the expansion of known drug classes to cover organisms resistant to earlier members of the class, i.e. the development of new variations of known antibiotics, e.g., cephalosporins, ß-lactams or macrolides. Apart from some short term advantages the main disadvantage of this strategy is cross resistance. Thus, this approach can only be considered at best a temporary solution to the problem of resistance.
- the reevaluation of un(der)explored molecules, especially a variety of synthetic and naturally occuring peptides with antiinfective activity is a promising approach for a new class of antiinfectious agents
- the classical screening of synthetic compounds and natural compounds isolated from fermentation broths of microorganisms, plants or other organisms
- and the identification of novel agents active against previously not-exploited or even unknown (novel) targets within the pathogen using the tools provided by genomics, proteomics, bioinformatics and high throughput screening of substances against known targets.

With prudent use it will be possible to control the spread of the resistance problem also in the long term. The therapeutic arsenal will grow in the short and medium term by traditional approaches (i-iii). In the long term, leading edge biochemical and molecular biological methods together with bioinformatics provide a good chance of controlling bacterial infections in entirely new ways.

Strategies for avoiding health problems of farmed animals

So far disease risk management is an underestimated instrument in disease combat programmes while emphasis has been on vaccination and medication. Of course sick animals should be given the best possible treatment in order to prevent suffering, death and economic losses. However, in the animal production it is too late to undertake first when clinical signs of disease have developed. Therefore, a health control scheme should be established that continuously focuses on disease prevention in order to avoid health problems. Appropriate measure can be summarised as follows:

- profound knowledge about and proper diagnosis of infectious diseases
- eradication of epizootic diseases, e.g. list A infections
- control, reduction or elimination of non-epizootic diseases on all levels of animal production, e.g., combat sources of infection, decrease of exposure, optimising hygiene, prudent use of antimicrobial treatment
- improve host resistance by e.g., breeding, optimal nutrition, optimal housing and ventilation, good management (e.g. all in all out), reduction of stress
- boost Immunity by e.g., vaccination, good maternal immunity, control of immunosuppressive diseases

The significance of the measures exemplified above can be better understood when considering that most infectious diseases caused by one specific microbe usually primarily have a multifactorial course. All factors thus decreasing the risk of an infection becoming established will contribute to an improved health situation in individual animal and on a herd basis.

Conclusion:

The intelligent use of the wide panorama of available disease preventive measures, as exemplified above, easily contributes to a good health situation and improved economy of animal production. The implementation on both herd and national level needs close co-operation between producer, stakeholders, vets and responsible authorities and sometimes also consumers. Economic incitements are usually a driving force and ideally a disease preventing health control should be driven from the producer. At herd level basic hygienic routines should first be implemented. Disease preventing health controls is a continuously ongoing process with the object to maintain and improve animal health.

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