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Pain in farm animals

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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

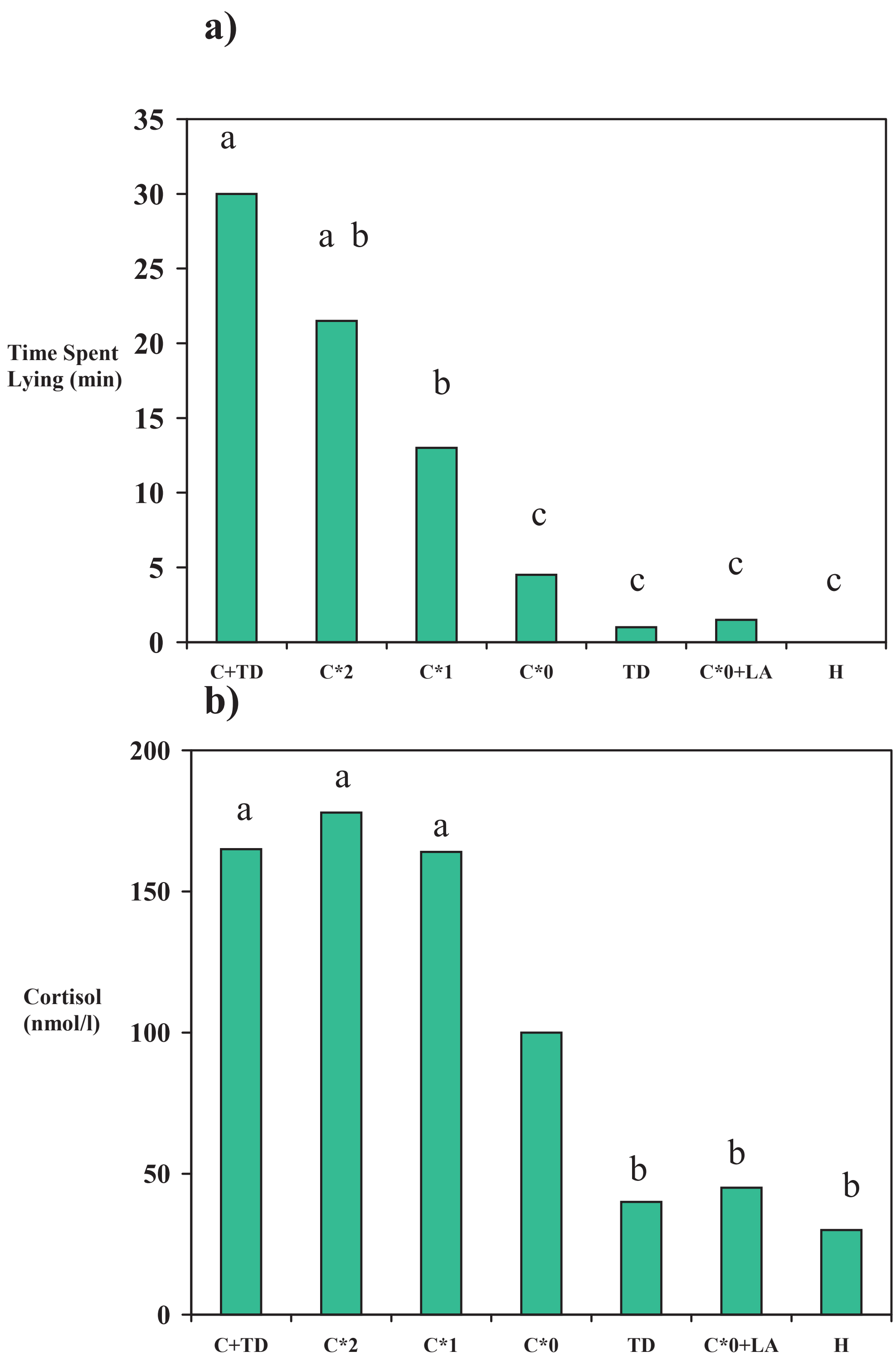

Figure 1. Responses of groups of 5- to 6-d-old crossbred lambs (n=7) to the following treatments of decreasing severity:castration and tail docking (C+TD); bilateral castration (c*2); unilateral castration (C*1); short scrotum castration (C*0); tail docking (TD); short scrotum castration and local anaesthesia (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).

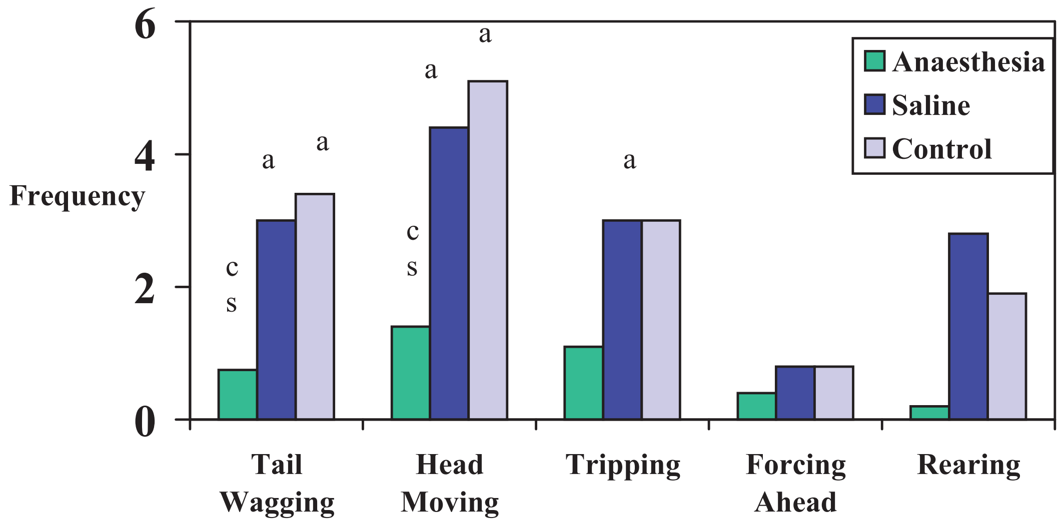

Figure 2. Frequency of behaviours (mean) in calves during dehorning after previous local anaesthesia, saline injection or untreated control. Significance:(a) differ significantly (P <0.05) from anaesthesia group, c) differ significantly from control group (s) differ significantly from saline group (Adapted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

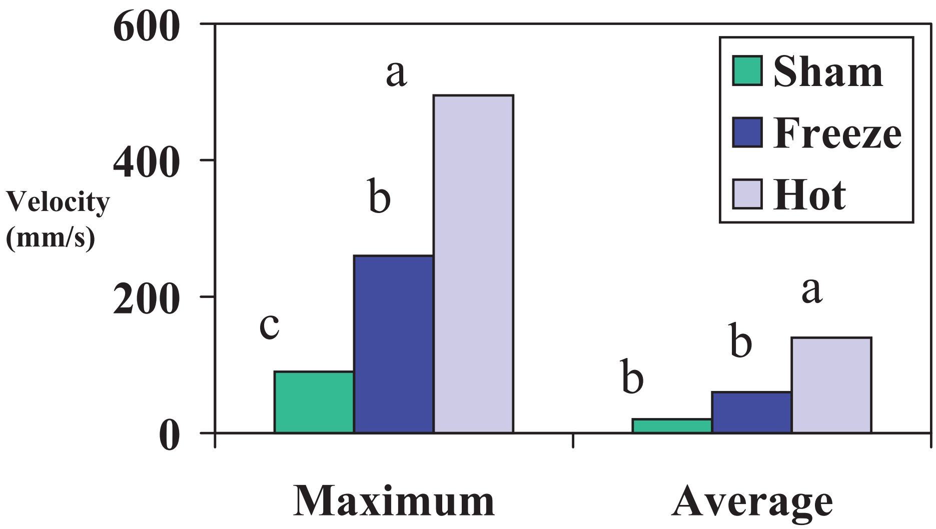

Figure 3. Maximum and average velocities of head movements measured by image analysis for sham, freeze, and hot iron-branded steers (n=11 per treatment). Means with the same letter (a, b, c) are not different (P >0.05; Adapted from Schwartzkopf-Genswein et al. 1998).

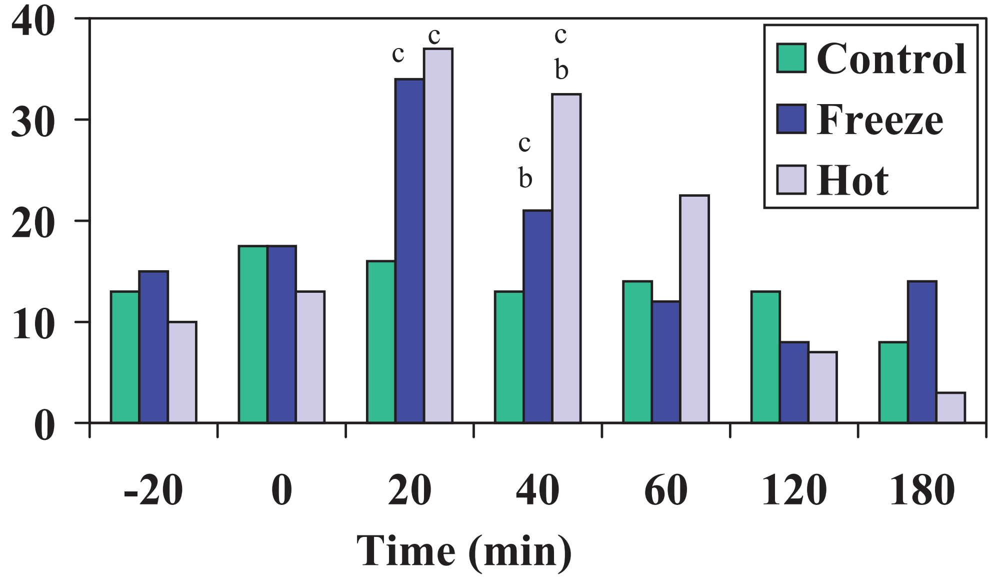

Figure 4. Mean plasma cortisol response of heifers before exposure to freeze or hot iron-branding and after exposure up to 180 min. Control values were obtained from heifers which were not branded. Significance: c) significantly different from control values (P <0.05); b) Significant difference between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

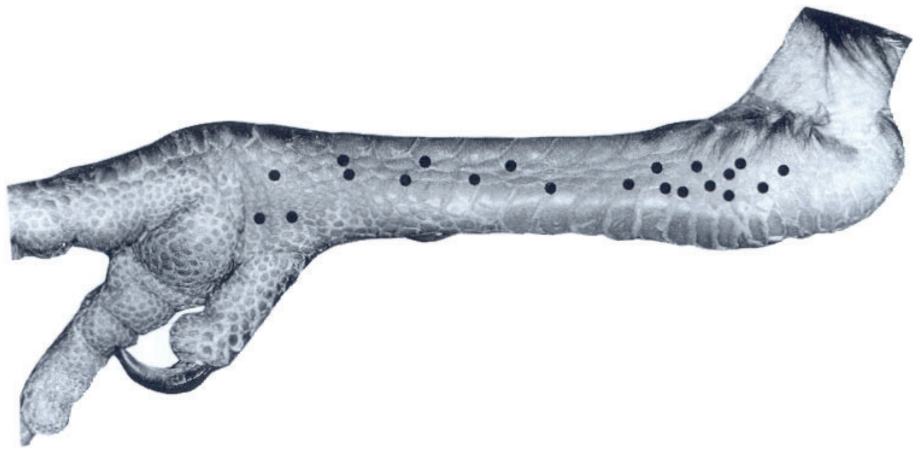

Figure 5. Lateral view of the skin over the tarsometatarsus showing positions of the centres of the receptive fields (1) of each of the nociceptors tested in eight chickens (Taken from Gentle & Tilston 2000).

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.

References

Alban L, Agger JF, Lawson LG (1996) Lameness in tied Danish dairy cattle: The possible influence of housing systems, management, milk yield and prior incidents of lameness. Prev. Vet. Med. 29 (2), 135-149

Barnett JL, Coleman GJ, Hemsworth PH, Newman EA, Fewings Hall S, Ziini C (1999) Tail docking and beliefs about the practice in the Victorian dairy industry. Aus. Vet. J. 77 (11), 742-747

Bateson P (1991) Assessment of pain in animals. Anim. Behav. 42 (5), 827-839

Bath GF (1998) Management of pain in production animals. App. Anim. Behav. Sci. 59 (1-3), 147-156

Breward J, Gentle MJ (1985) Neuroma formation and abnormal afferent nerve discharges after partial beak amputation (beak trimming) in poultry. Experientia, 41 (9),1132-1134

Calavas D, Bugnard F, Ducrot C, Sulpice P (1998) Classification of the clinical types of udder disease affecting nursing ewes. Small Rum. Res. 29, 21-31

Corr SA (1999) Avian gait analysis. Ph.D Thesis, University of Glasgow, pp 269

Cottrell DF, Molony V (1995) Afferent activity in the superior spermatic nerve of lambs: The effects of application of rubber castration rings. Vet. Res. Comm. 19, 503-515

Danbury TC, Weeks CA, Chambers JP, Waterman-Pearson AE, Kestin SC (2000) Self-selection of the analgesic drug carprofen by lame broiler chickens. Vet. Rec. 146, 307-311

Duncan IJH, Beaty ER, Hocking PM, Duff SRI (1991) Assessment of pain associated with degenerative hip disorders in adult male turkeys. Res. Vet. Sci. 50, 200-203

Esslemont RJ (1990) The cost of lameness in dairy herds. Update in cattle lameness. Proc. 6th Int. Symp. On Diseases of the Ruminant Digit, Liverpool, 237-251

Fraser D, Duncan IJH (1998) "Pleasures", "pains" and animal welfare: Toward a neutral history of effect. Anim. Welfare 7 (4), 383-396

Gentle MJ (1989) Cutaneous sensory afferents recorded from the nervus intramandibularis of Gallus gallus var domesticus. J. Comp. Physiol. A. 164 (6), 763-774

Gentle MJ, Breward J (1986) The bill tip organ of the chicken (Gallus gallus var. domesticus). J. Anat. 145, 79-85

Gentle MJ, Hunter LN, Corr SA (1997) Effects of caudolateral neostriatal ablations on pain-related behaviour in the chicken. Physiol. Behav. 61 (4), 493-498

Gentle MJ, Hunter LN, Waddington D (1991) The onset of pain related behaviours following partial beak amputation in the chicken. Neurosci. Lett. 128 (1), 113-116

Gentle MJ, Tilston VL (2000) Nociceptors in the legs of poultry: implications for potential pain in pre-slaughter shackling. Anim. Welfare 9 (3), 227-236

Gonyou HW (1994) Why the study of animal behaviour is associated with the animal welfare issue. J. Anim. Sci. 72 (8), 2171-2177

Graf B, Senn M (1999) Behavioural and physiological responses of calves to dehorning by heat cauterization with or without local anaesthesia. App. Anim. Behav. Sci. 62 (2-3), 153-171

Hassall SA, Ward WR, Murray RD (1993) Effects of lameness on the behaviour of cows during the summer. Vet. Rec. 132 (23), 578-580

Haussmann MF, Lay DC, Buchanan HS, Hopper JG (1999) Butorphanol tartrate acts to decrease sow activity, which could lead to reduced pig crushing. J. Anim. Sci. 77 (8), 2054-2059

Hemsworth PH, Barnett JL, Beveridge L, Matthews LR (1995) The welfare of extensively managed dairy cattle – a review. App. Anim. Behav. Sci. 42 (3), 161-182

Jacobsen KL (1996) The well-being of dairy cows in hot and humid climates. 2. Reducing stress. Compend. Contin. Edu. Prac. Veterin. 18 (9), s242-250

Kent JE, Jackson RE, Molony V, Hosie BD (2000) Effects of acute pain reduction methods on the chronic inflammatory lesions and behaviour of lambs castrated and tail docked with rubber rings at less than two days of age. Vet. J. 160 (1), 33-41

Kestin SC, Knowles TG, Tinch AE, Gregory NG (1992) Prevalence of leg weakness in broiler chickens and its relationship with genotype. Vet. Rec. 131, 190-194

Lay DC, Friend TH, Grissom KK, Bowers CL, Mal ME (1992) Effects of freeze or hot-iron branding of angus calves on some physiological and behavioral indicators of stress. App. Anim. Behav. Sci. 33 (2-3), 137-147

Ley SJ, Livingston A, Waterman AE (1991) Effects of chronic lameness on the concentrations of cortisol, prolactin and vasopressin in the plasma of sheep. Vet. Rec. 129 (3), 45-47

Ley SJ, Waterman AE, Livingston A, Parkinson TJ (1994) Effect of chronic pain associated with lameness on plasma cortisol concentrations in sheep – a field study. Res. Vet. Sci. 57 (3), 332-335

McGeown D, Danbury TC, Waterman-Pearson AE, Kestin SC (1999) Effect of carprofen on lameness in broiler chickens. Vet. Rec. 144 (24), 668-671

McGlone JJ, Nicholson RI, Hellman JM, Herzog DN (1993) The development of pain in young pigs associated with castration and attempts to prevent castration induced behavioral changes. J. Anim. Sci. 71 (6), 1441-1446

Molony V, Kent JE (1997) Assessment of acute pain in farm animals using behavioral and physiological measurements. J. Anim. Sci. 75 (1), 266-272

Molony V, Kent JE, Fleetwood-Walker SM, Munro F, Parker RMC (1993) Effects of xylazine and L659874 on behaviour of lambs after tail docking. Proc. 7th IASP World Cong. On Pain, Paris, p 80

Ong RM, Morris JP O'Dwyer JK, Barnett JL, Hemsworth PH, Clarke IJ (1997) Behavioural and EEG changes in sheep in response to painful acute electrical stimuli. Aust. Vet. J. 75 (3), 189-193

Riley CB, Farrow CS (1998) Partial carpal arthrodesis in a calf with chronic infectious arthritis of the corpus and osteomyelitis of the carpel and metacarpel bones. Can. Vet. J. 39 (7), 438-441

Rushen J, Foxcroft G, DePassille AM (1993) Nursing-induced changes in pain sensitivity, prolactin and somatotropin in the pig. Physiol. Behav. 53 (2), 265-270

Shearer JK, Hernandez J (2000) Efficacy of two modified non-antibiotic formulations (Victory) for treatment of papillomatous digital dermatitis in dairy cows. J. Dairy Sci. 83 (4), 741-745

Schwartzkopf-Genswein KS, Stookey JM (1997) The use of infrared thermography to assess inflammation associated with hot-iron and freeze branding in cattle. Can. J. Anim. Sci. 77 (4), 577-583

Schwartzkopf-Genswein KS, Stookey JM, Crowe TG, Genswein BMA (1998) Comparison of image analysis, exertion force and behaviour measurements for use in the assessment of beef cattle responses to hot-iron and freeze branding. J. Anim. Sci. 76 (4), 972-979

Schwartzkopf-Genswein KS, Stookey JM, dePassille AM, Rushen J (1997) Comparison of hot-iron and freeze branding on cortisol levels and pain sensitivity in beef cattle. Can J. Anim. Sci. 77, 369-374

Sparrey JM, Kettlewell PJ (1994) Shackling of poultry – is it a welfare problem? World's Poultry Sci. J. 50 (2), 167-176.

Thornton PD, Waterman-Pearson AE (1999) Quantification of the pain and distress responses to castration in young lambs. Res. Vet. Sci. 66 (2), 107-118

Weary DM, Braithwaite LA, Fraser D (1998) Vocal responses to pain in piglets. App. Anim. Behav. Sci. 56 (2-4), 161-172

Weary DM, Fraser D (1995) Signalling need – costly signals and animal welfare assessment. App. Anim. Behav. Sci. 44 (2-4), 159-169

Whay HR (1997) Pain in the lame cow. Vet. Rec. 50 (10), 603-609

Wood GN, Molony V, Fleetwood-Walker SM, Hodgson JC, Mellor DJ (1991) Effects of local anaesthesia and intravenous naloxone on the changes in behaviour and plasma concentrations of cortisol produced by castration and tail docking with tight rubber rings in young lambs. Res. Vet. Sci. 51, 193-199

Yeruham I, Avidar Y, Bargai U, Adin G, Frank D, Perl S, Bogin E (1999) Laminitis and dermatitis in heifers associated with excessive carbohydrate intake: skin lesions and biochemical findings. J. Sth. Afr. Vet. Ass. 70 (4), 167-171

Zanella AJ, Broom DM, Hunter JC, Mendl MT (1996) Brain opioid receptors in relation to stereotypies, inactivity, and housing in sows. Physiol. Behav. 59 (4-5), 769-775

Zimmerman M (1986) Physiological mecanisms of pain and its treatment. Klinische Anästhesiologie und Intensivtherapie, 32, 1-19