Investigation of the Use of Analgesics at the Time of

Castration and Tail-docking and Following Parturition

for Improving Performance and Reducing Pain in Pigs

by

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ABSTRACT

INVESTIGATION OF THE USE OF ANALGESICS AT THE TIME OF
CASTRATION AND TAIL-DOCKING AND FOLLOWING PARTURITION
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A number of routine painful procedures such as castration and tail-docking are currently performed in swine production without the benefit of anaesthesia or analgesia. In addition, parturition is generally considered painful. Providing analgesics at the time of castration and tail-docking lowered plasma cortisol levels of the piglets suggesting a reduction in pain associated with the procedures. The use of the non-steroidal antiinflammatory drug meloxicam also resulted in less isolated behaviour of male piglets following castration. Providing meloxicam routinely following parturition did not result in reduced neonatal mortality or piglet growth, but lowered plasma cortisol suggesting a reduction in pain. Producers in the future may need to consider using pain control as part of their standard operating procedures in order improve piglet welfare and meet their consumers' expectations, but are unlikely to see an economic return associated with improved productivity.

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CHAPTER 1: GENERAL INTRODUCTION AND LITERATURE REVIEW

1.1 General Introduction

A number of routine, painful procedures are currently carried out in swine production. Tail-docking and castration are both routine procedures performed during the piglets' first week of life. Despite evidence suggesting that both castration (Hay et al., 2003) and tail-docking (Noonan et al. 1994) causes pain, the use of anaesthesia or analgesia is not routinely practiced. In addition, pain may persist for several days (Hay et al., 2003) with the potential to cause reduced milk intake, reduced immune capacity, and lowered welfare (Hansson et al., 2011). The lack of pain control associated with these procedures is of growing scientific and public concern (Keita et al., 2010). It would be beneficial to pig welfare and the swine industry to develop commercially viable ways to reduce the pain associated with these routine procedures (Sutherland et al., 2011a).

Parturition is regarded as painful in any species (Mainau and Manteca, 2011) and is considered an important welfare issue in the swine industry due to the lack of pain control associated with the process. However, there is limited research relating to parturition pain in sows and its impact on health, welfare, and productivity (Mainau and Manteca, 2011). Providing pain relief after parturition may prove useful in alleviating sow discomfort in the immediate post-farrowing period and result in improved performance such as reduced preweaning mortality and heavier weaning weights.

Public concern over the welfare of farmed animals has increased in recent times, with pain management and its alleviation being important components of animal welfare (Anil et al., 2006). Fortunately, new products that are licensed for food-producing animals and that offer benefits as far as pain control are becoming available to pork producers. For example, non-

steroidal antiinflammatory drugs (NSAID) such as meloxicam and ketoprofen have been introduced for use in swine in several countries and may prove useful in the treatment of pain associated with routine management practices and parturition. This provides an opportunity to address a major welfare concern regarding the swine industry's need to perform certain painful surgical procedures on piglets such as castration and tail-docking, as well as provide pain control in the case of a difficult parturition.

1.2 Boar taint

Boar odour, or boar taint, is an unpleasant odour associated with heated fat from entire male pig carcasses (Aldal et al., 2005). Androstenone and skatole are regarded as the main contributors to boar taint in pork and these compounds accumulate in the adipose tissue of the male pig during sexual development (Dunshea et al., 2001). Produced and secreted by the testes, androstenone is a steroid hormone with a urine-like odour (Aldal et al., 2005). Skatole is produced by bacteria in the large intestine through the degradation of tryptophan and produces a fecal-like odour (Aldal et al., 2005). Boar taint has been shown to have negative effects on consumer perception of pork quality, but differences exist between people with regard to the levels of the compounds which cause dissatisfaction (Dunshea et al., 2001). In general, Orientals are more sensitive than other ethnic groups and women are more likely to find the smell objectionable than men (Dunshea et al., 2001).

The incidence of boar taint in entire males is highly variable and depends on numerous factors including housing, feeding, management, and slaughter weight (Leidig et al., 2009). Genetic factors and sexual development are the major factors affecting androstenone levels with increasing levels during growth and sexual development, although great variability exists

between individual animals (Aldal et al., 2005). On the other hand, feeding and rearing play important roles with regards to skatole levels (Aldal et al., 2005). The prevalence of pigs with high levels of skatole and androstenone slightly increases with increasing carcass weight, suggesting that slaughtering pigs at an earlier age or low slaughter weight may reduce or eliminate the problem of boar taint (Aldal et al., 2005). However, active steroidogensis as indicated by circulating testosterone may be found in pigs as light as 55kg (Dunshea et al., 2001). Pigs capable of producing high concentrations of testosterone also have the potential to produce androstenone, and therefore, may have detectable levels of taint in the carcass (Dunshea et al., 2001). Thus, although the incidence of boar taint may be reduced by slaughtering boars at lower weights, it will not guarantee meat that is free of boar taint (Dunshea et al., 2001).

Boar taint is generally prevented by castration of male piglets before the onset of sexual maturity (Dunshea et al., 2001). However, castration has adverse effects on production characteristics and requires considerable labour input (Aldal et al., 2005). There is increasing concern regarding castration based on animal welfare grounds, providing motivation for research in this area (Aldal et al., 2005).

1.3 Surgical castration

A number of painful procedures are currently carried out in livestock farming practice for purposes associated with the prevention of injurious behaviour, animal identification, improving management ease, or enhancement of product quality (Edwards et al., 2009). The most widespread amongst these practices is castration of male animals, performed in most species to avoid unwanted breeding, prevent the development of undesired and injurious male sexual behaviours, and prevent the development of unpalatable odours and flavours in the meat of males

(Edwards et al., 2009). It is common for pigs to be surgically castrated within the first week of life in the absence of any anaesthesia or post-operative analgesia (Baumgartner et al., 2010). However, this practice in piglets is of growing scientific and public concern due to the welfare issues associated with the procedure (Keita et al., 2010). Castration induces both behavioural and physiological responses indicative of pain, in addition to the stress and discomfort prior to, during, and following the procedure (Hay et al., 2003).

There is considerable variation in how castration is performed (Taylor and Weary, 2000) with a wide variation in the timing, methods, and extent of pain relief used in practice (Edwards et al., 2009). Surgical castration involves several events likely to be painful including scrotal incision, extraction of the testes, and severing the spermatic cords (Taylor and Weary, 2000). Surgical castration is more commonly performed using two incisions compared to one incision with 78% and 22% of producers performing castration in this way, respectively (Fredriksen et al., 2009). When two incisions are used, they are of longitudinal direction with each incision used for the removal of the respective testicle, whereas when a single incision is made, it is in a transverse direction allowing the extraction of both testicles (Fredriksen et al., 2009). Two common techniques are used for severing the spermatic cords; cutting the cords with a scalpel, or tearing the cords by pulling on the testicles (Hay et al., 2003; Taylor and Weary, 2000). Tearing the spermatic cords is believed to reduce bleeding compared to the clean cut of a scalpel blade, but healing may be more difficult due to a more ragged lesion (Hay et al., 2003; Taylor and Weary, 2000). Comparisons between the two techniques are limited (Hay et al., 2003), but Taylor and Weary (2000) found that piglets do not vocally respond differently to these two methods of severing suggesting that both methods inflict a similar level of pain on the piglet. However, Taylor and Weary (2000) also suggest a possibility of a ceiling to a piglet's ability to

vocalize and these two methods both evoke a maximum response. Alternative methods of restraining the piglet (Weary et al., 2006) or performing the surgery (Taylor and Weary, 2000) have been found to be no less painful.

Husbandry recommendations for performing on-farm surgical procedures such as castration and tail-docking within the first few weeks of life have largely been based on the long-standing assumption that neonatal animals have a reduced ability to perceive pain (Taylor et al., 2001). Ideally, piglets should be castrated at the age that causes the least amount of stress for the piglet for both animal welfare and economic reasons (Kielly et al., 1999). However, type of operation and available labour resources determine the age at which pork producers castrate pigs (McGlone et al., 1993), with producers typically castrating at a time that their labour and resources allow (Kielly et al., 1999). It is common for piglets to be castrated at 3-5 days of age or at 10-14 days of age in the Ontario swine industry (Kielly et al., 1999). Producers typically decide to castrate piglets at an early age (3-5 days) when iron is given in an attempt to reduce labour (Kielly et al., 1999). However, some producers find castrating piglets at an early age difficult due to the small testicle size and may decide to castrate at a later age (10-14 days) when they find castration to be technically easier and inguinal hernias are larger and easier to identify, reducing the potential for castration-associated mortality (Kielly et al., 1999). Current Canadian recommended code of practice for the care and handling of farm animals recommends that piglet castration should be performed before 3 weeks-of-age.

Suitable methods that reduce pain caused by surgical castration and alternatives to surgical castration are being explored by the pig production sector (Hansson et al., 2011). Some European countries such as Norway, the Netherlands and Switzerland have banned surgical castration in the absence of anaesthesia due to either national legislation or market-driven

initiatives run by major retail companies (Roest et al., 2009). Norwegian legislation, from 2002, states that anaesthesia is mandatory for surgical castration and only veterinarians may perform the procedure (Aldal et al., 2005). The intention of the Norwegian government was to completely ban castration by 2009, but this has been postponed indefinitely since acceptable alternative solutions to eliminate boar taint are still not available (Fredriksen et al., 2011). Surgical castration in the absence of anaesthesia is increasingly perceived as a practice to be banned within the European Union in the near future because of the animal welfare implications (Roest et al., 2009). Pork producers would rather not have to perform routine castration as it requires labour and intact boars produce leaner carcasses (McGlone and Hellman, 1988). However, routine castration of male piglets is necessary as consumers discriminate against meat with a boar odour (McGlone and Hellman, 1988). In Canada, there is no market for intact males so producers have no choice when it comes to castration. In addition, there are serious welfare concerns regarding the raising of aggressive, intact males as injury from fighting is higher (Baumgartner et al., 2010).

It is not clear whether surgical castration of male piglets has an impact on their weight gain in the subsequent few weeks following the procedure (Keita et al., 2010). There are mixed results in the literature. Keilly et al. (1999) found that early castration, or castration at 1-3 days of age, results in a temporary reduction in weight gain suggesting that 1 to 3-day-old pigs are susceptible to the negative impacts of castration. However, difference in weight gains between castrates and controls were absent by the time of weaning suggesting that there are no long-term negative implications of early castration. Similarly, McGlone et al. (1993) found that weight gain was greater in male pigs when they are castrated at 14 days of age rather than at 1 day of age. A possible explanation for this may be that piglets take around 48 hours to become established on a

nipple, and when this establishment within the litter is disrupted it can have negative effects on weight gain (Hay et al., 2003; Kielly et al. 1999; McGlone et al., 1993). In addition, lightweight pigs may experience a larger impact of early castration as they face a number of challenges in early life such as being more susceptible to hypothermia and not being able to fight as aggressively for the best nipple resulting in them becoming more susceptible to subclinical and clinical diseases (Kielly et al., 1999). Castration-induced stress at an early age has the potential to set piglets behind as it can reduce activity and decrease suckling behaviour during the critical period when they are competing with littermates to become established on the nipple and determine their place in the hierarchy of the litter (Kielly et al., 1999; McGlone et al., 1993). It has been suggested that postponing castration until after 3 days of age results in less stress for the piglet and maximizes growth rate during the neonatal period (Kielly et al., 1999). Studies measuring plasma cortisol concentrations support the suggestion that the pigs experience less stress with late castration compared to early castration (Kielly et al., 1999). This may be because, by this age, pigs have become firmly established within the litter and on the nipple and thus are able to rapidly return to normal behaviour and maintain a positive growth rate (Kielly et al., 1999). It has also been suggested that pigs of an older age are simply stronger and can handle the procedure better than younger pigs (Kielly et al., 1999). Other studies conclude that castration does not influence weight gain, irrespective of piglet age (Hay et al., 2003; Kielly et al., 1999; McGlone et al., 1993). In addition, many studies have found no relationship between pain management treatment and weight gain (Hansson et al., 2011; Hay et al., 2003; Keita et al., 2010; McGlone et al., 1993; McGlone and Hellman, 1988). Therefore, it is difficult to assess whether or not an improvement in performance should be expected with pain management. In fact, piglet preweaning growth rate can be quite variable depending on a variety of factors

including genetic potential, environmental conditions, availability of nutrition, and stressful effects (Kielly et al., 1999).

It has been shown that piglets castrated at less than 1 week of age experience no less pain than piglets castrated at 2 or 3 weeks of age based on vocalization measurements (Taylor et al., 2001). Taylor et al. (2001) found no effect of age on behavioural responses, and probably pain perception. This is in agreement with McGlone et al. (1993) who reported that behavioural effects of castration are similar between piglets aged 1 to 20 days. Thus, both studies indicate that no age-castration interaction exists and that castration at a younger age does not reduce the post-operative pain experienced by pre-weaned piglets. Therefore, although the factors affecting both castrated and sham-castrated piglets (handled in the exact manner without being castrated) such as distress due to restraint may vary with age, no evidence exists suggesting that the immediate pain due to castration is affected by age (Taylor et al., 2001).

It is now generally accepted that surgical castration of male piglets is a cause of serious distress and impairment of the piglets' welfare, and awareness of the problem has started the search for practical, more humane alternatives (Leidig et al., 2009). Suitable methods that reduce pain caused by surgical castration and alternatives to surgical castration are being explored by the pig production sector (Hansson et al., 2011). This method must be fast, cost effective, produce minimal stress and pain during castration, be safe for both the handler and the piglet, as well as ensure a quick recovery in order to minimize the risk of the sow crushing the piglet (Hansson et al., 2011). Most of these alternatives seem promising in the long term, but need further development and research before they can be implemented at the commercial level (Tuyttens et al., 2011). Improvac (Pfizer Animal Health Ltd.) is the first vaccine on the market registered to suppress boar taint in pigs and has been licensed in the EU since 2009 and in North

America since 2011, but has been used for many years in non-EU countries including Australia, New Zealand, Brazil and Mexico for the suppression of boar taint (Tuyttens et al., 2011). On the other hand, the United Kingdom and Ireland abandoned castration of piglets 20 to 30 years ago for the main reasons of economic benefits related to faster growth, better feed conversion, and leaner carcasses of entire males. However, rearing entire males might introduce some management challenges regarding the behaviour of entire male pigs in that males fight more and are sexually active by mounting each other which may lead to skin damage and leg problems (Fredriksen et al., 2009). Selection of boars for slightly later sexual maturity and slaughtering at lower carcass weights allows producers to enjoy the production benefits associated with rearing intact boars (Taylor and Weary, 2000). Another possible alternative to castration is the production of only female pigs based on sorting of semen according to sex (Fredriksen et al., 2009). However, this technique is not yet available for routine use in pigs and requires further development to become feasible in swine production (Fredriksen et al., 2009).

1.4 Tail-docking

Tail biting has long been recognized as a problem for the swine industry with significant economic losses due to reduced weight gains, secondary infections, and increased incidence of condemnation of carcasses at slaughter (Noonan et al., 1994). The practice of tail-docking as a solution to the problem has been subject to past and present attention from the public and media as a common means of preventing tail biting behaviour because it is a welfare issue as it causes acute trauma and pain (Sutherland et al., 2008). The procedure is also routinely practiced in the absence of any anaesthesia or analgesia for pain relief (Sutherland et al., 2008). It is also believed by some that the procedure is unwarranted as a preventive measure as outbreaks of tail

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biting still occur in groups of pigs that have had their tails docked (Noonan et al., 1994; Torrey et al., 2009). In addition, there is concern over the lack of research into ways of reducing pain and distress during and immediately following these procedures (Torrey et al., 2009). It would be beneficial to pig welfare and the swine industry to develop commercially viable ways to reduce the pain associated with the tail-docking procedure (Sutherland et al., 2011a).

Tail biting is an injurious and undesirable behaviour seen in pigs which presents a serious welfare problem (Sutherland et al., 2008). It can result in injuries ranging from minor to severe lesions, to the point where the tail is bitten to the rump and the animal may need to be euthanized (Sutherland et al., 2011b). Tail biting may begin with an individual pig playing with or manipulating the tail of a pen mate through sucking and biting behaviours (Sutherland et al., 2009). However, this wound becomes very attractive to not only the instigator of the biting, but also to other pigs in the pen (Noonan et al., 1994). Severe outbreaks of tail biting can progress to cannibalism (Noonan et al., 1994). The exact cause of tail biting episodes is currently unknown, but is thought to be multi-factorial (Sutherland et al., 2009). Wounds caused by tail biting can lead to an increased risk of infection and severe tail lesions are associated with reduced weight gain (Sutherland et al., 2009). Tail-docking appears to reduce tail biting behaviour, but it does not eliminate this undesirable and injurious behaviour (Sutherland et al. 2011b).

Although not completely effective, tail-docking is performed worldwide in an attempt to minimize tail biting among pigs (Noonan et al., 1994). The procedure is most often performed soon after piglets are born, usually within the first few days of life (Torrey et al., 2009), and may be carried out at the same time as other routine practices such as teeth clipping and ear notching. The idea behind the procedure is that it is believed that docking causes the remaining stump to become more sensitive to being bitten (Noonan et al., 1994). However, processing piglets early

in life may be detrimental to the development of suckling behaviour as the procedure is carried out at a time when piglets are competing with littermates for access to productive teats and establishing a teat order (Torrey et al., 2009). Two common tail-docking techniques currently used in pig production include surgical tail-docking (the tail is cut off using a sharp knife or cutting pliers) and heated docking iron (the tail is severed using a cautery iron). The intense heat associated with the heated docking iron may cause third degree burns resulting in the destruction of nociceptors in the immediate area, thereby reducing the perception of pain experienced by the animals (Sutherland et al., 2008). Sutherland et al. (2008) compared these two methods of tail-docking and found that surgical tail-docking caused an acute cortisol and behaviour response above that of using a heated docking iron. The cortisol response at 60 min following the procedure was elevated in piglets that were surgically tail docked compared to piglets tail docked using a heated docking iron and sham-processed piglets (Sutherland et al., 2008). At 90 min following the procedure, cortisol concentrations were reported to return to normal levels (Sutherland et al., 2008). Behavioural observations appear to be similar when comparing the two methods (Sutherland et al., 2008; Sutherland et al., 2009). Wound healing was found to not differ between the two methods over time (Sutherland et al., 2008). It has been suggested that tail biting may be prevented by tail-docking due to the increased sensitivity in the tip of the tail which may cause the pig to react more vigorously to pen mates chewing on their tails and motivate the pig to move preventing further tail biting and potential injury (Sutherland et al., 2009). However, evidence supporting this idea is limited (Sutherland et al., 2011b). Whether animals experience chronic pain or stress due to increased sensitivity in the tail stump is currently not known (Sutherland et al., 2011b).

Both behavioural and physiological changes in pigs after tail-docking indicates that the

procedure causes pain (Sutherland et al., 2011b). Tail-docking appears to cause pain and distress to newborn piglets resulting in changes to vocalizations and behaviour above those of handling alone (Torrey et al., 2009). Noonan et al. (1994) found piglets that were tail docked display significantly more grunts per second than piglets that were sham tail docked. Torrey et al. (2009) reported similar results that tail docked piglets produce more high frequency vocalizations and an overall greater vocalization frequency indicative of pain than sham-processed piglets (Torrey et al., 2009). Sutherland et al. (2008) also reported tail docked piglets to perform posterior scooting which is not considered a normal behaviour and is thought to be a behaviour performed to relieve discomfort caused by having their tail removed. However, this behaviour is only reported to be observed for up to 45 min following the procedure suggesting that the stress caused by tail-docking is not long lasting (Sutherland et al., 2008). An increase in tail jamming behaviour (jamming their tail between their legs) is seen in pigs that undergo tail-docking compared to non-processed piglets suggesting that it is not a normal behaviour and may indicate distress (Noonan et al., 1994; Torrey et al., 2009). Similarly, tail wagging is another behaviour that increases in pigs after they have been tail docked and suggests that the procedure causes some degree of pain from the tail region (Noonan et al., 1994). However, these behaviours are observed for up to 90 s after tail-docking and do not appear to be long lasting (Noonan et al., 1994). However, this does not diminish the importance to investigate ways in which we can diminish the pain experienced by piglets undergoing these procedures (Noonan et al., 1994). Processing treatments do not appear to affect suckling behaviour or induce changes in growth rates of piglets (Torrey et al., 2009). These behavioural results suggest that pigs experience acute pain in response to tail-docking. In addition, it has been shown that behaviours indicative of pain are more frequent immediately following management procedures such as tail-docking, teeth

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clipping, and ear notching when performed together compared to pigs undergoing only one

procedure suggesting that pigs experience longer lasting distress with multiple procedures

(Noonan et al., 1994).

There is also no age effect, because regardless of age, tail docked piglets vocalize at a

greater frequency and produce higher frequency calls than sham-processed piglets (Torrey et al.,

2009). Therefore, there does not appear to be any concrete evidence that processing piglets

earlier in life (1 day of age) is better or worse than later in life (3 days of age). Sutherland et al.

(2011a) tested different methods of anaesthesia during the tail-docking procedure including local

anaesthesia injected immediately before docking, local anaesthetic applied topically to the tail

wound after docking, and anaesthesia with carbon dioxide gas prior to docking and found that

none of the anaesthesia treatments tested eliminated or significantly reduced the pain-induced

stress response to surgical tail-docking.

1.5 Pain in farm animals

One major issue for animal welfare research is the assessment of pain under clinical

conditions (Stafford and Mellor, 2007). Pain may be defined as an unpleasant sensory and

emotional experience that is associated with actual or potential tissue damage (Lemke, 2004).

Pain is very subjective and, even if an animal has been identified as suffering pain, there is

further difficulty in quantifying that pain (Anil et al., 2006). When an animal is in pain, its

physiology and behaviour may change in an attempt to reduce or avoid the damage, which is also

aimed at avoiding its reoccurrence and promoting recovery of the affected tissue (Anil et al.,

2006). Public concern over the welfare of farmed animals has increased, and therefore, pain

management and its alleviation have become important issues (Anil et al., 2006).

Animal welfare has become a topic of public scrutiny regarding the swine industry over the past couple of decades (Millman, 2002). Surveys taken during this time indicate strong public concern about animal suffering (Millman, 2002). It is clear that concern for animal welfare is an important issue to consumers as demonstrated by the emergence of "welfare-friendly" product labels. Although consumers may not directly cite animal welfare as an issue of concern when buying products, emerging evidence suggests they use welfare considerations when making purchase decisions (Millman, 2002). Increased sales of organic foods and community supported agriculture projects also suggest that consumer concerns include animal welfare. As a consequence, increased regulations of farming practices through welfare standards developed by retailers and through legislation are being implemented and will likely continue (Millman, 2002).

1.6 Measurement of pain

Pain assessment in animals is challenging, but the use of behavioural and physiological scores can quantify the severity of pain and distress an animal experiences (Anil et al., 2006; Reyes et al., 2002). Expression of pain by animals is mostly through behavioural patterns and physiological changes (Anil et al., 2006). No single measurement is adequate for determining animal welfare, but it is possible that a combination of several indicators will help make a reasonable assessment of whether or not an animal is experiencing pain (Anil et al., 2006; Millman, 2002).

1.6.1 Behaviour

The most important single indicator of pain in animals is deviation from normal behaviour (Anil et al., 2006). For example, an animal may move away from other group

members when in pain (Anil et al,. 2006). On the other hand, other behavioural indicators may positively suggest the absence of pain. For example, signs of contentment in pigs may include play and vocalization such as "conversational" grunting, as well as good health and good growth and body condition (Anil et al., 2006). Behavioural observations are useful for evaluating the consequences of painful procedures such as surgical castration on the welfare of pigs (Moya et al., 2008). Behavioural indices such as postures, specific pain-related behaviours, and general behaviours are relevant parameters to assess pain and discomfort induced by painful procedures (Keita et al., 2010).

Results from direct behavioural observations from previous studies indicate that behavioural changes indicative of pain result from castration (Hay et al., 2003; Keita et al., 2010; McGlone et al., 1993; McGlone and Hellman, 1988; Moya et al., 2008; Taylor et al., 2001; Taylor and Weary, 2000). Immediately following castration and in the first few hours after the procedure, castrated piglets have been reported to spend less time suckling and massaging the udder compared to their littermates (Hay et al., 2003; McGlone et al., 1993; McGlone and Hellman, 1988). They also have been found to spend more time sitting or standing inactive and less time lying (Taylor et al., 2001; McGlone et al., 1993). However, after this time and up to 24 h following castration, castrated piglets will spend more time in contact with the sow massaging the udder compared to their non-castrated littermates (Taylor et al., 2001; McGlone et al., 1993; McGlone and Hellman, 1988; Moya et al., 2008). Piglets have been found to display teat-seeking activities after being subjected to painful procedures and this type of behaviour is known to help animals cope with stressful situations, possibly constituting a way of pain signalling towards the sow (Moya et al., 2008). It has also been suggested that suckling provides an analgesic effect in response to pain which can be exerted by gustatory and/or tactile activities (Moya et al., 2008).

In addition, many behavioural alterations indicative of pain persist beyond 24 hours, with some still present 4 to 5 days after the procedure (Hay et al., 2003). Thus, piglets seem to suffer from pain for longer than a few hours following castration, emphasizing the necessity to develop analgesic protocols or alternative methods to castration (Hay et al., 2003).

It is possible that castrated piglets avoid certain behaviours in an effort to minimize pain (Moya et al., 2008). Castrated piglets are less active and show more pain-related behaviours such as prostration, stiffness, trembling, and tail wagging following the procedure compared to their non-castrated littermates (Keita et al., 2010). Piglets will also show more rigid postures and huddling following castration, a behaviour that may be considered as protective allowing the animal to avoid the stimulation of painful tissue (Hay et al., 2003). In addition, during the first 2.5 h following castration, piglets will spend a reported 4% of their time trembling suggesting that this behaviour is due to the pain caused by castration (Hay et al., 2003). Furthermore, scratching their rump by rubbing it against the floor is a behaviour observed in castrated piglets which is nearly absent in uncastrated piglets suggesting an attempt to alleviate post-operative pain (Hay et al., 2003). Tail wagging can also be considered an attempt to remove stimuli causing pain (Hay et al., 2003). For example, tail wagging may be used to deter biting insects in species such as cows, but is questionable in pigs due to their much shorter and less motile tail which is unlikely to serve this same function (Hay et al., 2003). Lastly, reduced social cohesion is displayed by castrated piglets suggesting a protective reaction to avoid contact with littermates that could generate pain (Hay et al., 2003). Castrated piglets are found to avoid social contact and are often desynchronized and isolated compared to their littermates, an unusual behaviour for such social animals as pigs (Hay et al., 2003; Moya et al., 2008). Isolation is thought to be a behavioural adaption with a protective role as a way of stopping other animals from inflicting

more pain as a result of stimulation of affected tissues (Hay et al., 2003; Moya et al., 2008). Also, since castrated pigs have been found to spend less time standing and more time lying, and therefore, less time feeding than their littermates (Taylor et al., 2001; McGlone et al., 1993), it is possible that a reduction in productive performance may occur. Older piglets' (7 weeks of age) behaviour is changed for a greater duration than 14-day-old piglets with suppressed feeding and drinking times and increased lying times for 6 to 8 h following castration, even when given a general or local anaesthetic (McGlone and Hellman, 1988).

Behavioural indicators of pain have several limitations. Firstly, behavioural indicators of pain are indirect measures and may not predict the perception of the animal (Anil et al., 2006). Secondly, there are differences in pain-related behaviours between species and even within species, and they differ depending on age, gender, environment, the particular pain-causing experience, and previous experience (Stafford and Mellor, 2007; Anil et al., 2006). Thirdly, the behaviour of animals may not be correlated with intensity or noxiousness of the pain (Anil et al., 2006). There is also an issue of subjectivity in that it is difficult to ensure objectivity in the assignment of scores and the problem of individual and species variation of animals in their response to the same stimulus (Anil et al., 2006).

1.6.2 Vocalization

Vocalization is considered an important indicator of pain in various species such as pigs, lambs, kids, and puppies (Anil et al., 2006). Pitch and frequency of vocalizations made by piglets may reflect distress due to pain (Weary et al., 2006). Piglets typically vocalize a great deal when simply restrained, but this differs a great deal when comparing castrated to non-castrated or sham-castrated piglets (Hansson et al., 2011; Marx et al., 2003; Taylor and Weary, 2000; Weary

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et al., 2006; White et al., 1995). Vocalization evidence suggests that restraint itself is a stressor, but when restraint is combined with a procedure such as tail-docking or castration it results in an alteration of the behaviour from basal levels shown by piglets that were merely restrained for a similar time (Noonan et al., 1994). Multiple studies have shown a strong vocal response to the immediate pain of castration (Taylor and Weary, 2000; Weary et al., 2006; Taylor et al., 2001), or more specifically, piglets respond to castration by producing more high-frequency (>1000Hz) calls (Taylor et al., 2001). In fact, piglets produce vocalizations of higher intensity, more frequently, and of longer duration when submitted to castration compared to sham-castration (Keita et al., 2010; Marx et al., 2003; Taylor and Weary, 2000; Taylor et al., 2001) or castration under local anaesthesia (Hansson et al., 2011; Hay et al., 2003; Marx et al., 2003; Leidig et al., 2009; Weary et al., 2006; White et al., 1995). Based on vocalization studies, the most painful aspect of castration has been identified as when the piglet's spermatic cords are pulled (Hansson et al., 2011; Marx et al., 2003; Leidig et al., 2009; Taylor and Weary, 2000; Weary et al., 2006; White et al., 1995). It has been suggested that a parameter describing a single moment in the call, such as peak level or peak frequency, is more representative than parameters describing mean level (Hansson et al., 2011; Marx et al., 2003). Comparison of vocalization during treatment is a useful tool for the assessment of pain in pigs (Marx et al., 2003). For example, Marx et al. (2003) found that piglets produced almost double the amount of calls as well as higher frequency calls when castrated without local anaesthesia compared to after anaesthesia or mere restraint. With the administration of local anaesthesia prior to castration, piglet vocalization has been found to become more similar to control (Marx et al., 2003).

1.6.3 Plasma Cortisol

Levels of distress experienced by farm animals exposed to painful procedures such as castration and tail-docking can be assessed by measuring physiological changes in the animal (Hay et al., 2003). Cortisol release into the bloodstream or saliva is a common measure reported in such situations (Hay et al., 2003). Plasma cortisol can be used as an objective indicator of stress and pain (Hansson et al., 2011; Keita et al., 2010). Even though it is not always appropriate to use the plasma cortisol response as an indicator of pain or distress, if an animal has an unpleasant experience which results in a significant elevation of plasma cortisol concentration then it may be used as a guide in assessing the comparative intensity of that experience (Stafford et al., 2003). Acute activation of the hypothalamic-pituitary-adrenal axis (HPA) and of the sympathetic nervous system (SNS) is caused by castration (Hansson et al., 2011; Hay et al., 2003; White et al., 1995) which is followed by an increase in plasma cortisol concentrations (Keita et al., 2010; Prunier et al., 2005). Studies have found that plasma concentrations of cortisol significantly increase after castration when compared to that of handled piglets, with increased cortisol levels observable as early as 15 minutes and up to 90 minutes post-castration, regardless of age (Moya et al., 2008; Prunier et al., 2005). However, an increase of cortisol is also observed as a result of handling alone (Moya et al., 2008). Cortisol concentrations have been reported to peak between 30 and 60 minutes after surgical castration and return to pre-surgery levels within 3 hours (Prunier et al., 2005). The major drawback with plasma cortisol is that pain is not the only factor associated with changes in plasma concentrations which can be affected by different kinds of stress such as anger or fear (Hansson et al., 2011; Anil et al., 2006), making the evaluations less reliable.

1.7 Treatment of pain

In domestic animals, evidence-based pain management depends on being able to effectively and accurately assess pain under clinical conditions and having the tools with which to alleviate the identified pain (Stafford and Mellor, 2007). The difficulty in assessing pain is a serious handicap in ensuring the welfare of animals and the treatment of pain presents many clinical problems (Anil et al., 2006). One major limitation in the treatment of pain is simply the non-availability of a cheap, safe, and easy-to-use analgesic protocol (Anil et al., 2006). Animals in pain may consume less feed resulting in a negative energy balance and suboptimal performance (Anil et al., 2006). Therefore, prevention and treatment of pain is not only a central welfare concern, but also a productivity concern (Anil et al., 2006).

Different types of analgesics such as opioids, α2-adrenergic agonists, NSAIDs, and local anaesthetics may be administered to animals (Anil et al., 2006). However, the use of these analgesics in food animal species is limited to varying degrees for various reasons with food safety and the misuse of controlled drugs at the farm level being major concerns (Anil et al., 2006). Many analgesics such as opioids are limited in their practical utility at the farm-level due to their short duration of action (Anil et al., 2006). There are also practical difficulties in maintaining effective blood levels if the drug needs to be administered at frequent intervals (Anil et al., 2006). The NSAIDs are effective, but their use is restricted due to long withholding times for meat and high cost (Anil et al., 2006). In addition, there may be concerns that they may interfere with reproduction (Anil et al., 2006). Shortage of personnel, the need for specialized equipment, and the cost of testing may hinder the monitoring that is required to ensure proper pain alleviation in many post-operative situations (Anil et al., 2006).

The emergence of NSAIDs with analgesic properties in the last couple of decades has

revolutionized analgesia (Stafford and Mellor, 2007). Veterinarians in the1970s may have

ignored or underestimated pain and its importance because of their limited ability to easily deal

with it due to a much more limited suite of analgesics available to them (Stafford and Mellor,

2007). This attitude is much less defensible in the present decade as a wider knowledge of pain

has become an important facet of veterinary medicine making alleviation of pain, if not its

elimination, both easier and mandatory (Stafford and Mellor, 2007). Drug availability, food

safety, and market demand for analgesia for farm animals are all critical factors in deciding the

level of analgesic use in farm animals (Anil et al., 2006). Minimizing the pain associated with

routine farm procedures is reliant on performing these procedures for the right reason, using the

best method and proper equipment, at the right time, and to the right class of animal (Anil et al.,

2006). However, even though the use of analgesics may be an effective strategy when dealing

with acute pain which is generally easier to alleviate or prevent, chronic pain may not be as

easily addressed (Stafford and Mellor, 2007). Chronic pain and its duration remains difficult to

assess as distinct behaviours seen weeks after a procedure may be due to irritation rather than

pain (Stafford and Mellor, 2007). Therefore, pain management in food animals should primarily

focus on minimizing the incidence, duration, and intensity of painful conditions (Anil et al.,

2006).

1.7.1 Meloxicam

Piglets subjected to surgical castration exhibit normal physiological responses to pain that

can be managed with conventional analgesic therapy or anti-inflammatory drugs (Lemke, 2004).

NSAIDs have analgesic effects due to their anti-inflammatory actions in inhibiting prostaglandin

synthesis and are potentially useful in dealing with pain suffered after painful procedures such as

castration (Keita et al., 2010). The long acting NSAID meloxicam is marketed for the treatment of pain and inflammation associated with acute and chronic locomotive disorders and postoperative pain in humans and several domestic species of animals including pigs (Fosse et al., 2008). Meloxicam is licensed for the treatment of non-infectious locomotor disorders to reduce the clinical signs of lameness and inflammation. Additionally, meloxicam is licensed in Europe for minor soft tissue surgery such as castration. Meloxicam has been researched extensively for its analgesic properties in the postoperative period in various species and is a relevant candidate for the treatment of pain at castration (Keita et al., 2010; Reyes et al., 2002).

Meloxicam exerts inhibitory effects on cyclo-oxygenase (COX) enzymes, and subsequently, the production of prostaglandins and other inflammatory mediators responsible for sensitizing pain receptors which results in a lowered threshold of pain tolerance (Reyes et al., 2002). Meloxicam avoids adverse side effects due to the inhibition of the COX-1 isoform such as maintenance of renal and gastric mucosa and regulation of blood flow because of its relative specificity to the COX-2 isoform which is believed to play a major role in inflammation (Reyes et al., 2002). The potency of meloxicam for inhibiting COX-2 has been shown to be higher than the potency for inhibiting COX-1 (Fosse et al., 2008). Meloxicam may also inhibit pain at the spinal cord level via mechanisms other than COX inhibition (Reyes et al., 2002). Meloxicam is metabolized in the liver enzymatically and the metabolites are biologically inactive (Reyes et al., 2002). In pigs, the proposed metabolic pathway of meloxicam is hepatic oxidation to its 5-hydroxymethyl and 5-carboxyl metabolites which are both pharmacologically inactive (Fosse et al., 2008). It has recently been discovered that the COX enzymes are present in the kidneys under normal conditions and that NSAIDs may cause kidney damage through the inhibition of these enzymes (Reyes et al., 2002). However, there is no evidence that meloxicam causes kidney

or liver damage at therapeutic doses (Reyes et al., 2002). The use of meloxicam in pigs is not age restricted and no intolerance or deleterious effects have been reported in pigs, even at a dose of 2 mg/kg (equivalent to five times the recommended dose) administered to 5- to 6-month-old pigs once daily for six consecutive days (EMEA, 2001). The plasma clearance of meloxicam in piglets aged 16-23 days has been found to be low (0.06L/kg/h) and lower than what has been reported in heavier pigs (45kg), but higher than what has been recorded in horse, ponies, sheep, and goats (Fosse et al., 2008). Species differences in clearance have been reported for several NSAIDs and are likely due to differences in hepatic clearance (Fosse et al., 2008). Less than 3% of a dose is excreted as unchanged meloxicam in the urine of pigs (Fosse et al., 2008). The volume of distribution of meloxicam in pigs aged 16-23 days has been found to be low (0.19L/kg) and lower than what is reported in heavier pigs (45kg) (Fosse et al., 2008). In most species, the volume of distribution is low for most NSAIDs, likely due to the extensive binding of NSAIDs to plasma-protein limiting the drug from distribution into the tissues (Fosse et al., 2008). When comparing neonate and adult animals, differences in pharmacokinetics of NSAIDS have been demonstrated with reduced clearance, increased volume of distribution, and a prolonged half-life in neonates compared to adults (Fosse et al., 2008). The elimination half-life of meloxicam in piglets aged 16-23 days is slightly shorter in plasma (2.7 h) than in exudate (3.2 h), but at most time points the mean concentration of meloxicam in plasma exceeds the concentrations in exudate indicating a limited accumulation of the drug at the site of inflammation (Fosse et al., 2008). A number of NSAIDs including meloxicam have been shown to penetrate readily into and be cleared slowly from inflammatory exudates (Fosse et al., 2008).

Multiple studies have looked at the effects of different analgesics for the treatment of pain at surgical castration. McGlone et al. (1993) tested two non-narcotic analgesics (aspirin and

butorphanol) during castration and found that there was no effect of treatment on weight gain or any measurable behavioural changes. Reyes et al. (2002) tested the effects of two nonopioid analgesics (paracetamol and meloxicam) on postoperative pain after surgical castration in piglets and found that both were effective in reducing pain in the postoperative period, but that meloxicam was superior to paracetamol on behavioural criteria including a return of the overall pain scores to baseline values by 24 h postoperatively (Reyes et al., 2002). Previous studies looking at meloxicam and its analgesic properties have found meloxicam to have a positive effect on the relief of stress and pain caused by surgical castration in male piglets (Keita et al., 2010). Pre-operative administration of meloxicam has been shown to significantly reduce the short-term increase in blood concentrations of cortisol that usually follows surgical castration at 30 min post-castration (Keita et al., 2010), suggesting a reduction in the immediate effects of castration on stress and pain. In addition, mitigation of behavioural alterations indicative of pain between 2 and 24 h after surgical castration of male piglets is observed with pre-operative administration of meloxicam (Keita et al., 2010).

1.7.2 Ketoprofen

Ketoprofen (2-(phenyl 3-benzoyl) propionic acid) is an NSAID with analgesic, anti-inflammatory, and antipyretic effects (Fosse et al., 2010) which has been used in human medicine for the treatment of arthritis (Mustonen et al., 2011). In Europe, ketoprofen is currently licensed for the treatment of mastitis-metritis-agalactia (MMA) and for the treatment of fever and inflammation associated with respiratory infections in pigs (Mustonen et al., 2011). There is limited research on the use of ketoprofen for the treatment of pain associated with routine practices such as castration and tail-docking in swine. As with meloxicam, ketoprofen acts

through the inhibition of COX as the primary mechanism of action (Fosse et al., 2010).

Fosse et al. (2010) demonstrated ketoprofen to be effective in alleviating pain due to lameness in piglets, but the analgesic effects of ketoprofen on routine management practices such as castration and tail-docking remains to be clarified. Mustonen et al. (2011) reported ketoprofen to be efficient in alleviating the signs of non-infectious lameness in sows and gilts. In cattle, ketoprofen has been reported to be effective in lowering the cortisol response of bulls to castration compared to castration with no analgesia (Ting et al., 2003). In addition, it has been demonstrated that ketoprofen reverses the higher incidence of standing postures and lower incidence of lying postures observed in bulls subject to castration compared to control animals, suggesting reduced pain or discomfort with ketoprofen treatment (Ting et al., 2003). Cortisol concentrations of calves after dehorning have been shown to decrease and remain at pre-treatment levels between 2.5 and 8 h after the procedure with ketoprofen treatment (Stafford et al., 2003). Treatment with ketoprofen before castration of bulls does not have any effect on weight gain (Ting et al., 2003).

1.7.3 Anaesthesia

In the search for pain-free castration of piglets, anaesthetic treatment has been investigated. Local anaesthetic pre-treatment has been found to noticeably reduce time spent trembling in studies on lambs (Hay et al., 2003). McGlone et al. (1988) found that local anaesthesia provides some benefits in terms of piglet behaviour for piglets aged 10 to 14 days of age, but that it does not provide the same effective pain relief for 7-week-old pigs. However, handling time is significantly increased by the combination of local anaesthesia and subsequent castration and a significant proportion of the stress and discomfort experienced is a result of the

handling and manipulation of the piglets (Leidig et al., 2009). Some studies have shown a reduction in pain and stress induced by surgical castration when performed with local anaesthetic administered into the testicle (White et al., 1995), while other studies have provided evidence that administration of the local anaesthetic may produce as much pain and stress as the surgery itself (Leidig et al., 2009).

Beneficial effects of lidocaine treatment for local anaesthesia during castration have been identified in several studies (Hansson et al., 2011; Marx et al., 2003; White et al., 1995). Previous studies on piglet vocalization during castration show that piglets produce calls with a lower intensity when castrated with lidocaine compared to without lidocaine (Hansson et al., 2011; Marx et al., 2003). It has even been shown that similar calls are produced by piglets that are castrated with lidocaine and those that are sham-castrated (Hansson et al., 2011; Marx et al., 2003). Local anaesthesia at surgical castration has also been found to reduce resistance movements during castration (Hansson et al., 2011; Leidig et al., 2009). However, it has been reported that at 40 min following injection, lidocaine concentrations in the spermatic cords of the piglets is severely decreased implying a short period between lidocaine injection and castration for pain relief (Hansson et al., 2011).

The use of general anesthesia has been examined, but for the most part, this appears to be an impractical approach for a number of reasons. Thiopentol is the only registered general anaesthetic for pigs in Canada and must be given intravenously, with its use being restricted to veterinarians. Therefore, the practical application of an injectable general anaesthetic at the farm-level poses many challenges. General gas anaesthesia has been investigated for its potential use at castration, but is still considered to have too narrow safety margins with an unacceptable number of losses (Fredriksen et al., 2011). Gas agents also require specialized equipment and are

not licensed for food animals. In addition, the use of general anaesthesia involves risks and may disrupt normal nursing and heat-seeking behaviours post-operatively resulting in poor piglet recovery (McGlone and Hellman, 1988). McGlone et al. (1988) found that 14-day-old piglets receiving a general anaesthetic miss an average of 1.5 nursings in the following 3 h after treatment whereas control piglets did not miss any nursing opportunities, regardless of whether they were castrated or not. The extra time spent away from nursing was largely spent in uncoordinated behaviour and lying time away from the heat lamp (McGlone and Hellman, 1988). Administering a local anaesthetic rather than a general anaesthetic has been found to prevent castration-induced suppression in nursing behaviour and increased time lying away from the heat source to the level of uncastrated, unanaesthetized piglets in 14-day-old piglets (McGlone and Hellman, 1988).

It is difficult to assess effective induction of anaesthesia under practical conditions (Leidig et al., 2009). Effective anaesthesia may not be achieved due to the time allowed between anaesthesia and castration being too short or too long (Leidig et al., 2009). Studies on the use of anaesthesia during surgical castration have been carried out under research conditions with standardized procedures and transferability of these results into practice might be a further concern (Leidig et al., 2009). Anaesthesia during surgical castration of pigs for the domestic market is now mandatory in some European countries such as Norway, Switzerland and the Netherlands (Tuyttens et al., 2011).

1.8 Pain at parturition

There is limited research in relation to parturition pain in sows (Mainau and Manteca, 2011). In addition to limited research concerning the optimal management practices around

parturition, inadequate or lack of pain control during this process has been noted (Mainau and

Manteca, 2011). There is a need for more research concerning parturition pain in animals in an

effort to optimize the parturition process and reduce the negative impacts on health, welfare, and

productivity (Mainau and Manteca, 2011).

Pain and stress caused by parturition may modify the normal maternal behaviour of sows

during and after parturition and is a welfare concern (Mainau et al., 2012). It has been noted that

an increase in piglet mortality is associated with prolonged or difficult farrowings (Mainau et al.,

2012). Mainau et al. (2010) determined that shorter duration of farrowing, sow posture (lying

down), and sow activity (number of position changes) during the day before and the day of

farrowing appear to be important indicators of the ease of farrowing a sow experiences. Ease of

farrowing is also important for the newborn piglets as Mainau et al. (2010) showed that a high

percentage of piglets born with high viability show shorter total time spent standing or sitting on

the day of farrowing which is also associated with ease of farrowing. Irrespective of parturition

environment, the parturition phase in sows is associated with an increase in plasma cortisol

concentrations and could be attributed to pain and stress during farrowing (Meunier-Salaun et al.,

1991). In addition, farrowing can be disrupted in sows by stress through an opioid-mediated

inhibition of oxytocin secretion (Mainau and Manteca, 2011). Lower levels of oxytocin may

result in prolonged delivery of piglets as oxytocin plays a key role in sustaining an optimal level

of myometrial contractility (Mainau and Manteca, 2011).

1.9 Measuring pain at parturition

Both the recognition and control of pain are essential components of ensuring good

welfare (Mainau et al., 2012). Parturition in any species may be regarded as a painful process

(Mainau and Manteca, 2011). In addition, births associated with difficult parturitions or dystocia may cause unacceptably high levels of pain in the mother (Mainau and Manteca, 2011). The degree of pain caused by parturition may be modified by several factors such as parity and parturition difficulty (Mainau and Manteca, 2011). Total farrowing time from first to last piglet may average around 2.5 h and parturitions longer than 3 or 4 h are considered potentially problematic and more painful (Mainau and Manteca, 2011). Primiparous gilts are believed to experience more painful parturitions than multiparous sows due to longer parturition durations and a higher degree of effort associated with the first parturition compared to multiparous females (Mainau and Manteca, 2011).

One of the three following approaches tends to be used for pain assessment in animals: measures of general body functioning, physiological response, and behaviour (Weary et al., 2006). The combination of these three indicators in order to study the pain recovery associated to a painful process is common. Normal deliveries have been shown to cause changes in the three indicators of pain, but dystocic deliveries show the most marked differences (Mainau et al., 2012). Sows commonly have increased cardiac frequency, respiratory rates, and rectal temperatures during the period around parturition (Mainau et al., 2012). Body temperature is commonly used to determine the antipyretic and anti-inflammatory effects of NSAIDs (Fosse et al., 2010). Fever or pyrexia are indicated by higher values than 39.5°C around farrowing and could indicate more discomfort and a slow recovery after farrowing (Mainau et al., 2012). Elevated body temperature persisting for the first few days after farrowing is partly associated with normal physiology (Mainau et al., 2012). The normal temperature during the periparturient period has been characterized at below 39.5°C with higher values indicative of fever or pyrexia (Mainau et al., 2012). Around parturition, a reduction in feed intake is commonly seen in sows,

but larger than normal changes in dry matter intake during the periparturient has been used to identify sows at risk of post-partum complications (Mainau et al., 2012). A reduction in feed intake and the consequent weight loss is commonly seen in sows and cows after parturition, especially primiparous females (Mainau and Manteca, 2011). This reduction in food intake could be the result of pain (Mainau and Manteca, 2011). However, Proudfoot et al. (2009) compared cows with dystocia and normal calving and did not find any differences in dry matter intake during the 24 h and 48 h period after calving.

Sows have been found to appear uneasy and restless during the 24 h prior to parturition (Mainau et al., 2009). These researchers found that sows spend the majority of their time (greater than 82%) lying during the days around farrowing. After farrowing, the time sows spend lying is further increased (at least 90%). Maternal behaviour including the movements of the sow affects piglet mortality as crushing by the sow is the first cause of piglet death, and occurs mainly during the first 24 h after farrowing (Mainau et al., 2012). Individual differences exist in activity levels between sows which are especially marked from 1 day before until 1 day after farrowing (Mainau et al., 2009).

Optimal maternal behaviour during the initial hours after birth is characterized by passivity and lateral lying (Jarvis et al., 1999). Piglets may have ready access to the udder for warmth and nutrition during their very early life with the sow lying quietly (Mainau et al., 2012). Wischner et al. (2009) reported that sows which do not crush piglets performed significantly longer bouts of lateral lying than sows that crushed piglets during the first 24 h after farrowing, but not on the second day. Therefore, the behaviour of sows after farrowing and during lactation is crucial for the survival and growth of the piglets (Mainau et al., 2012).

1.10 Analgesics at parturition

Limited work exists on the impact of analgesia after parturition in pigs (Mainau and Manteca, 2011). The administration of NSAIDs after parturition should help reduce the associated inflammation and pain, improve sow health and welfare, and help to maintain subsequent fertility and milk yield (Richards et al., 2009). Although the licence to use anaesthetic and analgesic drugs in farm animals varies between countries, there is a general consensus for a need to approve these drugs for use in swine. The cost of providing analgesia or the inability to appreciate the level of pain the animal is experiencing may be limiting factors (Mainau and Manteca, 2011). Most analgesics are not licensed for use around parturition, with the exception of ketoprofen licensed for problems associated with calving in cattle (Mainau and Manteca, 2011).

Meloxicam is licensed for the treatment of non-infectious locomotor disorders in adult pigs (Friton et al., 2003). In Europe, it is also licensed for the treatment of minor soft tissue surgery such as castration (Keita et al., 2010). Therapy based on the use of NSAIDs will primarily control pain by reducing inflammation and swelling, in simple terms (Mainau et al., 2012). The safety of meloxicam in pigs has been demonstrated in the treatment of non-infectious locomotor disorders (Friton et al., 2003). Mainau et al. (2012) found that meloxicam affects the behaviour of sows causing an increase in their total time spent standing on day 3 compared with non-treated sows and suggest this indicates recovery of the sows from the farrowing process. However, they did not find any change in the number of position changes with the administration of meloxicam. Keller (2012) observed higher piglet survival rates in the first 5 days post-partum when sows were treated with meloxicam the day of farrowing and again the next morning compared to non-treated controls.

Schulze et al. (2012) demonstrated that a single dose of azaperone injected in sows at the end of farrowing has a positive effect on sow and piglet performance, with higher weaning weights of piglets from sows treated with azaperone. Haussmann et al. (1999) found a reduced number of body position changes 48 h after farrowing in sows treated with butorphanol within 4 hours after farrowing and suggested that this may lead to a decrease in the number of crushing deaths. However, no difference in the rate of crushing deaths was observed in either study (Mainau et al., 2012; Haussmann et al., 1999). Butorphanol and meloxicam both have analgesic properties, but differ in their mechanism of action. While testing the efficacy of meloxicam in sows with MMA, Hirsch et al. (2003) found that fewer piglets of diseased litters died in the meloxicam group (14%) compared to a group receiving flunixin (31.7%). They also found that the treatment of sows with MMA with either meloxicam or flunixin improves piglet weight gain compared to untreated sows.

Crushing deaths account for more than half of all neonatal piglet mortality and is a major problem in today's industry (Haussmann et al., 1999). If the number of body position changes could be reduced through administration of an analgesic, a significant reduction in the crushing rate could be realized (Haussmann et al., 1999). Analgesics would partially alleviate the pain experienced by sows, but would still allow her to perform her normal behaviours (Haussmann et al., 1999). Research evidence suggests that post-partum sows should at least be treated with NSAIDs after birth to help improve sow welfare and this may reduce piglet mortality (Keller, 2012). Many analgesics are not cost effective at this time, but with large enough interest, appropriate analgesics could be more affordably marketed (Haussmann et al., 1999).

1.11 References

Aldal, I., Andresen, Ø., Egeli, A.K., Haugen, J.E., Grødum, A., Fjetland, O., Eikaas, J.L.H., 2005. Levels of androstenone and skatole and the occurrence of boar taint in fat from young boars. Livest. Prod. Sci. 95, 121-129.

Anil, L., Anil, S.S., Deen, J., 2006. Measuring pain and pain control. Proc. Amer. Assoc. Swine Vet., 339-341.

Baumgartner, J., Laister, S., Koller, M., Pfutzner, A., Grodzycki, M., Andrews, S., Schmoll, F., 2010. The behaviour of male fattening pigs following either surgical castration or vaccination with a GnRF vaccine. Appl. Anim. Behav. Sci. 124, 28-34.

Dunshea, F.R., Colantoni, C., Howard, K., McCauley, I., Jackson, P., Long, K.A., Lopaticki, S., Nugent, E.A., Simons, J.A., Walker, J., Hennessy, D.P., 2001. Vaccination of boars with a GnRH vaccine (Improvac) eliminates boar taint and increases growth performance. J. Anim. Sci. 79, 2524-2535.

Edwards, S.A., von Borell, E., Bonneau, M., 2009. Guest Editorial: Scientific and practical issues associated with piglet castration. Animal. 3, 1478-1479.

European Medicines Agency (EMEA) (2001) EPARs for authorised medicinal products for veterinary use: European Public Assessment Report for Metacam®, Revision 7 − Published 25/11/09: Scientific discussion.
http://www.emea.europa.eu/vetdocs/vets/Epar/metacam/metacam.htm

Fosse, T.K., Haga, H.A., Hormazabal, V., Haugejorden, G., Horsberg, T.E., Ranheim, B., 2008. Pharmacokinetics and pharmacodynamics of meloxicam in piglets. J. Vet. Pharmacol. Therap. 31, 246-252.

Fredriksen, B., Font i Furnols, M., Lundstrom, K., Migdal, W., Prunier, A., Tuyttens, F.A.M., Bonneau, M., 2009. Practice on castration of piglets in Europe. Animal 3, 1480-1487.

Fredriksen, B., Johnsen, A.M.S., Skuterud, E., 2011. Consumer attitudes towards castration of piglets and alternatives to surgical castration. Res. Vet. Sci. 90, 352-357.

Friton, G.M., Phillip, H., Schneider, T., Kleemann, R., 2003. Investigation on the clinical efficacy and safety of meloxicam (Metacam®) in the treatment of non-infectious locomotor disorders in pigs. Berliner und Munchener 116, 421-426.

Hansson, M., Lundeheim, N., Nyman, G., Johansson, G., 2011. Effect of local anaesthesia and/or analgesia on pain responses induced by piglet castration. Acta Vet. Scand. 53:34.

Haussmann, M.F., Lay, D.C., Buchanan, H.S., Hopper, J.G., 1999. Butorphanol tartrate acts to decrease sow activity, which could lead to reduced pig crushing. J. Anim. Sci. 77, 2054-2059.

Hay, M., Vulin, A., Génin, S., Sales, P., Prunier, A., 2003. Assessment of pain induced by castration in piglets: behavioural and physiological responses over the subsequent 5 days. Appl. Anim. Behav. Sci. 82, 201-218.

Hirsch, A.C., Philipp, H., Kleemann, R., 2003. Investigation on the efficacy of meloxicam in sows with mastitis-metritis-agalactia syndrome. J. Vet. Pharmacol. Therap. 26, 355-360.

Jarvis, S., McLean, K.A., Calvert, S.K., Deans, L.A., Chirnside, J., Lawrence, A.B., 1999. The responsiveness of sows to their piglets in relation to the length of parturition and the involvement of endogenous opioids. Appl. Anim. Behav. Sci. 63, 195-207.

Keller, F., 2012. Improved early piglet survival after Metacam® treatment of sows post farrowing. 22nd International Pig Veterinary Society Congress Proceedings, PO-177.

Kielly, J., Dewey, C.E., Cochran, M., 1999. Castration at age 3 days of age temporarily slows growth of pigs. Swine Health Prod. 7, 151-153.

Keita, A., Pagot, E., Prunier, A., Guidarini, C., 2010. Pre-emptive meloxicam for postoperative analgesia in piglets undergoing surgical castration. Vet. Anaesth. Analges. 37, 637-374.

Leidig, M.S., Hertrampf, B., Failing, K., Schumann, A., Reiner, G., 2009. Pain and discomfort in male piglets during surgical castration with and without local anaesthesia as determined by vocalisation and defence behaviour. Appl. Anim. Behav. Sci. 116, 174-178.

Lemke, K.A., 2004. Understanding the pathophysiology of perioperative pain. Can. Vet. J. 45, 405-413.

Mainau, E., Dalmau, A., Ruiz-de-la-Torre, J.L., Manteca, X., 2009. Validation of an automatic system to detect position changes in puerperal sows. Appl. Anim. Behav. Sci. 121, 96-102.

Mainau, E., Manteca, X., 2011. Pain and discomfort caused by parturition in cows and sows. Appl. Anim. Behav. Sci. 135, 241-251.

Mainau, E., Ruiz-de-la-Torre, J.L., Dalmau, A., Salleras, J.M., Manteca, X., 2012. Effects of meloxicam (Metacam®) on post-farrowing sow behaviour and piglet performance. Animal 6, 494-501.

Marx, G., Horn, T., Thielebein, J., Knubel, B., von Borell, E., 2003. Analysis of pain-related vocalization in young pigs. J. Sound Vibrat. 266, 687-698.

McGlone, J.J., Hellman, J.M., 1988. Local and general anesthetic effects on behaviour and performance of two- and seven-week-old castrated and uncastrated piglets. J. Anim. Sci. 66, 3049-3058.

McGlone, J.J., Nicholson, R.I., Hellman, J.M., Herzong, D.N., 1993. The development of pain in young piglets associated with castration and attempts to prevent castration-induced behavioural changes. J. Anim. Sci., 71, 1441-1446.

Meunier-Salaun, M.C., Gort, F., Prunier, A., Schouten, W.P.G., 1991. Behavioural patterns and progesterone, cortisol and prolactin levels around parturition in European (Large-White) and Chinese (Meishan) sows. Appl. Anim. Behav. Sci. 31, 43-59.

Millman, S.T., 2002. Measurable outcomes for swine welfare. Proceedings Allen D. Leman Swine Conference, 188-191.

Moya, S.L., Boyle, L.A., Lynch, P.B., Arkins, S., 2008. Effect of surgical castration on the behavioural and acute phase responses of 5-day-old piglets. Appl. Anim. Behav. Sci. 111, 133-145.

Mustonen, K., Ala-Kurikka, E., Orro, T., Peltoniemi, O., Raekallio, M., Vainio, O., Heinonen, M., 2011. Oral ketoprofen is effective in the treatment of non-infectious lameness in sows. Vet. J. 190, 55-59.

Noonan, G.J., Rand, J.S., Priest, J., Ainscow, J., Blackshaw, J.K., 1994. Behavioural observations of piglets undergoing tail-docking, teeth clipping and ear notching. Appl. Anim. Behav. Sci. 39, 203-213.

Prunier, A., Mounier, A.M., Hay, M., 2005. Effect of castration, tooth resection, or tail-docking on plasma metabolites and stress hormones in young pigs. J. Anim. Sci. 83, 216-222.

Reyes, L., Tinworth, K.D., Li, K.M., Yau, D.F., Waters, K.A., 2002. Observer-blinded comparison of two nonopiod analgesics for postoperative pain in piglets. Pharmacology, Biochemistry and Behaviour. 73, 521-528.

Richards, B.D., Black, D.H., Chrisley, R.M., Royal, M.D., Smit, R.F., Dobson, H., 2009. Effects of the administration of ketoprofen at parturition on the milk yield and fertility of Holstein-Friesian cattle. Veterinary Record 165, 102-106.

Roest, K., Montanari, C., Fowler, T., Baltussen, W., 2009. Resource efficiency and economic implications of alternatives to surgical castration without anaesthesia. Animal 3, 1522-1531.

Schulze, M., Ruediger, K., Jung, M., Zechner, G., Jourquin, J., 2012. Post-farrowing stress management in sows by administration of azaperone. 22nd International Pig Veterinary Society Congress Proceedings, NO-267.

Stafford, K.J., Mellor, D.J., 2007. Pain: A developing issue in veterinary medicine. The Vet. J. 174, 225-226.

Stafford, K.J., Mellor, D.J., Todd, S.E., Ward, R.N., McMeekan, C.M., 2003. The effect of different combinations of lignocaine, ketoprofen, xylazine and tolazoline on the acute cortisol response to dehorning in calves. New Zealand Vet. J. 51, 219-226.

Sutherland, M.A., Bryer, P.J., Krebs, N., McGlone, J.J., 2009. The effect of method of tail-docking on tail-biting behaviour and welfare of pigs. Animal Welfare 18, 561-570.

Sutherland, M.A., Bryer, P.J., Krebs, N., McGlone, J.J., 2008. Tail-docking in pigs: acute physiological and behavioural responses. Animal 2, 292-297.

Sutherland, M.A., Davis, B.L., McGlone, J.J., 2011a. The effect of local or general anesthesia on the physiology and behaviour of tail docked pigs. Animal 5, 1237-1246.

Sutherland, M.A., Tucker, C.B., 2011b. The long and short of it: A review of tail-docking in farm animals. Appl. Anim. Behav. Sci. 135, 179-191.

Taylor, A.A., Weary, D.M., 2000. Vocal responses of piglets to castration: identifying procedural sources of pain. Appl. Anim. Behav. Sci. 70, 17-26.

Taylor, A.A., Weary, D.M., Lessard, M., Braithwaite, L., 2001. Behavioural responses of piglets to castration: the effect of piglet age. Appl. Anim. Behav. Sci. 73, 35-43.

Ting, S.T.L., Earley, B., Crowe, M.A., 2003. Effect of repeated ketoprofen administration during surgical castration of bulls on cortisol, immunological function, feed intake, growth, and behaviour. J. Anim. Sci. 81, 1253-1264.

Torrey, S., Devillers, N., Lessard, M., Farmer, C., Widowski, T., 2009. Effect of age on the behavioural and physiological responses of piglets to tail-docking and ear notching. J. Anim. Sci. 87, 1778-1786.

Tuyttens, F.A.M., Vanhonacker, F., Langendries, K., Aluwe, M., Millet, S., Bekaert, K., Verbeke, W., 2011. Effect of information provisioning on attitude toward surgical castration of male piglets and alternative strategies for avoiding boar taint. Res. Vet. Sci. 91, 327-332.

Weary, D.M., Niel, L., Flower, F.C., Fraser, D., 2006. Identifying and preventing pain in animals. Appl. Anim. Behav. Sci. 100, 64-76.

White, R.G., DeShazer, J.A., Tressler, C.J., Borcher, G.M., Davey, S., Waninge, A., Parkhurst, A.M., Milanuk, M.J., Clemens, E.T., 1995. Vocalization and physiological response of pigs during castration with or without a local anesthetic. J. Anim. Sci. 73, 381-386.

Wischner, D., Kemper, N., Stamer, E., Hellbruegge, B., Presuhn, U., Krieter, J., 2009. Characterization of sows' postures and posture changes with regard to crushing piglets. Appl. Anim. Behav. Sci. 119, 49-55.

CHAPTER 2: Investigation of the use of meloxicam for reducing pain associated with castration and tail-docking and improving performance in piglets.

2.1 Introduction

Castration of male piglets is a routine, painful procedure usually carried out in the piglets' first week of life. The primary purpose of castration is to prevent boar taint, an unpleasant odour associated with heated fat from entire male pig carcasses. Despite evidence suggesting that the procedure causes both acute and possibly long-term pain (Hay et al., 2003), the use of anaesthesia and post-operative analgesia is not common. The lack of pain control associated with this procedure is of growing scientific and public concern due to consideration of piglet welfare (Keita et al., 2010). Suitable methods that reduce pain caused by surgical castration and alternatives to surgical castration are being explored by the pig production sector (Hansson et al., 2011).

Tail-docking is another routinely performed procedure carried out on neonatal pigs. Tails are typically cut using side-cutters or a cauterizing tool. The reason for performing this surgery is to reduce the risk of tail-biting in later stages of production, the occurrence of which is a welfare problem and of economic concern for producers (Sutherland et al., 2011). It is not routine practice for analgesics or anaesthetics to be used to relieve the pain associated with the procedure. There is some research evidence that the tail-docking procedure causes distress to the animal (Noonan et al., 1994).

Non-steroidal antiinflammatory drugs (NSAIDs) are becoming licensed in food-producing animals providing an opportunity to address a major welfare concern regarding the swine industry's need to perform certain painful surgical procedures on piglets such as castration

and tail-docking. The long-acting NSAID meloxicam (Metacam[®], Boehringer Ingelheim Ltd., Burlington, ON) has been studied extensively for its analgesic properties in various species (Keita et al., 2010) and may prove useful in dealing with pain associated with piglet castration, thus improving welfare and possibly productivity.

Studies have found meloxicam to be effective for reducing post-operative pain and stress in piglets after castration. Keita et al. (2010) showed that pre-operative administration of meloxicam significantly reduced plasma cortisol concentrations and ACTH after surgical castration and mitigated behavioural alterations indicative of pain between 2 and 24 h after the procedure. Similarly, Hansson et al. (2011) demonstrated that piglets receiving meloxicam after castration displayed less pain-related behaviours on both castration day and the following day compared to those not given meloxicam. However, these studies tend to be relatively small and, therefore, not able to adequately measure analgesic effects on performance.

The objective of this study was to determine the efficacy of meloxicam administered as a routine measure to piglets prior to castration and tail-docking in order to reduce post-operative pain and possibly improve performance.

2.2 Materials and Methods

This study was approved by the University of Guelph Animal Care Committee in accordance with the Canadian Council of Animal Care Guidelines.

Herd and facilities

This study was carried out on a 600-sow commercial swine operation between May and November 2011. The sows were Landrace x Yorkshire crossbreds and the sires of the piglets were Duroc x Pietrain. All piglets were housed in 1 of 5 fully-slatted farrowing rooms, 4 rooms

containing 24 farrowing crates and 1 containing 12 crates. The rooms were mechanically ventilated and heat pads were provided in the creep area of each crate. Piglets were fed by suckling their mother's milk. No additional diet was offered. Piglets had unlimited access to water nipples. No piglets were subjected to teeth clipping. The rooms were filled in an all-in/all-out manner and were cleaned and disinfected between groups.

Study design

This study involved 2,888 piglets (1,499 males and 1,389 females) from 407 litters. Piglets received an injection of 200mg of iron and were ear notched within 48 h of birth. All piglets, gilts and barrows, were systematically allocated to 1 of the following treatment groups at least 30 min prior to tail-docking and castration:

- Group 1: males receiving an IM injection of 0.4 mg/kg of bodyweight of meloxicam, n=743

- Group 2: males receiving an IM injection of 0.4 mg/kg of bodyweight of a placebo, n=756

- Group 3: females receiving an IM injection of 0.4 mg/kg of bodyweight of meloxicam, n=684

- Group 4: females receiving an IM injection of 0.4 mg/kg of bodyweight of a placebo, n=705

All treatments were represented in each litter. All piglets were weighed on the day of tail-docking and castration (5-7 d of age) and prior to weaning (19-21 d of age). Piglets were first tail-docked using side-cutters and then castrated (if male) before being set down. Castration was carried out following methods of Van Beirendonck et al. (2011) by making an initial horizontal

incision in the scrotum with a scalpel after which the testicles were removed by tearing the spermatic cords. Castrations were performed in a systematic order within each litter. Cryptorchid pigs and pigs with inguinal hernias were tagged prior to treatment and not castrated. Mortality data were collected daily. Cross-fostering was applied within 48 h of birth and these piglets were not discriminated in the study as the researchers could not identify which piglets had been introduced into a given litter with all litters being treated in a similar manner. Researchers were blinded to treatment until the conclusion of the study.

Measurements

During castration, vocalization was measured on a subset of 150 male piglets using a decibel meter (Decibel Meter Pro, Performance Audio for iOs devices) measuring dB(A). The decibel meter was held as close to the snout as possible without touching it throughout the entire procedure. The call with the highest intensity level during the castration was recorded.

Following tail-docking and castration, piglet behaviour was observed through continuous observation of instantaneous behaviours for 30 min immediately following castration in subset of 132 piglets in15 litters. A detailed observation form with 9 separate behaviours was used (**Table 2.1**). Piglets were considered positive for a specific behaviour if that behaviour was observed during the period of observation. Piglets were identified by a number marked on the top of their head at the time of treatment and were studied from the back of the pen.

A total of 236 blood samples from piglets in 40 litters were collected at 30 min, 60 min, 90 min, and 4 h following tail-docking and castration for determination of cortisol concentrations. An individual pig was bled once. EDTA tubes were used for blood collection in order to prevent clotting prior to testing the plasma samples. The blood samples were centrifuged at 3900 x g at 5°C for 20 min, within 1 to 3 h after the collection. The plasma was stored in 2 mL

micro tubes, PP (Sarstedt) at -20°C until they were analyzed for cortisol with a solid-phase, competitive chemiluminescent enzyme immunoassay (Immulite®/Immulite® Cortisol 1000, Siemens Healthcare Diagnostic Products Ltd.). The test had an analytical sensitivity of 5.5 nmol/L with a calibration range of 28 to 1380 nmol/L.

All piglets in the study were individually weighed using a DYMO (Pelouze) shipping scale at castration (5-7 d of age) and prior to weaning (19-21 d of age). After zeroing the scale holding a crate, piglets were placed into the crate for weighing. The scale had a maximum capacity of 68 kg and a resolution of 0.1 kg.

Statistical Analysis

Statistical analysis was performed using Stata, version 10.0 (StataCorp, College Station, TX, USA) and Statistix, version 9.0 (Analytical Software, FL, USA). Homoscedasticity was examined by plotting the standardized residuals against the predicted values and normality was visually examined with a normal quantile plot. Quantitative, normally distributed data including ADG and vocalizations during castration were compared using an analysis of variance. Quantitative, not normally distributed data including plasma cortisol concentrations were compared using the Kruskal-Wallis non-parametric test. Qualitative data including mortality and behaviour following castration were compared using the Pearson chi-squared test. P-values ≤ 0.05 were considered significant, but values ≤ 0.10 were reported and considered as indicating a possible trend.

2.3 Results

There was not a significant difference between treatment groups with respect to average daily gain (ADG) (**Table 2.2**). Pigs given meloxicam prior to castration and tail-docking did not

grow faster than male pigs given the placebo (P=0.18). Likewise, gilts given meloxicam did not grow better than those given placebo prior to tail-docking (P=0.18).

There was not a significant difference between males receiving meloxicam and the placebo (P=0.67) and females receiving meloxicam and the placebo (P=0.30) with respect to mortality rate (**Table 2.2**). Mortality of gilts differed from that of barrows in that gilts had a mortality rate of 2.80% while barrows had a mortality rate of 4.16% (P=0.04). Causes of mortality appeared to be similar for each group and for gilts and barrows.

Barrows receiving meloxicam displayed significantly less tail jamming behaviour compared to barrows receiving the placebo, with 7.4±0.25% of piglets in Group 1 and 34.6±0.49% piglets in Group 2 displaying the behaviour (P=0.01). There was a tendency for barrows receiving meloxicam to display less isolated behaviour, with 18.5±0.39% of piglets in Group 1 and 38.5±0.49% of piglets in Group 2 showing isolated behaviour (P=0.10). There was not a significant difference between gilt treatment groups in the study for any of the observed behaviours (P>0.05).

No significant difference existed between treatment groups with respect to vocalizations during castration. Piglets in Group 1 produced 104.8±1.1 dB on average and piglets in Group 2 produced 104.8±1.0 dB on average (P=0.46). The most frequent vocalization produced by both groups was 105 dB.

There was a significant difference between groups for barrows with respect to plasma cortisol levels at 30 min, 60 min, and 90 min following castration and tail-docking (**Table 2.3**). There was a significant difference between piglets in Groups 1 and 2 at 30 min (P<0.01), at 60 min (P<0.01), and at 90 min following castration and tail-docking (P<0.01). There was not a significant difference between plasma cortisol levels of Groups 1 and 2 and with respect to

plasma cortisol levels at 4 h following castration and tail-docking ($P=0.45$).

When considering tail-docking gilts, there was not a significant difference between plasma cortisol concentrations between Groups 3 and 4 at 30 min ($P=0.13$), 60 min ($P=0.49$), 90 min ($P=0.46$), or 4 h ($P=0.92$) following the procedure.

2.4 Discussion

At present, there are no ideal methods of measuring the effectiveness of pain control. Blood cortisol levels are often used as an objective indicator of stress and pain in response to painful procedures such as castration, but there are limitations. For example, cortisol levels may become elevated as a result of stresses such as handling, or vary over the course of the day. There has been work to suggest that increased levels of plasma cortisol concentrations after castration can be attributed mainly to the procedure itself as they are of much lower amplitude and duration in sham-castrated pigs compared to surgically castrated animals, and that this difference is likely related to pain or tissue damage (Prunier et al., 2005). The present study found that plasma cortisol levels up to 90 min after castration were significantly reduced in the piglets that received meloxicam compared to the piglets that received the placebo, suggesting a reduction in the effects of castration on stress and pain in a short time period. Similar to the present study, Keita et al. (2010) found that plasma cortisol concentrations are significantly reduced 30 min post-castration with pre-operative administration of meloxicam compared to a placebo group. Also, in agreement with the present study, Prunier et al. (2005) observed that plasma cortisol concentrations were higher from 15 to 90 min in piglets that were castrated compared to those that were sham-castrated or not handled, with no difference between the sham-castrated and not-handled groups. In addition, Prunier et al. (2005) reported that peak

values of plasma cortisol were found between 30 and 60 min after surgical castration, and that the return to pre-surgery levels occurred within 3 h after the procedure. The present study supported this finding with no significant difference of plasma cortisol levels between treatment groups at 4 h following castration.

Tail-docking did not seem to elicit a physiological stress response in female piglets suggesting that there is an insufficient nociceptive stimulus caused by tail-docking. These results are supported by Prunier et al. (2005) who also found no significant changes in plasma cortisol concentrations after tail-docking. Similarly, Sutherland et al. (2008) found that anaesthetic treatment was not effective at significantly changing the physiological or behavioural response from tail-docking in pigs. However, Sutherland et al. (2008) found that cortisol concentrations were higher in tail-docked pigs compared to control-handled pigs 60 min after tail-docking and Noonan et al. (1994) observed that behaviours such as tail jamming and tail wagging were greater in tail-docked pigs compared to control-handled pigs. These results suggest that pigs do experience pain during and in the hours following tail-docking, but the results from the present study demonstrate that these effects may be of short duration and may not be improved through the administration of an analgesic.

The impact of surgical castration of male piglets on subsequent weight gain during the suckling period has been previously studied but results are mixed (Keita et al., 2010). Pre-weaning growth rates in pigs can be quite variable depending on a variety of factors, including genetic potential, environmental conditions, availability of nutrition, and stressful events (Kielly et al., 1999). It is, therefore, difficult to assess whether or not an improvement in performance should be expected with administration of analgesics (Keita et al., 2010). The present study suggests that production performance is not an adequate measure to determine if meloxicam is

effective in reducing post-operative pain associated with castration in that castrated pigs, whether receiving meloxicam or not, grew as well as non-castrated litter mates. Other studies have also found no relationship between pain control treatment at castration and weight gain (Hay et al., 2003; Keita et al., 2010; Hansson et al., 2011).

Behavioural indices such as vocalizations, postures, specific pain-related behaviours and general behaviours are relevant parameters to assess pain and discomfort induced by painful procedures (Keita et al., 2010). However, behavioural measurements tend to be subjective and observers must be kept "blind" to the treatment. In addition, behavioural indices of pain are difficult to assess because there is so much individual variation between animals and pain-related behaviours tend to be more difficult to assess after the acute phase (Hay et al., 2003).

Less tail jamming behaviour was observed in the first 30 min following castration in piglets receiving meloxicam compared to the placebo in the present study. This is in agreement with other studies which have found castrated piglets to display more rigid postures and huddling following castration, a behaviour that may be considered as protective allowing the animal to avoid the stimulation of painful tissue (Hay et al., 2003; Keita et al., 2010). An increase in tail jamming behaviour has also been reported in pigs that undergo tail-docking compared to non-processed piglets suggesting that it is not a normal behaviour and may indicate distress (Noonan et al., 1994). The present study did not find a statistical difference between treatment groups involving gilts which underwent tail-docking in any of the observed behaviours. The present study found that administering meloxicam to piglets before castration tended to result in less isolated behaviour. This is in agreement with previous studies which have demonstrated that castrated piglets avoid social contact with their littermates and are often desynchronized and isolated (Hay et al., 2003; Moya et al., 2008). This behaviour is unusual for such social animals

as pigs and suggests that the piglets may be experiencing pain (Hay et al., 2003). It is possible that castrates avoid certain behaviours in an effort to minimize pain and isolation is thought to be a behavioural adaption with a protective role as a way of avoiding contact with littermates that could generate pain as a result of stimulation of the affected tissues (Mellor and Stafford, 2003).

Although it is common for piglets to vocalize when they are handled, a clear difference between vocalizations produced when being handled and when being surgically castrated exists (Hansson et al., 2011). Piglets produce high frequency vocalizations of higher intensity and longer duration during surgical castration compared to when piglets are sham-castrated or castrated under local anaesthesia (Taylor and Weary, 2000). It has been suggested that a parameter describing a single moment in the call, such as peak level, is more representative than parameters describing mean level (Hansson et al., 2011). Therefore, in the present study, the vocalization with the highest intensity during castration was recorded. The present study did not find a difference between the vocalizations produced by the different treatment groups. This may be expected as surgical castration of male piglets induces both acute and long-term effects (Hay et al., 2003), and analgesic drugs do not prevent the acute pain experienced during castration, but instead mitigate the mid- and long-term pain experienced in the following hours after the procedure.

This current study supports earlier studies that have shown that pre-operative administration of meloxicam contributes to the relief of stress and post-operative pain associated with castration in piglets (Keita et al., 2010; Hansson et al., 2011). It can be concluded that meloxicam did not cause any negative effects when administered prior to castration and tail-docking based on the growth rate and mortality results of gilts and barrows from the presented findings. However, gilts had significantly lower mortality than barrows in the present study. Van

Beirendonck et al. (2012) found that piglets surviving the nursing period were significantly heavier at birth than piglets that died before weaning and that mortality rate is higher in processed piglets compared to non-processed piglets. Birth weights were not recorded in the present study, but mean weight at castration and tail-docking was similar between barrows and gilts with barrows weighing an average of 2.84 kg and gilts weighing an average of 2.78 kg. In the present study, barrows were subject to castration and tail-docking while gilts were only subject to tail-docking. Baxter et al. (2012) investigated sex-biased mortality and found that males had significantly higher preweaning mortality compared to females, despite having a higher average birth weight. Male piglets tend to suffer more from crushing by the sow and disease-related deaths compared to females, and also show impaired thermoregulation compared to females (Baxter et al., 2012).

Although evidence exists that castration induces pain in piglets, castration is usually preformed in the absence of analgesia (Hay et al., 2003). Some European countries have banned surgical castration in the absence of anaesthesia and other countries may follow (Tuyttens et al., 2011). However, studies have found a less favourable attitude of the farming community towards alternative strategies to surgical castration (Tuyttens et al., 2011). This current study illustrates that castrated pigs perform as well as female pigs suggesting that castration does not impact piglet performance during their suckling period. Therefore, farmers are unlikely to see an economic return associated with using analgesia, however, producers in the future may need to consider using pain control as part of their standard operating procedures in order to meet their costumer's expectations.

2.5 Implications

- Meloxicam appears effective in the treatment of post-operative pain associated with surgical castration and tail-docking of male piglets based on plasma cortisol levels and behavioural observations.

- Growth performance of barrows and gilts, and the performance of barrows receiving meloxicam and barrows given the placebo were similar, suggesting that the pain associated with castration may not be of sufficient intensity or duration to cause reduced performance during the suckling period.

2.6 References

Baxter, E., Jarvis, S., Palarea-Albaladejo, J., Edwards, S., 2012. The weaker sex? The propensity for male-biased piglet mortality. PLoS ONE 7(1): e30318.
doi: 10.1371/journal.pone.0030318.

Hansson, M., Lundeheim, N., Nyman, G., Johansson, G., 2011. Effect of local anaesthesia and/or analgesia on pain responses induced by piglet castration. Acta Veterinaria Scandinavica. 53:34.

Hay, M., Vulin, A., Génin, S., Sales, P., Prunier, A., 2003. Assessment of pain induced by castration in piglets: behavioural and physiological responses over the subsequent 5 days. Appl. Anim. Behav. Sci. 82, 201-218.

Keita, A., Pagot, E., Prunier, A., Guidarini, C., 2010. Pre-emptive meloxicam for postoperative analgesia in piglets undergoing surgical castration. Vet. Anaesth. Analges. 37, 637-374.

Kielly, J., Dewey, C.E., Cochran, M., 1999. Castration at age 3 days of age temporarily slows growth of pigs. Swine Health Prod. 7, 151-153.

Mellor, D.J., Stafford, K.J., 2003. Assessing the welfare status of newborn farm animals. Animal Welfare 12, 695-698.

Moya, S.L., Boyle, L.A., Lynch, P.B., Arkins, S., 2008. Effect of surgical castration on the behavioural and acute phase responses of 5-day-old piglets. Appl. Anim. Behav. Sci. 111, 133-145.

Noonan, G.J., Rand, J.S., Priest, J., Ainscow, J., Blackshaw, J.K., 1994. Behavioural observations of piglets undergoing tail-docking, teeth clipping and ear notching. Appl. Anim. Behav. Sci. 39, 203-213.

Prunier, A., Mounier, A.M., Hay, M., 2005. Effect of castration, tooth resection, or tail-docking on plasma metabolites and stress hormones in young pigs. J. Anim. Sci. 83, 216-222.

Sutherland, M.A., Bryer, P.J., Krebs, N., McGlone, J.J., 2008. Tail-docking in pigs: acute phase physiological and behavioural responses. Animal 2, 292-297.

Sutherland, M.A., Davis, B.L., McGlone, J.J., 2011. The effect of local or general anaesthesia on the physiology and behaviour of tail docked pigs. Animal 5, 1237-1246.

Taylor A.A., Weary, D.M., 2000. Vocal responses of piglets to castration: identifying procedural sources of pain. Appl. Anim. Behav. Sci. 70, 17-26.

Tuyttens, F.A.M., Vanhonacker, F., Langendries, K., Aluwe, M., Millet, S., Bekaert, K., Verbeke, W., 2011. Effect of information provisioning on attitude toward surgical castration of male piglets and alternative strategies for avoiding boar taint. Res. Vet. Sci. 91, 327-332.

Van Beirendonck, S., Driessen, B., Verbeke, G., Geers, R., 2011. Behaviour of piglets after castration with or without carbon dioxide anaesthesia. J. Anim. Sci. 89, 3310, 3317.

Van Beirendonck, S., Driessen, B., Verbeke, G., Permentier, L., Perre, V., Geers, R., 2012. Improving survival, growth rate, and animal welfare in piglets by avoiding teeth shortening and tail-docking. J. Vet. Behav. 7, 88-93.

Table 2.1: Description of piglet behaviours used to assess post-operative pain.

Behaviour	Description of behaviour
Lying down	Body weight supported by belly or side
Standing	Body weight supported by four legs
Walking	Moving on four legs
Head Low	Standing idle with the head held low, below the shoulder
Isolated	Lying or standing away from the main group of piglets
Tremble	Piglet's body is trembling
Tail-Jam	Tail held tight against body
Tail-Wiggle	Tail wagging back and forth rather than hanging down, relaxed
Scooch	Piglet dragging its rump along the floor

Table 2.2: ADG of treatment groups receiving meloxicam or a placebo prior to tail-docking and (in the case of males) castration from the day of castration and tail-docking (5-7 d of age) to weaning (19-21 d of age).

Group	Treatment	Sex	N	Mean ± sd (g/day)[2]	Mortality (%)[2]
Group 1	Meloxicam[1]	Male	743	171.9 ± 53.8	4.38
Group 2	Placebo	Male	756	173.6 ± 52.3	3.94
Group 3	Meloxicam	Female	684	169.3 ± 54.2	3.25
Group 4	Placebo	Female	705	172.3 ± 51.9	2.35

[1]Metacam®, Boehringer Ingelheim Ltd., Burlington, ON
[2]$P>0.05$.

Table 2.3: Average plasma cortisol concentrations from pigs at various times after processing (tail-docking for females with the addition of castration for males).

	Time	N	Plasma Cortisol ± sd (nmol/L)	N	Plasma Cortisol ± sd (nmol/L)	P-value[2]
			Meloxicam[1]		Placebo	
Barrows (Groups 1, 2)	30 min	12	169.4 ± 50.8	13	344.4 ± 150.0	<0.01
	60 min	7	107.9 ± 29.6	14	292.5 ± 210.0	0.02
	90 min	25	79.2 ± 44.7	20	156.4 ± 105.4	<0.01
	4 hr	19	106.2 ± 60.0	13	124.6 ± 48.9	0.45
Gilts (Groups 3,4)	30 min	10	106.7 ± 71.3	13	117.2 ± 107.4	0.13
	60 min	10	78.1 ± 38.6	13	67.7 ± 24.1	0.49
	90 min	19	98.8 ± 62.7	19	72.4 ± 28.8	0.46
	4 h	17	89.4 ± 53.6	12	79.8 ± 35.7	0.92

[1]Metacam®, Boehringer Ingelheim Ltd., Burlington, ON

[2]Determined by Kruskal-Wallis One-Way ANOVA.

CHAPTER 3: Investigation of the use of meloxicam post-farrowing for improving sow performance and reducing pain.

3.1 Introduction

Pre-weaning mortality is an important issue in pig production, with more than 10% of live-born piglets dying before weaning and 80% of those in the first 3 days after birth (Svendsen, 1992). Crushing of piglets by the dam is a major cause of this neonatal mortality, with losses estimated at between 4.8 and 18% of all piglet mortality (Haussman et al., 1999). In addition to preventing accidental trauma, another important reason that the sow must quickly settle after parturition and begin to nurse is so that the piglets are able to consume colostrum, for energy and immunity.

It is generally accepted that parturition in any species is a painful process and even in species that give birth to litters of relatively small offspring there is potential for considerable pain to occur in the case of dystocia or small parity-1 sows farrowing large piglets (Mainau and Manteca, 2011). Analgesics such as meloxicam, a relatively long-acting non-steroidal anti-inflammatory drug (NSAID), are becoming licensed for food-producing animals. There is limited published research on the impact of analgesia after parturition in sows. In cattle, Richards et al. (2009) found that administration of ketoprofen (a NSAID) at parturition is clinically advantageous when fetal membranes are likely to be retained, but debated whether all calving cows should be treated. Administering analgesics to sows at farrowing may alleviate pain and allow them to lie more restfully, and thus provide piglets more opportunity for colostrum intake without the risk of being crushed.

The objective of this trial was to determine the effect of meloxicam administered to sows

at the time of parturition on nursing behaviour and piglet survival and growth.

Materials and Methods

This study was approved by the University of Guelph Animal Care Committee in accordance with the Canadian Council of Animal Care Guidelines.

Herd and facilities

This study was carried out on a 600-sow commercial swine operation between May 2011 and November 2011. The sows were Landrace x Yorkshire crossbreds and the sires of the piglets were Duroc x Pietrain. All piglets were housed in 1 of 5 fully-slatted farrowing rooms (4 rooms containing 24 farrowing crates and 1 containing 12 crates). The rooms were mechanically ventilated and heat pads were provided in the creep area of each crate. Apart from nursing, no additional diet was offered to piglets. Piglets had unlimited access to water nipples. Teeth clipping of piglets was not practiced. The rooms were filled in an all-in/all-out manner and were cleaned and disinfected between groups.

Study Design

This study involved 289 litters and 3,006 piglets. Piglets received an injection of 200mg of iron and were ear notched within 12 h of birth. Sows were systematically allocated to receive a single intramuscular injection of one of the following treatments within 12 h of farrowing: an IM injection of 0.4 mg/kg of bodyweight of meloxicam (Metacam[®], Boehringer Ingelheim Ltd., Burlington, ON) or an IM injection of 0.4 mg/kg of bodyweight of a placebo. All piglets were weighed within 12 h of birth, at castration and tail-docking (5-7 d of age), and prior to weaning (19-21 d of age). Piglets were first tail-docked using side-cutters and males were castrated before being set down. Castration was carried out following methods of Van Beirendonck et al. (2011)

by making an initial horizontal incision in the scrotum with a scalpel after which the testicles were severed by tearing the spermatic cords. Castrations were performed in a systematic order within each litter. Cryptorchid pigs and pigs with inguinal hernias were tagged and not castrated. Mortality data were collected daily. Cross-fostering was applied within 48 h of birth and these piglets were not discriminated in the study as the researchers could not identify which piglets had been introduced into a given litter with all litters being treated in a similar manner. Researchers were blinded to treatment until the conclusion of the study.

Measurements

Twenty sows were blood-sampled from an ear vein at treatment and 4 h post-treatment for determination of cortisol concentrations (10 sows from each treatment). The blood samples were centrifuged at 3900 x g at 5°C for 20 min, within 1 to 3 h after the collection. The plasma was stored in 2 mL micro tubes, PP (Sarstedt) at -20°C until they were analyzed for cortisol with a solid-phase, competitive chemiluminescent enzyme immunoassay (Immulite[®]/Immulite[®] Cortisol 1000, Siemens Healthcare Diagnostic Products Ltd.). The test had an analytical sensitivity of 5.5 nmol/L with a calibration range of 28-1380 nmol/L.

HOBO® data loggers were used on a total of 43 sows to record position changes for the first 24 h after treatment. Data loggers were attached to the right hind leg of the sow after treatment and recorded positional changes at 5 sec intervals. Data loggers were protected in a waterproof pocket and securely fastened with Vet Rap® and tape. Each data point was converted into an acceleration unit (g) and a sow was recorded as 'standing' when the X axis was > or = 0.59 g, otherwise the posture was recorded as 'other'. The outcomes calculated were the proportion of standing time during the 24 h and the mean time of standing bouts during the 24 h per sow.

Rectal temperatures were recorded for a total of 30 sows at treatment, 4 h post-treatment, and at 24 h post-treatment. Temperatures were taken from the rectum using a digital thermometer (MC-343HP, Omron). Feed intake of these sows was recorded at 24 h post-treatment using a 1-3 scale (ate nothing-ate everything).

Piglets in the study were individually weighed using a DYMO (Pelouze) shipping scale within 12 h of birth, at castration (5-7 d of age) and prior to weaning (19-21 d of age). After zeroing the scale holding a crate, piglets were placed into the crate for weighing. The scale has a capacity of 68 kg and a resolution of 0.1 kg.

Statistical Analysis

Statistical analysis was performed using Stata, version 10.0 (StataCorp, College Station, TX, USA) and Statistix, version 9.0 (Analytical Software, FL, USA). A mixed-effect linear regression model was run with ADG as the outcome to test the effects of treatment and parity as well as any interaction present. A multi-level mixed effects logistic regression model was run with mortality as the outcome to test the effects of treatment and parity as well as any interaction present. Plasma cortisol concentrations were plotted on a histogram to determine normality and then analyzed by Two-Sample T-Test to test the effects of treatment. P-values ≤ 0.05 were considered significant.

Results

There was no significant difference in average daily gain (ADG) from birth to weaning (19-21 d of age) between treatment groups as piglets of sows receiving meloxicam did not differ ($P=0.65$) from sows receiving the placebo (234.8±65.6 g/day vs. 231.9±68.0 g/day, respectively). Gilts and barrows grew at a similar rate. Average litter size and weight also did not

differ between treatment groups (**Table 1**). Parity was found to not significantly affect ADG in the model ($P=0.99$) and no interaction between parity and treatment existed ($P=0.91$).

There was no significant difference in mortality rate between treatment groups, with 11.59% mortality in the meloxicam group and 10.54% in the placebo group ($P=0.46$). Parity was found to significantly affect mortality in the model ($P<0.001$), but did not cause a significant change in the outcome of the model. No interaction between treatment and parity existed ($P=0.42$).

There was a tendency for sows receiving meloxicam after farrowing to have lower plasma cortisol levels than sows receiving the placebo after farrowing at 4 h following treatment ($P=0.09$) (**Table 2**). There was no significant difference in cortisol concentrations between groups at the time of treatment following farrowing ($P=0.25$).

No significant difference existed between treatment groups with respect to rectal temperatures of the sows after farrowing at treatment ($P=0.85$), 4 h following treatment ($P=0.52$), or 24 h following treatment ($P=0.42$). Sows receiving meloxicam had average temperature of 38.8°C at treatment, 4 h after treatment and 24 h after treatment. Average temperatures of 38.8°C, 38.9°C, and 38.7°C were observed for sows receiving the placebo at treatment, 4 h after treatment and 24 h after treatment, respectively.

There was not a significant difference of feed intake 24 h post-treatment between groups with 44.4% and 43.8% of sows finishing all of their feed the next morning when receiving meloxicam and the placebo, respectively ($P=0.98$).

Whether receiving meloxicam or the placebo, sows did not differ in their postural changes in the first 24 h following treatment. There was not a significant difference in standing time between treatment groups with sows receiving meloxicam standing an average of 65.5±38.2

min or 4.6% of the time and sows receiving the placebo standing an average of 77.3±67.1 min or 5.4% of the time (P=0.92).

Discussion

Most piglet mortality occurs within the first day of life (Weary et al., 1996). It is very important for piglets to obtain colostrum within the first 24 h of life in order to obtain sufficient energy and adequate immunological protection (Svendsen, 1992). Starving piglets spend more time in close proximity to the sow in an attempt to increase their milk intake, but consequently, are at a higher risk of being crushed (Weary et al., 1996).

The present study did not find meloxicam to be effective in reducing the proportion of time sows spent standing during the first 24 h after farrowing and subsequent treatment. Mainau et al. (2009) found that sows appear uneasy and restless during the 24 h prior to parturition and spend most of their time (more than 82%) lying during the days around farrowing with this behaviour increasing (at least 90%) after farrowing. The present study found that sows spent the majority of their time lying (95%) whether or not they received meloxicam. In agreement with the present study, Haussman et al. (1999) reported that sows given an analgesic (butorphanol tartrate) every 6 h until 3 days after farrowing had reduced position changes during 48 h to 72 h, but not from farrowing to 48 h with no decrease in the rate of crushing over the 3 days. Lying behaviour around farrowing may be affected by various factors which cannot be controlled with the administration of an analgesic. For example, Mainau et al. (2009) found that there are individual differences in activity levels between sows with more marked variation from 1 day before until 1 day after farrowing. In addition, they found that human activity on the farm or environmental stress coincided with increased activity. This was not controlled for in the present

study.

No ideal measurement of the effectiveness of pain control currently exists in pigs. Behavioural observations may be used in assessing pain such as sow activity as discussed above, but measurements tend to be subjective and there is much individual variation. Physiological indicators of pain may include responses of the sympathetic-adrenomedullary system such as changes in heart rate and rectal temperature or responses of the hypothalamic-pituitary-adrenocortical system which may result in changes in cortisol levels (Mainau and Manteca, 2011). Blood cortisol levels may be used as an objective indicator of stress and pain, but they may also become elevated as a result of stresses such as handling. In addition, research has suggested there are circadian cycles so that blood cortisol concentrations rise and fall during the day, regardless of stress (Griffith and Minton, 1991). The present study found that sows receiving meloxicam tended to have lower plasma cortisol levels compared to those sows receiving the placebo, suggesting that the administration of meloxicam causes reduced pain after the stressful event of farrowing. Irrespective of the parturition environment, the parturition phase is associated with increased plasma cortisol concentrations (Meunier-Salaun et al., 1991) suggesting that it is a stressful and painful process. Induced stress can disrupt the expression of normal maternal behaviour and decrease the welfare of both the sow and their piglets. Future studies should investigate this further to determine if there is an advantage to administer NSAIDs in certain situations such as difficult farrowings, as it is possible that some sows may find the post-farrowing experience more stressful than others. For example, a gilt that required manual assistance to deliver large piglets might benefit more from analgesia than an older sow following a relatively quick and uneventful farrowing.

A reduction in feed intake is commonly seen in sows after parturition, especially in

primiparous pigs, and could be attributed to pain (Mainau and Manteca, 2011). The present study did not find a difference in feed intake between treatment groups. This is in agreement with Mainau et al. (2012). In cattle, Proudfoot et al. (2009) found that cows undergoing a difficult calving did not differ in their feed intake in the first 24 h after calving compared to cows undergoing a normal calving. Feed intake during lactation is affected by a variety of factors including season, lactation length, and genetic variation among individual sows (Lewis and Bunter, 2011). It is important to consider factors such as feed delivery practices, environmental conditions, and individual sow health status when interpreting information on feed intake during lactation (Lewis and Bunter, 2011). This was not recorded in the current study.

It can be concluded that meloxicam did not cause any negative effects based on the growth rate and mortality results gathered. The results suggest that production performance is not improved through the routine administration of meloxicam to all sows at farrowing. Piglets of sows receiving meloxicam did not differ in their ADG compared to piglets from sows receiving the placebo. There was also no difference between treatment groups with respect to average litter size or weight at birth, castration or weaning. Production performance in pigs can be quite variable depending on a variety of factors, including genetic potential, environmental conditions, availability of nutrition, and stressful events (Kielly et al., 1999) and may not be a good measure to determine whether meloxicam did reduce pain and made the sow more comfortable immediately after farrowing. Hirsch et al. (2003) found that the use of meloxicam to treat mastitis-metritis-agalactia syndrome (MMA) in sows increased the weight gain and decreased the mortality of piglets.

The routine use of meloxicam to all sows post-farrowing did not appear to result in a significant improvement in performance. However, it is possible that some sows may find the

post-farrowing experience more stressful. Primiparous gilts are believed to experience more painful parturitions than multiparous sows due to the lack of experience at first parturition and a higher degree of effort compared to multiparous females (Mainau and Manteca, 2011). Keller (2012) found meloxicam treatment of sows post partum improves piglet survival in the first 5 days suggesting that sows may suffer from pain after parturition. Therefore, the use of analgesics to alleviate pain immediately after farrowing may be a useful tool for a subset of animals (possibly those with prolonged or difficult parturitions), and this area will require further study.

At present, there are few North American farms where pain control is considered for the post-farrowing sow. The present study has found that routine use of meloxicam did not improve productivity, but there was some indication that meloxicam may have reduced pain based on plasma cortisol levels. It is possible that among farrowing sows there are some that experience more pain and have more need for pain control than others. Further research should concentrate on examining the benefits of analgesia on this particular subset of animals, both with respect to improved productivity but also in order to determine if meloxicam is effective in reducing post-operative pain in these sows.

Implications

- Meloxicam given to sows after farrowing might be useful in reducing pain, but further work is necessary to verify.

- Routine use of meloxicam to all sows post-farrowing does not result in improved piglet survival and growth, but possibly improved performance would be noted in a subset of sows such as those with a difficult farrowing, but further studies are required to confirm.

References

Griffith, M.K., Minton, J.E., 1991. Free-running rhythems of adrenocorticotropic hormone (ACTH), cortisol and melatonin in pigs. Domest Anim Endocrinol 8, 201-208.

Haussman, M.F., Lay, D.C., Buchanan, H.S., Hopper, J.G., 1999. Butorphanol tartrate acts to decrease sow activity, which could lead to reduced pig crushing. J. Anim. Sci. 77, 2054-2059.

Hirsch, A.C., Philipp, H., Kleemann, R., 2003. Investigation on the efficacy of meloxicam in sows with mastitis-metritis-agalactia syndrome. J. Vet. Pharmacol. Therap. 26, 355-360.

Keller, F., 2012. Improved early piglet survival after Metacam® treatment of sows post farrowing. 22nd International Pig Veterinary Society Congress Proceedings, PO-177.

Kielly, J., Dewey, C.E., Cochran, M., 1999. Castration at age 3 days of age temporarily slows growth of pigs. Swine Health Prod. 7, 151-153.

Lewis, C.R.G., Bunter, K.L., 2011. Body development in sows, feed intake and maternal capacity. Part 1: performance, pre-breeding and lactation feed intake traits of primiparous sows. Animal 512, 1843-1854.

Mainau, E., Dalmau, A., Ruiz-de-la-Torre, J.L., Manteca, X., 2009. Validation of an automatic system to detect position changes in puerperal sows. Appl. Anim. Behav. Sci. 121, 96-102.

Mainau, E., Manteca, X., 2011. Pain and discomfort cause by parturition in cows and sows. Appl. Anim. Behav. Sci. 135, 241-251.

Mainau, E., Ruiz-de-la-Torre, J.L., Dalmau, A., Salleras, J.M., Manteca, X., 2012. Effects of meloxicam (Metacam®) on post-farrowing sow behaviour and piglet performance. Animal 6, 494-501.

Meunier-Salaun, M.C., Gort, F., Prunier, A., Schouten, W.P.G., 1991. Behavioural patterns and progesterone, cortisol and prolactin levels around parturition in European (Large-White) and Chinese (Meishan) sows. Appl. Anim. Behav. Sci. 31, 43-59.

Proudfoot, K.L., Huzzey, J.M., von Keyserlingk, M.A.G., 2009. The effect of dystocia on the dry matter intake and behaviour of Holstein cows. J. Dairy Sci. 92, 4937-4944.

Richards, B.D., Black, D.H., Chrisley, R.M., Royal, M.D., Smit, R.F., Dobson, H., 2009. Effects of the administration of ketoprofen at parturition on the milk yield and fertility of Holstein-Friesian cattle. Veterinary Record 165, 102-106.

Svendsen, J., 1992. Perinatal mortality in pigs. Anim. Rep. Sci. 28, 59-67.

Van Beirendonck, S., Driessen, B., Verbeke, G., Geers, R., 2011. Behaviour of piglets after castration with or without carbon dioxide anaesthesia. J. Anim. Sci. 89, 3310, 3317.

Weary, D.M., Pajor, E.A., Thompson, B.K., Fraser, D., 1996. Risky behaviour by piglets: a trade off between feeding and risk of mortality by maternal crushing? Anim. Behav. 51, 619-624.

Table 3.1: Mean litter size, litter weight, and piglet weight of sows in different treatment groups receiving meloxicam or a placebo from birth to weaning (19-21 d of age).

	Treatment	Mean Litter Size ± sd	Mean Litter Weight ± sd (kg)	P-value[2]	Mean Piglet Weight ± sd (kg)	P-value[3]
Day 0	Meloxicam[1]	11.37 ± 1.95	17.27 ± 3.78	0.63	1.65 ± 0.37	0.12
	Placebo	11.28 ± 2.20	16.90 ± 3.77		1.63 ± 0.36	
Castration	Meloxicam[1]	10.29 ± 1.64	28.24 ± 6.47	0.19	2.90 ± 0.73	0.41
	Placebo	10.06 ± 1.82	27.35 ± 6.39		2.86 ± 0.74	
Weaning	Meloxicam[1]	9.81 ± 1.89	60.34 ± 15.05	0.25	6.44 ± 1.51	0.58
	Placebo	9.57 ± 1.86	58.59 ± 12.70		6.41 ± 1.53	

[1]Metacam®, Boehringer Ingelheim Ltd., Burlington, ON

[2]Determined by Wilcoxon Rank Sum Test

[3] Determined by one-way ANOVA

Table 3.2: Mean plasma cortisol concentrations from sows following farrowing at treatment (@txt) and 4-6 h after treatment.

Time	N	Plasma Cortisol (nmol/L)	Standard Deviation	N	Plasma Cortisol (nmol/L)	Standard Deviation	*P*-value[2]
	Meloxicam[1]			Placebo			
@ txt	9	149.7	113.5	10	191.5	145.0	0.25
4-6 h	9	99.2	55.5	10	144.2	89.2	0.09

[1]Metacam®, Boehringer Ingelheim Ltd., Burlington, ON

[2]Determined by Two-Sample T-Test

CHAPTER 4: A comparison of two different analgesics given prior to castration and tail-docking to relieve post-surgical pain in piglets.

4.1 Introduction

Castration of male piglets is a routine, painful procedure usually carried out in the piglets' first week of life for the prevention of boar taint, an unpleasant odour associated with heated fat from entire male pig carcasses. Despite evidence suggesting that the procedure causes both acute and long-term pain in the animals (Hay et al., 2003), the use of anaesthesia and post-operative analgesia is not common. The lack of pain control associated with this procedure is of growing scientific and public concern due to consideration of piglet welfare (Keita et al., 2010). Suitable methods that reduce pain caused by surgical castration and alternatives to surgical castration are being explored by the pig production sector (Hansson et al., 2011).

Tail-docking is another routinely performed procedure carried out on neonatal pigs. Tails are typically cut using side-cutters or a cauterizing tool. The reason for performing this surgery is to reduce the risk of tail-biting in later stages of production, the occurrence of which is a welfare problem and of economic concern for producers (Sutherland et al., 2011). There is some research evidence that the tail-docking procedure causes distress to the animal (Noonan et al., 1994), but the use of analgesics or anaesthetics for pain relief is not routine practice.

Non-steroidal antiinflammatory drugs (NSAIDs) are becoming licensed in food-producing animals providing an opportunity to address a major welfare concern regarding the swine industry's need to perform certain painful surgical procedures on piglets such as castration and tail-docking. Keita et al. (2010) showed that pre-operative administration of meloxicam significantly reduced plasma cortisol concentrations after surgical castration and mitigated

behavioural alterations indicative of pain between 2 and 24 h after the procedure. In cattle, Earley and Crowe (2002) demonstrated that the NSAID ketoprofen was effective in suppressing the overall plasma cortisol elevation associated with castration of bulls. NSAIDs may prove useful in dealing with pain associated with piglet castration, thus improving welfare and possibly productivity.

The objective of this 2-part study was to compare the efficacy and cost of two NSAIDs (meloxicam and ketoprofen) administered as a routine measure to piglets prior to castration and tail-docking in order to reduce post-operative pain and possibly improve performance.

4.2 Materials and methods

This study was approved by the University of Guelph Animal Care Committee in accordance with the Canadian Council of Animal Care Guidelines.

Herd and facilities

Two studies were carried out on the same 600-sow commercial swine operation between May 2010 and November 2011. The sows were Landrace x Yorkshire crossbreds and the sires of the piglets were Duroc x Pietrain. All piglets were housed in 1 of 5 fully-slatted farrowing rooms, 4 rooms containing 24 farrowing crates and 1 containing 12 crates. The rooms were mechanically ventilated and heat pads were provided in the creep area of each crate. Piglets were fed by suckling their mother's milk. No additional diet was offered. Piglets had unlimited access to water nipples. No piglets were subjected to teeth clipping. The rooms were filled in an all-in/all-out manner and were cleaned and disinfected between groups.

Study design

The two studies involved a combined total of 2,990 male piglets from 997 litters (study 1:

1,499 piglets from 407 litters; study 2: 1,491 piglets from 590 litters). Piglets received an

injection of 200mg of iron and were ear notched within 48 h of birth. In both studies, piglets

were randomly allocated to receive an IM injection of either the analgesic (study 1 (meloxicam;

Metacam®, Boehringer Ingelheim Ltd., Burlington, ON): 0.4mg/kg; study 2 (ketoprofen;

Anafen®, Merial Canada Inc., Baie DèUrfé, QC): 3mg/kg) or a placebo at least 30 min prior to

castration. Both treatments were represented in each litter. All piglets were weighed on the day

of castration and tail-docking (5-7 d of age) and prior to weaning (study 1: 19-21 d of age; study

2: 19-23 d of age). Piglets were first tail-docked using side-cutters and then castrated (if male)

before being set down. Castration was carried out following methods of Van Beirendonck et al.

(2011) by making an initial horizontal incision in the scrotum with a scalpel after which the

testicles were severed by tearing the spermatic cords. Treatments were assigned in a systematic

order within each litter. Cryptorchid pigs and pigs with inguinal hernias were tagged and not

castrated. Mortality data were collected daily. Cross-fostering was applied within 48 h of birth

and these piglets were not discriminated in the study in that researchers could not determine if a

piglet on the trial was initially from a different litter. Researchers were blinded to treatment until

the conclusion of the study.

Measurements

A total of 243 blood samples from piglets in 63 litters (study 1: 123 piglets from 40

litters; study 2: 120 piglets from 23 litters) were collected at 30 min, 60 min, 90 min, and 4 h

following castration and tail-docking for determination of cortisol concentrations. An individual

pig was bled once. The blood samples were centrifuged at 3900 x g at 5°C for 20 min, within 1

to 3 h after the collection. The plasma was stored in 2 mL micro tubes, PP (Sarstedt) at -20°C

until they were analyzed for cortisol with a solid-phase, competitive chemiluminescent enzyme

immunoassay (Immulite[®]/Immulite[®] Cortisol 1000, Siemens Healthcare Diagnostic Products

Ltd.). The test had an analytical sensitivity of 5.5 nmol/L with a calibration range of 28 to 1380

nmol/L.

All piglets in the study were individually weighed using a DYMO (Pelouze) shipping

scale at castration and tail-docking (5-7 d of age) and prior to weaning (19-21 d of age). After

zeroing the scale holding a crate, piglets were placed into the crate for weighing. The scale had a

maximum capacity of 68 kg and a resolution of 0.1 kg.

Retail prices of the drugs were determined by contacting a local veterinary clinic.

Statistical Analysis

Statistical analysis was performed using Stata, version 10.0 (StataCorp, College Station,

TX, USA) and Statistix, version 9.0 (Analytical Software, FL, USA). Quantitative, normally

distributed data such as ADG were compared using an analysis of variance. Quantitative, not

normally distributed data such as plasma cortisol concentrations were compared using the

Kruskal-Wallis non-parametric test. Qualitative data such as mortality were compared using the

Pearson chi-squared test. *P*-values ≤0.05 were considered significant, but values ≤0.10 were

reported and considered as indicating a possible trend.

4.3 Results

There was not a significant difference between treatment and placebo with respect to

average daily gain (ADG) for meloxicam (*P*=0.18), but there was a trend in the case of

ketoprofen (*P*=0.08) (**Table 4.1**).

There was not a significant difference between treatment groups with respect to mortality

rate. Piglets receiving meloxicam had a mortality rate of 3.18% and piglets receiving the placebo

had a mortality rate of 3.84% (*P*=0.33). Piglets receiving ketoprofen had a mortality rate of 2.91% whereas piglets receiving the placebo had a mortality rate of 3.94% (*P*=0.27).

There was a significant difference between treatment and placebo with respect to plasma cortisol levels at 30 min, 60 min, and 90 min following castration and tail-docking for both meloxicam and ketoprofen, but not at 4 h (**Table 4.2**). Plasma cortisol levels of piglets receiving the placebo did not differ between studies at 30 min (*P*=0.73), 60 min (*P*=0.11), 90 min (*P*=0.57), or 4 h (*P*=0.32).

The retail price of meloxicam was $92.26 for 50 mL whereas the retail price of ketoprofen was $91.51 for 50 mL. At a dose of 0.4 mg/kg for meloxicam, treatment costs approximately $0.09 per pig. Ketoprofen has a dosage of 3 mg/kg and treatment costs approximately $0.14 per pig.

4.4 Discussion

Blood cortisol levels are often used as an objective indicator of stress and pain in response to painful procedures such as castration, but they may become elevated as a result of stresses such as handling (Moya et al., 2008).The present study found that plasma cortisol levels were significantly reduced in the piglets that received either meloxicam or ketoprofen compared to the piglets that received the placebo up to 90 min after the procedure, suggesting a reduction in the effects of castration on stress and pain in a short time period. This is similar to past studies (Keita et al., 2010; Prunier et al., 2005). In addition, Prunier et al. (2005) reported that peak values of plasma cortisol were found between 30 and 60 min after surgical castration, and that the return to pre-surgery levels occurred within 3 h after the procedure. The present study supported this finding with no significant difference of plasma cortisol levels between treatment

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groups at 4 h following castration.

The impact of surgical castration of male piglets on subsequent weight gain during the suckling period has been previously studied, but results are mixed (Keita et al., 2010). Pre-weaning growth rates in pigs can be quite variable depending on a variety of factors, including genetic potential, environmental conditions, availability of nutrition, and stressful events (Kielly et al., 1999). It is, therefore, difficult to assess whether or not an improvement in performance should be expected with administration of analgesics. The present study is in agreement with other studies which found no relationship between pain control treatment at castration and weight gain (Hay et al., 2003; Keita et al., 2010; Ting et al., 2003). It is important to note that these studies were carried out at different times and are not exactly the same with respect to experimental protocol. Study 2 (ketoprofen) used the larger male piglets in the litter for treatment resulting in a much better ADG compared to study 1 which used all piglets in a given litter. There was no statistical difference in growth rate for analgesic treatment over placebo in either trial. However, pigs receiving ketoprofen showed a slight trend to better ADG, but this small increase would not likely be of economic significance to a producer.

It can be concluded that both meloxicam and ketoprofen did not cause negative effects when administered prior to castration based on the growth rate and mortality results from the presented findings and we conclude that they both appear to be safe analgesics to use in young piglets. This current study supports earlier studies that have shown that pre-operative administration of meloxicam contributes to the relief of stress and post-operative pain associated with castration in piglets (Keita et al., 2010; Hansson et al., 2011). There is limited research on the use of ketoprofen for the treatment of pain associated with routine practices such as castration and tail-docking in swine, but research in cattle has demonstrated ketoprofen to be

effective in the treatment of pain in bulls after castration (Ting et al., 2003).

The use of ketoprofen for pain relief during castration and tail-docking is more expensive than the use of meloxicam based on the retail prices of the drugs obtained from a local veterinary clinic. Labour costs would not differ as piglets could receive an injection while they are handled for the procedure as analgesics do not deal with the acute pain suffered at the time of the procedure. Presently, the cost of using analgesics during castration and tail-docking is relatively high, but new products may emerge that reduce this cost and make this more attractive to producers. The cost of approximately $0.10 per pig is relatively similar to using a routine injection of an antibiotic to all pigs as a preventative measure, which is common practice. The cost is not impractical and shouldn't be a deterrent if industry is serious about reducing pain during routine procedures.

Despite pressure for animal welfare advancement, the use of analgesia or anaesthesia in farm animals during routine painful procedures is still not a routine practice (Keita et al., 2010). Future consumer expectations may require producers to consider using pain control as part of their standard operating procedures. This current study illustrates that castrated pigs perform as well as uncastrated pigs and that farmers are unlikely to see an economic return associated with using analgesia at the time of painful procedures in order to provide better welfare for their animals. The NSAIDs meloxicam and ketoprofen appear effective in the treatment of post-operative pain associated with surgical castration of male piglets based on plasma cortisol levels.

4.5 References

Earley, B., Crowe, M.A., 2002. Effects of ketoprofen alone or in combination with local anaesthesia during the castration of bull calves on plasma cortisol, immunological, and inflammatory responses. J. Anim. Sci. 80, 1044-1052.

Hansson, M., Lundeheim, N., Nyman, G., Johansson, G., 2011. Effect of local anaesthesia and/or analgesia on pain responses induced by piglet castration. Acta Veterinaria Scandinavica. 53:34.

Hay, M., Vulin, A., Génin, S., Sales, P., Prunier, A., 2003. Assessment of pain induced by castration in piglets: behavioural and physiological responses over the subsequent 5 days. Appl. Anim. Behav. Sci. 82, 201-218.

Keita, A., Pagot, E., Prunier, A., Guidarini, C., 2010. Pre-emptive meloxicam for postoperative analgesia in piglets undergoing surgical castration. Vet. Anaesth. Analges. 37, 637-374.

Kielly, J., Dewey, C.E., Cochran, M., 1999. Castration at age 3 days of age temporarily slows growth of pigs. Swine Health Prod. 7, 151-153.

Moya, S.L., Boyle, L.A., Lynch, P.B., Arkins, S., 2008. Effect of surgical castration on the behavioural and acute phase responses of 5-day-old piglets. Appl. Anim. Behav. Sci. 111, 133-145.

Noonan, G.J., Rand, J.S., Priest, J., Ainscow, J., Blackshaw, J.K., 1994. Behavioural observations of piglets undergoing tail-docking, teeth clipping and ear notching. Appl. Anim. Behav. Sci. 39, 203-213.

Prunier, A., Mounier, A.M., Hay, M., 2005. Effect of castration, tooth resection, or tail-docking on plasma metabolites and stress hormones in young pigs. J. Anim. Sci. 83, 216-222.

Sutherland, M.A., Davis, B.L., McGlone, J.J., 2011. The effect of local or general anaesthesia on the physiology and behaviour of tail docked pigs. Animal 5, 1237-1246.

Ting, S.T.L., Earley, B., Crowe, M.A., 2003. Effect of repeated ketoprofen administration during surgical castration of bulls on cortisol, immunological function, feed intake, growth, and behaviour. J. Anim. Sci. 81, 1253-1264.

Table 4.1: ADG of treatment groups receiving NSAID (meloxicam or ketoprofen) or a placebo prior to tail-docking and castration from the day of castration and tail-docking (5-7 d of age) to weaning (19-23 d of age).

Treatment Group	N	Mean ± sd (g/day)	*P*-value[3]
Meloxicam[1]	743	172 ± 53.8	0.18
Placebo	756	174 ± 52.3	
Ketoprofen[2]	755	279 ± 0.08	0.08
Placebo	736	272 ± 0.08	

[1]Metacam®, Boehringer Ingelheim Ltd., Burlington, ON
[2]Anafen®, Merial Canada Inc., Baie D'Urfé, QC
[3]Determined by one-way ANOVA

Table 4.2: Average plasma cortisol concentrations (nmol/L) from male piglets at various times after castration and tail-docking.

	Time	N	Plasma Cortisol ± sd (nmol/L)	N	Plasma Cortisol ± sd (nmol/L)	P-value[3]
			Meloxicam		Placebo	
Meloxicam[1]	30 min	12	169.4 ± 50.8	13	344.4 ± 150.0	<0.01
	60 min	7	107.9 ± 29.6	14	292.5 ± 210.0	0.02
	90 min	25	79.2 ± 44.7	20	156.4 ± 105.4	<0.01
	4 hr	19	106.2 ± 60.0	13	124.6 ± 48.9	0.45
			Ketoprofen		Placebo	
Ketoprofen[2]	30 min	15	178.2 ± 104.0	15	370.3 ± 215.7	<0.01
	60 min	16	129.6 ± 236.3	16	177.8 ± 85.6	<0.01
	90 min	12	46.1 ± 17.0	15	127.8 ± 73.8	<0.01
	4 h	15	76.0 ± 40.7	16	108.0 ± 51.1	0.09

[1]Metacam®, Boehringer Ingelheim Ltd., Burlington, ON

[2]Anafen®, Merial Canada Inc., Baie D'Urfé, QC

[3]Determined by Kruskal-Wallis One-Way ANOVA

CHAPTER 5: CONCLUSIONS

5.1 Summary of findings and implications

In this study, we examined the use of analgesics for the control of pain for the sow post-farrowing and for the control of pain caused by routine surgical procedures in suckling piglets. Due to increased public concern over the welfare of farmed animals, pain management and its alleviation have become important issues for the swine industry (Anil et al., 2006). The assessment of pain in animals is difficult, but the use of behavioural and physiological scores can quantify the severity of pain and distress an animal experiences (Anil et al., 2006). Behavioural indices such as postures, specific pain-related behaviours, and general behaviours are relevant parameters to assess pain and discomfort in animals (Keita et al., 2010). Cortisol release into the bloodstream or saliva is a common measure reported when animals are experiencing pain and can be used as an objective indicator of stress and pain (Keita et al., 2010). While the difficulty in assessing pain is a serious handicap in ensuring the welfare of animals, the treatment of pain also presents many clinical problems (Anil et al., 2006). One major limitation in the treatment of pain is simply the non-availability of a cheap, safe, and easy-to-use analgesic protocol (Anil et al., 2006). In this thesis, we evaluated the use of meloxicam, an NSAID, which has been licensed for use in cattle in Canada and has potential to receive approval for use in swine. Meloxicam has been shown in previous trials to be safe in swine (Hay et al., 2003; Keita et al., 2010).

We examined the use of meloxicam for pain control post-farrowing. Pre-weaning mortality is an important issue in pig production. Crushing of piglets by sows is a major source of economic loss and reduced welfare, with most deaths occurring within the piglets' first 24 hours of life (Haussman et al.,1999). Piglets must quickly gain access to a teat and consume colostrum soon after birth in order to obtain sufficient energy supplies and protection from

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disease. Therefore, it is important that a sow settles quickly after farrowing and readily begins to nurse her litter. It has been suggested that NSAIDs may prove useful in alleviating sow discomfort in the immediate post-farrowing period. Other studies have used meloxicam to treat sows with medical problems after farrowing and noted improvement (Hirsch et al., 2003).

In our study, we evaluated the value of using meloxicam routinely for all sows post-farrowing. There was a tendency for sows receiving meloxicam after farrowing to have lower plasma cortisol levels than sows receiving a placebo at 4 h following treatment. Therefore, meloxicam may be effective in the treatment of post-farrowing pain based on plasma cortisol levels, but a larger sample size is needed to evaluate this further. It is possible that some sows may find the post-farrowing experience more stressful than others (Mainau and Manteca, 2011). For example, a gilt that required manual assistance to deliver large piglets might benefit more from analgesia than an older sow following a relatively quick and uneventful farrowing. The use of analgesics to alleviate pain immediately after farrowing may be a useful tool for a subset of animals, and this area will require further study. There were no significant treatment effects for piglet weight gain or mortality or sow position changes, rectal temperatures, and feed intake scores in our trial. In contrast, other studies have shown a benefit when a subset of sows, such as those with dystocia, are provided with pain control (Keller, 2012).

Castration and tail-docking of piglets are routine, painful procedures carried out in the swine industry. Despite evidence suggesting that both castration (Hay et al., 2003) and tail-docking (Noonan et al., 1994) cause pain, anaesthesia and post-operative analgesia are not routinely employed. The lack of pain control associated with these procedures is of growing scientific and public concern (Keita et al., 2010). In addition, there are few products licensed for use in food-producing animals for pain control, and few studies have been done to compare their

relative effectiveness.

In our study, meloxicam appeared effective in the treatment of post-operative pain associated with surgical castration and tail-docking of male piglets based on plasma cortisol levels and behavioural observations. Piglets receiving meloxicam had lower plasma cortisol levels at up to 90 min following castration compared to piglets receiving a placebo. Piglets also displayed less isolation and tail jamming behaviour when receiving meloxicam compared to the placebo, behaviours thought to have a protective role and suggest that a piglet may be experiencing pain (Mellor and Stafford, 2003). No treatment effects were observed for mortality or growth rate.

Likewise, treatment with ketoprofen was found to result in lower plasma cortisol levels for up to 90 min following castration and tail-docking compared to piglets receiving a placebo. Similarly, there were no differences between pigs receiving a placebo or ketoprofen on mortality or growth rate following castration. Both analgesics appeared to reduce post-operative pain, but have no impact on performance. This is of possible concern because there is no obvious economic incentive for producers. It has been determined that meloxicam treatment is slightly less expensive than treatment with ketoprofen. At present, it is difficult to know whether the general public will accept the use of an analgesic to control the post-operative pain as sufficient or whether additional steps such as anaesthesia for the control of the acute pain at the time of castration is also required. From the producer standpoint, the use of analgesia is a difficult sell in that there is no economic incentive and the benefits of pain control are very subtle and not likely obvious to the herdsman. Further research investigating the use of analgesics in conjunction with other methods such as anaesthesia to deal with the acute pain caused by routine painful procedures is needed.

As analgesics become available, it will be necessary for producers to examine their standard operating procedures and determine how to incorporate pain control. We have examined procedures and processes that cause pain in pigs, such as farrowing and piglet processing, for which pain control is not routinely provided. New codes of practice are currently being created and pain control will be carefully reviewed, and in all likelihood, analgesics will be a requirement for CQA approval in the future.

5.2 References

Anil, L., Anil, S.S., Deen, J., 2006. Measuring pain and pain control. Proc. Amer. Assoc. Swine Vet., 339-341.

Earley, B., Crowe, M.A., 2002. Effects of ketoprofen alone or in combination with local anaesthesia during the castration of bull calves on plasma cortisol, immunological, and inflammatory responses. J. Anim. Sci. 80, 1044-1052.

Haussmann, M.F., Lay, D.C., Buchanan, H.S., Hopper, J.G., 1999. Butorphanol Tartrate Acts to Decrease Sow Activity, Which Could Lead to Reduced Pig Crushing. J. Anim. Sci. 77, 2054-2059.

Hay, M., Vulin, A., Génin, S., Sales, P., Prunier, A., 2003. Assessment of pain induced by castration in piglets: behavioural and physiological responses over the subsequent 5 days. Appl. Anim. Behav. Sci. 82, 201-218.

Hirsch, A.C., Philipp, H., Kleemann, R., 2003. Investigation on the efficacy of meloxicam in sows with mastitis-metritis-agalactia syndrome. J. Vet. Pharmacol. Therap. 26, 355-360.

Keita, A., Pagot, E., Prunier, A., Guidarini, C., 2010. Pre-emptive meloxicam for postoperative analgesia in piglets undergoing surgical castration. Vet. Anaesth. Analges. 37, 637-374.

Keller, F., 2012. Improved early piglet survival after Metacam® treatment of sows post farrowing. 22nd International Pig Veterinary Society Congress Proceedings, PO-177.

Mainau, E., Manteca, X., 2011. Pain and discomfort caused by parturition in cows and sows. Appl. Anim. Behav. Sci. 135, 241-251.

Mellor, D.J., Stafford, K.J., 2003. Assessing the welfare status of newborn farm animals. Animal Welfare 12, 695-698.

Noonan, G.J., Rand, J.S., Priest, J., Ainscow, J., Blackshaw, J.K., 1994. Behavioural observations of piglets undergoing tail-docking, teeth clipping and ear notching. Appl. Anim. Behav. Sci. 39, 203-213.

Sutherland, M.A., Davis, B.L., McGlone, J.J., 2011. The effect of local or general anesthesia on the physiology and behaviour of tail docked pigs. Animal 5, 1237-1246.

Taylor, A.A., Weary, D.M., 2000. Vocal responses of piglets to castration: identifying procedural sources of pain. Appl. Anim. Behav. Sci. 70, 17-26.