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Report 85

Castration under anaesthesia and/or analgesia in commercial pig production

December 2007

ANIMAL SCIENCES GROUP
WAGENINGEN UR

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Publisher
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Redactie
Communication Services

Abstract
In this study the effects were investigated of the use of anaesthesia and/or analgesia during castration of young male piglets. Pain was looked into both during castration and in the days thereafter. Calculations of workload and costs were made with respect to different scenarios in which either veterinarians or farmers applied the anaesthetics or analgesics. In addition, a pilot study was carried out to study the possibilities of the use of carbon dioxide as an anaesthetic.

Keywords
Castration, piglets, anaesthesia, analgesia, behaviour, labour demand, cost price, carbon dioxide

Referate
ISSN 1570 – 8616
Influence of anaesthesia/analgesia during castration of piglets on welfare during and after castration, as well as on labour and costs. Possibilities of carbondioxide anaesthesia.

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Foreword

The castration of male piglets without the use of anaesthesia is meeting with increasing resistance from society and from the pig-production sector itself. Castration is widely carried out in the Netherlands to prevent boar taint (an unpleasant odour) in the meat of male pigs (boars) during preparation. Because there are, as yet, no suitable alternatives for preventing boar taint in uncastrated animals, temporary solutions are being explored, such as the use of anaesthesia and analgesia during and after castration. The purpose of the research described in this report is to support sector and government policy decisions with regard to castration under anaesthesia.
The co-operation of the Sterksel practical research centre (ASG), research farm 'De Tolakker' (Faculty of Veterinary Medicine) and five pig farms was invaluable in carrying out this study. We would therefore like to give a word of thanks to those involved at the research centre, and to 'De Tolakker', Mr Donkers, Mr and Mrs Logtenberg, Mr Harmsen, Mr Thijssen and Mr Van de Looi.
The contribution of the members of the project's supervisory group was also of great value. The critical questions and constructive remarks and ideas of the representatives of LTO, NVV, VBV, Biologica, VION, KNMvD, Dierenbescherming and UNILEVER made a valuable contribution to the study.
The research was carried out with financial support from the Ministry of Agriculture, Nature and Food Quality, whereby the aim has always been to provide a study that will contribute to the considerations for legislation with regard to improving the welfare of piglets during castration. We are confident that this will be the case.

Paul Vriesekoop
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Summary

The present study addresses the question of whether the use of a local anaesthetic and/or analgesic (meloxicam) leads to a reduction in the pain caused in piglets during and after castration. On the basis of a number of scenarios, the study has also identified the consequences of castrating under anaesthesia in terms of labour and costs. Finally, a pilot study was carried out to assess the possibilities (and constraints) for using CO2 inhalation anaesthesia during castration.
Pain is a subjective experience/perception that cannot be measured objectively with only a single parameter. However, specific aspects of vocalisation, physiology and behaviour in animals relate to pain. In order to obtain as clear a picture as possible of pain perception during the castration of piglets, the most widely known standard parameters from the scientific literature were used.
Given the different parameter values, it is not easy to reach a single statement with regard to pain. In order to address this difficulty, the results of the research before and after castration are summarised in two figures, in which the three treatment groups (local anaesthesia with lidocaine, analgesia with meloxicam and the combination of both) are compared to two control groups (sham castration and castration without anaesthesia). The assumption is that the piglets in the sham group (not castrated) experience the least pain, and those in the group of piglets castrated without anaesthesia experience the most pain.

Acute effects on vocalisations and stress physiology
The effect on the welfare of male piglets during castration was established for the following 5 treatments:

1. Castration without anaesthesia (standard practice)
2. Castration 15 minutes after local anaesthesia with lidocaine
3. Castration 15 minutes after local anaesthesia with lidocaine and administration of meloxicam (analgesic)
4. Castration 15 minutes after administration of meloxicam
5. Sham castration (piglets handled twice with 15-minute interval)

In order to reduce litter influences, the treatments were assigned at random to male piglets in the litters. In total, 32 litters were used. During castration, vocalisations (squeals) were recorded, and blood samples were taken from the piglets 15 minutes before and 20 minutes after castration. In these blood samples, the level of glucose, lactate, creatine kinase and cortisol were measured using validated analysis methods. The skin temperature of the piglets was measured four times (15 minutes before, just before, just after, and 20 minutes after castration).
During castration, various characteristics in vocalisation showed that the score in terms of pain indicators was consistently and significantly higher among piglets castrated without anaesthesia. Piglets castrated without anaesthesia squealed longer and louder than piglets treated with lidocaine (with or without analgesic). Lidocaine therefore reduces the pain perception of male piglets during castration. The squealing of the animals that were treated only with an analgesic most resembled that of the piglets castrated without anaesthesia. Therefore an additional impact of the analgesic could not be established.
An analysis of the differences between groups in which lidocaine was used and groups in which it was not used (regardless of whether the piglets received the analgesic), reinforces the impression that lidocaine reduces pain perception. A comparable analysis of the effects of the analgesic showed that this also reduced pain during castration.
The group treated with lidocaine showed a significantly smaller increase in plasma cortisol levels in comparison with the group that did not receive an anaesthetic and the group that received an analgesic. Raised plasma cortisol levels are associated with reduced wellbeing. The increase in plasma cortisol in the sham group was significantly lower than in all other groups. In terms of the increase in cortisol levels, the group treated with lidocaine as well as an analgesic differed significantly only from the sham group.
With regard to the effect of castration on lactate levels, the only significant difference was that between the group treated with lidocaine and the group that received analgesia. Lactate indicates the level of acidosis is of muscle tissue after physical exertion. In the group treated with lidocaine, the lactate level fell after castration but increased in all other treatments. It is not clear why the lactate level fell in the lidocaine group. The reason may be that less lactate was produced (due to reduced muscle activity) and/or that it dispersed more quickly (due to increased blood flow).
There were no significant differences between treatment groups in terms of increases in glucose and creatine-kinase levels.
The skin temperature of piglets in all the treated groups was significantly lower just before and just after castration than that of piglets in the sham group. Generally speaking, the skin temperature of animals falls when they are stressed. Skin temperature fell in all piglets placed in the restraining device (all treatments except sham castration). There was no difference between treatments. Just after castration, the skin temperature of piglets treated with lidocaine or with lidocaine and analgesic was significantly higher than that of the piglets castrated

without anaesthesia. In terms of skin temperature, the analgesic group differed neither from the group treated without anaesthesia, nor from the group treated with lidocaine.

Effects on behaviour during 4 days after treatment

The effect on the welfare of male piglets after castration was established for the following 6 treatments:

1. Castration without anaesthesia (standard practice)
2. Castration 15 minutes after local anaesthesia with lidocaine
3. Castration 15 minutes after local anaesthesia with lidocaine and administration of meloxicam (analgesic)
4. Castration 15 minutes after administration of meloxicam
5. Sham castration (piglets handled twice with 15-minute interval)
6. Non-handled

In order to reduce litter influences, the treatments were assigned at random to male piglets in the litters. In total, 24 litters were used, in two rounds.

During the four days following castration, the piglets' behaviour (general behaviour and specific pain-related behaviour) was observed for three hours (scan-sampling, 12 min interval) every morning and every afternoon. In addition, growth until weaning was measured and the quality of wound healing in the castrated animals was assessed on the fourth day after castration.

The tendency observed over the whole observation period was that piglets castrated without anaesthesia and piglets castrated under anaesthesia with lidocaine showed more pain-related behaviour than piglets that underwent sham castration. The piglets treated with lidocaine as a local anaesthetic showed significantly more specifically pain-related behaviour ('tail-wagging') than the piglets in the other treatment groups. The effect on behaviour was greatest during the first afternoon after castration.

In the observation periods, other behaviours showed a treatment effect or trend only sporadically. Consistent effects over several periods were not found. The various castration treatments had no effect on daily growth rate in the first four days after treatment or until weaning.

The expectation was that local anaesthesia with lidocaine would eliminate the pain caused by castration, and would possibly also have an effect on pain-related behaviour after castration, compared with piglets castrated without anaesthesia. However, the behaviour study showed no such effect. It is likely that lidocaine has such a limited time of action that there is no measurable effect after castration. The increase in pain-related behaviour in the lidocaine treated group could be caused by the lidocaine partly penetrating the surrounding tissue, and when wearing off leading to a sensation that increases tail-wagging.

Labour and costs

The influence of pain reduction during castration of piglets was studied in terms of labour and cost. Five treatments were compared:

1. Castration by stockman, without anaesthetia or analgesia
2. Local anaesthetia administered by veterinarian, castration by stockman
3. Anaesthesia and castration by stockman
4. Analgesia and castration by stockman
5. Anaesthesia, analgesia and castration by stockman

The experiments were carried out at six pig farms (three conventional farms, two organic farms and an experimental farm). The treatments were incorporated in the farms' normal work methods, whereby castration was combined with other treatments for the piglets. Time studies were carried out on all the farms during the treatment of at least five litters per treatment.

The use of analgesia during the castration of piglets increases the labour requirement on farms and, depending on the treatment, the labour of veterinarians. There are also additional costs for the medications required (anaesthetic and analgesic, Lidocaine and Novem® 5 respectively).

When calculating costs, it was assumed that all other piglet treatments (iron injection, ear tagging, tail-docking) are carried out before the veterinarian's visit, and that the male piglets have already been placed in bins. If one person carries out this work, he must begin 70 minutes (12.5 litters on a farm with 300 sows) to 3 hours (30.7 litters on a farm with more than 400 sows) before the veterinarian arrives. Because it is not desirable to separate the piglets from the sows for too long, in practice two people will do this work on large farms.

If the veterinarian cannot work continuously because the time between anaesthesia and castration would exceed 20 minutes, labour costs increase for the veterinarian. On average, the veterinarian will have to wait after anaesthetising eight litters, because administering the anaesthetic takes less time than castration. This means that there is no waiting time for the veterinarian on farms with less than 200 sows (6.9 litters/week), but there is waiting time on larger farms. On farms with 200 to 400 sows or more than 400 sows (12.5 and 30.7 litters/week on average, respectively) on average he has nothing to do for between 5 and 27 minutes

respectively if one person performs the castration. In practice, many stockmen will limit or eliminate the waiting time by deploying two people to perform the castration.
With regard to working conditions: pain reduction during castration was not found to influence equivalent noise level during the combination of tasks that the stockmen carried out in relation to castration. Because approximately 20 to 30% more time was required to do the work, total noise exposure increased. In all cases, noise levels were so high (87 to 90 dB(A)) that ear protection was required. Because of the time required between administering the anaesthetic or analgesic and castration, stockmen have to lift up the piglets (approx. 1.5 kg each) at least one extra time, and this almost always involves a forward-bending posture. Once the piglet has been lifted, the work posture varies from person to person. If the stockman stands up straight, the work posture need not be physically demanding. Because the stockman must ensure that there is an interval of 10 to 20 minutes between anaesthesia and castration, the psychological load is greater than for castration without an. If analgesia is used, the waiting time is less critical and the stockman can pay less attention to it.
If anaesthesia is carried out by a veterinarian, annual costs at farm level increase by € 1,950 for farms with less than 100 sows and by € 6,900 for farms with more than 400 sows. The cost per castrated piglet varies from € 0.78 on farms with more than 400 sows to € 2.99 on farms with less than 100 sows. These costs vary depending on the frequency of castration operations. If castration is carried out once a week on a farm with 200 to 400 sows, the additional cost per castrated piglet is approximately € 1. Overall, 80% of these additional costs are due to extra visits and the labour time of the veterinarian. The cost of the drugs and additional labour on the farm accounts for approximately 10% of the costs. If castration is carried out twice a week, costs increase by 30% to 75%, depending on the size of the farm (larger increase on small farms). Costs would increase less if castration were carried out once every two weeks. However, this means that some of the piglets to be castrated are older and therefore heavier than usual, and this is detrimental to the welfare and health of the piglet, and to the stockman's working conditions. If the anaesthetic, analgesic or both are administered by the stockman, the extra cost per male piglet is € 0.28, € 0.19 and € 0.42 respectively. The size of the farm does not influence these costs, because no veterinarian is involved.
At national level, the annual cost is estimated at € 13 million if castration is carried out once a week and the anaesthetic is administered by a veterinarian. In terms of veterinarians, this scenario requires an equivalent of 75 FTEs. Twice-weekly castration increases the cost to € 19 million and requires an extra 125 FTEs. Farm size does not influence total cost if the stockman can administer the anaesthetic and/or analgesic, because it is not necessary to pay call-out fees for veterinarians. The cost of local anaesthesia administered by stockmen is € 3 million, and the cost of pain reduction with an analgesic is € 2 million. If the anaesthetic *and* analgesic are administered by the stockman, the annual national cost is approximately € 5 million.

Inhalation anaesthesia
A pilot study was carried out to assess whether a mixture of 70% CO_2 + 30% O_2 is appropriate for castrating piglets. The aim of this experiment was to establish whether the length and depth of anaesthesia was sufficient in all piglets to guarantee a painless castration procedure. In addition, the experiment examined how long the piglets can safely remain in this mixture, and whether a concentration of 60% CO_2 + 20% O_2 also induces a sufficient anaesthetic effect.
In the experiment, 25 piglets were fitted with subcutaneous electrodes to measure brain activity (EEG) and heart rate (ECG), and placed in a box filled with a mixture of 70% CO_2 + 30% O_2. Two blood samples were taken from each animal at the start of the experiment and immediately after castration in order to measure blood gas values and metabolites. Behaviour was monitored during the induction phase (consciousness) as well as the maintenance phase (unconsciousness).
During the induction phase, heavy breathing was observed to be the only typical behaviour. In the 70/30 mixture, all the animals lost consciousness after an average of 30 seconds. Immediately after loss of consciousness, most of the animals experienced one or more convulsions (involuntary muscle spasms). Reduced brain activity was observed after an average of 19 seconds. This suppression of alpha and beta frequencies indicates loss of consciousness. Suppression of theta and delta frequencies occurred after 34 seconds on average. During this phase, brain activity is minimal, i.e. this is a phase of deep unconsciousness. The animals' heart rates were severely elevated at the beginning of the experiment due to handling, blood sampling and the inserting of the electrodes. After a slow reduction in heart rate during the induction phase, a serious drop in heart rate occurred as the piglets lost their posture. Immediately after this, heart rate fell to almost 0 or became very irregular and slow. Thirty seconds after loss of consciousness, the piglets were removed from the gas and castrated, and a blood sample was taken. None of the animals showed any reaction to castration in the EEG or ECG readings. After an average of 59 seconds the piglets had regained consciousness, EEG had returned to its pre-induction pattern and the piglets could stand up again. Heart rate returned to normal after an average of 120 seconds.
In order to determine the maximum time for safe use, five piglets were placed in the 70% CO2+ 30% O2 for three minutes after loss of posture. Two of the piglets died. Four piglets were then placed in the box for two

minutes after loss of posture. One of these piglets died. Since such losses are unacceptable, the maximum acceptable time for safe use is therefore less than two minutes.
In order to establish the critical composition of the gas mixture, 24 animals were exposed to a mixture of 60% CO_2 + 20% O_2 and then castrated and monitored in a similar way as for the 70/30 mixture. In 16 of the 24 animals, there was a visible reaction as well as an EEG reaction to castration. It can therefore be concluded that a concentration of 60% CO_2 + 20% O_2 is too low to induce a sufficiently deep unconsciousness in a period of 30 seconds.
An important conclusion from this experiment is that it is possible to anaesthetise piglets using a mixture of 70% CO_2 + 30% O_2, but there is a narrow safety margin, both with regard to the concentration of CO2 and to amount of time the animals remain in the mixture. In order to realise a practical application, further research is needed. It is essential to establish the minimum concentration and the minimum and maximum length of anaesthesia in order to ensure, on one hand, that anaesthesia is sufficiently long and, on the other hand, that no piglets die. In addition a practical system needs to be designed that is workable as well as safe for stockmen and piglets.

Conclusion
The administration of local anaesthesia to piglets before castration, compared to castration without anaesthesia, results in a demonstrable reduction in pain perception and stress response during castration. Although clearly demonstrable, the positive effect of local anaesthesia with lidocaine on piglet welfare during castration is relatively limited. Compared to the piglets that were handled twice (sham injection and castration), there is still a considerably stronger pain and stress response. It must be remembered, also, that injecting lidocaine into the testicles is likely to produce an extra pain response, although this is not dealt with in the present study. Administering an analgesic before castration has very little effect at the time of castration.
Behavioural observations during the four days after castration showed that the use of local anaesthesia leads to an increase in pain-related behaviour. This disadvantage is removed if an analgesic is also administered. In general, the piglets treated with an analgesic showed less pain-related behaviour in the first few days after castration.

If the local anaesthetic has to be administered by a veterinarian, the cost of castration increases by € 1.00 per male piglet. If the stockman can administer the anaesthetic, the increase in cost is only € 0.28 per male piglet. At national level, the cost of local anaesthesia if administered by veterinarians is € 13 million. If administered by stockmen, the cost of local anaesthesia is € 3 million. The latter method, however, is prohibited by law.

Apart from demonstrable advantages for the piglets, the use of general anaesthesia with CO_2 still has a number of practical disadvantages. The advantages are complete loss of consciousness and the complete absence of pain at the moment of castration, plus the fact that other painful procedures can be carried out at the same time. The main disadvantages are the narrow safety margins (CO_2 concentration, time) and the fact that a design for general use is not yet available. Further research is essential in order to establish the limits for use and to develop a reliable and practical design for use in practice.

Contents

1 General introduction

M. Kluivers-Poodt

The aim of the research described in this report is to establish to what extent local anaesthesia and analgesia can reduce the negative effect on the welfare of piglets during castration. The cost in terms of money and labour was calculated for a number of possible methods. The possibilities for using CO_2 as a general anaesthetic were also explored.

In most pig-producing countries in Europe, male piglets are castrated at a young age in order to prevent boar taint in the meat. Boar taint is an unpleasant odour and flavour caused mainly by the presence of androstenone and skatole (Claus, 1979). Castration prevents not only boar taint, but also aggressive behaviour and difficulties in animal management (Carroll, 2006). Despite intensive research, surgical castration is still the most effective and reliable method for preventing boar taint. According to EU Commission Directive 2001/93/EC, piglet castration may be performed without any form of anaesthesia or analgesia within the first seven days of life. After that, it must be performed under anaesthetic by a veterinarian and with additional prolonged analgesia. A supplementary EU regulation, to be complied with by Member States from 2003, stipulates that spermatic cord must be severed other than by tearing (EU Council Directive 2001/88/EC).
A number of European countries have supplementary legislation or different practices relating to castration. Norway prescribes “appropriate analgesia” in the Norwegian Animal Welfare Act and the Regulations Concerning Swine Husbandry (Ministry of Agriculture and Food, Norway), but does not specify the type or duration. Since 2002, all piglets in Norway have been given local anaesthesia and are castrated by a veterinarian. The country wants to ban the castration of piglets from 2009. Switzerland is also planning to do this. Great Britain produces mainly boars. In Spain, Portugal and Ireland, not all boars are castrated. In 2004, in 25 EU countries, a total of approximately 100 million piglets were castrated, i.e. 80% of male pigs in the EU (EFSA, 2004).

There are strong indications that castration causes pain in piglets, not only during the procedure itself, but also for several days afterwards (Henke and Ehrhardt, 2004; Taylor et al., 2001; Hay et al., 2003). Pain responses are produced when an incision is made in the skin, when the testicles and spermatic cords are manipulated, and when the spermatic cords are cut. The manipulation and severing of the spermatic cord causes the most pain (White et al., 1995; Taylor and Weary, 2000). Taylor and Weary (2000) found no difference in the pain response between severing and pulling the spermatic cord. This may be different in the case of local anaesthesia because, in the case of pulling, the spermatic cord is often severed in the abdominal cavity, and it is reasonable to assume that there is less lidocaine present at this location and that it is less effective than if the spermatic cord is severed nearer the testicle.

Pain is a subjective experience, described by the International Association for the Study of Pain (IASP) in 1979 as: “an unpleasant sensory and/or emotional experience associated with actual or potential tissue damage, or described in terms of such damage”. There is no specific parameter for measuring pain. However, it is generally accepted that piglets react to stimuli in three ways: physiologically, behaviourally and through vocalisation.
The physiological response to pain and stress during castration consists of an acute activation of the sympathetic nervous system (White et al., 1995; Prunier et al., 2001) and of the hypothalamus-pituitary-adrenal gland axis. Adrenaline and cortisol are released, and in turn cause an increase in the level of glucose and lactate (amongst others) in the blood. The literature also shows that, during castration, piglets squeal more often, more loudly and at a higher pitch than piglets that are only being held, or piglets being castrated under local anaesthetic (White et al., 1995; Weary et al., 1998; Taylor and Weary, 2000; Taylor et al., 2001). Animals that have received local anaesthetic on one side vocalise less when the anaesthetised testicle is removed, although this varies widely from animal to animal (Gutzwiller et al., 2003). For a few days after castration, the procedure leads to abnormal postures and behavioural changes indicative of pain (Wemelsfelder and Van Putten, 1985; McGlone and Hellman, 1988; McGlone et al., 1993; Taylor and Weary, 2000; Taylor et al., 2001; Hay et al., 2003)). Age appears to have little influence on the pain response. Taylor et al. (2001) found no difference in vocalisation and behaviour between piglets castrated at the age of 3, 10 or 17 days.

The possibilities for using anaesthesia are limited. It is not sufficient if the technique itself causes little stress and is effective and cost-efficient. It must also be short-acting and alleviate pain after the procedure, and it must be possible to administer it in a way that is fast and safe for the handler as well as the piglet. Anaesthesia can be local or general, and there are many ways to administer it: by injection (in the neck muscle for general anaesthesia, in the testicles for local anaesthesia), by gas inhalation or, for example, by means of a spray in the nose or mouth.

The most widely used anaesthesia method for castration is the injection of lidocaine into the testicle, possibly combined with subcutaneous anaesthesia of the scrotum. A local anaesthetic can also be administered in the spermatic cord. Injecting into the spermatic cord is technically more difficult, and the lidocaine may accidentally be injected directly into the blood, which can lead to inadequate anaesthesia in young piglets, and even to toxic effects. When administered into the testicle, lidocaine disperses into the spermatic cord in approximately ten minutes (Ranheim et al., 2003). Lidocaine is tissue-friendly and has an effect for approximately four hours (Werner, 2001). It is a medication that must be administered by veterinarians only.
Haga and Ranheim (2005) showed, by means of EEGs, heart rate and blood pressure, that injecting with lidocaine is less painful than castration without anaesthesia. In addition, various other studies have shown that the intratesticular administration of lidocaine reduces the pain sensation at the moment of castration. There is, for example, less disruption to suckling behaviour after castration, and the animals struggle less, particularly when the spermatic cord is cut (McGlone and Hellman, 1988; Von Waldmann et al., 1994; Horn et al., 1999). However, the pain response does not disappear completely, which could be due to the uneven distribution of the lidocaine in the spermatic cord and insufficient anaesthesia of the cremaster muscle. It is also possible that the scrotal ligament, which has to be teared during castration, and the part of the spermatic cord in the abdominal cavity are not fully anaesthetised (Ranheim et al., 2005). According to Horn et.al. (1999), subcutaneous anaesthesia produces no additional benefits.

A combination of azaperone and ketamine is used for general anaesthesia by injection in pigs. But this has many disadvantages. The level of reduced consciousness and analgesia is much less than with narcosis. During castration, the animals still struggle, albeit to a lesser extent (Lahrmann et al., 2004; Kmiec, 2005). The incidence of mortality and poor wound healing is higher than in unanaesthetised control groups (Kmiec, 2005; McGlone and Hellman, 1988). Blood pressure falls and coordination is impaired as the anaesthetic wears off. This means that the piglets may become trapped under the sow and crushed. When this combination is administered through the nose, the percentage of animals that are anaesthetised is highly variable and often low.
General anaesthesia through inhalation (inhalation anaesthesia) takes effect quickly and ensures good muscle relaxation and loss of consciousness. A disadvantage is that many gases can be used only under strictly controlled conditions, in line with health and safety considerations. In addition, gases are generally expensive. Carbon dioxide is an exception. It is relatively cheap and not subject to strict regulation – it can be used by stockmen, for example. CO_2 reduces struggling during castration, but powerful struggling and a great deal of squealing during the induction phase can be observed (Kohler et al., 1998).

The administering of a painkiller (analgesic) prior to castration reduces (and may even eliminate) postoperative pain. It is equally important that the pain system is protected in this way against excessive activation and sensitisation to subsequent pain stimuli (Song and Carr, 1999; Sumihisa, 2005). Meloxicam is a Non-Steroidal Anti-Inflammatory Drug (NSAID), permitted for use on pigs under Annex I of EC Council Regulation 2377/90/EC. It inhibits the synthesis of the prostaglandins that cause pain, inflammation and fever when tissue damage occurs. Meloxicam is effective for approximately 24 hours.

Limited research has been carried out into the cost of castration under anaesthesia. On the basis of local anaesthesia with lidocaine administered by a veterinarian, Eijck et al. (2007) calculated an additional cost of € 0.01 per kilo of meat for the Dutch organic pig sector.

2 The effect of anaesthesia and/or analgesia on the response of piglets during castration

M. Kluivers-Poodt, S.R.M. Robben (FD), A. van Nes (FD), B.B. Houx (FD)

2.1 Introduction

Pain is a complex and individual sensation, which means that it is difficult to measure and compare in animals (Sneddon and Gentle, 2000). However, there are specific parameters of vocalisation, physiology and behaviour that relate to pain. According to the scientific literature, these parameters can vary depending on the circumstances. In order to obtain as full a picture as possible of pain perception in piglets during castration, the most valid parameters were measured in this experiment.
On the basis of the scientific literature, the acute stress response of piglets at the moment of castration was measured in terms of vocalisations (squealing), physiological blood values (glucose, lactate, creatine kinase and cortisol) and changes in skin temperature. Since 1995, several researchers have used vocalisation as an indication of pain during castration (White et al., 1995; Weary et al., 1998; Taylor and Weary, 2000; Taylor et al., 2001). It is clear that piglets squeal more during castration than after it, and the calls are on average longer and louder, purer and often higher in pitch.
When the body is subjected to stress, it usually tries to release more energy in order to counter the threat through fight or flight. But if the stress response is likely to be unsuccessful, the body conserves energy and attempts to evade the threat: the conservation-withdrawal response (Sapolsky, 1992; Korte et al, 2005, Korte, 2001). In the case of the active response, the blood glucose level increases due to the mobilisation of glycogen from the lever and muscles, under the influence of the hypothalamus-pituitary-adrenal axis. Lactate increases as a result of anaerobic (without oxygen) burning of glycogen in the muscles. It is then used in the liver as a substrate for gluconeogenesis (production of sugar). Creatine kinase is a muscle enzyme that is released when a muscle is damaged or under extreme physical exertion, but acute psychological stress combined with physical exertion can also cause an increase in creatine kinase (Zöls et al., 2006). Cortisol, produced in the adrenal glands under the influence of the hypothalamus-pituitary axis, increases during periods of acute stress.
Plasma concentrations of these substances can therefore be used indicator of stress (Sapolsky et al., 2000). In male piglets cortisol production takes on a circadian rhythm around approximately 10 days of age, which means that the cortisol level then varies according to the time of day at which the sample is taken. In response to stress, blood is diverted in order to enable a 'fight or flight' response. This means that blood is diverted from the skin to the organs that are required for this response. This results in decreased blood flow to the skin and a lowering of skin temperature.
Heart-rate variability is often measured in research into stress. This parameter is a measure of the interplay between the activity of the parasympathetic and sympathetic parts of the nervous system, and is influenced by physical activity as well as by psychological load of the animal. It is a useful measure in animals subject to prolonged periods of stress (e.g. during transport). However, the castration of piglets involves short-term stressors combined with considerable physical activity, which varies widely from piglet to piglet. As Von Borell et al. (2007) indicate in their review, ideally, for reliable analysis, periods of at least 5 minutes must be recorded, in piglets showing similar behaviour. Even then, adjustment for physical activity is necessary in order to analyse and interpret the stress components of HRV between piglets. There is not a great deal of literature on HRV as an indicator of stress in pigs. The studies that have been carried out are largely biomedical, and were carried out using Yucatan and Göttinger miniature pigs. Only one study used commercial finishing pigs. Von Borell et al. (2007) conclude that existing data show that HRV is a promising stress indicator, but that a great deal of further research is required in order to explain the regulatory mechanisms that influence HRV in pigs. Further research is necessary into the species-specific range of variation in HRV, in order to determine the numbers of animals required in experiments, into the individual characteristics of animals and the relationship to individual ways of responding to stress (coping style and temperament), and into the precise relationship between HRV and pain. Heart-rate variability is therefore not a sufficiently reliable indicator to be included in this study.
A method for measuring the pain stimulus rather than the pain sensation is to determine the expression of c-Fos receptors in the dorsal horn of the spinal cord (Nyborg et al., 2000; Svendsen, 2005). A disadvantage of this method in this context is that it has not yet been validated for pigs. The method is also inadequate compared with vocalisations in terms of expressing how animals *experience* pain. From an ethical point of view, this method of measurement is less preferable because all the animals in the experiment must be euthanised in order to perform the measurement.

2.2 Materials and method

2.2.1 Animals and housing

The research protocol was approved by the Animal Experiments Committee (DEC) in Lelystad.
The experiment was carried out at experimental farm De Tolakker of the Faculty of Veterinary Medicine in Utrecht. The sows (Topigs, Netherlands) were kept in a farrowing section with ten pens. The sows were fed twice a day, at 8.15 a.m. and 3.45 p.m., in accordance with CVB guidelines (CVB feed table). At the front of the farrowing pens there was a nest area for the piglets, with a solid floor, floor heating and a heat lamp. The temperature in the farrowing section was set at 20°C until the first sow had given birth, then raised to 23°C. A total of 160 piglets from 32 litters were used, over a period of seven weeks. Each week, four to six litters from the same farrowing section were treated.

2.2.2 Treatments

The experiment was carried out with 160 piglets of 3-5 days old. In each litter, five male piglets were randomly assigned to one of the treatments (see Table 2.1). Within each litter, the treatments were performed in a random sequence. Prior to the experiment, no other treatments or interventions (i.e. eartagging, iron injection) were carried out on the pigs.

Table 2.1 Description of treatments

	Treatment	Description
1	Castration without anaesthesia (CAST)	Castration without prior medication
2	Castration with local anaesthesia (LIDO)	Administration, left and right, of 0.8cc lidocaine in the testicle and 0.2cc under the skin, 15 minutes prior to castration.
3	Castration with local anaesthesia and analgesia (L+M)	Administration, left and right, of 0.8cc lidocaine in the testicle and 0.2cc under the skin, and 0.2cc meloxicam (Novem 5) intramuscularly (in the neck muscle), 15 minutes prior to castration.
4	Castration with analgesia (MELO)	Administration of 0.2cc meloxicam (Novem 5) intramuscularly (in the neck muscle), 15 minutes prior to castration.
5	Sham castration (SHAM)	Pick up twice, 15 minute interval

Prior to the treatment, five male piglets from a litter were numbered and placed in a box. Fifteen minutes before castration, all piglets were placed in a restraining device (Schippers, Bladel) so that blood samples could be taken. The piglets for treatments 2, 3 and 4 were then given their medication (lidocaine and/or meloxicam), and returned to the box until castration, 15 minutes later. The piglets for treatment 1 were only picked up for castration (positive control), the piglets in treatment 5 were picked up twice but not castrated (negative control). The piglets were also fixed in the device during castration. Before the incision was made, the scrotum was disinfected with alcohol (70%, methylated). The scrotum was opened by means of a horizontal incision over both testicles, into the tunica vaginalis. Both testicles were exposed and the spermatic cords severed with a scalpel in accordance with European regulations. After castration, the piglets were put back into the box until all procedures had been carried out.
Lidocaine and meloxicam were administered by a veterinarian. The castration was carried out by a stockman.

2.2.3 Measurement of parameters

Throughout the castration procedure, all vocalisations of the piglets were recorded with a microphone (Sennheiser, MKH106), which was positioned approximately half a metre from the piglet's head. The vocalisations were recorded with a DAT recorder (AIWA, HD-S100) and digitised using a personal computer (Dell Dimension 8200 with a Creative SB live! soundcard) or recorded directly onto a laptop (HP Compaq nx9110). The sound was digitised (24 bit, 22050 Hz sampling rate) with Avisoft software (Avisoft-RECORDER version 4.40, 2007).
Blood samples were taken fifteen minutes before castration, during treatments 2, 3 and 4 just before the administration of lidocaine and/or meloxicam. For this purpose, the piglets were placed in the castration clamp and the blood was taken from the vena jugularis. This was repeated twenty minutes after castration. The blood was divided

between a blood tube with EDTA and one with heparin, and kept on ice until it was transported to the laboratory for further processing. In the laboratory, the blood samples were centrifuged for ten minutes at 3500 rpm. The serum was kept at 6-8°C until it was analysed. The glucose, lactate, creatine kinase (CK) and cortisol levels were analysed in all samples at the same time.
The skin temperature of the piglets was measured four times: just before the first blood sample was taken (15 minutes before castration), just before castration, just after castration, and just before the second blood sample was taken (20 minutes after castration). Skin temperature was measured in the inguinal region using an infrared thermometer (Raytec).
The male piglets were weighed on the day of castration, at weaning, and four weeks after weaning. The individual weights were used to calculate growth in three periods: (1) growth from castration to weaning, (2) growth from weaning to 4 weeks later, and (3) growth from castration to four weeks after weaning.

2.2.4 Statistical procedure

Vocalisation
The castration process was divided into three phases. The first phase was the pre-surgical phase, in which the piglets were placed in the castration device. This was followed by the surgical phase, beginning at the moment of incision in the scrotum and ending with the severing of the second spermatic cord. Finally, the third phase was the post-surgical phase, which ended when the piglet was removed from the clamp. The sound analysis focused on the surgical phase, in order to establish the direct effects of castration.
Calls are defined as continuous vocalisations separated by episodes without vocalisation. Calls were automatically detected by Avisoft SASlab pro (version 4.40, 2007). Background noise mistaken for a call was manually excluded from the analysis. Undetected calls were marked manually. The calls were analysed separately for the three periods. Measurements were calculated in SASlab pro 27 to describe specific call characteristics (see Table 2 for the most important definitions). Means for all measurements were calculated separately for each animal in each period.
Piglets that made no sound during one of the periods could not be included in the calculation of parameters for characterising call quality. However, observations for every pig were included in the call rates. In order to compare the differences between the five treatment groups, a GLM procedure was used for repeated measures in SPSS (version 12.0.1). The Greenhouse-Geisser univariate test was used. Estimated marginal means were calculated and their differences were tested pairwise (Bonferroni). Transformation was applied to parameters in order to ensure normal distribution. In a second GLM repeated-measures procedure, the effectiveness of lidocaine and meloxicam was tested directly by taking them as two separate factors, each with two levels: administered or not administered.

Table 2.2 Definitions of call parameters

Parameter	Description	
Temporal parameters		
Call rate	Number of calls per second	s^{-1}
Duration	Duration of the call	s
Waveform parameter (computed from the waveform for the entire element)		
Peak to peak	Peak to peak amplitude	Volts
Spectrum-based parameters (derived directly from the spectra of the spectrogram)		
Peak amplitude	Maximum amplitude[1] of the call	dB
Main amplitude	Highest amplitude in the mean spectra of the call	dB
MAX peak amplitude	Maximum value for peak amplitude[1] for the entire series of calls for a piglet	dB
Peak frequency	Frequency of the peak amplitude	Hz
Main frequency	Frequency of highest amplitude in the mean spectra of the call	Hz
Bandwidth	Difference between the max. and Min. frequencies at which the amplitude exceeds a threshold of -20dB measured at the point of maximum amplitude of the call	Hz
Quartile 75%	Below this frequency is 75% of the total energy	Hz
Quartile 25%	Below this frequency is 25% of the total energy	Hz
Range between 75^{th} and 25^{th} quartiles (max)	75^{th} quartile – 25^{th} quartile at the point of maximum amplitude of the call. Measure of the pureness of the sound.	Hz
Range between 75^{th} and 25^{th} quartiles (mean)	75^{th} quartile – 25^{th} quartile at the point of maximum amplitude in the mean spectra of the call. Measure of the pureness of the sound	Hz
Entropy	Ratio between geometric mean and arithmetic mean of the amplitude of the spectrum at the moment of maximum amplitude of the element. Gives a measure for the pureness of the sound (0 is a pure tone; 1 is random noise).	

[1]Amplitude values are negative; higher values are louder

Blood parameters
For each registration moment, histograms of the measurements were produced and the skewness coefficients calculated using the data from the blood parameters (glucose, lactate, creatine kinase and cortisol) and skin temperature. The histograms and the calculated skewness coefficients show that the measured concentrations of the blood parameters are asymmetrically distributed. Logarithmic transformation was therefore applied in order to obtain more symmetrically distributed data and to stabilise the variance. Further analyses were carried out for the log10 values.
The influenced of litters and treatments on the responses for the measured variables was examined by means of regression analysis; the following model was used:

$$Y = c + \text{litter} + \text{treatment} + e$$

where Y is the measured response, and litter and treatment are the corresponding effects. Further, e is the residual effect. The model assumes that e is normally distributed with mean 0 and variance σ^2. F-tests were used to test litter and treatment differences. In cases where the F-tests were significant ($P<0.05$), all pairwise treatment differences were tested by means of t-tests. The above model was also used to analyse the difference in measurements between two consecutive registration moments for the physiological variables.

2.3 Results

2.3.1 Vocalisation

As is customary (e.g. Weary et al., 1998), the calls were divided into two types: 'high calls' (>= 1000Hz) and 'low calls' (< 1000Hz). The analysis showed that the number of piglets with low calls was so low that no significant differences could be shown. All analyses were therefore carried out on high calls only. The results of the analysis of the piglets' vocalisations are shown in Table 2.3. The table gives only those measurements of vocalisation relating to piglet castration that are mentioned as meaningful in the literature (Puppe et al., 2005, Marx et al., 2003, Taylor et al., 2000, Weary et al, 1998, White et al., 1995), as well as measurements that show significant differences between treatment groups.

Table 2.3 Parameters with a significant treatment effect in the surgical phase (estimated marginal mean ± SE) (different superscripts within a row indicate a significant (p<0.05) difference between treatments)

Parameter	Sham castration (n=11)	Castration without anaesthesia (n=11)	Castration with local anaesthesia (n=11)	Castration with meloxicam (n=11)	Castration with local anaesthesia and meloxicam (n=11)
Call rate F(2.22) = 3.7, p=0.039	1.395±.134[a]	1.111±.085[a]	1.052±.106[a]	1.046±.098[a]	0.902±.098[a]
Duration F(3.26) = 4.1, p=0.022	0.485±.043[a]	0.807±.068[b]	0.735±.077[ab]	0.903±.101[b]	0.753±.090[ab]
Peak to peak (sqrt transformation) F(3.28) = 10.6, p<0.001	0.671±.061[a]	1.023±.035[b]	0.641±.061[a]	0.801±.082[ab]	0.585±.061[a]
Peak amplitude (max) F(3.28) = 5.5, p=0.005	-31.5±2.23[ab]	-25.2±1.35[b]	-33.5±2.22[a]	-29.6±2.91[ab]	-36.4±2.41[a]
Main amplitude (mean) F(3.26) = 4.7, p=0.013	-45.5±2,43[ab]	-39.7±1.34[b]	-48.7±1.98[a]	-44.6±3.09[ab]	-49.4±2.27[a]
MAX peak amplitude F(2,23) = 2.8, p=0.074	-22.9±2.76 a	-17.4±1.25 a	-24.6±3.44 a	-21.1±2.56 a	-28.6±4.01 a
Peak frequency (max) F(3.32) = 5.5, p=0.003	3848±238[a]	4736±262[ab]	5736±372[b]	4968±444[ab]	5355±308[b]
Main frequency (mean) F(2.25) = 3.7, p=0.032	3180±174[a]	4464±289[b]	3894±490[ab]	4181±561[ab]	2770±459[ab]
Bandwidth (max) F(3.26) = 3.7, p=0.028	5572±377[a]	6748±265[a]	7718±723[a]	6160±422[a]	7165±568[a]
Range 2575 max F(3.31) = 1.0, p=0.407	2479±133 a	2907±87 a	2575±230 a	2573±243 a	2680±186 a
Range 2575 mean F(2.24) = 5.4, p=0.008	2778±161[a]	3224±63[a]	3985±185[b]	3345±271[ab]	3967±357[ab]
Entropy (max) F(3.32) = 6.6, p=0.001	0.460±.016[a]	0.568±.017[b]	0.475±.026[a]	0.505±.021[ab]	0,493±,021[ab]

Thirteen piglets were silent during castration. Four of these were from the sham group, six from the lidocaine group, and three from the lidocaine and meloxicam group. Piglets that were castrated without anaesthesia, or treated only with meloxicam, were never silent.

As expected, the piglets castrated without anaesthesia showed the strongest indication of pain, and the sham-castrated piglets the least. The lidocaine group differed for five parameters (primarily loudness, interquartile range and entropy) from the piglets castrated without anaesthetic. The piglets from the meloxicam group showed no differences in relation to the piglets castrated without anaesthesia. The group treated with lidocaine and meloxicam showed fewer indications of pain, as did the lidocaine group. This impression was refined in a second GLM analysis, with lidocaine and meloxicam as factors, each with two repeated levels (administered / not administered). The most important results are shown in Table 2.4.

Table 2.4 Key results of the GLM analysis with lidocaine and meloxicam as factors, each with two repeated levels (administered / not administered) (averages ± SE, significant main effects shown in bold, n=17)

	lidocaine		**p**	**meloxicam**		**p**
	administered	**not administered**		**administered**	**not administered**	
Call rate	1.016±.068	1.202±.105	**0.016**	1.151±.136	1.066±.065	0.542
Duration	0.763±.037	0.824±.054	0.408	0.797±.042	0.790±.037	0.893
Peak to peak	0.480±.101	0.888±.079	**<0.001**	0.595±.088	0.773±.089	**0.010**
Peak amplitude (max)	-33.6±2.43	-26.1±1.63	**<0.001**	-31.4±2.09	-28.3±1.87	**0.016**
Main amplitude (mean)	-47.5±2.32	-40.5±1.76	**<0.001**	-45.1±2.11	-42.9±1.91	0.099
peak amplitude (maxentire)	-33.6±2.43	-26.2±1.66	**0.001**	-31.4±2.09	-28.5±1.84	**0.019**
MAX peak amplitude (max)	-25.7±2.95	-18.2±1.29	**0.004**	-23.5±2.37	-20.4±1.78	**0.047**
peak frequency (max)	5140±224	4794±219	0.247	4922±213	5012±194	0.701
Main frequency (mean	3165±257	4319±267	**0.001**	3344±264	4140±241	**0.007**
Min frequency (max)	1241±187	1906±145	**0.002**	1625±185	1522±139	0.547
Min frequency (maxentire)	5909±707	8436±303	**0.002**	6807±509	7538±425	0.115
bandwidth (max)	7311±409	6395±259	**0.026**	6727±285	6978±367	0.442
bandwidth (mean)	9270±207	8821±224	0.106	8883±213	9207±229	0.260
bandwidth (maxentire)	8866±233	8090±185	**0.019**	8395±180	8560±210	0.526
25th quartile (mean)	3139±184	3477±140	0.063	3077±207	3539±124	**0.031**
range2575 (max)	2744±130	2767±108	0.881	2732±132	2779±118	0.779
range2575 (mean)	3925±144	3256±104	**0.002**	3659±160	3523±87	0.477
entropy (max)[1]	0.497±.015	0.532±.013	**0.043**[1]	0.500±.013	0.529±.014	**0.038**[1]
entropy (mean)	0.685±.017	0.715±.010	0.122	0.678±.013	0.722±.014	**0.011**
entropy (max entire)	0.716±.009	0.723±.008	0.554	0.708±.009	0.730±.008	**0.043**

[1] interaction effect between lidocaine and meloxicam ($F(1,16) = 8.6$, $p=0.010$)

This shows that lidocaine, but not meloxicam, reduces the number of calls (call rate) and increases the bandwidth of the sound. Both lidocaine and meloxicam reduce the loudness of the calls and the pitch. Meloxicam increases tonality (characterised by a lower entropy) of the calls. There were no interactions between lidocaine and meloxicam, except for entropy (max).

2.3.2 Blood parameters

Table 2.5 shows the average blood values per treatment, before and after castration.

Table 2.5 Absolute values in the blood 15 minutes before and 20 minutes after castration

	Glucose (mmol/L)		Lactate (mmol/L)		CK (U/L)		Cortisol (nmol/L)	
	before	after	before	after	before	after	before	after
No anaesthetic	6.7	6.7	7.0	8.0	1837	1942	135	421
Lidocaine	6.6	6.5	7.2	6.7	1609	2845	139	376
Lidocaine+meloxicam	6.8	6.6	6.7	7.3	2119	1908	153	400
Meloxicam	6.1	6.6	6.9	8.2	1567	1022	170	453
Sham	6.8	7.0	6.5	7.3	781	1137	140	269

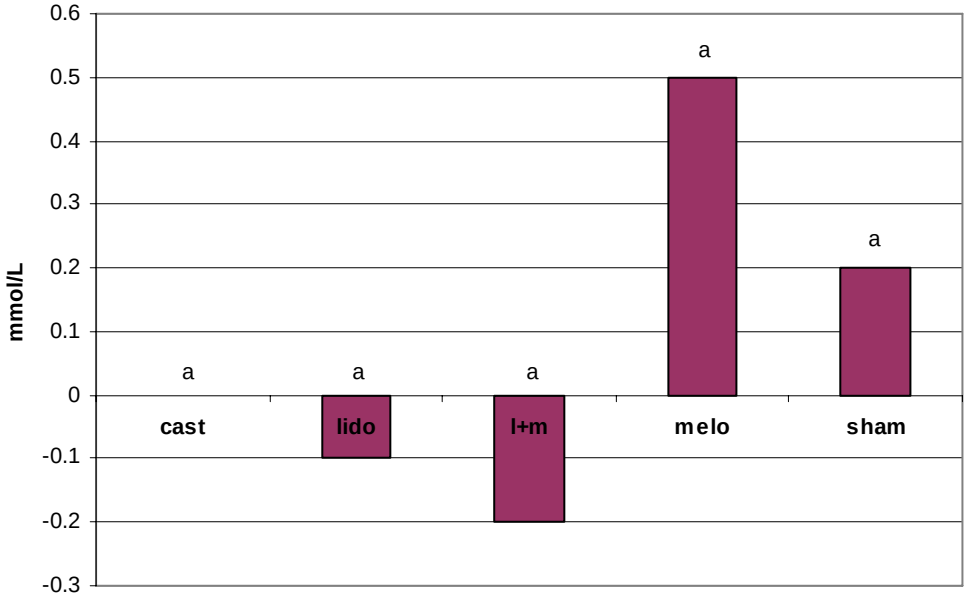
The blood parameters were analysed to establish increases or decreases as a result of castration (blood value after castration minus blood value before castration). Prior to the analysis, a log10 transformation was performed. The calculated P-values of the F-tests for litter and treatment effects are shown in Table 2.6.

Table 2.6 Calculated P-values of the F-tests for litter and treatment effects

	Litter	Treatment
Log10-glucose after castration – before castration	0.05	0.31
Log10-lactate after castration – before castration	0.41	0.05
Log10-creatine kinase after castration – before castration	0.36	0.48
Log10-cortisol after castration – before castration	<0.001	<0.001

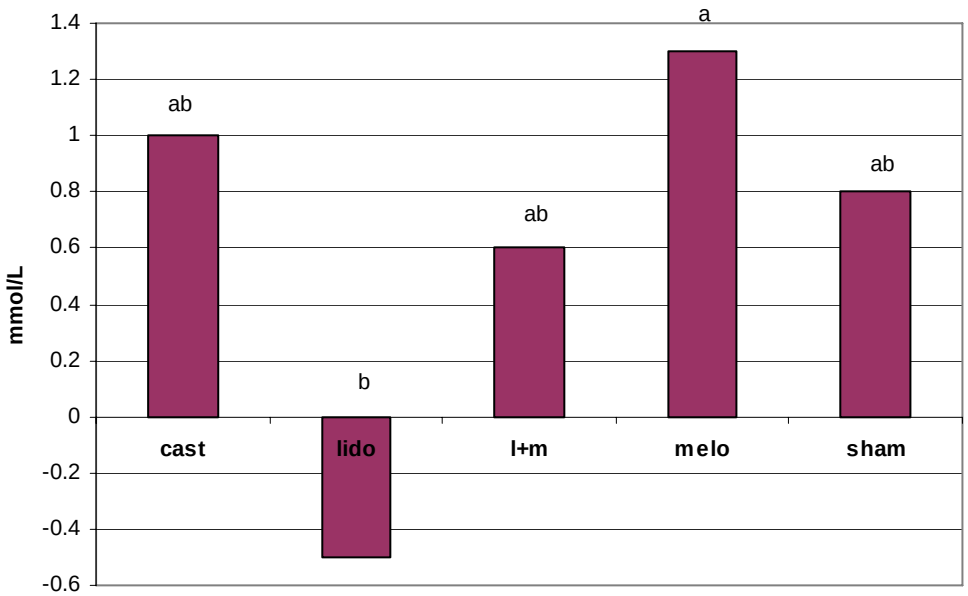
A litter effect is present for log10-glucose and log10-cortisol. Treatment effects are present for log10-lactate and log10-cortisol. Figures 2.1 to 2.4 show the effects found for each treatment group. The absolute differences in blood concentration before and after castration are shown, the significances apply to the log10 values.

Figure 2.1 Increase in glucose due to castration (different letters indicate significant differences between treatments)



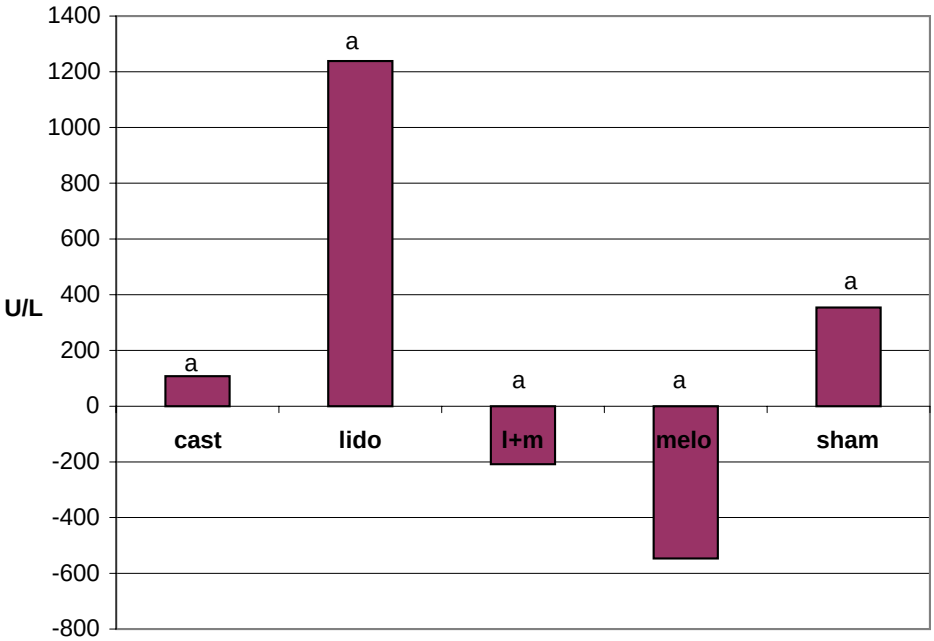
For log10-glucose, on the basis of the reliability intervals, there is no significant increase for meloxicam; there is no significant change for the other treatments. T-tests of pairwise differences showed no significant differences between treatments.

Figure 2.2 Increase in lactate due to castration (different letters indicate significant differences between treatments)



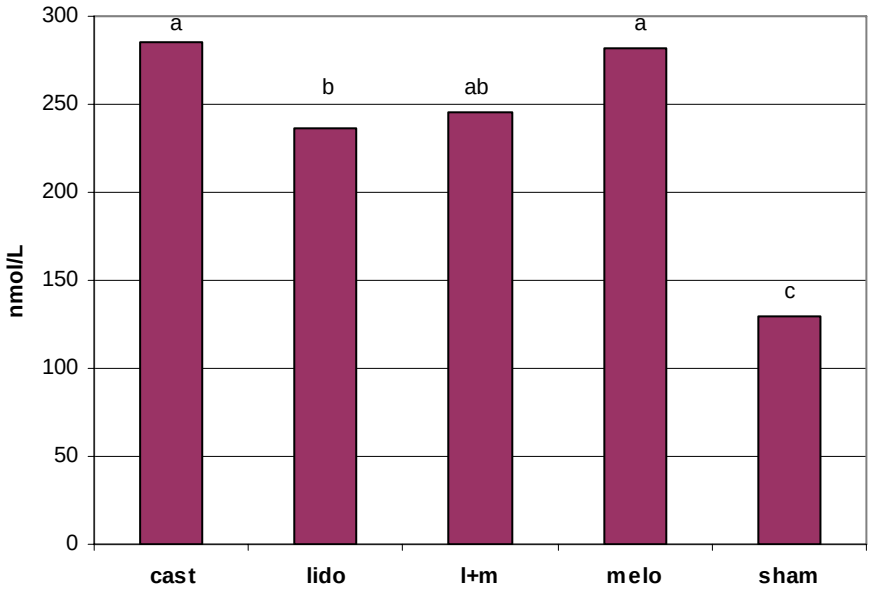
For log10-lactate there is a significant increase in piglets castrated without anaesthesia and in piglets castrated after administration of meloxicam. For other treatments, the change does not differ significantly from 0. The only treatment differences are between the piglets treated with lidocaine and the piglets treated with meloxicam; the other treatments do not differ significantly from either of these two.

Figure 2.3 Increase in creatine kinase due to castration (different letters indicate significant differences between treatments)



There is no significant increase or decrease for log10-creatine kinase in any of the treatments, neither are there significant differences between treatments.

Figure 2.4 Increase in plasma cortisol due to castration (different letters indicate significant differences between treatments)

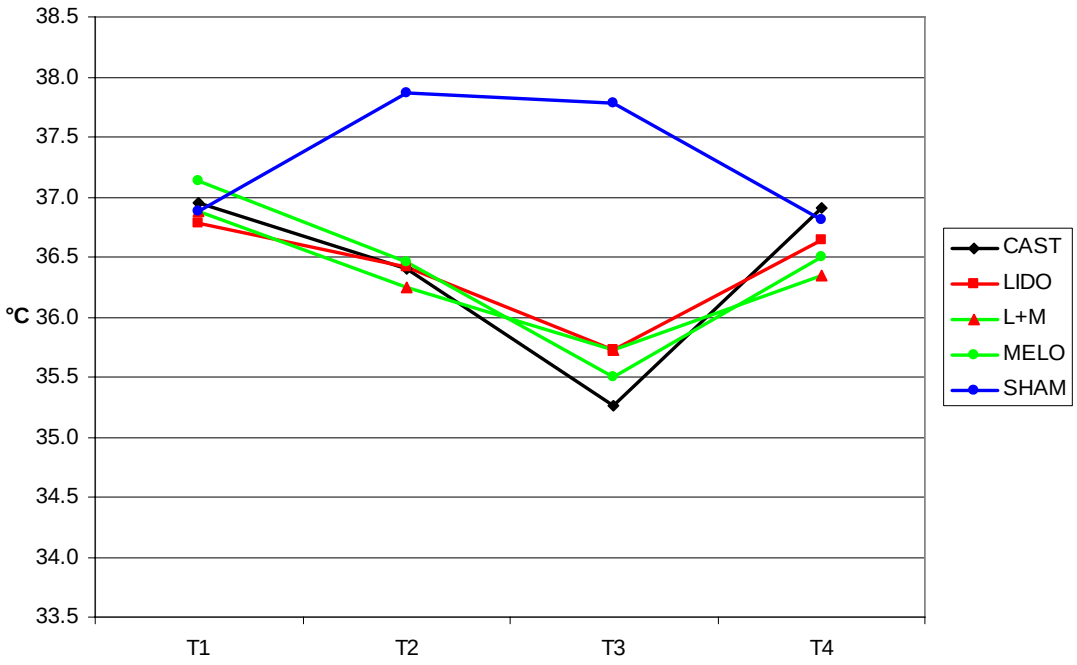


Log10-cortisol shows a significant increase for all treatments. The increase in the sham-castration group is significantly lower than in all other treatments. In the treatments that involved actual castration, the group treated with lidocaine shows a significantly lower increase compared to the unanaesthetised group and the group castrated with meloxicam. The group treated with a combination of lidocaine and meloxicam does not differ from any of these three groups.

2.3.3 Skin temperature

Figure 2.5 shows the changes in skin temperature.

Figure 2.5 Skin temperature 15 minutes before castration (T1), just before castration (T2), just after castration (T3) and 20 minutes after (T4)



Skin temperature was analysed in order to establish increases and decreases between two consecutive measurements. The calculated P-values of the F-tests for litter and treatment effects are shown in Table 2.7.

Table 2.7 Calculated P-values of the F-tests for litter and treatment effects

Parameter	Litter	Treatment
Skin temperature interval T1-T2	0.019	<0.001
Skin temperature interval T2-T3	0.29	<0.001
Skin temperature interval T3-T4	<0.001	<0.001

A litter effect is present for intervals T1-T2 and T3-T4, and treatment effects are present for all intervals. In interval T1-T2 there is a significant increase in skin temperature in the sham-castrated piglets and a significant decrease in other treatments. The other treatments do not differ significantly from each other. In interval T2-T3, skin temperatures decreases significantly in all treatments, with the exception of the sham-castrated piglets. The significant differences between the treatments are shown in Table 2.8.

Table 2.8 Reduction in skin temperature due to castration or sham castration

	Skin temperature interval T2-T3 (°C)	P<0.05
No anaesthetic	-1.2	a
Lidocaine	-0.7	ab
Lidocaine+meloxicam	-0.5	bc
Meloxicam	-1.0	ab
Sham	-0.1	c

Interval T3-T4 shows a significant decrease in skin temperature. In the other treatments, skin temperature increases significantly after castration, whereby the piglets castrated without anaesthesia show the greatest increase on average.

2.3.4 Piglet growth

The piglets' growth performance was measured at three stages: on the day of castration, on the day of weaning, and four weeks after weaning. Weights and growth are shown in Table 2.9. The calculated P-values of the F-tests for litter and treatment differences are shown in 2.10.

Table 2.9 Average weight (kg) per treatment at castration, weaning, and 4 weeks after weaning

	Castration	Weaning	4 wks after weaning	Growth from castration to weaning	Growth from weaning to 4 wks later	Growth from castration to 4 wks after weaning
No anaesthetic	2.42	8.81	19.96	6.41	11.15	17.56
Lidocaine	2.46	9.06	19.94	6.63	10.88	17.51
Lidocaine+meloxicam	2.31	8.49	19.27	6.18	10.78	16.96
Meloxicam	2.35	8.21	18.76	5.86	10.56	16.41
Sham	2.37	8.37	19.43	6.00	11.06	17.06

Table 2.10 Calculated P-values of F-tests for litter and treatment effects

	Litter	Treatment
Weight at castration	<0.001	0.54
Weight at weaning	<0.001	0.16
Weight at 4 wks after weaning	0.036	0.68
Growth from castration to weaning	<0.001	0.13
Growth from weaning to 4 wks later	0.046	0.94
Growth from castration to 4wks after weaning	0.070	0.70

The analysis of the weights and growth performance in the intervening periods shows that the litter effects are significant in the majority of cases, but there are no significant treatment differences.

2.4 Discussion

Vocalisation

As expected, vocalisations indicated in various ways the pain experienced by the piglets. The number of calls (call rate) is a readily observed parameter that increases in the event of stress and pain (Weary et al., 1998; Taylor and Weary, 2000), although a pain effect is not always found (Puppe et al., 2005). In the first GLM analysis, a significant general difference in call rate was found, but in the post-hoc test there was no difference between the groups. In the second GLM analysis, lidocaine (but not meloxicam) was shown to reduce the call rate significantly.
Compared to the sham-castrated piglets, the calls of the group castrated without anaesthetic and the group treated with meloxicam were significantly longer, which is indicative of greater pain. The length of calls in both groups that received lidocaine (with and without meloxicam) was between that of these two groups and did not differ significantly from the other groups. The effect on duration was not confirmed in the second GLM analysis.
Various parameters were used to measure the loudness of the calls. All parameters showed a consistent pattern, in line with previous studies. Both GLM analyses showed that piglets treated with lidocaine squealed significantly less loudly, which indicates less pain. In the second GLM analysis, the calls of the piglets treated with meloxicam were also less loud, although the effect was less clear. The max peak amplitude parameter, which is comparable to the widely used sound volume meter (Gerrits, 2006), showed significant effects only in the second GLM.
There are indications that piglets experiencing pain squeal at higher frequencies (Puppe et al., 2005). However, the literature is not consistent in this (Marx, 2003). One of the reasons for this is the fact that studies differ in the way they categorise and measure different types of call, such as low calls and the high calls and squeals. In this study we found no clear differences in peak frequency (the frequency at the loudest part of the call), but the results for the mean main frequency (the most obvious part of the whole call) were clearly in line with Puppe et al. (2005). The second GLM analysis showed that the calls of piglets treated with lidocaine as well as meloxicam were at a lower frequency than those of the piglets castrated without anaesthesia.
The bandwidth, interquartile range and entropy are all indicative of the distribution of energy over the frequencies in the call and of the 'pureness' or, conversely, the 'noisiness' (Puppe et al., 2005). The second GLM analysis showed that lidocaine increased the bandwidth and interquartile range, which is an indication of reduced pain (Puppe et al., 2005). Such an effect was not present in the meloxicam group, although meloxicam clearly reduced the entropy. Lidocaine lowered only the maximum entropy. The effect observed on entropy is the only result that is not in line with previous research. Given that only Puppe et al. (2005) have reported on this parameter, we will refrain from drawing further conclusions.

Blood values

The glucose level in the blood increases in response to stress under the influence of glucocorticoids, including cortisol, produced in the adrenal gland. Within a few minutes of the onset of stress, the increase can be as much as 10% (Zöls et al., 2006). The reference values given by Heinritzi and Plonait (2004) are 4.00-6.36 mmol/L in serum. Zöls et al. (2006) found test group averages of 6.2-6.8 mmol/L. The latter is in line with the averages from the treatments in this study (6.1-6.8 mmol/L). In this study, the influence of castration on glucose level (increases) does not differ between the groups. This is in line with the findings of Prunier et al. (2005) and Zöls et al. (2006). A possible explanation is the low glycogen level in the liver of newborn piglets (Prunier et al., 2005), so that in a stress situation, also under the influence of stress hormones, there is simply no glycogen available for mobilisation. This would mean that glucose is a less appropriate stress parameter for newborn piglets.
Lactate levels increase under stress in order to meet the increased demand for energy. Lactate is produced during anaerobic (without oxygen) glycolysis in the muscles during increased exertion. In their study, Zöls et al. (2006) found an average lactate level of 4.3-5.7 mmol/L prior to castration. In our study, the level before castration was 6.5-7.2 mmol/L. This difference in baseline values could be due to a different method of restraint during blood sampling. In the study by Zöls, the piglets were restrained on their back. In our study, they were restrained in a castration clamp. Prunier et al. (2005) found basal concentrations of 2.4 mmol/L when samples were taken via a catheter, i.e. .virtually stress-free. They found that, after castration, lactate levels in the blood reached the maximum of 7.2 mmol/L within 2 minutes and returned to the basal level 1 hour after castration. It is therefore possible that the restraining method in our study had an influence on basal lactate levels. In our study, lactate increased in all groups as a result of castration, except in the lidocaine group, which showed a decrease. However, only the group treated with meloxicam and the group treated with lidocaine differed significantly from each other. The decrease in lactate in the lidocaine group cannot be readily explained on the basis of the existing literature. Zöls et al. (2006) found a significant increase in lactate one hour after castration in the group treated with procaine, but they also found no significant differences between the groups.
Creatine kinase is a muscle enzyme that occurs in equal amounts in white and red striated muscle cells. The level of creatine kinase in the blood can increase as a result of physical as well as psychological stress. Although the group treated with lidocaine showed a considerable increase in creatine kinase due to castration, there were no significant differences between the tst groups. This can be caused by the very large individual differences in reaction as seen in the wide variation. Zöls et al. (2006) found a maximum creatine kinase concentration in the blood 4 hours after

castration. However, at that stage the standard deviation in the group castrated without anaesthesia also showed a very marked increase. This also indicates that individual reactions vary widely.
Molony and Kent (1997) concluded from their findings that cortisol is the most straightforward way to measure the activity of the hypothalamic-pituitary-adrenal axis. They found a close relationship between the behavioural changes observed in lambs after castration and the measured plasma cortisol concentrations. Other authors have also concluded from their findings that cortisol is a useful stress parameter (Morton et al., 1985; Schönreiter et al., 1999; Ting et al., 2003; Mellor and Stafford, 2004; Prunier et al., 2005). However, the cortisol in the blood has a delayed reaction to the stressor. In pigs, it is not known when the increase begins and ends, or when the maximum concentration is reached. It has been shown that, in dogs, plasma cortisol reaches a maximum 30 minutes after application of the stressor, and returns to the basal level after 30 minutes (Vincent and Michell, 1992) or 60 minutes (Beerda et al., 1998). The cortisol measurements in our study show that sham castration and handling the pigs twice without actually castrating them causes a clear increase in cortisol. This is not in line with the findings of Prunier et al. (2005) and Zöls et al. (2006), where no increase in cortisol was seen in the control animals that were not castrated. This difference in the findings could be due to the use of a different method for handling and restraining the piglets, but it is possible that the piglets' previous experiences also play a role. In our experiment, no other procedures had been carried out on the piglets, while in the experiment of Zöls et al. (2006), for example, tail-docking, tooth-clipping and ear-tagging had been carried out on the first day after birth. However, in our study the increase in the uncastrated animals was significantly lower than in all other castrated treatment groups. In relation to the animals castrated without anaesthesia and the animals that received only meloxicam, the group treated with lidocaine showed a significantly lower increase. The group treated with lidocaine as well as meloxicam did not differ from these groups. In their study, Zöls et al. (2006) found the increase in cortisol one hour after castration in animals treated with procaine to be greater than in the animals castrated without anaesthesia, which is indicative of greater pain. This effect had disappeared after four hours. In the study by Zöls et al. (2006), one hour after castration, the group treated with meloxicam showed cortisol levels comparable to the sham-castrated group. In our study, such an effect was not observed when samples were taken 20 minutes after castration. It is possible that the time between administering the meloxicam and taking the blood sample was too short (35 minutes vs. 75 minutes by Zöls et al.), whereby the maximum analgesic effect of the meloxicam had not yet occurred.

Skin temperature
Little is known about how pain and stress affect skin temperature. When the body is under threat, the *fright-flight-fight* response (described by Cannon as early as 1914) is triggered. Blood is redirected to the organs that are essential to the response, and away from the organs that are less essential (the skin). This leads to a decrease in skin temperature. In our experiment, skin temperature of the piglets castrated without anaesthetic decreased significantly more than in the group treated with lidocaine and meloxicam, and the sham group. This could be an indication of a greater shock reaction, resulting from a heavier pain stimulus, which means that blood flow to the skin falls more sharply than in the other treatments. The group treated with lidocaine and meloxicam did not differ significantly from the sham-castration group.

Growth
The absence of significant differences in growth performance between the treatment groups is in line with the findings of Hay et al. (2003). McGlone et al. (1993) observed an age effect on growth performance. They reported that pigs castrated at 14 days of age weighed more when weaned than piglets castrated at the age of 1 day. It is highly possible that castration affects growth performance to a lesser extent if the piglets have already determined their suckling hierarchy. Kielly et al. (1999) found that growth was slowed in piglets castrated at 3 days of age, but this effect was no longer present at weaning.

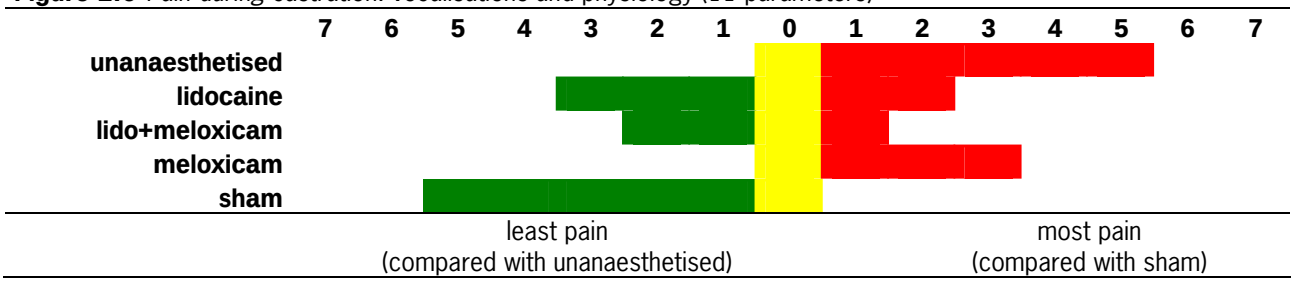
2.5 Conclusion

In the first GLM analysis of the vocalisations it became clear that, during castration, several call-characteristics in the piglets castrated without anaesthesia were consistently indicative of greater pain (longer and louder high-pitched squeals) than in the sham-castrated piglets. All results were as expected, on the basis of the available literature. As expected, the pattern in both groups treated with lidocaine most resembled the calls of the piglets in the sham-castrated piglets. The group treated with meloxicam did not differ significantly from the sham-castrated group (except for the duration of the calls) or the group castrated without anaesthesia. In the second GLM analysis, the effect of lidocaine and meloxicam was tested more directly. Again, lidocaine was shown to significantly reduce vocal indications of pain. Meloxicam also appeared to reduce vocal pain expression, albeit less markedly. Indications of an interaction between both drugs were not found. The conclusion is that lidocaine reduces the direct vocal expression of pain more clearly than meloxicam.
The findings for the blood parameters show that the use of local anaesthesia with lidocaïne resulted in a significantly lower increase in cortisol, compared with the groups that were castrated without anaesthesia, or with the use of meloxicam, or with the use of the combination lidocaine and meloxicam. Sham castration resulted in a significantly

lower increase in cortisol, but handling the piglets twice did produce an increase. Anaesthesia and/or analgesia showed no effect on the glucose and creatine kinase levels in the blood. The decrease in lactate in the group anaesthetised with lidocaïne is difficult to explain. On the basis of the blood parameters, no unequivocal conclusions can be drawn with regard to differences in pain perception. Only cortisol appears to be positively influenced by lidocaine.
On the basis of the results for skin temperature, it may be cautiously concluded that the greatest pain response was produced when the piglets were castrated without anaesthetic, with lidocaine only, and with meloxicam only. When a combination of lidocaine and meloxicam was used, there was no significant difference from the sham-castration group. Anaesthesia and/or analgesia showed no effect on growth performance.

We have made an attempt to put the treatments on a scale. Figure 2.6 shows the expressions of pain during castration. This involves a scale division with the parameters (from vocalisation, blood, skin temperature and growth) in which a significant difference was found in relation to one of the two control groups. The right-hand section of the figure(s) shows the number that differ from the sham group: the higher the number, the more indications of **more** pain. The left-hand section shows the number that differ from the unanaesthetised group: the higher the number, the more indications of **less** pain. The number of parameters stated above the figure is the maximum number of parameters showing a reliable significant effect.

Figure 2.6 Pain *during* castration: vocalisations and physiology (11 parameters)



The considerable difference between the unanaesthetised group and the sham group shows that the parameters have good statistical power. Both the groups treated with lidocaine show a clear reduction in pain expression; the group treated with an analgesic to a lesser extent.

Conclusion:
The use of lidocaine during the castration of male piglets significantly reduces the pain perception as well as the stress response. This is demonstrated, respectively, in vocalisations during castration, and in plasma cortisol levels and skin temperature. However, in comparison to the reactions of piglets during sham castration (which involved only picking up the piglets twice) the effects appear to be limited and, despite local anaesthesia, castration still has a considerable effect. The analgesic appears to have a very limited added value during castration.

3 Effect of anaesthesia and analgesic on piglet behaviour during subsequent days

J.J. Zonderland, J. Verbraak

3.1 Introduction

Surgical castration is usually performed without the use of any anaesthesia or analgesia, although the suggestion that piglets' perceive pain during castration has been abundantly supported (Weary et al, 1998; Taylor and Weary, 2000; Taylor et al, 2001). Piglets submitted to castration show a stronger vocal response compared with piglets submitted to sham castration or piglets castrated under local anesthesia (White et al., 1995; Weary et al., 1998; Taylor and Weary, 2000; Taylor et al., 2001). Castration also induces acute activation of the hypothalamic–pituitary–adrenal axis (HPA) and of the sympathetic nervous system (SNS) (White et al., 1995; Prunier et al., 2001). Lastly, castration leads to abnormal postures and behavioural changes indicative of pain (Wemelsfelder and van Putten, 1985; McGlone and Hellman, 1988; McGlone et al., 1993; Taylor and Weary, 2000; Taylor et al., 2001). Apart from the acute pain, induced by the castration procedure, piglets experience pain during the days following castration (McGlone et al, 1993; Hay et al., 2003). Hay et al. (2003) showed that the magnitude of behavioural changes is especially important within the first few hours following castration, but also over subsequent days. This persistence of behavioural alterations beyond 24 h is in agreement with observations in older pigs (Wemelsfelder and van Putten, 1985), some of these changes are still present four days after castration. This strongly suggests that piglets experience pain for more than a few hours following surgical castration.
Injecting local anesthesia in both testicles and scrotum can reduce pain during and shortly after surgical castration. Haga and Ranheim (2005) have shown lidocaine injections to affect EEG and cardiovascular responses. However, these alterations were less pronounced than those in unanaesthetised piglets during castration, suggesting the injection is less painful than castration without local anesthetic. Based on heart rate and vocalizations, White et al. (1995) reported that castration of 8 days-old piglets with local anaesthesia was less painful compared to castration without anaesthesia. McGlone and Hellman (1988) found that after castration of 7 day-old piglets without anesthesia the time piglets spend nursing was reduced, castration with local anesthesia using lidocaine neutralized this effect. Although the acute effects of anaesthesia during castration have been investigated, their longer term post operative effects on pain relief have yet to be investigated.
Post operative pain relief is generally targeted through the administration of analgesia. The use of analgesia protects the pain system from excessive activation and sensibilisation with consecutive pain stimulus (Song and Carr, 1999; Sumihisa, 2005). The pain relieving effects of analgesia on piglet behaviour during the days after castration have not been investigated.
Therefore, this study investigated the relative merits of local anaesthesia as well as general analgesia on piglet's behavioural response during four days following surgical castration.

3.2 Animals, materials and methods

3.2.1 Animals and housing

The experiment was performed at the Research Centre Sterksel of the Animal Sciences Group of Wageningen UR. Yorkshire x NL sows were kept in a farrowing room containing 12 crates (1.8 m x 2.4 m) and fed twice daily at 8.15 and 15.45 h. From the offspring of 24 sows a total of 144 male crossbred piglets were used in two successive replicates. Sows were moved into one of the twelve pens approximately one week before farrowing. They were kept in metal farrowing crates with their head to the wall and their rear to the control alley. The pen floor was fully slatted with exception of a one or two heated plate(s) for the piglets, situated on one or both side(s) of the sow. Piglets could move freely around the pen and had access to a nipple drinker fitted in each pen. During the experiment, lights were on from 7.30 to 16.30 h (between 40 and 80 lx at piglets level) and during the night the room was illuminated by two artificial standard lightning tubes (between 5 and 20 lx). Fresh air entered to room above the sows' head and the room temperature was automatically regulated by forced ventilation. Temperature was set at 20 °C until the first sows gave birth to their litter. Then room temperature was set to 23 °C until the end of the observations.

3.2.2 Experimental treatments

Within 24 hours after birth litters were standardized to 12 piglets (seven male and five female). During this procedure all piglets were weighted and the seven male piglets were individually marked on their backs, using three colours of spray (red, blue and green). Within each litter, the male piglets were randomly assigned to one of the six castration treatments. The seventh male piglet was also marked, but only used when one of the other male piglets died in the days before treatment. No further procedures were performed on the piglets before the treatment was administered. At the start of the observation week, on Monday morning, one of the six treatment was given (Table 3.1), at that time the piglets were 2 to 5 days old. Before administering treatment, all male piglets from one litter were confined in the corner of the farrowing crate, except the spare male piglet.

Table 3.1 Description of treatments

	Treatment	Description
1	None (NONE)	Piglets were not subjected to any procedures and left in the farrowing crate.
2	Castration with anesthesia (LIDO)	Piglets received two injections of 1.0 cc lidocaine. Per injection, 0.8 cc was injected into the testicle and the remaining 0.2 cc subcutaneous into the scrotum during withdrawal of the needle from the testicle.
3	Castration with analgesic (MELO)	Piglets received 0.2 mg meloxicam (Novem 5) intramuscularly into the neck.
4	Castration with anesthesia and analgesic (L+M)	Piglets received anesthesia and analgesic as described at treatment 2 and 3.
5	Castration without anesthesia or analgesic (CAST)	Piglets were castrated without anesthesia or analgesic.
6	Sham castration (SHAM)	Piglets were handled in the same way as the treatments with anesthesia and or analgesic, except for the injections, restraining and castration itself.

The piglets that received anesthesia, analgesic or both were castrated after a waiting period of 15 minutes. During this waiting period these piglets were placed back in the confinement with the other male piglets. During castration piglets were restrained using a castration clamp (Schippers Bladel) and the skin around the testicles was disinfected with alcohol. With a scalpel a horizontal incision in the scrotum was made, the testicles pushed out and the spermatic cords cut with the scalpel. After this castration, the piglets were weighed, spray marked and then placed back into the farrowing crate. A veterinarian administered the anesthesia and analgesic, castration was done by a trained technician. Treatment of the twelve litters took from 10.00 to 11.30 h. Between 12.00 and 12.30 h the behavioural observations started.

3.2.3 Observations

Behavioural observations started on Monday (D1) and the last observation was on Friday morning (D5). Using scan sampling, behaviour of each experimental piglet was recorded every 12 min during six periods: D1-PM (12:00–15:36 h), D2-AM (8:00–11:36 h), D2-PM (13:00–16:36 h), D3-AM (8:00–11:36 h), D3-PM (13:00–16:36 h), D4-AM (8:00–11:36 h), D4-PM (13:00–16:36 h), D5-AM (8:00–11:36 h). Each observation period of 3 h and 36 m included a 24 m break midway, resulting in a total of 16 scans per experimental piglet per period. Behaviours are described in Table 3.2, a modified ethogram after Hay et al. (2003). Observations were performed using a Psion Workabout (Noldus, Wageningen, The Netherlands). After each observation the data was uploaded into the “Observer” software (Noldus, Wageningen, The Netherlands). All observations were realized by a single observer from the feeder passage. The identification marks on the piglets did not correspond with the treatments and the observer did not know which piglet had received which treatment.

Table 3.2 Description of ethogram

"Non-specific" behaviours	
Suckling	Teat in the mouth. Vigorous and rhythmic suckling movements.
Looking for teat	Attempts to find a teat by walking and pushing other piglets while most of the others are suckling.
Nosing	The snout is close to or in contact with a substrate or a pen-mate. Snout movements may be observed.
Belly-nosing	Repeated up and down massage movements with the snout onto another piglet or the sow (except the udder).
Manipulating	Nibbling, chewing or licking at littermates, floor, pen walls or substrates.
Playing	Head shaking, springing (sudden jumping or leaping), running with vertical and horizontal bouncy movements. Can involve partners (gentle nudging or pushing, mounting, chasing).
Aggression	Forceful interactions, pushing with the head or biting littermates in a violent manner.
Walking	Slowly moving forward with one leg at a time.
Awake inactive	No special activity but awake. Lying, sitting or standing.
Sleeping	Lying down, eyes closed.
Pain related behaviours	
Prostrated	Awake, sitting or standing motionless, with the head down, lower than shoulder level.
Huddled up	Lying with at least three legs tucked under the body.
Stiffness	Lying with extended and tensed legs.
Trembling	Shivering as with cold. The animal may be lying, sitting or standing.
Spasms	Quick and involuntary contractions of the muscles under the skin, of a leg.
Scratching	Scratching the rump by rubbing it against the floor or the pen walls.
Tail wagging	Tail's movements from side to side or up and down.
None	No pain related behaviour visible.
Social cohesion	
Isolated	Spatially isolated from other piglets, alone or with one pen-mate at the most. A distance of at least 40 cm (about the width of two piglets) separates the animal fro the closest group of littermates.

At each scan Non-specific behaviour, Pain related behaviour and Social cohesion was scored for each treated piglet. In some cases the piglet was not visible for the observer (e.g. when some piglets laid on top of each other) and observation was scored as Missing Value. Within the pain related behaviour, tail wagging was scored separately, because this behaviour appeared frequently in combination with other pain related behaviours. With tail wagging, each piglet was scored for four behaviours within every scan. After the final observation, frequencies (percentage of observations) of the different behavioural elements were calculated and used for further statistical analyses.

3.2.4 Growth performance and infection score

The male piglets were weighed within 24 hours after birth, on day 0 of castration, on day 4 and at weaning. Furthermore, on day 4 and day of weaning the scrotum area around the incision of the castrated male piglets was scored for infection signs using three parameters (table 3.3).

Table 3.3 Description parameters for scoring castration wound

	Open wound	Wound fluid	Inflammation
1	Closed	None	None
2	Open	Little fluid	Red colouring around the wound edges
3		Pus leaking from wound	Red colouring and swollen parts of scrotum

Individual daily weight gain of the piglets was calculated for three periods: 1) before treatment, 2) during observation period and 3) until weaning (from observation period onwards). Together with the birth weight, calculated individual daily weight gain per piglet for each period was used for further statistical analyses.

3.2.5 Statistical procedure

Statistical analysis was performed by fitting linear mixed models to the data using the method of residual maximum likelihood (REML) of the statistical program Genstat. To stabilize the variance of the behavioral data obtained with scan sampling arcsine-square root transformation was applied prior to analysis
To the behavioral data of all observation periods the following linear mixed model was fitted:

$$y_{ijkl} = m + r_i + t_k + p_l + rt_{ik} + rp_{il} + tp_{kl} + rl_{ij} + a_{ijk} + \varepsilon_{ijkl} \qquad (1)$$

Where y_{ijkl} is arcsine-square root transformed behavioural incidence, the fixed model terms are : m the overall constant; r_i effect of replicate i ; t_k effect of treatment k; p_l effect of period l; rt_{ik}, rp_{il}, tp_{kl} corresponding interactions. The remaining model terms rl_{ij} effect of litter j within replicate i and a_{ijk} effect of animal with treatment k in litter j of replicate i are assumed random to describe the covariance structure in the repeated measurement data . ε_{ijkl} is the random error

To the behavioral data of a separate observational period the following linear mixed model was fitted:

$$y_{ijk} = m + r_i + t_k + rt_{ik} + rl_{ij} + \varepsilon_{ijk} \qquad (2)$$

Where y_{ijk} is arcsine-square root transformed behavioural incidence, the fixed model terms are : m the overall constant; r_i effect of replicate i ; t_k effect of treatment k; rt_{ik} corresponding interaction. rl_{ij} effect of litter j within replicate is assumed random to describe the covariance structure in the repeated measurement data . ε_{ijk} is the random error

Daily weight gain per period was analyzed using mixed model (2).

Fixed model effects are tested using the corresponding Wald tests. For significant treatment and period x treatment interaction, differences between pairwise treatment means were tested using t-tests.

3.3 Results

From three piglets no observations were obtained, in two litters two piglets died in the day's prior to treatment and only one spare male piglet per litter was available (both treatment NONE), and one piglet died during the observation week (treatment CAST).

3.3.1 Behavioural observations

Table 3.4 shows the mean occurrence of non-specific behaviours, pain related behaviours and social cohesion during the total observation period.

Table 3.4 Mean occurrence (%) and SEM of non-specific behaviours, pain related behaviours and social cohesion during the total observation period

	NONE	SHAM	L+M	LIDO	MELO	CAST	*P-value*	
							T[a]	*T x P*[b]
"Non-specific" behaviours								
Active	19.0 ± 3.6	19.7 ± 3.3	20.2 ± 3.4	18.5 ± 3.5	22.2 ± 3.6	15.8 ± 3.8	0.46	0.86
Suckling	8.1 ± 1.7	7.8 ± 1.8	7.9 ± 1.8	7.7 ± 1.8	7.6 ± 1.7	7.1 ± 1.7	0.91	1.00
Looking for teat	11.2 ± 2.5	10.2 ± 2.2	10.4 ± 2.3	10.7 ± 2.4	12.1 ± 2.4	10.5 ± 2.5	0.40	0.98
Nosing	1.2 ± 0.9	1.0 ± 0.7	0.9 ± 0.7	1.4 ± 0.9	1.3 ± 0.8	1.5 ± 0.9	0.24	0.44
Belly-nosing	0.1 ± 0.2	0.2 ± 0.3	0.1 ± 0.3	0.2 ± 0.3	0.2 ± 0.3	0.1 ± 0.2	0.87	0.60
Manipulating	4.4 ± 1.5	4.8 ± 1.6	4.7 ± 1.6	4.6 ± 1.6	4.2 ± 1.7	4.6 ± 1.8	0.83	0.59
Playing	0.5 ± 0.5	0.7 ± 0.6	0.5 ± 0.6	0.6 ± 0.6	0.2 ± 0.4	0.5 ± 0.6	0.15	0.25
Aggression	0.4 ± 0.4	0.2 ± 0.3	0.2 ± 0.3	0.3 ± 0.4	0.4 ± 0.5	0.1 ± 0.2	0.26	0.79
Walking	4.3 ± 1.4	3.5 ± 1.3	3.4 ± 1.3	4.9 ± 1.6	4.4 ± 1.6	4.2 ± 1.5	0.19	0.11
Inactive	69.7 ± 3.6	71.4 ± 3.3	71.7 ± 3.4	69.4 ± 3.5	69.6 ± 3.6	67.6 ± 4.5	0.51	0.91
Awake inactive	11.9 ± 3.8	11.9 ± 3.8	12.4 ± 3.8	12.7 ± 4.0	12.1 ± 3.9	12.1 ± 4.4	0.99	0.04
Sleeping	57.8 ± 2.4	59.5 ± 2.3	59.3 ± 2.5	56.7 ± 2.6	57.5 ± 2.3	55.6 ± 2.5	0.16	0.99
Pain related behaviours (PRB)								
Total PRB	16.1 ± 1.4	16.5 ± 1.5	17.8 ± 1.8	18.6 ± 1.7	16.4 ± 1.6	18.0 ± 1.9	0.21	0.52
Prostrated	0.4 ± 0.5	0.3 ± 0.4	0.6 ± 0.5	0.2 ± 0.3	0.4 ± 0.4	0.5 ± 0.5	0.48	0.50
Huddled up	12.3 ± 2.9	12.3 ± 2.9	12.4 ± 2.6	13.3 ± 3.0	11.7 ± 2.6	13.1 ± 2.9	0.82	0.75
Stiffness	1.8 ± 1.0	2.1 ± 1.1	2.3 ± 1.1	2.5 ± 1.1	2.5 ± 1.2	2.8 ± 1.4	0.42	0.78
Trembling	0.0 ± 0.0	0.1 ± 0.2	0.0 ± 0.0	0.1 ± 0.2	0.0 ± 0.1	0.0 ± 0.0	0.31	0.31
Spasms	1.5 ± 0.9	1.6 ± 0.9	2.1 ± 1.0	2.1 ± 1.2	1.6 ± 0.9	1.4 ± 1.1	0.29	0.67
Scratching	0.1 ± 0.2	0.2 ± 0.3	0.5 ± 0.5	0.4 ± 0.5	0.3 ± 0.4	0.2 ± 0.3	0.23	0.68
None PRB	83.5 ± 3.1	83.2 ± 3.3	81.6 ± 3.3	80.8 ± 3.4	83.3 ± 3.3	77.9 ± 4.6	0.09	0.52
Tail wagging	3.0 ± 1.3	3.4 ± 1.4	4.6 ± 1.7	8.2 ± 2.3	4.1 ± 1.5	3.7 ± 1.6	<0.001	0.13
Social cohesion								
Isolated	2.9 ± 1.5	3.0 ± 1.6	2.6 ± 1.6	2.7 ± 1.4	2.5 ± 1.4	1.7 ± 1.2	0.47	0.22

[a] Treatment effect
[b] Treatment × period interaction

In some cases the Non Specific Behaviour (NSB) or Pain Related Behaviour (PRB) were not visible (e.g. when piglets lay on top of each other), which resulted in a 'missing' score. This represents the difference between 100% minus Active and Inactive for Non Specific Behaviour and 100% minus total PRB and None PRB for pain related behaviours.
For all non specific behaviours there was an effect of period and, except for Walking, also an replica*period interaction. For Walking and Manipulating, a replica effect, for Inactive awake a period*treatment interaction and for Sleeping a replica*treatment was found.
For PRB, a significant treatment effect was found for Tail wagging, LIDO piglets showed more tail wagging compared to the rest. For None PRB, there was a tendency of an treatment effect, CAST and LIDO piglets showed more pain related behaviour compared to SHAM piglets. Furthermore, except for Spasm, all pain related behaviours and Isolated showed a period effect and replica*period interaction. For the behavioural element Spasms only a period effect was found and Huddled up, Stiffness and None PRB showed an effect of replica.

3.3.2 Non specific behaviour per period

The piglets spent less than one percent of the observation time belly-nosing, playing and aggressive encounters. These behaviours could not be analyzed per period. Effects of non specific behaviour per observation period are in table 3.5.

Table 3.5 Estimated P-values for treatment effects of non specific behaviour per observation period

	D1-PM	**D2-AM**	**D2-PM**	**D3-AM**	**D3-PM**	**D4-AM**	**D4-PM**	**D5-AM**
Inactive	0.23	0.73	0.82	0.82	0.75	0.07[#]	0.35[a]	0.06[#]
Sleeping	0.50	0.10[a]	0.99	0.06[#]	0.40	0.48	0.33	0.45[a]
Awake inactive	0.26	0.19[a]	0.88	0.27	0.24	0.05[*]	0.34	0.21
Suckling	0.37	0.42	0.94	0.89	0.98	0.19	0.29	0.85
Walking	0.87	0.63	0.89	0.02[*]	0.11	0.07[#]	0.04[*]	0.37
Searching teat	0.46	0.46	0.92	0.49	0.92	0.60	0.30	0.38
Nosing	0.07[#]	0.07[#]	0.46	0.22[a]	0.69	0.84	0.47	0.54
Manipulating	0.82	0.76	0.45	0.05[*]	0.34	0.53[a]	0.94	0.77

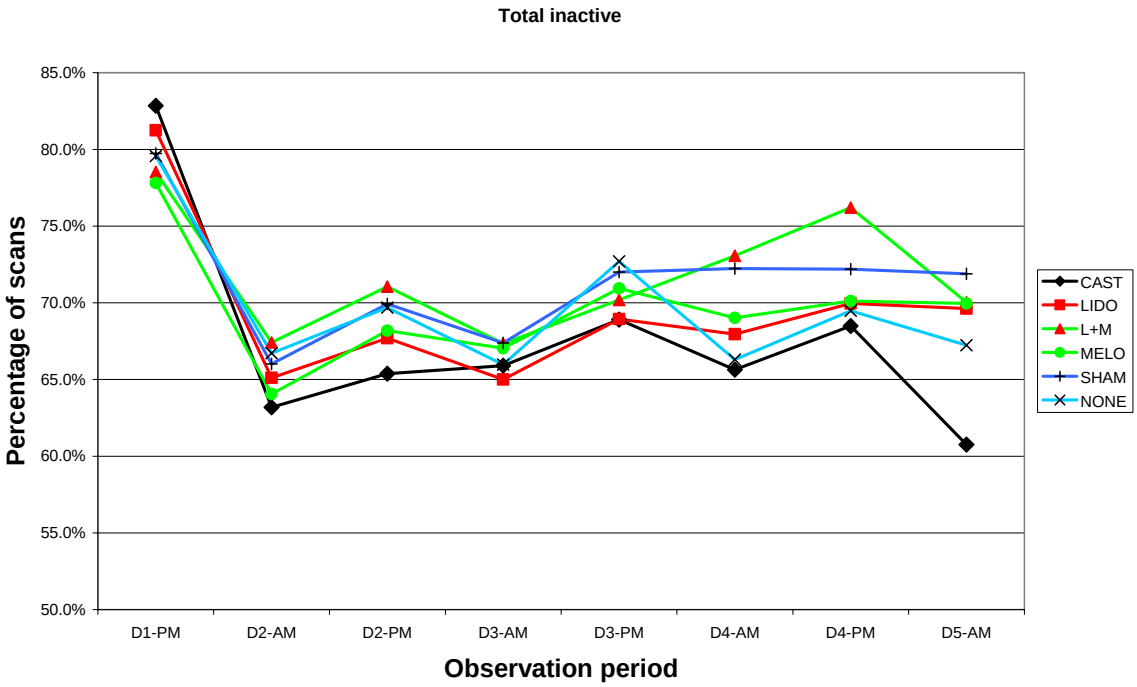
[#] $P<0.1$ and [*] $P<0.05$
[a] Significant replica*treatment interaction

Effects for Inactive were comparable with effects of Active, therefore only effects of Inactive are given in table 3.5.

Total inactive

In figure 3.1 the mean percentage of inactive piglets is given per treatment for all eight observation periods.

Figure 3.1 Percentage of inactive piglets per treatment group per observation period and the minimum and maximum standard error of means (SEM). Different letters per row within observation period indicate significant (P<0.05) differences between treatment groups



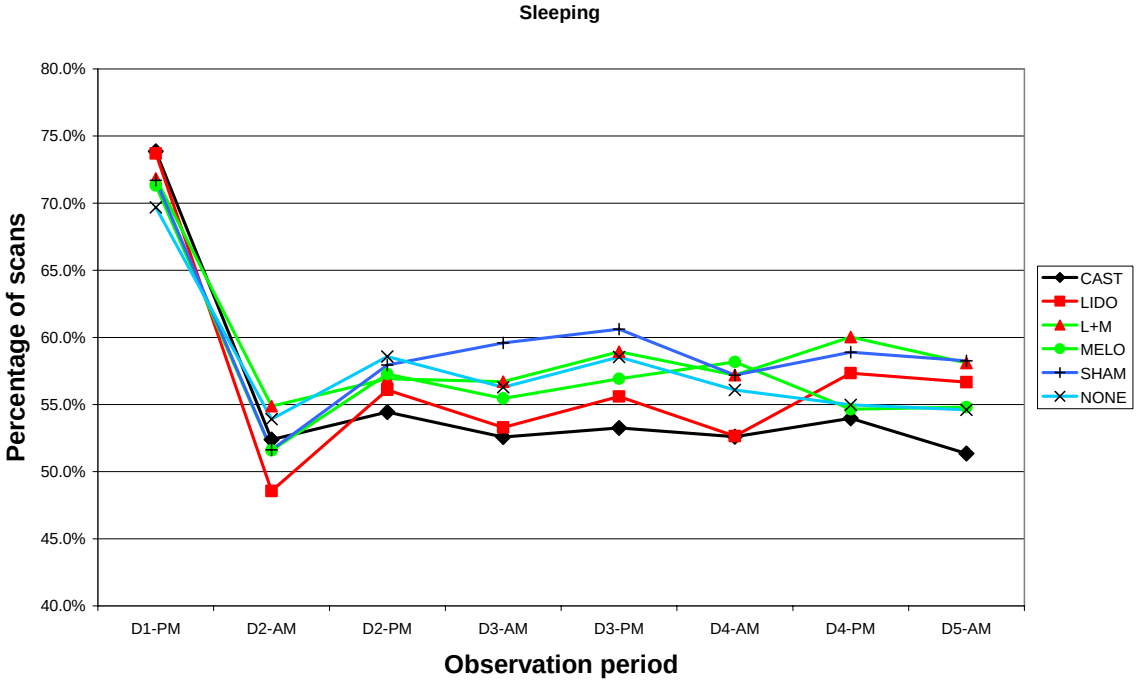
	D1-PM	D2-AM	D2-PM	D3-AM	D3-PM	D4-AM	D4-PM	D5-AM
CAST	82.8	63.2	65.4	65.9	68.9	65.6^{abc}	68.5	60.8^{a}
LIDO	81.3	65.1	67.7	65.0	68.9	68.0^{ab}	70.0	69.6^{b}
L+M	78.5	67.4	71.1	67.3	70.2	73.1^{c}	76.2	70.0^{b}
MELO	77.8	64.1	68.2	67.0	70.9	69.0^{abc}	70.1	70.0^{b}
SHAM	79.7	66.0	69.9	67.4	72.0	72.2^{bc}	72.2	71.9^{b}
NONE	79.6	66.7	69.7	66.0	72.7	66.3^{a}	69.5	67.2^{ab}
SEM_{min}	2.5	2.9	3.2	2.8	2.8	3.0	2.9	3.3
SEM_{max}	3.3	4.5	4.8	4.7	4.2	4.5	4.4	4.7

Piglets of all treatments were between 65 and 75% of the observed time inactive, except on D1 PM were they were inactive around 80%. There was little difference in the amount of inactivity between the treatments. On D4-AM a tendency was found that piglets of the L+M treatment were more inactive (i.e. were less active) compared to LIDO and NONE. SHAM piglets were also more active compared to NONE. On D5-AM CAST piglets tended to be more active compared to the other treatments except for NONE piglets.

Sleeping

In figure 3.2, the mean percentage of sleeping piglets is given per treatment for all the eight observation periods.

Figure 3.2 Percentage of sleeping piglets per treatment group per observation period and the minimum and maximum standard error of means (SEM). Different letters per row within observation period indicate significant (P<0.05) differences between treatment groups



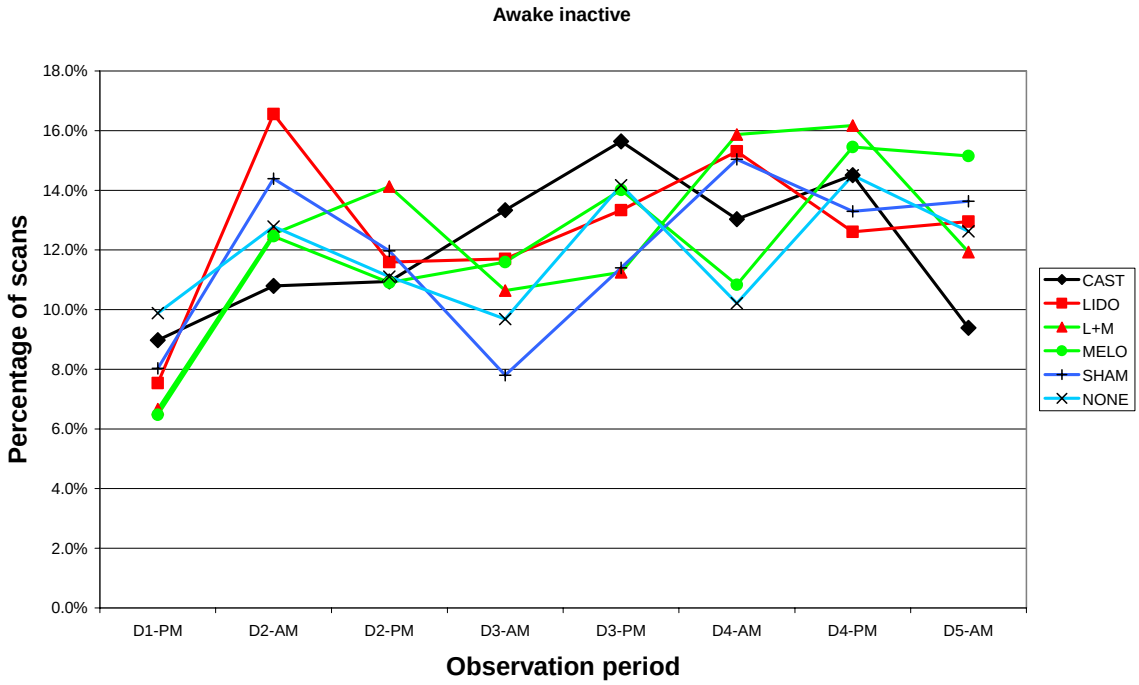
	D1-PM	D2-AM	D2-PM	D3-AM	D3-PM	D4-AM	D4-PM	D5-AM
CAST	73.9	52.4	54.4	52.6[a]	53.3	52.6	54.0	51.4
LIDO	73.7	48.6	56.1	53.3[a]	55.6	52.7	57.3	56.7
L+M	71.9	54.9	56.9	56.7[ab]	58.9	57.2	60.0	58.1
MELO	71.3	51.6	57.3	55.5[a]	56.9	58.2	54.7	54.8
SHAM	71.7	51.6	58.0	59.6[b]	60.6	57.2	58.9	58.3
NONE	69.7	53.9	58.6	56.3[ab]	58.5	56.1	55.0	54.6
SEM_{min}	2.7	3.1	3.5	3.2	2.8	3.2	3.4	3.7
SEM_{max}	3.2	4.2	4.3	4.5	4.1	4.7	4.4	4.7

The mean percentage piglets sleeping per observation period has a similar pattern as total inactive. Differences between treatments are small and only on D3-AM a tendency was found for SHAM treated piglets to sleep more compared to CAST, LIDO and MELO piglets.

Awake inactive

In figure 3.3, the mean percentage of piglets awake inactive is given per treatment for all the eight observation periods.

Figure 3.3 Percentage of awake but inactive piglets per treatment group per observation period and the minimum and maximum standard error of means (SEM). Different letters per row within observation period indicate significant ($P<0.05$) differences between treatment groups



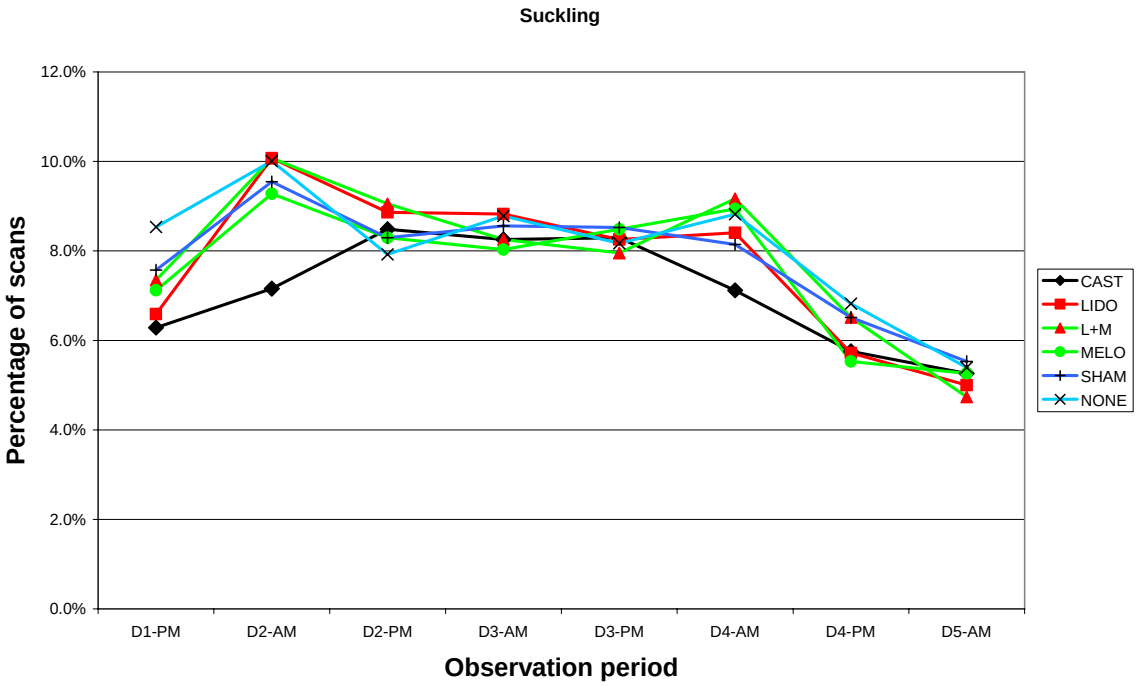
	D1-PM	D2-AM	D2-PM	D3-AM	D3-PM	D4-AM	D4-PM	D5-AM
CAST	9.9	12.8	11.1	9.7	14.2	10.2^{b}	14.5	12.6
LIDO	8.5	12.8	9.6	11.8	14.9	14.5^{b}	13.3	14.5
L+M	7.5	16.6	11.6	11.7	13.3	15.3^{b}	12.6	13.0
MELO	9.0	10.8	10.9	13.3	15.6	13.0^{ab}	14.5	9.4
SHAM	6.5	12.5	10.9	11.6	14.0	10.8^{b}	15.5	15.2
NONE	6.7	12.5	14.1	10.6	11.3	15.9^{a}	16.2	11.9
SEM_{min}	1.5	2.0	2.0	1.7	2.3	1.9	2.1	2.4
SEM_{max}	2.7	3.1	3.0	2.8	2.7	2.8	2.8	3.0

Only on D4-AM there was a difference in the percentage piglets awake and inactive. During that observation period CAST, LIDO, L+M and SHAM piglets were more awake and inactive compared to NONE piglets.

Suckling

In figure 3.4, the mean percentage suckling piglets are given per treatment for all the eight observation periods.

Figure 3.4 Percentage of suckling piglets per treatment group per observation period and the minimum and maximum standard error of means (SEM). Different letters per row within observation period indicate significant (P<0.05) differences between treatment groups



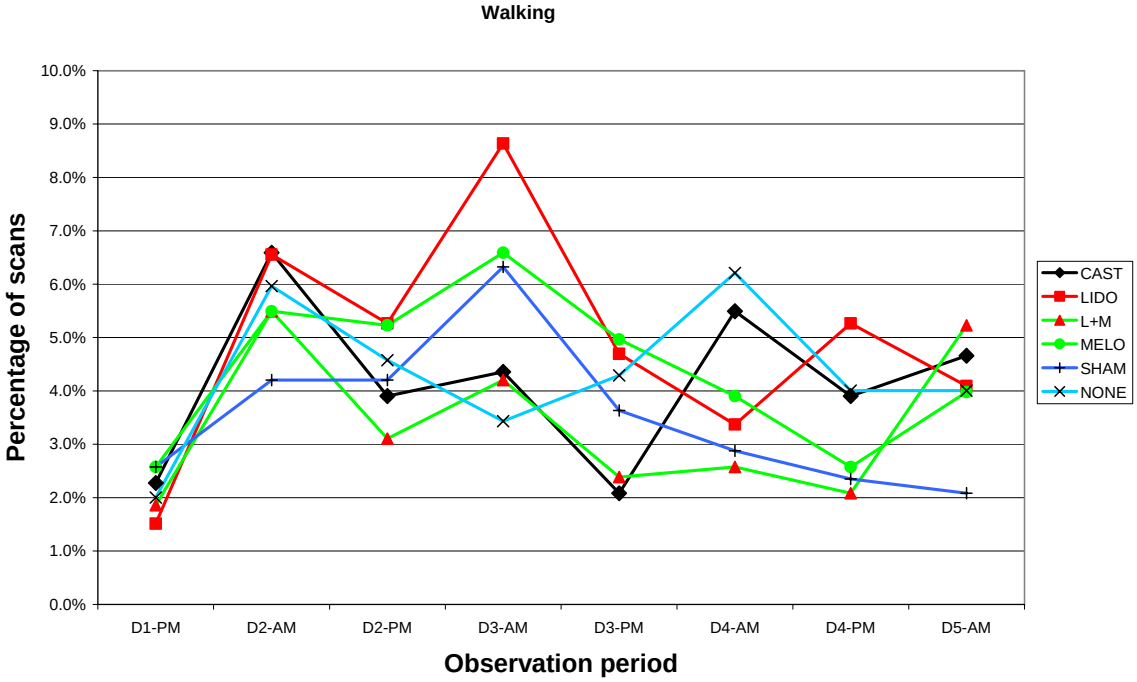
	D1-PM	D2-AM	D2-PM	D3-AM	D3-PM	D4-AM	D4-PM	D5-AM
CAST	6.3	7.2	8.5	8.3	8.3	7.1	5.8	5.3
LIDO	6.6	10.1	8.9	8.8	8.3	8.4	5.7	5.0
L+M	7.3	10.1	9.1	8.3	8.0	9.2	6.5	4.7
MELO	7.1	9.3	8.3	8.0	8.5	8.9	5.5	5.3
SHAM	7.6	9.5	8.3	8.6	8.5	8.1	6.5	5.5
NONE	8.5	10.0	7.9	8.8	8.2	8.8	6.8	5.4
SEM_{min}	1.7	1.7	1.8	1.5	1.6	1.6	1.4	1.4
SEM_{max}	1.8	2.2	2.2	1.9	1.9	1.7	1.6	1.5

Piglets spent on average around 8% of the observed time suckling and this percentage decreased over time, except for the first observation period. No differences in suckling behaviour between treatments was found during any of the observation periods.

Walking

In figure 3.5, the mean percentage piglets walking are given per treatment for all the eight observation periods.

Figure 3.5 Percentage of walking piglets per treatment group per observation period and the minimum and maximum standard error of means (SEM). Different letters per row within observation period indicate significant (P<0.05) differences between treatment groups



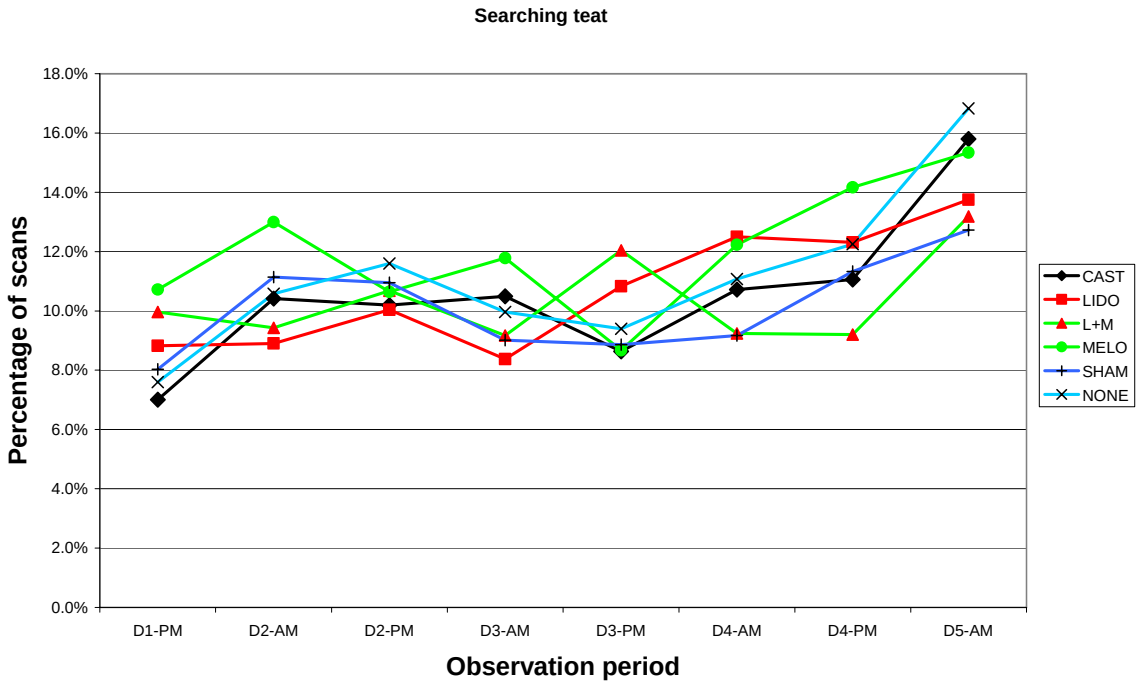
	D1-PM	D2-AM	D2-PM	D3-AM	D3-PM	D4-AM	D4-PM	D5-AM
CAST	2.3	6.6	3.9	4.4^{ab}	2.1	5.5^{bc}	3.9^{ab}	4.7
LIDO	1.5	6.6	5.3	8.6^{c}	4.7	3.4^{ab}	5.3^{b}	4.1
L+M	1.9	5.5	3.1	4.2^{ab}	2.4	2.6^{a}	2.1^{a}	5.2
MELO	2.6	5.5	5.2	6.6^{abc}	5.0	3.9^{abc}	2.6^{a}	4.0
SHAM	2.6	4.2	4.2	6.3^{bc}	3.6	2.9^{ab}	2.3^{a}	2.1
NONE	2.0	6.0	4.6	3.4^{a}	4.3	6.2^{c}	4.0^{ab}	4.0
SEM_{min}	0.9	1.3	1.1	1.1	1.0	1.1	1.1	1.0
SEM_{max}	1.4	2.0	1.6	2.2	1.6	1.7	1.5	1.8

Differences between treatments were found on D3-AM and D4-PM and a tendency on D4-AM (see Figure 3.5). LIDO piglets were observed walking more compared to CAST, L+M and NONE on D3-AM and to L+M, MELO and SHAM on D4-PM.

Searching teat

In figure 3.6, the mean percentage piglets searching teat are given per treatment for all the eight observation periods.

Figure 3.6 Percentage of piglets searching for teat per treatment group per observation period and the minimum and maximum standard error of means (SEM). Different letters per row within observation period indicate significant (P<0.05) differences between treatment groups



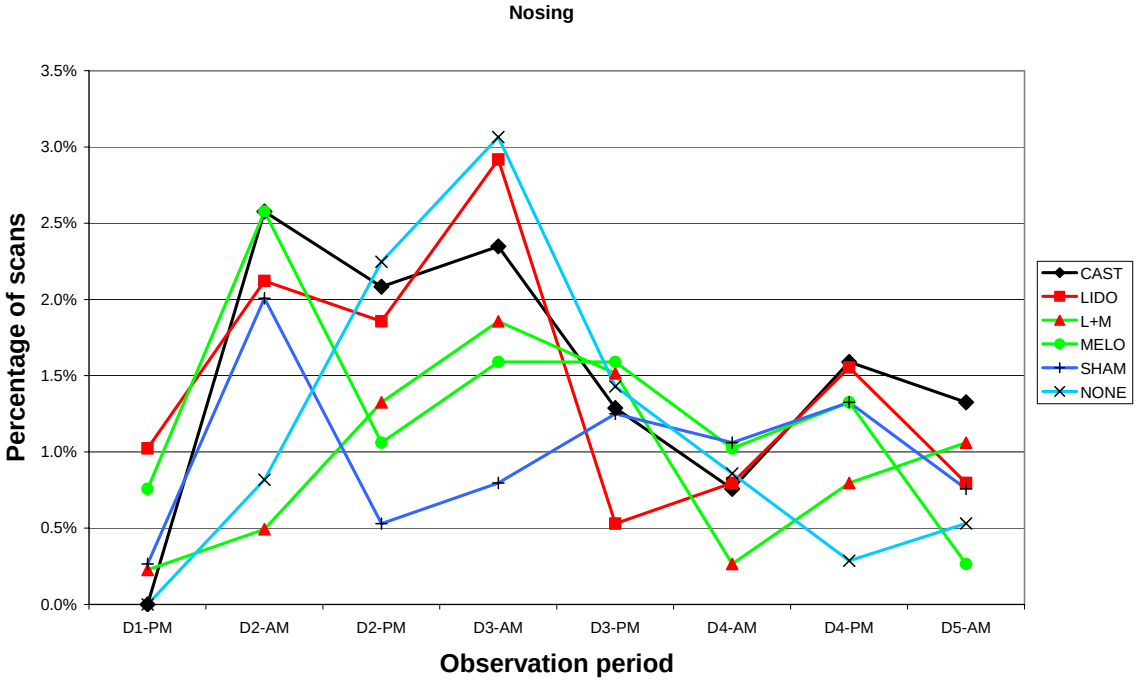
	D1-PM	D2-AM	D2-PM	D3-AM	D3-PM	D4-AM	D4-PM	D5-AM
CAST	7.0	10.4	10.2	10.5	8.6	10.7	11.1	15.8
LIDO	8.8	8.9	10.0	8.4	10.8	12.5	12.3	13.8
L+M	10.0	9.4	10.7	9.2	12.0	9.2	9.2	13.2
MELO	10.7	13.0	10.6	11.8	8.7	12.2	14.2	15.3
SHAM	8.0	11.1	10.9	9.0	8.9	9.2	11.3	12.7
NONE	7.6	10.6	11.6	10.0	9.4	11.1	12.3	16.8
SEM_{min}	1.8	2.1	2.1	1.9	1.7	1.8	2.2	2.1
SEM_{max}	2.4	2.6	2.7	2.4	2.7	2.4	2.9	3.3

No differences in the percentage of time spent searching for teat between the treatment was found during any of the observation periods.

Nosing

In figure 3.7, the mean percentage nosing piglets are given per treatment for all the eight observation periods.

Figure 3.7 Percentage of nosing piglets per treatment group per observation period and the minimum and maximum standard error of means (SEM). Different letters per row within observation period indicate significant (P<0.05) differences between treatment groups



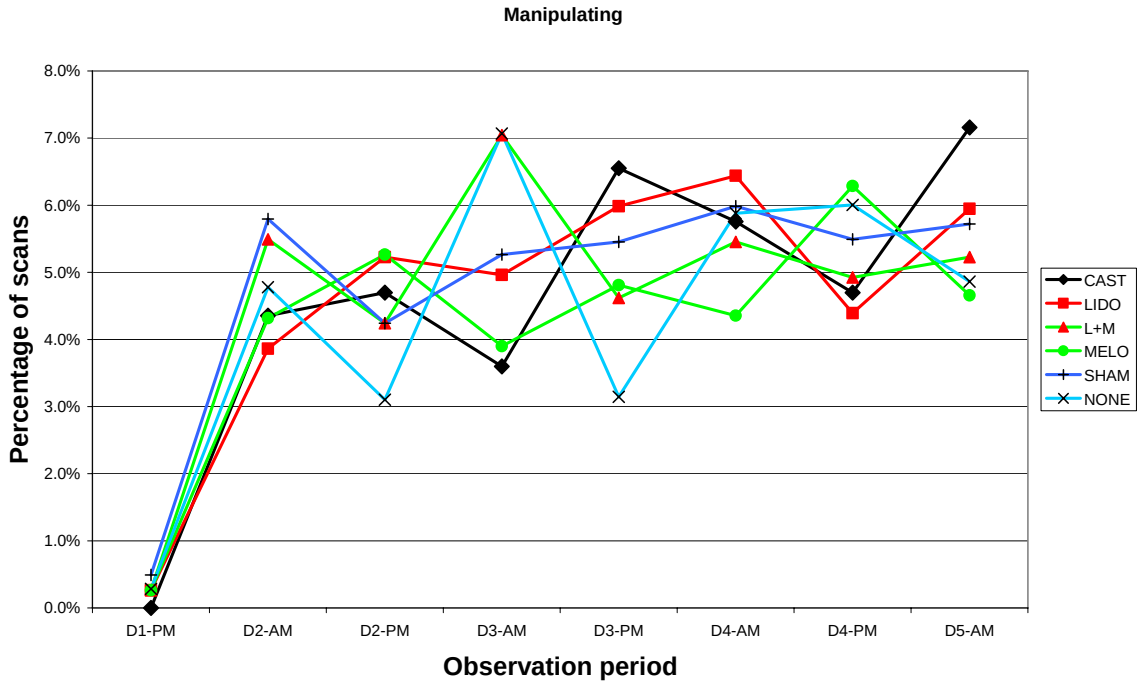
	D1-PM	D2-AM	D2-PM	D3-AM	D3-PM	D4-AM	D4-PM	D5-AM
CAST	0.0^{a}	2.6^{c}	2.1	2.3	1.3	0.8	1.6	1.3
LIDO	1.0^{b}	2.1^{abc}	1.9	2.9	0.5	0.8	1.6	0.8
L+M	0.2^{ab}	0.5^{a}	1.3	1.9	1.5	0.3	0.8	1.1
MELO	0.8^{ab}	2.6^{bc}	1.1	1.6	1.6	1.0	1.3	0.3
SHAM	0.3^{ab}	2.0^{abc}	0.5	0.8	1.3	1.1	1.3	0.8
NONE	0.0^{a}	0.8^{ab}	2.2	3.1	1.4	0.9	0.3	0.5
SEM_{min}	-	0.5	0.5	0.8	0.5	0.4	0.4	0.4
SEM_{max}	0.7	1.2	1.2	1.7	0.9	0.9	1.0	0.8

On D1-PM LIDO piglets tended to spent more time nosing compared to CAST and NONE piglets, while on D2-AM CAST piglets spent more time nosing compared to L+M and NONE piglets.

Manipulating

In figure 3.8, the mean percentage of piglets manipulating surrounding, sow or penmates is given per treatment for all the eight observation periods.

Figure 3.8 Percentage of manipulating piglets per treatment group per observation period and the minimum and maximum standard error of means (SEM). Different letters per row within observation period indicate significant (P<0.05) differences between treatment groups



	D1-PM	D2-AM	D2-PM	D3-AM	D3-PM	D4-AM	D4-PM	D5-AM
CAST	0.0	4.4	4.7	3.6[a]	6.6	5.8	4.7	7.2
LIDO	0.3	3.9	5.2	5.0[ab]	6.0	6.4	4.4	5.9
L+M	0.3	5.5	4.2	7.0[b]	4.6	5.5	4.9	5.2
MELO	0.3	4.3	5.3	3.9[a]	4.8	4.4	6.3	4.7
SHAM	0.5	5.8	4.2	5.3[ab]	5.5	6.0	5.5	5.7
NONE	0.3	4.8	3.1	7.1[b]	3.1	5.9	6.0	4.9
SEM_{min}	-	1.4	1.4	1.4	1.4	1.5	1.3	1.3
SEM_{max}	0.5	1.9	1.6	1.7	2.2	2.0	2.2	2.2

On D1-PM piglets spent very little time manipulating, while the rest of the observation period they spent around 5% manipulating their surroundings. Only on D3-AM their was a difference in manipulating time, where MELO and CAST piglets spent less time manipulating compared to L+M and NONE.

3.3.3 Pain related behaviours and isolation per period

From all Pain Related Behaviours the frequencies of Prostrated, Trembling and Scratching were recorded less than 0.5 percent of the time. These observations could not be analyzed per period, however, they are still included in the total percentage pain related behaviour. Effects of Pain Related Behaviour and Isolated per observation period are presented in Table 3.6. Effects on Total Pain Related Behaviours were inversely comparable to effects on None pain related behaviours, therefore only effects on None pain related behaviours are given in table 3.6.

Table 3.6 Estimated P-values for treatment effects of pain related behaviour and isolation per observation period

	D1-PM	**D2-AM**	**D2-PM**	**D3-AM**	**D3-PM**	**D4-AM**	**D4-PM**	**D5-AM**
Huddled up	0.07#[a]	0.57	0.29	0.92 [a]	0.32	0.96	0.84	0.66
Stiffness	0.90	0.49	0.70	0.34	0.86	0.11	0.29	0.41
Spasms	0.87	0.10	0.22	0.45	0.37	0.88	0.36	0.76
None PRB	0.03*	0.12	0.80	0.85 [a]	0.32	0.42	0.17	0.50
Tail wagging	<0.001***	<0.001***	<0.001***	<0.001***	0.34	0.58	0.08#	0.04*
Isolated	0.71	0.47	0.51	0.65	0.02*	0.26 [a]	0.19	0.41

# $P<0.1$, * $P<0.05$ and *** $P<0.001$

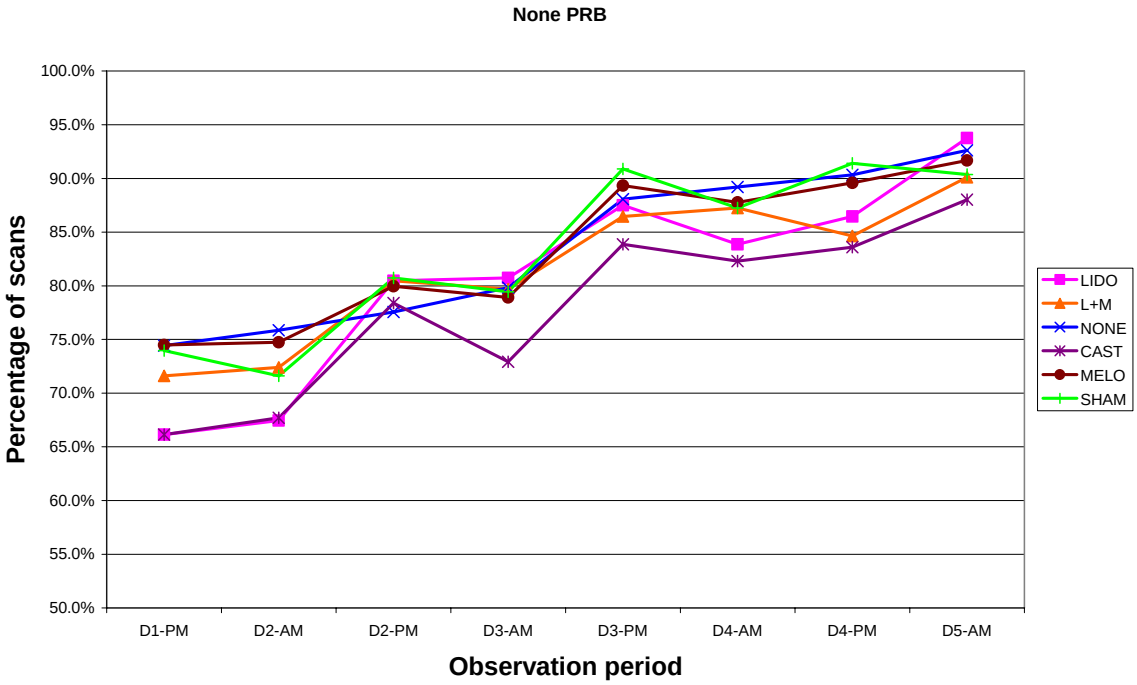
[a] Significant replica*treatment interaction

Per behaviour, mean occurrences (including SEM) per treatment per period are given below.

None pain related behaviour

In figure 3.9, the mean percentage of piglets showing no pain related behaviour is given per treatment for all the eight observation periods.

Figure 3.9 Percentage of piglets showing no pain related behaviour per treatment group per observation period and the minimum and maximum standard error of means (SEM). Different letters per row within observation period indicate significant (P<0.05) differences between treatment groups



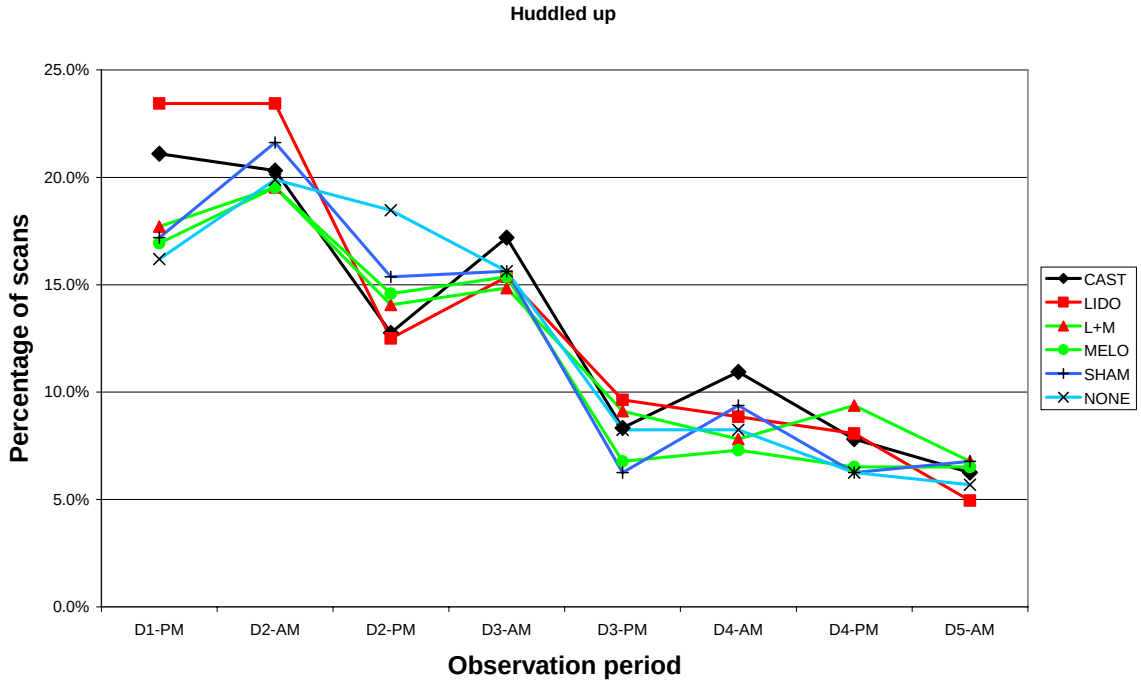
	D1-PM	D2-AM	D2-PM	D3-AM	D3-PM	D4-AM	D4-PM	D5-AM
CAST	66.1[a]	67.7[a]	78.4	72.9	83.9	82.3	83.6	88.0
LIDO	66.1[a]	67.4[ab]	80.5	80.7	87.5	83.9	86.5	93.8
L+M	71.6[ab]	72.4[ab]	80.5	79.7	86.5	87.2	84.6	90.1
MELO	74.5[b]	74.7[b]	79.9	78.9	89.3	87.8	89.6	91.7
SHAM	74.0[b]	71.6[ab]	80.7	79.4	90.9	87.2	91.4	90.4
NONE	74.4[b]	75.9[b]	77.6	79.8	88.1	89.2	90.3	92.6
SEM_{min}	3.1	3.4	2.6	3.1	2.2	2.4	2.0	2.0
SEM_{max}	3.6	4.7	4.3	4.7	4.1	4.7	4.5	4.4

The percentage of observations with no pain related behaviour increases over the observation period for all treatments. On D1-PM LIDO and CAST piglets showed more pain related behaviour compared to MELO, SHAM and NONE piglets. On D2-AM CAST piglets showed more pain related behaviour compared to MELO and NONE piglets.

Huddled up

In figure 3.10, the mean percentage of huddled up piglets is given per treatment for all the eight observation periods.

Figure 3.10 Percentage of piglets huddled up per treatment group per observation period and the minimum and maximum standard error of means (SEM). Different letters per row within observation period indicate significant (P<0.05) differences between treatment groups



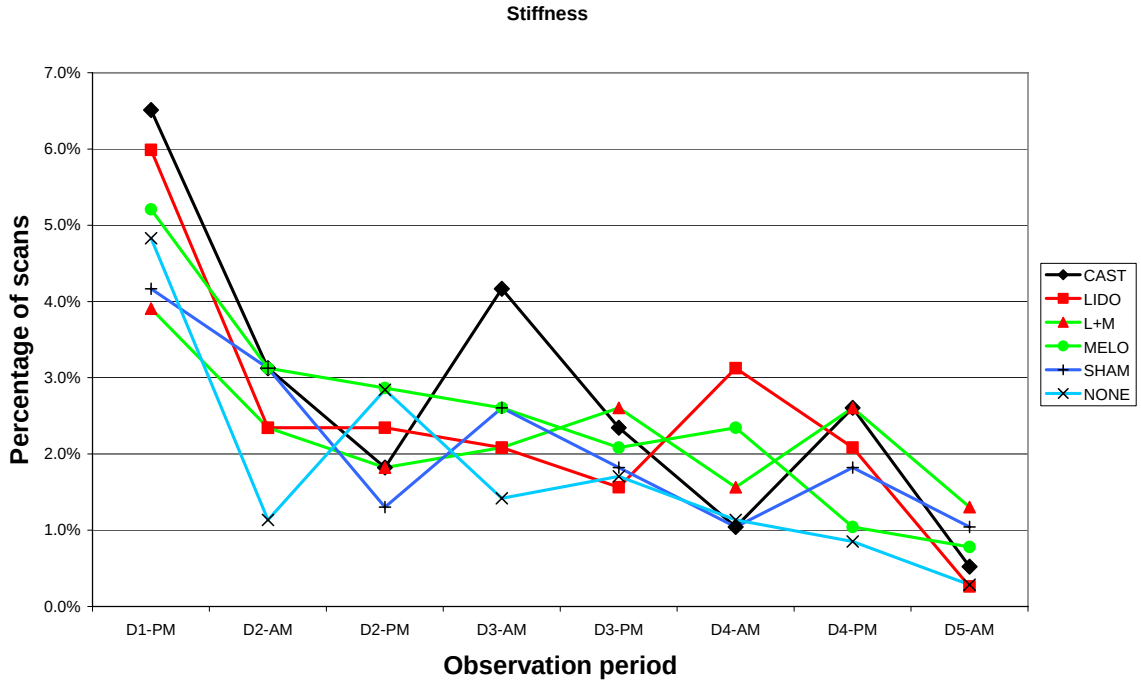
	D1-PM	D2-AM	D2-PM	D3-AM	D3-PM	D4-AM	D4-PM	D5-AM
CAST	21.1^{ab}	20.3	12.8	17.2	8.3	10.9	7.8	6.3
LIDO	23.4^{b}	23.4	12.5	15.4	9.6	8.9	8.1	4.9
L+M	17.7^{a}	19.5	14.1	14.8	9.1	7.8	9.4	6.8
MELO	16.9^{a}	19.5	14.6	15.4	6.8	7.3	6.5	6.5
SHAM	17.2^{ab}	21.6	15.4	15.6	6.3	9.4	6.3	6.8
NONE	16.2^{a}	19.9	18.5	15.6	8.2	8.2	6.3	5.7
SEM_{min}	2.8	2.8	2.3	2.6	1.8	1.7	1.6	1.9
SEM_{max}	3.3	3.6	3.2	3.2	2.2	3.0	2.4	2.8

During the observation period, piglets of all treatments spent less observation time in huddling position. On D1-PM LIDO piglets spent more time in a huddled position compared to L+M, MELO and NONE.

Stiffness

In figure 3.11, the mean percentage of piglets with stiffness is given per treatment for all of the eight observation periods.

Figure 3.11 Percentage of piglets with stiffness per treatment group per observation period and the minimum and maximum standard error of means (SEM). Different letters per row within observation period indicate significant (P<0.05) differences between treatment groups



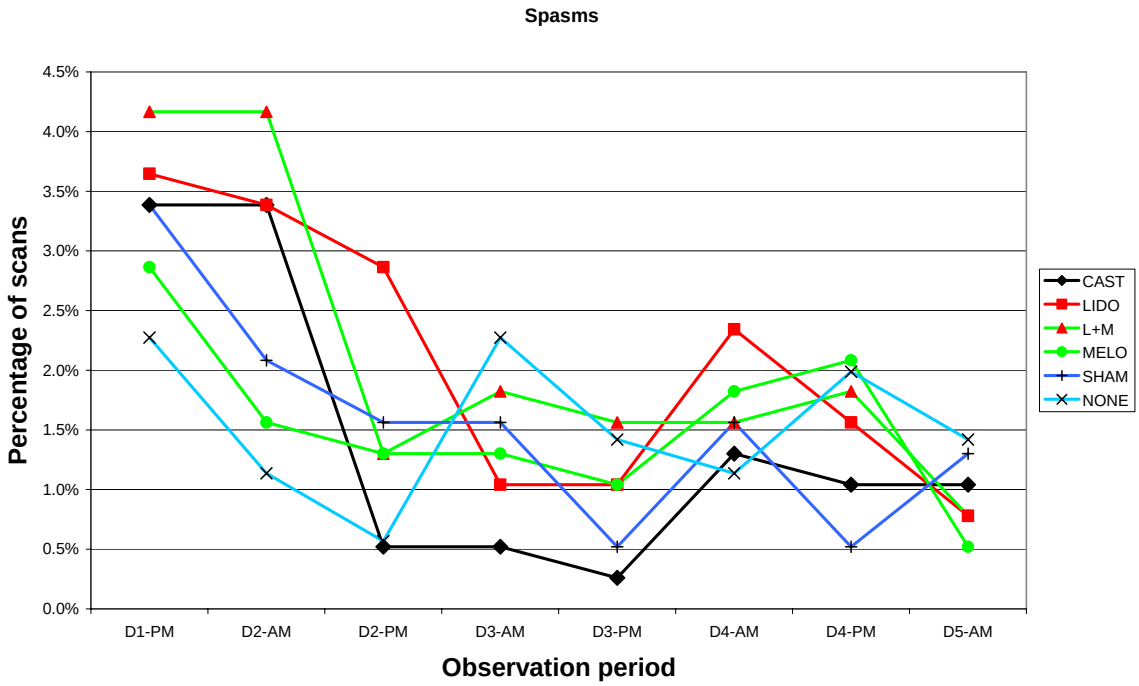
	D1-PM	D2-AM	D2-PM	D3-AM	D3-PM	D4-AM	D4-PM	D5-AM
CAST	6.5	3.1	1.8	4.2	2.3	1.0	2.6	0.5
LIDO	6.0	2.3	2.3	2.1	1.6	3.1	2.1	0.3
L+M	3.9	2.3	1.8	2.1	2.6	1.6	2.6	1.3
MELO	5.2	3.1	2.9	2.6	2.1	2.3	1.0	0.8
SHAM	4.2	3.1	1.3	2.6	1.8	1.0	1.8	1.0
NONE	4.8	1.1	2.8	1.4	1.7	1.1	0.9	0.3
SEM_{min}	1.3	0.7	0.8	0.8	0.9	0.7	0.7	0.4
SEM_{max}	2.5	1.5	1.5	1.6	1.2	1.2	1.2	0.8

The percentage piglets observed in stiff postures (lying with extend or tense legs) was highest on D1-PM for all treatments and decreased over the observation period. No differences in the percentage time spent searching for teat between the treatment was found in any of the observation periods.

Spasms

In figure 3.12, the mean percentage of piglets with spasms is given per treatment for all the eight observation periods.

Figure 3.12 Percentage of piglets with spasms per treatment group per observation period and the minimum and maximum standard error of means (SEM). Different letters per row within observation period indicate significant (P<0.05) differences between treatment groups



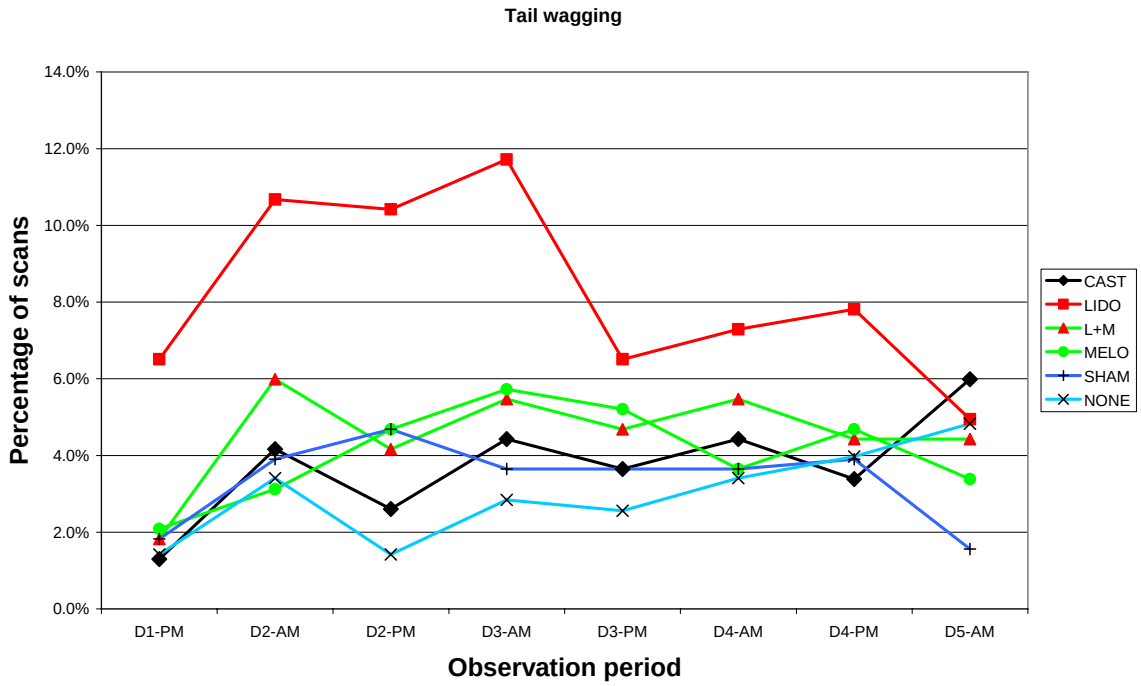
	D1-PM	D2-AM	D2-PM	D3-AM	D3-PM	D4-AM	D4-PM	D5-AM
CAST	3.4	3.4	0.5	0.5	0.3	1.3	1.0	1.0
LIDO	3.6	3.4	2.9	1.0	1.0	2.3	1.6	0.8
L+M	4.2	4.2	1.3	1.8	1.6	1.6	1.8	0.8
MELO	2.9	1.6	1.3	1.3	1.0	1.8	2.1	0.5
SHAM	3.4	2.1	1.6	1.6	0.5	1.6	0.5	1.3
NONE	2.3	1.1	0.6	2.3	1.4	1.1	2.0	1.4
SEM_{min}	1.1	0.9	0.5	0.5	0.4	-	-	-
SEM_{max}	1.7	1.8	1.3	1.1	0.9	0.9	0.6	0.5

Differences between treatments are relatively small and no differences in the percentage of time spent searching for teat between the treatment was found in any of the observation periods.

Tail wagging

In figure 3.13, the mean percentage of tail wagging piglets is given per treatment for all the eight observation periods.

Figure 3.13 Percentage of tail wagging piglets per treatment group per observation period and the minimum and maximum standard error of means (SEM). Different letters per row within observation period indicate significant (P<0.05) differences between treatment groups



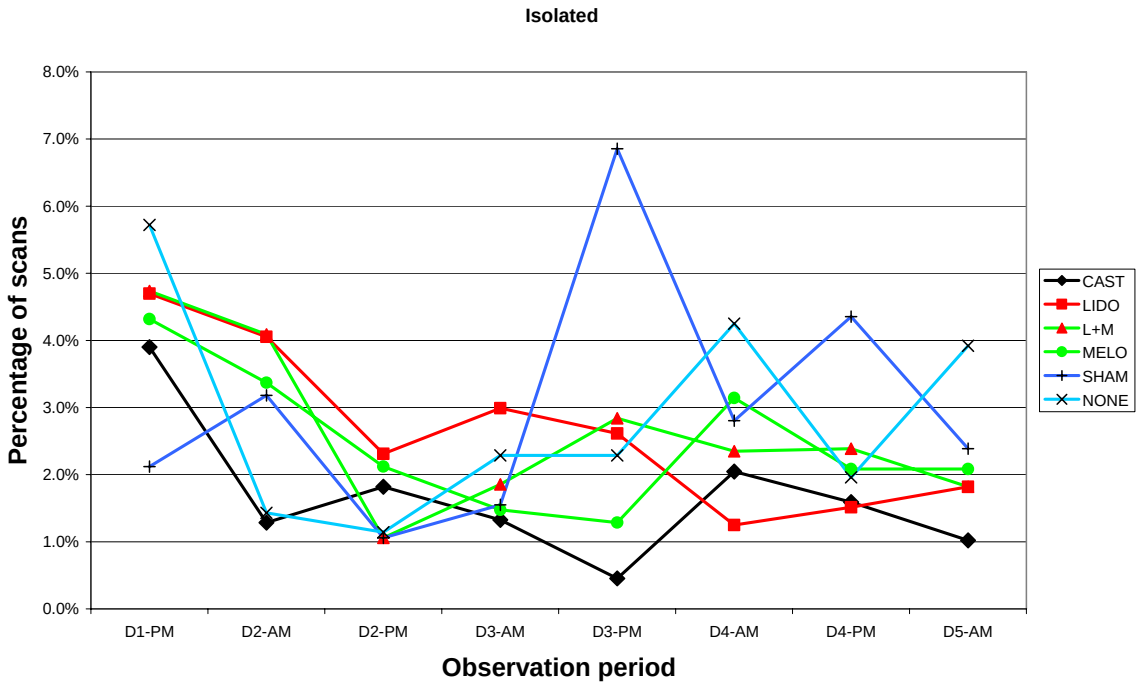
	D1-PM	D2-AM	D2-PM	D3-AM	D3-PM	D4-AM	D4-PM	D5-AM
CAST	1.3^{a}	4.2^{a}	2.6^{ab}	4.4^{a}	3.6	4.4	3.4^{a}	6.0^{b}
LIDO	6.5^{b}	10.7^{b}	10.4^{c}	11.7^{b}	6.5	7.3	7.8^{b}	4.9^{b}
L+M	1.8^{a}	6.0^{a}	4.2^{ab}	5.5^{a}	4.7	5.5	4.4^{a}	4.4^{ab}
MELO	2.1^{a}	3.1^{a}	4.7^{b}	5.7^{a}	5.2	3.6	4.7^{a}	3.4^{ab}
SHAM	1.8^{a}	3.9^{a}	4.7^{ab}	3.6^{a}	3.6	3.6	3.9^{a}	1.6^{a}
NONE	1.4^{a}	3.4^{a}	1.4^{a}	2.8^{a}	2.6	3.4	4.0^{ab}	4.8^{b}
SEM_{min}	0.8	1.1	1.0	1.5	1.0	1.3	1.2	1.0
SEM_{max}	1.8	2.9	2.6	3.0	2.3	2.2	1.8	2.2

Piglets observed tail wagging was lowest during the first observation and relatively constant throughout the rest of the observation period. LIDO piglets were scored tail wagging more often during the first four observation periods compared to the other treatments.

Isolated

In figure 3.14, the mean percentage isolated piglets are given per treatment for all the eight observation periods.

Figure 3.14 Percentage of isolated piglets per treatment group per observation period and the minimum and maximum standard error of means (SEM). Different letters per row within observation period indicate significant (P<0.05) differences between treatment groups



	D1-PM	D2-AM	D2-PM	D3-AM	D3-PM	D4-AM	D4-PM	D5-AM
CAST	3.9	1.3	1.8	1.3	0.5[a]	2.0	1.6	1.0
LIDO	4.7	4.1	2.3	3.0	2.6[ab]	1.3	1.5	1.8
L+M	4.7	4.1	1.1	1.9	2.8[ab]	2.3	2.4	1.8
MELO	4.3	3.4	2.1	1.5	1.3[a]	3.1	2.1	2.1
SHAM	2.1	3.2	1.1	1.6	6.9[b]	2.8	4.4	2.4
NONE	5.7	1.4	1.1	2.3	2.3[a]	4.2	2.0	3.9
SEM_{min}	1.0	0.8	0.7	0.8	0.5	0.8	1.0	0.7
SEM_{max}	2.9	2.1	1.3	1.5	2.7	1.8	1.9	2.0

Only on D3-PM a different in the number of isolated piglets per treatment was found, SHAM piglets were observed more isolated compared to piglets CAST, MELO and NONE piglets.

3.3.4 Growth performance gain and infection scores

Growth performance
Average birth weights and growth for the periods until castration, during the observation period, and for the period following observation until weaning as well as total growth from birth until weaning are shown in table 3.7.

Table 3.7 Growth per treatment for different periods and birth weight of the piglets

	NONE	SHAM	L+M	LIDO	MELO	CAST	P-value
Birth weight (g)	1570 ± 57	1465 ± 54	1590 ± 63	1480 ± 62	1491 ± 52	1400 ± 53	0.08
Growth observation period (g/day)	307 ± 26	246 ± 20	232 ± 14	219 ± 14	216 ± 10	223 ± 17	0.73
Growth after observation until weaning (g/day)	263 ± 10	273 ± 11	259 ± 11	242 ± 11	264 ± 14	252 ± 11	0.50
Total growth until weaning	241 ± 9	247 ± 9	237 ± 9	222 ± 9	242 ± 12	227 ± 9	0.39

Only for birth weight a tendency between treatments was found. CAST piglets had a lower birth weight compared to L+M and NONE piglets

Infection score
Almost all the castration incisions healed well and infection scores in the first replica were all negative (no open wounds, no fluids and no inflammation), in the second replica there were two piglets with open wound and little fluid (both LIDO) at D5. On the day of weaning none of the piglets had an open wound, fluid or inflammation. During the second replica thickening of the scrotum area was found in several piglets. In total 16 piglets, 6 LIDO piglets, 6 L+M piglets and 4 MELO piglets. In some cases a thickening of one side of the scrotum was found, in most cases both sides of the scrotum was thickened.

3.4 Discussion

With this experiment we wanted to test the effect of anesthesia and/or analgesic administering before castration compared to no castration and castration without any anesthesia or analgesic. For this we used an experimental design where all treatments were present in each litter. Although Hay et al. (2003) also used this experimental design in her study, we realized that with all treatments in the same litter there was a chance that piglets would influence each others behaviour. Perhaps not so much for pain related behaviours, but especially for social cohesion behaviour. The alternative however, one treatment per litter, was not chosen because this required many more replicates due to large between litter variation and was therefore not an option.
The time to perform all the treatments, weighing and remarking of the 72 piglets took about two hours total (including preparation time). To work as efficient as possible, all the handling took place in the farrowing room. Although all the sows and piglets were calm during this period, working in the farrowing room might have had some effect on the behaviour pattern of the piglets, as the piglets were more inactive during the D1-PM observations. However, this arousal during administering treatments had little effect on the pain related behaviours, where frequencies of most pain related behaviours were highest during the D1-PM observation.

Non specific behaviour
From the non specific behaviours no significant effects over all periods was found. Hay et al. (2003) found an effect of castration without anesthesia or analgesic on Walking only: castrated piglets walked more compared to non-castrated piglets. They also found on D1-PM that non-castrated piglets performed more suckling-udder massage behaviour compared to castrated piglets. This in contrast with Moya et al. (in press), who found more udder massage behaviour in castrated piglets (without anesthesia or analgesic) compared to handled piglets on D1-PM. In this study no effect of treatment was found on suckling behaviour. From the other non specific behaviour within the eight periods sporadic differences between treatments were recorded and little consistency in treatment effect on non specific behaviour was found. The non specific behaviours have little discrimination strength in measuring pain after castration with or without anesthesia and/or analgesic compared to non castration.

Pain related behaviour
Hay et al. (2003) found a distinct difference in the percentage of time spent in huddling position between castrated piglets and non-castrated piglets. Our results on D1-PM show a similar pattern between CAST piglets and NONE or SHAM piglets. However, LIDO piglets spent even more time huddled up compared to piglets castrated without anesthesia and analgesic. Reason for this higher percentage Huddled up of these piglets remains unclear.
For all pain related behaviours, except for Tail wagging, Hay et al. (2003) found a high occurrence on D1-PM for piglets castrated without anesthesia and analgesic. In our study this was also found for Stiffness en Spasms. Stiffness is together with Huddled up considered as protective, allowing the piglet to avoid stimulation of painful tissue (Hay et al., 2003). Both Spasms and Trembling are contractions of muscles and because this behaviour was scored in a split second, differences between these two behaviours were hard to distinguish. Therefore, the total frequency of Trembling and Spasms are well scored but the proportion of Trembling or Spasms could be under or over estimated.
LIDO piglets showed more Tail wagging compared to the other treatments, especially the first days after castration. An explanation might be that due to the injection with anesthesia, tissue underneath the scrotum is damaged and causes irritation after the anesthesia has worn off. This irritation could induce extra tail wagging according to Kiley-Worthington (1975), who suggested that frustrated pigs show higher frequencies of tail wagging. This could be related to the thickening of the scrotum found mostly in LIDO treated piglets. Although this thickened scrotum was also found in L+M and MELO piglets, no increase in levels of Tail wagging was found. This might be explained by the effect of the pain killer, which reduces the irritation in the scrotum during the first days after treatment.

Compared to our study, the experiment of Hay et al. (2003) showed more distinct pain related behaviour differences between handled piglets (16.1% and 16.9% respectively) and surgical castrated piglets without anesthesia (18.0% and 25.6% respectively). In contrast to the piglets in our study, piglets in the study of Hay et al. (2003) received surgical procedures (tail docking and iron injection) prior to the treatment. Surgical injuries are known to induce hypersensitivity at the injury site, but also in adjacent tissues, called secondary hyperalgesia (Lavand'homme, 2006). Secondary hyperalgesia is considered a consequence of central sensitization and results from enhanced response of dorsal horn neurons in the spinal cord to peripheral inputs, with magnitude and duration related to the degree of tissue injury. Brennan et al. (1996) found that incision into the muscle of a rat's foot caused hyperalgesia for several days. When the incision included only skin and fascia, hyperalgesia was less severe. Amputation of a part of the body often leads to persistent pain which can last for months to years, including stump and phantom pain (Weinstein, 1994). In addition to phantom pain hyperalgesia has been reported in the stump as well as adjacent areas (Zhuo, 1998). Therefore, docking piglet' tails could induce hyperalgesia in the hind area of the piglet including the scrotum. When piglets are subsequently castrated a couple of days after tail docking, this could inflict a increased pain sensation to the piglet, resulting in higher frequencies of pain related behaviour of castrated piglets.
If this hypothetical explanation is correct, it would plead for single surgery (with several procedures like tail docking, identification marks, castration, etc.) to newborn piglets in contrast to surgery procedures on different days within the first week. This hypothesis needs further investigation.

Social cohesion
On D3-PM an effect of treatment on Isolation was found and, in contrast to what was expected, SHAM piglets were observed in isolation more often compared to the other treatments. Hay et al. (2003) observed castrated piglets three times more isolated on D1-PM compared to non-castrated piglets and Moya et al. (In press) also found a tendency for castrated piglets to be more isolated compared to handled piglets over the 5-day-observation period. It remains unclear why no differences in isolation between treatments was found in our study. Isolation is know to e a protective reaction to avoid contact with pen-mates that could generate pain (Hay et al. 2003), and is unusual in social animals such as pigs (Arnold, 1985).

Growth performance
Previous studies suggests that the impact of castration on weight gain varies according to the age of piglets at castration. It seems that piglets castrated at a very young age (1–3 days of age) display growth depression, whereas there is no weight gain deficit in piglets castrated at a later age (McGlone et al., 1993; Kielly et al., 1999). In accordance with these studies no reduction of weight gain after treatment was found in this study where piglets were castrated between 3-6 days of age.

4 The effect of anaesthesia and/or analgesic during castration of piglets on labour demand and cost price

P.F.M.M. Roelofs, W.H.M. Baltussen (LEI)

4.1 Introduction

In the Netherlands and the other countries in the European Union, there has already been discussion for several years about the desirability of castration of male piglets, and about possibilities to make castration less painful. The 'Study group on alternatives for castration of pigs' (Werkgroep alternatieven voor het castreren van varkens, 2005) presents three routes to 'ease, reduce and finally finish' castration. One of these routes is anaesthesia during castration.
As a preliminarily to the decision on whether or not the Netherlands should pioneer in this matter, it is desirable to know the effect of anaesthesia and analgesia during castration on labour demand and labour organization, and on the cost of production of pig meat. These effects have been studied, assuming that pig producers will be allowed to supply Lidocaine (anaesthesia) by themselves or by their animal keepers. In this study the use of anaesthesia and/or analgesia were compared with the normal castration, without pain reduction. No comparison was made with a situation without castration.

Effect on labour demand
Most pig producers combine castration of the male piglets with other treatments of all piglets in the litter, like administration of iron (injection), oral administration of a medicine against diarrhoea and tail docking. Since it wasn't known if anaesthesia or analgesia would affect labour demand for these other treatments, this was also measured.
In Norway, male piglets have to be castrated under anaesthetic since 2002 and both anaesthesia and castration have to be done by a veterinarian (Ten Hooven, 2005). A journal article describes that the pig producer places the male piglets in plastic bins before the veterinarian arrives at the farm; he needs about 2.5 minutes per litter for this. Then the piglets are anaesthetized by two persons: the pig producer holds the piglet, the veterinarian injects Lidocaine into both testicles (using a repeat-syringe) and the pig producer places the piglet in another bin. About ten minutes later, the pig producer picks the piglets up again, holds them on his knee and pulls the hind legs forward. The veterinarian cleans the testicles using a tissue, pushes the testicles backwards and pulls the skin tight with his thumb. Then he makes a cut in both the skin and testicle, pushes the testicles out and cuts the spermatic cord. Using this described work method, castration takes about 15 seconds per piglet.

Effect on cost of production
To calculate the effect of anaesthesia or analgesia during castration on cost of productuon, the results of labour time measurements were used and combined with information concerning prices and tariffs that was collected during these measurements. In this study only direct costs were included, like labour of the pig farmer, animal keepers and the veterinarian (including preparation time and clearing-up time), drugs and instruments. Possible indirect costs, such as an effect on performance of the piglets, were not included.

4.2 Materials and methods

This study contains a limited literature search and extensive measurements of labour times on six pig farms. On each farm, measurements were done during the same five treatments regarding pain reduction during and after castration (including no pain reduction) of male piglets. For calculation of the effect on cost of production of pig meat, prices and tariffs were needed. These were based on tariffs of the veterinarians who anaesthetized piglets during this study on the six participating farms. Measurements were done at the Practice Centre Sterksel (experimental farm of Wageningen UR), two commercial organic pig farms and three commercial conventional pig farms. The commercial pig farms were recruited by the 'Nederlandse Vereniging van Varkenshouders' (NVV; Dutch Union of Pig Producers), the Land- en Tuinbouw organisatie (LTO; Organization for Agriculture and Horticulture) and the 'Vereniging voor Biologische Varkenshouders (VBV; Union of Organic Pig Producers).

4.2.1 Participating pig farms and test persons

In table 4.1 characteristics of the pig farms and of the test persons who castrated male piglets during the study are presented.

Table 4.1 Characteristics of the participating pig farms and of the test persons

pig farm			test person							
number	type	average # sows	sex	age (years)	length (cm)	weight (kg)	BMI [1]	physical complaints	experience (years) [1]	freq. [2]
1	regular	325	female	37	173	62	20.7	none	15	14
2	organic	64	male	45	175	70	22.9	none	20	3
3	organic	240	male	52	174	79	26.1	none	40	0
			male	26	178	72	22.7	none	14	10
4	regular	300	male	49	178	89	28.1	none	40	4
			female	22	180	73	22.5	none	2	13
5	regular	600	male	30	185	80	23.4	none	8	6 [4]
6	regular	700	male	63	170	95	32.9	none	52	15-20

[1] Body Mass Index: an estimation of the health risk due to body weight. A BMI between 18.5 and 25 is advised. People with a BMI between 25 and 30 have overweight and a BMI over 30 is classified as obesity (www.voedingscentrum.nl).
[2] experience = number of years that the person has castrated piglets (without pain reduction)
[3] freq. = frequency: average number of litters the animal keeper castrates per week
[4] At present. A few years ago this animal keeper castrated much more piglets each week

Farm 6 was large enough to do all measurements on one day. Since Practice Centre Sterksel (farm 4) works according to a three week production system (piglets are weaned once every three weeks), all measurements here were also done on one day. At the other farms, measurements were done during two, three or five (farm 2) days. On all farms all measurements for a treatment (see 4.2.2) were done in succession on one day.
Table 4.1 also shows that the test persons were experienced with unanaesthetized castration of piglets. Most of them have done this for more than 14 years, and the two animal keepers with shorter experience have done many castrations during the last years.
Five test persons had a normal body weight, two had some degree of overweight and test person 6 suffered obesity. None of them reported physical complaints.
On two farms (number 3 and number 4) castration was done by two persons working together, at the other farms this work was done by one person.

4.2.2 Treatments

During this study the pig producers castrated their male piglets in the way in which they were accustomed. This means that castrating was combined with other treatments, such as tail docking, administration of iron, attachment of I&R ear tags and/or other treatments. Also, the working method, such as the use of a castration clamp (to restrain the piglets) and the way of castration (by making one horizontal incision or two vertical incisions) was in accordance with the usual working methods on the farms. The working methods applied are described in chapter 4.3.1. The treatments concerned the use of anaesthesia or analgesia before castration. The treatments are presented in table 4.2.

Table 4.2 Description of the treatments

	Treatments	Description
A	anaesthesia by veterinarian	An experienced veterinarian injects 0.8 ml Lidocaïne into each testicle and 10 up to 20 minutes later the pig farmer castrates the piglets.
B	no pain reduction	The pig producer castrates piglets in the way that is usual on his farm.
C	anaesthesia by pig farmer	The pig farmer injects 0.8 ml Lidocaïne into each testicle and 10 up to 20 minutes later he castrates the piglets.
D	analgesia by pig farmer	The pig farmer injects 0.2 ml meloxicam in the neck of the piglets and 10 up to 20 minutes later he castrates the piglets.
E	anaesthesia and analgesia by pig farmer	The pig farmer injects 0.8 ml Lidocaïne into each testicle and 0.2 ml meloxicam in the neck of the piglets and 10 up to 20 minutes later he castrates the piglets.

At each of the six participating pig farms, at least 5 litters of piglets were treated according to each of the five treatments; therefore at least 25 litters were treated on each farm. To affect the working methods on the farms as little as possible, the litters were not standardized. Therefore, the number of male piglets was not equal for all treatments. Further, the order of the treatments was randomized, but all litters with the same treatment were treated one after another.

4.2.3 Data collection

Data were collected by measurements of the labour demand and of the sound exposure of the pig producer and by video recording. Other data, such as the prices of anaesthesia, analgesia and instruments and the tariffs of the veterinarian were collected during the other measurements or found in literature.

Time studies were done by an experienced research worker, using an electric stopwatch that measured time in centiminutes (cmin, 0.01 minute). The times measured in the livestock building were written on a piece of paper. Since data collection started immediately when the first litters were treated, several data were missed during these measurements. Therefore video recordings were made, to facilitate collection of labour data afterwards. For data collection based on images from television, the electric stopwatch was also used.
Labour data were collected at the work element level (e.g. catching a litter of piglets), to be able to test the effect of the treatments on labour demand for each work element separately.

Regarding to labour conditions posture and noise level were measured. Data concerning posture were collected in accordance with Voskamp et al. (2005). Data concerning noise level were collected using a type 4436 Noise Dose Meter (Bruel & Kjær, Copenhagen, Denmark) with an external microphone. This equipment is suitable for personal measurements, with the external microphone fixed at the collar of the pig farmer, and collects the A-weight equivalent noise level per minute (L_{Aeqw}).

4.2.4 Data analysis

Labour data were originally written on paper (as described in 4.2.3) and were typed manually into an Excel database. As far as possible, missing data were added (based on the video tapes) using the electric stopwatch.
After checking the data, average labour time and standard deviation were calculated for each work element per farm and treatment. If the working methods were affected by the treatment, the statistical significance of differences in labour time was tested by variance analysis (one-way Anova SPSS).
Next, for each farm and treatment, the labour demand was standardized per treatment (including castration) for a litter with six male and six female piglets. It was assumed that there were eight pens in a farrowing room and that each farmer worked – apart from anaesthesia and/or analgesia – by the working method that was normal on that farm. If the working method for a work element was not affected by the treatment (no significant differences between labour times), average labour times per farm were used. If the measured labour times were different ($p < 0.05$) average labour times per farm and treatment were used.
Noise data were initially analysed using Bruel & Kjær software (BZ 7028, Bruel & Kjær 1992), after which an overview of the course of equivalent noise levels was made using Excel. Then the L_{Aeqw} and noise dose (as percentage of the

maximal accepted total noise dose per day) was calculated for each period when a treatment was done, using the Bruel & Kjær software.

Postures were analysed by judgement of characteristic postures on the video tapes during anaesthesia or analgesia. This was done in accordance with Voskamp et al. (2005), which means that the head, trunk, arms and legs were judged separately for the extent to which their posture caused physical load. Postures of these parts of the body were divided into categories, whereby category 1 was not heavy, category 2 was heavy and category 3 was very heavy. The amount of physical load determines the total time per day that this posture is acceptable. However, Voskamp et al. (2005) assume that the postures are known for a whole working day, and not only for several minutes per day. Therefore only a qualitative judgement is presented, since not enough quantitative data were available.

4.2.5 Economic analysis

Economic analysis was done at farm level and at national level. All costs mentioned in these analyses include VAT (6% for drugs and 19 % for labour costs).

Effects at farm level

The estimation of extra costs of using anaesthesia during castration of male piglets is based on the results of the labour measurements as described previously. The extra costs for farmers (all treatments are compared with the case that no anaesthesia and analgesia are used) consists of:

a. additional time for the veterinarian to administer the lidocaïne;
b. additional time for the pig producer to administer the lidocaïne and/or meloxicam;
c. visiting fee for the veterinarian, including time for hygienic measures before entering and after leaving the livestock building;
d. costs of materials (drugs).

The additional time for the veterinarian and for the pig farmer was determined by work studies (see table 4.2.3 and 4.3.4). Except for the extra labour costs for the pig producers themselves, all costs are also out of pocket costs (or expenses) for a pig farmer. For the bigger farms, extra labour costs are expenses too, because the extra work is done by employees. All presented costs are expressed per castrated piglet.
Part of the costs, especially visiting fees for the veterinarian (mentioned under c.), strongly depend on the size of the farm and the frequency of castration (times per week).
In all five treatments the castration is executed by the farmer. Since it is not common to castrate piglets younger than two days and for castration of piglets older than seven days the administration of analgesia and anaesthesia is legally obliged, this means that the castration process has to be executed at least twice a week. The anaesthesia should be administered by a veterinarian, therefore in many cases the veterinarian will have to visit the farms twice a week to administer the anaesthesia. In the economic evaluation, the results are calculated for situations in which the castration process is executed once or twice a week. Also, the case of one visit in two weeks is taken into consideration. In this case the veterinarian is supposed to administer the anaesthesia (obliged to conform to the rules) while the farmer administers the analgesia and castrates the piglets.
Finally, in the calculations it is supposed that the working method is adapted in such a way by the farmer that veterinarians don't have to wait during the process, and castration is executed between 10 and 20 minutes after administration of anaesthesia or analgesia.

Basic assumptions for the economic evaluation

In the former section, it is stated that the extra costs strongly depend on the farm size (measured in number of sows). In table 4.3 some figures are given for the Dutch situation in 2006. It is assumed that all farms produce 2.34 litters per sow per year and each litter has 6 boars. On average 12.3 piglets per litter were born alive (Agrovision, 2006).

Table 4.3 Farm structure of all farms with sows in 2006

Farm size (# sows)	Number of farms	% of farms	# sows (x1000)	% of sows	Sows per farm	Litters per farm per week
< 100	708	19	36	4	51	2.3
100 - 200	1056	29	162	17	153	6.9
200 - 400	1334	37	371	39	278	12.5
> 400	553	15	377	40	682	30.7
Total	3651	100	946	100	259	11.7

From table 4.3 it can be concluded that 79% of the sows are held on farms with more than 200 sows. These farms produce at least 12 litters a week. A further 17% of the sows are held on farms with 100 up to 200 sows per farm, producing about 7 litters per week.
Besides the extra time for administration of Lidocaine, the veterinarian has to increase the number of farm visits. In the economic evaluation, only the costs for extra visits are taken into account. The price for an extra visit by a veterinarian (including the hygienic measures) is supposed to be € 40 per visit. This includes the visiting fee (about € 25) and time for entering and leaving the livestock building (on average 9 minutes per visit, tariff is € 100, therefore € 15).
For scenarios with castration without pain reduction, the annual number of visits by a veterinarian is assumed to be 13, independent of the number of sows. In treatment A (anaesthesia by a veterinarian) the number of visits is dependent on the frequency of castration. It is assumed that the veterinarians will visit the small farms (less than 100 sows) at most once a week. With only a few litters per week (mean is 2.3) there is no reason to visit these farms more often.
In the calculations, the labour tariffs for veterinarians and farmers are set at € 100 and € 25 per hour, respectively.
The costs for drugs are calculated per male piglet. A bottle with 100 ml lidocaine costs € 5.68. Per piglet 1.6 ml is needed, resulting in € 0.10 additional costs per castrated piglet. A bottle of 100 ml Novem®5 (meloxicam) costs € 40, and per piglet 0.2 ml is used. This results in additional costs of € 0.08 per castrated piglet. Other costs like needles and disinfectants are neglected in this study.

Effects at national level
To calculate the economic effects on a national level two indicators are used:
1. The total additional costs for farmers compared with the situation without pain reduction;
2. The additional number of veterinarians that is needed for anaesthesia of all male piglets in the Netherlands before castration.

Both indicators are calculated for scenarios where the castration process is executed once a week, twice a week or once in two weeks.

4.3 Results

4.3.1 Work methods and labour demand per farm

Farm 1
Sows and piglets were housed in regular farrowing pens, with diagonally placed sow crates. The male piglets were castrated when they were between 3 and 10 days old, at least one day after the iron administration. Castration was combined with tail docking and attachment of I&R (Identification and Registration) ear tags. These treatments were done by one person, using a piglet treatment trolley (see figure 4.1). The trolley contains two crates; therefore piglets can be moved from one crate into the other after each treatment.

Figure 4.1 Piglet treatment trolley

Regular work method
The animal keeper collects a litter of piglets and places them in one of the crates on the treatment trolley. Then he takes up the piglets one by one and – sitting on a pen partition – docks the tail using an electric tail docker and places the piglets in the other crate. Then he stands up and attaches an I&R ear tag in one ear of all piglets, without lifting them. After or during attaching the ear tags, he puts the female piglets back into the farrowing pen and moves the male piglets into the first crate.
Then he puts the castration clamp on the pen partition. The castration clamp contains a dish with water to place the scalpel in. In each room the dish is filled with fresh water, using a water nipple for the piglets. After placing the castration clamp, the animal keeper castrates the male piglets, standing in the farrowing pen. During castration the piglets hang in the castration clamp, with the head below, and after castration they are placed back into the farrowing pen. The castration includes four incisions: two vertical cuts and two cuts through the spermatic cord. Boars with undescended testes are marked by attaching a second I&R ear tag, and also a marking pen is available.

Work method when painkiller is used
Instead of castrating the male piglets, they are placed into a plastic bin. When the preliminary work in the room is finished the veterinarian or the animal keeper administers lidocaine and/or meloxicam, using a revolver syringe. After a waiting period (between 10 and 20 minutes) the animal keeper castrates the piglets and moves them into the farrowing pen.

Averages and standard deviations of measured labour times per work element are presented in appendix 7.1 (table 7.1.1). Table 4.4 presents labour times per treatment for a litter with 12 piglets, of which 6 are boars. The table presents frequency (freq.) of the work element for treatment of 12 piglets, average labour time (av., based on table 7.1.1) and total labour time for this work element (tot.), successively.

Table 4.4 Labour demand (cmin) for treatment of a litter with 12 piglets (6 boars) on farm 1

	test treatment														
	anaesthesia by veterinarian			no pain reduction			anaesthesia by pig farmer			analgesia by pig farmer			anaesthesia and analgesia by pig farmer		
work element	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.
go into next room	0.125	115.3	14.41	0.125	115.3	14.41	0.125	115.3	14.41	0.125	115.3	14.41	0.125	115.3	14.41
prepare castration clamp	0.125	28.5	3.56	0.125	28.5	3.56	0.125	28.5	3.56	0.125	28.5	3.56	0.125	28.5	3.56
go with trolley to next pen	1	16.64	16.64	1	16.64	16.64	1	16.64	16.64	1	16.64	16.64	1	16.64	16.64
collect litter of piglets	1	52.94	52.94	1	52.94	52.94	1	52.94	52.94	1	52.94	52.94	1	52.94	52.94
heat electric tail docker	1	36.32	36.32	1	36.32	36.32	1	36.32	36.32	1	36.32	36.32	1	36.32	36.32
dock tail	12	14.21	170.5	12	14.21	170.5	12	14.21	170.5	12	14.21	170.5	12	14.21	170.5
attach ear tag	12	13.06	156.7	12	13.06	156.7	12	13.06	156.7	12	13.06	156.7	12	13.06	156.7
separate males/females	1	38.03	38.03	1	38.03	38.03	1	38.03	38.03	1	38.03	38.03	1	38.03	38.03
prepare castration	1	21	21	1	21	21	1	21	21	1	21	21	1	21	21
castrate	6	23.95	143.7	6	23.95	143.7	6	23.95	143.7	6	23.95	143.7	6	23.95	143.7
bin into farrowing pen	1	36.63	36.63			0	1	36.63	36.63	1	36.63	36.63	1	36.63	36.63
administer meloxicam			0			0			0	6	8.65	51.9	6	11.85	71.1
put castration clamp in pen			0			0	1	23.71	23.71			0	1	23.71	23.71
administer lidocaine	6	25.24	151.4			0	6	27.04	162.2			0	6	29.06	174.4
lay aside the syringe			0			0	1	9.8	9.8	1	9.8	9.8	2	9.8	19.6
get out of room	1	89.67	89.67	1	89.67	89.67	1	89.67	89.67	1	89.67	89.67	1	89.67	89.67
take all bins out of room	1	64.5	64.5			0	1	64.5	64.5	1	64.5	64.5	1	64.5	64.5
Total			996			744			1040			906			1133

Farm 2
Sows and piglets were housed in farrowing pens for organic pig production, but without an outdoor area. The sows could use the entire pens with the exception of one corner; the creep area for the piglets. The rooms with three pens each were located at one side of a passage. Before collecting piglets the farmer moved the sows from the farrowing pen to a separate pen in the room for pregnant sows, for his own safety.
The male piglets were castrated when they were about 7 days old, not at a fixed day of the week. Castration was combined with administration of an iron injection and a Mycoplasma vaccine and with attachment of I&R ear tags. This was done by one person, sometimes assisted by someone else. Data are analysed for a one-person work method.

Regular work method
The animal keeper opens the farrowing pens and herds the sows through the passage to a common pen in the room for pregnant sows. Next he locks the piglets in a corner of the pen and closes this with a pen partition. When all piglets in the room are locked in, he gets a box with all instruments he needs (e.g. syringes, drugs, knife, ear tags) and places it on a pen partition. He takes up the piglets one by one and – successively – applies ear tags, administers an iron injection and a Mycoplasma vaccine, castrates the male piglets and moves them into the pen. The animal keeper fixes the piglets between his legs during castration and needs three incisions for castration: one horizontal cut through the

skin and two cuts through the spermatic cord. He makes the incisions as small as possible and sprays iodine into the wound.

Work method when painkiller is used
During this study, anaesthesia before castration became compulsory for organic pig production and therefore became regular. This treatment was as described before, with the exception of movement of the piglets after application of the ear tags. The female piglets were placed in their pen and the male piglets were placed into the closed corner. The preliminary work was organized so that all male piglets were locked up when the veterinarian arrived, who anaesthetized them in succession (two-persons work method: animal keeper fixed the piglets and veterinarian injected lidocaine) after which the animal keeper placed them into the closed corner again. After the waiting period the animal keeper castrated the piglets as described before.
During administration of lidocaine (in treatment C and E) the animal keeper fixed the piglets between his legs. During administration of meloxicam in the neck (in treatment D and E) he held them in his hand, as during the administration of iron. He used revolver syringes.

Averages and standard deviations of measured labour times per work element are presented in appendix 7.1 (table 7.1.2). Table 4.5 presents labour times per treatment for a litter with 12 piglets, of which 6 are boars. The table presents frequency (freq.) of the work element for treatment of 12 piglets, average labour time (av., based on table 7.1.2) and total labour time for this work element (tot.), successively.

Table 4.5 Labour demand (cmin) for treatment of a litter with 12 piglets (6 boars) on farm 2

	test treatment														
	aneasthesia by veterinarian			no pain reduction			aneasthesia by pig farmer			analgesia by pig farmer			aneasthesia and analgesia by pig farmer		
work element	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.
start-up time	0.125	998	124.8	0.125	998	124.8	0.125	998	124.8	0.125	998	124.8	0.125	998	124.8
go into next room	0.375	120.7	45.25	0.375	120.7	45.25	0.375	120.7	45.25	0.375	120.7	45.25	0.375	120.7	45.25
get material	0.125	84.73	10.60	0.125	84.73	10.60	0.125	84.73	10.60	0.125	84.73	10.60	0.125	84.73	10.60
go to next pen	1	26.67	26.67	1	26.67	26.67	1	26.67	26.67	1	26.67	26.67	1	26.67	26.67
take ear tags from carton	1	10	10	1	10	10	1	10	10	1	10	10	1	10	10
get sow out of pen	1	96.25	96.25	1	96.25	96.25	1	96.25	96.25	1	96.25	96.25	1	96.25	96.25
herd sows in common pen	0.375	101.1	37.93	0.375	101.1	37.93	0.375	101.1	37.93	0.375	101.1	37.93	0.375	101.1	37.93
walk back	0.375	23.83	8.94	0.375	23.83	8.94	0.375	23.83	8.94	0.375	23.83	8.94	0.375	23.83	8.94
lock the piglets into corner	1	107.8	107.8	1	107.8	107.8	1	107.8	107.8	1	107.8	107.8	1	107.8	107.8
ear tag in tag-pincers	12	12.79	153.5	12	12.79	153.5	12	12.79	153.5	12	12.79	153.5	12	12.79	153.5
take up a piglet	12	6.22	74.64	12	6.22	74.64	12	6.22	74.64	12	6.22	74.64	12	6.22	74.64
adjust ear tag	12	6.43	77.16	12	6.43	77.16	12	6.43	77.16	12	6.43	77.16	12	6.43	77.16
administer Mycoplasma	12	7	84	12	7	84	12	7	84	12	7	84	12	7	84
administer iron			0	6	6.84	41.04	6	6.84	41.04	6	6.84	41.04	6	6.84	41.04
admin. iron & piglet in pen	12	8.67	104.0	6	8.67	52.02	6	8.67	52.02	6	8.67	52.02	6	8.67	52.02
administer meloxicam													6	8.95	53.7
adm. melox. & piglet in pen			0			0			0	6	7.49	44.94			
take up and fix piglet	6	19.6	117.6			0			0			0			0
adm. lidocaine & piglet pen			0			0	6	21.03	126.2			0	6	25.55	153.3
adm. lidocaine (2 persons)	12	14.65	175.8			0			0			0			0
move piglet into pen	6	3.06	18.36			0			0			0			0
prepare castration / room	0.375	104.7	39.26			0	0.375	104.7	39.26	0.375	104.7	39.26	0.375	104.7	39.26
go to next pen	1	18.36	18.36			0	1	18.36	18.36	1	18.36	18.36	1	18.36	18.36
take up and fix boar	6	13.36	80.16			0	6	13.36	80.16	6	13.36	80.16	6	13.36	80.16
castrate	6	30.86	185.2	6	30.86	185.2	6	30.86	185.2	6	30.86	185.2	6	30.86	185.2
adm. iodine and move p.	6	6.66	39.96	6	6.66	39.96	6	6.66	39.96	6	6.66	39.96	6	6.66	39.96
return 3 sows to pens	1	135.8	135.8	1	135.8	135.8	1	135.8	135.8	1	135.8	135.8	1	135.8	135.8
recover 3 farrowing pens	0.375	137.3	51.48	0.375	137.3	51.48	0.375	137.3	51.48	0.375	137.3	51.48	0.375	137.3	51.48
finishing time (clean up)	0.125	52	6.5	0.125	52	6.5	0.125	52	6.5	0.125	52	6.5	0.125	52	6.5
Total			1830			1369			1633			1552			1714

Farm 3
Sows and piglets were housed in farrowing pens for organic pig production with an outdoor area. The sows could use the entire pens with the exception of one corner; the creep area for the piglets. Rooms bordered on one another, with a passage in the middle of each room and pens at both sides. Between two of the three rooms was a treatment room where piglets were treated. To get there, a litter of piglets was placed in the piglet treatment trolley and moved through the corridor to this treatment room.
The male piglets were castrated when they were between 3 and 5 days old. Castration was combined with administration of iron and a Mycoplasma vaccine and with attachment of I&R ear tags. These treatments were done by two persons, working together.

Regular work method
The animal keepers push the piglet treatment trolley to the right pen, collect a litter of piglets and place them in one of the crates on the treatment trolley. Sometimes the sow reacts aggressive and the animal keepers have to act very carefully. When all piglets are collected the animal keepers push the piglet treatment trolley to the treatment room and both take a revolver syringe. One animal keeper takes up the piglets one by one, administers an iron injection and gives them to the second animal keeper. He administers the Mycoplasma vaccine and places the piglets in the second crate on the treatment trolley. Next one animal keeper applies the I&R ear tags and places the males and the females in different crates. At the same time the second animal keeper castrates the male piglets, and sometimes has to wait for a moment. During the castration he fixes the piglets between his knees and he castrates the piglets by four incisions: two vertical cuts and two cuts through the spermatic cord. Next he sprays a disinfectant (Betadine) into the wound.
When all piglets in a litter are treated, the animal keepers push the treatment trolley back to the right pen, unload it and collect – if necessary – the next litter.

Work method when painkiller is used
During this study, anaesthesia before castration became compulsory for organic pig production and therefore became regular. This treatment was as described before, with the exception of movement of the piglets after adjustment of the ear tags. The female piglets were moved into the crates at the piglet treatment car, but the male piglets were placed into a plastic bin in the treatment room and stayed there. The females were returned to their pen and a new litter of piglets was collected.
The preliminary work was organized so that all male piglets were lying in bins when the veterinarian arrived, who anaesthetized them in succession (one-person work method) and placed them back into the bins. After the waiting period the animal keeper castrated the piglets as described before, after which they were returned to their pens. Since this work method causes a lot of waiting time (due to gearing of their activities) this part of the treatment is mostly done by one person.
In treatment C, D or E (anaesthesia and/or analgesia by animal keepers) the second animal keeper lifts the piglets by their hind legs and fixes the testicles using his thumb, enabling him to administer lidocaine and/or meloxicam using the revolver syringe in his other hand. Then, the male piglets are placed in plastic bins to wait for 10 up to 20 minutes, and the female piglets are returned to the pens. When the preliminary work in all litters is done, one animal keeper starts castrating and the other one starts another activity.

Averages and standard deviations of measured labour times per work element are presented in appendix 7.1 (table 7.1.3). Table 4.6 presents labour times per treatment for a litter with 12 piglets, of which 6 are boars. The table presents frequency (freq.) of the work element for treatment of 12 piglets, average labour time (av., based on table 7.1.3) and total labour time for this work element (tot.), successively.

Table 4.6 Labour demand (cmin) for treatment of a litter with 12 piglets (6 boars) on farm 3

	test treatment														
	aneasthesia by veterinarian			no pain reduction			aneasthesia by pig farmer			analgesia by pig farmer			aneasthesia and analgesia by pig farmer		
work element	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.
trolley to next pen	2	12.67	25.34	2	12.67	25.34	2	12.67	25.34	2	12.67	25.34	2	12.67	25.34
collect litter of piglets	24	84.56	169.1	24	84.56	169.1	24	84.56	169.1	24	84.56	169.1	24	84.56	169.1
trolley to treatment room	2	36.71	73.42	2	36.71	73.42	2	36.71	73.42	2	36.71	73.42	2	36.71	73.42
admin. Fe and Myco (2p)	24	9.78	234.7	24	9.78	234.7	24	9.78	234.7	24	9.78	234.7	24	9.78	234.7
adjust ear tags & sex	1	18.46	18.46	1	18.46	18.46	1	18.46	18.46	1	18.46	18.46	1	18.46	18.46
wash hands before castr.	0.125	21.2	2.65	0.125	21.2	2.65	0.125	21.2	2.65	0.125	21.2	2.65	0.125	21.2	2.65
return females to pen	2	35.71	71.42			0	2	35.71	71.42	2	35.71	71.42	2	35.71	71.42
unload trolley (females)	2	20.08	40.16			0	2	20.08	40.16	2	20.08	40.16	2	20.08	40.16
bin into farrowing pen	1	14.6	14.6			0	1	14.6	14.6	1	14.6	14.6	1	14.6	14.6
place boar into bin	1	67	67												
adm. meloxicam (& in bin)			0			0			0	6	10.03	60.18	6	7.43	44.58
gearing loss meloxicam			0			0			0	1	10.31	10.31	1	10.31	10.31
prepare syringe			0			0	1	12	12	1	12	12	1	12	12
adm. lidocaine (& into bin)	6	23.31	139.9			0	6	19.74	118.4			0	6	16.5	99
gearing loss lidocaine			0			0	1	16	16			0	1	16	16
lay aside the syringe			0			0	1	11.5	11.5	1	11.5	11.5	1	11.5	11.5
move bin with boars	1	9.89	9.89			0	1	9.89	9.89	1	9.89	9.89	1	9.89	9.89
castrate	6	29.48	176.9	6	29.48	176.9	6	29.48	176.9	6	29.48	176.9	6	29.48	176.9
adm. betadine & into crate	6	9.01	54.06	6	10.75	64.5	6	9.01	54.06	6	9.01	54.06	6	9.01	54.06
return boars to pen	0.5	36.22	18.11	0.5	30.6	15.3	0.5	36.22	18.11	0.5	36.22	18.11	0.5	36.22	18.11
unload trolley (boars)	1	24.49	24.49	1	30.6	30.6	1	24.49	24.49	1	24.49	24.49	1	24.49	24.49
empty trolley to treatm. rm	0.5	25.83	12.92	0.5	25.83	12.92	0.5	25.83	12.92	0.5	25.83	12.92	0.5	25.83	12.92
store bins	1	13	13	1		0	1	13	13	1	13	13	1	13	13
store syringes	0.25	91	22.75	0.25	91	22.75	0.25	91	22.75	0.25	91	22.75	0.25	91	22.75
finishing time (clean up)	0.125	70	8.75	0.125	70	8.75	0.125	70	8.75	0.125	70	8.75	0.125	70	8.75
Total			1198			855			1149			1085			1184

Farm 4

Sows and piglets were housed in regular farrowing pens, with sow crates straight through the pens. Piglets were castrated when they were between 2 and 9 days old. Castration was combined with an iron injection (Prevan 200) and an antibiotics injection (Albipem) in the neck and oral administration against diarrhoea (Baycox). This combination of treatments was done by two animal keepers, using a piglet treatment trolley.

Regular work method

The animal keepers collect a litter of piglets and place the piglets in one of the crates on the treatment trolley. Then animal keeper A takes up the piglets one by one and administers the iron injection (using a revolver syringe) into the neck, while animal keeper B administers the antibiotics into the other side of the neck. After these injections the piglets are placed into the other crate on the trolley.

When all piglets are treated animal keeper B takes up the piglets, administers Baycox and places the female piglets into the pen and the males into the first crate. Animal keeper A takes these boars in his hand and castrates them, holding them with the head down. He pushes the testicles up with his thumb, makes two vertical incisions and pulls the spermatic cord apart. Next he checks the piglet and moves it into the pen.

Work method when painkiller is used

The preliminary work is the same, but instead of castrating the male piglets animal keeper A places them into a crate in the pen (aneasthesia by veterinarian) or injects lidocaine into the testicles and/or meloxicam into the neck (other treatments) before placing them into the crate. After the waiting period, animal keeper A castrates the piglets and moves them into to farrowing pen. Meanwhile animal keeper B collects piglets in the next pen.

Averages and standard deviations of measured labour times per work element are presented in appendix 7.1 (table 7.1.4). Table 4.7 presents labour times per treatment for a litter with 12 piglets, of which 6 are boars. The table presents frequency (freq.) of the work element for treatment of 12 piglets, average labour time (av., based on table 7.1.4) and total labour time for this work element (tot.), successively.

Table 4.7 Labour demand (cmin) for treatment of a litter with 12 piglets (6 boars) on farm 4

	test treatment														
	aneasthesia by veterinarian			no pain reduction			aneasthesia by pig farmer			analgesia by pig farmer			aneasthesia and analgesia by pig farmer		
work element	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.
start-up time		763.0	0		763.0	0		763.0	0		763.0	0		763.0	0
go with trolley to next pen	1	19.94	19.94	1	19.94	19.94	1	19.94	19.94	1	19.94	19.94	1	19.94	19.94
collect litter (2 persons)	2	49.00	98	2	49.00	98	2	49.00	98	2	49.00	98	2	49.00	98
pick up & fill syringe	2	44.80	89.6	2	44.80	89.6	2	44.80	89.6	2	44.80	89.6	2	44.80	89.6
adm. Fe & antibiotics (2p.)	24	7.14	171.4	24	7.14	171.4	24	7.14	171.4	24	7.14	171.4	24	7.14	171.4
pick up Baycox	1	8.96	8.96	1	8.96	8.96	1	8.96	8.96	1	8.96	8.96	1	8.96	8.96
replace bottle Baycox			0			0		69.00	0			0			0
administer Baycox & sex	12	11.04	132.5	12	11.04	132.3	12	11.04	132.3	12	11.04	132.3	12	11.04	1323
crate into farrowing pen	1	*20.40*	20.4	1		0	1	*20.40*	20.4	1	*20.40*	20.4	1	*20.40*	20.4
replace bottle lidocaine	0.096	81.00	7.78			0	0.096	81.00	7.776			0	0.096	81.00	7.776
administer lidocaine	6	**19.41**	116.5			0	6	**20.50**	123			0			0
replace bottle meloxicam										0.012	*81.00*		0.012	*81.00*	
administer meloxicam			0			0			0	6	**8.07**	48.42			0
adm. lidoc. & melox. (2p)			0			0			0			0	12	**30.69**	368.3
go to next pen (castration)	1	34.29	34.29			0	1	34.29	34.29	1	34.29	34.29	1	34.29	34.29
castrate	6	36.73	220.4	6	36.73	220.4	6	36.73	220.4	6	36.73	220.4	6	36.73	220.4
crates out of farrow. pens	1	20.40	20.4			0	1	20.40	20.4	1	20.40	20.4	1	20.40	20.4
Total			940.1			740.7			946.6			864.2			1192

Farm 5

Sows and piglets were housed in farrowing pens with the sow crates straight through the pens and with movable floors besides the sow crate. Castration was combined with tail docking, an iron injection and an antibiotic injection and application of I&R ear tags. A piglet treatment trolley was used.

Regular work method

The animal keeper collects a litter of piglets and places the piglets in the crates on the treatment trolley; the males in one crate and the females in the other. Then he applies the ear tags, males get them in the left ear and females in the right ear. Next he administers an antibiotic injection and an iron injection, each time replacing the piglets from one crate into the other.

The animal keeper puts the plug of the electric tail docker into the socket and administers Baycox (against diarrhoea). When this is finished, the tail docker is heated and he starts tail docking, replacing the female piglets into the pen and the boars into one of the crates. Finally he takes the boars between his knees and castrates them, making two horizontal incisions and next cutting the spermatic cord. (The animal keeper is more experienced with breaking the spermatic cord. For this work method he keeps the piglet in his hand and stands straight.) After castration he disinfects the wound and places the piglet into the pen.

Work method when painkiller is used

For treatment A (anaesthesia by veterinarian) the animal keeper places the boars after tail docking into plastic bins in the passage in the room. The preliminary work is done before the veterinarian arrives, so he can anaesthetise them all without waiting. (He works alone and places the piglet from one bin into another. He keeps the piglets in his hand during anaesthesia.) After the waiting period (10-20 minutes) the animal keeper castrates the piglets as described before and places them into the farrowing pen.

When the animal keeper administers lidocaine and/or meloxicam by himself, he doesn't use the bins but marks the boars after collecting the piglets using a marking pen. The preliminary work is done at the usual way except the castration: boars are not castrated but moved into the pen after administration of lidocaine and/or meloxicam. During anaesthesia he holds the piglet in his left hand, fixes the testicles using his thumb and injects using a revolver syringe in his right hand. (This is easier with small piglets then with larger piglets.) After this he puts the cap on the needle. He is more anxious about pricking himself on this needle than on the needle of the iron syringe.

After the waiting period the animal keeper collects the marked piglets (this goes relatively quickly since the floors of the farrowing pen move down) into the crate on the piglet treatment car. Then he castrates them by the usual method, disinfects the wounds and places the piglets in the farrowing pen again.

Averages and standard deviations of measured labour times per work element are presented in appendix 7.1 (table 7.1.5). Table 4.8 presents labour times per treatment for a litter with 12 piglets, of which 6 are boars. The table presents frequency (freq.) of the work element for treatment of 12 piglets, average labour time (av., based on table 7.1.5) and total labour time for this work element (tot.), successively.

Table 4.8 Labour demand (cmin) for treatment of a litter with 12 piglets (6 boars) on farm 5

	test treatment														
	aneasthesia by veterinarian			no pain reduction			aneasthesia by pig farmer			analgesia by pig farmer			aneasthesia and analgesia by pig farmer		
work element	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.
go with trolley to next pen	1	13.70	13.7	1	13.70	13.7	1	13.70	13.7	1	13.70	13.7	1	13.70	13.7
collect litter piglets & sex	1	66.38	66.38	1	66.38	66.38	1	66.38	66.38	1	66.38	66.38	1	66.38	66.38
mark boars (marking pen)			0			0	1	13.47	13.47	1	13.47	13.47	1	13.47	13.47
heat electric tail docker	1	26.80	26.8	1	26.80	26.8	1	26.80	26.8	1	26.80	26.8	1	26.80	26.8
pick up I&R tag-pincers	1	12.43	12.43	1	12.43	12.43	1	12.43	12.43	1	12.43	12.43	1	12.43	12.43
adjust ear tag	12	12.10	145.2	12	12.10	145.2	12	12.10	145.2	12	12.10	145.2	12	12.10	145.2
lay aside I&R tag-pincers	1	12.00	12	1	12.00	12	1	12.00	12	1	12.00	12	1	12.00	12
take up syringe (Fe/antib.)	2	6.50	13	2	6.50	13	2	6.50	13	2	6.50	13	2	6.50	13
administer antibiotics	12	5.00	60	12	5.00	60	12	5.00	60	12	5.00	60	12	5.00	60
administer Fe	12	5.03	60.36	12	5.03	60.36	12	5.03	60.36	12	5.03	60.36	12	5.03	60.36
take up Baycox bottle	1	7.00	7	1	7.00	7	1	7.00	7	1	7.00	7	1	7.00	7
administer Baycox (oral)	12	4.97	59.64	12	4.97	59.64	12	4.97	59.64	12	4.97	59.64	12	4.97	59.64
bin into farrowing pen	1	7.00	7												
take up syringe (lidocaine)	1	6.00	6			0	1	8.33	8.33			0	1	8.33	8.33
go to next pen (anaesth.)[1]	1	9.00	9			0			0			0			0
administer lidocaine			0			0	6	17.93	108			0	6	17.93	108
adm. lido. & piglet in crate	6	15.69	94.1			0			0			0			0
lay aside syringe (lidocaine)			0			0	1	8.50	8.5			0	1	8.50	8.5
take up syringe (meloxicam			0			0			0	1	5.00	5	1	5.00	5
administer meloxicam			0			0			0	6	7.78	46.7	6	5.78	34.7
lay aside syringe (meloxic.)			0			0			0	1	8.50	8.5	1	8.50	8.5
install electric tail docker	1	10.10	10.1	1	10.10	10.1	1	10.10	10.1	1	10.10	10.1	1	10.10	10.1
clean electric tail docker	1	54.00	54	1	54.00	54	1	54.00	54	1	54.00	54	1	54.00	54
tail docking	12	12.48	150	12	12.48	150	12	12.48	150	12	12.48	150	12	12.48	150
lay aside tail docker	1	17.36	17.4	1	17.36	17.4	1	17.36	17.4	1	17.36	17.4	1	17.36	17.4
go to next pen	1	9.00	9												
go to next pen with trolley			0			0	1	20.38	20.4	1	20.38	20.4	1	20.38	20.4
collect boars into crate			0			0	1	41.57	41.6	1	41.57	41.6	1	41.57	41.6
castrate	6	33.43	201	6	33.43	201	6	33.43	201	6	33.43	201	6	33.43	201
disinfect & piglet into pen	6	6.08	36.5	6	6.08	36.5	6	6.08	36.5	6	6.08	36.5	6	6.08	36.5
bins out of farrowing pens	1	7.00	7			0	1	7.00	7	1	7.00	7	1	7.00	7
Total			1077			944.8			1152			1087			1200

[1] Work element 'go to next pen' occurs only in treatment A (anaesthesia by veterinarian), since administration of lidocaine and/or meloxicam by the animal keeper is combined with other work elements (e.g. iron injection and attachment of I&R ear tag)

Farm 6

Sows and piglets were housed in regular farrowing pens, with diagonally placed sow crates. Castration was combined with oral administration of Baycox (against diarrhoea), iron injection, vaccination against Mycoplasma, attachment of I&R ear tags and tail docking. These treatments were done by one person, using a piglet treatment trolley.

Regular work method

The animal keeper collects a litter of piglets and places them in the crates on the treatment trolley. He uses a stick to facilitate collection of piglets at the other side of the sow. He administers (two sessions) Baycox and iron and places the piglets – sorted by sex – in the crates on the piglet treatment trolley. Then he administers the Mycoplasma vaccine to all boars, applies I&R ear tags, places them – one by one – in a castration trough, castrates them and docks the tails. Finally he moves them into the farrowing pen.

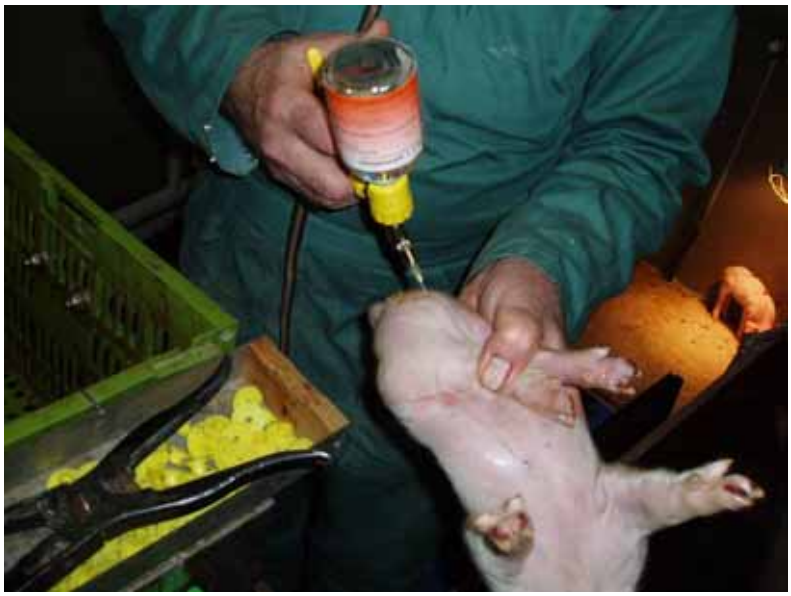
Then he administers the Mycoplasma vaccine to the female piglets, applies I&R ear tags and moves them into the farrowing pen too. After all piglets in the room are treated he sands 'silver dust' (a disinfecting powder) into the pens.

Work method when painkiller is used

This work method is like the regular one, except castration and tail docking of the piglets. In treatment A (anaesthesia by veterinarian) they are placed in crates in the farrowing pens. The veterinarian arrives when all male piglets are shut in. Piglets are anaesthetised by two persons: the animal keeper fixes them and pushes the hind legs forward and the veterinarian injects lidocaine.

When the animal keeper administers lidocaine and/or meloxicam by himself, he fixes the piglet in his left hand and injects using a revolver syringe his right hand (see figure 4.2) and places them into the crate in each farrowing pen. After the waiting period he castrates them and docks their tails in the regular way.

Figure 4.2 Administration of lidocaine by the animal keeper at farm 6



Averages and standard deviations of measured labour times per work element are presented in appendix 7.1 (table 7.1.6). Table 4.9 presents labour times per treatment for a litter with 12 piglets, of which 6 are boars. The table presents frequency (freq.) of the work element for treatment of 12 piglets, average labour time (av., based on table 7.1.6) and total labour time for this work element (tot.), successively.

Table 4.9 Labour demand (cmin) for treatment of a litter with 12 piglets (6 boars) on farm 6

	test treatment														
	aneasthesia by veterinarian			no pain reduction			aneasthesia by pig farmer			analgesia by pig farmer			aneasthesia and analgesia by pig farmer		
work element	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.	freq	av.	tot.
with trolley to next room	0.13	100.5	12.56	0.13	100.5	12.56	0.13	100.5	12.56	0.13	100.5	12.56	0.13	100.5	12.56
with trolley to next pen	1	35.27	35.27	1	35.27	35.27	1	35.27	35.27	1	35.27	35.27	1	35.27	35.27
collect litter of piglets	1	81.78	81.78	1	81.78	81.78	1	81.78	81.78	1	81.78	81.78	1	81.78	81.78
administer Baycox	12	6.5	78.00	12	6.5	78.00	12	6.5	78.00	12	6.5	78.00	12	6.5	78.00
administer Fe & sex	12	9.15	109.8	12	9.15	109.8	12	9.15	109.8	12	9.15	109.8	12	9.15	109.8
adm. Mycoplasma vaccine	12	8.26	99.12	12	8.26	99.12	12	8.26	99.12	12	8.26	99.12	12	8.26	99.12
replace bottle iron		131	0.00		131	0.00		131	0.00		131	0.00		131	0.00
replace bottle vaccine		115	0.00		115	0.00		115	0.00		115	0.00		115	0.00
adjust I&R ear tag	12	16.02	192.2	12	16.02	192.2	12	16.02	192.2	12	16.02	192.2	12	16.02	192.2
taildocking female & in pen	6	7.09	42.54	6	7.09	42.54	6	7.09	42.54	6	7.09	42.54	6	7.09	42.54
to next pen (anaesthesia)	1	27	27.00			0.00			0.00			0.00			0.00
open crate with boars	1	13.29	13.29			0.00			0.00			0.00			0.00
administer lidocaine	6	18.03	108.2			0.00	6	19.46	116.8			0.00	6	19.46	116.8
close crate & stone on it	1	9.2	9.20			0.00			0.00			0.00			0.00
administer meloxicam			0.00			0.00			0.00	6	8.06	48.36	6	8.06	48.36
crates & stones into room	0.13	79	9.88			0.00	0.13	79	9.88	0.13	79	9.88	0.13	79	9.88
crate into farrowing pen	1	29.45	29.45			0.00	1	29.45	29.45	1	29.45	29.45	1	29.45	29.45
place boars into crate	1	26.06	26.06			0.00	1	26.06	26.06	1	26.06	26.06	1	26.06	26.06
close crate & stone on it	1	15.5	15.50			0.00	1	15.5	15.50	1	15.5	15.50	1	15.5	15.50
to next pen (castration)	1	31.36	31.36			0.00	1	31.36	31.36	1	31.36	31.36	1	31.36	31.36
boars on trolley & crate out	1	48.38	48.38			0.00	1	48.38	48.38	1	48.38	48.38	1	48.38	48.38
beer into castration trough	6	10	60.00	6	10	60.00	6	10	60.00	6	10	60.00	6	10	60.00
castrate	6	18.22	109.3	6	18.22	109.3	6	18.22	109.3	6	18.22	109.3	6	18.22	109.3
tail docking boars	6	5.22	31.32	6	5.22	31.32	6	5.22	31.32	6	5.22	31.32	6	5.22	31.32
boar out of trough into pen	6	5.32	31.92	6	5.32	31.92	6	5.32	31.92	6	5.32	31.92	6	5.32	31.92
sand 'zilver dust'	0.13	108	13.50	0.13	108	13.50	0.13	108	13.50	0.13	108	13.50	0.13	108	13.50
crates out of room	0.13	48	6.00	0.13	48	6.00	0.13	48	6.00	0.13	48	6.00	0.13	48	6.00
Total			1222			903			1181			1112			1229

4.3.2 Labour demand per treatment

In table 4.10 total labour demands for treatment of a litter of piglets (6 males and 6 females) at the participating farms are compared for each treatment. Since there were differences between the treatments at the six farms (iron injection, administration of Baycox, tail docking), total labour times can not be directly compared between farms to judge labour efficiency. Table 4.4 up to and including table 4.9 show which work elements were included in the treatments at all farms.

Table 4.10 Survey of labour demand (cmin/litter with 12 piglets of which 6 are boars) per treatment per farm

	treatment					
farm	anaesthesia by veterinarian [1]		no pain reduction	anaesthesia by pig farmer	analgesia by pig farmer	anaesthesia and analgesia by pig farmer
farm 1	987	151	751	1037	913	1132
farm 2	1830	224	1369	1633	1552	1714
farm 3	1198	140	855	1149	1085	1184
farm 4	940	124	741	947	864	1192
farm 5	1077	94	945	1152	1087	1200
farm 6	1222	158	903	1181	1112	1229
average	1209	149	927	1183	1094	1275
SEM[2]	132	18	94	97	103	89

[1] The left column presents total labour demand (of veterinarian and animal keepers), the right column presents labour demand of the veterinarian only. (Labour demand of the veterinarian needed to change clothes and eventually take a shower – about 9 minutes per visit – are not included here. These costs are included in the visiting fees.)
[2] Standard Error of the Means

Since the objective of this study was not to compare differences between farms, but to find the effect of pain reduction on labour demand, table 4.11 shows the extra labour demand for the treatments compared to the regular work method (without pain reduction).

Table 4.11 Additional labour demand (cmin/litter with 12 piglets of which 6 are boars) per treatment per farm, compared to the regular work method ('no pain reduction')

	treatment					
farm	aneasthesia by veterinarian [1]		no pain reduction	aneasthesia by pig farmer	analgesia by pig farmer	aneasthesia and analgesia by pig farmer
farm 1	236	151	0	286	162	381
farm 2	461	224	0	264	183	345
farm 3	343	140	0	294	230	329
farm 4	199	124	0	206	123	451
farm 5	132	94	0	207	142	255
farm 6	319	158	0	278	209	326
average	282^{cd}	149	0^{a}	256^{cd}	175^{b}	348^{d}

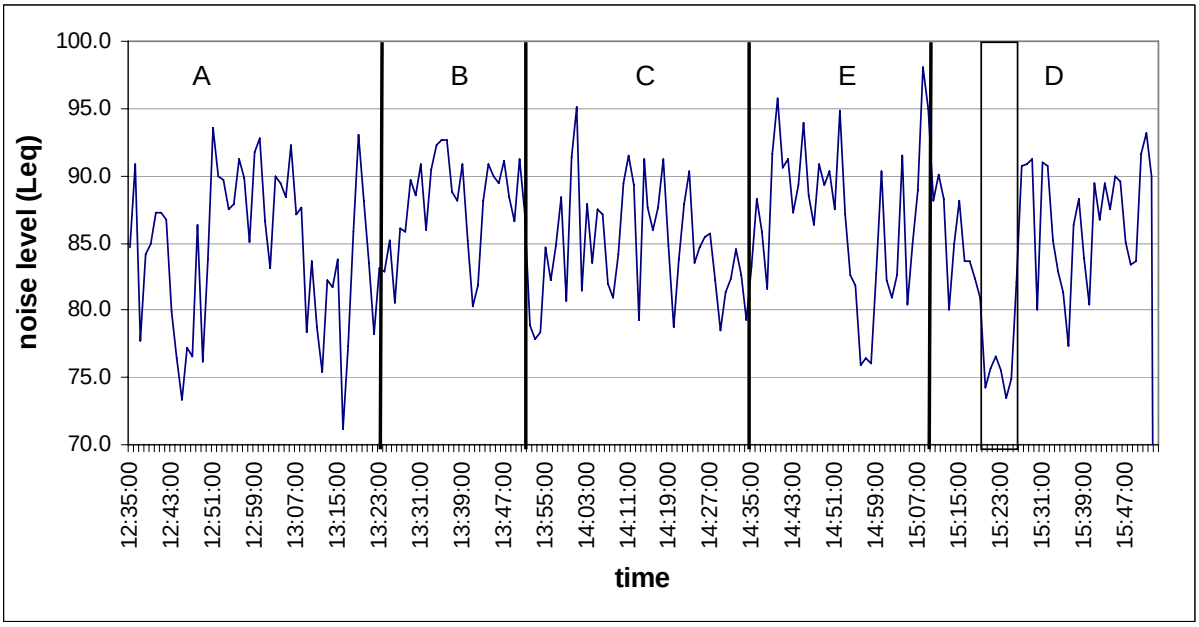
[1] The left column presents total labour demand (of veterinarian and animal keepers), the right column presents labour demand of the veterinarian only. (Labour demand of the veterinarian needed to change clothes and eventually take a shower – about 9 minutes per visit – are not included here. These costs are included in the visiting fees.)
[a, b, c, d] Differences between numbers with different superscripts are statistically significant

Table 4.11 shows that less labour is needed for castration without pain reduction compared to the other treatments. When the pig farmer (or his animal keepers) administers meloxicam into the neck of the piglets before castration, labour demand increases by 1.8 minutes per litter ($p<0.001$). For administration of lidocaine into both testicles even more time is needed ($p<0.05$): extra labour demand is 2.6 and 2.8 minutes per litter for administration of lidocaine by the animal keepers or by the veterinarian, respectively. The 2.8 minutes for anaesthesia by a veterinarian includes 1.5 minutes for the veterinarian and 1.3 minutes for the animal keepers.
Most labour is needed for treatment E (aneasthesia and analgesia by pig farmer), labour demand increases by 3.5 minutes/litter compared to 'no pain reduction'.

4.3.3 Noise exposure of animal keepers during castration

Due to differences between rooms at the same farm, differences between weather conditions (and therefore noise level of ventilators) and a failure in the measurement equipment, it is not possible to compare noise levels between the treatments measured on most farms. Only the measurements of noise levels during the treatments on farm 4 can be compared. Those measurements were done in succession and in rooms that were almost equal. Figure 4.3 shows the course of A-weight equivalent noise levels (L_{Aeqw}) during the periods when a treatment was executed. A part of the data in test period D is not included in the further calculations since the work was interrupted for a while.

Figure 4.3 Course of A-weight equivalent noise levels (L_{Aeqw}) during the periods when a treatment was executed at farm 4



As figure 4.3 shows L_{Aeqw} varied considerably during the individual treatment periods (A, B,C, D and E). Each treatment period contains periods with relatively low noise levels and periods with very high noise levels. Noise levels below 70 dB(A) are rare since mostly the animals and ventilators produce more noise than that. Figure 4.3 and the original data (not published) don't indicate that noise levels during castration were higher than noise levels during other work elements when piglets were handled. The A-weight equivalent noise levels during the periods when treatments were executed are presented in table 4.12.

Table 4.12 A-weight equivalent noise levels during the periods when treatments were executed (farm 4)

Treatment		noise level (dB(A))	duration (minutes)	proportion of accepted dose per day (%)
A	anaesthesia by veterinarian	87.3	48	17
B	no pain reduction	88.8	29	15
C	anaesthesia by pig farmer	86.9	42	14
D	analgesia by pig farmer	87.3	33	15
E	anaesthesia and analgesia by pig farmer	90.1	35	24

Table 4.12 doesn't suggest a relation between treatment and noise level at the ear of the animal keepers. Without pain reduction (treatment B), the noise level seems a little higher than with anaesthesia (treatment A and C) or analgesia (treatment D), but during the treatment with anaesthesia and analgesia (treatment E) it seems to be even higher. Further comparison between farms doesn't show a consistent treatment effect: at farm 1 noise level was higher during treatment D (85.3 dB(A)) than during treatment B (83.2 dB(A)), while the situation at farm 4 was just the opposite (see table 4.12). Further, at farm 2 noise level was higher during treatment A (88.1 dB(A)) than during treatment B (82.9 dB(A)), while at farm 4 this was also opposite.
It is notable that the noise exposure of the animal keepers during castration at farm 4 was considerably higher during treatment E (24% of accepted daily dose) than during the other treatments (on average 15% of accepted daily dose). However, due to variations as described no conclusions can be drawn on these data.

4.3.4 Postures

Scores of observed postures during administration of lidocaine or meloxicam are presented in table 4.13.

Table 4.13 Posture scores (category 1, 2 or 3) during anaesthesia by veterinarian (A) or by the pig farmer (C), or during analgesia (D) at the six farms

	farm 1			farm 2			farm 3			farm 4			farm 5			farm 6		
part of the body	A	C	D	A	C	D	A	C	D	A	C	D	A	C	D	A	C	D
head	1	2	1	1	2	1	2	2	2	1	1	1	1	1	1	1	1	1
back	3	1	1	2	1	1	2	1	1	1	1	1	2	1	1	1	2	1
arms	2	1	1	2	1	1	3	3	1	1	1	1	1	1	1	1	1	1
wrists	1	1	2	2	2	1	1	2	2	1	1	1	1	1	1	1	2	1
legs	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1

Table 4.13 shows a large variation between farms, or in fact between farmers or animal keepers.
In general the heads don't hang very much, but category 2 (bend more than 25°) occurs more during administration of lidocaine (C) than during administration of analgesia (D). This is due to more precision work during administration of lidocaine into the testicles than during administration of meloxicam into the neck.
During administration of meloxicam, the back was hardly bent (less than 20°), but during administration of lidocaine it was. Also this is due to precision work. However, especially the bend of the back differs a lot between persons. The veterinarians at farm 1 and farm 3 bent their back very far (more than 60°), causing a serious physical load. At farm 1 the veterinarian bent towards the pig farmer who was standing in the farrowing pen when he fixed the piglets. At farm 5 the veterinarian stood bent over the pig with piglets when he administered lidocaine. The other veterinarians and animal keepers stood almost straight during administration of lidocaine. Use of a castration clamp during administration of lidocaine, as on farm 1, stimulates a good posture of the back.
In general, the arms were not held in a loading posture, except at farm 3 where both the veterinarian and the animal keeper bent an upper arm backwards during administration of lidocaine, resulting in posture score 3.
The posture of the wrists depends strongly on the design of the syringe. When a revolver syringe is used, posture of the wrist and hand that hold the syringe is not loading. Posture of the other wrist and hand depend of the way the piglets are fixed. Used of a castration clamp stimulates a good posture of the wrist too.
Since almost all veterinarians and animal keepers worked standing, posture of the legs was not loading except at farm 5 where the veterinarian worked sitting on his heels.
It must be mentioned that posture scores in table 4.13 were only observed during administration of lidocaine or meloxicam. It depends on the way of handling the piglets whether or not the other work elements are physically loading. Usually they are lifted from a crate or bin, causing bending of the back during a longer or shorter period.

4.3.5 Economic evaluation

Based on the measurements of labour demand, it was concluded that for all treatments for pain reduction more labour is needed than for castration without pain reduction. The amount of extra labour demand differs between farms. In the calculations the additional labour demand per piglet as shown in table 4.14 is used. These data are derived from table 4.11.

Table 4.14 Extra labour demand (cmin/castrated piglet) per treatment

Treatment		Extra time veterinarian			Extra time farmer		
		Mean	Min.	Max.	Mean	Min.	Max.
A	aneasthesia by veterinarian	25	16	37	22	6	40
B	no pain reduction	0	-	-	0	-	-
C	aneasthesia by pig farmer	0	-	-	43	34	49
D	analgesia by pig farmer	0	-	-	28	13	38
E	aneasthesia and analgesia by pig farmer	0	-	-	58	43	75

Treatment A: Anaesthesia by veterinarian
In table 4.15 the costs structure and total additional costs for anaesthesia by a veterinarian are presented.

Table 4.15 Additional costs (Euro/male piglet) for anaesthesia by a veterinarian in different scenarios for farm size and frequency of castration

	Farm size (number of sows)			
	< 100	100-200	200-400	> 400
Castration once a week				
Costs of visits	2.38	0.79	0.44	0.17
Costs labour time for anaesthesia veterinarian	0.42	0.42	0.42	0.42
Costs labour time for farmer	0.09	0.09	0.09	0.09
Costs of materials	0.10	0.10	0.10	0.10
Total	2.99	1.40	1.05	0.78
Castration twice a week				
Costs of visits		1.85	1.02	0.41
Costs labour time for anaesthesia veterinarian		0.42	0.42	0.42
Costs labour time for farmer		0.09	0.09	0.09
Costs of materials		0.10	0.10	0.10
Total		2.45	1.63	1.02
Castration once in two weeks (including analgesia by farmer)				
Costs of visits	0.79	0.26	0.15	0.06
Costs labour time for anaesthesia veterinarian	0.42	0.42	0.42	0.42
Costs labour time for farmer	0.21	0.21	0.21	0.21
Costs of materials	0.18	0.18	0.18	0.18
Total	1.60	1.07	0.91	0.87
Castration once in two weeks (no additional analgesia)				
Costs of visits	0.79	0.26	0.15	0.06
Costs labour time for anaesthesia veterinarian	0.42	0.42	0.42	0.42
Costs labour time for farmer	0.09	0.09	0.09	0.09
Costs of materials	0.10	0.10	0.10	0.10
Total	1.40	0.87	0.75	0.67

Table 4.15 demonstrates that the total additional costs vary between € 0.67 per male piglet (visit once per two weeks on farms with more than 400 sows and without additional use of analgesia) and € 2.99 per piglet on farms with less than 100 sows.
Table 4.15 also demonstrates that the number of visits (the number of times per week the castration process is executed) affects the total costs greatly. On a farm with 100 up to 200 sows, the costs per piglet increase by 75% if castration is done twice a week instead of once a week. Even on farms with more than 400 sows the costs increase more than 30% if castration is done twice a week instead of once a week.
Total costs reduce if castration is done once in two weeks (instead of every week) and additional analgesia is administered by the farmer, except for farms with more than 400 sows.
If castration is done only once in every two weeks the administration of analgesia is assumed to be legally obliged because most piglets are older than seven days.

Table 4.16 presents the total additional costs at farm level. They vary between € 1000 and € 2000 on farms with less than 100 sows and between € 5,800 and € 9,000 on farms with more than 400 sows. Also, this table shows that additional costs are lowest if castration is done once in two weeks without additional administration of analgesia. Additional costs are highest if piglets are castrated twice a week.

Table 4.16 Total additional costs (€/farm) for anaesthesia by a veterinarian, depending on farm size and frequency of castration.

frequency of castration	Farm size (in number of sows)			
	<100	100-200	200-400	>400
Once a week	1950	2750	3725	6900
Twice a week	Not relevant	4825	5825	9000
Once in two weeks[1]	1050	2100	3400	7575
Once in two weeks without analgesia	925	1725	2700	5850

[1] with additional analgesia by animal keeper (farmer)

Treatment C: Anaesthesia by pig farmer
If lidocaine can be administered by the farmer (or animal keepers) no extra visits of veterinarians are needed and therefore additional costs will not depend on the farm size (all costs depend on the number of piglets).
Total costs are € 0.10 for lidocaine and about € 0.18 for additional labour of the farmer. These costs will differ among farmers. In this study, the minimal and maximal times needed by the farmer were 0.34 minutes and 0.49 minutes, respectively. Therefore total extra costs per castrated piglet vary between € 0.24 and € 0.30.

Treatment D: Analgesia by farmer
The extra time farmer the farmer needs for administration of meloxicam is about 0.28 minutes per male piglet. Costs for the drug are estimated at € 0.08 per piglet. Therefore total extra costs for administration of analgesia (meloxicam) are € 0.19 per castrated piglet.
In this study, the minimal and maximal times needed by the farmer were 0.13 minutes and 0.38 minutes, respectively. Therefore total extra costs per castrated piglet vary between € 0.13 and € 0.24.

Treatment E: Anaesthesia and analgesia by pig farmer
Also for this treatment there are no extra costs for veterinarians and therefore the costs don't differ among farms with different herd sizes. The total extra costs (€ 0.42 per male piglet) consist of € 0.24 labour costs of the animal keepers (0.58 minutes at € 25/hour) and € 0.18 for drugs.
In this study, the minimal and maximal times needed by the farmer were 0.43 minutes and 0.75 minutes per castrated piglet, respectively. Therefore total extra costs per castrated piglet vary between € 0.36 and € 0.49.
The total costs of this treatment are almost the same as the sum of the additional costs of treatment C and treatment D (between € 0.37 and € 0.54).

4.3.6 Effects at national level

Cost at a national level are calculated by multiplying the additional costs per male piglet (table 4.15) by the number of piglets (based on table 4.3).
Treatment A (anaesthesia by veterinarian) costs € 13 million when all farmers castrate their piglets once a week. If this is done twice a week the costs of this treatment are about € 19 million. If castration is done once in every two weeks costs are € 9 million without additional analgesia and € 12 with additional analgesia.
The extra costs are mainly labour costs for the veterinarians. Therefore, more veterinarians are needed if this work method becomes legally required. Supposing a veterinarian works 1600 hours/year, about 76 full time veterinarians are needed if castration is done once a week at every farm. If castration is done twice a week or once in every two weeks the number of additional veterinarians needed is 124 and 47, respectively.
Cost for veterinarians can be presented in another way too. If a veterinarian costs € 125.000 per year, 47 up to 124 additional veterinarians cost between € 6 million and € 16 million. Not included in these costs are labour costs for the animal keepers (€ 2.5 million) and for drugs (€ 2.5 million).
Between almost 50% and 75% of the costs for veterinarians are visiting fees and labour costs for entering the livestock building, changing clothes and other hygienic measures. Only between 25% and 50% of the costs for veterinarians are needed for actual administration of lidocaine.

The economic consequences of treatments C, D and E (anaesthesia and/or analgesia by the pig farmer) are smaller. National total costs of anaesthesia by farmers, using lidocaine, are € 3.4 million. For analgesia, using meloxicam, these costs are € 2.3 million. Combination of these (treatment E) costs about € 5 million per year. Of course, no additional veterinarians are needed in these scenarios.

The additional costs for anaesthesia and/or analgesia during castration can be expressed in different ways. Which way is the most relevant depends on the question whether, and how, pig farmers can pass on these costs to their customers. Table 4.17 presents an overview of the pig meat production chain, from pig producer to supermarket. The additional costs at national level are expressed for several intermediary products in the production chain for treatment A (anaesthesia by veterinarian, once a week) and treatment E (anaesthesia and analgesia by pig farmers). It shows for instance that additional costs for anaesthesia by veterinarians are € 0.50 per piglet born alive, and € 0.14 per kilogram fresh Dutch pig meat sold in Dutch supermarkets.

Table 4.17 Costs of pain reduction during castration, expressed in several intermediary products in the Dutch pig meat production chain (base year 2005, source PVV, adapted by LEI)

intermediary product	quantity	Anaesthesia by veterinarians, once a week (treatment A); total costs € 12 million.	Anaesthesia and analgesia by pig farmers; total costs € 5 million.
Piglets (born alive)	24 million	€ 0.50/piglet	€ 0.20/piglet
piglets (25 kg)	21 million		
piglets exported (net export)	4 million		
growers-finishers (x million)	16.8 – 16.3	€ 0.74/pig	€ 0.30/pig
export finishing pigs (net export)	2 million		
slaughtered pigs in the Netherlands	14.2 million		
pig meat (x 1000 tons, with bones)	1,300	€ 0.01/kg pig meat	€ 0.004/kg pig meat
imported pig meat (x 1000 tons, with bones)	236		
exported pig meat (x 1000 tons, with bones)	855		
Dutch consumption of pig meat (x 1000 tons, with bones)	681	€ 0.02/kg consumed pig meat	€ 0.008/kg consumed pig meat
Dutch consumption of fresh Dutch pig meat, sold in supermarkets (x 1000 tons, with bones)	82	€ 0.14/kg fresh Dutch pig meat, sold in supermarkets	€ 0.06/kg fresh Dutch pig meat, sold in supermarkets

4.4 Discussion

4.4.1 Optimization of scenarios with anaesthesia by veterinarians

Optimization of tactics

Table 4.15 shows that the optimized frequency of castration including anaesthesia by a veterinarian depends strongly on the number of sows at the farm. At farms with less than 200 sows it is cheapest to castrate once in every two weeks (and use additional analgesia, since many piglets will be older than seven days). For farms with 200 up to 400 sows this frequency is also the least expensive option, but weekly castration is not much more expensive (€ 0.13 per male piglet) for them.

It must be mentioned that – on average – piglets are older and therefore heavier in scenarios with castration every two weeks than in scenarios with weekly castration. Therefore, labour demand for anaesthesia and castration will increase (see appendix 7.2). This effect is not included in table 4.15. Further, welfare of the piglets, animal keepers and veterinarians decreases when piglets are older and heavier at castration.

For pig farmers with more than 400 sows total costs are lowest with weekly castration.

Work organization around castration if anaesthesia is done by a veterinarian

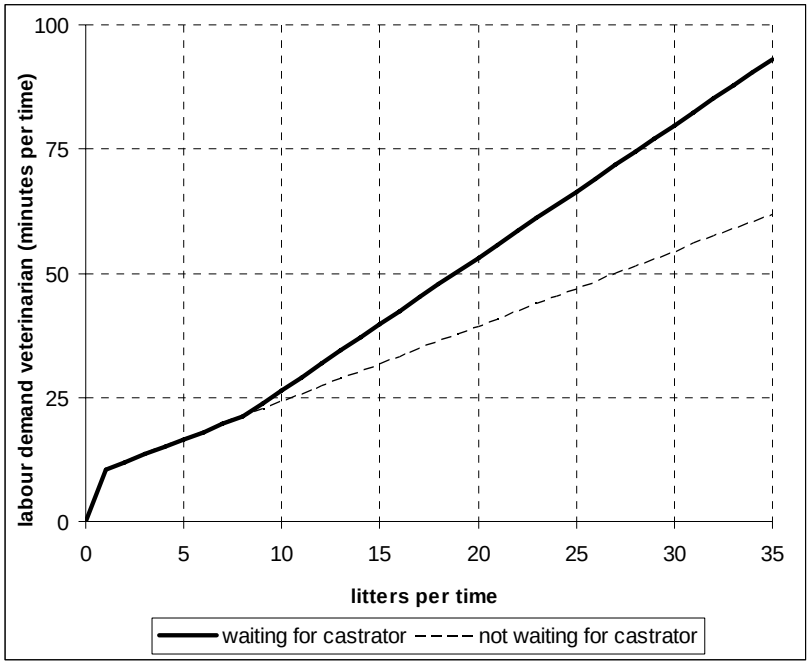
Almost all pig farmers combine several treatments of the piglets, to reduce the number of times they have to collect the piglets. Table 4.18 shows that the labour time for the veterinarian to anaesthetize the piglets is shorter than the labour time for castration by the animal keepers. Since castration has to be done between 10 and 20 minutes after anaesthesia, one animal keeper can't do any additional treatments without increasing the waiting time of the veterinarian.

Table 4.18 Labour demand (cmin/litter) for work element affecting work organization around castration, difference between labour demand for castration and for anaesthesia, and number of litters that can be treated before the veterinarian has to wait

	farm 1	farm 2	farm 3	farm 4	farm 5	farm 6	average	s.d.
preliminary work	508	697	700	265	907	533	601	218.7
anaesthesia	151	224	140	124	109	158	151	39.9
castration	165	324	299	255	246	312	267	58.9
difference anaesthesia – castration	13.3	99.8	159.1	130.4	136.9	154.6	115.7	54.4
number of litters	75.4	10	6.3	7.7	7.3	6.5	18.9	27.7

To reduce the waiting time for the veterinarian, the animal keepers will collect all piglets and do all the preliminary work (iron injection, application of I&R ear tags, tail docking *et cetera*) and place the male piglets in crates or bins before the veterinarian arrives for anaesthesia. But, even then, the veterinarian works much faster than the animal keeper.
Table 4.18 presents the number of litters (with on average six boars per litter) that can be anaesthetized without creating waiting time for the veterinarian or exceeding the maximum time (20 minutes) between anaesthesia and castration. At farm 1 castration is done very quickly, the other animal keepers needed considerably more time. Therefore farm 1 was excluded and it is concluded that – to realize a waiting period between 10 and 20 minutes – no more than eight litter can be castrated by one animal keeper without creating a waiting time for the veterinarian. If more litters need to be castrated and the work method is not adapted, labour time (and therefore costs) for the veterinarian increase as shown in figure 4.4. The vertical space between 'waiting for castrator' and 'not waiting for castrator' demonstrates the waiting time for the veterinarian.
A practical measure to prevent these additional costs is castration by two animal keepers, since the tariff of a veterinarian (€ 100/hour) is much more than the tariff for animal keepers (€ 25/hour).

Figure 4.4 Labour demand (minutes/time) for anaesthesia by a veterinarian with and without waiting for the castrator



Hour tariffs of veterinarian
In the calculation it is assumed that veterinarians cost € 100/hour. The tariffs of the veterinarians at the farms in this study varied between € 65 and € 120/hour. In most cases there is a relation with the visiting fee (low visiting fee and high fee per hour and vice versa).
If the tariff of the veterinarian is not € 100 but € 80/hour, the decline of total costs will be between € 1million and € 1.5 million in scenarios with treatment A.

4.4.2 Variation among farmers

Due to large differences between farms it is difficult to draw general conclusions. This concerns labour demand (table 4.11) as well as visiting fees (table 4.15) and noise exposure (table 4.12). (The latter is partly dependent on labour demand.)
Additionally, the noise levels measured in this study match well with results from Roelofs and Adams (not published, 2000), namely 85.4 dB(A) during tail docking, castrating, tooth cutting and iron injecting and 90.5 dB(A) during castration only.
The extra labour demand for analgesia by the pig farmer (treatment D) varied between 0.13 and 0.38 minutes per piglet (table 4.13). For farms with 400 sows a difference of 0.25 minutes per piglet results in a difference of 20 hours per year. With a tariff of €25/hour the extra costs are € 500/year. However, it should be mentioned that tempo is not the only important factor. If fast castration results in more castration wounds – or even more dead piglets – the extra costs will quickly exceed the benefits of the labour savings. It is more important that the total process of castration (including all other treatments) is executed in a good way than that this process is executed fast, both from an economic and from an ethical point of view.
Further, it is not always possible to apply the work method that is economically optimal or otherwise desired by a pig farmer. For example the location of the buildings and the design of the rooms affect run lines and equipment (like piglet treatment trolleys) that can be used.

4.4.3 Costs related to income

The calculated total costs for anaesthesia by a veterinarian (treatment A, castration once per week) are between € 2,000 at a farm with less than 100 sows and € 7,000 at a farm with more than 400 sows.
On average, between 2001 and 2005 the income of pig farmers with less than 300 sows was € 13,500, while farmers with more than 300 sows earned € 63,250 per year. The period 2001-2005 includes three poor years (2001-2003) and two good years (2004-2005) for pig farmers.
Relating € 2,000 to € 13,500 and relating € 7,000 to € 63,250 results in an income decline of 15% and 11%, respectively. This comparison is not quite accurate, since farm size in both groups is not equal.
Explicitly for farms with 200 – 400 sows, the additional costs for anaesthesia by a veterinarian during castration are about € 3,725. The annual income of these farmers between 2001 and 2005 was € 33,000. Therefore, for these farmers the additional costs of anaesthesia by a veterinarian are more than 11% of the average income during the past years.

4.4.4 Comparison with other studies

In Norway, male piglets have to be anaesthetized and castrated by a veterinarian since 2002. The extra costs of anaesthesia are estimated by farmers and veterinarians at € 12.70 and € 13.10 per litter, respectively (Frederiksen, 2007a). Per visit, about 8 to 10 litters are castrated at an age of approximately 8 days. Although a mean farm has only 105 litters annually, this is enabled by group farrowing (Frederiksen, 2007b). This also enables veterinarians to combine 66% of the farm visits for castration with the 'regular' farm visits.
Compared to the results of this study (between € 6 and € 7.50 per litter) additional costs in Norway are high. Reasons are that in Norway the veterinarian also has to castrate the piglets (in the Netherlands the pig farmer or the animal keepers castrate) and that pig farms in Norway are smaller than the Dutch. (In Norway it is not allowed to have more than 105 sows or more than 50 sows and their finishing pigs at one location. To protect their pig farmers, the government levies very high taxes on imported meat (Ten Hooven, 2005).

Eijck *et al.* (2007) have estimated the extra costs for anaesthesia on organic pig farms at about € 2 per litter. That is considerably less than the € 6 - € 7.50 in this study. However, the additional labour demand that was measured in both studies was almost equal. Eijck *et al.* (2007) found 1.32 minutes for anaesthesia of five piglets, and in this study 1.35 minutes was found. Labour demand for castration was 2.38 minutes and 2.37 minutes, respectively. The differences in costs found in this study and found by Eijck *et al.* (2007) can be explained, since:

a) Eijck *et al.* (2007) include five boars in each (organic) litter, while in this study six boars are included;
b) Eijck *et al.* (2007) assume an hour tariff of € 80 for veterinarians, while in this study € 100 is assumed;
c) Eijck *et al.* (2007) assume € 30 visiting fees and no additional costs for hygienic measures (changing clothes, showering), while this study is calculated with € 40, including € 25 visiting fees and € 15 labour costs (9 minutes) for hygienic measures;
d) Eijck *et al.* (2007) spread visiting fees over 100 sows, while in this study farms with less than 100 sows have on average only 51 sows (table 4.3);
e) Eijck *et al.* (2007) did not include labour costs of the farmer (or animal keepers);
f) Eijck *et al.* (2007) did include some of the minor costs, which are not included in this study.

4.4.5 Other points of interest

- The cleaning of the crates or bins wherein the boars are separated while they are waiting for the veterinarian and/or waiting between anaesthesia/analgesia and castration needs more attention. During the experiments none of the farmers cleaned the crates or bins, although some of them placed fresh wood shavings in the bins. To prevent transfer of infections from one room to another, a set of bins for each room is needed, but even then cleaning is still desirable.
  Anyway, even in the regular work methods (without pain reduction) most pig farmers push a piglet treatment trolley from one room to another and collect piglets in the crates on this trolley without any cleaning and disinfection.
- Not all bins and crates, used in this studywere very suitable to cage the male piglets, since piglets could escape if there were many boars in a litter. (The time needed to collect them again was not included in the tables and in the calculations).
- Several pig farmers and animal keepers mentioned that castration with anaesthesia 'felt' different than castration without pain reduction or with analgesia. The injection of lidocaine damaged the testicles, which made it more difficult to grip them. One of the animal keepers frequently had to grip twice. This did not result in significant extra labour demand for castration after anaesthesia. It isn't known if this effect will disappear when the animal keepers get more experienced with this treatment.
  Further, the piglets seemed to bleed more after castration with anaesthesia than after castration without.
- For smooth anaesthesia and to reduce the risk of pricking the needle in a finger, a very sharp needle that is not too long is needed. Nevertheless one of the animal keepers pricked in his fingers, which is undesirable.

4.5 Conclusions

- Pain reduction during castration results in an additional labour demand for pig farmers (or animal keepers) of 0.25 minutes/male piglet when a veterinarian anaesthetizes using lidocaine, 0.43 minutes/male piglet when the animal keepers anaesthetize using lidocaine, 0.28 minutes/male piglet when the animal keepers inject an analgesia (meloxicam) into the neck and 0.58 minutes/male piglet when animal keepers administer lidocaine and meloxicam. When a veterinarian anaesthetizes, an additional 0.22 minutes/male piglet are needed for the veterinarian.
- Pain reduction (anaesthesia and/or analgesia) seriously affect work organization around castration. Due to the waiting period of at least 10 minutes between anaesthesia/analgesia and castration, the boars have to be separated and work elements can not be executed directly one after another.
- If anaesthesia is done by a veterinarian, the preliminary work should be done before the veterinarian arrives at the farm. This means that male piglets are separated and waiting for anaesthesia.
  When more than eight litters must be castrated, it is advised to have two animal keepers castrating. If not, the (expensive) veterinarian will have to wait or the waiting time between anaesthesia and castration will exceed 20 minutes (the maximal waiting period).
- If anaesthesia is done by animal keepers, they will continuously have to consider the waiting time. Most times they will have to do the preliminary work (including anaesthesia) in two of three litters and return to the first pen for castration.
- In the case of analgesia, the length of the waiting time is more flexible, due to the long-term effectiveness of meloxicam.
- The equivalent noise level is not strongly affected by the tested treatments for pain reduction. Due to increased labour demand, the total noise exposure of the animal keeper increases between 20% and 30%.
  During all treatments (including castration without pain reduction) the noise level (between 87 dB(A) and 90 dB(A) was so high that hearing protection products should be worn.
- Due to the waiting time between anaesthesia and/or analgesia, the male piglets will have to be picked up at least once more in treatments with pain reduction than according to the regular work method. Most times, this means that the animal keepers have to bend their back greatly once more for every male piglet, and that piglets of about 1.5 kg have to be lifted.
  The posture of the body is very dependent of personal habits. If animal keepers and veterinarian stand straight as much as possible, the posture is not physically loading.
- If castration is executed once a week on a farm with 200 – 400 sows, the additional costs for labour and drugs are € 1, € 0.28, € 0.19 and € 0.42 per male piglet for anaesthesia by a veterinarian, anaesthesia by animal keepers, analgesia by animal keeper and anaesthesia and analgesia by animal keepers, respectively.
- Farm size strongly affects extra costs for 'anaesthesia by veterinarian'. The additional costs on small farms (€ 1.40 per male piglet) are at least twice the costs on large farms (€ 0.67 per piglet).

- For treatment A (anaesthesia by veterinarian) extra costs depend strongly on the number of times per week castration is executed. If it is done twice a week instead of once a week, the total cost increases by 30 % on large farms and 75% on farms with 100 up to 200 sows.
- At a national level, total extra costs for treatment A (anaesthesia by veterinarian) are estimated to be between € 9 million and € 19 million per year. When all farmers castrate their piglets once a week, total costs are estimated at € 13 million per year.
- A large part of the total costs are out of pocket costs for farmers to hire a veterinarian for the anaesthesia. Especially visiting costs will increase substantially if anaesthesia has to be done by veterinarian. The average income of pig farmers will reduce by 10% up to 15%.
- If anaesthesia and/or analgesia can be administered by the farmer, the total extra costs on a national level will be between € 2 million and € 5 million per year. Administration of the analgesia meloxicam will cost about € 2 million, administration of anaesthesia (lidocaine) € 3 million.
  Considering that about 12 million piglets are castrated annually, the costs per castrated piglet for administration of analgesia, anaesthesia and both are € 0.19, € 0.28 and € 0.42, respectively (costs of drugs included).
- There is a huge variation among farmers (and also among veterinarians) in labour time needed to administer drugs. This results in a variation in the total costs. It should be mentioned that labour time is not the only point of interest: if a lower labour demand goes together with a poor quality of administration of drugs or castration, 'fast' can be very expensive (e.g. if piglets die).

5 Castration of piglets using carbondioxide anaesthesia

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5.1 Introduction

Pain can be described as an aversive and sensitive experience representing an awareness of damage to the tissues (Molony and Kent, 1997). The purpose of anaesthesia is to remove this awareness. Inhalant anaesthetics can be very effective in this respect. They evaporate readily at room temperature and can therefore be administered via the airways. They cause a depression of the central nervous system, resulting in muscle relaxation and loss of consciousness.
Inhalation anaesthesia also has limitations. An overdose leads to paralysis of the respiratory muscles, which leads to death by suffocation. In addition, during induction there is an excitation phase, i.e. a period of increased activity and strong uncontrolled movements. Compared with injectable anaesthetics, this phase lasts for a long time. The weaker the anaesthetic effect, the longer the excitation phase.
The anaesthetics halothane and methoxyflourane cause little excitation and are therefore widely used in surgery. However, prolonged inhalation is harmful (liver cirrhosis), and they must therefore be used in air-conditioned rooms (Zutphen et al, 1991).
A low dose of CO_2 (approx. 20%) also has a narcotic effect in several animal species (Dannemann et al, 1997; Gerritzen et al, 2006). CO_2 is often used in combination with other gases, producing potentiation and/or reduced excitation, but the mechanism is not always clear. An example is reduced excitation if a combination of CO_2 and O_2 is used (Coenen et al, 1995; McKeegan et al, 2005).
Currently, a gas mixture of 40% CO_2 + 30% O_2 + 30% N_2 is used to stun broilers and turkeys prior to slaughter. After 2 minutes, the animals are placed in an environment with 70% CO_2 in order to euthanise them (Hoen and Lankhaar, 1998). In the case of slaughter pigs, only high concentrations (> 80% CO_2) are used to kill the animals, which has the disadvantage of a severe excitation phase as the anaesthetic takes effect (Martoft, 2001). A mixture of 70 - 80% CO_2 + 20 - 30% O_2 has been used experimentally to anaesthetise pigs during castration (Svendsen, 2006).
An electroencephalogram (EEG) is used in humans and animals to assess brain activity in different circumstances in terms of state of consciousness and possible deviations. The registered electrical signals from the brain can be divided into four groups: delta (< 4 Hz), theta (4 – 7 Hz), alpha (8 – 13 Hz) and beta (> 13 Hz) waves. Alpha and beta waves indicate a conscious state (Kooi et al, 1978). With most anaesthetics, the EEG moves progressively towards waves with a lower frequency and higher amplitude (theta and delta waves) as more of the anaesthetic is administered. It is known that an isoelectric line can indicate deep anaesthesia as well as brain death (Eger, 1981). An electrocardiogram (ECG) was used to assess heart function. Changes in frequency and characteristics can indicate the effectiveness of heart function (Dubin, 1999).
The aim of this study is to determine which CO_2 / 0_2 ratio is most suitable for anaesthetising piglets in an acceptable way. The most promising mixture was analysed to assess its suitability for castrating piglets painlessly while they are unconscious. Exploratory research was also carried out to establish how long the piglets can safely remain in this mixture.

5.2 Materials and methods

This section describes three phases: 1) establishing gas concentrations, 2) the castration experiment, and 3) experiment to establish maximum exposure time for safe use. The experiments for all three elements were reviewed and approved in advance by the Animal Experiments Committee of ASG-WUR and the University of Utrecht.
The data obtained from the castration experiment were analysed in order to establish effective anaesthesia with a confidence level of 95% . The probability of effective anaesthesia was established according to beta distribution as described by Johnson and Kotz (1969). On the basis of the number of animals that are effectively anaesthetised, beta distribution predicts the percentage of properly anaesthetised animals in a population, with a confidence level of 95%.

5.2.1 Establishing gas concentrations

First, an anaesthesia box was constructed for testing different gas mixtures. The desired mixtures (see Table 5.1) were obtained by mixing CO_2, O_2 and N_2 in different proportions using a three-phase gas mixer. The test mixtures flowed from the gas mixer into the anaesthesia box via a buffer tank. The gas concentration in the box was continuously monitored using a CO_2 / O_2 analyser, and adjusted as necessary. A slight overpressure was maintained in the gas box. Exit gas was carried out of the box through a tube on the lid of the test box (see Fig. 5.1).

Table 5.1 Description of treatments

	Treatments
1	70% CO_2 + 30% O_2. + N_2
2	50% CO_2 + 10% O_2. + N_2
3	60% CO_2 + 20% O_2. + N_2
4	40% CO_2 + 10% O_2. + N_2
5	30% CO_2 + 15% O_2. + N_2
6	30% CO_2 + 30% O_2. + N_2

Figure 5.1 Overview of test situation

Piglets of 3-5 days old were placed in the box. Their behaviour was recorded on video. Once the animals had completely lost their balance, and were lying on their side, they were left for approximately 1 further minute in the CO_2 / O_2 mixture, after which they were taken out and allowed to recover in a plastic box. The anaesthesia status was assessed on the basis of behaviour and clinical reflexes.

Animals: 5 piglets per gas concentration.
Behaviour: loss of posture, duration and intensity of excitation phase
Clinical: posture, eye reflex, pain stimulus (nociception)
Recovery: length of time until the animal can sit and stand

5.2.2 Castration experiment

Piglets were placed individually in a box filled with a gas combination from the pilot experiment. The animals were fitted with EEG and ECG electrodes shortly before they were placed in the gas mixture. The needle electrodes for EEG as well as ECG were inserted subcutaneously and secured with elastic bandage tape. Once anaesthetised, the piglet was taken out of the box after 30 seconds and castrated immediately.
Blood samples were taken shortly before the piglets were placed in the gas mixture and immediately after castration in order to analyse the blood gasses glucose and lactate.

The EEG and ECG readings were used to determine whether the animals were unconscious and insensible before and during castration. The impact on the animals' wellbeing was assessed on the basis of behaviour, electrophysiology and blood values.

Animals: 25 piglets of 5 days old per gas concentration.
Gases: 2 gas combinations 70% CO_2 + 30% O_2 and 60% CO_2 + 20% O_2 + 20% N_2.
EEG: amplitude, waveform and recovery.
ECG: heart rate and waveform
Behaviour: excitation during induction of the gas, reaction to castration, recovery.
Clinical: posture, eye reflex, pain perception during castration procedure.
Blood samples: pH, pCO_2, pO_2, ABE, glucose, lactate.

5.2.3 Establishing the limits

In order to assess the robustness of the system, it is necessary to obtain an impression of the safety margins for the piglets and of how far the gas concentration can be reduced whilst still ensuring full unconsciousness and sufficient freedom from pain.
If the animals remain for too long in an atmosphere with a high percentage of CO_2, death can result. In this respect, this study is a first exploration. In order to determine the maximum length of time that piglets can safely remain in a mixture of 70% CO_2 + 30% O_2, 5 piglets were placed in CO_2/O_2 mixture for 3 minutes, and 3 piglets for 2 minutes. The effects of this were monitored as described in section 3.2.
The gas concentration in the box can decrease as the piglets are placed in the box and taken out of it. It is therefore important to establish the limit for ensuring proper anaesthesia. In order to determine the lower limit, a group of 24 piglets were treated as described in section 3.2, but this time using a gas concentration of 60% CO_2 + 20% O_2 (with N_2 added).

5.3 Results

The results of the three elements of this project are described separately below.

5.3.1 Establishing the gas concentration

In order to determine which gas mixtures are most suitable for castrating painlessly and while the animals are unconscious, 5 animals were exposed to 6 different CO_2 / O_2 mixtures. On the basis of behaviour, the most promising mixture was selected for castration using inhalation anaesthesia. The results are shown in Table 5.2 as mean ± standard error of the mean.

Table 5.2 Effects of different concentrations of O_2 and CO_2 on posture changes of piglets of 3 – 5 days old

General		Treatment		Anaesthesia		Recovery		Remarks
Treatment	Weight kg	O_2 %	CO_2 %	Sittings	Loss of Postures	Sittings	Standings	
1	3.9 ± 0.4	28 ± 0	72 ± 0	13 ± 4	32 ± 7	67 ± 13	103 ± 32	
2	3.2 ± 0.2	11 ± 0	51 ± 1	24 ± 5	41 ± 18	38 ± 8	57 ± 17	1 piglet >300 s
3	3.1 ± 0.7	19 ± 0	60 ± 2	16 ± 5	30 ± 5	45 ± 10	70 ± 14	
4	3.5 ± 0.3	12 ± 0	43 ± 2	29 ± 6	77 ± 24	57 ± 27	61 ± 26	
5	3.4 ± 0.4	14 ± 1	31 ± 2	69 ± 52	86 ± 83	6 ± 8	10 ± 11	
6	3.5 ± 0.4	26 ± 0	30 ± 1	52 ± 9	314 ± 141	27 ± 33	29 ± 38	

The most important findings from this experiment are as follows:

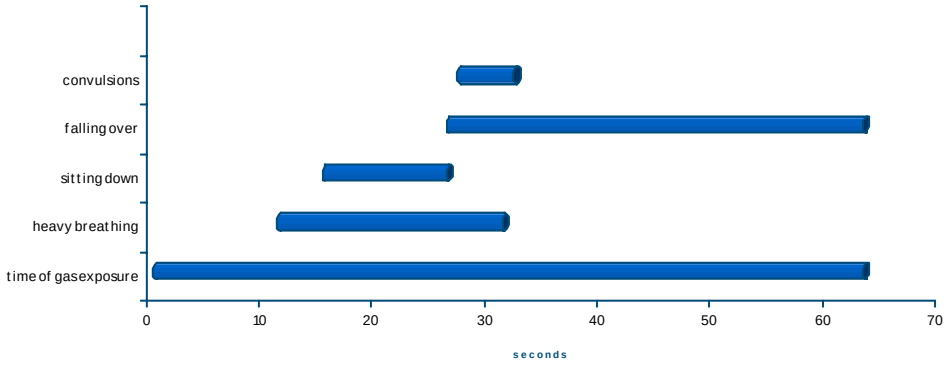
- After placing in the gas box, all animals showed increased respiration, which became heavy when the oxygen level was low
- All animals showed mild to strong convulsions (muscle cramps after loss of posture). The higher the oxygen level, the less strong the convulsions
- All animals turned blue when the oxygen percentage was 14% or lower
- There was doubt as to whether the animals were unconscious during treatments 5 and 6.

On the basis of these results, it was decided to carry out the castration experiment with the 70% CO_2 + 30% O_2 mixture.

5.3.2 Castration experiment

Twenty-five animals were used in this experiment. They were fitted with subcutaneous electrodes to record brain activity and heart rate. The duration and sequence of the observed behaviours are shown in Figure 5.2. During the induction phase, the only typical behaviour exhibited by the piglets was heavy breathing. In the 70/30 mixture, all the animals lost consciousness within 30 seconds. Most of the animals showed one or more convulsions immediately after losing consciousness.

Figure 5.2 Start and duration of behaviours in relation to the moment of placing in the gas mixture (t=0)



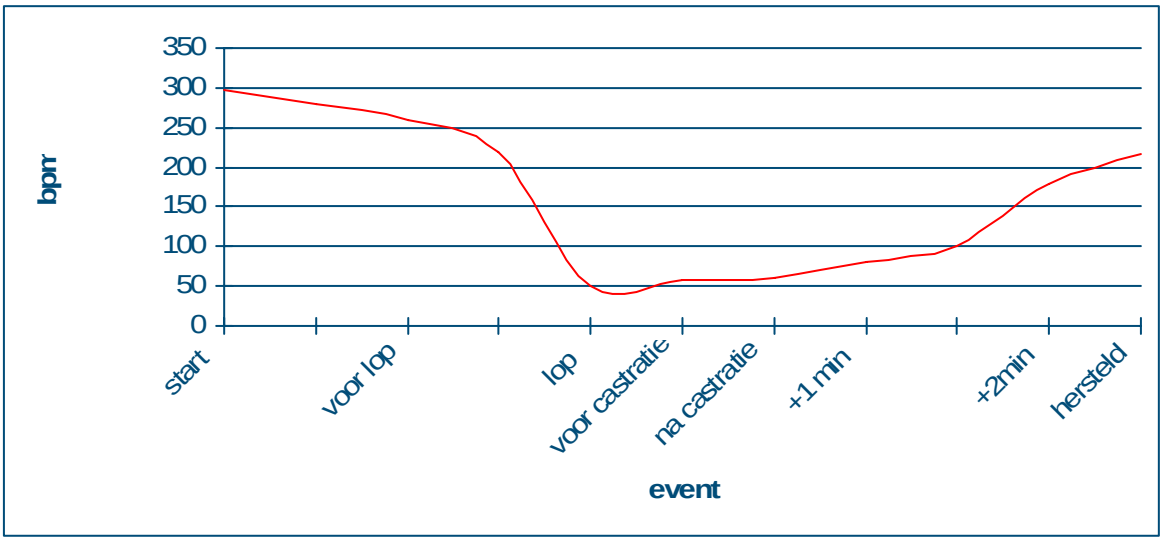
Reduced brain activity (Table 5.3) was observed after an average of 19 seconds. The suppression of alpha and beta frequencies and the onset of theta and delta waves indicated the onset of unconsciousness. Suppression of the theta and delta frequencies occurred after approximately 34 seconds. During this phase there is minimal brain activity and therefore deep unconsciousness.

Table 5.3 Interpretation of the EEG signal

Parameter	70% CO_2 + 30% O_2
No. of animals	24
Unconscious (s)	19
Minimal brain activity (s)	34
Recovery (s)	59
Castration (s)	17
Reaction to castration	0 / 24

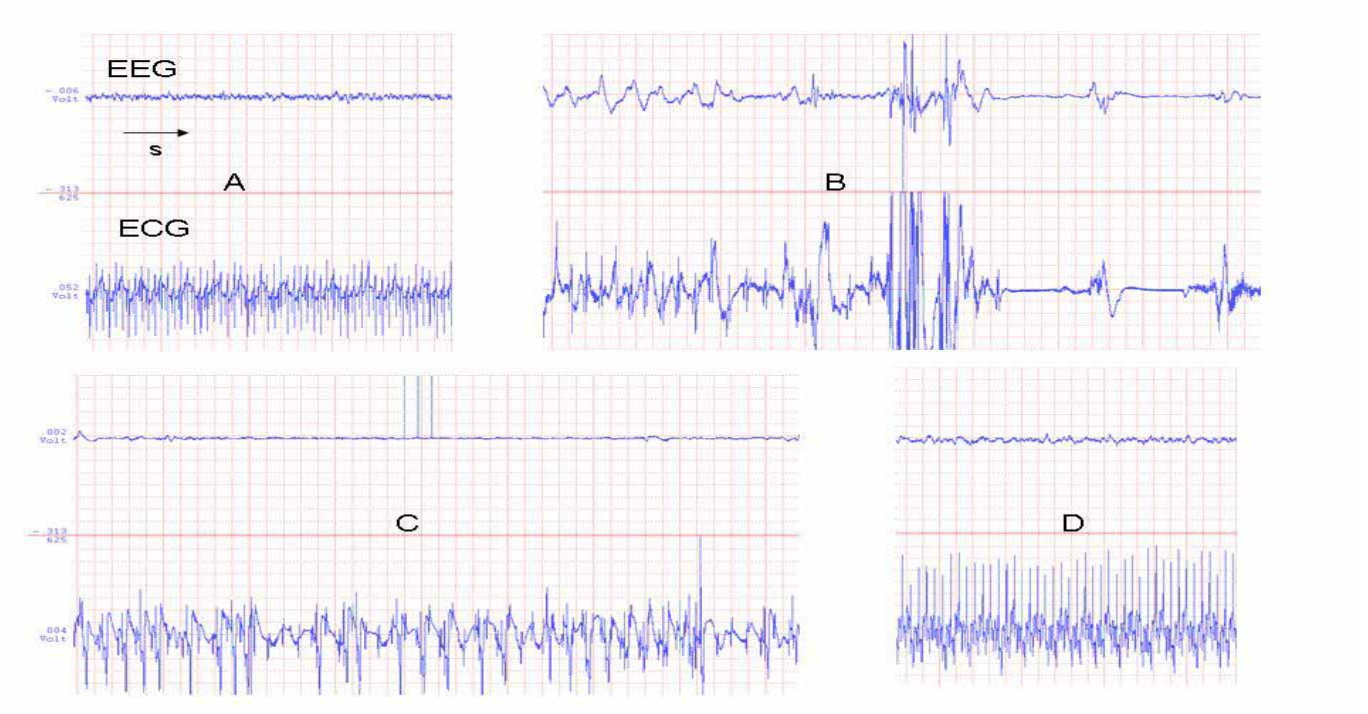
The heart rate of all animals was severely elevated at the beginning of the experiment due to handling, blood sampling and the insertion of the electrodes.
After a slow reduction in heart rate during the induction phase, a serious drop in heart rate occurred as the piglets lost their posture. Immediately after this, heart rate fell to almost 0 or became very irregular and slow. Heart rate began to recover immediately after the piglets were removed from the gas mixture (Fig. 5.3).

Figure 5.3 Typical heart rate



Thirty seconds after losing consciousness, the piglets were removed from the gas mixture and castrated, and blood samples were taken. None of the EEG and ECG readings showed a response to castration in any of the animals. After an average of 59 seconds the piglets had regained consciousness, EEG had returned to its pre-induction pattern and the piglets could stand up again. Heart rate returned to normal after an average of 120 seconds.
Figure 5.4 shows an example of an EEG and ECG.

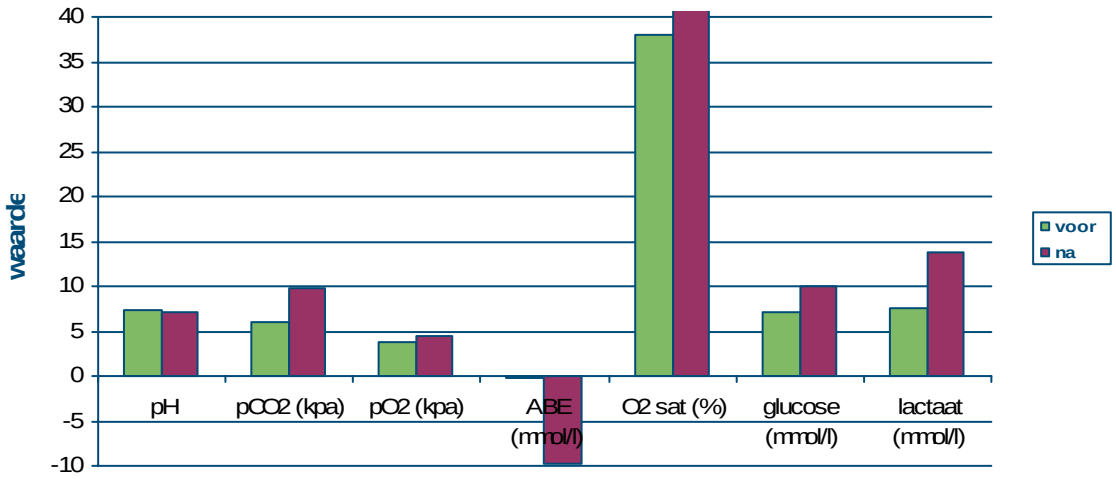
Figure 5.4 Example of EEG and ECG readings: A=period prior to anaesthesia, B=loss of consciousness (strong readings as pig falls over), C=unconsciousness (the three lines at the top in C indicate the moment of castration), D=recovery of consciousness after anaesthesia



According to the EEG and ECG readings, the piglet showed no reaction at the movement of castration (indicated by the three lines in C).

Exposure to the gas mixture had an effect on various blood values (Fig. 5.5).

Figure 5.5 Blood gas values prior to placing in the gas mixture and 30 seconds after removal from the mixture



This led to a fall in pH (from 7.4 to 7.1) 30 seconds after the piglets were removed from the box, compared to the basal level prior to placing in the gas mixture. De pCO_2 rose from 6kpa to 9.7 kpa and pO_2 rose slightly from 3.8 kpa to 4.5 kpa. The O_2 saturation rose slightly from 38% to 42%. As a result of the increase in pCO_2 and the decrease in pH, the acid-base equilibrium (ABE) shifted from average 0 to average -10. Glucose as well as lactate levels rose during the experiment: glucose from 7.2 to 9.4 mmol/l and lactate from 7.6 to 13.8 mmol/l.

5.3.3 Establishing the limits

Lower limit of CO_2 concentration
In a mixture of 60% CO_2 + 20% O_2, 24 animals were monitored as for the 70/30 mixture. In 16 of the 24 animals there was a visible response to castration and an EEG response. It can be concluded that the concentration of CO_2 is too low to achieve sufficiently long anaesthesia if the animals remain in the mixture for 30 seconds.

Maximum length of time in mixture
In order to establish the maximum time that piglets can remain in the gas mixture, 5 piglets were placed in the 70% CO_2+ 30% O_2 mixture for 3 minutes. Two of these piglets died. Four piglets were then placed in the box for 2 minutes. One of these piglets died.
Prolonged exposure to the gas mixture led to a decrease in pH (from 7.4 to 7.0), while pCO_2 increased sharply from 6.5 kPa to 15.6 kPa and pO_2 rose slightly from 2.6 kPa to 9.2 kPa. The O_2 saturation rose sharply from 27% to 73%. As a result of the increase in pCO_2 and the decrease in pH, the acid-base equilibrium (ABE) shifted from average 1 to average -10. The glucose as well as lactate level rose during the experiment, glucose from 6.5 to 10.3 mmol/l and lactate from 7.2 to 12.5 mmol/l. No differences were found between the animals that survived and the animals that did not survive, although it is characteristic that the animals did not die until a few minutes (approx. 3-4) after they had been removed from the gas mixture.

5.4 Discussion

A problem when administering anaesthetic gases is that of excitation, a stage of increased activity and strong uncontrolled muscle movements. The animals are not always unconscious at this stage, so this can result in considerable distress (Dannemann, 1997; Lambooij, 1990; Lambooij et al, 1999). High concentrations of carbon dioxide (CO_2) produce a high level of excitation. A mixture with a low CO_2 + a high O_2 concentration (e.g. in broiler chickens) produces virtually no excitation (Coenen et al, 1995; Coenen et al, 2000; McKeegan et al, 2006?). The duration and intensity of excitation depend on the gas mixture, the way in which it is administered, and the breed of animal.
When the piglets are placed in the box filled with the gas mixture of 70% CO_2 + 30% O_2, they remain standing on the same spot. Respiration increases quickly, the animals sit down and then fall over. These behaviours are not always indicating distress.

A pilot-experiment with a few pigs of 4 to 5 kg showed that they recoiled when confronted with 70% CO_2 + 30% O_2, but on the following day they had no memory of this experience (Lambooij, 1990). It is possible that this combination produces less excitation, as has been observed in other animal breeds (Coenen et al, 1995; McKeegan et al, 2005). During the induction period for slaughter pigs in 70% CO_2 + air, EEGs showed that they were conscious during the first 20 seconds, and during the following 10 seconds they showed reduced consciousness, followed by a period of deep narcosis. Muscle contractions were observed during deep narcosis (Forslid, 1987).
The piglets in this experiment fell over after approximately 25 seconds and were unconscious after approximately 19 seconds. The muscle contractions were observed after falling over and when the animals were in deep narcosis according to the EEG. These muscle contractions do not therefore have a negative effect on the wellbeing of the piglets. This is supported by research into ducks and chickens. Animals show reduced consciousness (theta and delta waves) when they fall over (Gerritzen et al., 2006).
Breathing is controlled in the brain by the medulla oblongata. This part of the brain measures the acidity (pH) of the blood. Acidity is determined by the levels of CO_2 and O_2 in the blood. If pH falls, this is registered and the rate of lung ventilation increases. This means that the animal breathes faster and more heavily, and takes in more CO_2. It appears that a decrease in blood pH is followed by a decrease in pH in the cerebral fluid (Martoft et al, 2003). The normal pH value of this fluid is 7.4, and a state of unconsciousness is induced if this falls to 7.1 (Eisele et al, 1967).
A similar decrease was observed in the piglets in our experiment, whereby acidosis was evident through the shift in the acid-base equilibrium (Figure 5). According to the EEG, the piglets were anaesthetised, both in the mixture of 70% CO_2 + 30% O_2 as well as a mixture of 60% CO_2 + 20% O_2. Animals placed in the latter mixture were not sufficiently anaesthetised, and a reaction to castration was clear visible on their EEG signals as well as in their behavioural reaction, while the fall in blood pH was comparable. Pigs can regain consciousness quickly when they are taken out of the gas mixture (Martoft, 2001). It is possible that 60% CO_2 in the gas mixture is too low, and that the piglets regain consciousness by the time castration takes place.
An excessive rise in pCO_2 in the blood eventually leads first to respiratory depression, then to respiratory stimulation, thereby creating a vicious circle that ends in death (Guyton and Hall, 1994). If blood pH in pigs falls to 6.6, death may result (Martoft, 2001). This value has also been measured in ducks and turkeys, and the animals died (Gerritzen et al, 2007). Changes in the pH of the blood affect enzyme reactions that relate to energy production, changes in membrane permeability and electrolyte balance. This appears to be the point at which regeneration is no longer possible.
According to Svendson (2006), there is a risk of mortality if the piglets remain in the gas concentration of 70% CO_2 + 30% O_2 for longer than 4 minutes. In our study, death occurred when animals remained in this concentration for more than 2 minutes. Given that the pH value of the blood of the piglets that died in this experiment were not abnormal, recovery should have been possible. Notably, the heart did not recover.
It is therefore apparent that the composition of the gas mixture and length of time that the piglets remain in it are critical in the incidence of unconsciousness and death in piglets of 3-6 days old.

5.5 Conclusion and recommendations

An important conclusion from this experiment is that anaesthetising pigs with a mixture of 70% CO_2 + 30% O_2 leads to a period of unconsciousness and painlessness that is long enough to castrate the animals under anaesthetic. It can be said, with a confidence level of 95% (n=25), that between 89% and 100% of all piglets between 3 to 6 days old can be castrated effectively under anaesthetic with this mixture.
It is also clear that the safety limits for the piglets require that the gas mixture and timing be carefully controlled. Further research is required to develop an application for general use. It is essential to establish a minimum concentration and a minimum and maximum period that the animals can safely remain in the mixture, not only so that a sufficiently long period of anaesthesia is induced but also so that no piglets die. In addition, it will be necessary to design a practical system that is workable as well as safe for stockman and piglet.

6 General conclusion

M. Kluivers-Poodt

Local anaesthesia of piglets prior to castration, in comparison to unanaesthetised castration, demonstrably reduces pain perception and stress response during castration. Although clearly demonstrable, the positive effect of local anaesthesia with lidocaine on wellbeing during castration is relatively limited. In relation to the piglets that were only handled twice (sham injection and castration), there was still a considerable pain and stress response. It must be remembered, however, that injecting lidocaine into the testicles is likely to produce an extra pain response (which is not dealt with in the present study), thereby reducing the advantage of using anaesthesia for castration. The administration of meloxicam prior to castration has very little effect at the moment of castration.
With regard to pain after castration, it can be said, on the basis of behaviour observation for four days after castration, that castration under local anaesthesia is accompanied by more pain-related behaviour (i.e. tail wagging) than unanaesthetised castration. However, this disadvantage is removed if meloxicam is also given. In general, the animals that received meloxicam showed less pain-related behaviour in the first few days after castration.
If the local anaesthetic has to be administered by a veterinarian, the cost of castration increases by € 1.00 per male piglet. If the stockman can administer the anaesthetic, the increase in cost is much lower (€ 0.28 per male piglet). At national level, the cost of local anaesthetic if administered by veterinarians is € 13 million, and €3 million if administered by stockmen.
The use of general anaesthesia with CO_2 has demonstrable advantages for the piglets, but also a number of practical disadvantages. The advantages are that the piglets are fully unconscious at the moment of castration, that there is complete pain alleviation, and that other painful treatments can also be carried out while the piglet is anaesthetised. The main disadvantages are the narrow safety margins (CO_2 concentration, time), and the fact that a practical system has not yet been designed for general use. Further research is needed in order to determine the limits of use and realise a reliable and workable design.

Appendices

Appendix 1 Measured labour demand per work element (in centiminutes per time) per farm

Table 7.1.1 Labour demand (cmin) per work element at farm 1

	test treatment														
	anaesthesia by veterinarian			no pain reduction			anaesthesia by pig farmer			analgesia by pig farmer			anaesthesia and analgesia by pig farmer		
work element	#	av.	sd	#	av.	sd	#	av.	sd	#	av.	sd	#	av.	sd
go with trolley to next room	-	-	-	2	70.00	25.46	1	242.0	-	2	41.50	12.02	1	227.0	-
go to vorige room (castration)	-	-	-				2	66.50	0.71	-	-	-	-	-	-
prepare castration clamp	-	-	-	2	34.00	7.07	1	21.00	-	1	25.00	-	-	-	-
go with trolley to next pen	4	10.25	9.18	7	23.14	18.15	3	10.33	12.70	3	21.67	16.77	5	13.40	6.11
collect litter of piglets	6	45.33	12.85	7	51.00	9.43	6	52.33	8.45	5	52.80	12.32	7	62.00	10.82
heat electric tail docker	6	32.33	6.74	7	39.57	12.73	6	42.50	20.96	5	36.00	7.58	7	31.43	11.87
dock tail	57	15.53	4.60	71	12.59	2.86	60	13.58	3.18	50	12.42	2.06	71	16.55	4.32
attach I&R ear tag	57	11.53	3.08	73	12.90	4.25	54	13.31	5.80	49	13.53	5.68	71	13.93	5.04
separate males/females	5	36.20	9.78	8	35.75	18.27	5	36.60	9.92	5	50.40	12.58	7	34.14	8.93
prepare castration (place clamp) [1]	5	30.80	17.92	8	22.25	10.94	5	18.00	7.21	5	16.80	2.39	4	22.00	3.37
place bin with boars on passage										4	21.00	14.99			
castrate [1]	25	22.36	5.35	34	25.24	7.84	28	23.36	4.06	21	25.00	4.52	36	23.69	9.28
bin into farrowing pen [1]	-	-	-				5	29.60	16.94	5	51.80	15.93	6	29.83	19.86
fill syringe with meloxicam										23	16.65	11.33			
administer meloxicam [1]										23	8.65	2.06	34	11.85	6.38
place castration clamp (anaesthesia)							6	25.33	11.99				7	18.86	12.88
administer lidocaine [1]	25	25.24	7.93				27	27.04	5.42				34	29.06	6.46
replace needle syringe	-	-	-				-	-	-	-	-	-	1	147	-
lay aside syringe (cap on needle)										5	9.80	3.42			
move boars from crate into bin										5	29.40	18.88			
go with trolley out of the room	-	-	-	2	105.0	12.73	1	118.0	-	2	78.50	9.19	1	63.00	-
all bins out of the room	-	-	-				-	-	-	1	67.00	-	1	62	-

[1] Significance of differences between the test treatments is statistically tested

Differences between labour demands for the test treatments were not significant, except for work element 'administer meloxicam' ($p < 0.05$). For 'administer lidocaine' $p < 0.1$.

Table 7.1.2 Labour demand (cmin) per work element at farm 2

	test treatment														
	anaesthesia by veterinarian			no pain reduction			anaesthesia by pig farmer			analgesia by pig farmer			anaesthesia and analgesia by pig farmer		
work element	#	av.	s.d.	#	av.	s.d.	#	av.	s.d.	#	av.	s.d.	#	av.	s.d.
start-up time							1	802.0	-				1	1194	-
go into next room	1	167.0	-				1	148.0	-						
collect material needed	1	21.00	-	3	51.33	13.65	3	118.3	117.1	3	59.00	12.29	1	225.0	-
go to next pen	3	32.33	18.01				4	19.75	24.80	2	63.50	7.78	3	5.67	5.51
take ear tags from carton (once/pen)				1	29.00	-	7	45.00	20.13	1	40.00	-	2	83.00	4.24
get sow out of farrowing pen				6	74.17	29.70	6	161.8	110.4	3	50.33	29.16	5	71.60	42.27
herd sows in common pen				2	108.0	33.94	2	80.50	85.56	1	22.00	-	2	154.5	0.71
walk back				2	33.00	7.07	1	18.00	-	2	17.00	11.31	1	25.00	-
lock the piglets into a corner	1	58.00	-	6	123.0	24.17	6	118.8	44.87	4	91.75	47.63	5	99.00	39.12
ear tag in tag-pincers	12	10.83	2.25	61	12.26	3.16	74	12.03	2.39	78	14.42	4.79	37	12.38	2.83
take up a piglet	12	6.00	1.91	59	5.32	1.86	75	5.89	3.27	80	7.21	3.06			
adjust an ear tag				72	7.03	2.41	75	6.16	2.66	81	6.02	3.37			
take up a piglet en adjust an ear tag													44	12.20	4.04
adjust an ear tag and fig a piglet	2	17.50	9.19												
adjust an ear tag and put piglet in pen	11	4.91	1.64												
administer Mycoplasma vaccine				39	6.46	1.59	75	6.43	2.80	81	6.80	2.72	44	9.05	2.57
administer iron injection [1]				72	6.49	1.78	36	7.17	2.59	43	6.40	1.72	20	7.75	2.69
administer iron and put piglet into pen							39	8.77	2.70	37	7.14	2.44	25	10.80	4.06
place female piglet into farrowing pen	50	3.06	0.84	24	3.08	1.79									
adm. meloxicam and piglet into pen										43	7.49	2.18			
administer meloxicam													19	8.95	3.12
take up and fix male piglet	20	19.60	6.70												
administer lidocaine and piglet into pen							36	21.03	5.07				20	25.55	5.42
administer lidocaine (2 persons)	23	14.65	7.95												
replace piglet into farrowing pen	50	3.06	0.84												
prepare castration per room[1]							2	111.0	0.00	2	107.5	23.34	2	95.50	58.69
go to next pen							4	21.75	25.77	6	15.83	7.52	1	20.00	-
take up and fix boar [1]	26	17.38	12.39				35	10.40	3.83	40	13.30	11.40			
castrate piglet [1]	26	22.69	5.66	38	36.29	7.40	36	29.22	8.99	40	32.48	33.47			
take up and castrate boar													20	41.90	10.03
administer iodine and boar into pen [1]	26	6.27	1.89	35	6.89	1.61	36	6.61	1.25	40	6.50	1.32	20	7.40	1.35
return sow into farrowing pen				3	139.3	48.95	6	115.7	50.48	9	98.33	40.61	5	225.6	
recover three farrowing pens				1	134.0	-	2	162.0	56.57	1	148.0	-	1	77.00	-
finishing time (clean up)							1	52.00	-						

[1] Significance of differences between the test treatments is statistically tested

Differences between labour demand for the test treatments were not significant, except for the work elements 'administer lidocaine and piglets into pen' ($p < 0.01$), 'take up and fix male piglet' ($p < 0.05$) and 'castrate piglet' ($p < 0.05$).
For 'take up and fix piglet' more labour was needed in test treatment A (anaesthesia by veterinarian) than in test treatment C (anaesthesia by pig farmer). For 'castrate piglet' less labour was needed in test treatment A (anaesthesia by veterinarian) than in test treatment B (no pain reduction). However, since the work methods for these work elements was not effected by the test treatment, and since in test treatment A (anaesthesia by veterinarian) more labour was needed for 'take up and fix male piglet', bus less labour was needed for 'castrate piglet', over-all averages of labour demand were used to calculate labour demand per litter.

Table 7.1.3 Labour demand (cmin) per work element at farm 3

	test treatment														
	anaesthesia by veterinarian			no pain reduction			anaesthesia by pig farmer			analgesia by pig farmer			anaesthesia and analgesia by pig farmer		
work element	#	av.	sd	#	av.	s.d.	#	av.	s.d.	#	av.	s.d.	#	av.	s.d.
trolley to next pen	3	9.67	9.07	4	13.25	2.63	6	11.33	8.14	3	18.67	3.79	2	11.00	15.56
collect litter of piglets	3	193.3	177.3	5	98.80	30.70	6	119.3	53.85	5	47.00	15.38	2	38.50	9.19
trolley to treatment room	3	56.00	6.56	4	47.75	8.85	6	22.17	3.37	5	43.40	25.00	3	20.67	1.53
fill syringe with iron													1	84.00	-
administer Fe and Myco vaccine (2p.)				56	9.79	3.83	19	8.16	3.98	52	10.54	14.95	54	9.61	4.59
administer iron injection (1 person)							45	8.09	1.99						
administer iron injection & sex	61	9.54	2.96												
replace bottle iron	1	63.00	-												
administer Mycoplasma vaccine (1p.)	61	5.59	2.33				45	6.69	2.11						
adjust an ear tag and sex piglets				53	21.32	5.04	61	16.70	4.61	53	15.70	4.14	55	17.65	4.26
adjust ear tag	57	15.53	4.10												
wash hands before castration				3	30.33	12.34				1	7.00	-	1	8.00	-
wash hands and new knife (castration)				2	50.00	1.41									
return trolley female piglets to pen	3	42.67	20.26				4	25.50	10.64	5	48.40	12.52	2	14.00	5.66
female piglets from trolley into pen	3	20.67	13.32				4	26.75	9.22	4	12.25	3.40	2	21.50	6.36
place bin into farrowing pen	3	13.00	1.73							2	17.00	0.00			
place boar into bin	3	67.00	5.57												
administer meloxicam [1]										31	10.03	4.66	28	7.43	4.11
gearing loss administration melox. [1]										8	8.88	3.80	8	11.75	6.27
prepare syringe lidocaine							1	10.00	-				1	14.00	-
administer lidocaine and piglet in bin [1]	51	23.31	5.67				34	19.74	5.93				30	16.50	5.60
gearing loss administration lidocaine							3	14.33	11.15				7	16.71	6.02
lay aside syringe (cap on needle)							2	11.50	2.12						
male piglets into bin (sex)										3	67.00	5.57			
move bin with boars [1]	5	10.00	1.73				4	7.00	4.83				2	11.00	0.00
lift bin with boars on trolley										5	18.60	6.15			

	test treatment														
	anaesthesia by veterinarian			no pain reduction			anaesthesia by pig farmer			analgesia by pig farmer			anaesthesia and analgesia by pig farmer		
work element	#	av.	sd	#	av.	s.d.	#	av.	s.d.	#	av.	s.d.	#	av.	s.d.
castrate male piglets [1]	50	28.24	8.19	21	34.48	15.46	34	30.35	6.33	28	27.29	7.26	28	29.11	7.15
gearing loss castration				2	62.50	0.71									
administer betadine & into crate [1]	50	8.68	1.88	21	11.90	5.74	33	9.70	2.28	29	8.83	1.87	28	9.00	2.09
replace bin with male piglets										2	8.50	0.71			
return trolley with male piglets to pen	6	32.17	11.79	4	30.60	9.67	5	17.20	4.66	3	44.33	10.79	2	29.50	16.26
unload trolley (male piglets)	11	24.27	9.46	5	30.60	9.86	4	40.75	3.30	5	14.60	2.61	2	18.00	4.24
with empty trolley to treatment room	6	25.83	13.01												
store bins	1	20.00	-				-	-	-	-	-	-	1	13.00	-
store syringes	2	108.0	31.11										1	74.00	-
finishing time (clean up)	1	70.00	-												

[1] Significance of differences between the test treatments is statistically tested

Differences between labour demand for the test treatments were not significant, except for the work elements ‘administer meloxicam’ ($p < 0.05$), ‘administer lidocaine and piglet in bin’ ($p < 0.05$) and ‘administer betadine & into crate‘ ($p < 0.1$).

Table 7.1.4 Labour demand (cmin) per work element at farm 4

	test treatment													
	anaesthesia by veterinarian			no pain reduction			anaesthesia by pig farmer			analgesia by pig farmer			anaesthesia and analgesia by pig farmer		
work element	#	av.	sd	#	av.	sd	#	av.	sd	#	av.	sd	#	av.	sd
start-up time	1	763.0	-												
go with trolley to next pen	3	19.33	9.45	3	17.67	15.70	3	30.67	25.58	3	26.33	1.53	4	9.25	6.80
collect litter (two persons)	4	51.50	11.93	5	43.00	6.96	5	52.20	10.01	2	67.50	12.02	2	32.50	3.54
replace piglets from bin to crate (lorry)	5	30.20	4.09							3	30.67	13.58	3	21.00	2.65
pick up and fill syringe	5	44.80	27.82	6	31.67	26.43	9	40.22	38.02	5	46.60	30.44	5	26.40	12.74
fill syringe	1	29.00	-												
administer Fe en antibiotics (2persons)	55	7.80	1.45	67	7.49	1.54	61	7.11	1.14	56	6.57	1.68	47	6.55	1.18
pick op Baycox bottle	5	13.20	7.33	6	9.83	4.40	5	9.40	7.37	5	6.00	1.00	4	5.50	1.29
replace bottle Baycox							1	69.00	-						
administer Baycox en sex piglets	57	8.93	2.77	28	12.64	3.87	58	12.72	4.72	14	10.43	4.47	30	10.57	3.55
replace bottle lidocaine							2	81.00	0.00				1	142.0	-
administer lidocaine	17	19.41	9.58				28	20.50	8.62						
administer meloxicam										30	8.07	2.59			
adm. lidocaine and meloxicam (2pers)													29	30.69	4.81
go to next pen (castration) [1]	3	19.33	8.73				5	47.60	33.32	4	44.00	44.21	9	27.56	7.80
castrate piglet [1]	17	36.00	5.42	24	37.50	6.87	27	36.11	5.40	32	38.41	7.70	23	34.87	4.77
take bins out of farrowing pen	5	20.40	7.02												

[1] Significance of differences between the test treatments is statistically tested

Differences between labour demands for the test treatments were not significant.

Table 7.1.5 Labour demand (cmin) per work element at farm 5

	test treatment														
	anaesthesia by veterinarian			no pain reduction			anaesthesia by pig farmer			analgesia by pig farmer			anaesthesia and analgesia by pig farmer		
work element	#	av.	sd	#	av.	sd	#	av.	sd	#	av.	sd	#	av.	sd
go with trolley into next pen	4	20.50	2.38	4	8.00	2.94	5	18.20	6.46	4	7.25	2.87	2	13.00	7.07
collect litter of piglets & sex				5	71.20	19.34	5	59.40	21.17	5	69.00	11.07	6	66.00	9.98
mark boars with marking pen							5	16.80	4.66	5	12.00	2.65	5	11.60	3.65
heat electric tail docker	5	26.60	7.83	5	30.80	9.39	5	21.80	5.45	5	27.00	8.63	5	27.80	8.70
take up I&R tag-pincers	3	13.33	7.57							2	7.50	2.12	2	16.00	5.66
adjust ear tag	47	13.00	3.30	52	11.77	2.49	58	11.64	2.57	53	12.42	2.87	50	11.82	2.80
lay aside I&R tag-pincers	1	2.00	-	1	12.00	-	1	12.00	-						
take up syringes (Fe/antibiotics)	6	6.50	3.73												
replace bottle Fe										1	43.00	-			
administer antibiotics	51	4.51	1.07	52	6.42	1.95	58	4.59	1.46	53	4.43	1.61	50	5.12	1.80
administer Fe	51	4.78	1.10	54	6.17	2.80	59	4.78	1.51	53	4.81	1.70	50	4.58	1.25
pick op Baycox bottle										1	7.00	-			
administer Baycox	51	5.31	2.29	53	6.30	1.81	58	4.57	1.69	53	4.40	1.74	50	4.26	1.83
take up syringes (lidocaine)	1	6.00	-				1	13.00	-				1	6.00	-
go to next pen (anaesthesia.)	4	9.00	4.08												
administer lidocaine [1]							30	18.20	6.41				26	17.62	5.79
administer lidocaine and mark (pen)	10	23.00	6.39												
administer lidocaine & piglet in crate	16	15.69	4.25												
lay aside syringe (lidocaine)							3	7.67	0.58				1	11.00	-
take up syringe (meloxicam)										1	5.00	-			
administer meloxicam [1]										27	7.78	2.85	27	5.78	2.69
lay aside syringe (meloxicam)										3	9.00	-	1	7.00	-
install electric tail docker	2	9.00	0.00	2	14.00	4.24	4	10.75	2.50	4	6.75	2.50	3	12.00	6.93
clean tail docker	1	43.00	-	2	41.50	12.02				1	90.00	-			
dock tail	50	13.34	3.47	53	16.21	3.65	58	10.78	2.12	53	11.47	2.82	48	10.67	3.02
lay aside tail docker	5	18.20	3.63	5	16.60	2.19	5	11.80	6.38	5	19.40	9.94	5	20.80	4.27
go to next pen	4	9.00	4.08												
go to next pen with trolley							5	13.40	8.11	4	15.25	12.04	4	34.25	14.45
collect boars into crate							5	50.80	21.56	5	39.00	17.07	4	33.25	4.86
take up knife	4	8.00	2.16												
replace knife										1	59.00	-			
castrate piglet cutting sperm. cord [1]	26	31.77	8.39	27	35.04	7.69									
castrate piglet pushing sperm. Cord [1]							30	20.63	4.00	28	20.32	5.10	28	20.54	4.99
disinfect wound (spray) & into pen [1]	26	6.42	2.42	27	7.63	1.84	30	5.57	1.10	28	5.50	5.46	28	5.39	1.07
bins out of farrowing pens	3	7.00	2.64												

[1] Significance of differences between the test treatments is statistically tested

Differences in labour demand were not significant, except for 'administer meloxicam' ($p < 0.05$) and for 'disinfect wound (spray) & into pen' ($p < 0.05$ between treatment 'no anaesthesia or analgesia' and 'anaesthesia and analgesia by stockmen'). For this reason different times are used to calculate labour demand for 'administer meloxicam' in the two relevant treatments. Since there is no systematic reason for different labour times in the mentioned operations for 'spray disinfect wound (spray) & into pen' and there are no significant differences between the other treatments, for this operation the main average labour times are used.

Table 7.1.6 Labour demand (cmin) per work element at farm 6

	test treatment														
	anaesthesia by veterinarian			no pain reduction			anaesthesia by pig farmer			analgesia by pig farmer			anaesthesia and analgesia by pig farmer		
work element	#	av.	sd	#	av.	sd	#	av.	sd	#	av.	sd	#	av.	sd
go with trolley to next room				1	36.00	-							1	165.0	-
go with trolley to next pen	4	35.75	20.24	4	30.25	21.41	4	37.75	14.43	3	29.00	11.53	3	44.33	1.53
collect a litter of piglets	4	71.25	18.41	5	93.00	30.49	5	92.80	21.25	5	84.20	35.89	4	61.50	14.39
administer Baycox	46	7.63	8.90	57	6.11	1.95	52	5.94	2.56	46	6.61	2.73	47	6.36	1.73
administer Fe and sex	57	8.05	2.37	57	9.19	4.39	53	8.91	4.71	46	9.85	6.06	54	9.93	5.36
administer Mycoplasma vaccine	57	7.42	3.60	58	8.03	4.25	51	9.61	6.36	57	8.04	4.15	55	8.33	4.32
replace bottle with Fe				1	137.0	-							1	125.0	-
replace bottle with vaccine				1	115.0	-									
adjust I&R ear tag	57	15.16	6.91	54	15.85	5.29	49	16.00	7.20	57	16.60	6.61	58	16.48	6.26
dock tail of female piglet & into pen	26	7.88	2.46	28	6.36	1.73	21	7.81	3.84	28	7.39	2.84	34	6.41	2.22
go to next pen (for anaesthesia)	5	27.00	4.18												
open crate with boars	5	13.29	4.54												
administer lidocaine [1]	31	18.03	3.23				30	20.37	4.60				24	18.33	5.72
close crate with piglets & stone on it	5	9.20	0.45												
administer meloxicam [1]										29	8.17	3.74	24	7.92	4.96
bring crates and stones into room							1	150.0	-	2	43.50	0.71			
place crate in farrowing pen	5	22.71	11.88				5	30.40	7.83	5	27.60	18.88	5	36.86	18.14
collect male piglets in crate [1]	4	25.00	8.17				5	29.00	14.49	4	27.75	11.33	3	20.33	5.51
close crate with boars & stone on it	5	12.40	5.03							2	9.50	0.71	5	21.00	14.58
go to next pen (castration)	2	41.00	24.04				5	31.80	24.14	3	54.00	42.93	5	27.80	14.79
boars from crate on trolley	5	29.20	7.53				5	32.20	9.91				2	32.00	1.41
b. from crate on trolley & crate out										5	63.80	26.97	3	43.67	4.51
boar into castration trough	28	9.64	1.42	26	10.73	5.02	27	8.63	2.27	29	9.72	2.51	18	12.00	3.60
castrate piglet [1]	28	16.68	2.67	26	17.35	4.06	28	19.82	3.37	29	17.69	3.42	18	20.22	7.35
castrate piglet (no castr. trough used)													3	22.67	3.06
dock tail of male piglet [1]	28	4.93	2.31	26	5.31	2.06	29	5.00	1.10	29	5.69	1.20	22	5.14	1.08
boar from castration trough into pen [1]	28	5.32	1.09	26	5.12	1.24	29	5.55	1.24	29	5.31	1.07	22	5.27	1.88
crate out of farrowing pen	3	14.33	2.08				3	7.67	1.53				2	17.00	8.49
sand 'silver dust'	1	114.0	-							1	102.0	-			
all crates out of room													1	48.00	-

[1] Significance of differences between the test treatments is statistically tested. Differences between labour demands for the test treatments were not significant.

Appendix 2 Effect of piglet weight on labour demand

At farm 1, the stockmen have been on holiday and after this some litters of piglets were castrated when they were two weeks old instead of one week. After castration of the boars in two litters, labour demand seemed to be larger than usual. Therefore measurements started again and the data collected during treatment of these older piglets are not used in this study.
In table 7.2.1 labour demand for treatment (including castration) of these older piglets (aged between 10 and 17 days) is compared with labour demand for treatment of 'normal' piglets (aged between 3 and 10 days).

Table 7.2.1 Comparison of labour demand (cmin) for treatment (including castration) of 'regular' piglets (aged between 3 and 10 days) with labour demand for treatment of older piglets (aged between 10 and 17 days)

	Older piglets		Regular piglets		Significance
work element	average	#	average	#	
collect piglets & into crate	70.5	2	58.6	5	n.s.
adjust I&R ear tags	13.2	21	14.2	50	n.s.
dock tail	19.3	21	15.4	50	$p < 0.001$
sex (male/female in different crates)	34.0	1	34.2	1	n.s.
administer meloxicam	18.3	12	8.3	22	$p < 0.001$
administer lidocaine	31.2	12	27.9	22	n.s.
castrate piglet	28.9	14	20.4	22	$p < 0.01$

= number of observations

Table 7.2.1 shows that labour demand for 'tail docking', 'administration of meloxicam' and for 'castration of older piglets' was larger than labour demand for these treatments at regular piglets.

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