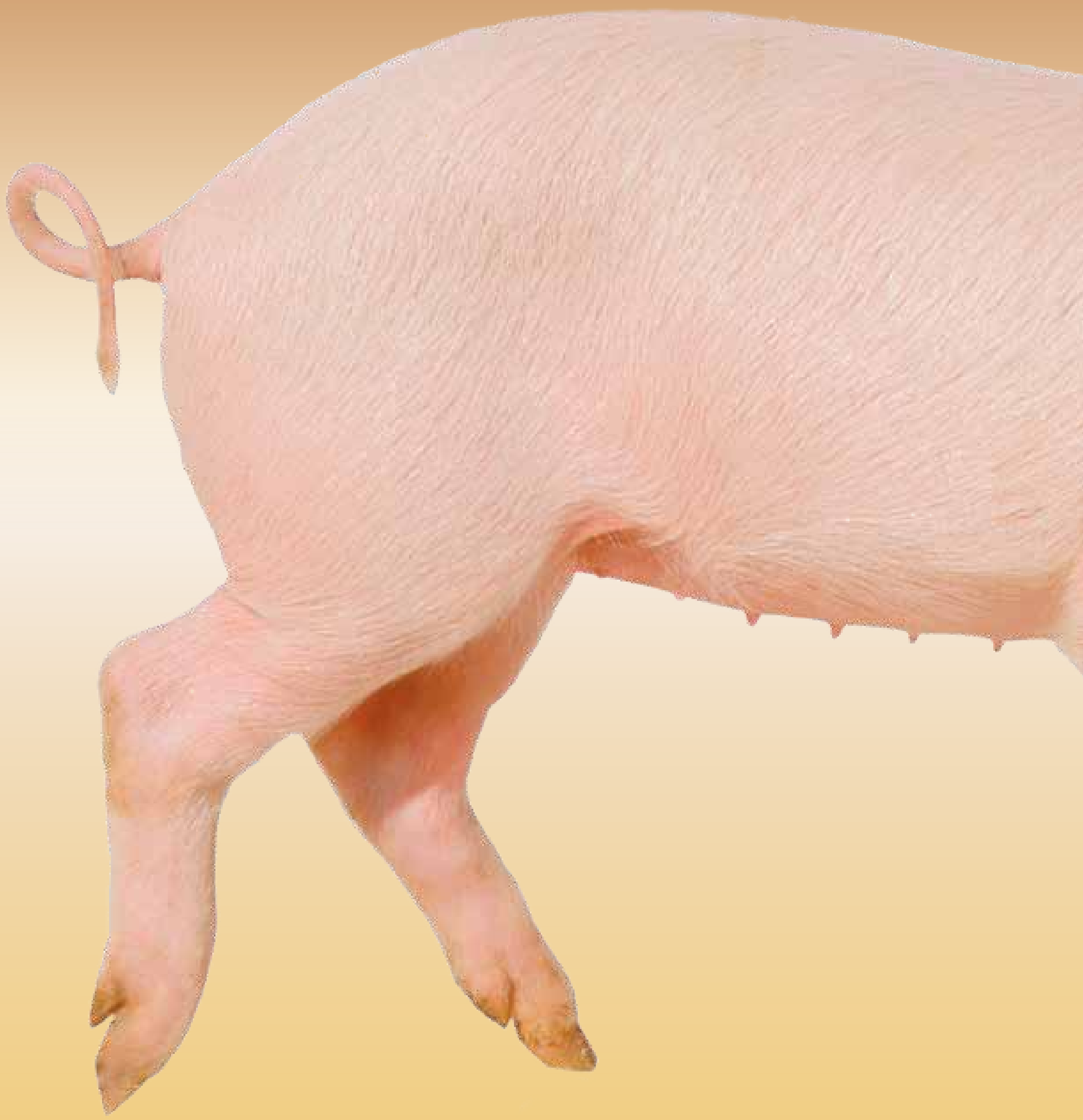
Talking Tails

- Quantifying the development of tail biting in pigs -



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Thesis

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Abstract

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Tail biting is an adverse behaviour characterised by manipulation of a pig's tail by another pig resulting in tail damage and a possible tail biting outbreak. Tail biting is a common problem in the pig husbandry causing economic losses and reduced animal welfare worldwide. To prevent tail biting, the majority of newborn piglets are tail docked, a procedure which is not only painful but generates more and more public concern. This emphasizes the need to prevent the occurrences of tail biting without having to dock a pig's tail. So far, research focused mainly on the risk factors that can induce tail biting. However, the way a tail biting outbreak evolves in a group of pigs (the 'aetiology') is still poorly understood. For that reason, the main aim of this thesis was to gain more insight in the aetiology of a tail biting outbreak. This will not only enhance our understanding of the current preventive and curative treatments of tail biting, but can also generate more effective measures to prevent, predict and counteract a tail biting outbreak. Therefore, the development of tail biting behaviour and tail damage was studied in relation to preventive and curative measures, group composition and indicators for an upcoming tail biting outbreak. The results showed that the provision of twice daily a handful of long straw strongly reduced tail biting. Furthermore, this measure was also effective in counteracting an ongoing tail biting outbreak (an outbreak was defined as the first day with a minimum of one piglet with a tail wound or two piglets with bite marks in a pen), although this outbreak could not be totally eliminated. In pens without straw almost all pigs performed and received tail biting behaviour at low levels prior to a tail biting outbreak. However, considerable variation in tail biting behaviour between pigs was found. In most pens one or a few pigs could be identified as pronounced biters prior to the tail biting outbreak. Although less clear, often one or a few pigs could similarly be identified as pronounced victims. In mixed-sex pens male pigs developed tail damage most rapidly, while in single-sex pens the quickest tail damage development was found in all-female groups. These results indicate that female pigs are more likely to become biters and male pigs are

more likely to become victims. More detailed study of pronounced biters and victims showed that prior to a tail biting outbreak, biters not only directed more of their biting behaviour to their penmates' tail, but also to the enrichment device. Victims were the heavier pigs in the pen and tended to be more often male and more restless preceding an outbreak. Victims also performed more aggressive behaviour, while biters tended to receive more aggressive behaviour. Furthermore, it was found that tail posture is a predictor for tail damage. Pigs with their tail between the legs had a higher chance of tail damage 2-3 days later.

Based on the results of this research an aetiology model of a tail biting outbreak was developed. Subsequently practical suggestions were given to prevent (e.g. providing effective environmental enrichment), predict (e.g. observing the pigs' tail posture) and counteract (e.g. removing the biter) a tail biting outbreak. This provides opportunities to omit tail docking without the negative consequence of tail biting.

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Chapter 1

General introduction

Pigs have been domesticated for over 7000 years and until the 1960's farmers often only had a few pigs. These pigs were kept in pens with straw and outdoor area. At that time tail biting already occurred, but it was not a major problem (Sambraus, 1985). Tail biting is an adverse behaviour performed by pigs who are likely to be bored or frustrated and has been found mainly among weaned piglets and finishing pigs. Also biting behaviour directed at penmates' ears, legs and flanks are considered an adverse behaviour like tail biting. During the 1960's pig production was intensified and new husbandry techniques became available. Specifically liquid-manure-handling systems using slatted floors were introduced and quickly adopted, especially on farms with finishing pigs (Lindqvist, 1974). Bedding materials like straw caused blockages of these manure-handling systems and subsequently the use of bedding materials ceased. It has been suggested that at the same time the tail biting incidence increased (Van Putten, 1969; Lindqvist, 1974). In the intensified pig housing systems routine tail docking of newborn piglets increased as a measure to prevent tail biting at a later age. With tail docking a part of the piglet's tail is removed, normally without using anaesthetics and leaving only a few centimeters of a tail stump.

Simultaneously, public awareness of how farm animals are handled in intensive animal housing systems grew (Appleby, 1999). Growing public awareness of farm animal welfare led to responses like in 1964 with the book 'Animal Machines' from Ruth Harrisson, which described the intensive livestock farming. In 1965 the commission Brambell suggested the five animal freedoms as a base for animal welfare. These five freedoms were elaborated into more detail by the British Farm Animal Welfare Council in 1993 (FAWC, 1993). Over the last decades, in the European Union (a number of initiatives promoting) legislation defining minimum standards of animal care in farm animal production have appeared (Lassen et al., 2006). In 1991 EU legislation appeared in relation to the prevention of tail biting. Directive 91/630/EEC stated that tail docking on a routine basis is prohibited and that all pigs should have access to straw or other material suitable to satisfy behavioural needs.

Nowadays, in the 25 member countries of the EU more than 146 million pigs are slaughtered annually (Eurostat, 2008). These pigs, but also the majority of pigs in other continents, are typically housed in barren pens with partly or fully-slatted floors in groups of varying sizes (mainly 10-40 pigs). For environmental enrichment, the pigs are mainly provided with toys (e.g. metal chain with rubber ball or suspended rubber tubes). Currently more than 90% of the EU pigs are tail docked (EFSA, 2007) and in some countries, like the Netherlands, almost 100% of the intensively kept pigs are docked. Despite tail docking, tail damage due to tail biting still occurs to a greater or lesser extent in all countries and in all housing systems. The prevalence of damaged tails was estimated around 3% of docked pigs in the EU, with 0.5-1% of pigs having a fresh injury and infection (EFSA, 2007). In pigs with intact tails the prevalence of tail damage was estimated to be higher, around 6-10%, with 2-3% of pigs suffering from severe lesions and infection (EFSA, 2007). A Finnish study even reported up to 30% damaged tails among pigs with intact tails (Valros et al., 2004). Damaged tails due to tail biting can, besides causing welfare problems, result into considerable economic losses. Tail biting can reduce production results, increase on-farm costs (e.g. labour and treatment costs) and lead to a variety of secondary pathological changes in different parts of the body creating abscesses (Schrøder-Petersen and Simonsen, 2001). Such pathological changes can lead to carcass condemnation and result in financial losses for the farmer and the abattoir. Quantitative information on the economic consequences regarding tail damage for a pig farmer and the pig sector is scarce. Moinard et al. (2003) estimated in 1999 that the cost of tail biting in the UK was over 4 million euro due to reduced weight gain, on-farm veterinary treatment, culling and carcass condemnation. A preliminary cost estimation of tail damage among pigs in the Netherlands indicates a financial loss of over 8 million euro for the pig sector (unpublished data). This calculation included similar criteria as Moinard et al. (2003) and was based on an average tail damage prevalence of 2.1% (Smulders et al., 2008) for weaned piglets as well as finishing pigs.

1.1 What is tail biting?

The term 'tail biting' has been used to describe several behaviours in pigs, ranging from gentle oral manipulation of the tail to biting that inflicts skin wounds and amputation of portions of the tail or even the rump (Taylor et al., 2010). Most scientists refer to tail biting as the behaviour of biting in the tails of penmates that results in tail lesions (Schrøder-Petersen and Simonsen, 2001). Two stages are often distinguished in the development of tail biting (Fraser, 1987b; Schrøder-Petersen and Simonsen, 2001). Stage 1 is tail biting behaviour in the pre-injury stage, before any tail damage is present. In some cases this is followed by stage 2, the injury stage or 'tail biting outbreak', where at least one tail in a pen is damaged and bleeding. In the injury stage, the severity of tail damage can range from small bite marks (size of pinheads) to amputated tails with a severe tail wound and from one to all pigs in the pen.

In this thesis a clear distinction is made between tail biting behaviour and the clinical consequences; tail damage. A 'biter' is the pig who performs tail biting behaviour and a bitten pig or 'victim' the pig who receives this tail biting behaviour. Tail damage is referred to when a pig's tail shows clinical signs varying from bite marks to a tail wound. In case of a tail wound, a (large) part of the tail might be bitten off. A tail biting outbreak was defined as the first day with a minimum of at least one pig with a tail wound or two pigs with bite marks.

1.2 Aetiology: how does tail biting behaviour start?

For the aetiology of tail biting behaviour in a group of pigs, most scientists suggest that this behaviour evolves from the motivation to explore (Figure 1.1). When there is lack of proper environmental enrichment, the chance increases that this exploration behaviour becomes redirected (and misdirected) to penmates' tails (Van Putten, 1980; Feddes et al., 1993; Petersen, 1994; Schrøder-Petersen and Simonsen, 2001). When pigs explore their surroundings, they may do so with a distinct purpose of e.g. finding feed or an attractive place to lie down, or they may explore to gather general information on their surroundings (Wood-Gush and Vestergaard, 1989). Foraging behaviour (as part of the exploration behaviour) has an immediate goal and is motivated by a need of consuming feed. Although intensively housed pigs are fed unrestricted, it does not eliminate the motivation to perform foraging behaviour (Day et al., 1995; Beattie and O'Connell, 2002). This probably represents the baseline level of foraging behaviour and e.g. hunger increases the intensity of this behaviour (Wood-Gush et al., 1990; Young et al., 1994; Day et al., 1995; Beattie and O'Connell, 2002). Another part of exploration behaviour is not controlled by an acute need, but has an internal motivation (often referred to as curiosity). Curiosity motivates the pig to search for novelty or changes in the environment and serves to keep the pig informed about the environment and the resources available in it. Therefore, all pigs have a strong motivation to explore their surrounding. When the pig's surrounding provides materials that are suitable for exploration (enrichment) the pigs will mainly direct their exploration behaviour at this enrichment (Figure 1.1) and to lesser extend at their penmates. Environmental enrichment like plenty of straw is known to increase the exploration behaviour (specifically rooting and chewing behaviour) directed to this straw and reduce penmate manipulation (Fraser et al., 1991; Pearce, 1993; Guy et al., 2002; Van de Weerd et al., 2005). Therefore, providing pigs with a large amount of straw can reduce the chance of tail biting and subsequent tail damage. In contrast, enrichments materials like a rubber toy fail to prevent the occurrence of tail damage (Van de Weerd et al., 2005). In these cases, a large part of the exploration behaviour is directed to a penmate's tail (i.e. tail biting behaviour). This increase in performed tail biting behaviour of the biter will result in an increased receipt of tail biting behaviour (victim) and subsequently to an increased chance of tail damage (Figure 1.1).

Apart from tail biting evolving from redirected exploration behaviour, several other suggestions have been made for tail biting evolving from other redirected behaviours (Figure 1.1). These suggestions include redirected suckling behaviour following early weaning (Algers, 1984), redirected social behaviour (Jeppesen, 1981) and redirected sexual behaviour (Simonsen, 1995; Schrøder-Petersen et al., 2004).

Another aetiology for tail biting behaviour is that of a learnt response (Schrøder-Petersen and Simonsen, 2001). In line with this aetiology Hansen and Hagelsø (1980) suggested that tail biting is a special fighting technique. This unnatural expression of tail biting behaviour as a fighting behaviour was used to get close to the feeder, but also resulted in an increased chance of damaged tails (Figure 1.1). In addition, Blackshaw (1981) stated that tail biting is a learnt response spread by visual communication. Whether tail biting behaviour evolves from a redirected behaviour, a learnt response or a combination is not clear. It may be that the aetiology of tail biting differs depending on the circumstances (Widowski, 2002).

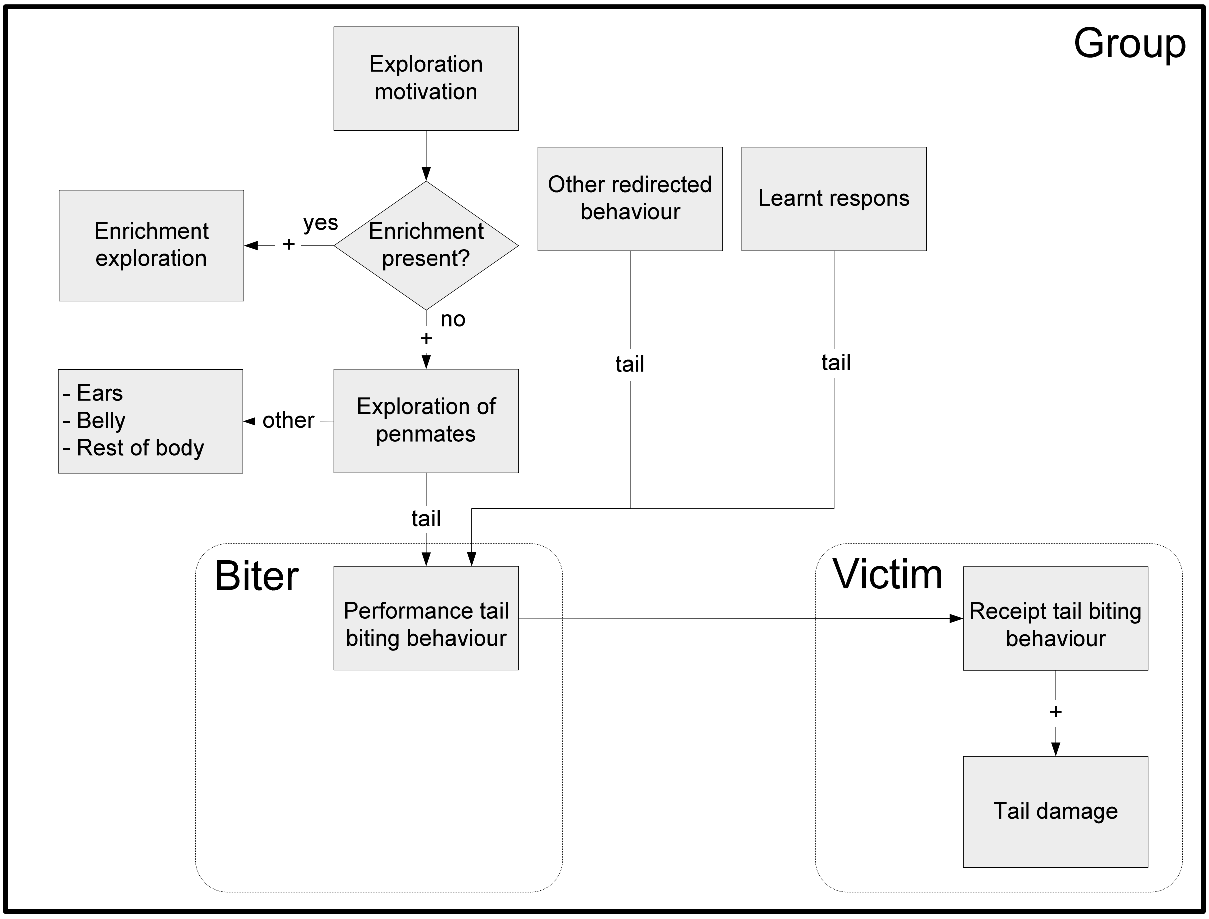

Figure 1.1 Behavioural pathways that can lead to tail biting behaviour and tail damage in a group of weaned piglets or finishing pigs (+ = increased chance).

1.3 What causes a tail biting outbreak?

Although never quantified, it has been suggested that after the first wounded pig tail is present in a pen, often more victims with tail damage follow rapidly (EFSA, 2007) and a tail biting outbreak occurs. Several aspects have been mentioned to be responsible for this rapid increase. The blood on the tail is suggested to stimulate tail biting behaviour, as pigs showed a higher attraction to a rope impregnated with blood (Fraser, 1987a; Fraser, 1987b; Fraser et al., 1991; McIntyre and Edwards, 2002; Jankevicius and Widowski, 2004). Furthermore, victims with tail damage move around more than their penmates, probably because of the discomfort caused by the damaged tail. This increased activity may disturb penmates and encourage further tail biting (Colyer, 1970). Equally, the irritation of the victim's damaged tail may cause an increase of tail movement what attracts biters (Van Putten, 1979). Tail posture may also be relevant, as Feddes and Fraser (1994) showed that the presence of an exposed 'tail' (rope) end attracted more biting behaviour compared with a loop without an end.

1.4 Risk factors

A whole range of factors has been associated with the occurrence of tail biting behaviour. These risk factors can be divided into internal (i.e. pig-related characteristics) and external factors (related to the physical- and social environment).

1.4.1 Internal risk factors

Genetics (e.g. certain breeds), gender and the pig's health status are probably the most important internal risk factors.

Genetic factors appear to have a considerable influence on tail biting, although the effects are not clear and their mechanism is unknown (EFSA, 2007). Floppy-eared pigs, such as Landrace, have been suggested to be the more often biters (Fraser and Broom, 1990). However, the variation within breeds is large.

Gender differences have been found in many studies and male pigs (non-castrated or castrated) are more at risk of obtaining tail damage compared with female pigs (e.g. Penny et al., 1972; Hunter et al., 1999; Valros et al., 2004; Kritas and Morrison, 2007). While male pigs are more often victims, so far no clear evidence exists that females are more often the biters (Breuer et al., 2003; Van de Weerd et al., 2005).

It has been suggested that pigs in poor health are more often biters (Taylor et al., 2010). Alternatively, it was suggested that ill pigs may be reluctant or unable to avoid tail biting behaviour from penmates and become a victim (Taylor et al., 2010).

1.4.2 External risk factors

Physical surroundings (enrichment, floor, feeding, climate) and social environment (stocking density, mixing after weaning and group composition) are important external risk factors that can lead to tail biting in pigs

A barren environment is undoubtedly the most important external risk factor related to the occurrence of tail biting. The absence of suitable environmental enrichment like straw, peat or garden mould increases the risk of tail biting (Haske-Cornelius et al., 1979; Sambraus and Kuchenhoff, 1992; Huey, 1996; Beattie et al., 1998; Guise and Penny, 1998; Guy et al., 2002; Van de Weerd et al., 2005; Scott et al., 2007).
On fully slatted floors approximately twice as much tail biting has been reported compared with half-slatted floors (Madsen, 1980). This could be caused by an unclear distinction of function areas (i.e. space for resting, feeding, exploring and excretion) in a pen with a fully slatted floor.
A shortage of feeding space has been found to induce tail biting (Hansen and Hagelsø, 1980; Hsia and Wood-Gush, 1982). Since feeding is a socially facilitated behaviour (pigs tend to synchronise their feeding behaviour), limited feeding space can lead to competition and subsequent tail biting. Feed quality and diet composition, such as deficiencies (e.g. mineral, protein) and low fibre have been found to result in more tail biting (EFSA, 2007). Also the feed form could have an effect on the occurrence of tail biting, although several contradicting results have been found between e.g. liquid and pellet feeding (Guise and Penny, 1998; Hunter et al., 2001; Moinard et al., 2003; Smulders et al., 2008). Furthermore, sudden diet changes have also been linked to tail biting (EFSA, 2007).
Climatic conditions can also induce tail biting (EFSA, 2007), however, climate is a complex factor. Climate consists of many different factors and both high and low values may be detrimental, e.g. high airspeeds or draughts appeared to induce tail

biting (Coyler, 1970). Also heat stress has been reported to induce tail biting (Penny et al., 1981).

Besides the physical surroundings, the social environment can also play an important role in the occurrence of tail biting. High stocking density can lead to tail biting behaviour (Haske-Cornelius et al., 1979; Fritschen and Hogg, 1983; Geers et al., 1985; Arey, 1991). Mixing of piglets after weaning has been found to increase the chance of tail biting (e.g. Hansen and Hagelsø, 1980), although the research results are not consistent (EFSA, 2007).

Group composition (mixed-sex groups versus single-sex groups) has been found to affect the occurrence of tail biting. Hunter et al. (2001) found among finishing pigs lower tail damage levels in mixed-sex groups compared with single-sex groups. In contrast, Schrøder-Petersen et al. (2003) found lower levels of tail-in-mouth (TIM) behaviour in single-sex weaned piglet groups compared with mixed-sex groups.

1.4.3 How are risk factors estimated?

Studying the effect of risk factors on pigs that initiate a tail biting outbreak (i.e. the biter) is difficult, because it takes detailed observation to identify the primary biter before or in an early stage of an outbreak. In a later stage of the outbreak often more biters are active. Indeed, tail biting outbreaks occur sporadic and unpredictable and are difficult to initiate (Van Putten, 1969; Ewbank, 1973). Therefore, many studies estimated the effect of risk factors based upon the consequence of tail biting: tail damage of the victims. The accuracy of these estimated risk factors can be impaired, especially when there exists a large time gap between the tail biting outbreak and tail damage recordings (e.g. with recordings at abattoirs). During the in between time tail biting behaviour can change as pigs grow older (Van de Weerd et al., 2005), husbandry circumstances can change or tail damage can heal. Additional, no clear criteria exist for scoring tail damage at farm level or in abattoirs, what makes inter-study comparison difficult.

1.5 How to prevent tail biting?

The most commonly used measure to prevent tail damage among pigs is tail docking (EFSA, 2007). Tail docking may reduce tail biting behaviour by reducing the attractiveness of (what is left of) the tail and by increasing the responsiveness of the (potential) victim. However, tail docking does not eliminate the cause responsible for the occurrence of tail biting behaviour (EFSA, 2007).

Other preventive measures are intended to reduce the internal and/or external risk factors in order to decrease the occurrence of tail biting behaviour. One of the most successful preventive measures for tail biting is to provide environmental enrichment, although the rate of prevention depends on the material provided. Adequate enrichment keeps the pigs occupied so less attention is paid towards penmates' tails. Providing substantial amounts of straw or other substrates reduces the chance of tail biting (Van Putten, 1969; Bøe, 1993; Petersen et al., 1995). Other enrichment devices or 'toys' such as iron chains, rubber hoses and wooden beams can keep pigs more occupied. This might reduce the chance of tail biting (Sambraus and Kuchenhoff, 1992), although so far no results have been reported that toys prevented tail biting in pigs.

1.6 How to treat a tail biting outbreak?

Once a tail biting outbreak is present in a group of pigs, curative measures are needed to prevent the further development of this outbreak and reduce the number of subsequent victims. Several curative recommendations have been made such as providing pigs with lots of straw, extra fresh air, extra feed or to darken the room (Van Putten, 1968). Schrøder-Petersen and Simonsen (2001) suggested isolation of the biter, provided that such an individual can be identified. Arey (1991) advised coating of bitten tails in substances with an aversive taste such as wood tar. However, so far no scientific support is available for the effectiveness of these suggested curative measures.

1.7 Aim and outline of thesis

Many risk factors are known to increase the chance of a tail biting outbreak, however how a tail biting outbreak evolves in a group pigs (aetiology) is still poorly understood. Therefore, the main aim of this thesis was to gain more insight in this aetiology of a tail biting outbreak, enhancing our understanding of: 1) why and how risk factors contribute to a tail biting outbreak, 2) the effectiveness of preventive measures for a tail biting outbreak and 3) the effectiveness of curative measures to counteract an ongoing tail biting outbreak. Furthermore, insight in this aetiology can generate more effective measures to prevent, predict and counteract a tail biting outbreak.

1.7.1 Outline

An experiment was set up on an experimental farm with existing tail biting problems to study the effect of four preventive treatments on the development of tail damage among weaned piglets with intact tails (Chapter 2). In addition, the effectiveness of two curative treatments to counteract a tail biting outbreak was tested. Although it was hypothesised that changes to the housing environment (e.g. enrichment) can be effective in reducing tail biting, all subsequent studies were carried out in the original housing conditions, which were rather similar to the standard intensive pig housing system. Chapter 3 describes a second experiment in which the development of tail damage was studied in relation to gender (males and females) in mixed- and single-sex groups. In the following study, video recordings of tail biting outbreak from the first experiment were used to quantify differences in the individual piglet's development of tail biting behaviour (Chapter 4). Subsequently pronounced biters and victims (identified in Chapter 4) were observed in more detail to identify any (behavioural) differences compared with their penmates in the period prior to a tail biting outbreak (Chapter 5). Furthermore, in Chapter 6 it was specifically tested whether tail posture or tail motion of piglets could predict future tail damage. In the general discussion (Chapter 7), the major findings from Chapter 2 to 6 are discussed and an aetiology model for tail biting outbreaks is proposed. Finally, several practical and ethical considerations that can be drawn from the results are reflected upon.

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Chapter 2

Prevention and treatment of tail biting in weaned piglets

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Abstract

The aims of this study were to evaluate four preventive measures and two curative treatments of tail biting. The preventive measures were: chain, rubber hose, straw rack (5g/pig/day) and the provision of long straw on the floor twice daily by hand (2x10g/pig/day). The two curative treatments, which were applied following the onset of tail biting in a pen, were: straw twice daily (as in the fourth preventive measure) and the removal of the biter. In total, 960 weaned piglets with intact tails (10 piglets per pen) were observed during five weeks. Tail lesions (none, bite marks and wounds) were recorded daily. The incidence of pens with wounded pig tails was significantly lower when twice daily straw was provided (8% of pens) compared with the chain (58% of pens) and rubber hose (54% of pens), but did not differ significantly from the straw rack (29% of pens). The incidence of pens containing pigs with bite marks was significantly lower when twice daily straw was provided (16% of pens) compared with the chain (88% of pens), rubber hose (79% of pens) and straw rack (75% of pens). No significant difference was found between the curative treatments. Both treatments showed a reduced incidence of red fresh blood on the tails at days 1 to 9 following curative treatment, compared with day 0. However, neither curative treatment eliminated tail biting entirely. In conclusion, this study indicates that tail biting is best prevented with provision of twice daily a small amount of straw and to a lesser extent with a straw rack, compared with providing a chain or a rubber hose. Once tail biting occurred, provision of twice daily a small amount of straw and removing the biter appears to be equally effective.

2.1 Introduction

In most countries the tails of young pigs are docked to prevent tail biting later in life (McGlone et al., 1990). Tail docking is not only painful for the animals, it also conceals the presence of a more chronic animal welfare problem, namely behavioural deprivation and boredom.

Several studies suggest that environmental enrichment, especially the provision of straw, reduces the chance of tail biting (Van Putten, 1969) and tail biting behaviour (e.g. Bøe, 1993; Petersen et al., 1995). However, most pig husbandry systems in Western Europe cannot be equipped with large amounts of straw, because this would block their slurry-based manure systems. Other enrichment devices were developed for these systems such as the provision of iron chains, rubber hoses, car tyres and wooden beams. Such ‘toys’ may provide some occupation and reduce general penmate-directed behaviours (Sambraus and Kuchenhoff, 1992), but the degree depends on the provided materials. Van de Weerd et al. (2003) investigated 74 different enrichment objects during 5 days in order to find the characteristics that the favoured objects had in common. They found that the main characteristics for intense use were, among other things, ingestibility, chewability and destructibility. Zonderland et al. (2003) suggested that a combination of flexibility and destructibility might be relevant material characteristics to attract the pigs’ attention. This may help to reduce tail biting as tail biting has been suggested to be redirected exploration behaviour (Van Putten, 1980). However, research comparing the effects of different enrichment treatments on the prevention of tail biting is limited, mainly because tail biting outbreaks may be difficult to predict and hard to initiate (Van Putten, 1969; Ewbank, 1973). Therefore, research on tail biting prevention used mainly indirect parameters like tail in mouth behaviour (Schrøder-Petersen et al., 2004), epidemiological risk factor surveys (e.g. Moinard et al., 2003) or tail damage surveys in abattoirs (e.g. Hunter et al., 1999). Since tail biting was regularly observed among the weaned piglets at the Pig Research Unit of the Animal Sciences Group in Lelystad, the Unit offered a unique opportunity to study tail biting directly.

In addition to preventing tail biting, a need exists for more scientific information on curative treatments once tail biting has started, to limit the negative consequences of tail biting outbreak. Several recommendations have been made once the first signs of tail biting are present, such as providing pigs with lots of straw, extra fresh air, an extra meal or to darken the room (Van Putten, 1968). Schrøder-Petersen and Simonsen (2001) suggested isolation of the tail biter, provided that such an individual can be identified. Arey (1991) advised coating of bitten tails in substances with an aversive taste such as wood tar, or isolation of the wounded animals when coating of the tail did not help. However, such recommendations have never been studied. Therefore, in this experiment the effects of two curative treatments (removing biter and twice daily straw provision), were tested in pens subjected to four different preventive measures against tail biting (suspended chain, suspended rubber hose, straw rack and twice daily straw provision). Regarding the straw treatments, it was tried to combine partly slatted floors with the provision of small amounts of long straw without blocking the slurry-based manure system.

2.2 Animals, materials and methods

2.2.1 Animals

In total 960 experimental animals (523 male and 437 female) crossbred weaned piglets were used. They were allocated to 96 groups of 10 animals with mixed sex. At the start of the experiment, the average age was 27.9 ± 2.8 days and live-weight was 8.1 ± 1.4 kg. At the end of the 5-week experimental period, the animals were weighing on average 27.5 ± 4.0 kg. Contrary to common practice, the piglets were not docked and not tail clipped, and the males were not castrated. Animals were individually marked on their backs, using three colours of spray (red, blue and green).

2.2.2 Housing and husbandry

The experiment was conducted in two rooms at the High Health Pig Research Unit of the Animal Sciences Group in Lelystad between August and November. In each experimental room, the environmental temperature was automatically regulated by forced ventilation, and was set at 28 °C when the piglets entered. This temperature was gradually lowered to 26 °C after 5 days, to 23 °C after 21 days and then to 22 °C after 28 days until the end of the experiment (35 days). The room was illuminated by fluorescent light from 07.00 till 19.00 hour with an average light intensity of 50 lux.

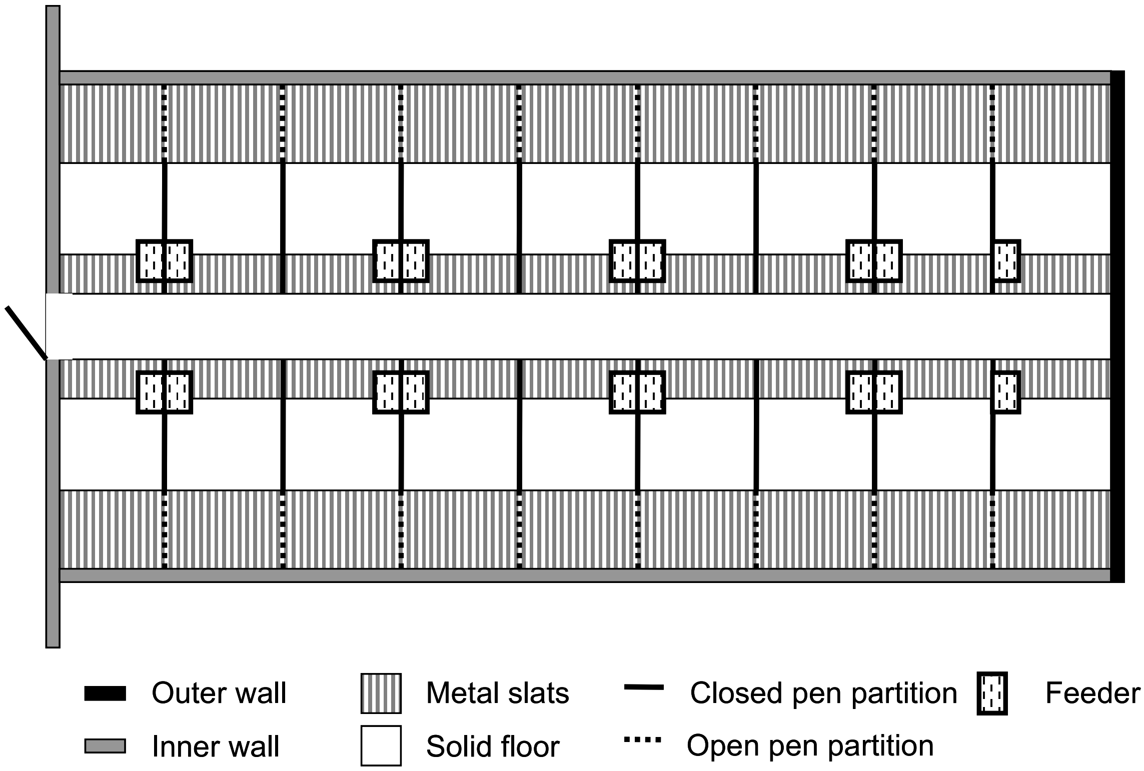

Figure 2.1 Layout of the experimental rooms

Each room contained 18 identical part-slatted pens (Figure 2.1) measuring 2.95m x 1.42m (0.4 m^2/piglet). In each pen, the front 0.35m and the rear 1.10m of the floor had metal slats and the remaining area was a solid sloped concrete floor with floor heating. The pen walls were constructed from solid plastic panels in the front and sides, and vertical metal bars adjacent to the slatted area in the rear of the pen. Each pen contained a two-space dry-feeder. Piglets were fed ad libitum. A water bowl drinker was available next to the feeder.

2.2.3 Treatments

The following four treatments to prevent tail biting and two curative treatments were tested.

Preventive measures

1. Chain: a 0.5m metal chain with about 20mm links was suspended from the pen partition fixed to a horizontal metal pipe above the slatted area in the back of the pen. The distance between the chain, pen partition and back wall were 0.2m and 0.9m respectively. The chain hung at piglets' eye level.
2. Rubber hose: two rubber hose tubes (length 0.4m and diameter 30mm) were tied in a cross shape and suspended on a chain. The rubber hoses were soft enough to be chewed on, but strong enough to prevent the weaned piglets from destroying it. The position of the rubber hose in the pen was similar to the chain in the previous treatment.
3. Straw rack: the straw rack was a converted double space dry-feeder added with three metal chains and a horizontally placed 25 mm thick round plastic bar (Figure 2.2). A metal rack with openings of 50x50mm replaced the sloped front panel. Straw was ad libitum available from the straw rack; the racks were checked daily and refilled with long straw when half empty. The piglets used on average 5 g of straw per pig per day.
4. Twice daily provision of straw: Twice daily approximately 100 g of long straw was provided by hand on the solid floor (i.e. a total of 20 g/pig/day). This was enough to provide the pigs with straw 24 hours per day. A hardwood barrier was placed between the solid sloped floor and the slats in the back of the pen. The slats in the front of the pen were covered with a metal plate in order to prevent large amounts of straw from disappearing into the manure system and leading to blockage. When a part of the solid floor became soiled, straw and manure were removed manually.

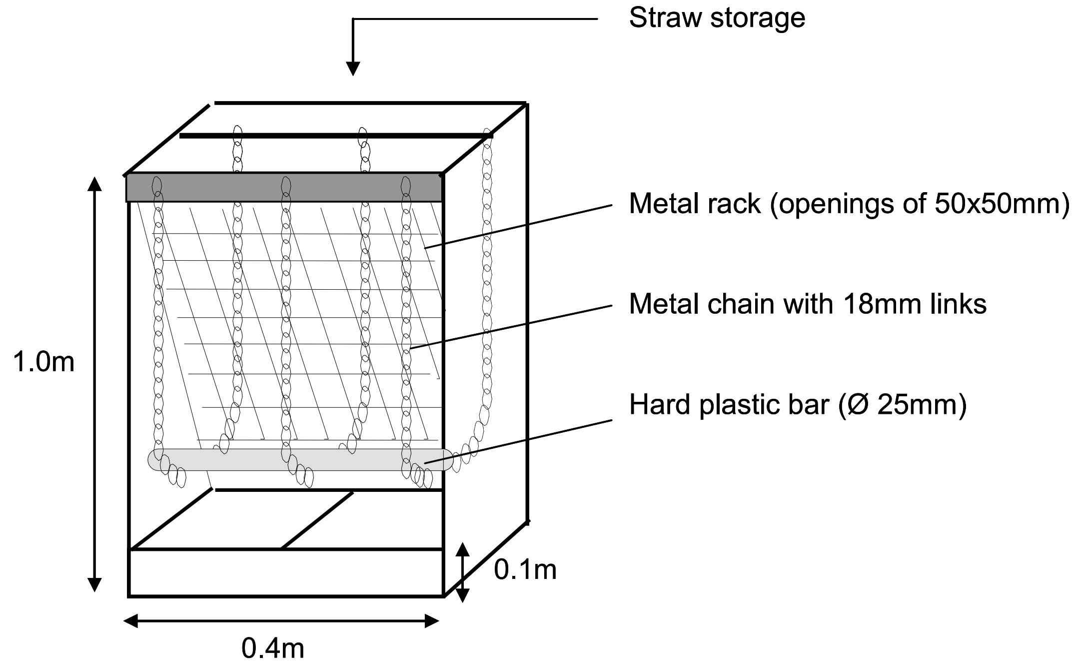

Figure 2.2 Dimensions and lay out of the straw rack.

Curative treatments

Tail damage of individual piglets was scored daily using a protocol (see section 2.2.4). An outbreak of tail biting was defined as an instance where at least one piglet was observed with a fresh tail wound and at least one other piglet was observed simultaneously with either a fresh tail wound or with bite marks. For tail biting pens one of the following two curative treatments was applied.

a. Twice daily provision of straw: Similar as the fourth preventive measure

b. Removal of biter: removal of one or two biters.

For ethical reasons all pens where an outbreak occurred were treated.

No curative treatment was required for pens receiving twice daily straw, because no outbreaks of tail biting were observed in these pens. Alternately, one of the two curative treatments was carried out after an outbreak of tail biting had been observed in a pen. For the identification of the biters (piglets excessively biting a pen mate’s tail) the animals were observed through a monitor connected to the camera above the pens for a maximum of 2x30 minutes. When one or two biters were identified, they were removed. When no biter could be identified or when three or more biters were identified, for ethical reasons, the curative treatment for this pen became ‘twice daily straw provision’. These pens were left out of the statistical analysis. In order to balance the number of pens per curative treatment, the next pen with a tail biting outbreak would receive the curative treatment 'removal of the biter'.

2.2.4 Observations

During the entire experimental period (5 weeks) each piglet’s tail was scored daily using two tail parameters (Table 2.1):

a. Tail damage (3 classes).

b. Blood freshness (4 classes).

Table 2.1

Scores for the two tail parameters; tail damage and blood freshness.

	Tail damage	**Description**
1	No	No tail damage visible
2	Bite marks	Small damages/bite marks are visible. These individual bite marks have the size of a pinhead
3	Wound	Clearly visible wound
	Blood freshness	
1	No	No blood visible
2	Dried	Old dried black blood in the form of a scab
3	Sticky	Sticky dark red blood, mainly a half day to day old.
4	Fresh	Fresh bleeding wound

To standardize the application of the observed parameters, a leaflet with photos for each score was used by each of the five different observers, who collected data 7 days per week. Before the experiment started it was checked how different observers scored the tail damage and blood freshness. This information was used to improve the experimental protocol. During tail damage scoring, the observer stood in the middle of the pen checking each individual’s tail while surrounded by the piglets.

2.2.5 Experimental design

Of the 18 pens in each of the two experimental rooms, only 16 were used in this experiment, the two pens against the outer walls were left out the experiment. The pens were grouped into four equal blocks of four pens. Within each block, the four preventive measures were assigned randomly. The experiment was carried out in three consecutive batches (with 3 weeks between batches).

2.2.6 Statistical procedures

Preventive measures

The occurrence of tail biting was expressed as a binary variable at the level of individual pens, in the following two ways: (1) no tail damage versus tail damage (either bite marks or wound) and (2) no serious tail damage (either no tail damage or bite marks) versus tail wound. A pen was labelled 'bite marks' when during the observation period at least one pig was observed with bite marks. Similarly, a pen was labelled 'tail wound' when at least one piglet was observed with a tail wound. The effect of preventive measures on these binary variables was analysed using logistic regression analysis with the treatment effect on logit scale (Logit(p)=Log(p/(1-p))) and a binomial distribution.

$$\text{Log}(p/(1-p)) = \text{Logit}(p) = \mu + \text{batch} + \text{room} + \text{block} + \text{preventive measure}$$
$$\text{Var}(Y) = p(1-p)$$

With Y as the 0-1 variable and p the chance of a 'bite marks' pen or a 'tail wound' pen. Differences between classes of preventive measures were tested pair wise using Fisher's LSD test (p=0.05; Genstat, 2002).

Curative treatment

The effect of the curative treatment was derived from the blood freshness parameter. During a healing process wounds with fresh blood (score 4) were anticipated to dry up (dark red blood; score 3), form a scab (black dried blood; score 2) and eventually recover (no blood, score 1). The percentage of pigs exhibiting wounds with fresh blood was used as a parameter for the effectiveness of the curative treatments. For each pen where a curative treatment was applied (either removing the biter(s) or provision of straw twice daily) the percentage of pigs exhibiting wounds with fresh blood was calculated on each day over a period of 10 successive days following treatment. The effect of the curative treatment was analysed using non-parametric tests. Due to the limited number of pens with a curative treatment (n=20), the possible interaction between the effects of preventive and curative treatments on the percentage of pigs with fresh blood on the tail could not be analysed.

First, to examine the possible interaction between curative treatment and time (i.e. day following treatment), differences in percentage of piglets with fresh bleeding tails per pen between successive days were calculated. These differences were analysed with a Mann-Whitney U test, comparing the two curative treatments. Here, a non-significant Mann-Whitney-U test result indicates that the percentage of pigs with fresh blood shows similar time-courses for both curative treatments. Since all Mann-Whitney-tests were non-significant ($P>0.05$ for all tests, results not shown), differences between days in the percentage of pigs with fresh bleeding tails were analysed across curative treatments, using Wilcoxon matched pairs signed rank tests. Each successive day following treatment was compared with the day prior to the application of the curative treatment (i.e. day 0).

2.3 Results

In this experiment, no tail biting was observed in 34 of the 96 pens. Piglets with a maximum of bite marks (but no wounds) were observed in 27 different pens (63 piglets with bite marks and 207 without tail damage). Piglets with tail wounds were observed in 35 different pens (156 piglets with tail wounds, 107 piglets with bite marks and 87 piglets without tail damage).

Average daily weight gain of the pigs during the weaning period was 539 g/day and feed conversion ratio was 1.45.

2.3.1 Development of tail damage

Figure 2.3 shows the overall development of the percentages of piglets with bite marks or wounds on their tail for respectively tail biting pens (20 pens) and non tail biting pens (76 pens).

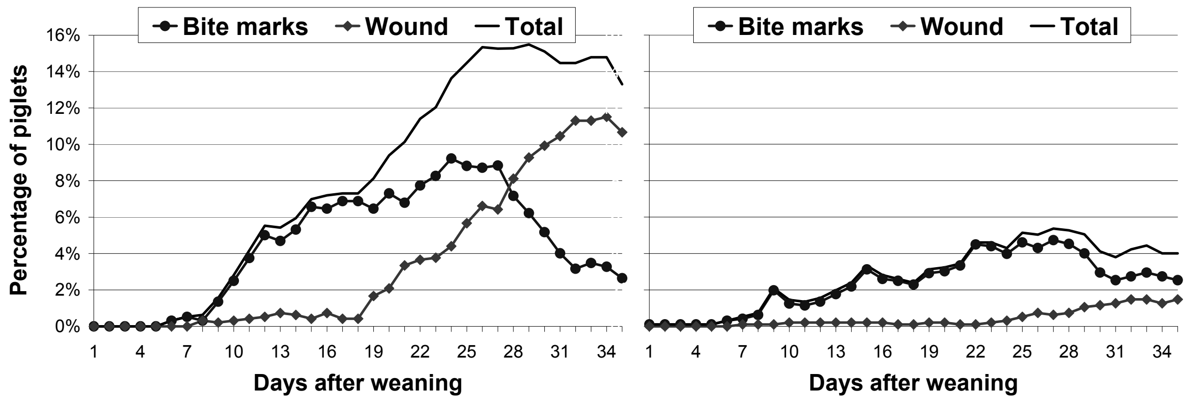

Figure 2.3 Development of the number of piglets (%) with bite marks or wounds on their tail for tail biting pens (left: 20 pens) and non tail biting pens (right: 76 pens).

For both tail biting and non tail biting pens, the number of piglets with bite marks increases after day 5, especially in tail biting pens. After day 28 the number of animals with bite marks decreased, mainly because these bite marks developed into tail wounds. The number of piglets with tail wounds is logically higher in tail biting pens. Although 15 non tail biting pens contained piglets with tail wounds at one point, these pens did not meet our criterion to start a curative treatment (i.e. there was not at least one piglet with a fresh tail wound and another piglet with a fresh tail wound or bite marks present at the same time).

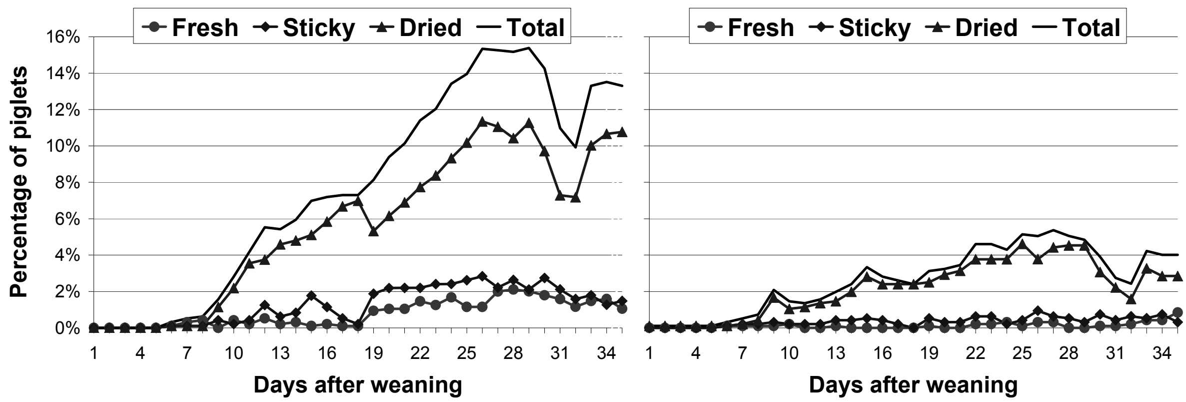

Figure 2.4 Development of the number of piglets (%) with fresh, sticky or dried blood on their tail for tail biting pens (left: 20 pens) and non tail biting pens (right: 76 pens).

The number of animals with fresh, sticky or dried blood (Figure 2.4) seems to follow a pattern similar to the pattern of the tail damage. The tail biting pens contain a small, but persistent proportion of piglets with fresh blood (1-2%), indicating that each day tails of new piglets get wounded. The total number of piglets with blood on their tail appeared to decrease in the last observation week for both tail biting and non tail biting pens. This decrease may indicate a small recovery of the tail damage at the end of the observation period, but this cannot be ascribed to the curative treatments, because a similar pattern is shown in the pens without curative treatment (the non tail biting pens).

2.3.2 Preventive measures

During the experiment, the chains and rubber hoses were not damaged and lasted throughout the 5-week experimental period. Twice daily straw provisions lead in a few occasions to manure blockages of the small manure channel of the pen, but this blockage could be removed easily. In almost half of the pens with twice daily straw, the solid floor was soiled. Therefore soiled straw was regularly removed, and the removed straw replenished. These pens had a higher straw usage compared with non-soiled pens. Figure 2.5 shows the predicted means of the percentages of pens with one or more animals with bite marks and tail wounds per preventive measure.

Fewer pens with straw provided twice daily contained piglets with bite marks compared with any of the other treatments (which did not differ from each other). Fewer pens with straw provided twice daily contained piglets with tail wounds compared with pens with a chain or rubber hose and straw rack pens were intermediate and did not differ significantly from the other treatments.

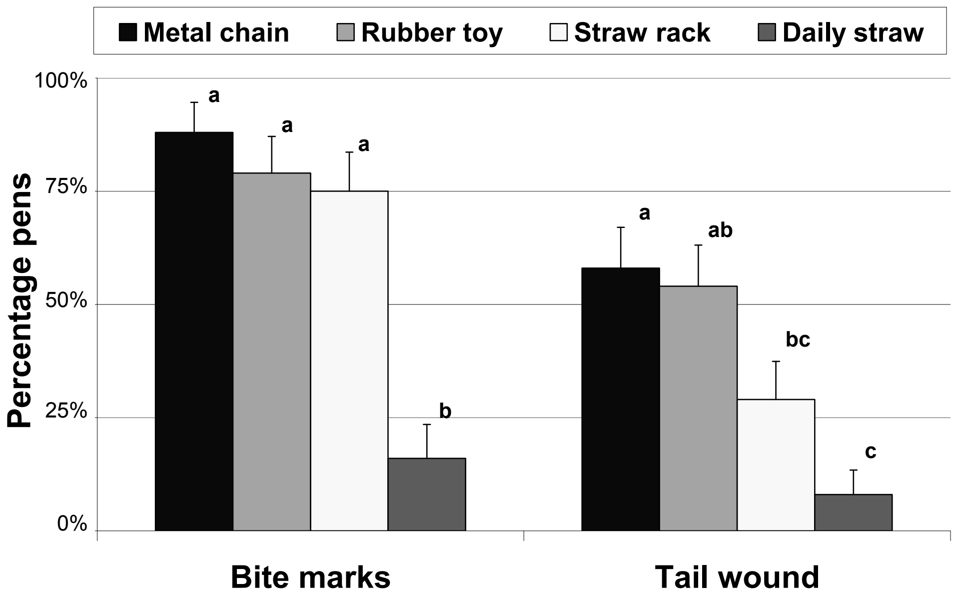

Figure 2.5 Predicted means of the percentage of pens where at least one pig exhibited bite marks and tail wounds respectively. Different characters with a tail damage class indicate a significant difference (P<0.05).

2.3.3 Curative treatments

Curative treatment was applied in 20 pens (21% of all pens). In 10 pens one or two biters were identified (9 pens with one biter and 1 pen with two biters) and removed. In one pen the biter could not be identified and in one pen there were more than two biters identified. These two pens were provided with twice daily straw, but left out of the statistical analysis. The remaining 8 pens with twice daily straw were included in the analysis. In total 11 biters were identified of which 5 males and 6 females with an average start weight of 7.4 ± 1.4 kg compared with 7.7 ± 1.0 kg of the pen average (P>0.05), which the pigs were removed from.

Curative treatments were applied most often in pens with a chain (10), followed by the rubber hose (7) and straw rack (3) (Table 2.2). Pens with twice daily straw needed no curative treatment. Curative treatments were administered mainly at the end of the experimental period (median 24 days, range 8-31 days). The amount of tail biting did not escalate further after administering one of the two curative treatments and no extra piglets had to be removed.

Table 2.2
Number of pens with a tail biting outbreak (including the observation day) per preventive treatment.

Preventive	Total pens	Curative	Nr pens	Observation day
Chain	24	Removing biter(s)	5	21, 22, 26, 29, 29
		Straw	5	13*, 26, 27, 29, 31
Rubber hose	24	Removing biter(s)	3	19, 20, 24
		Straw	4	12, 20, 21*, 30
Straw rack	24	Removing biter(s)	2	8, 23
		Straw	1	28
Straw	24	Removing biter(s)	0	-
		Straw	0	-

* Excluded from the analysis (no biter identified or more than 3 biters)

There was no effect of treatment (twice daily straw or removing biter) on the number of piglets with fresh blood on their tail. Figure 2.6 shows the percentage piglets per pen with fresh blood on their tail after curative treatment had been implemented.

Compared with day 0, significantly fewer pigs had fresh blood on their tails on days 1- 9 after curative treatment had started (day 10 showed a trend). However, curative treatment did not reduce the number of piglets with fresh blood to the level observed in pens without curative treatment (on average 0.1% of the piglets per pen).

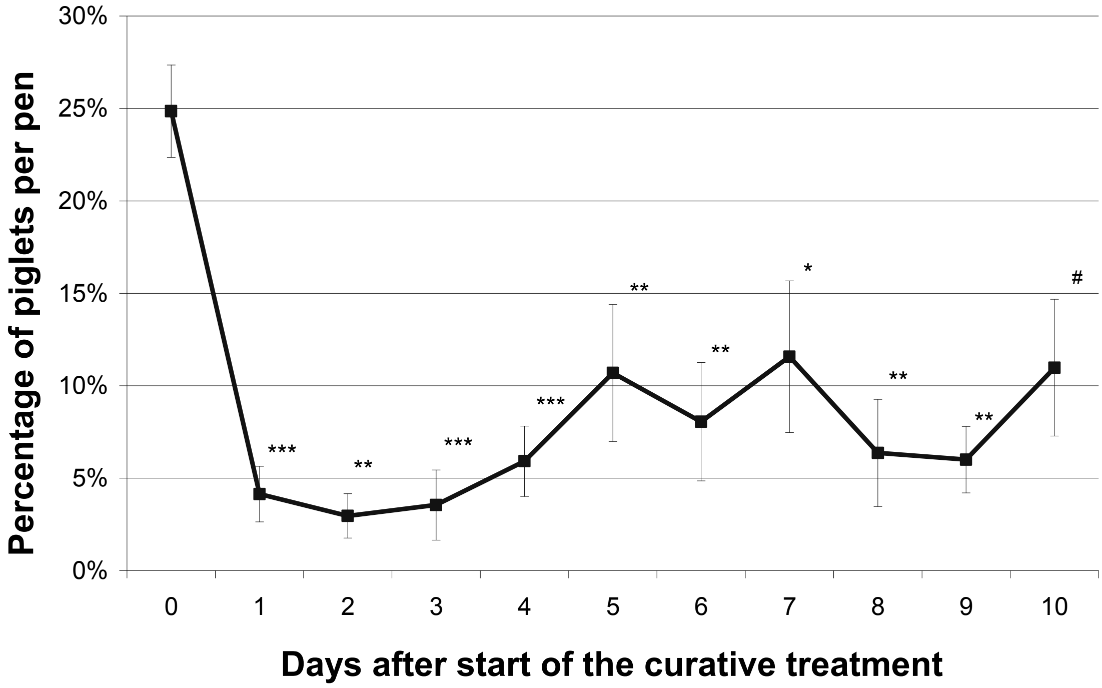

Figure 2.6 Percentage of pigs per pen with freshly bleeding tails in pens where a curative treatment was provided. Significance level indicates a difference between day1-10 compared with day 0 ***P<0.001, **P<0.01, *P<0.05 and $^{\#}$P<0.1.

2.4 Discussion

The aim of this study was to quantify the relative merits of four measures to prevent tail biting and two curative treatments intended to counteract a tail biting outbreak. The tail biting problem in the weaned piglets at the Pig Research Unit in Lelystad enabled us to conduct this study without inducing tail biting experimentally. In addition, a curative treatment was applied to limit the discomfort of the piglets. As a consequence, tail biting did not escalate during the experiment and no additional piglets had to be removed once curative treatments had been provided. The tail damage scoring protocol (Bracke, 2007) was a useful tool to systematically assess tail damage in the individual pig. We had to use several observers in order to score all tails every day. Although this is not ideal, since the observations of the different observers were proportionally divided over the treatments, treatment effects could be estimated correctly.

2.4.1 Development of tail biting

Fraser (1987) distinguished two stages of tail biting. Stage 1 is the pre-injury stage, before any visual wound is present on the tail. This stage may be followed by stage 2, the injury stage, where the tail is damaged and bleeding. Effective management of tail biting could benefit from (early) diagnosis of the pre-injury stage. Most often, however, tail biting is not diagnosed and treated until a wound is present (Schrøder-Petersen and Simonsen, 2001). In the present study, tails with bite marks could be considered to represent tail biting in the pre-injury stage 1. Bleeding tail wounds in this study corresponded to the injury stage 2. The blood released in the injury stage may act as an extra incentive for tail biting, resulting in the escalation of tail biting into cannibalism (Schrøder-Petersen and Simonsen, 2001). This research provided a detailed overview of the development of tail damage and such escalation of tail biting did not occur during the current experiment. Transition from bite marks into a tail wound was observed in 16% of the piglets and averaged 7.5 days. However, there was a large variation (standard deviation: 5.4 days) and in 2% of the cases transition was within one day. Therefore, it is important to take sufficient measures, preferably before the first animals have tail wounds with fresh blood (Van Putten, 1968). This implies a need for predictors indicating an outbreak of tail biting and further research is necessary to find suitable indicators of a tail biting outbreak.

2.4.2 Preventive measures

Previously Day et al. (2002) found that a small quantity of straw (92 g/pig/day) could reduce damaging behaviour like tail biting. We have now shown that even smaller amounts (20 g/pig/day) can substantially reduce tail biting, not only tail wounds, but also much smaller bite marks. This amount of straw is much less than what has been used in most other studies e.g. Fraser et al. (1991; 1000 g/pig/day), Bøe (1992; 192 g/pig/day), Van Putten (1980; 100 g/pig/day) and Day et al. (2001; 100 g/pig/day). Previously Fraser et al. (1991) showed that providing 63 g/pig/day in a straw rack can reduce biting in growing pigs. Our study now showed a significant reduction in tail wounds with as little as 5 g/pig/day in a rack compared with providing a metal chain (Figure 2.5). We used lower amounts of straw in order to diminish the chance of blockage of the manure channel (even though we did not completely succeed in this). Nevertheless, providing the piglets with on average 20 g of straw per pig per day (in two portions), was effective in reducing (but did not completely eliminate) bite marks and tail wounds. Since the straw rack (5 g/pig/day; refilled once or twice per week) was considerably less effective than providing straw twice daily, perhaps the frequency of straw provision (twice daily) and the way it is provided (loose on the floor) were important in addition to the actual amount provided. Every time straw was provided on the floor, the piglets became very active and started manipulating the straw immediately, which was also reported by Fraser (1991). Furthermore, straw has some nutritional value that will reinforce chewing behaviour (Day et al., 1996) and keep pigs occupied for a longer period. Pens with a chain or rubber hose did not differ in their effectiveness to prevent bite marks or tail wounds. This is surprising since Grandin and Curtis (1984) found that piglets manipulated a rubber hose more compared with a metal chain and in addition, Van de Weerd et al. (2003) found that chewability of the rubber hose (compared with lack of chewability of the chain) resulted in maintained interest. Apparently, in our study, the difference between chain and hose did not result in a difference in prevention of clinical tail damage. Both, the rubber hose and chain were much less effective in preventing tail biting than the provision of straw twice daily. This is consistent with the outcome of a review conducted by Bracke et al. (2006), who failed to find studies using simple metal objects, rubber or plastic toys reporting significant reductions of tail biting behaviour. Beattie et al. (1995) also stated that a toy alone was not sufficient to reduce harmful social behaviour such as tail biting and that toys only stimulate behaviour when 'novel'. According to Scott et al. (2006), no form of enrichment reliably provides the same level of occupation as seen with straw and further study is necessary to find reasons for differences in occupation time between straw and enrichment objects.

2.4.3 Curative treatments

We did not include a control treatment without any curative treatment in case of a tail biting outbreak, because this was ethically not acceptable. As a consequence, we cannot conclude that the reduction in fresh blood after curative treatment was actually due to the curative treatments administered. This is likely, however, since tails covered with blood tend to induce further tail biting (Van Putten, 1968; Fraser, 1987; McIntyre et al., 2001). Biters removed from a pen with a tail biting outbreak have to be put in another pen. Special pens (sickbay) are usually available to isolate an occasional biter, but with larger outbreaks involving a large number of biters the animals may have to be regrouped. In our experiment we regrouped several biters into the same pen more than once and this did not lead into a tail biting outbreak in that pen. Both curative treatments fully reduced the tail biting outbreak, but reduced the blood score only temporarily. This suggests that in case of removing the biter(s): not all biters were identified at the moment of removal; or that other piglets developed tail biting after removal. Leaving piglets with damaged tails in the pens might be an incentive for the other pigs to start tail biting resulting in an increased blood score a few days after the start of the curative treatment. Therefore, as suggested by Van den Berg (1982), removal of the biter may benefit from simultaneous removal of all wounded pigs from a pen as an effective curative treatment. Removal of biter and wounded pigs supplemented with straw provision would possibly be an even more effective curative treatment.

2.5 Conclusions and implications

Daily twice provision of a small amount of long straw (2x10 g/pig/day) considerably reduced the occurrence of bite marks and tail wounds in weaned piglets compared with the provision of a chain or rubber hose, while a straw rack showed an intermediate effect. Once tail biting had started, both removing the biter and daily twice straw provision, reduced tail biting temporarily, but not permanently.

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Chapter 3

Gender effects on tail damage development in single- or mixed-sex groups of weaned piglets

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Abstract

While extensive research on tail biting among pigs has focused on external factors (e.g. enrichment material), less research has been conducted on internal factors (e.g. gender, breed or age), which may effect the predisposition of pigs to start tail biting. Furthermore, to test internal or external factors, most previous studies used end point observations (e.g. tail damage at abattoirs). However, the potential factors causing tail biting, and the expression of tail biting itself can change over time as pigs grow older. Tail damage development over time might provide more accurate information on external and internal factors affecting tail biting than end point observation. Using tail damage development, we studied the effect of gender in single-sex and mixed-sex groups on tail biting. Tail damage development was recorded two ways: a) number of days before 40% of the piglets was observed with tail damage (40% incident point) and b) number of days a piglet was observed with tail damage (tail damage duration). A 2x2 factorial design was used and this resulted in four treatment categories: (1) all-male groups, (2) all-female groups, (3) males in mixed-sex groups and (4) females in mixed-sex groups. During the observation period tail damage (no damage, bite marks or tail wound) of 700 weaned piglets were scored three times per week for 32 days. Following the onset of tail biting, all-female groups had a lower 40% tail damage incident point (10.9 days), compared with the other three treatment categories (average of 16 days; $P<0.05$). In all-female groups, piglets also had a higher tail damage duration (20.2 days), compared with the other three treatment categories (average of 16 days; $P<0.05$). Several interactions between gender and mixing were found ($P<0.05$); males in mixed-sex groups had a lower 40% tail damage incident point and a higher tail damage duration than females in mixed-sex groups. These results indicate that female piglets are more likely to tail bite compared with male piglets. Furthermore, at the end of the observation period tail damage had developed to high levels in all groups and, at that point, differences between all-female groups and the other groups were absent. Tail damage development is therefore a better way to analyse effects of external and internal factors that result in tail biting, compared with methods based on end point analyses.

3.1 Introduction

Tail biting in pigs has a negative effect on pig welfare and causes considerable economic losses in pig production. The underlying causes of tail biting are considered multi-factorial (e.g. Van Putten, 1969; Sambraus, 1985; Bracke et al., 2004a, b; EFSA, 2007) and its expression is influenced by external factors such as environmental enrichment, housing climate, stocking density, sex-ratio, feeding management (Schrøder-Petersen and Simonsen, 2001) and internal factors such as breed (Breuer et al., 2003), gender (Hunter et al., 1999) or age (Schrøder-Petersen et al., 2003). These internal factors are important, because they may affect the predisposition to start tail biting and may also influence the extent to which external factors lead to tail biting (EFSA, 2007).

The effects of gender and sex-ratio on tail biting have been investigated in numerous studies and two factors can be distinguished: (a) gender (male versus female) and (b) mixing (mixed-sex groups with both males and females and single-sex groups with either all- males or all-females).

For the factor gender, non-castrated or castrated male pigs are, according to mainly abattoir studies, more at risk of obtaining tail damage during their life than females (e.g. Penny et al., 1972; Hunter et al., 1999; Valros et al., 2004; Kritas and Morrison, 2007).

For the factor mixing, Hunter et al. (2001) found lower levels of tail damage at slaughter in pigs that had been housed in mixed-sex as opposed to single-sex groups. In contrast, Schrøder-Petersen et al. (2003) found in mixed-sex groups of weaned piglets higher levels of tail biting behaviour compared with single-sex groups. Moinard et al. (2003) found no association between single-sex or mixed-sex groups and tail biting in an epidemiological case-control study on commercial farms.

For the combination of gender and mixing, Van de Weerd et al. (2005) observed that non-castrated male growing/finishing pigs in mixed-sex groups were more likely to be bitten. Furthermore, Walker and Bilkei (2006) observed that the prevalence of bitten male growing/finishing pigs was positively correlated with the proportion of females. In contrast, Blackshaw (1981) and Breuer et al. (2003) observed no differences in tail biting behaviour between male and female pigs within mixed-sex groups.

Summarizing, earlier studies suggest that within mixed-sex groups, male piglets are more likely to be bitten. The interactive effect of gender and mixing, however, remains unclear. Furthermore, previous studies used different observation methods and mostly used end point observations (e.g. tail damage at abattoirs). However, the potential factors causing tail biting and the expression of tail biting itself can change over time as pigs grow older. For example, Van de Weerd et al. (2005) found a decrease in tail biting behaviour with the increase of age.

We tested gender effects on tail damage development in single- and mixed-sex groups of weaned piglets. We used two parameters; number of days before 40% of the piglets was observed with tail damage (40% incident point) and the number of days a piglet was observed with tail damage (tail damage duration). Furthermore, the effect of tail damage duration on production was tested. This was possible due to the unique situation at the Pig Research Unit of the Animal Sciences Group in Lelystad, where tail biting outbreaks among weaned piglets occurred during the observation period.

3.2 Animals, materials and methods

3.2.1 Animals

The experiment was conducted at the Pig Research Unit of the Animal Sciences Group in Lelystad between September and November. In two batches, a total of 700 crossbred piglets (340 males and 360 females) were used, allocated to groups of 10 piglets. At birth, the piglets' tails were not docked, the teeth were not clipped and the males were not castrated. After weaning at the age of 4 weeks, the piglets were moved to the weaning facility and they were regrouped (based on body weight) in either all-male, all-female or mixed-sex pens (5 male and 5 female). They were given an ear-tag for individual identification during observations. At the start of the experiment, the average age of the weaned piglets was 29.5 ± 3.1 days and body weight was 7.8 ± 1.6 kg (standard deviation of body weight within pens was 0.6 kg).

3.2.2 Housing and husbandry

For the experiment two rooms were used. Each room contained 18 identical partly-slatted pens (see Zonderland et al., 2008 for detailed room design) with 0.4 m^2 space per piglet. Each pen contained a dry-feeder with two feeding spaces and piglets were fed ad libitum. The first eight days after weaning the piglets received creep feed (14.06 MJ Metabolic Energy (ME)). In the next four days the feed was gradually switched to a pre starter diet (13.81 MJ ME), which was fed until day 26 after weaning. From day 26 until day 30 after weaning the feed gradually switched to a starter diet (13.48 MJ ME), which was fed until the end of the weaning period. Next to the dry-feeder, a separate water bowl drinker was available. A metal chain was suspended above the slatted area as environmental enrichment. The environmental temperature was automatically regulated by forced ventilation and was set at 28 °C when the piglets entered. This temperature was gradually lowered to 21 °C at the end of the weaning period at 10 weeks of age. The piglets were inspected twice daily by professional care takers to ensure animal health and welfare.

3.2.3 Experimental design

The factors gender (male versus female) and mixing (mixed-sex versus single-sex) were tested in a 2x2 factorial design (see Figure 3.1). Within this experimental design, four different treatment categories could be distinguished; (1) males in single-sex groups (all-male), (2) females in single-sex groups (all-female), (3) males in mixed-sex groups (mixed-male) and (4) females in mixed-sex groups (mixed-female). On pen level, three different sex-ratio's could be distinguished; all-male (15 pens), all-female (17 pens) and mixed-sex (38 pens). We used a double number of mixed-sex pens to end up with an equal number of male and female piglets within the mixed-sex groups and the single-sex groups.

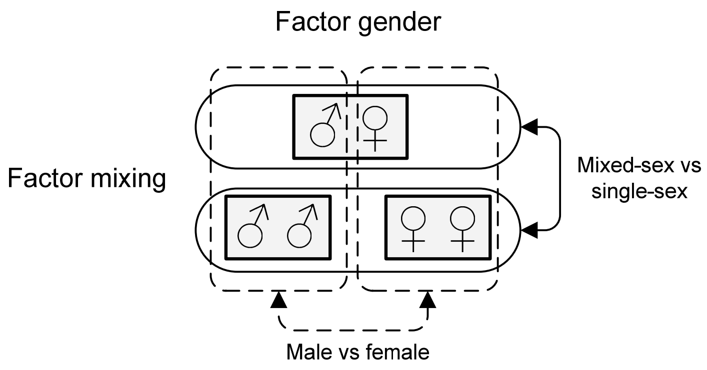


Figure 3.1 Experimental design.

3.2.4 Data collection

The observation period lasted 32 days, starting at weaning. Tail damage was scored by a single observer using a protocol modified after Zonderland et al. (2008). Three tail damage classes were used; 1) tails without damage, 2) tails with bite marks and 3) tails with a wound. Tails were scored three times per week resulting in a total of 14 observations. During tail damage scoring, the observer stood in the middle of the pen and, while surrounded by the piglets, checked each individual piglet's tail. Furthermore, individual piglets were weighted when moved into and out of the weaning facility (start weight and end weight) and per pen feed intake was recorded.

3.2.5 Statistical procedures

The following groups within each treatment category were the experimental unit for the different analyses: all-male (10 piglets per group), all-female (10 piglets per group), mixed-male (5 piglets per group) and mixed-female (5 piglets per group). Exception was the analysis for feed intake, in this case pen was the experimental unit (all-male, all-female and mixed-sex: each 10 piglets per pen). The effect of gender and mixing was analysed for: a) piglets with bite marks, b) piglets with a tail wound and c) piglets with tail damage, which involved all the piglets with either bite marks or a tail wound.

To analyse the effect of gender and mixing on tail damage development, we used two parameters: i) number of days before 40% of the piglets was observed with tail damage (40% incident point) and ii) the number of days a piglet was observed with tail damage (tail damage duration). We used the 40% incident point, although for the development rate of tail damage a 50% point would be the appropriate measure. However, the mixed-female and mixed-male groups contained five piglets and therefore the percentage piglets with tail damage leaps from 40% to 60%. In our analyses, the estimations of the 40% tail damage incident points were more accurate compared with the 60% and therefore the 40% incident point was chosen.

For comparison with the two tail damage development measures, the effect of gender and mixing on tail damage was tested at the end of the observation period. For completeness, also all the other observation moments prior the end of the observation period were analysed. Furthermore, the effect of tail damage duration on production was tested.

Analysis of the 40% incident points

For the 40% tail damage incident point, the day (between 0 and 32) at which at least 40% of the piglets within a treatment category had tail damage, was estimated. A distinction was made for either tail damage (bite marks or a tail wound; 40% tail damage incident point) or a tail wound (40% tail wound incident point). Estimation of the 40% incident point for bite marks was not possible, because during the observation period the number of piglets with bite marks first increased and subsequently decreased (for many piglets bite marks developed into a tail wound). A linear interpolation procedure (Genstat, 2002) was used to estimate these 40% incident points. Groups that failed to reach the 40% incident point before the last observation day, the Censor procedure (Genstat, 2002) was used to estimate the 40% incident point beyond 32 days. This method estimated the expected value of each censored observation iteratively conditional that the value must be greater than 32 days and based on the other observations in the experiment (Taylor, 1973). Table 3.1 shows the number of groups per treatment category for which the censor procedure was used. No difference was found in the number of groups within each treatment category that needed a censor procedure to estimate the 40% incident point.

Estimated 40% tail damage incident points and 40% tail wound incident points were normally distributed. To test the effect of gender and mixing on the estimated 40% incident points, a residual maximum likelihood (REML) procedure was used with the following mixed model (1).

Model (1): y = Mixing + Gender + Mixing * Gender + $\varepsilon_B + \varepsilon_{BR} + \varepsilon_{BRP} + \varepsilon_{BRPG}$

Where:

y = 40% tail damage incident points or 40% tail wound incident points

Mixing = fixed effect of mixed-sex versus single-sex groups

Gender = fixed effect of female versus male piglets

ε_B = random effect of batch, ε_{BR} = random effect of room, ε_{BRP} = random effect of pen and ε_{BRPG} = random (residual) effect of gender group within pen

Table 3.1

Per treatment category the number of groups for which the censor procedure was used for estimating the 40% incident point.

	All-male	**All-female**	**Mixed-male**	**Mixed-female**	**Total**
Total number of groups	15	17	38	38	108
Tail wound [1]	1	2	9	12	24
Tail damage [2]	0	0	1	1	2

[1] χ^2 = 4.0, P=n.s., [2] χ^2 = 0.8, P=n.s.

Analysis per observation moment

At each of the 14 individual observation moments, the level of tail damage was expressed as the number of piglets per treatment group with no tail damage, bite marks or a tail wound. The effects of gender and mixing on these nominal variables were analysed per observation moment using the following ordinal response model (McCullagh and Nelder, 1989):

Model (2): $Log[\gamma_i/(1-\gamma_i)] = Logit(\gamma_i) = \theta_i -$ (Mixing + Gender + Mixing * Gender + $\varepsilon_B + \varepsilon_{BR} + \varepsilon_{BRP}$) ; i=1,2

Where:

γ = tail damage (no tail damage, bite marks or a tail wound)

i = number of transitions between observation classes

Mixing = fixed effect of mixed-sex versus single-sex groups

Gender = fixed effect of female versus male piglets

ε_B = random effect of batch, ε_{BR} = random effect of room and ε_{BRP} = random effect of pen

Analysis of tail damage duration

Per individual piglet the number of days with bite marks, tail wound or tail damage was computed. Subsequently, the average bite marks, tail wound and tail damage duration score per treatment category were calculated and these duration scores were analysed using a REML procedure with mixed model (1).

Analysis of tail damage duration on the piglet's production

The damage duration scores (see previous paragraph) were used to assess the effect of tail damage on piglet's daily weight gain (DWG) and feed intake. The effects of the average bite marks, tail wound and tail damage duration scores on DWG were separately analysed using model (1), after adding respectively bite marks, tail wound or tail damage duration to the fixed model. DWG was normally distributed.

To analyse the effect of damage duration on feed intake, first the bite marks, tail wound and tail damage duration scores were computed per sex-ratio (i.e. per pen). Subsequently, the effect of damage duration on feed intake was analysed using a REML procedure with mixed model (3). Feed intake was also normally distributed.

Model (3): y = (Mixing + Gender (Mixing) + Damage duration + $\varepsilon_B + \varepsilon_{BR} + \varepsilon_{BRP}$)

Where:

y = feed intake

Mixing = fixed effect of mixed-sex versus single-sex groups

Gender (Mixing) = fixed effect of all-female, all-male within single-sex groups
Damage duration = bite marks, tail wound or tail damage duration
ε_B = random effect of batch, ε_{BR} = random effect of room and ε_{BRP} = random effect of pen

The fixed model effects for models (1), (2) and (3) were tested using the corresponding Wald tests. For significant treatment effects, significant differences between pair wise treatment means were tested using Fisher's LSD test (P=0.05; GenStat, 2002).

3.3 Results

Of the 700 individual piglets 95% was observed with tail damage at some stage within the observation period, either bite marks (21%) or a tail wound (74%). From the piglets that were scored with a tail wound, 63.5% showed this after one or more observations with bite marks, while 36.5% of the piglets were scored with a tail wound straight away. Approximately 6.5% of all the piglets showed signs of (temporary) healing, changing from bite marks to no tail damage or from a tail wound to bite marks. On pen level, in all 70 pens one or more piglets were observed with tail damage during the observation period. At the end of the observation period in 98% of the pens three or more piglets were scored with a tail wound and in 77% of the pens five or more piglets were scored with a tail wound.

3.3.1 Treatment effects on the 40% incident points

Table 3.2 shows the results of the statistical analysis for the tail damage development per treatment category, using model (1). For the 40% tail damage incident point an interaction between gender and mixing was found (P<0.05). For the 40% tail wound incident point a mixing effect (P<0.05) and an indication of interaction between mixing and gender (P<0.1) were found.

Table 3.2

Per treatment category, the predicted mean number of days and standard error of differences (minimum and maximum s.e.d. between means per treatment category), before 40% of the piglets in a group was scored with tail damage or a tail wound.

	All-male	Mixed-male	All-female	Mixed-female	S.e.d. min-max
Number of piglets	150	190	170	190	
Tail damage	15.5^{b}	15.5^{b}	10.9^{a}	15.8^{b}	1.0 – 2.1
Tail wound	23.0^{ab}	23.5^{ab}	19.3^{a}	26.7^{b}	1.6 – 3.2

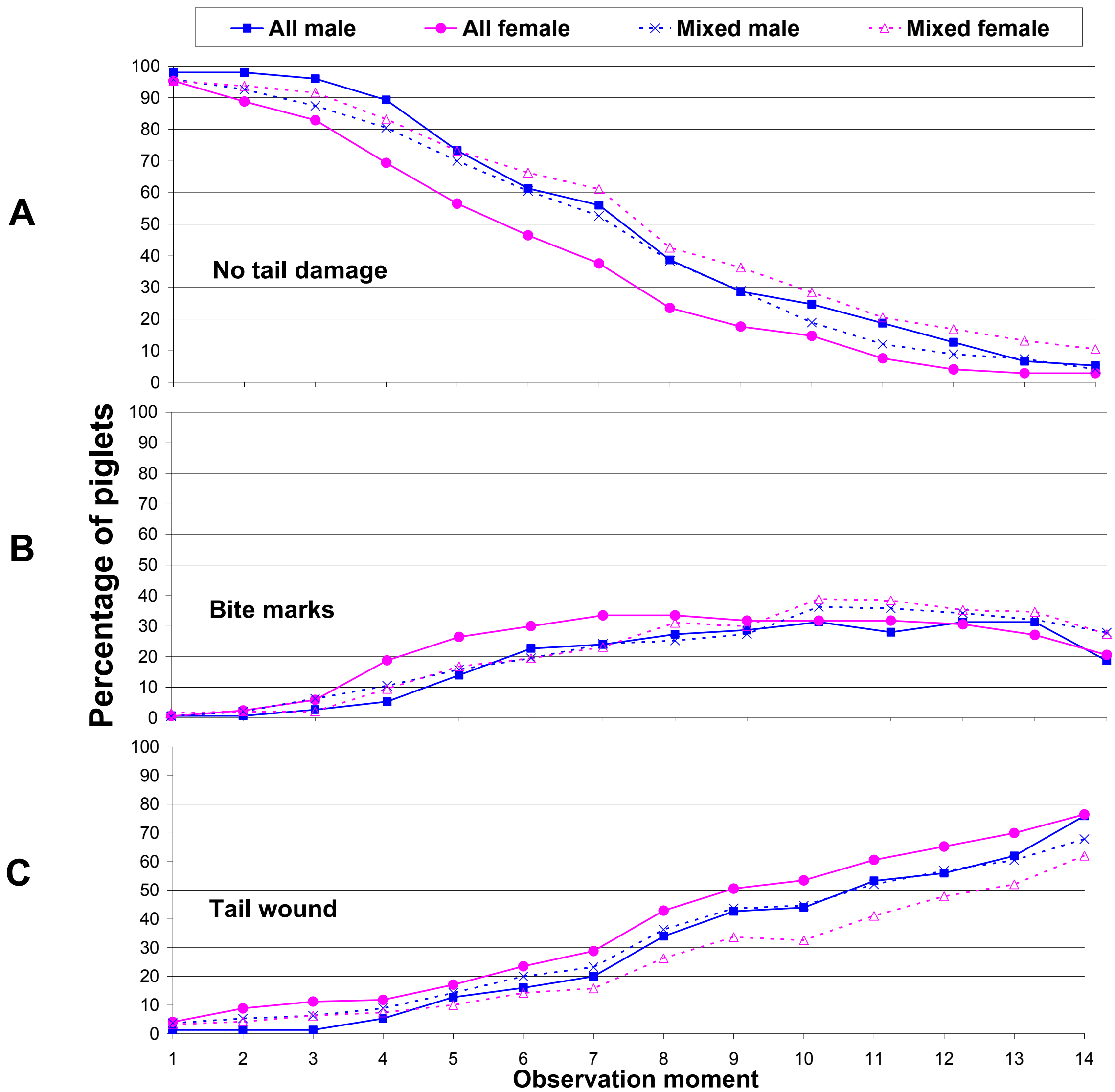
Different superscripts in a row indicate a significant difference (a, b: P<0.05).

For the 40% tail damage incident point, all-female groups reached this point earlier (10.9 days) compared with the other treatment categories. For the 40% tail wound incident point, all-female groups also reached this point earlier (19.3 days), compared with mixed-female groups (26.7 days), but not earlier compared with all-male (23.0 days) or mixed-male groups (23.5 days). No difference in the 40% tail damage or tail wound incident points were found between all-male, mixed-male and mixed-female groups.

3.3.2 Treatment effects per observation moment

Figure 3.2 shows per observation moment and per treatment category the mean percentage of piglets with no tail damage, bite marks and a tail wound. The table below Figure 3.2 shows per observation moment the results of the statistical analysis using model (2). For observations with a significant effect, differences between the treatment categories are shown in arced cells.

During observations 1 to 5, the percentage piglets with no tail damage (Figure 3.2A) decreased more rapidly in the all-female groups and remained lower during the whole observation period compared with the other treatment categories. During observations 1 to 4, the all-male groups showed the highest percentage piglets with no tail damage. However, from observation 5 onwards, the mixed-female groups had the highest percentage piglets with no tail damage. At the end of the observation period the percentage piglets with no tail damage within each treatment category had decreased to less than 11%. From observation 4 to 7, the all-female groups showed a relatively strong increase in the percentage of piglets with bite marks (Figure 3.2B). The mixed-male and mixed-female groups showed relatively more piglets with bite marks from observation 10 to 14 compared with the all-male and all-female groups. The percentage of piglets with a tail wound (Figure 3.2C) was highest for the all-female groups throughout the observation period. The all-male groups had the lowest percentage of piglets with a tail wound during observations 1 to 3 (average of 1.3%). This group, however, showed a relatively strong increase in piglets with a tail wound at the end of the observation period and ended with a similar percentage (76.0%) compared with the all-female groups (76.5%). The mixed-male groups showed, compared with the mixed-female groups, a stronger increase in the percentage of piglets with a tail wound from observation 1 to 10 (12.1% higher). The percentage piglets with a tail wound in the mixed-male group remained higher until the end of the observation period compared with the mixed-female, but the difference decreased slightly. A significant interaction between gender and mixing was found from observation 2 until 11 (Figure 3.2D); within single-sex groups female piglets had more tail damage compared with male piglets, but within mixed-sex groups male piglets had more tail damage. Furthermore, a gender effect was found in observation 10 and a mixing effect in observation 14. From observation 2 to 5, all-female groups had more tail damage than all-male groups. From observation 4 to 13, the all-female groups showed more tail damage than the mixed-female groups. At the end of the observation period, piglets in single-sex groups showed more tail damage than piglets in mixed-sex groups.



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Gender	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	#	ns	ns	ns
Mixture	ns	ns	ns	ns	ns	ns	ns	ns	#	ns	ns	ns	ns	*
Interaction	ns	*	***	**	*	*	*	*	*	*	*	#	#	ns
♀♀ > ♂♂ [1]														
♂♀ > ♂♂ [2]														
♀♀ > ♀♂ [3]														
♂♀ > ♀♂ [4]														
S-sex > m-sex [5]														

Ns = not significant, # = P<0.1, * = P<0.05, ** = P<0.01, *** = P<0.001

[1] ♀♀ > ♂♂ = all-female groups have more tail damage than all-male groups

[2] ♂♀ > ♂♂ = mixed-male groups have more tail damage than all-male groups

[3] ♀♀ > ♀♂ = all-female groups have more tail damage than mixed-female groups

[4] ♂♀ > ♀♂ = mixed-male groups have more tail damage than mixed-female groups

[5] S-sex > m-sex = piglets in single-sex groups have more tail damage than piglets in mixed sex groups

Figure 3.2 Mean percentage of piglets with no tail damage (A), bite marks (B) and tail wound (C) per observation moment for the four treatment categories. In the list (D) below the graphics, per observation moment the effects of gender, mixing and their interactions on tail damage are given together with significant differences between the treatment categories (arced areas).

3.3.3 Treatment effects on tail damage duration

Table 3.3 shows the results of the statistical analysis using model (1) for the average bite marks, tail wound and tail damage duration scores. There was no effect of gender or mixing on the bite marks duration scores. A significant interaction between gender and mixing (P<0.01) was found on tail damage duration and a tendency for the same interaction (P<0.1) on tail wound duration.

Table 3.3

Predicted mean bite marks, tail wound and tail damage duration scores (days) per treatment category and corresponding standard error of differences (s.e.d.; minimum and maximum).

	All-male	**Mixed-male**	**All-female**	**Mixed-female**	**S.e.d. min-max**
Bite marks duration (days)	6.2^{a}	6.8^{a}	7.4^{a}	7.1^{a}	0.3-0.5
Tail damage duration (days)	15.8^{a}	16.8^{a}	20.2^{b}	15.4^{a}	0.3-0.7
Tail wound duration (days)	9.7^{ab}	10.0^{ab}	12.0^{b}	8.2^{a}	0.4-0.9

Different superscripts in a row indicate a significant difference (a, b: P<0.05).

All-female groups had a higher tail damage duration score (20.2 days) compared with the other three treatment categories. Furthermore, all-female groups had a higher tail wound duration score (12.0 days) compared with the mixed-female groups (8.2 days), but not compared with the all-male and mixed-male groups. Spearman's rank correlation test showed a high negative correlation between the 40% tail damage incident point and tail damage duration score (r = -0.857; P<0.001) and between 40% tail wound incident point and tail wound duration score (r = -0.861; P<0.001).

3.3.4 Effect of tail damage duration on piglet's production

A gender effect (P<0.01) was found for DWG. Female piglets had a higher DWG (560 g/day) than male piglets (536 g/day). Furthermore, a significant interaction on DWG between gender and tail damage duration (P<0.01) was found. In Figure 3.3, the DWG is shown in relation to the tail damage duration for male piglets and female piglets separately.

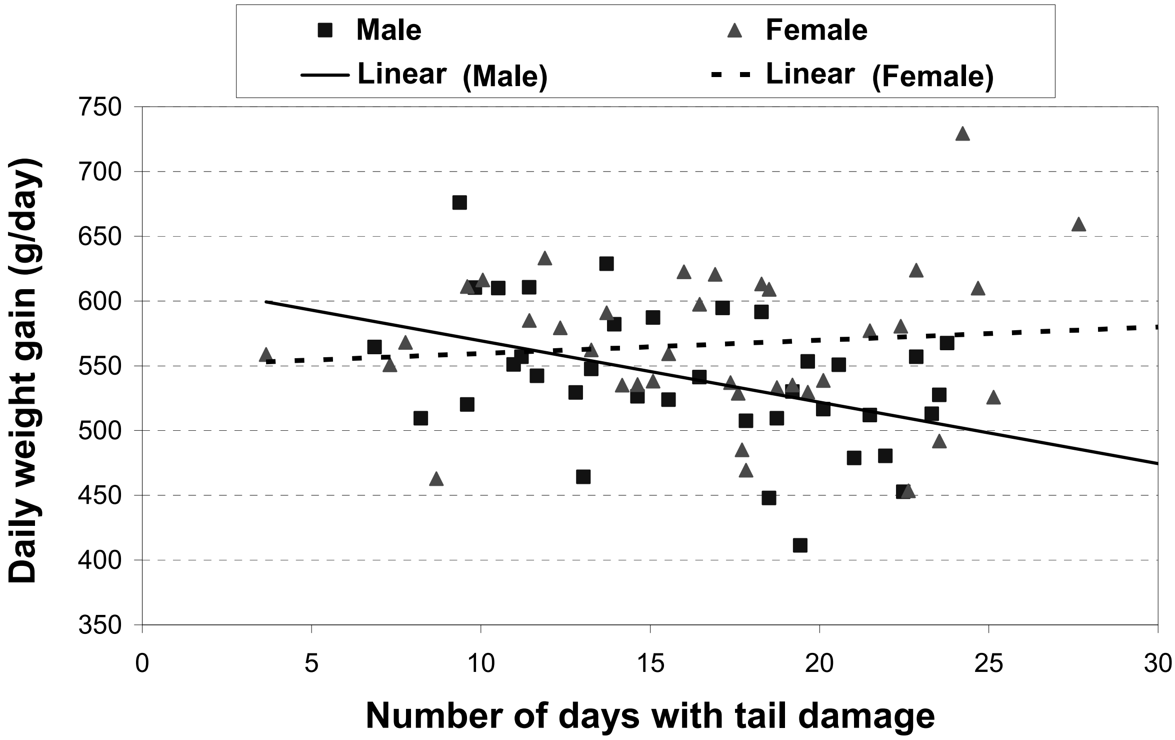

Figure 3.3 For male and female groups, the average daily weight gain (g/day) plotted against the tail damage duration, including a linear trend line.

For male piglets, the DWG reduced as tail damage duration increased (see solid trend line in Figure 3.3). In contrast, DWG for female piglets increased as tail damage duration increased (see dashed trend line). A similar significant interaction on DWG was found between gender and tail wound duration ($P<0.001$).

No differences in feed intake were found between the three sex-ratio groups (25.2, 27.1 and 26.0 kg for all-male, all-female and mixed-sex pens). However, a significant interaction between sex-ratio and tail damage duration ($P<0.001$) was found. In Figure 3.4, the feed intake in relation to the tail damage duration is shown for the three different sex-ratios.

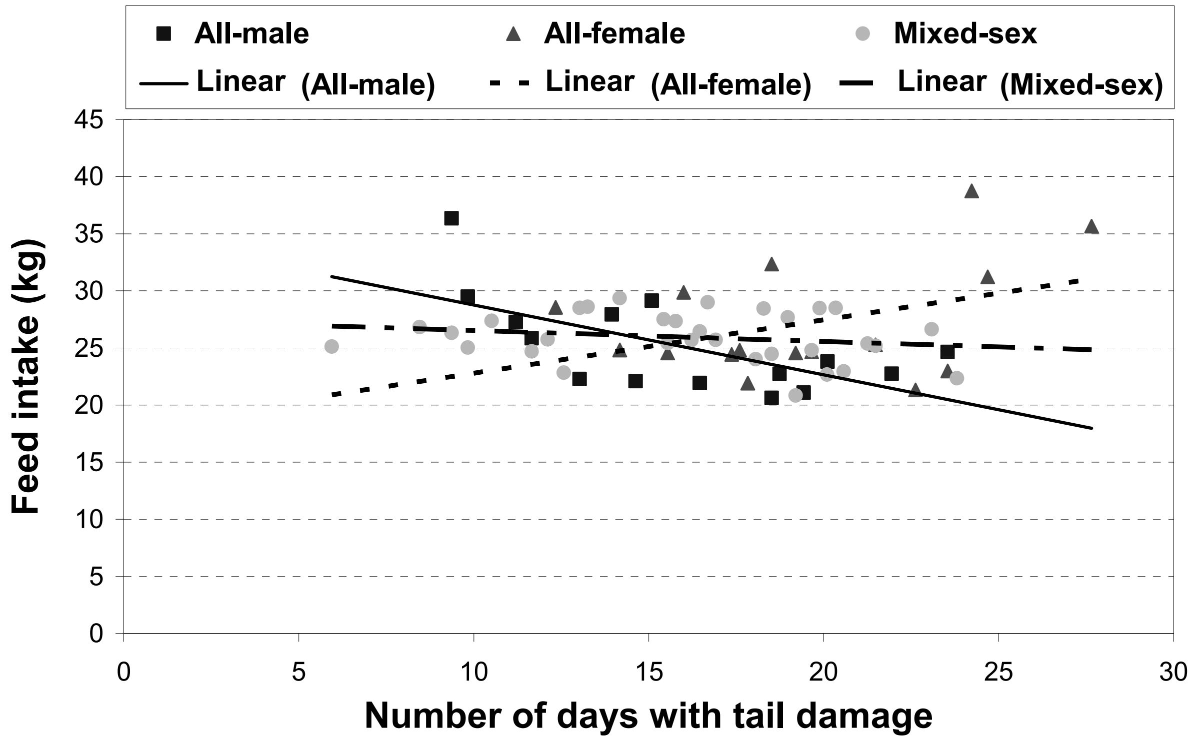

Figure 3.4 For the different sex-ratios (all-male, all-female and mixed-sex pens), the average feed intake (kg) over the observation period is plotted against the tail damage duration, including a linear trend line.

In all-male pens feed intake decreased as tail damage duration increased (see solid trend line in Figure 3.4). In contrast, feed intake in all-female pens increased as tail damage duration increased (see short dashed trend line in Figure 3.4). Feed intake in mixed-pens remained relatively constant as tail damage duration increased and was not significantly different from all-male or all-female pens (see dashed trend line in Figure 3.4). A similar significant interaction on feed intake was found between gender and tail wound duration ($P<0.001$).

3.4 Discussion

After tail biting started, all-female groups had a lower 40% tail damage incident point compared with all-male, mixed-male and mixed-female. Similar, all-female groups had a higher tail damage duration score compared with the other three treatment categories. These results are in agreement with Schrøder-Petersen et al. (2004), who found that among pigs between 40 and 50 kg tail-in-mouth (TIM) behaviour was higher in all-female groups compared with all-male groups. This indicates that female piglets are more prone to tail bite compared with male piglets, or that female piglets are more likely to become victims of tail biting. We found an interaction between gender and mixing for both the 40% tail damage incident point and the tail damage duration score. Male piglets in mixed-sex groups developed tail damage more rapidly compared with female piglets in mixed-sex groups. These findings are in agreement with Kritas and Morrison (2004), who observed in mixed-sex groups twice as much tail damage of castrated males (21%) compared with females (9.8%). Also, Hunter et al. (1999) found that males in mixed-sex groups had 1.4 times more chance of being bitten than female pigs. With this interaction for tail damage development, our results indicate that female piglets are more likely to tail bite than male piglets.

The reason why female piglets are more likely to tail bite is not clear. Sambraus (1985), Simonsen (1995) and Schrøder-Petersen and Simonsen (2001) speculated that as female pigs start to become sexually mature, they become more active and also more interested in ano-genital investigation. Furthermore, pigs have been observed to perform more ano-genital manipulation before and after TIM behaviour than any other behaviour (Schrøder-Petersen, 2005). The higher motivation of female pigs to direct their ano-genital behaviour to (if present) the opposite sex (Schrøder-Petersen and Simonsen, 2001), can explain the higher tail damage among male piglets compared with the females in our mixed-sex groups. Furthermore, Breuer et al. (2003) investigated the manipulation motivation of 300 weaned piglets in a ‘Tail Chew Test’ and found that females had a tendency to manipulate a rope more often than the non-castrated males (2.0 versus 1.0, P=0.07). This higher motivation to perform manipulating behaviour and/or higher motivation to perform ano-genital behaviour among female piglets could explain the higher tail damage development in the all-female groups.

Beside the role of the biter within a group, there might also be a role of the victims. Presumed lower levels of activity can make males more attractive targets for tail biting by penmates (EFSA, 2007). For more evidence to support these hypotheses, further study on characteristics of biters and victims is necessary.

Differences in tail damage averages per pen at the end of the observation period were small; tail damage had developed to high levels in all groups. At this point our results showed a mixing effect (piglets in single-sex groups had more tail damage than in mixed-sex groups). This is in contrast with our conclusion that all-female groups had the highest tail damage development. Therefore, looking only at the end of the observation period leads to different conclusions about the effect of gender and mixing on tail damage compared with looking at tail damage development. For an effective treatment of tail biting, it must be diagnosed and treated in an early stage in order to minimize the negative consequences of tail damage (Zonderland et al., 2008). This suggests that it is important to test the effect of internal or external factors on the early development of tail biting. Therefore tail damage development is a more appropriate measure to test these effects compared with end point observations. Both 40% tail damage incident point and tail damage duration can be used. In our experiment these two parameters were highly correlated.

We found that female piglets had a higher DWG compared with male piglets. Van der Mheen and Spoolder (2003) found no difference in DWG between male and female piglets (uncastrated weaned piglets housed in mixed-pens) in the same experimental facility, but without tail biting problems. Furthermore, DWG of males decreased as the number of days with tail damage or with a tail wound increased. This is in agreement with several studies that showed a negative effect of tail damage on DWG (e.g. Wallgren and Lindahl, 1996). In contrast, DWG of females increased as the number of days with tail damage or a tail wound increased. In addition, a higher feed intake was found in all-female pens as the number of days with tail damage or a tail wound increased. The reason why females with tail damage had a higher DWG and feed intake is not clear. A possible explanation could be that piglets with a high DWG and feed intake are probably the heavier and more dominant piglets. These piglets will occupy the feeder during the active periods of the day, when all piglets want to feed. While standing at the feeder, these piglets are an easy target for tail biters. It is most likely that these heavier female piglets also experienced a negative effect from tail damage and might have had even higher DWG when they had no tail damage. However, further research on potential victims and their dominance status is necessary to support this hypothesis.

3.5 Conclusions and implications

When tail biting starts, all-female groups had a higher tail damage development compared with all-male and mixed-sex groups. At the end of the observation period this difference between all-female groups and the other treatment categories was not found. At that point tail damage developed to high levels in all groups. Tail damage development is therefore a better way to analyse effects of external and internal factors resulting in tail biting, compared with methods based on end point analyses.

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Chapter 4

Individual piglets' contribution to the development of tail biting

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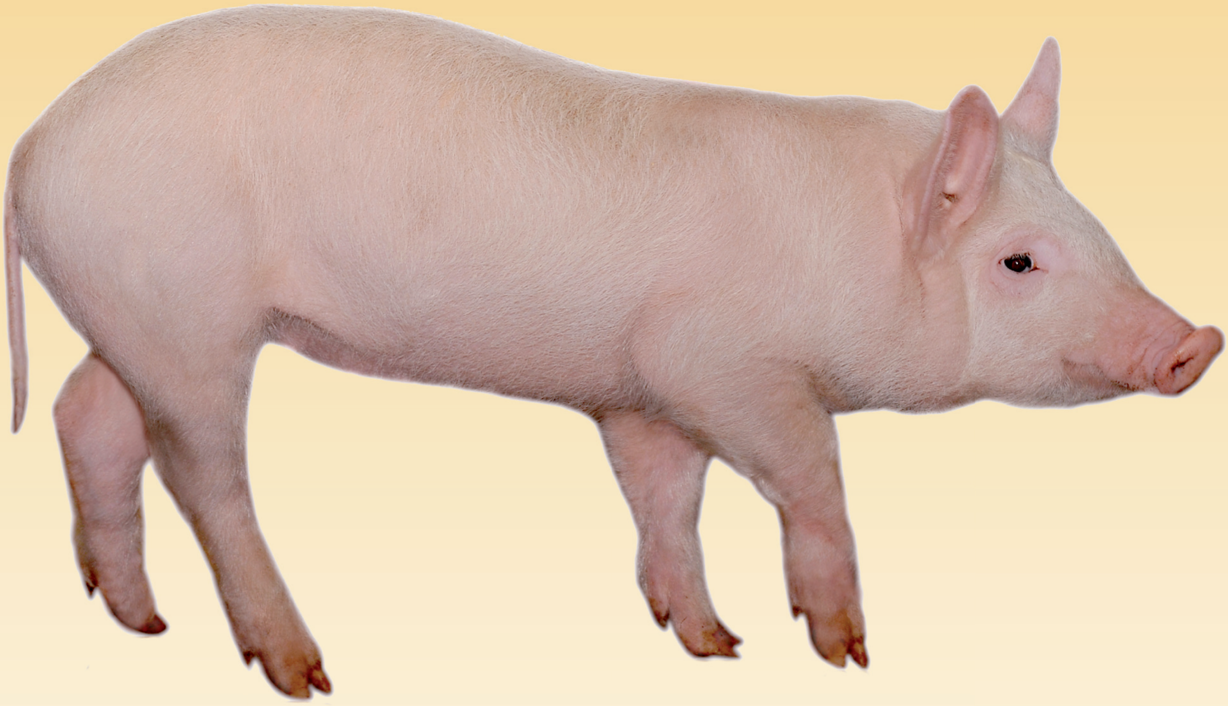
H.A.M. Spoolder



Animal (2010), Accepted.

Abstract

Conflicting hypotheses exist about the contribution of individual pigs to the development of a tail biting outbreak but there is limited quantitative information to support or dismiss them. The present study aims to quantify the development of tail biting behaviour at pen and individual piglet level, before and after the first visible tail damage. Video recordings of fourteen pens with tail biting outbreaks and individually marked weaned piglets were used to observe tail biting incidents (TBI; piglet biting a penmate's tail). When visible tail damage was first observed in a pen (i.e. day of tail biting outbreak; D_0) the video recordings of the previous 6 (till D_{-6}) and the following 6 days (till D_6) were analysed every other day for TBI's and the identities of the biter and bitten piglet were recorded. The average TBI's per individual piglet (within each pen) per observation day were analysed to quantify the development of tail biting behaviour and to identify pronounced biters and/or bitten piglets. The (absence of) coherence for performed TBI's in a pen was used to test whether biters preferred a specific penmate. There was an exponential increase in the intensity (linear on log-scale) of the TBI's from an average of 0.7 bites/h at D_{-6} to 2.3 bites/h at D_6. An additional negative quadratic component in the final statistical model suggests that a plateau for tail biting behaviour was reached by the end of the observation period. Before any visible tail damage was observed (i.e. before D_0), 82% of the piglets performed and 96% of them received tail bites. After D_0, the figures were 99% and 100%, respectively. One or a few pronounced biters could be identified in almost all pens. These biters already showed more tail biting at D_{-6} than their penmates. Furthermore, these biters showed a greater increase in tail biting behaviour during the observation period than the average frequency of their penmates. In contrast, for pronounced bitten piglets this greater increase in receipt of bites during the observation period was not apparent, although these bitten piglets already had been bitten more than their penmates at D_{-6}. Finally, there was no significant coherence between biters and bitten piglets, indicating that biters showed no preference for biting particular penmates, even when some of them had a damaged tail. The present results show that, by using observations of TBI's, possible biters or bitten piglets can already be identified six days before tail damage is first apparent in a pen.

4.1 Introduction

Tail biting is an adverse behaviour characterised by manipulation of a pig's tail by another pig resulting in tail damage of varying severity (Penny et al., 1981; Sambraus, 1985; Fraser, 1987; Schrøder-Petersen et al., 2003). The underlying causes of tail biting are multi-factorial (Van Putten, 1969; Sambraus, 1985; Bracke et al., 2004a, b) and the likelihood of its expression is influenced by external factors such as environmental enrichment, housing system, climate, stocking density and feeding management as well as internal factors like breed, gender and age (Schrøder-Petersen and Simonsen, 2001). Two stages can be distinguished in the development of tail biting (Fraser, 1987; Schrøder-Petersen and Simonsen, 2001). The first is the pre-injury stage (before tail damage occurs) and this may be followed by the injury stage (Stage 2), where the tail is damaged and bleeding.

Van Putten (1969) and Fraser (1987) stated that in the pre-injury stage a few pigs lightly chew on penmates' tails and the recipients usually tolerate this. It has been suggested that this light or non-destructive chewing, also known as tail-in-mouth behaviour or TIM, may be a normal low-frequency behaviour performed by all pigs and the precursor to tail biting (Feddes et al., 1993; Schrøder-Petersen et al., 2003). In contrast, Van Putten (1968) argued that only some pigs show light chewing before tail damage occurs while Blackshaw (1981) and Edwards (2006) proposed that often only a single pig shows this initial tail biting behaviour. The pre-injury stage may, more or less rapidly, progress to the injury-stage (Fraser, 1987). Blood attracts pigs and several penmates may become involved as biters or as victims leading to a rapid escalation of the tail biting problem (Blackshaw, 1981; Fraser, 1987; EFSA, 2007). Conversely, it has been suggested that usually one victim is attacked in a pen and that the other pigs "hunt this victim" (EFSA, 2007).

To summarize, the contribution of particular pigs to the development of tail biting in the pre-injury and injury stages is controversial. Furthermore, there is little quantitative information about the development of tail biting behaviour and whether or not biters victimize specific penmates.

The present study aims to quantify the development of tail biting behaviour at pen and piglet level, both before and after the tail biting outbreak. By quantifying tail biting incidents from 6 days before till 6 days after the tail biting outbreak in a pen we addressed the following three questions:

a. How many piglets in a pen are involved in performing and receiving tail biting behaviour before and after the tail biting outbreak?
b. Is it possible to identify pronounced biters and/or bitten piglets in a pen?
c. Do biters prefer specific penmates or do they bite randomly?

4.2 Animals, materials and methods

A library of video recordings of 96 mixed-sex pens of 10 weaned piglets had been built in a previous study (Zonderland et al., 2008). During this experiment tail damage was scored every morning using three classes; 0 = no tail damage, 1 = bite marks (small damages with the size of a pinhead), 2 = tail wound (clearly visible wound with blood). For present purposes we selected the video recordings for 14 of these pens based on the appearance of tail damage and the availability of records for the required D_{-6} to D_6 observation period. These records were examined in greater detail in the present study (see below).

The fourteen identical pens were fitted with partially slatted floors and provided with a space allowance of 0.4 m^2 per weaned piglet (Zonderland et al., 2008). Each pen contained a dry-feeder with two feeding spaces and piglets were fed ad libitum. The 140 piglets were not tail docked after birth and not teeth clipped, and the males were not castrated. The piglets were weaned at the age of 4 weeks. The piglets received creep feed for the first 8 days after weaning (14.06 MJ Metabolic Energy (ME), 180 g/kg protein, 11.88 g/kg lysine, 3.0 g/kg Na (as-fed basis)). Over the next 4 days this was gradually switched to a pre starter diet (13.81 MJ ME, 175 g/kg protein, 11.54 g/kg lysine, 2.5 g/kg Na), which was fed until day 26. Thereafter the feed was gradually switched to a starter diet (13.48 MJ ME, 175 g/kg protein, 10.30 g/kg lysine, 1.2 g/kg Na), which was fed until the end of the weaning period. A water bowl drinker (situated next to the dry-feeder) provided unlimited water intake. The pens were located in rooms where the environmental temperature was automatically regulated by forced ventilation. Room temperature was set at 28 ºC when the piglets entered, 26 ºC after 5 days, 23 ºC after 21 days and then 22 ºC after 28 days until the end of the experiment (32 days). Enrichment devices were either a 0.5m metal chain suspended from the pen partition or two rubber hose tubes (length 0.4m and diameter 30mm) tied in a cruciform shape and suspended on a chain (rubber toy). Each pen was digitally video recorded (Poseidon, DVR, 8 frames per second) using colour cameras (TC-506CEX) every other day between 14.00h and 19.00h. Markings on the back facilitated individual recognition of the piglets, using three colours of spray (red, blue and green).

4.2.1 Observations

When a tail biting outbreak became apparent in a pen (i.e. D_0; minimal one piglet with a tail wound or at least two piglets with bite marks) the video recordings for the previous 6 (till D_{-6}) and the following 6 days (till D_6) were analysed every other day. Tail biting incidents (TBI; piglet biting a penmate's tail) were scored and the identities of the biter and bitten piglet were recorded. This procedure continued until video recordings had been analysed for the 14 pens for 7 observation days (ideally D_{-6}, D_{-4}, D_{-2}, $D_{0,}$ D_2, D_4 and D_6). Occasionally, no video recordings were available for the pre-selected days because recording was only done on every other day, so video recordings obtained on the previous days were used. A recording period of 14.00 to 19.00h was used because a preliminary study revealed a daily peak in TBI from mid-day to late afternoon, corresponding to the pig's diurnal pattern of general activity. A similar pattern was also found for chewing behaviour by Feddes et al. (1993). Video records were analysed for the first ten minutes of each half hour between 14.00 and 19.00 h, i.e. 14.00-14.10, 14.30-14.40, 15.00-15.10, etc.; see Figure 4.1) using behavioural sampling (Observer XT, Noldus), resulting in a total of more than 163 hours of observation. All fourteen pens were watched in random order by a single observer.

Tail biting behaviour was scored during each 10-minute observation period using tail biting incidents (TBI's). A TBI was scored when one piglet (biter) was observed with the tail of a penmate (bitten piglet) in its mouth while making clear biting movements. A TBI was also scored when the biter manipulated a penmate (bitten piglet) near its tail and this behaviour elicited a clear response from the bitten piglet (standing, jumping up or a quick turn of the head towards the biter). The second part of the above definition was applied in cases where a bitten piglet's tail was not visible, e.g. when it was obstructed by another piglet. For each TBI, we recorded the identities of the biter and the bitten piglet. Per observed hour the number of TBI's per piglet was summed for each of the two 10-minute observation periods and multiplied by three to calculate the average TBI per piglet per observed hour. Per observation days (D_{-6} to D_6) these individual TBI's per piglet per hour were averaged and this average TBI per piglet per observation day was used for further analyses.

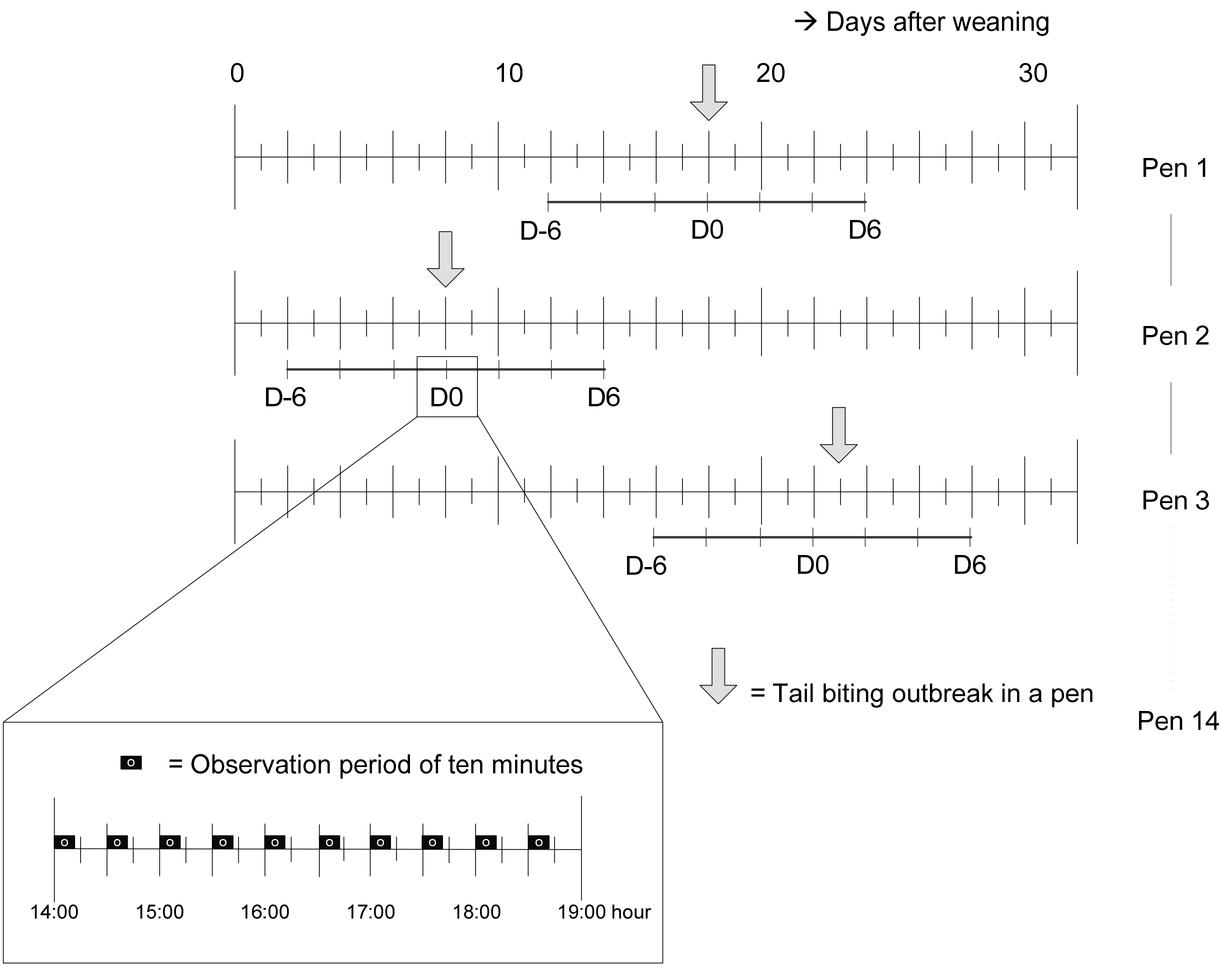


Figure 4.1 Example of selected observation days per pen before and after the first visible tail damage.

4.2.2 Statistical procedures

First, to quantify the development of tail biting before and after the tail biting outbreak in a pen and to identify possible pronounced biters and/or bitten piglets within a pen, the average TBI's per piglet per observation day (D_{-6} to D_6) were analysed using Model (1). Second, to analyse whether piglets prefer to bite specific penmates, the coherence between biters and bitten piglets was analysed using Model (2). Third, the relationship between tail damage and the received number of tail bites was estimated in order to validate the observation method used. All analyses were performed using Genstat software version 11.1 (VSN International Ltd). Fixed model effects were tested using the corresponding Wald tests. Differences between pair wise treatment means were tested using Fisher's LSD test.

The recorded TBI's were used to analyse if a particular kind of development (e.g. linear) in biting and being bitten was apparent (at pen and individual level) before and after the tail biting outbreak (D_0). The numbers of bites performed and bites received per piglet were analysed separately. For biting, we used the average log-transformed number of bites performed per piglet (within pens) per observation day (data was normally distributed after log-transformation). First, a Restricted Maximum Likelihood (REML) variance components analysis with mixed Model (1) was used to determine any inclines in biting. Subsequently, the pen slope was used as a fixed factor in the model to identify a pronounced biter in a pen. The analysis showed that on pen level the overall development of performed bites had significant linear ($P<0.001$) and negative quadratic ($P<0.05$) components. In Model (1) these two components are represented by β_1 and β_2. Model (1) represents the final model for bites performed.

Model (1):

$$Log(y) = (\beta_0 + \varepsilon_{\beta 0-pen} + \varepsilon_{\beta 0-pig}) + (\beta_1 + \varepsilon_{\beta 1-pig}) * t - \beta_2 * t^2 + \varepsilon_{pen*day} + \varepsilon_{pig*day} + \varepsilon_{pen*pig*day}$$

Where:

y = number of bites performed per observation day

t = day of observation (D_{-6} to D_6)

Fixed effect: incline in pen with linear (β_1) and negative quadratic (β_2) component

Random effects:

$\varepsilon_{\beta 0\text{-pen}}$ = differences in intercept between pens (i.e. the predicted mean level of TBI at D_{-6})

$\varepsilon_{\beta 0\text{-pig}}$ = differences in intercept between piglets

$\varepsilon_{\beta 1\text{-pig}}$ = differences in TBI development between piglets (slope)

$\varepsilon_{pen*day}$ = day effects of pens (auto regression)

$\varepsilon_{pig*day}$ = day effects of piglets

$\varepsilon_{pen*pig*day}$ = residual variation

A similar procedure was used to analyse bites received. Analysis of the average log-transformed numbers of received bites per piglet (within pens) per observation day showed a significant linear ($P<0.001$) component (β_1). Therefore, to determine if some piglets in a pen received pronounced biting, Model (1) was used without the negative quadratic component (β_2) as fixed factor.

For each pen a 10x10 matrix with the number of bites performed and received per each of the 10 piglets was calculated. This resulted in a three-dimensional cross table (pen, biter and bitten piglet). To test the absence of coherence between biters and bitten piglets (i.e. the hypothesis that piglets showed no preference to bite a specific penmate (based on a poisson distribution)), the three-dimensional cross table was analysed using a generalized linear regression model (Model (2)) and with logarithm as link function. To test whether tail damage had a specific effect on the preference of biting piglets for a specific penmate, the coherence after the tail biting outbreak in a pen was analysed separately. Therefore a subsets was created with data from D_0 to D_6 and again analysed using Model (2).

Model (2):

$$Log(Ey_{ijk}) = Log(n) + \log(p_{ij.}) + \log(p_{i.k})$$

Where:

Ey_{ijk} = the estimated number of TBI's per piglet combination per pen

n = total number of TBI's

i = pen

j = biter

k = bitten piglet

The residual variation of the model was tested for independence using a χ^2- test ($P<0.05$).

A REML procedure was used to estimate the relationship between the level of tail damage (no damage, bite marks or a tail wound) at D_0 and the cumulative received tail bites prior this day (i.e. D_{-6} to D_{-2}). The mean number of received tail bites per hour per tail damage level prior to D_0 was estimated in the REML procedure with tail damage as fixed and pen as random component. Similarly, the mean number of received tail bites per hour was estimated per tail damage level prior to D_2, D_4 and D_6.

4.3 Results

The average age of the weaned piglets at the start of the experiment was 28.2 (± 3.2) days and start weight was 7.9 (± 1.3) kg. At the end of the 32-day weaning period, the average end weight was 26.7 (± 3.9) kg. During this weaning period 76 piglets out of the 140 piglets were observed with a tail wound on one or more observation days. Another 49 piglets were observed with bite marks, but no tail wound, on one or more observation days and the remaining 15 piglets had an undamaged tail throughout the period. For piglets that were observed with a tail wound and previously with bite marks, this deterioration of tail damage took on average 7.0 days (± 4.5 days). In total 9% of the piglets were observed with a tail wound without bite marks on a previous observation.

4.3.1 Development of TBI's

Before the tail biting outbreak, i.e. D_{-6} to D_{-2}, 115 of the 140 piglets (82%) were observed biting a penmate one or more times (Table 4.1). In the same period, 135 of the 140 piglets (96%) were bitten by a penmate one or more times. After the tail biting outbreak was present, i.e. D_0 to D_6, 138 piglets (99%) were seen biting a penmate while every piglet was bitten.

The overall average number of TBI's per piglet per hour increased from 0.73 to 2.30 between D_{-6} and D_6. The number of biters increased from 67 at D_{-6} to 102 at D_0 and then remained relatively constant. The average number of bites performed per biting piglet increased after D_0 from 0.015 to 0.022. The number of piglets receiving bites increased steadily from 77 at D_{-6} to 122 at D_6 and the bites received per bitten piglet increased also steadily from 0.009 at D_{-6} to 0.019 at D_6.

Table 4.1

Per observation day, the average number of tail biting incidents (TBI's) per piglet per hour (including the standard deviation), the observed number of biters and bitten piglets and the average number of performed and received bites per biting and bitten piglet.

	D_{-6}	D_{-4}	D_{-2}	D_0	D_2	D_4	D_6
Average TBI's per piglet per hour	0.73 ±0.6	0.93 ±0.8	1.21 ±0.8	1.51 ±1.2	1.68 ±1.1	1.86 ±1.1	2.30 ±1.7
Piglets observed performed bites*	67	84	80	102	105	94	103
Piglets observed receiving bites*	77	86	108	112	119	117	122
Average number of bites performed per biting piglet (bites/piglet/hour)	0.011	0.011	0.015	0.015	0.016	0.020	0.022
Average number of received bites per bitten piglet (bites/piglet/hour)	0.009	0.010	0.011	0.014	0.014	0.016	0.019

* Total number of piglets was 140.

Figure 4.2 shows the development of tail biting and of tail damage at pen and individual piglet level overall and for each of the fourteen pens.

At pen level, the positive linear (β_1) component in Model (1) corresponds with the increase in TBI's per pen (Figure 4.2, second column) during the first half of the observation period. From D_0 some pens still showed an increase in TBI's (e.g. pen 4), but the TBI's of several pens reached a plateau or even a decrease (e.g. pen 3). This latter corresponds with the significant negative quadratic (β_2) component in Model (1). From D_0 onwards the average tail damage increased in most pens, especially in those with a high average number of TBI's. In some pens, however, tail damage either remained relatively constant (e.g. pen 10) or decreased even though the TBI's still showed an increase (e.g. pen 14).

At individual piglet level, Figure 4.2 shows that in at least ten pens the model fits for bites performed (visually) deviated for one or a few piglets. Model (1) reveals a significant intercept ($\varepsilon_{\beta 0-pig}$: P<0.001) and slope ($\varepsilon_{\beta 1-pig}$: P<0.001) for bites performed per piglet. This means that in a pen at D_{-6} one or a few piglets already performed more tail biting behaviour compared with the pen average (e.g. pen 1 and 2). Furthermore, within a pen one or a few piglets showed a higher increase in bites performed than the pen average (e.g. pen 5).

At individual piglet level, the model fits for received bites per piglet were visually less pronounced than those for biting piglets. One bitten piglets visually deviated from the rest of their penmates in pens 1, 2 and 6. Model fits for bites received per piglet revealed a significant intercept ($\varepsilon_{\beta 0-pig}$: P<0.001). As for bites performed, at D_{-6} one or a few piglets in a pen received more tail biting behaviour compared with the pen average. However, unlike the findings for bites performed, bitten piglets showed no significantly higher increase in received bites than the pen average.

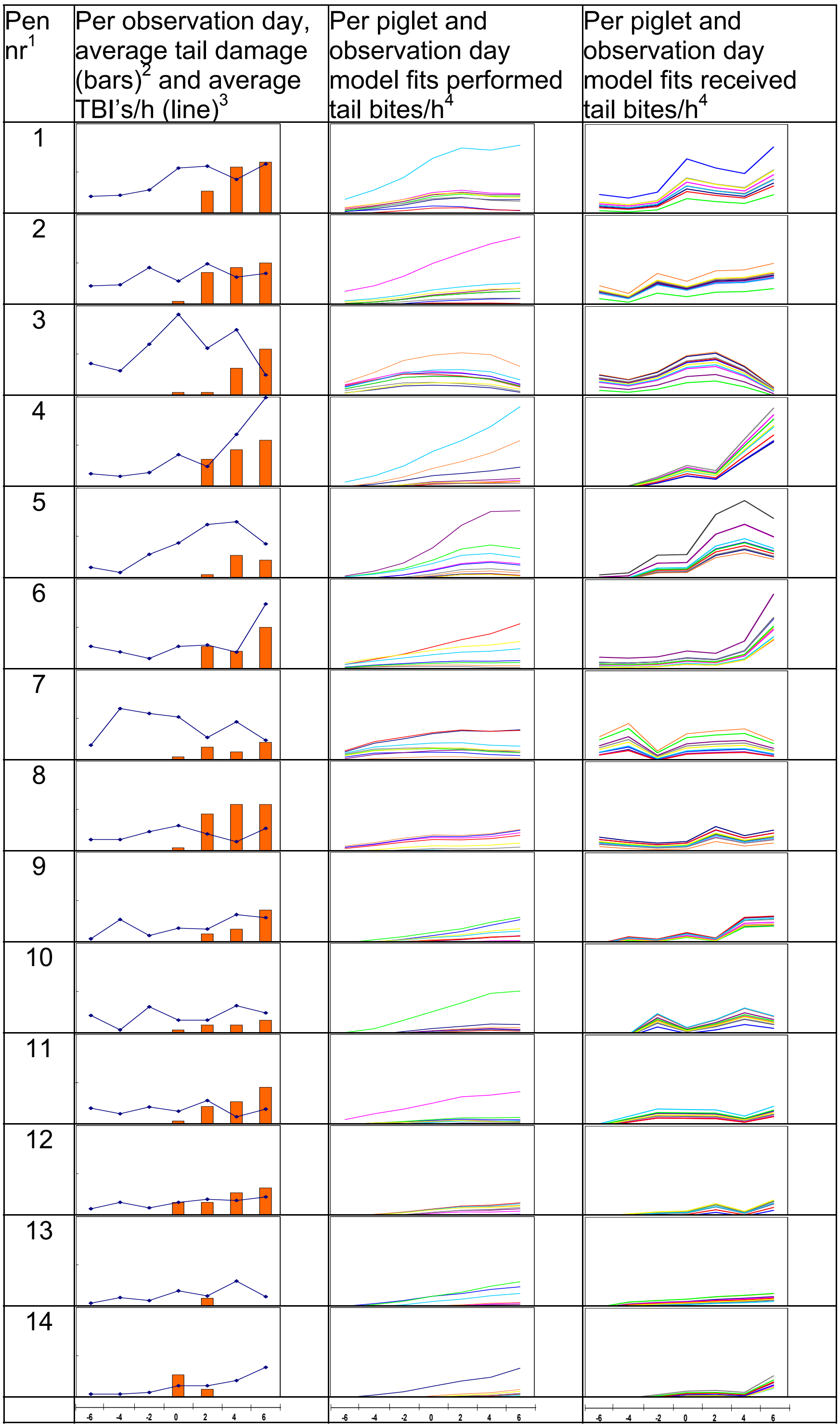


Figure 4.2 Per pen and observation day, the average tail damage (bars) and the average number of TBI's per hour (line). Furthermore, per observation day and per individual piglet the back transformed model fits for respectively performed and received bites per hour.

[1]Pens are sorted by the average TBI's (tail bite incidents) per pen (first row is highest). [2]The range for tail damage is from 0 to 2, with 0=no tail damage, 1=bite marks and 2=tail wound. [3]The range for TBI's/h is from 0 to 6 bites per hour. [4]The range for back transformed tail bites/h is from 0 to 6 bites per hour.

4.3.2 Preference of biters for a specific penmate

Analyses of the three-dimensional matrix from D_{-6} to D_6 of bites performed and received using Model (2) showed that the residual variation of the model was significantly different ($\chi^2_{(1355;1133)}$ < 0.001) from a poisson distribution. This indicates that certain biters preferred to bite a specific penmate. However, further investigation revealed a high number of TBI's involving the same biter and bitten piglet in pen 5 at $D_{0;}$ this sort of relationship was not apparent in the other pens. ($\chi^2_{(1115;1053)}$ = 0.09). This means that apart from pen 5 at D_0, biters tended to have no preferences for a specific penmate. Furthermore, no coherences between biter and bitten piglets was found in the separate analysis of the periods after D_0 (D_0 – D_6; excluding pen 5, $\chi^2_{(1039;1053)}$ = 0.61).

4.3.3 Relationship between tail damage and received tail bites

Table 4.2 presents the relationship between the level of observed tail damage and the cumulative received number of tail bites per hour prior to this day.

Table 4.2

Mean number of cumulative received tail bites per hour (including the number of piglets) per tail damage class (no tail damage, bite marks or tail wound) prior to the day tail damage was observed (D_0, D_2, D_4 and D_6), including the standard error of differences (s.e.d).

	No tail damage	Bite marks	Tail wound	S.e.d.	P-value
D_0	0.9^a (102)	1.2^b (35)	1.0^{ab} (3)	0.4	0.08
D_2	1.0^a (77)	1.3^b (60)	1.1^{ab} (3)	0.4	0.10
D_4	1.0^a (60)	1.3^b (72)	2.1^c (8)	0.3	0.005
D_6	1.1^a (54)	1.4^a (68)	2.0^b (18)	0.2	0.002

Different superscripts in a row indicate a significant difference (a, b, c: P<0.05).

At D_0 and D_2 a trend was found between the level of tail damage and the cumulative number of received tail bites per hour prior this day. Piglets with bite marks received more tail bites compared with piglets with no tail damage. At D_4 and D_6 piglets with a tail wound received significantly more tail bites compared with piglets with no tail damage and at D_4 also compared with piglets with bite marks.

4.4 Discussion

The pens used in this study are similar to most of those used in the EU for housing weaned piglets and finishing pigs, i.e. small barren pens for around ten pigs with partly slatted floors and one feeder. A major difference was that our piglets had intact tails rather than docked ones. Due to the selection of pens with a tail biting outbreak, the percentage of piglets with tail damage (89%) was considerably higher compared with the tail damage in the whole population (34%) used in the study of Zonderland et al. (2008). However, the transition from bite marks into a tail wound took in the selected pens 7.0 days what is comparable with the 7.5 days found in the whole population (Zonderland et al., 2008). This indicates that in pens with a tail biting outbreak (as used in this study), the speed of tail damage deterioration into a tail wound is comparable with the speed in pens with only one or two piglets with tail damage. Such development of tail damage best fits the description a of a ‘two-stage’ outbreak with gentle tail manipulation in the pre-injury phase and more forceful biting in the injury phase, as described by Taylor et al. (2010). Other types of tail biting, like ‘sudden-forceful’ or ‘obsessive’ tail biting which include grabbing and yanking of the bitten tail leading to severe wounds in a relatively short period have also been suggested by Taylor et al. (2010). These types of tail biting might have been present in this study (indeed 9% of the piglets were observed with a tail wound without previous observation of any bite marks), however, grabbing and yanking of a penmate’s tail has been observed rarely during the 163 hours of observation.

4.4.1 Development of TBI’s

Most (82%) of our piglets were observed tail biting penmates and almost all (96%) received tail bites before any tail damage was apparent in the pen. We also found large individual variation; in 10 out the 14 pens, one or a few piglets noticeably performed more tail biting than their penmates. As far as we know, such results have not been reported before. Schrøder-Petersen et al. (2003) reported that all pigs performed low frequency tail-in-mouth (TIM) behaviour, which is considered a precursor for tail biting behaviour (EFSA, 2007). Furthermore, this TIM behaviour was also performed with considerable variation among the individual pigs (Schrøder-Petersen, 2005). In contrast with our results, several scientists suggested that only one or a couple of pigs show tail biting before an outbreak occurs (Van Putten, 1968, Blackshaw, 1981, Beattie et al., 2005, Edwards, 2006). However, these authors may have focused only on pigs that showed a higher frequency of tail biting than the rest of their penmates.

The number of observed biters in a pen increased prior to the tail biting outbreak and afterwards remained relatively constant. Tail biting behaviour per individual piglet increased exponentially (i.e. linear on log scale) over the whole observation period. Additional analysis showed that this exponential increase per piglet was also found for the period prior to he tail biting outbreak ($P<0.01$). This indicates that other factors beside the presence of damaged tails with blood enhances tail biting behaviour of biters. It is possible that the subsequent reaction of the bitten piglet has a rewarding effect, motivating the biter to search for more tails to bite. Not only did these biters increase their biting frequency, but it was also noticed that their tail biting behaviour changed; instead of biting a penmate's tail that they come across occasionally, they seemed to specifically search for penmates' tails. They bit a tail until the bitten piglet reacted (mostly by walking away) and then turned to another piglet and repeated this behaviour. This pattern seems comparable to an earlier report of 'fanatical' tail biters that were hyperactive and moved from tail to tail to bite (Van de Weerd et al., 2005). However, in our study piglets with the highest levels of tail biting behaviour (20 - 55 bites per hour) showed this high level tail biting only on one day and had lower levels on following or previous observation days. One explanation might be that tail biting is performed in bouts and that our observation periods missed some of these bouts. Another more likely explanation is that 'fanatical' biters reported by Van de Weerd et al. (2005) belonged to the category of 'obsessive' tail biting (Taylor et al., 2010) rather than to the 'two-stage' outbreaks that probably occurred in our pens.

Like biters, some piglets already received more bites compared with their penmates six days before the tail biting outbreak. This indicates that individual piglets also play a role in the development of a tail biting outbreak and that some piglets are more predisposed to become a 'victim'. However, unlike biters, victims' frequencies of received bites were more evenly distributed among the penmates; all piglets are potential victims. There seemed to be almost no escape from this tail biting behaviour in a pen and even pronounced biters received their share of tail bites.

The results show that prior to a tail biting outbreak in a pen often both a biter and a victim can be identified. This suggests a predisposition to become a 'biter' or to a lesser extent become a 'victim', although the underlying mechanism remains unclear. It has been proposed that many animals (including pigs) may either show (pro)active or reactive coping styles when exposed to stressful events (reviewed by Koolhaas et al., 1999). It was then suggested that a predisposition to become a 'biter' or a 'victim' might be mediated by differences in coping style; piglets with an active coping style might increase tail biting when stressed whereas passive copers might become more inactive and more likely to receive tail bites (Schrøder-Petersen, 2005). However, more research is needed to confirm this suggestion.

4.4.2 Preference of biters for specific penmate

Biters had no preferences for a specific penmate, even when this penmate had a damaged and bleeding tail (after D_0). This was in contrast what we expected, as Fraser (1987) suggested that pigs are attracted to blood and damaged tissue. Our finding that no one pig was targeted in any pen is also in contrast with an earlier report that one pig was bitten 11 times by ten different pigs (Blackshaw, 1981). There are no clear explanations for these disparities although it might be argued that other incentives for biting may exist (e.g. the reaction of the bitten piglet) or that bitten piglets adjust their behaviour and protect their tail from further biting (Zonderland et al., 2009).

4.4.3 Relationship between tail damage and received tail bites

Although only a trend was found for the level of tail damage at D_0 and D_2 and the cumulative number of bites received prior these days, piglets with bite marks received generally more tail bites compared with piglets with no tail damage. At D_0

and D_2, piglets with a tail wound received a similar amount of tail bites compared with piglets with no tail damage. This might be explained by the small number of piglets with a tail wound at D_0 and D_2, but it is also possible that not all tail bites are equally damaging (e.g. light chewing causes less damage than firm biting). At D_4 and D_6 piglets with a tail wound had received more tail bites compared with piglets with no tail damage or bite marks. Our results show that tail damage can be predicted from the observed level of TBI's.

4.5 Conclusions and implications

Our results show that tail biting increased exponentially during the first part of the observation period and then tended to reach a plateau. This developmental profile was mainly caused by an increase in biting frequency rather than in the number of biting piglets. We can also conclude that:

a. Most piglets performed and received tail bites before any tail damage was apparent, indicating that biting-induced tail damage is a cumulative process. Once tail damage was present, almost all piglets in the pen became involved in the biting process.
b. One or a few pronounced biters could be identified in most pens. Though less obvious, bitten piglets (victims) could also be identified.
c. Biters did not prefer to bite a specific penmate, even if it had a damaged tail. This suggests that removal of the biter would be a more effective remedy than removal of the bitten pig.

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Chapter 5

Characteristics of biter and victim piglets apparent before a tail biting outbreak

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Abstract

Little is known about the characteristics of biters and victims prior to the appearance of a tail biting outbreak in groups of pigs. The present study aimed to characterize biters and victims (according to gender and performance) and to quantify their behavioural development during the six days preceding the tail biting outbreak. The hypotheses tested were: a) biters are more often female, are lighter pigs in group, are more restless and perform more aggressive behaviour, and b) victims are more often male, heavier and less active. Using video recordings we carried out a detailed study of fourteen pens with a tail biting outbreak among the weaned piglets. All piglets were individually marked and we observed the behaviour of biters, victims and control piglets (piglet types). In every pen each piglet type was observed every other day from 6 days before (D_{-6}) to the day of the first visible tail damage (i.e. day of tail biting outbreak; D_0). While the number of male biters (6 of the 14 biters) and male victims (11 of the 14 victims) was not significantly different (p=0.13), this numerical contrast was considerable. The start weight of victims was significantly (P=0.03) higher (8.6 kg) than those of biters (7.5 kg) and control piglets (8.0 kg). Biters tended (P=0.08) to spend longer sitting/kneeling (3.1 min/h) than controls (1.7 min/h) but no differences were seen in the times spent lying or standing. Victims tended (P=0.07) to change posture more often (restlessness) than controls and chased penmates more (P=0.04) than biters. Victims also performed more (P=0.04) aggressive behaviour than biters and controls. In contrast, biters tended (P=0.08) to be chased by penmates more often and tended (P=0.06) to receive more aggressive behaviour than controls. Furthermore, biters spent longer manipulating the enrichment device (P=0.01) and the posterior/tail (P=0.02) of their penmates than controls and tended (P=0.06) to perform more tail bites than victims. Victims received more posterior/tail manipulation (P=0.02) and tail bites (P=0.04) than controls. It was also noticed that, independent of piglet type, restlessness (P=0.03) increased and the frequency of performed tail bites tended (P=0.08) to increase in the six days preceding a tail biting outbreak. These findings may contribute to the early identification of biters or victims and support the development of strategies to minimise the occurrence of tail biting.

5.1 Introduction

Tail biting is an adverse behaviour performed by pigs who are likely to be bored or frustrated and not only reduces the welfare among pigs but also has significant economic consequences (Bracke et al., 2004). Tail biting is often found among finishing pigs, but is also increasingly found among weaned piglets (Bracke et al., 2004). So far, most tail biting studies have focused on the herd or group level, but while the resultant information is useful for evaluating epidemiological risk factors it does not provide a mechanistic understanding of the development of tail biting behaviour at the individual animal level (Edwards, 2006). Before a tail biting outbreak occurs, it is often only one or a few pigs which perform this tail biting behaviour with a higher frequency (so-called biters), and only one or a few victims that receive tail biting with a higher frequency (Zonderland et al., Accepted). However, little is known about the characteristics of such biters and victims before and during a tail biting outbreak. Early recognition of biters and victims in practice would be very helpful in order to apply appropriate measures at an early stage and to prevent a tail biting outbreak.

Although there is some debate (Blackshaw, 1981; Breuer et al., 2005), it has been proposed that biters are the lighter pigs in the pen (Fritschen and Hogg, 1983; Sambraus, 1985). Indeed, Van de Weerd et al. (2005) found that the more ‘fanatical’ biters (individuals who were hyperactive, biting tail after tail during a tail biting outbreak) were the lighter pigs in the group while victims were the heavier ones. Furthermore, Zonderland et al. (2010) found that female pigs were more often biters compared with intact male pigs. On the other hand, more males (intact and castrated) than females became victims (Penny et al. 1972; Valros et al. 2004; Kritas and Morrison, 2007). It has also been suggested that biters are more active than their penmates in the week before a tail biting outbreak (Svendsen et al., 2006), show more aggressive behaviour (Hansen and Hagelsø, 1980) and that victims tend to be more inactive (Van Putten, 1980; EFSA, 2007).

The present study aimed to clarify the characterization (gender and performance) of biters and victims and to quantify their behavioural development during the six days preceding the tail biting outbreak. This could improve our understanding of the 'individual piglet contribution' to a tail biting outbreak and thereby provide predictors to identify potential biters or victims at an early stage.

5.2 Animals, materials and methods

A library of video recordings of 96 mixed-sex pens of 10 weaned piglets had been built in a previous experiment (Zonderland et al., 2008; see section 'Husbandry'). For present purposes we used the video recordings for 14 selected pens (see Zonderland et al., Accepted), based on the appearance of tail damage and the availability of records for the required observation period. This observation period ranged from 6 days before (D_{-6}) to the first day with a minimum of one piglet with a tail wound or at least two piglets with bite marks (i.e. tail biting outbreak; D_0).

5.2.1 Husbandry

The fourteen identical pens were fitted with partially slatted floors and provided a space allowance of 0.4 m^2 per weaned piglet (Zonderland et al., 2008). Each pen contained a dry-feeder with two feeding spaces and piglets were fed *ad libitum*. The 140 weaned piglets were not tail docked after birth and not teeth clipped, and the males were not castrated. The average age of the weaned piglets at the start of the experiment was 28.2 ± 3.2 days and start weight was 7.9 ± 1.3 kg. At the end of the 32-day weaning period, the average end weight was 26.7 ± 3.9 kg. The weaned piglets received creep feed for the first 8 days after weaning (14.06 MJ Metabolic Energy (ME), 180 g/kg protein, 11.88 g/kg lysine, 3.0 g/kg Na (as-fed basis)). Over the next 4 days this was gradually switched to a pre starter diet (13.81 MJ ME, 175 g/kg protein, 11.54 g/kg lysine, 2.5 g/kg Na), which was fed until day 26. Thereafter the feed was gradually switched to a starter diet (13.48 MJ ME, 175 g/kg protein, 10.30 g/kg lysine, 1.2 g/kg Na), which was fed until the end of the weaning period. A water bowl drinker (situated next to the dry-feeder) provided unlimited water. The pens were located in rooms where the environmental temperature was automatically regulated by forced ventilation. The room temperature was set at 28 ºC when the piglets entered, 26 ºC after 5 days, 23 ºC after 21 days and then 22 ºC after 28 days until the end of the experiment (32 days). No bedding material was provided, but environmental enrichment devices, either a 0.5m metal chain suspended from the pen partition or two rubber hose tubes (length 0.4m and diameter 30mm) tied in a cruciform shape and suspended on a chain (rubber toy). Each pen was digitally video recorded (Poseidon, DVR, 8 frames per second) using colour cameras (TC-506CEX) every other day between 14.00h and 19.00h. Spray paint markings (red, blue and green) on the back facilitated individual recognition of the piglets.

5.2.2 Biters, victims and control piglets

Based on the previous tail biting data (Zonderland et al., Accepted), the weaned piglet performing the most tail bites in the period from 6 days before (D_{-6}) the first tail biting outbreak to 6 days after (D_6) was selected as the biter in each of the 14 pens. Similarly, the weaned piglets receiving the most tail bites were designated the victims. In one pen, the biter and victim were the same piglet. To prevent any distortion of the data this piglet was excluded from the observations and the ones with the second highest performed tail bites and the second highest received tail bites were selected instead. Finally, one piglet with an intermediary frequency for both performed and received tail bites was selected as a control in each pen. These were the designated biters, victims and control piglets and observed in depth.

5.2.3 Observations

When the tail biting outbreak became apparent in a pen (i.e. D_0), video recordings of D_{-6}, D_{-4}, D_{-2} and D_0 (observation days) were used for behavioural observations of the biter, victim and control piglet for each of the fourteen pens. The 14 tail biting outbreaks occurred throughout the 32-day observation period (average of 16.6 ± 6.7 days after weaning). Due to the labour intense character of these observations, the piglets types were observed only a part of the day. From the previous study on tail biting behaviour it became clear that the pig's activity was highest in the in the late afternoon (Zonderland et al., Accepted). Also other studies showed activity peak late in the afternoon (e.g. Feddes et al., 1993). It was expected that the behavioural differences between the piglet types was highest during the late afternoon and therefore the piglet types were observed between 16.00-16.10h, 16.30-16.40h, 17.00-17.10h, 17.30-17.40h, 18.00-18.10h and 18.30-18.40h. The piglet types were observed individually using focal sampling (Martin and Bateson, 1986) and appropriate software (Observer XT, Noldus). In total, 1008 ten-minute video recordings were observed (14 pens * 4 observation days * 6 observation times * 3 piglet types). These recordings were observed in random order by three observers who were unaware of the piglet type. A broad behavioural ethogram was used (Table 5.1) to characterize the piglet types. This ethogram was partly based on descriptions of pig behaviours from earlier studies (Zonderland et al., 2004; Bolhuis et al., 2005) and partly on the visibility of the piglets' behaviour. During observation, two behavioural categories were used: behavioural states (duration of behaviour) and behavioural events (frequency of behaviour). Per 10-minute video observation, piglets' posture and performed behavioural states were recorded simultaneously. Performed behavioural events and received behaviours (states and events) were recorded separately. If the observed piglet performed an unlisted behaviour (state), this was recorded as undefined/unknown. The cumulative duration when the behaviour of the observed piglet was not clearly visible was also recorded as undefined/unknown. Furthermore, in some cases the observed piglet spent time interacting with unknown piglets from the neighbouring pen; this time was again recorded as undefined/unknown.

Per piglet type, the durations of each posture and behavioural state were summed within and over the observation days (D_{-6}, D_{-4}, D_{-2} and D_0) and converted into a behavioural duration expressed as minutes per hour. Similarly, the behavioural frequencies were treated and expressed as number per hour. The behavioural durations and frequencies per piglet type per observation day were used for statistical analyses. To the observed list of behaviours, three behavioural measures were added.

Table 5.1
Ethogram

Behaviour[1]	Description
Posture	
Lateral lying	Lying on one side with no legs tucked underneath the body
Ventral lying	Lying ventrally with least two legs tucked underneath the body
Sitting/kneeling	Body supported by hind-quarters and stretched front legs or by hind legs and bent front legs
Standing	Body supported by four stretched legs
Performed behavioural states	
Inactive	No activity is shown
Locomotion	Walking without performing any other described behaviour
Feeding	Head in the food trough
Drinking	Head near the water nipple
Playing	Gambolling, pivoting, rolling, romping[3]
Elimination	Defaecating or urinating
Mounting[2]	Two front legs are placed on the back of a standing or walking penmate.
Manipulating (total)	
Floor	Sniffing, rooting, licking the floor.
Pen	Sniffing, rooting, licking, biting the pen partition or the feeder.
Enrichment	Sniffing, rooting, licking, biting or chewing the enrichment (chain or rubber toy)
Penmate	
Posterior/tail[2]	Sniffing, rooting, licking, biting or chewing a penmate's tail or immediate surrounding
Anterior/ear[2]	Sniffing, rooting, licking, biting or chewing a penmate's ear or immediate surrounding
Ventral/belly[2]	Sniffing, rooting, licking, biting or chewing the ventral part of a penmate's abdomen
Rest body[2]	Sniffing, rooting, licking, biting or chewing other body parts of a penmate
Undefined/ unknown	Activities, other than the ones described or activities that can not be properly identified
Received behavioural states	
Mounted[2]	Two front legs of a penmate are placed on the back
Manipulated	
Posterior/tail[2]	A penmate is sniffing, rooting, licking, biting or chewing tail or immediate surrounding
Anterior/ear[2]	A penmate is sniffing, rooting, licking, biting or chewing ear or immediate surrounding
Ventral/belly[2]	A penmate is sniffing, rooting, licking, biting or chewing ventral part of the abdomen
Rest body[2]	A penmate is sniffing, rooting, licking, biting or chewing other body parts
Performed behavioural events	
Tail biting[2]	Biting a penmate's tail, with a sudden reaction of the penmate
Ear biting[2]	Biting of one of a penmate's ears, with a sudden reaction of the penmate
Performed aggressive behaviour	
Pushing[2]	Moving a penmate from its location by non-forceful pushing with the head
Fighting initiated[2]	Forceful pushing of a penmate with or without biting (excl. ear biting and tail biting)[4]
Chasing[2]	Chasing a penmate for at least 2 seconds[4]
Received behavioural events	
Tail bitten[2]	A penmate is biting the subject's tail and elicits a reaction
Ear bitten[2]	A penmate is biting one of the subject's ears and elicits a reaction
Received aggressive behaviour	
Pushed[2]	A penmate moves the subject from its location by non-forceful pushing with its head
Fighting received[2]	A penmate pushes the subject forcefully with or without biting (excl. ear and tail biting)[4]
Chased[2]	A penmate chases the subject for at least 2 seconds[4]

[1] Behaviour was recorded as time spent (state) or frequency (events).
[2] This behaviour involved a penmate whose identity was recorded. Normally the penmate receiving the behaviour was recorded, but in the case of 'Interactions-received', the identity of the penmate performing this behaviour was recorded.
[3] Gambolling: running across the pen, occasionally accompanied by jumping/bouncing, nudging, pushing gently or chasing penmates; Pivoting: jumping and turning around the body axis; Rolling: lying on the back and moving from side to side; Romping: combination of mutual pushing and gentle fighting, often accompanied by chasing.
[4] These events may occasionally have a long duration. In that case the event will be scored, while the remainder of the time will be scored as undefined/unknown.

As a measure of restlessness the parameter ‘Posture changes’ (Harris and Gonyou, 1998) was calculated from the number of changes in postures (lateral lying, ventral lying, sitting/kneeling and standing) per ten-minute observation period and converted into a frequency of posture changes per hour. The parameter ‘Performed aggressive behaviour’ was added by summing the frequency of performed fighting, pushing and chasing. Similar, the parameter ‘Received aggressive behaviour’ was added by summing the frequency of received fighting, pushed and chased.

The genders, start and end weights (i.e. when moved respectively in and out of the weaning facility) and daily weight gains per individual piglet were available from the previous records (Zonderland et al., 2008).

5.2.4 Statistical procedures

Genstat was used for all statistical procedures (Genstat 11.1; VSN International Ltd). All fixed factors in the statistical models were tested using the corresponding Wald tests. Differences between pair wise treatment means were tested using Fisher’s LSD test.

Differences in performance characteristics (start weight, end weight and daily weight gain) between the three piglet types were tested using a Restricted Maximum Likelihood (REML) procedure with pen as a random factor and piglet type as a fixed factor. Differences in the male:female ratio in each piglet type group were analysed using a χ^2 - test on the percentage of male piglets per piglet type group.

To quantify the behavioural development of the three piglet types during the six days preceding a tail biting outbreak, differences in behavioural durations and behavioural frequencies were analysed using several statistical procedures. The behaviours lateral lying, ventral lying, sitting/kneeling, standing, posture changes, inactive, locomotion, feeding, undefined/unknown, manipulation (total), manipulating floor, manipulating pen and manipulating rest of body were normally distributed. Drinking, playing, manipulating penmate, manipulating enrichment, manipulating posterior/tail, manipulating anterior/ear, manipulating rest of body, mounted, manipulated posterior/tail, manipulated anterior/ear, performed aggressive behaviour and received aggressive behaviour were log-transformed to achieve normal distribution. The above behaviours were all analysed using an ANOVA with blocks of observation day per piglet type per pen, to test the effects of piglet type, observation day and their interaction. Elimination, mounting, manipulating ventral/belly and manipulated ventral/belly were still skewed after log-transformation and were therefore analysed using an IRREML procedure with binomial distribution, with piglet type within pens as a random factor and piglet type and observation day as fixed factors. The behavioural frequencies (except for performed and received aggressive behaviour) were tested using a similar IRREML procedure, but with a poisson rather than a binomial distribution.

Furthermore, to test whether the behavioural differences between piglet types preceding a tail biting outbreak were caused by a difference in activity level, all the behavioural durations per piglet type per observation day were expressed as the proportion of being active (ranging from 49 to 100%). The activity-corrected behavioural durations were analysed similar as described above.

5.3 Results

The following tables and figures present the effects of piglet type (including standard error of differences: s.e.d.) and observation days. Only one significant interaction was found between piglet type and observation period (received tail bites); this is described but the non-significant interactions were omitted.

5.3.1 Gender and performance

There were no significant gender effects on performance characteristics (start and end weights, daily weight gain) and behaviours, so gender was omitted from the end model for both performance and behaviour.

The numeric difference between male victims (11) and male biters (6) failed to reach significance across the piglet types (χ^2- test: P=0.13; Table 5.2). Victims had a higher start weight than biters and control piglets. There was no piglet type effect on end weight and daily weight gain.

Table 5.2

Male:female ratio and the predicted mean and standard error of differences (s.e.d.) of start weight, end weight and daily weight gain per piglet type (including P-values).

	Biter	Victim	Control	S.e.d.	P-value
Male:female ratio	6:8	11:3	7:7		n.s.*
Start weight (kg)	7.5^{b}	8.6^{a}	8.0^{b}	0.37	0.03
End weight (kg)	26.6	29.1	28.1	1.26	n.s.
Daily weight gain (g/day)	530	570	557	32.7	n.s.

Different superscripts in a row indicate a significant difference (a, b: P<0.05)

* χ^2 - test on the percentage male piglets per piglet type.

5.3.2 Posture and posture changes

Control piglets tended (P=0.08) to spend less time sitting/kneeling (1.7 min/h; s.e.d.=0.6) than biters (3.1 min/h). There were no significant differences between types in the other postures.

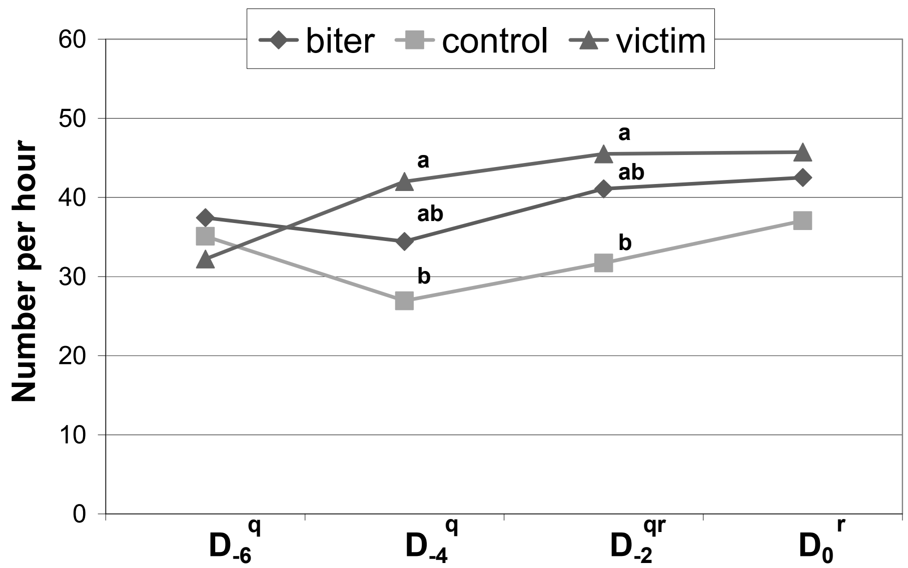


Figure 5.1 The predicted mean frequencies (times/h) of posture changes per piglet type (biter, victim and control piglet; s.e.d.=3.7) on each observation day (s.e.d.=2.8). Different superscripts between piglet type (a, b) and between observation days (q, r) indicate a significant difference (P<0.05). No interaction between piglet type and observation period was found.

The overall time spent lying ventrally decreased (P=0.05) over time (24.8, 25.5, 21.6 and 22.2 min/h at D_{-6}, D_{-4}, D_{-2} and D_0; s.e.d.=1.6) while sitting/kneeling increased (P=0.001) during the observation period (1.9, 1.9, 3.1 and 3.4 min/h at D_{-6}, D_{-4}, D_{-2} and D_0; s.e.d.=0.4). Control piglets tended (P=0.07) to change posture less often (38.9 times/h; s.e.d.=3.7) than victims (41.4 times/h). At D_{-4} and D_{-2}, victims showed more posture changes than control piglets (Figure 5.1). The frequency of posture changes increased (P=0.03) during the observation period (34.9, 34.5, 39.4 and 41.8 times/h at D_{-6}, D_{-4}, D_{-2} and D_0; s.e.d.=2.8).

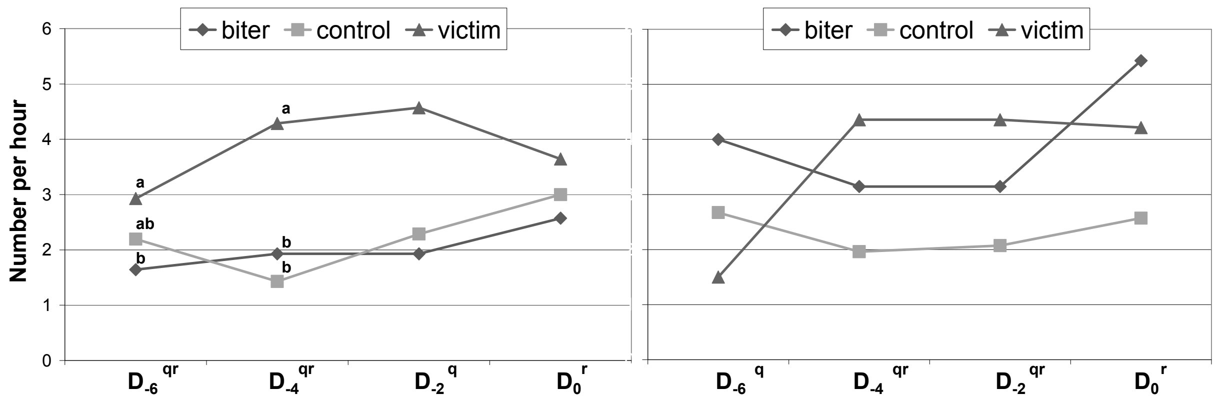
5.3.3 Aggressive behaviour

Victims were chasing (P=0.04) their penmates more often (0.23 times/h; s.e.d.=0.1) than biters (0.04 times/h). Furthermore, victims showed (P=0.02) aggressive behaviour more often (4.09 times/h; s.e.d.=0.7) than both biters (2.06 times/h) and control piglets (2.40 times/h; Figure 5.2A). In contrast, biters tended (P=0.08) to be chased by penmates more often (0.32 times/h; s.e.d.=0.1) and tended (P=0.06) to receive more aggressive behaviour (4.25 times/h; s.e.d.=0.7) than controls (respectively 0.11 and 2.43 times/h). The frequency at which piglets were pushed by a penmate increased (P=0.02) over time (1.1, 1.0, 1.1 and 2.1 times/h at D_{-6}, D_{-4}, D_{-2} and D_0; s.e.d.=0.4). Despite a tendency (P=0.06) for biters to receive more aggressive behaviour than controls there was no significant difference between piglet type across the observation days (Figure 5.2B).

5.3.4 General behaviour

The general behaviours consisted inactivity, total manipulation, locomotion, playing, feeding, drinking, mounting, elimination and undefined/unknown. There were no significant differences in general behaviours between piglet types.

Period effects were found for inactivity and undefined/unknown behaviours. Piglets inactivity decreased (P=0.01) during the observation period (26.6, 26.4, 23.1 and 21.0 min/h at D_{-6}, D_{-4}, D_{-2} and D_0; s.e.d.=1.8), while the average time spent in undefined/unknown behaviours increased (11.7, 14.5, 15.3 and 17.8 min/h at D_{-6}, D_{-4}, D_{-2} and D_0; s.e.d.=1.2).



A: Performed aggressive behaviour B: Received aggressive behaviour

Figure 5.2 The predicted mean frequencies (times/h) of performed aggressive behaviours (A) per piglet type (biter, victim or control piglet; s.e.d.=0.7) per observation day (s.e.d.=0.7) and received aggressive behaviours (B) per piglet type (s.e.d.=0.8) per observation day (s.e.d. =0.8). Different superscripts between piglet type (a, b) and between observation days (q, r) indicate a significant difference (P<0.05). No interaction between piglet type and observation period was found.

5.3.5 Manipulation behaviour

Biters tended (P=0.09) to perform more total (directed at either floor, pen, penmate or enrichment) manipulative behaviour (13.9 min/h; s.e.d.=1.6) than control piglets (10.3 min/h; Table 5.3). Of total manipulation, biters spent longer manipulating the enrichment device (1.8 min/h; s.e.d.=0.4) compared with control piglets (0.5 min/h) but there were no other detectable piglet type effects.

Total manipulation behaviour decreased (P=0.04) during the observation period (13.6, 11.0, 12.0 and 10.9 min/h at D_{-6}, D_{-4}, D_{-2} and D_0; s.e.d.=1.0). Also manipulation of the floor (9.3, 6.5, 8.0 and 7.1 min/h at D_{-6}, D_{-4}, D_{-2} and D_0; s.e.d.=0.8) and of penmates (2.6, 2.6, 1.6 and 2.0 min/h at D_{-6}, D_{-4}, D_{-2} and D_0; s.e.d.=0.4) decreased over the observation period.

Table 5.3

Predicted mean durations (min/h) and standard errors of differences (s.e.d.) of total manipulation, manipulating the floor, penmate, enrichment device and pen per piglet type (biter, victim or control piglet) and the P-values of piglet type and observation period.

					P-value	
	Biter	**Victim**	**Control**	**S.e.d.**	**Type**	**Obs. per.**
Total manipulation	13.8^{z}	11.6^{yz}	10.3^{y}	1.57	0.09	0.04
Floor manipulation	8.6	7.7	6.8	1.19	n.s.	0.003
Penmate manipulation	2.5	2.2	1.9	0.66	n.s.	0.02
Enrichment manipulation	1.8^{b}	1.0^{ab}	0.5^{a}	0.38	0.01	n.s.
Pen manipulation	0.9	0.8	1.0	0.19	n.s.	n.s.

Different superscripts in a row indicate a significant difference (a, b: P<0.05) or a tendency (y, z: P<0.10).

Table 5.4

Predicted mean duration (min/h) and standard error of differences (s.e.d.) for manipulating (received and performed) specific body parts per piglet type (biter, victim or control piglet) and the P-values of piglet type and observation period.

					P-value	
	Biter	**Victim**	**Control**	**S.e.d.**	**Type**	**Obs. per.**
Performed manipulation						
Posterior/tail	0.65^{b}	0.22^{a}	0.26^{a}	0.15	0.02	n.s.
Anterior/ear	0.58	0.38	0.31	0.19	n.s.	n.s.
Ventral/belly	0.06	0.06	0.48	0.27	n.s.	n.s.
Rest of body	1.23	1.52	0.88	0.40	n.s.	0.04
Received manipulation						
Posterior/tail	0.35^{a}	0.47^{b}	0.28^{a}	0.07	0.02	n.s.
Anterior/ear	0.48	0.38	0.59	0.17	n.s.	0.004
Ventral/belly	0.29	0.38	0.44	0.25	n.s.	n.s.
Rest of body	1.01	1.42	1.38	0.29	n.s.	n.s.

Different superscripts in a row indicate a significant difference (a, b: P<0.05).

Of penmate manipulation, biters directed more at the posterior/tail part of the penmate's body compared with victims and control piglets (Table 5.4). Victims received more posterior manipulation than biters and controls. Manipulation of the rest of body decreased over the observation period (1.6, 1.4, 0.8 and 1.1 min/h at D_{-6}, D_{-4}, D_{-2} and D_0; s.e.d.=0.3). The frequency of received anterior/ear manipulation increased over time (0.3, 0.5, 0.3 and 0.9 min/h at D_{-6}, D_{-4}, D_{-2} and D_0; s.e.d.=0.2).

5.3.6 Correction for activity

After the correction for activity was applied, the significant differences in duration of activities across piglet types was still apparent, except for the trend that biters perform more total manipulative behaviour than control piglets. This difference was no longer found after correction.

5.3.7 Tail and ear biting

Biters tended to perform more tail bites (0.52 times/h; s.e.d.=0.1) than victims (0.14 times/h; Table 5.5).

Table 5.5

Predicted mean frequencies (times/h) and standard errors of differences (s.e.d.) of performed and received tail and ear bites per piglet type and the P-values of piglet type and observation period.

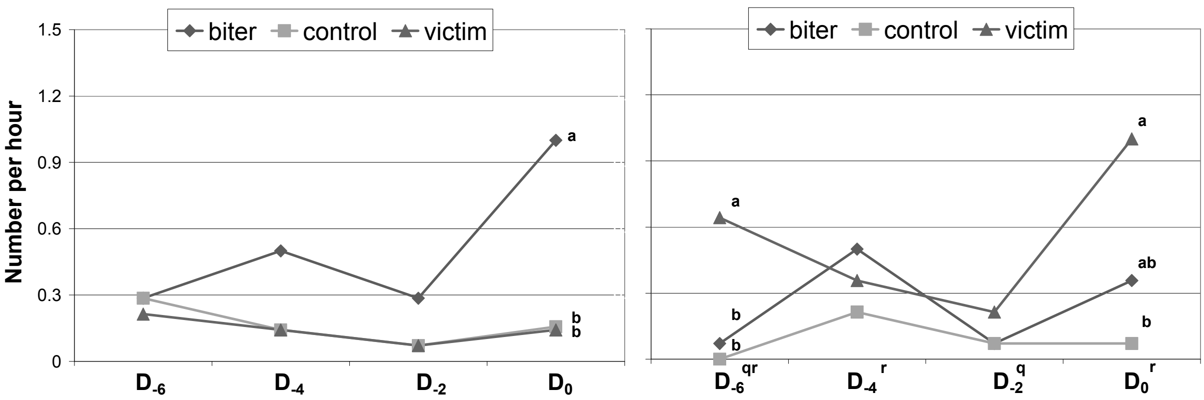
					P-value	
	Biter	**Victim**	**Control**	**S.e.d.**	**Type**	**Obs. per.**
Performed tail bites	0.52^{z}	0.14^{y}	0.16^{yz}	0.14	0.06	0.08
Performed ear bites	0.41	0.16	0.11	0.14	n.s.	0.007
Received tail bites	0.25^{ab}	0.55^{b}	0.09^{a}	0.16	0.04	0.007
Received ear bites	0.32	0.34	0.14	0.12	n.s.	0.001

Different superscripts in a row indicate a significant difference (a, b: P<0.05) or a tendency (y, z: P<0.10).

The frequency of performed tail bites was higher for biters than victims and controls at D_0 (P<0.05), but no differences were found at the other observation days (Figure

5.3A). A significant interaction between piglet type and observation period was found for received tail bites ($P<0.05$) and the differences between piglet types varied between observation days (see Figure 5.3B). The frequency of received tail bites was higher for victims than controls at D_{-6} and D_0 ($P<0.05$), but no differences were found at D_{-4} and D_{-2}.

The frequency of tail bites received by victims increased over time (0.2, 0.4, 0.1 and 0.5 times/h at D_{-6}, D_{-4}, D_{-2} and D_0; s.e.d.=0.1). For performed and received ear bites and received tail bites, a period effect was found (see Table 5.5). The frequency of performed ear bites increased over time (0.2, 0.2, 0.1 and 0.5 times/h at D_{-6}, D_{-4}, D_{-2} and D_0; s.e.d.=0.2). Similar the frequency of received ear bites increased over time (0.1, 0.2, 0.2 and 0.5 times/h at D_{-6}, D_{-4}, D_{-2} and D_0; s.e.d.=0.2).



A: Performed tail bites B: Received tail bites

Figure 5.3 The predicted mean frequencies (times/h) of performed tail bites (A) per piglet type (biter, victim or control piglet; s.e.d.=0.1) per observation day (s.e.d.=0.1) and received tail bites (B) per piglet type per observation day (s.e.d. interaction=0.2). Different superscripts between piglet type (a, b) and between observation days (q, r) indicate a significant difference ($P<0.05$). For the frequency received tail bites an interaction between piglet type and observation period was found ($P<0.05$).

5.4 Discussion

With the current characterization (gender and performance) of biters and victims a previous suggestion that biters were more likely to be female (Zonderland et al., 2010) was not supported by the present findings (6 male versus 8 female biters). A numeric difference for more victims to be male than female found in the present study was consistent with previous observations (e.g. Penny et al. 1981; Hunter et al. 1999; Zonderland et al., 2010). We found no effect of gender on activity, although it has been suggested that the lower activity levels of male pigs might make them more attractive targets for tail biting by penmates (EFSA, 2007). The present victims had a higher start weight than biters or control piglet, which is in agreement with Van de Weerd et al. (2005). It has been suggested that heavier and more dominant piglets will be the first ones to start feeding during the active periods, and it is conceivable that the exposed tails of feeding pigs could make them a target for tail biters (Taylor et al., 2010; Zonderland et al., Accepted). Indeed, it was earlier found that victims were more often the dominant pigs (Ushijima et al., 2009). In contrast, our hypothesis that biters are the lighter pigs in the group must be rejected because both the start and end weights of biters and controls were similar. Whether so-called 'fanatical' biters (animals that are hyperactive during an outbreak and are moving from tail to tail to bite; Van de Weerd et al., 2005) are the lighter pigs in the group could not be concluded from our data.

With the quantification of the behavioural development of biters and victims during the six days preceding the tail biting outbreak, an indication was found that the restlessness in a pen increased prior this outbreak. This was shown by the increase in total activity and posture changes prior the outbreak, while the time spent lying ventrally decreased. This increase in activity could also reflect an ageing effect of the weaned piglets. However, the probability of an age effect within such a short period is small. Furthermore, a higher general activity in a pen prior to a tail biting outbreak was also found by Statham et al. (2009) and earlier mentioned by Van Putten (1969) and Svendsen et al. (2006).

Neither general activity nor the frequency of posture changes were significantly higher for biters than victims or controls. Conversely, victims tended to change posture more often and were more active than controls, suggesting that victims became more restless before the outbreak. This fact has not been reported before and might reflect greater disturbance of victims being bitten by biters, as these biters increased their tail-directed behaviour.

Biters performed the lowest number of aggressive behaviours but received more than victims and controls. This refutes our hypothesis that biters are more aggressive. A surprising finding was that victims initiated the most aggressive interactions. Certainly, tail bites from the biter can lead to an aggressive reaction from the victim. However, this can only partly explain the received aggression of the biters because this frequency is higher (4.25 times/h) than the frequency of tail bites (0.52 times/h). Another explanation might be that these aggressive interaction reflect confrontations of a dominant piglet (victim) with a subordinate penmate (biter). This is in line with observations by Ushijima et al. (2009), who found victims being more often dominant and biters being more often subordinate. Subordinate piglets may become frustrated due to restricted access to food and water during preferred feeding and drinking periods. This frustration may result in the redirection of feeding-related behaviour to penmates or enrichment device, or in a heightened motivation to perform unusual forms of aggressive behaviour directed at the posterior/tail (Hansen and Hagelsø, 1980; Morrison et al., 2007).

As expected, biters showed significantly more tail bites as well as longer posterior/tail manipulation. The average duration of posterior/tail manipulation of biters prior to the tail biting outbreak remained relatively constant, however, the biters tail biting frequency increased by a factor of 3.5 from D_{-2} to D_0. This strong increase in tail biting behaviour by the biters several days prior to the tail biting outbreak in the pen is in accordance with the exponential increase in tail biting behaviour from D_{-6} to D_0 reported by Zonderland et al. (Accepted). This increase in biting behaviour might be explained by the presence of blood (Sambraus, 1985; Fraser, 1987). Indeed, at D_0 some tails with blood were present in the group. However, even though a few bleeding tails were apparent here, they mainly showed bite marks with little fresh blood. Hence, the blood-induced escalation of biting is unlikely to be the sole factor involved. An additional explanation might be that the reaction of the bitten piglet (e.g.

vocalizing or moving away) has a rewarding effect that increases the biter's motivation to specifically search for more tails to bite (Zonderland et al., Accepted).
The overall time spent manipulating the penmates' bodies did not differ between biters, victims or control piglets. This suggest that biters directed their attention primarily to the posterior/tail region while victims and control piglets directed their manipulation more to the other body parts. This might be related to the motivation for sexual behaviour as Schrøder-Petersen et al. (2004) speculated that as females approach sexual maturity they show more ano-genital investigation, especially of the opposite sex. Indeed, Ford (1990) showed that sexual behaviour between male and female pigs is already different as early as one month of age. However, in our study we found no gender effect in the performance of posterior/tail manipulation.
Biters spent longer manipulating the enrichment devices (chain, rubber toy) before the tail biting outbreak occurred than either victims or controls; (both devices drew comparable amounts of attention from the biters). Similarly, pigs with a high propensity to chew suspended ropes subsequently performed more tail biting behaviour (Breuer et al., 2001). Increased manipulation of enrichment devices might be useful in identifying potential biters in practice, e.g. using automated recordings of animal-material interactions (Zonderland et al., 2003). Furthermore, the increase in restlessness might be a good indicator for an upcoming tail biting outbreak. Therefore, using automated activity monitoring in practice, a relative increase in activity, what may indicate an upcoming outbreak, could be easily detected and the necessary measure taken to prevent this outbreak.

5.5 Conclusions and implications

The main aim of this study was to characterize biters and victims according to gender and performance and to quantify the behavioural development during the six days preceding a tail biting outbreak. The main conclusions can be summarized as follows:

- Biters were neither the lighter pigs in the group, nor were they more often female.
- Biters tended to receive more aggressive behaviour than victims or control piglets.
- Though there were no effects of piglet type on general manipulative behaviour, biters directed their manipulation more to the enrichment device and to their penmates' posterior/tail body parts.
- Victims were the heavier pigs in the pen.
- Victims tended to be more restless preceding the tail biting outbreak. They also performed more aggressive behaviour and received more tail manipulation.

These potential characteristics could conceivably contribute to an early identification of biter or victim piglets and thereby guide the development of practical strategies to minimise tail biting.

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Chapter 6

Tail posture predicts tail damage among weaned piglets

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Abstract

Tail biting in pigs is a widespread behavioural vice with significant animal welfare and economic consequences. All too often, tail biting is not diagnosed nor dealt with until tail damage is present. To effectively reduce the negative effects of tail biting, it must be diagnosed in an early stage. So far no predictors for tail damage have been found. Predictors that recognise tail biting in an early stage, however, would be helpful in practice. We tested the hypothesis that tail behaviour can predict tail damage. To analyse this, we observed tail posture, tail motion and tail damage of 992 weaned piglets on an experimental farm with known tail biting problems. Tail posture (curled tail, hanging tail or tail between legs), tail motion (motionless, wagging or intense wagging) and tail damage (no damage, bite marks or a tail wound) were observed three times a week during the 32 days post-weaning period. Results showed that both tail posture and tail motion were related to tail damage at the same observation moment ($P<0.001$). Furthermore, tail posture could predict tail damage ($P<0.001$), but tail motion had no predictive value for tail damage ($P>0.05$). When a piglet was observed with a curled tail (and no tail damage), the chances of bite marks or a tail wound 2 to 3 days later were 8.6% and 3.1%. When a piglet was observed with its tail between the legs (and no tail damage), the chances of bite marks or a tail wound 2 to 3 days later increased to 22.3% and 8.5%. Furthermore, when a piglet was observed with its tail between the legs (and no tail damage) in two consecutive observations, the chances of bite marks or a tail wound 2 to 3 days later increased to 32.4% and 23.7%.

It was concluded that a piglet’s tail posture is strongly related to tail damage at the same moment and can predict tail damage 2 to 3 days later. Checking tail postures on a regular basis increases early recognition of tail biting. This can help pig farmers to take appropriate measures to prevent further escalation of the problem.

6.1 Introduction

Tail biting in pigs is a widespread behavioural vice with significant animal welfare and economic consequences (Bracke et al., 2004a, b). Two stages can be distinguished in the development of tail biting, as suggested by Fraser (1987) and Schrøder-Petersen and Simonsen (2001). Stage 1 is the pre-injury stage, before any tail damage is present. In some cases this is followed by stage 2, the injury stage, where the tail is damaged and bleeding. All too often, tail biting is not diagnosed nor dealt with until tail damage is present in the injury stage (Schrøder-Petersen and Simonsen, 2001). To reduce the likelihood of negative tail biting effects, it would be helpful to recognize it in the pre-injury stage before any tail is damaged and bleeding. The fact is, blood (and other tissue) is attractive to many pigs (Fraser, 1987), and may act as an extra incentive for tail biting, resulting in a tail biting outbreak with numerous damaged tails in a group of pigs (Schrøder-Petersen and Simonsen, 2001). Predictors that identify tail biting in an early stage would be helpful in practice (Zonderland et al., 2008). Several parameters that are related to ongoing tail biting have already been found (McGlone et al., 1990; Keeling et al., 2004; Statham et al., 2008). Furthermore, several suggestions of potential tail biting predictors have been made (Van Putten, 1969; Schrøder-Petersen et al., 2003; Keeling et al., 2004; Svendsen et al., 2006). However, so far no predictors for tail biting have been identified.

For parameters that relate to ongoing tail biting, Keeling et al. (2004) found that in pens where tail biting occurred, pigs tended to walk more and sat significantly less than pigs in control pens. Pigs in pens with tail biting also performed more head knocks and tended to show more avoidance and less exploration of the pen. McGlone et al. (1990) showed that during a tail biting outbreak, pigs with intact tails tended to keep their tails between the legs, while curled tails were more present in pens without a tail biting outbreak. Also Statham et al. (2008) found that within groups where a tail biting outbreak occurred, more pigs kept their tail between the legs. Besides this potential relation between tail posture and a tail biting outbreak, also suggestions on a relation between tail motion and tail biting have been made. Kiley-Worthington (1976) reported that tail wagging increased significantly in a food frustration situation. Increased amounts of tail wagging were also found after surgical procedures like tail docking (Noonan et al., 1994) and castration (Hay et al., 2003). Kiley-Worthington (1976) suggested that tail wagging may be caused by skin irritation. In case of a damaged tail this skin irritation is expected to be present.

For potential parameters that can predict a tail biting outbreak, Schrøder-Petersen et al. (2003) suggested that tail-in-mouth (TIM) behaviour was more prevalent before a tail biting outbreak. A higher general activity was mentioned to be seen prior to a tail biting outbreak (Van Putten, 1969; Svendsen et al., 2006). Also Keeling et al. (2004) proposed that future work should focus on increased general activity levels before a tail biting outbreak occurs. However, Zonderland et al. (2003) did not find an increase in general activity two days prior to a tail biting outbreak.

It was noticed, during tail damage observations in earlier research with weaned piglets (Zonderland et al., 2008), that before any piglet with tail damage was observed, some piglets already kept their tail down instead of keeping it curled. This made us wonder whether tail behaviour had a predictive value for tail damage. To test this hypothesis, we observed tail posture, tail motion and tail damage of 992 weaned piglets on a experimental farm with known tail biting problems.

6.2 Animals, materials and methods

6.2.1 Animals

The experiment was conducted at the Pig Research Unit of the Animal Sciences Group in Lelystad. In three batches, a total of 992 crossbred piglets (512 male and 480 female) were observed, allocated to in total 101 pens with on average 9.8 piglets per pen. At birth the piglets' tails were not docked, the teeth were not clipped and the males were not castrated. With weaning, the piglets were moved to the rearing facility and regrouped based on body weight. In the first batch the piglets were grouped in mixed-sex groups. In the second and third batches the piglets were grouped in either all-male (10 male piglets), all-female (10 female piglets) or mixed-sex (5 male and 5 female piglets) groups to test the effects of gender and mixing on tail damage development (see Zonderland et al., 2010). Piglets were given a numbered ear-tag for individual identification during observations. At weaning the piglets average age was 28.9 ± 3.2 days and average body weight was 7.8 ± 1.7 kg.

6.2.2 Housing and husbandry

For the experiment two similar rooms were used. Each room contained 18 identical partly-slatted pens (see Zonderland et al., 2008 for detailed room design) with 0.4 m^2 space per piglet. Each pen contained a dry-feeder with two feeding places and piglets were fed ad libitum. Next to the dry-feeder, a separate water bowl drinker was available. A metal chain was suspended above the slatted area as environmental enrichment. The environmental temperature was automatically regulated by forced ventilation and was set at 28 °C when the piglets entered. This temperature was gradually lowered to 21 °C at the end of the weaning period when the piglets were 10 weeks of age.

6.2.3 Observations

During the observation period of 32 days (weaning period), tail damage, tail posture and tail motion were scored per individual piglet three times per week (a total of 14 observations) using the classification presented in Table 6.1. Classifications were based on the tail damage protocol of Zonderland et al. (2008) and the tail posture protocol of Kleinbeck and McGlone (1993). During tail scoring, the observer stood in the middle of the pen and, while surrounded by the piglets, checked each individual piglet's tail. Tail damage, tail motion and tail posture were scored simultaneously. Little movement is possible when a piglet has a curled tail or its tail between the legs. Therefore a curled tail and tail between legs were always scored in combination with no visible tail motion (motionless).

Table 6.1

Classification of the three tail parameters; tail damage, tail posture and tail motion. Classifications were based on the tail damage protocol of Zonderland et al. (2008) and the tail posture protocol of Kleinbeck and McGlone (1993).

Parameter			Description
Tail damage	1	No tail damage	No visible tail damage.
	2	Bite marks	Visible small tail damages/bite marks with the size of a pinhead.
	3	Tail wound	Clearly visible tail wound with (fresh or dried) blood.
Tail posture	1	Curled	Curled piglet's tail (partly or completely) in an upward position. Incomplete tails in an upward position were also scored as curled.
	2	Hanging	Intermediate piglet's tail postures between curled tail and tail between legs. Tail posture varied between striking straight out to hanging down, while the tail tip was still loose from the piglet's back.
	3	Between legs	Piglet's tail vertically down and squeezed between the hind legs.
Tail motion	1	Intense wagging	Piglet's tail is wagging vigorously sideways with the widest angle possible.
	2	Wagging	Intermediate piglet's tail motion between intense wagging and motionless.
	3	Motionless	No tail movement visible.

6.2.4 Statistical procedures

Firstly, the relationship between tail behaviour and tail damage was analysed. In case we found a relationship between a certain tail behaviour (tail posture and/or tail motion), subsequently tail behaviour as predictor for tail damage was analysed.

Relationship between tail behaviour and tail damage

Tail behaviour had a relationship with tail damage when this behaviour related to tail damage (bite marks or a tail wound) within the same observation (i.e. t_0).

To test whether tail behaviour had a relationship with tail damage, we used logistic regression models with tail damage on logit scale (Logit(p)=Log(p/(1-p)) and a binomial distribution. Two models were composed. The first (Model 1) estimated the chance of tail damage (bite marks or a tail wound). The second (Model 2) estimated the chance of a tail wound, given the presence of tail damage. Tail posture, tail motion and their interaction at t_0 were tested, but only significant terms were included in Model (1) and Model (2), which represent the final models.

Model (1) : Log(p/(1-p)) = μ + Tail posture (t_0) + Tail motion (t_0) + ε_B

Var (Y) =p (1-p)

Model (2) : Log(p/(1-p)) = μ + Tail posture (t_0) + ε_B

Var (Y) =p (1-p)

ε_B = random effect of batch, $\varepsilon_B \sim N(0,\sigma_B^2)$

Reference level for these models are:

Tail posture(t_0) = 1 (curled tail)

Tail motion (t_0) = 1 (intense wagging)

Tail behaviour as tail damage predictor

Tail behaviour predicted tail damage when the combination of tail behaviour and no tail damage at t_{-1} (i.e. 2-3 days earlier) related to tail damage (bite marks or a tail wound) at t_0 (i.e. current observation). Similarly, when the combination of tail behaviour at t_{-2} (4-6 days earlier) and no tail damage at t_{-1} had a relationship with tail damage at t_0, tail behaviour 4-6 days earlier predicted tail damage at t_0. When the combination of tail behaviour (at t_{-1} or t_{-2}) and bite marks at t_{-1} related to a tail wound at t_0, this indicated that tail biting was already ongoing but in an early stage. To test the hypothesis that tail behaviour predicted tail damage, it was necessary to analyse the following three tail damage transitions:

1. No tail damage at t_{-1}; bite marks at t_0
2. No tail damage at t_{-1}; a tail wound at t_0
3. Bite marks at t_{-1}; a tail wound at t_0

These three tail damage transitions represented a deterioration of tail damage. The remaining tail damage transitions (e.g. going back from bite marks to no tail damage) had little value in the prediction of tail damage and were therefore not analysed. Each

individual piglet had a maximum of two tail damage transitions during the observation period. Piglets' individual tails were scored 14 times during the observation period. For the first observation (out of the total of 14 observations) the corresponding previous observation (t_{-1}) could not be calculated and therefore were excluded from the dataset. A similar approach was used for the observations of t_{-2} (i.e. two earlier observations) and these observations were also excluded from the dataset.
To test whether tail behaviour predicted tail damage, similar models as for the relationship with tail damage were used, only with the addition of tail damage, tail posture and tail motion at t_{-1} and t_{-2}. Model (3) and Model (4) represent the final models, in which only significant terms were included.

Model (3) : Log(p/(1-p)) = μ + Tail damage (t_{-1}) + Tail posture(t_{-1}) + Tail posture (t_{-2}) + ε_B

Var (Y) = p(1-p)

Model (4) : Log(p/(1-p)) = μ + Tail damage (t_{-1}) + Tail posture(t_{-1}) + Tail posture (t_{-2}) + Tail damage (t_{-1}) * Tail posture (t_{-1}) + ε_B

Var (Y) = p(1-p)

ε_B = random effect of batch, $\varepsilon_B \sim N(0,\sigma_B^2)$

Reference level for these models are:

Tail damage (t_{-1}) = 1 (no tail damage)

Tail posture(t_0), (t_{-1}) and (t_{-2}) = 1 (curled tail)

For all models, fixed model effects were tested using the corresponding Wald tests. For significant treatment effects, significant differences between pair wise treatment means were tested using Fisher's LSD test (P=0.05; GenStat, 2002).

6.3 Results

Of the 992 weaned piglets a total of 13,888 observation records on tail damage, posture and motion were collected during the 32-days observation period with 14 observation moments. In 347 records, tail posture and tail motion could not be scored because the piglets' tails were too short due to tail biting.

6.3.1 Relationship between tail behaviour and tail damage

Statistical analyses with models (1) and (2) showed that both tail posture and tail motion had a significant relationship (P<0.001) with the occurrence of tail damage. Furthermore, tail posture had a relationship with the occurrence of a tail wound (P<0.001). Table 6.2 describes the observed percentages (of total observations) for tail behaviour related to tail damage.

Table 6.2

Scored observations of tail behaviour related to tail damage (given in % of total observations).

	Tail behaviour					
	Curled	**Hanging**			**Between legs**	
Tail damage	**Motion less**	**Intense wagging**	**Wagging**	**Motion less**	**Motion less**	***Total***
No damage	39.7	0.5	2.3	11.4	0.4	*54*
Bite marks	9.0	0.5	2.0	6.6	1.4	*20*
Tail wound	6.0	0.5	2.5	9.2	7.8	*26*
Total	*55*	*2*	*7*	*27*	*10*	*100*

In 46% of the observations, a piglet was scored with tail damage, either bite marks (20%) or a tail wound (26%). Of all the observations on tail posture, a curled tail was most often scored (55%), whereas tail between legs least often (10%). Some combinations of tail biting behaviour and tail damage were observed more often than were to be expected based on chance (P<0.001).

a. Piglets with a curled tail were more often observed with no tail damage
b. Piglets with a hanging tail were more often observed with bite marks
c. Piglets with a hanging tail or tail between legs were more often observed with a tail wound

In almost 90% of the observations, the tail was scored motionless. Piglets with tail damage were observed more often with tail wagging or intense tail wagging than a motionless tail ($P<0.05$).

6.3.2 Tail behaviour as tail damage predictor

Especially for tail posture, a strong relationship with tail damage at the same observation moment (t_0) was found. As a first step to investigate the relationship between tail posture at t_{-1} and tail damage at t_0 (i.e. prediction of tail damage), Table 6.3 presents the percentage observation per tail posture at t_{-1} and t_0 related to tail damage at t_0.

Table 6.3

Average percentage observations (of row totals) with curled, hanging and tail between legs at t_{-1} and t_0 related to tail damage at t_0.

Tail posture t_{-1}	**Tail posture t_0**	**No tail damage t_0**	**Bite marks t_0**	**Tail wound t_0**	**Total (number of obs.)**
Curled	Curled	83.8	15.8	0.4	100 (4752)
	Hanging	66.0	30.8	3.2	100 (1382)
	Between legs	55.8	32.6	11.6	100 (946)
Hanging	Curled	43.2	55.2	1.6	100 (1614)
	Hanging	25.9	64.5	9.6	100 (1133)
	Between legs	13.5	61.1	25.4	100 (1626)
Between legs	Curled	40.5	51.4	8.1	100 (37)
	Hanging	11.6	60.5	27.9	100 (129)
	Between legs	5.2	37.2	57.5	100 (935)

When piglets were observed with a curled tail in both t_{-1} and t_0, in the majority of observations (83.8%) at t_0 no tail damage was observed, while only in a small percentage (0.4%) a tail wound was observed. When piglets were observed with a hanging tail at t_{-1}, in more than 50% of the observations bite marks were observed at t_0, independent of the observed tail posture at t_0. When piglets were observed with their tail between legs at both t_{-1} and t_0, in 57.5% of the observations at t_0 piglets were observed with a tail wound.

Secondly, to test the hypothesis that tail behaviour can predict tail damage, we analysed the data using models (3) and (4). Both tail posture on t_{-1} ($P<0.001$) and t_{-2} ($P<0.01$) had an effect on tail damage and a tail wound at t_0. Furthermore, we found an interaction between tail posture t_{-1} and tail damage t_{-1} on the occurrence of a tail wound at t_0. This meant that no tail damage or bite marks at t_{-1}, tail posture at t_{-1} had no effect on the chance of a tail wound at t_0. With a tail wound at t_{-1}, tail posture at t_{-1} had an effect on the chance of a tail wound at t_0. Tail motion at t_{-1} had no effect on tail damage or a tail wound at t_0 ($P>0.05$). From the models (3) and (4), predicted chances of bite marks or a tail wound were derived for the three tail damage transitions and are shown in the tables 6.4 and 6.5.

Table 6.4 describes, per tail damage transition, the predicted chance of bite marks or a tail wound given the tail posture in the previous observation.

Table 6.4

The predicted tail damage chances (in %) at t_0 per tail damage transition for the three tail postures at t_{-1}.

		Tail posture (t_{-1})		
	Tail damage transition	**Curled**	**Hanging**	**Between legs**
1	No tail damage at t_{-1} and bite marks at t_0	8.6^a	10.4^a	22.3^b
2	No tail damage at t_{-1} and a tail wound at t_0	3.1^a	4.3^a	8.5^b
3	Bite marks at t_{-1} and a tail wound at t_0	13.2^a	18.0^a	32.0^b

Different superscripts in a row indicate a significant difference (a, b: $P<0.05$).

Of the three tail postures only tail between legs at t_{-1} predicted bite marks or a tail wound at t_0. When a piglet was observed with no tail damage and a curled tail at t_{-1}, this piglet had a chance of 8.6% to have bite marks at t_0. This percentage increased significantly to 22.3% when this piglet was observed with its tail between legs at t_{-1}. The chance that a piglet with no tail damage and a curled tail at t_{-1} had a tail wound at t_0 was 3.1%. This increased to 8.5% when this piglet was observed with its tail between legs at t_{-1}. A piglet that already had bite marks and kept its tail between legs at t_{-1} had a 32% chance that its tail damage deteriorated into a tail wound at t_0.
Similar to tail posture at t_{-1}, we found that for piglets with their tail between legs at t_{-2} (but no tail damage at t_{-1}) also the chance of bite marks or a tail wound at t_0 increased. The other two tail postures at t_{-2} had no effect on the chance of tail damage at t_0. For piglets that kept their tails between legs at t_{-2}, Table 6.5 describes the predicted chance of bite marks or a tail wound given the tail posture at t_{-1}.

Table 6.5
The predicted tail damage chances (in %) at t_0 per tail damage transitions for the three tail postures at t_{-1}, given tail between legs in the previous observation (t_{-2}).

		Tail posture (t_{-1})		
	Tail damage transition	**Curled**	**Hanging**	**Between legs**
1	No tail damage at t_{-1} and bite marks at t_0	16.3^a	18.6^a	32.4^b
2	No tail damage at t_{-1} and a tail wound at t_0	11.3^a	14.5^a	23.7^b
3	Bite marks at t_{-1} and a tail wound at t_0	22.9^a	29.8^a	47.6^b

Different superscripts in a row indicate a significant difference (a, b: P<0.05).

Compared with the results without knowing that a piglet had kept its tail between legs at t_{-2} (see Table 6.4), the chance of bite marks at t_0 (given no tail damage at t_{-1}) increased from 8.6% to 16.3%. Similar increase of chances were found for a hanging tail and tail between legs at t_{-1}. For piglets that were observed with their tail between legs at both t_{-2} and t_{-1}, the chance of a tail wound at t_0 (and no tail damage or bite marks at t_{-1}) increased by more than 15% (from 8.5% to 23.7% and from 32.0% to 47.6%).

6.4 Discussion

Results from our experiment showed that tail posture is strongly related to tail damage and can predict tail damage 2 to 3 days later. Piglets with their tail between the legs had a higher chance of future tail damage. Two consecutive observations of a single piglet with a tail between legs (and no tail damage) increased its chance of tail damage 2-3 days later. Three consecutive observations on tail posture were also analysed, but did not increase the chance of future tail damage.

Similar to our results, McGlone et al. (1990) and Statham et al. (2008) previously showed a relationship between tail posture and tail damage. They found that during a tail biting outbreak, the pigs tended to keep their tails between the legs, while curled tails were more present when no tail biting outbreak occurred. Our research adds that tail posture can predict tail damage; piglets that kept their tails between legs had a chance of future tail damage. It is known that tail biting behaviour occurs, in the so-called pre-injury stage, before any tail damage is visible (Schrøder-Petersen and Simonsen, 2001). In response, it is likely that bitten piglets will keep their tails between legs to prevent further biting. McGlone et al. (1990) stated that maintaining the tail down clearly decreases its exposure to other pigs' assaults and this could be interpreted as an attempt to avoid further biting when some tail biting is already present. Furthermore, Chermat (2006) observed that in the presence of a tail wound, pigs reacted more when their tail was touched/chewed by another pig (mostly with avoidance), compared with bitten pigs without a tail wound.

Our results showed that tail motion had no value in predicting tail damage, but tail motion had a relationship with tail damage at the same observation moment. Piglets with tail damage were observed more often with (intense) tail wagging. These results are in agreement with suggestions of Kiley-Worthington (1976). She suggested that skin irritation (which is likely for pigs with tail damage) would induce tail wagging.

There is very little quantitative information available on tail behaviour among pigs. We found that among weaned piglets without tail damage 73% had a curled tail and 26% had their tail hanging. Kleinbeck and McGlone (1993) found that during a control period (i.e. without a potential stressor) 30% of the pigs had a curled tail and 63% of

the pigs had their tail hanging. However, in our experiment the observer would stand in the pen surrounded by the piglets, while checking and touching each individual piglet's tail. This situation is comparable with the situation of a familiar person touching the pigs, as described in the research of Kleinbeck and McGlone (1993). In this specific situation more than 60% of the pigs had a curled tail and 36% had their tail hanging. These percentages are more in agreement with our results.
Tail posture of a pig depends on its activity. Resting pigs will keep their tail mostly relaxed and hanging, while active pigs keep their tail more in a upwards curl (Kleinbeck and McGlone, 1993). Furthermore, it has been suggested that tail posture can be an indicator for the emotional state of the animal (e.g. Scheurmann, 1974; Kleinbeck and McGlone, 1993). Noonan et al. (1994) suggested that tail jamming (clamping of tail stump between hind limbs without movement) may indicate stress (they found more tail jamming after piglets were tail docked). We observed tail posture of active exploring piglets and tail posture during this activity can predict tail damage. Whether tail postures during other activities (e.g. lying inactive) can also predict tail damage could not be concluded from our data.

In practice, tail biting is not often diagnosed and dealt with by pig farmers until a wound is present in the injury stage (Schrøder-Petersen and Simonsen, 2001). However, future tail damage can be predicted using tail posture. Although our predictions on tail damage are based on individual piglets, these results are also relevant for groups of pigs. Looking for pigs with their tail between the legs is a good reason for further inspection. Even when this pig has no visible tail damage, it is worthwhile marking this pig. When in a next observation again this pig keeps its tail between the legs, the chance of future tail damage has increased. Checking tail posture in practice could be combined with the pig farmer’s daily health and feed intake checks. For uniform observations on tail posture over time, pig farmers could provide small amounts of substrate or feed on the floor. This will preoccupy the pigs while the pig farmer checks the pigs' tail postures.

6.5 Conclusions and implications

Our research showed that the piglet's tail posture is strongly related to tail damage and can predict tail damage. Weaned piglets with their tail between legs had a higher chance of tail damage 2-3 days later. Furthermore, two consecutive observations of a single piglet with its tail between legs (and no tail damage) increased its chance of tail damage 2-3 days later. Checking tail postures on a regular basis increases early recognition of tail biting. This can help pig farmers to take appropriate measures to prevent further escalation of the problem.

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Chapter 7

General discussion

The majority of the world's weaned piglets and finishing pigs are kept in intensive housing systems under circumstances which increase the risk of adverse behaviours like tail biting. Tail biting is a complex and multi-factorial problem and many risk factors are known to increase the chance of a tail biting outbreak. Although provision of substantial amounts of environmental enrichment materials (e.g. straw, mushroom compost, branches) has proven to reduce the occurrence of tail biting (Bøe, 1992; Beattie et al., 1995; Petersen et al., 1995; Day et al., 2001), the usage of these materials in intensive pig housing systems is limited mainly due to practical (e.g. blockages of the manure-handling system) and economical reasons. Alternative measures to prevent tail biting in these systems have so far only had a limited effect, also due to the limited understanding of how a tail biting outbreak evolves in a group of pigs (aetiology). Disentangling the aetiology of a tail biting outbreak may lead to a better understanding of how risk factors increase the chance of tail biting, more effective preventive measures, but also better curative measures to counteract an ongoing tail biting outbreak. Therefore, the main aim of this thesis was to gain more insight in the aetiology of a tail biting outbreak by quantifying the development of tail biting behaviour and tail damage on individual and pen level. In this chapter, while proposing a model for the aetiology of a tail biting outbreak (aetiology model), the results from the previous chapters are discussed. Furthermore, suggestions for practical implications are given. This includes a consideration of the ethical aspects of tail docking as preventive measure for tail biting.

7.1 Aetiology of a tail biting outbreak

In current intensive housing systems pigs are kept within limited space and circumstances that provide little stimuli for the pigs. Under these circumstances a certain level of arousal (i.e. a state of increased physiological activity) in a pen is present (Stolba and Wood-Gush, 1980). This level of arousal is not a steady state, but can change over time due to changes in the environmental conditions, changes in (feeding) management or other disturbing events. Within these circumstances most scientists suggest that tail biting behaviour and subsequent tail damage evolves from an exploration motivation that becomes redirected to penmates' tails (or other parts of the body) as was outlined in Chapter 1. This aetiology of tail biting behaviour from exploration motivation, including the presence of a certain level of arousal, can be used as a starting model (Figure 7.1). In the following sections, the results from the previous chapters will be discussed and used for additions to this proposed aetiology model.

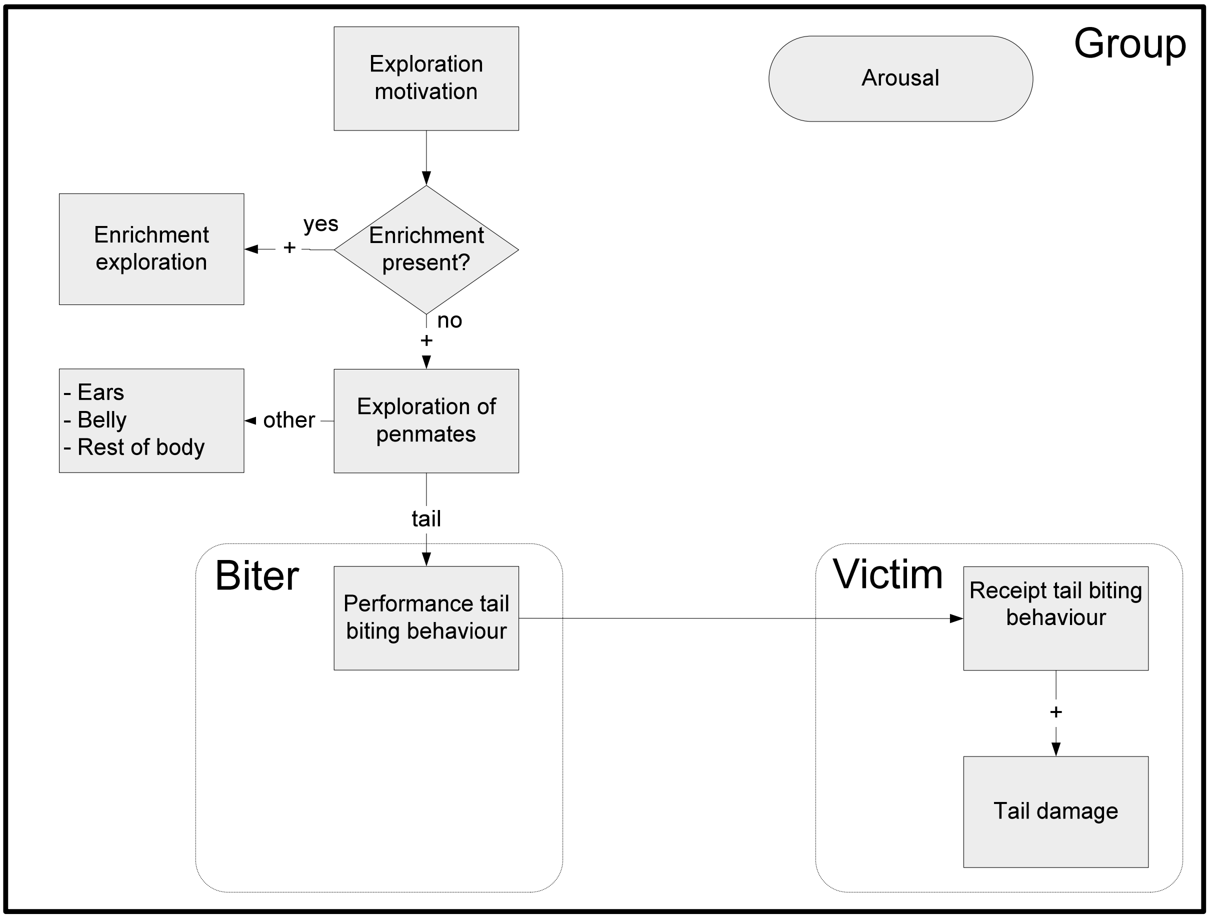

Figure 7.1 Aetiology model with exploration motivation leading to tail biting behaviour and tail damage in a group of pigs (+ = increased chance).

7.1.1 Performance and receipt of tail biting behaviour

Chapter 4 showed that in the period preceding a tail biting outbreak, 82% of the pigs in the group performed tail biting behaviour and 96% of the pigs received tail biting behaviour. Schrøder-Petersen et al. (2003) reported that all pigs performed low frequencies of tail-in-mouth (TIM) behaviour, which is considered a precursor for tail biting behaviour (EFSA, 2007). Results from Chapter 4 and Schrøder-Petersen et al. (2003) dismisses previous suggestions that only one or a couple of pigs perform tail biting behaviour before an outbreak occurs (Van Putten, 1968; Blackshaw, 1981; Beattie et al., 2005; Edwards, 2006). Chapter 4 also showed a large variation in the frequency of tail biting behaviour performed by individual pigs in the group (shown in Figure 7.2 as the frequency of performed tail biting behaviour of pigs 1, 2, 3, etc).

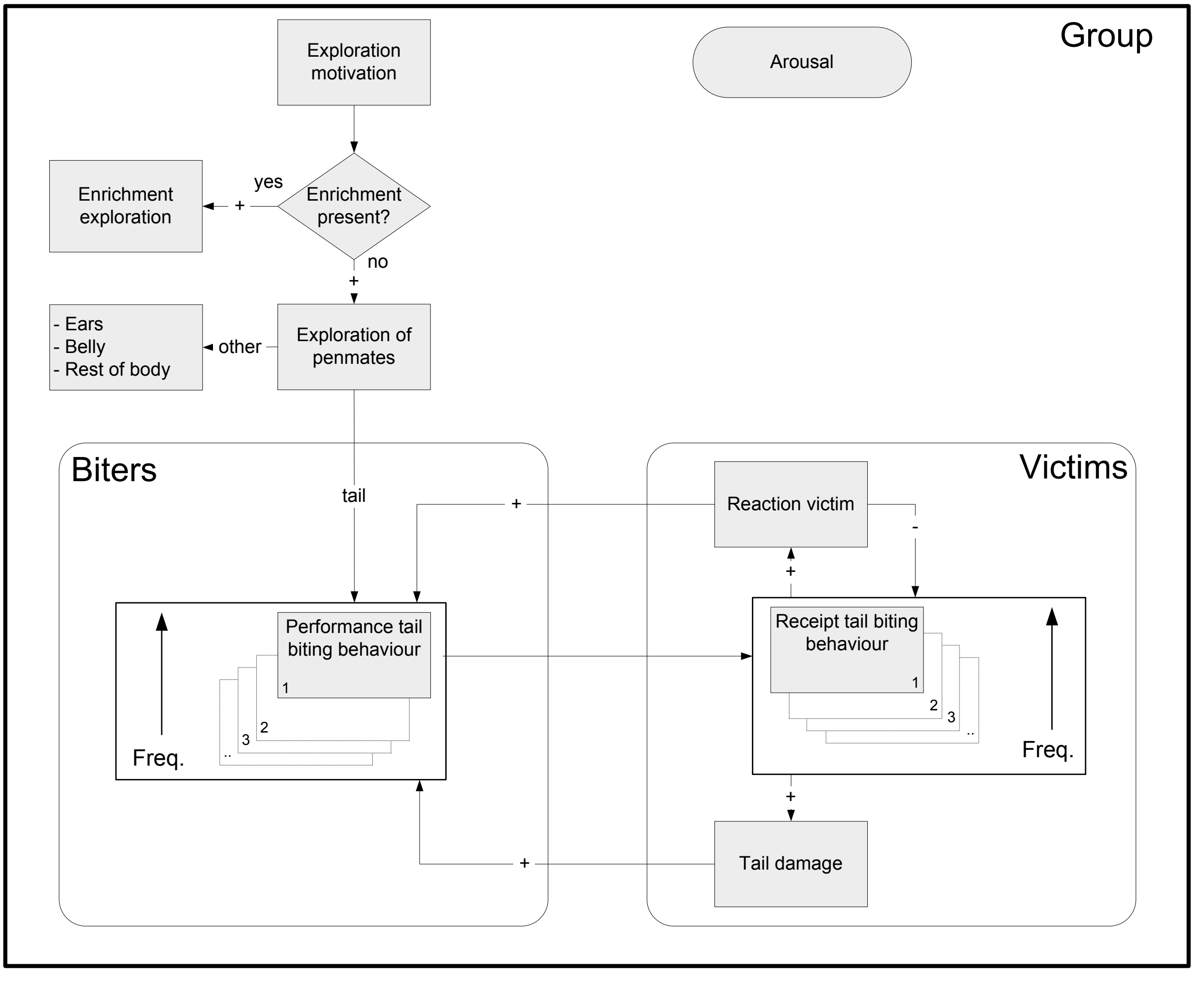

Figure 7.2 Aetiology model with exploration motivation leading to tail biting behaviour and tail damage in a group of pigs (+ = increased chance; - = decreased chance).

Also Schrøder-Petersen (2005) observed a high individual variation in the pig's performance of TIM behaviour. Furthermore, in ten (out of the fourteen) pens one or a few individual pigs performed this tail biting behaviour with a significant higher frequency compared with their penmates. These pigs were considered the pronounced biters.

Similar to the performed tail biting behaviour, the frequency of received tail biting behaviour varied among the pigs (shown in Figure 7.2 as the frequency of received tail biting behaviour of pigs 1, 2, 3, etc). Although less clear as for biters, in a number of pens one or a few pigs received more tail biting behaviour compared with their penmates and were considered pronounced victims. Except for one out of the fourteen pens, the pronounced biter and victim were two different pigs.

In conclusion, most pigs within a group perform and receive tail biting behaviour but with considerable variation in frequency. Most often one or a few pigs perform or receive more tail biting behaviour compared with their penmates and are considered the pronounced biters and victims.

7.1.2 Tail damage

After the first visible tail damage was present in a pen, pigs with tail damage had received more tail biting behaviour prior this day compared with pigs without tail damage (Chapter 4). This indicates that pigs who receive a higher frequency of tail biting behaviour have a higher chance to obtain tail damage in a later stage (Figure 7.2). This confirms earlier statements of Fraser and Broom (1990) and Schrøder-Petersen et al. (2003) that with the receipt of tail biting behaviour the chance of the skin breaking at some point increases, leading to tail damage like bite marks or a tail wound.

7.1.3 Increase in tail biting behaviour

After the first tail damage was present in a pen, an exponential increase of tail biting behaviour was found (Chapter 4). This supports earlier suggestions that a bleeding tail will stimulate further tail biting behaviour (+ in Figure 7.2), as pigs showed a higher attraction to a rope impregnated with blood (Fraser, 1987a; Fraser, 1987b; Fraser et al., 1991; McIntyre and Edwards, 2002; Jankevicius and Widowski, 2004). However, blood is unlikely to be the sole factor involved in the increase of tail biting behaviour. Chapter 4 showed that biters had no preference for a specific penmate even when this penmate had a bleeding tail. Furthermore, Chapter 4 showed that the total frequency of tail biting behaviour in a pen already exponentially increased before any tail damage was present. Therefore, it was suggested that the reaction of the victim or tail biting behaviour itself has a reinforcing effect on the performance of tail biting behaviour (Chapter 4).

7.1.4 Reaction of victim

When bitten, the immediate reaction of the victim can vary from reluctantly moving away to a vigorously reaction with vocalisation or even an aggressive reaction towards the biter. For a biter housed under stimulus-deprived circumstances, an immediate reaction of the victim can have a rewarding effect and subsequently encourage the performance of more tail biting behaviour (Chapter 4). Also Blackshaw (1981) suggested that a vocal reaction of the victim encourages further biting.

Victims can also react with a general change in their behaviour. Victims with tail damage were observed more often tail wagging (Chapter 6) and this can attract more attention of penmates as was suggested by Van Putten (1979). Similar, pigs with tail damage were more often observed with a hanging tail (Chapter 6) and, as suggested by Feddes and Fraser (1994), an exposed tail receives more tail biting behaviour compared with a curled tail. On the other hand, pigs with tail damage kept their tail more often between the legs compared with pigs without tail damage (Chapter 6). This change in tail posture is most likely performed to prevent the receipt of further tail biting behaviour (McGlone et al., 1990). McGlone et al. (1990) found that during a tail biting outbreak the pigs tended to keep their tails between the legs, while curled tails were more present when no tail biting outbreak occurred. Also Statham et al. (2009) found that in pens with several pigs keeping their tail ‘tucked under’ more often a tail biting outbreak was observed.

In conclusion, both an immediate reaction (e.g. vocalisation) and general behavioural changes of the victim (e.g. tail wagging) can increase subsequent receipt of tail biting behaviour (+ in Figure 7.2). In addition, general behavioural changes of the victim (e.g. keeping the tail between the legs) can also decrease subsequent performance of tail biting behaviour (- in Figure 7.2).

7.1.5 Increase in arousal

The whole process of the occurrence of tail biting behaviour and tail damage in a group of pigs, including the reaction of the victims, is likely to enhance the arousal in this group and subsequently increases the motivation to explore. In turn, this leads to an increase of tail biting behaviour and the chance of subsequent tail damage. Chapter 5 showed that prior to a tail biting outbreak the overall restlessness in the pen increased and also a high degree of restlessness for both biters and victims was found. Svendsen et al. (2006) found that one week before tail biting occurred biters were 10% more active compared with the average pen activity. Statham et al. (2009) also found a higher activity four days prior to a tail biting outbreak. In conclusion, the occurrence of tail biting behaviour (including the reaction of the victims) and tail damage enhances group arousal with a subsequent increase of exploration motivation (Figure 7.3).

Apart from the increase in arousal from tail biting behaviour, tail damage and reaction of the victims, also several risk factors (see Chapter 1) can enhance the group arousal and subsequently the motivation to explore. For example, it was suggested that a nutritional imbalance of pigs increases the group arousal and the motivation to explore. This was explained as the pigs continue to seek feed to give the correct balance of nutrients (Taylor et al., 2010). Also, a suboptimal climate like draught (forced cold air) resulted in more activity (arousal) and also in a more exploration behaviour (Scheepens et al., 1991).

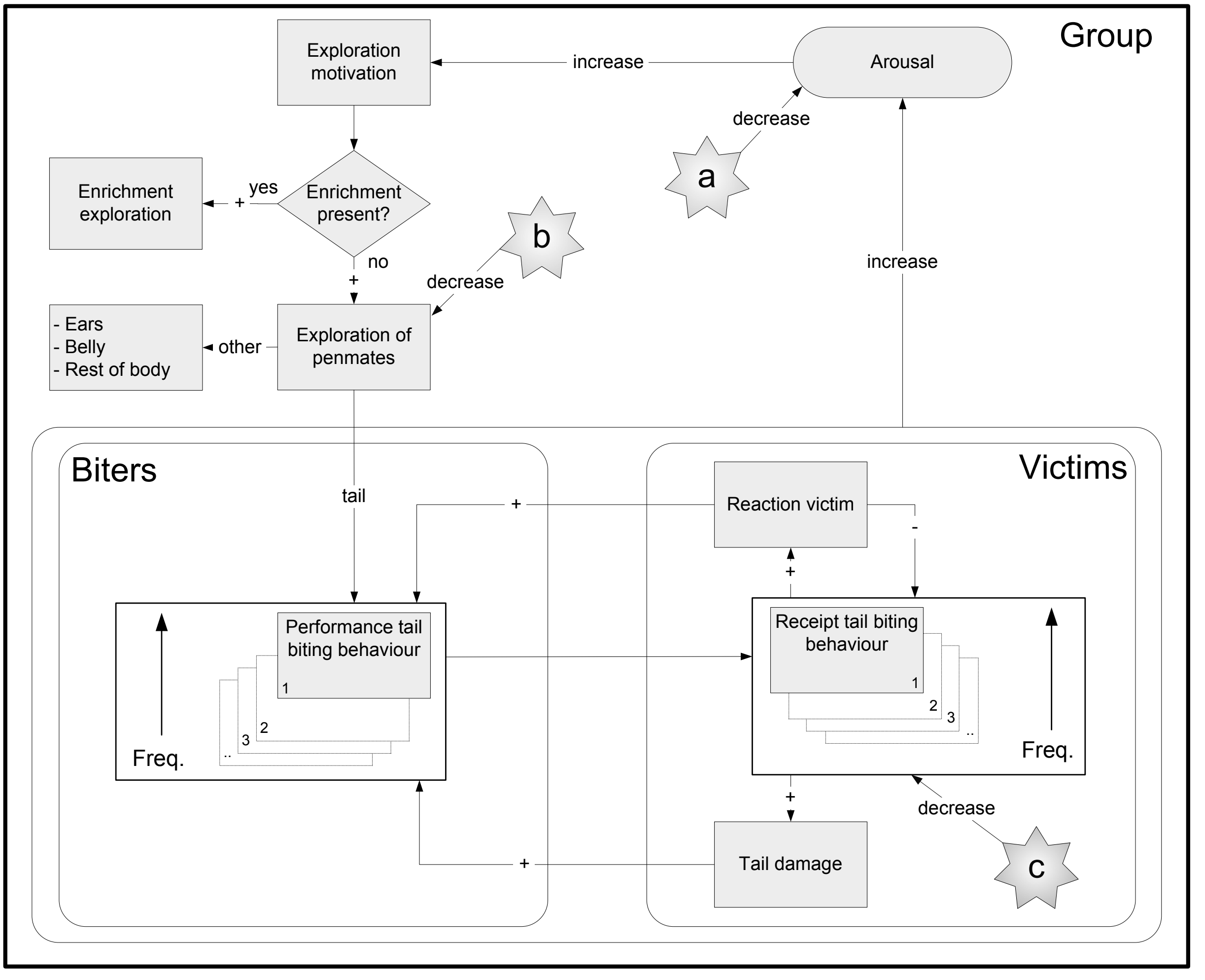

Figure 7.3 Aetiology model with exploration motivation leading to tail biting behaviour and tail damage in a group of pigs (+ = increased chance; - = decreased chance), including key points for preventive measures (a, b and c).

7.1.6 Development of subsequent tail biting behaviour and tail damage

After a tail biting outbreak started tail biting behaviour increased exponential until a certain plateau was reached (Chapter 4). So far it remains unknown why tail biting behaviour stabilized at a higher level or even decreased again (as found in three pens in Chapter 4). During this period of exponential increase in tail biting behaviour, subsequent victims appeared and tails with bite marks often deteriorated into (severe) wounds. Although differences in the development rate of tail damage have been suggested before (e.g. Fritschen and Hogg, 1983), quantification of this difference in tail damage development has so far been limited. Chapter 2 showed that the transition from bite marks into a tail wound took on average 7.5 days, with considerable variation (standard deviation: 5.4 days) and in 2% of the cases this transition occurred within one day.

7.1.7 Alternative aetiologies for tail biting behaviour

Several results from the previous chapters might indicate other aetiologies for how tail biting behaviour evolves or alternatively might indicate a risk factor that increases the motivation to explore.

Aggression

Victims initiated more aggressive interactions compared with biters and control pigs. Obviously the receipt of tail biting behaviour can lead to an aggressive reaction from this victim. However, Chapter 5 showed that 87% of the victim's performed aggression involved no tail biting behaviour. In contrast, biters tended to receive more aggressive behaviour (Chapter 5). Therefore it was suggested that these aggressive interactions reflected a confrontation between a victim with a high social status (dominant) and a biter with a lower social status (subordinate). This is supported by earlier studies that proposed biters weight less than their penmates (Fritschen and Hogg, 1983; Sambraus, 1985; Van de Weerd et al., 2005), while victims weight more than their penmates (Van de Weerd et al., 2005; Ushijima et al. 2009). Since subordinate pigs may suffer restricted access to feed and water during preferred feeding and drinking periods, they are likely to be more frustrated. These pigs may redirect their aggressive behaviour towards a penmate's tail in order to gain access to the feeding or drinking place (Hansen and Hagelsø, 1980). Taylor et al. (2010) defined this aetiology of redirected aggressive tail biting behaviour as 'sudden-forceful' tail biting with the penmates' tails being seized and yanked or bitten forcefully. This aggressive act due to frustration (Widowski, 2002) is generally seen without an observed period of gentle manipulation (Taylor et al., 2010). However, this description of tail biting behaviour was rarely observed during the observations in Chapter 4. It is possible that the observed tail biting outbreak in Chapter 4 involved mainly the aetiology of exploration motivation and that under different circumstances the aetiology of redirected aggressive behaviour becomes more apparent.

An alternative explanation is that subordinate pigs with restricted access to resources increase their motivation to explore (exploration aetiology) and direct this exploration towards other items in their surrounding. Poletto et al. (2010) found an indication that subordinate pigs, compared with dominant pigs, performed more investigatory behaviour towards a penmate like sniffing or massaging. This could also explain why biters manipulated both the enrichment device and the tails of their penmates more compared with victims or control pigs (Chapter 5). The exposed tails of feeding pigs make them a relatively easy target (Sambraus and Kuchenhoff, 1992), which explains the higher prevalence of tail damage among the heavier pigs in Chapter 5.

In conclusion, from the differences in aggressive behaviour between biters and victims it is possible that tail biting behaviour can evolve from redirected aggressive behaviour or that the social status is a risk factor. In this latter case dominant pigs have a higher risk of receiving tail biting behaviour and subordinate pigs a higher risk of performing tail biting behaviour.

Gender

Chapter 3 showed that gender affected the development rate of tail damage. Male pigs were more at risk to become a victim, which is in agreement with previous studies (e.g. Penny et al., 1972; Hunter et al., 1999; Valros et al., 2004; Kritas and Morrison, 2007). Furthermore it was suggested that female pigs were more likely to become a biter (Chapter 3). Also Svendsen et al. (2006) found that of their 27 identified biters 70% were female. Schrøder-Petersen et al. (2003) found that in mixed-sex pens female pigs also performed more TIM behaviour than male pigs and Breuer et al. (2003) found that female pigs had a tendency to manipulate a rope more often in a tail-chew-test than male pigs. Other studies found no difference in the performance of tail biting behaviour between male and female pigs (Breuer et al., 2005; Van de Weerd et al., 2005; Elkmann and Hoy, 2008). The reason why female pigs perform more tail biting behaviour is unclear. Sambraus (1985), Simonsen (1995) and Schrøder-Petersen and Simonsen (2001) speculated that tail biting behaviour evolves from redirected sexual behaviour. They suggested that as female pigs start to become sexually mature, they become more active to perform sexual behaviour and also more interested in ano-genital investigation. Indeed, Ford (1990) showed that sexual behaviour between male and female pigs is already different as early as one month of age. Mounting of penmates was observed more frequently from males than from females. However, whether one month-old female pigs also perform more ano-genital behaviour what could lead to tail biting behaviour could not be confirmed in Chapter 5.

An alternative explanation is that female pigs perform more exploration behaviour compared with male pigs. This was shown in several studies (Breuer et al., 2003; Bolhuis et al., 2005; Elkmann and Hoy, 2008; Poletto et al., 2010), although in Chapter 5 no gender effect was found in the performance of manipulative behaviour. Furthermore, several studies showed that male pigs were less active and spent more time eating at the trough (Stookey and Gonyou, 1994; Elkmann and Hoy, 2008). Therefore, a higher motivation of female pigs to perform exploration behaviour and male pigs being an easy target, either standing at the feeder or lying inactive, could lead to more male victims. In conclusion, from the found gender differences it remains unclear whether 1) tail biting behaviour can evolve from a redirected sexual behaviour or 2) that gender should be considered a risk factor with female pigs having a higher motivation to explore.

7.2 Preventive measures

In the aetiology model for tail biting behaviour (Figure 7.3), three key points were identified for applying measures to prevent a tail biting outbreak: a) prevent group arousal, b) prevent exploration of penmates and c) prevent the receipt of tail biting behaviour. These key points (letters a, b, and c in Figure 7.3) will be briefly discussed below.

7.2.1 Prevent group arousal (a)

Group arousal can be reduced by meeting the behavioural needs of all pigs in a group (e.g. available feed and water, exploration possibilities, suitable lying place, stable social environment, comfortable climate). For example, providing a comfortable climate can reduce the group arousal. Scheepens et al. (1991) showed that the unexpected occurrence of draught resulted in a three times higher activity level of pigs and five times higher redirected exploration behaviour towards penmates. Furthermore, a clear distinction of functional areas within a pen (i.e. space for feeding, resting, exploring and excretion) can decrease the chance of a pig encountering resting penmates and causing arousal. Also reducing the need for competition can reduce arousal in a pen, e.g. providing the pigs with multiple feed spaces

7.2.2 Prevent exploration of penmates (b)

The occurrence of tail damage was almost fully prevented when pigs were provided with twice daily 10 g/pig/day of long straw (Chapter 2). Although earlier studies showed that straw provision increased the group arousal, this increased activity was mainly directed to the provided straw (Fraser et al., 1991; Beattie et al., 1995; Bolhuis et al., 2005). Therefore, even with an increased group arousal, the motivation to explore can be redirected with environmental enrichment and penmate exploration prevented. When redirecting exploration behaviour, important characteristics of successful environmental enrichment include ‘ingestible’, ‘odorous’, ‘chewable’, ‘deformable’ and ‘destructible’ (Van de Weerd et al., 2003). These characteristics are present when e.g. long straw is provided. Simple toys lack several of these characteristics and Chapter 2, as well as a study of Van de Weerd et al. (2005), showed that such toys were unable to prevent tail damage. In addition, Zonderland et al. (2003) suggested that novelty is a relevant material characteristics to attract the pigs’ attention. Also Hunter et al. (2001) and Moinard et al. (2003) suggested that enrichment is more effective when it is replenished daily. Providing straw twice daily and loose on the floor are probably important reasons for the difference in effectiveness to prevent tail biting compared with a straw rack (replenished about once a week; Chapter 2). Effective environmental enrichment like long straw may indeed lead to practical and economical problems when used in large amounts. However, Chapter 2 already showed that, when provided frequently, a small amount of long straw is also effective in preventing tail biting. It requires further investigation to analyse whether these small amounts, or even smaller amounts, of long straw will be effective under practical circumstances for groups of weaned piglets and finishing pigs.

7.2.3 Prevent receipt of tail biting behaviour (c)

Tail docking may prevent tails from being bitten by reducing the attractiveness of (what is left of) the tail and by increasing the responsiveness of the (potential) victim (EFSA, 2007). However, tail docking on a routine basis is forbidden in the EU and application of this measure is therefore limited. Another suggestion to prevent the receipt of tail biting behaviour is by covering the tails with a repellent substance such as tar (e.g. Arey, 1991; Wallgren and Lindahl, 1996). Bracke (2009) tested the efficacy of two repellents (Stockholm tar and Dippel's oil) in preventing the receipt of tail biting behaviour using ropes as tail models. During the one hour measurement after applying the repellent, a reduction in tail rope manipulation was found for both repellents. However, it requires further investigation whether such repellent substances are also effective in reducing the receipt of tail biting behaviour.

7.3 Curative measures

Chapter 2 showed that after the start of a tail biting outbreak curatively removing the identified biter in a pen temporarily reduced the occurrence of subsequent victims. However, removal of the biter did not entirely eliminate subsequent victims, most likely because other penmates already increased their tail biting behaviour. Similar to removing the biter, curatively providing twice daily a handful long straw also temporarily counteracted the tail biting outbreak (Chapter 2). The reason why twice daily straw was unable to eliminate the tail biting outbreak remained unclear. In Chapter 4 it was suggested that sometimes the behaviour of a biter changed during the tail biting outbreak. E.g. the biter developed a strong preference for biting penmates' tails specifically. It is possible that the biter preferred biting tails even when straw was available. Therefore, recognition of tail biting behaviour in a pen before the first pig with tail damage is present seems crucial to effectively counteract an outbreak.

Chapter 5 showed that in the six days prior to a tail biting outbreak, the behaviour of biters and victims deviated from control pigs in the same pen. Furthermore, the arousal in the group (total level of restlessness) in the pen increased in the six-day period prior to a tail biting outbreak (Chapter 5) and potential victims already changed their tail posture (Chapter 6). Although it must be noted that considerable variation existed between pens, several behavioural changes occurred prior a tail biting outbreak. This opens opportunities for pig farmers to recognize these early signs of an upcoming tail biting outbreak in order to take appropriate measures to prevent this outbreak. However, more research is needed to confirm these results under varying practical circumstances.

7.4 Ethical and practical considerations

In the current intensive pig housing systems more than 90% of the annually 146 million slaughtered pigs in the EU are tail docked with the reason to prevent the occurrence of tail biting in a later stage. From ethical point of view animal integrity should be pursued (Rutgers and Heeger, 1999) and tail docking omitted. However, the occurrence of tail biting outbreaks will also reduce the welfare of pig's. This pleads to search for alternatives to prevent the occurrence of tail biting in groups of pigs with intact tails. In the following sections the consequences of tail biting and tail docking for the pigs and the pig farmer are listed together with alternative preventive measures for tail biting. This is followed by several suggestions for short- and long-term actions to prevent occurrences of tail biting and reduce the need for tail docking.

7.4.1 Consequences of tail biting for the pigs

Tail biting behaviour represents an underlying problem that certain pigs' behavioural needs are not met (EFSA, 2007). When tail biting in a group of pigs occurs, it is likely that the welfare of most pigs in this group is impaired. The majority of the pigs in a group perform and receive tail biting behaviour (Chapter 4) and this will increase group arousal. An increased group arousal can in turn lead to subsequent tail biting behaviour and eventually this can escalate into a tail biting outbreak with multiple victims and severe tail damage. Biters do not only receive their share of tail biting behaviour (Chapter 4), but biters also receive more aggression from penmates (Chapter 5). For a victim is a damaged tail not only painful (van Putten, 1969), but also increases the chance of subsequent infections. Therefore, in a pen where tail biting occurs, the whole group experiences a reduced welfare with additional welfare impairment for the biters and especially for the victims.

7.4.2 Consequences of tail biting for pig farmers

The unpredictability of a tail biting outbreak and the effort required to counteract this outbreak, can give pig farmers a feeling of limited control and impair their job satisfaction. Other negative consequences of tail biting for the farmers are extra costs and financial losses. The amount will vary between farms and depends on the seriousness of the tail biting outbreaks. Victims with serious tail damage need treatment and measures need to be taken to counteract an outbreak. Depending on the treatment of victims and curative measures, this can result in extra labour, material cost and medicine cost. Other examples of financial losses are a reduced weight gain of victims (Wallgren and Lindahl, 1996) and carcass condemnation due to abscesses (Huey, 1996). A preliminary cost estimation indicates a yearly financial loss of almost € 6.000,- (unpublished data) for farms with 4000 finishing pigs and with a tail damage prevalence of 5%.

7.4.3 Consequences of tail docking for pigs

With the tail docking procedure the tail of a newborn piglet is surgically removed without any anaesthesia. Since the tail of newborn piglets is already innervated, tail docking causes acute pain (Simonsen et al., 1991). In addition, docked pigs may also suffer from long-term pain. During and after the process of repair, Simonsen et al. (1991) and Done et al. (2003) observed the presence of neuromas (random proliferation of axons and glial support cells) that are known to be very sensitive. However, McIntyre (2003) found no differences in the pain sensitivity of pigs with intact tails compared with medium or short docked pigs. In addition, long term pain may also occur due to stump pain or phantom pain (EFSA, 2007). Furthermore, the tissue lesion due to tail docking may compose a bacterial entry and consequently lead to infection. Data from Riising et al. (1976) showed that tail docking increased the incidence of fatal streptococcal infections. Another effect of tail docking is a possible change or disappearance of the tail function. Tail posture is a means of communication, e.g. during greeting tail elevation or a curl in the tail is clearly visible (Kiley-Worthington, 1976).

The efficacy of tail docking to reduce tail biting is very difficult to estimate (EFSA, 2007). Tail docking certainly does not eliminate the underlying motivation of pigs to perform tail biting behaviour (Figure 7.3). A summary of published information (EFSA, 2007) suggests that among pigs with intact tails the prevalence of pigs with tail damage is about a factor 2-3 higher than among docked pigs. Because pigs with intact tails are often kept under different circumstances, an objective comparison with docked pigs is almost impossible (EFSA, 2007). However, docking tails is likely to reduce the chance of tail damage with more than a factor 2-3.

7.4.4 Alternative preventive measures

The aetiology model (Figure 7.3) shows that with reducing the occurrence of penmate exploration, tail biting behaviour and subsequent tail damage will decrease. Decreasing stocking density and providing appropriate environmental enrichment are two examples of measures that will reduce the occurrence of penmate exploration. Appropriate environmental enrichment will additionally facilitate the performance of species-specific behaviour, in this case especially exploration behaviour. Facilitating the behavioural needs of pigs will reduce arousal in a pen and subsequent tail biting. EU legislation (Commission Directive EC 2001/93, article 8 of the annex) already states that before carrying out tail docking, other measures should be taken to prevent tail biting (considering environment and stocking densities). However, omitting the tail docking procedure straight away in the current EU intensive pig housings systems might fail to improve pig welfare. But in order to reduce the need for tail docking, several actions on the short term as well as the long term can be suggested.

7.4.5 Short term actions

Of all the pig farms that use tail docking on a routine basis, a distinction can be made between pig farms with and without tail biting problems. In a recent survey among Dutch pig farmers, 53% of the farmers stated to have tail biting problems among their pigs (De Lauwere et al., 2009). For the group of pig farms with tail biting problems, despite tail docking, it is suggested that they first try to solve their tail biting problems. Due to the complex and multi-factorial aspects of tail biting, there exists a large variation between pigs farms in the possible occurrence of a tail biting outbreak. Therefore on each individual pig farm an inventory should be made of the existing risk factors. Subsequently, the aetiology model (Figure 7.3) can be used as guidance to determine the most effective measures to prevent tail biting.

For the group of pig farms without tail biting problems, there exists no need to continue tail docking on a routine basis. Omitting tail docking straight away for all newborn piglets on the farm could, but not necessarily, lead to a strong increase of tail biting outbreaks and discourage any further attempt to omit tail docking. An alternative for these pig farmers is to start raising a small number of pigs with intact tails (e.g. a couple of pens in each batch). Within this small number of pens a better view of any tail biting problem is apparent and escalation of a tail biting outbreak is therefore less likely to occur. These pig farmers can try different preventive measures (e.g. twice daily a handful long straw), monitor behavioural indicators for an upcoming tail biting outbreak (e.g. tail posture) and take action in case of an emerging outbreak (e.g. removing the biter). Consequently, these pig farmers will gain experience with keeping pigs with intact tails and discover measures that on their specific farm will prevent and counteract a tail biting outbreak. When raising small numbers of pigs with intact tails is a success, the next step can be taken to a larger number of pigs with intact tails and eventually to the whole farm population.

7.4.6 Long term actions

When short term actions fail to generate circumstances in which pigs with intact tails can be kept with no or limited tail biting problems, long term actions (with a focus of more than five years) might provide a solution. One long term suggestion is to invest into new husbandry facilities that meet the species-specific needs of pigs. The Comfort Class facility is an example of a housing system based on the pigs' needs (De Greef et al., 2009). This systems provides more space (2.4 m^2 per finishing pig) and more environmental enrichment compared with the current intensive pig housing systems. So far, the pigs with intact tails kept in this Comfort Class system have had little tail biting problems (De Greef et al., 2009). However, the housing costs of this Comfort Class system is estimated twice the housing costs for the current intensive housing systems and so far without an increase in revenues. This shows that a positive effect for animal welfare can have a negative consequence (trade-off) for other sustainability aspects like in this case economics. Alternatively, new housing systems that take the pig's needs into account should also take the needs of the pig farmer, environment and consumers/civilians into account (Van Eijk et al., 2009).

Another long term suggestion is to investigate what underlying pig factors are responsible for the strong individual increase in tail biting behaviour under certain circumstances. The performance of tail biting behaviour differed between individual pigs (Chapter 4), what suggests that the predisposition to develop this behaviour is likely to differ between pigs as well. This may reflect an inability of certain pigs to cope with stressful circumstances. Adaptations to stressors take place at different levels (immunologic, neuroendocrine and behavioural responses) and are aimed at reaching homeostasis (Wiepkema and Schouten, 1990). If an animal fails to reach homeostasis, this will have a negative effect and may lead to adverse behaviours like tail biting. So far, little is known about individual differences in the predisposition to develop tail biting behaviour and about the role of underlying traits, such as fearfulness and exploration motivation. For feather pecking, which is an adverse behaviour among poultry comparable to tail biting behaviour, it has been suggested that underlying fearfulness predisposes laying hens to exhibit feather pecking

(Rodenburg et al., 2004). It would be worthwhile to investigate whether underlying traits can be identified to predict the predisposition of tail biting behaviour in pigs.

The results in this thesis have given more insight in how a tail biting outbreak evolves in groups of pigs kept in an intensive housing system. The proposed aetiology model provides a better understanding on how certain risk factors increase the chance of a tail biting outbreak and how measures can prevent or counteract a tail biting outbreak. Additional observations under practical circumstances are needed to confirm the proposed measures to predict, prevent and counteract a tail biting outbreak. However, with the current knowledge practical actions on short and long term can already be taken to reduce the chance of tail biting and omit the need for tail docking.

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Summary
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Summary

Tail biting is an adverse behaviour that is commonly observed in intensive pig housing systems and which can lead to damaged tails and cannibalism. Tail biting is a multi-factorial problem and most tail biting research focused on internal risk factors (e.g. breed, gender and age) and external risk factors (e.g. environmental enrichment, housing climate, stocking density and feeding management) that influence the occurrence of this problem. However, the way a tail biting outbreak evolves in a group of pigs (the 'aetiology') is still poorly understood. Therefore, the main aim of this thesis was to gain more insight in this aetiology of a tail biting outbreak, enhancing the understanding of: 1) why and how risk factors contribute to a tail biting outbreak, 2) the effectiveness of preventive measures for a tail biting outbreak, 3) the effectiveness of curative measures to counteract an ongoing tail biting outbreak. Furthermore, insight in this aetiology can generate more effective measures to prevent, predict and counteract a tail biting outbreak.

In the first experiment (Chapter 2) the development of tail damage was studied in relation to four treatments to prevent tail biting and two treatments to counteract an ongoing tail biting outbreak. Tail damage (no damage, bite marks and tail wound) of 960 weaned piglets with intact tails (10 piglets per pen) was recorded daily during a five-week period after weaning. The preventive measures were: a metal chain, a rubber hose, a straw rack (average straw use 5 g/pig/day) and the provision of long straw on the floor twice daily by hand (average 2x10 g/pig/day straw provision). Two curative treatments that were applied following the onset of a tail biting outbreak (an outbreak was defined as the first day with a minimum of one piglet with a tail wound or two piglets with bite marks in a pen) in a pen were also tested: straw twice daily (as in the fourth preventive measure) and the removal of the biter. The incidence of pens with wounded pig tails was significantly lower when twice daily straw was provided (8% of pens) compared with the chain (58% of pens) and rubber hose (54% of pens) treatment, but did not differ from the straw rack treatment (29% of pens). Once tail biting occurred, providing long straw twice daily and removing the biter were equally effective. They reduced the incidence of piglets with fresh blood on the

tails at days 1 to 9 following curative treatment, but neither curative treatment eliminated tail biting entirely.

To gain more insight in the aetiology of a tail biting outbreak under intensive conditions, the occurrences of such outbreaks were required. Therefore the subsequent studies were performed on a farm with known tail biting problems and pigs kept in barren circumstances without straw.

In the second experiment (Chapter 3), gender effects were tested in single- and mixed-sex groups of weaned piglets using a new parameter; the development rate of tail damage. A 2x2 factorial design was used to study four treatment categories: (1) all-male groups, (2) all-female groups, (3) males in mixed-sex groups and (4) females in mixed-sex groups. During the observation period after weaning, tail damage (no damage, bite marks or tail wound) of 700 weaned piglets was scored three times per week for 32 days. The number of piglets with tail damage in all-female groups developed more rapidly (40% of the piglets had tail damage within 10.9 days after weaning) compared with the other three groups (average of 16 days). Within the mixed-sex groups, male piglets had more tail damage compared with female piglets. The results indicated that female piglets were more likely to perform tail biting behaviour while male piglets were more likely to receive tail biting behaviour and subsequent tail damage. In the same experiment the hypothesis was tested that tail behaviour (posture and motion) can predict tail damage (Chapter 6). Additional observations on tail posture (curled tail, hanging tail or tail between legs) and tail motion (motionless, wagging or intense wagging) were performed. Results showed that both tail posture and tail motion were related to tail damage at the same observation day, but only tail posture could predict tail damage 2 to 3 days later. When a piglet had a curled tail (and no tail damage), the chance of bite marks or a tail wound present 2 to 3 days later were 8.6% and 3.1%. When a piglet had the tail between the legs (but no tail damage), the chance of bite marks or a tail wound 2 to 3 days later increased to 22.3% and 8.5%. Furthermore, when a piglet held its tail between the legs (and no tail damage) in two consecutive observations, the chance of bite marks or a tail wound 2 to 3 days later increased to 32.4% and 23.7%. Therefore, checking tail postures on a regular basis can increase early recognition of a tail biting outbreak.

In Chapter 4, pens with a tail biting outbreak from the first experiment (Chapter 2) were studied in more detail to quantify the development of tail biting behaviour at pen and piglet level. The following three questions were investigated:

a. How many piglets in a pen are involved in performing and receiving tail biting behaviour before and after the tail biting outbreak?
b. Is it possible to identify pronounced biters and/or bitten piglets in a pen?
c. Do biters prefer specific penmates or do they bite penmates randomly?

Video recordings of fourteen pens with tail biting outbreaks and individually marked weaned piglets were used to observe tail biting incidents (TBI; piglet biting a penmate's tail). When tail damage was first observed in a pen (i.e. day of tail biting outbreak: D_0) the video recordings for the previous six (till D_{-6}) and the following six days (till D_6) were analysed every other day for TBI's and the identities of the biter and bitten piglet were recorded. The results showed an exponential increase in the TBI frequency (linear on log-scale) from an average of 0.9 bites/h at D_{-6} to 2.3 bites/h at D_6. This increase of tail biting behaviour was mainly caused by an increased biting frequency rather than by an increased number of biting piglets. Before the tail biting outbreak (i.e. before D_0), 82% of the piglets performed tail bites and 96% of them received tail bites. After D_0, these percentages increased to 99% and 100% respectively. In almost all pens one or a few pronounced biters could be identified. These biters already showed more tail biting behaviour at D_{-6} than their penmates. Furthermore, these biters showed a greater increase in tail biting behaviour over the observation period than the average frequency of their penmates. In contrast, for pronounced bitten piglets this greater increase in receipt of bites during the observation period was not apparent, although these bitten piglets already had been bitten more than their penmates at D_{-6}. Finally, biters showed no preference for biting particular penmates, even when some of them had a damaged tail.

The most pronounced biter and victim in each of the fourteen pens from Chapter 4 were studied in Chapter 5 in order to characterize these piglets (gender and performance) and to quantify their behavioural development in the six days preceding the tail biting outbreak. Therefore, in every pen one biter, one victim and one control piglet (piglet types) were observed every other day from six days before (D_{-6}) to the day of the tail biting outbreak (D_0). The results showed that biters directed their manipulation behaviour more to the enrichment device (1.8 min/h compared with 0.5 min/h for control piglets) and to their penmates' posterior/tail body parts (0.65 min/h compared with 0.22 and 0.26 min/h for victims and control piglets). Furthermore, biters tended to receive more aggressive behaviour. Victims were the heavier pigs in the pen (8.6 kg compared with 7.5 and 8.0 kg for biters and control piglets) and tended to be more often male. Victims tended to be more restless preceding an outbreak. They also performed more aggressive behaviour (4.06 times per h compared with 2.06 and 2.40 times per h for biters and control piglets) and received more posterior/tail manipulation (0.47 min/h compared with 0.35 and 0.28 min/h for biters and control piglets). These findings show that differences in characteristics of biters and victims are already present prior to the tail biting outbreak. This can contribute to the early identification of biters or victims in order to prevent the occurrence of a tail biting outbreak.

The results from the previous chapters were used in the General discussion (Chapter 7) to develop a model for the aetiology of a tail biting outbreak. Tail biting behaviour most likely develops from exploring and feeding behaviour that becomes redirected to penmates and specifically the penmate's tail. General arousal (i.e. a state of increased physiological activity) in a pen, which is influenced by many internal and external risk factors, can enhance the motivation of pigs to explore and increase the performance of tail biting behaviour. Tail biting behaviour and damaged tails can induce more tail biting behaviour and can also increase the level of arousal in the group what leads to even more tail biting behaviour. This process seems self-reinforcing and stimulates an exponential increase in tail biting behaviour. Based on the results of this thesis, practical suggestions are given to prevent (e.g. providing effective environmental enrichment), predict (e.g. observing the pigs’ tail posture) and counteract (e.g. removing the biter) a tail biting outbreak. This provides opportunities to omit tail docking without the negative consequence of tail biting.

Samenvatting

Staartbijten is een afwijkend gedrag bij varkens dat regelmatig voorkomt in de intensieve varkenshouderij en kan leiden tot varkens met een staartverwonding en kannibalisme. Staartbijten is een multifactorieel probleem. Tot nu toe heeft het onderzoek zich vooral gericht op de interne (bv. ras, geslacht en leeftijd) en externe risicofactoren (bv. hokverrijking, klimaat, dierdichtheid en voermanagement) die van invloed zijn op het optreden van staartbijten. Er is echter relatief weinig bekend over het ontstaan van een staartbijtuitbraak in een groep van varkens (de 'etiologie'). Het hoofddoel van dit proefschrift is dan ook om meer inzicht te krijgen in het ontstaan van een staartbijtuitbraak en hiermee beter te begrijpen: 1) hoe risicofactoren bijdragen aan het ontstaan van een uitbraak, 2) hoe effectief preventieve maatregelen zijn om een uitbraak te voorkomen en 3) hoe effectief curatieve maatregelen zijn om een uitbraak te stoppen. Daarnaast kan inzicht in het ontstaan van een staartbijtuitbraak leiden tot nieuwe en effectievere maatregelen om een uitbraak te voorspellen, te voorkomen of terug te dringen.

In het eerste experiment (Hoofdstuk 2) werd de ontwikkeling van staartschade geanalyseerd met betrekking tot vier behandelingen om staartbijten te voorkomen en twee behandelingen om een staartbijtuitbraak terug te dringen. De staartschade (geen, bijtpuntjes en staartwonden) werd gedurende 5 weken dagelijks geregistreerd bij in totaal 960 gespeende biggen met intacte staart (10 biggen per hok). De preventieve behandelingen waren: ketting, rubberen speeltje, stroruif (gemiddelde stroverbruik 5 g/dier/dag) en het dagelijks verstrekken van tweemaal een handjevol lang stro op de dichte vloer (gemiddelde stroverstrekking 2x10 g/dier/dag). De twee curatieve behandelingen bij het begin van een staartbijtuitbraak (een staartbijtuitbraak in een hok was gedefinieerd als de eerste dag waarop minimaal één varken een staartwond had of twee varkens bijtpuntjes op de staart hadden) waren: tweemaal daags een handjevol lang stro (zelfde als vierde behandeling bij preventie) en het verwijderen van de geïdentificeerde bijter. De incidentie van hokken met één of meerdere dieren met een staartwond was significant lager bij het verstrekken van tweemaal daags lang stro (8%) vergeleken met een ketting (58%) en

een rubberen speeltje (54%), maar verschilde niet van hokken met een stroruif (29%). Bij een staartbijtuitbraak was het verstrekken van tweemaal daags lang stro en het verwijderen van de bijter even effectief in het terugdringen van staartbijten. Deze curatieve behandelingen zorgden voor een verlaging van het aantal staarten met vers bloed gedurende 9 dagen na de uitbraak. Maar geen van de twee curatieve behandelingen kon het staartbijten volledig terugdringen.

Om meer inzicht te krijgen in het ontstaan van een staartbijtuitbraak onder intensieve omstandigheden, zijn uitbraken onder deze omstandigheden gewenst. Daarom werden de vervolgstudies verricht op een bedrijf met staartbijtproblemen en met varkens die gehuisvest waren in relatief kale omstandigheden zonder stro.

In een tweede experiment (Hoofdstuk 3) werd het effect van geslacht (mannelijke of vrouwelijke dieren) getest in gemengde (mannelijke én vrouwelijke dieren) en ongemengde groepen (mannelijke óf vrouwelijke dieren). Hiervoor werd een nieuwe parameter gebruikt, namelijk de ontwikkelingssnelheid van staartschade in een hok. Vier categorieën werden in een 2x2 factoriële proefopzet onderzocht: (1) groepen met alleen mannelijke dieren, (2) groepen met alleen vrouwelijke dieren, (3) mannelijke dieren in gemengde groepen (evenveel mannelijke als vrouwelijke dieren) en (4) vrouwelijke dieren in gemende groepen. Gedurende 32 dagen na spenen werd van 700 gespeende biggen (10 dieren per hok) driemaal per week de staartschade (geen, bijtpuntjes en staartwonden) gescoord. Het aantal dieren met staartschade ontwikkelde zich sneller in groepen met alleen vrouwelijke dieren (40% van de biggen had staartschade binnen 10,9 dagen na spenen), vergeleken met de drie andere groepen (gemiddeld binnen 16 dagen na spenen). Binnen de gemengde groepen hadden de mannelijke dieren meer staartschade dan de vrouwelijke dieren. Deze resultaten duiden erop dat vrouwelijke varkens meer de neiging hebben om op staarten van hokgenoten te bijten, terwijl mannelijke dieren vaker slachtoffer zijn. Tijdens het experiment werd eveneens de hypothese onderzocht of je aan de staart (houding en beweging) staartschade kunt voorspellen (Hoofdstuk 6). Hiervoor werden aanvullende waarnemingen gedaan aan de staarthouding (krulstaart, hangende staart of staart tussen de poten) en staartbeweging (bewegingsloos, kwispelen of intens kwispelen). Uit de analyse bleek dat zowel staarthouding als staartbeweging gerelateerd waren aan staartschade op hetzelfde observatiemoment. Maar alleen aan de hand van de staarthouding kon de staartschade 2 tot 3 dagen later voorspeld worden. Bij een zichtbaar onbeschadigde krulstaart was 2 tot 3 dagen later de kans op bijtpuntjes of een staartwond klein (respectievelijk 8,6% en 3,1%). Wanneer een big de verder onbeschadigde staart tussen de poten hield was 2 tot 3 dagen later de kans op bijtpuntjes of een staartwond bijna driemaal zo groot (respectievelijk 22,3% en 8,5%). Als deze big in twee opeenvolgende observatiemomenten de staarten tussen de poten hield zonder dat er staartschade zichtbaar was, werd de kans 2 tot 3 dagen later op bijtpuntjes of een staartwond nog hoger (respectievelijk 32,4% en 23,7%). Regelmatig de staarthouding van varkens controleren kan daarom helpen om een staartbijtuitbraak in een vroegtijdig stadium te herkennen.

In Hoofdstuk 4 werd de ontwikkeling van staartbijtgedrag op hok en dierniveau gekwantificeerd in de hokken met een staartbijtuitbraak uit het eerste experiment (Hoofdstuk 2). Hierbij werden de volgende vragen onderzocht:

a. Hoeveel biggen zijn per hok betrokken bij het uitvoeren en ontvangen van staartbijtgedrag in de periode voor en na de staartbijtuitbraak?
b. Is het mogelijk om uitgesproken bijters en gebeten biggen te identificeren?
c. Hebben bijters een specifieke voorkeur voor hokgenoten of bijten ze willekeurig in de staarten van hokgenoten?

Videobeelden van veertien hokken met individueel gemarkeerde gespeende biggen zijn gebruikt om staartbijtincidenten (SBI; big die in de staart van een hokgenoot bijt) te observeren rondom een uitbraak van staartbijten. Op de dag van de uitbraak (D_0), werden de videobeelden van de zes voorgaande dagen (tot D_{-6}) en de zes volgende dagen (tot D_6) om de dag geobserveerd voor SBI's. Hierbij werden de identiteit van bijters en gebeten biggen vastgelegd. Uit de resultaten bleek dat de frequentie van SBI's exponentieel (lineair op log-schaal) toenam van gemiddeld 0,9 beten/uur op D_{-6} naar 2,3 beten/uur op D_6. Deze toename in SBI's werd voornamelijk veroorzaakt door een stijging van de bijtfrequentie per big en in mindere mate door een toename van het aantal bijtende biggen. Voor D_0 werd bij 82% van de biggen staartbijtgedrag geobserveerd en 96% van de biggen werd één of meerdere malen in de staart gebeten. Na D_0 liepen deze percentages op tot respectievelijk 99% en 100%. In bijna alle hokken konden één of een paar uitgesproken bijters geïdentificeerd worden. Deze bijters vertoonden op D_{-6} al meer bijtgedrag dan hun hokgenoten. Daarnaast steeg het bijtgedrag gedurende de observatieperiode bij deze bijters ook sneller dan het gemiddelde van hun hokgenoten. Uitgesproken slachtoffers werden ook al vaker gebeten op D_{-6}. Maar in tegenstelling tot de bijters was er bij deze dieren geen sprake van een snellere stijging gedurende de observatieperiode. Bijters hadden geen voorkeur voor het bijten van specifieke hokgenoten, zelfs al hadden sommige van deze hokgenoten een beschadigde staart.

In Hoofdstuk 5 werd uit elk van de veertien hokken uit Hoofdstuk 4 de meest uitgesproken bijter en gebeten big (slachtoffer) gekarakteriseerd (geslacht, productietechnische gegevens) en hun gedrag gekwantificeerd gedurende zes dagen voorafgaand aan de staartbijtuitbraak. Hiervoor werd in elk hok één bijter, één slachtoffer en één controlebig (type big) om de dag geobserveerd van zes dagen voor (D_{-6}) tot de dag van de staartbijtuitbraak (D_0). Uit de resultaten bleek dat bijters hun manipulatiegedrag meer op het afleidingsmateriaal richten (1,8 min/uur vergeleken met 0,5 min/uur voor controlebiggen) en op de achterkant/staart van hun hokgenoten (0,65 min/uur vergeleken met 0,22 en 0,26 min/uur voor slachtoffers en controlebiggen). Daarnaast was er een tendens dat bijters vaker agressief gedrag ontvingen. Slachtoffers bleken zwaarder te zijn bij spenen (8,6 kg vergeleken met 7,5 en 8,0 kg voor bijters en controlebiggen). Verder was er een tendens dat slachtoffers vaker mannelijke dieren waren en dat slachtoffers onrustiger waren voorafgaand aan de staartbijtuitbraak. Slachtoffers waren vaker agressief richting hokgenoten (4,06 keer per uur vergeleken met 2,06 en 2,40 keer per uur voor bijters en controlebiggen) en werden meer gemanipuleerd aan de achterkant/staart (0,47 min/uur vergeleken met 0,35 en 0,28 min/uur voor bijters en controlebiggen). Deze resultaten laten zien dat karakteristieken van bijters en slachtoffers al verschillen voorafgaand aan de staartbijtuitbraak. Dit kan bijdragen aan het vroegtijdig identificeren van bijters en slachtoffers om een mogelijke staartbijtuitbraak te voorkomen.

Op basis van de resultaten uit de eerdere hoofdstukken is in de algemene discussie (Hoofdstuk 7) een model ontwikkeld over het ontstaan van een staartbijtuitbraak. Waarschijnlijkheid ontwikkelt het staartbijtgedrag van varkens zich vanuit exploratiegedrag en foerageergedrag dat is omgericht naar de staarten van hokgenoten. Onrust (d.w.z. een staat van verhoogde fysieke activiteit) in het hok kan de exploratiemotivatie van varkens verhogen waardoor de kans op staartbijtgedrag toeneemt. Deze onrust wordt beïnvloed door vele interne en externe risicofactoren. Staartbijtgedrag en varkens met staartschade kunnen meer staartbijten onder hokgenoten oproepen waardoor de onrust in de groep eveneens groter wordt. Dit lijkt een vliegwieleffect te creëren waardoor staartbijtgedrag exponentieel toeneemt. Het proefschrift eindigt met praktische handreikingen om staartbijten te voorkomen (bv. verstrekken van effectief afleidingsmateriaal), te voorspellen (bv. door naar staarthouding te kijken) en uitbraken in te dammen (bv. door de bijter uit de groep te halen). Dit geeft nieuwe mogelijkheden om het couperen van varkensstaarten in de toekomst achterwege te laten zonder dat dit tot meer staartbijtproblemen leidt.

Dankwoord

Het is 18 januari 1963 en in Friesland is het -18° Celsius met een stormachtige oostenwind en een dik pak sneeuw van 20 cm. De 17-jarige Sjouke Zonderland start samen met nog tienduizend andere toerrijders aan de 200 kilometer van de 12^{e} Elfstedentocht. Door de duisternis, door sneeuwbanken en over ijs met ontelbare scheuren ploetert deze jongen voort om uiteindelijk met nog 68 andere toerrijders "De Hel van '63" te volbrengen. Dit was een bijzondere prestatie onder uitzonderlijke omstandigheden, al zei mijn vader zelf dat het wel meeviel. Zelf heb ik de Elfstedentocht nooit geschaatst. Ik ben niet verder gekomen dan het fietsen van de Elfstedentocht. Maar wat heeft een Elfstedentocht te maken met het volbrengen van een promotietraject? Op het eerste gezicht niet veel, maar toch zijn er overeenkomsten. Zo geldt dat voor beide een goede voorbereiding nodig is en uithoudingsvermogen, maar vooral ook de hulp en steun van je naasten. Tijdens mijn promotietraject langs de elf steden hebben velen mij gesteund en hen wil ik dan ook graag bedanken. Allereerst hebben mijn directe leidinggevenden, eerst Ina Enting en daarna Kees de Koning, mij de mogelijkheid geboden om deze tocht te ondernemen. Daarnaast was het materiaal om de tocht te maken aanwezig in de vorm van twee experimenten uitgevoerd op het toenmalige Varkensproefbedrijf Waiboerhoeve te Lelystad. De medewerkers van het proefbedrijf hebben samen met Maaike Wolthuis-Fillerup, Maudia van Wijhe-Kiezebrink en Gerriëtte Timmerman voor twee succesvolle experimenten gezorgd en de materiële basis gelegd voor dit promotietraject. Tijdens de Elfstedentocht is een goede verzorging van essentieel belang. Het begeleidingsteam met Hans Spoolder, Marc Bracke, Bas Kemp en Leo den Hartog hebben mij van uitstekende zorg voorzien. Obstakels werden tijdens de tocht veelal klunend overwonnen. Met de statistische ondersteuning van Johan van Riel, grafische ondersteuning van Fred van Welie en dierethische ondersteuning van Elsbeth Stassen ging het klunen een stuk makkelijker. Met veel tegenwind is schaatsen op de vaarten en meren vaak flink doorploeteren. Gelukkig hebben velen mij op deze stukken uit de wind gehouden en werk uit handen genomen. Vooral John de Leeuw, Anita Beijers en Femke Schepers hebben veel kopwerk verricht. Elk stad op de Elfstedenroute is een bron van inspiratie en weer nieuwe motivatie om de tocht voort te zetten. Voor mij was het Melkveeproefbedrijf Nij Bosma Zathe en hun medewerkers een bron van inspiratie en motivatie om het laatste stuk van de tocht te volbrengen. En dan zijn er de supporters die langs de kant van het traject je aanmoedigen en stimuleren. Tijdens mijn tocht waren dit er velen: mijn collega's binnen Wageningen UR, mijn vrienden en in het bijzonder mijn familie. Met zoveel support voelt het alsof je constant de wind in de rug hebt. Voor de laatste loodjes op de Bonkevaart werd ik bijgestaan door mijn twee paranimfen Maikel Timmerman en Kees van Reenen. Aan de finish gloort de beloning van zoveel inspanning; het Elfstedenkruisje. Mijn Elfstedenkruisje heeft een krul in het lintje. Bij de finish volgt dan eindelijk de hereniging met je geliefden.

Lieve Marlies, tijdens deze Elfstedentocht heb ik jou ontmoet en vanaf dat moment ben je met me meegereden. Jij was niet alleen mijn bron van liefde, inspiratie en motivatie, maar jij was tegelijkertijd mijn grootste criticus. Samen met jou was deze tocht vele malen lichter! En nu gaan we samen met onze zoon Mike in Nieuw Zeeland aan een nieuwe tocht beginnen. Een tocht zonder ijs.

Curriculum Vitae

About the author

Johan Jacobus Zonderland was born on the 10th of November 1973 in Tjerkgaast (The Netherlands). In 1992 he graduated from the secondary school Magister Alvinus in Sneek and started in 1993 his study ‘Zoötechniek’ at Wageningen Agricultural University (nowadays Wageningen University). During his study he went for an internship to Massey University in New Zealand and participated in research on anthelmintec resistance in sheep. For Holland Genetics, he wrote his MSc thesis about the evaluation of a multhiphasic model for reproductive efficiency of dairy bulls. After receiving his MSc degree in 1997 he started working as a researcher at the Research Institute for Pig Husbandry in Rosmalen (nowadays part of the Animal Sciences Group of Wageningen UR). His main research topics in the following years were pig behaviour, farm management and farm system innovations. In 2005, he started his PhD research on tail biting in pigs at the Adaptation Physiology Group of Wageningen University. The PhD research was finished in 2010 and is described in this PhD thesis. Currently, he is working as a senior researcher at Wageningen UR Livestock Research and will leave for New Zealand in November 2010.

Training and supervision plan

Graduate School WIAS

Name: Johan Zonderland
Group: Adaptation Physiology Group
Period: 2005-2010

	Year	Credits*
The Basic Package		
WIAS Introduction Course	2007	1.5
International conferences		
Int. Farm Management Association (IFMA), Perth, Australia	2003	1.8
Int. Society for Applied Ethology (ISAE), Helsinki, Finland	2004	1.5
Int. Farm Management Association (IFMA), Campinas, Brazil	2005	1.8
Int. Society for Applied Ethology (ISAE), Bristol, UK	2006	1.5
Int. Society for Applied Ethology (ISAE), Dublin, Ireland	2008	1.5
Measuring Behaviour, Maastricht	2008	1.2
Seminars and workshops		
Farewell Seminar Willem Schouten, Wageningen, 7 dec 2005	2005	0.1
KLV meeting Animal Welfare, Wageningen	2007	0.1
Tail biting workshop, Petersborough, UK	2007	0.6
3x Tail biting workshop NKJ project (Finland, Denmark and Norway)	2008-10	1.8
Presentations		
Pig manager programm (IFMA), Perth, Australia	2003	1.0
Tail biting in pigs (ISAE), Helsinki, Finland	2004	1.0
Labour productivity pig farms (IFMA), Campinas, Brazil	2005	1.0
Pigs vision, NVG, Dalfsen	2006	1.0
Environmental enrichment, Wijchen	2007	1.0
Castration and behaviour (ISAE), Dublin, Ireland	2008	1.0
Welfare research approaches, Hamilton, New Zealand	2009	1.0
Tail biting in pigs and enrichment, British FACW, Raalte	2009	1.0
In-Depth Studies		
Course applied statistics	2001	2.0
PHLO course "Biologische landbouw - naar een gesloten kringloop"	2002	1.0
Course "Methodische toerusting en begeleiding bij systeeminnovaties"	2006	1.5
Science meets society - "robuustheid"	2007	1.0
WBS course "EU-beleid voor landbouw, voedsel en groen"	2010	1.0
Professional Skills Support Courses		
Course "Writing and presenting scientific papers"	2001	0.6
Course "projectmatig werken - kwaliteit op tijd"	2002	0.5
Course "effectief schrijven"	2002	0.5
Course "Situationeel Leiding geven"	2005	0.3
Course "Writing for Academic Publication"	2006	1.5
Course "Mobilising your scientific Network"	2008	1.0
Research Skills Training		
Preparing own PhD research proposal	2005	6.0
Preparing PhD project "Quantifying underlying traits of adaptive capacity pigs"	2009	3.0
Didactic Skills Training		
Lecture HAS Larenstein Environmental enrichment	2006	0.2
Lecture ForFarmers about labour productivity in pigs	2005	0.2
Lecture "Producentenvereniging De Hoeve" about tail biting	2005	0.2
Supervisor BSc thesis (3 students)	2005-6	3.0
Supervisor MSc thesis (1 student)	2006	1.5
Management Skills Training		
Organising welfare session within Sector day Pigs, Wijchen	2007	1.0
Total		**42**

*one ECTS (European Credit Transfer System) credit equals a study load of approximately 28 hours

List of publications

Refereed scientific journals

Bracke, M.B.M., **Zonderland, J.J.**, Bleumer, E.J.B., 2007a. Expert judgement on enrichment materials for pigs validates preliminary RICHPIG model. Appl. Anim. Behav. Sci. 104, 1-13.

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Colophon

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