A tale of tails

Prevention of tail biting by early detection and straw management

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A tale of tails. Prevention of tail biting in pigs by early detection and straw management

Abstract

Pigs in their natural environment spend the majority of their time exploring their surroundings through rooting, sniffing and chewing to find food and resting places. Rooting under commercial conditions is often fully dependent on the provision of rooting material. Lack of rooting opportunity may redirect the exploratory behaviour and cause tail biting, an abnormal behaviour that causes acute, long- and short-term pain. Tail biting is a common issue in modern pig production, reducing health, profitability and animal welfare. To fulfil pigs' explorative needs, the Council Directive 2008/120/EC states that pigs should have permanent access to a sufficient amount of material, such as straw, to enable proper investigation and manipulation activities.

However, instead of improving pig environment to reduce tail biting, >90% of pigs in the EU are tail docked despite the prohibition of routine docking. Docked pigs have a less attractive and more sensitive tail tip and are less willing to allow biting. Docking aims at reducing the symptoms of tail biting rather than eliminating the cause. One argument for not increasing exploration through e.g. straw provision is fear of poor hygiene.

The overall aim of this thesis was to investigate the effect of straw on tail lesions, behaviour and hygiene (Studies I and II) as well as investigating tail position as a method for early detection of tail biting (Study III) in commercial production. Study I showed that 99% of Swedish farmers provide their pigs with straw ($median_{growers}$: 29 gram/pig/day; $median_{finishers}$: 50 gram/pig/day). The amount of tail biting recorded at the abattoir was on average 1.7%. Study II showed that an increased straw ration decreased presence of tail wounds and initiated more straw-directed behaviour. Straw had little effect on hygiene. Study III showed that tail posture (hanging or curled) at feeding correctly classified 78% of the pigs with tail wounds. Less severe tail damage, e.g. swelling or bite marks, did not affect the tail posture.

The main conclusions are that increased straw reduces tail damage as well as pen-directed behaviours. Instead, straw increases straw-directed behaviours, while not affecting pig and pen hygiene negatively. Hence, it should be possible to rear pigs with intact tails without the use of tail docking in the EU.

Keywords: pig, finisher, grower, intact tail, tail lesions, enrichment, tail docking, pen hygiene, pig hygiene, housing environment.

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A tale of tails. Förebyggande av svansbitning hos gris genom tidig upptäckt och halm

Sammanfattning

I naturen spenderar grisar majoriteten av sin tid genom att utforska sin omgivning för att hitta mat och viloplatser. I produktionsmiljöer är möjligheten att utföra detta utforskande beteende ofta helt beroende av tillgången till material att undersöka. Grisar som inte får utlopp för sitt undersökande beteende kan omdirigera beteendet till andra grisar och börja svansbita. Svansbitning är ett onormalt beteende som orsakar akut, kort och långvarig smärta samt försämrar hälsa, produktion och djurvälfärd. För att uppfylla grisarnas utforskande behov anges i (Europa) Rådets Direktiv 2008/120/EG att grisar ska ha permanent tillgång till tillräcklig mängd material, såsom halm, för att möjliggöra undersökande beteende.

Trots att rutinmässig svanskupering är förbjudet inom EU kuperas >90% av grisarna som produceras inom EU istället för att lösa problemet genom förbättrad uppfödningsmiljö. Kuperingen tros skapa en mindre attraktiv och känslig svansspets som gör grisarna mindre villiga att tillåta svansbitning i framtiden. Kuperingen syftar till att reducera symptomen av svansbitning snarare än orsaken. Ett argument för att inte förbättra uppfödningsmiljön och ge exempelvis halm istället är oron att det skall leda till försämrad hygien.

Det övergripande syftet med denna avhandling var att undersöka effekten av halm på svansskador, beteende och hygien (Studie I och II) samt utveckla en metod för tidig upptäckt av svansbitning (Studie III) i kommersiell produktion. Studie I visade att 99% av svenska bönder ger grisarna halm ($median_{tillväxtgrisar}$: 29 gram/gris/dag; $median_{storgrisar}$: 50 gram/gris/dag). I genomsnitt registrerades 1,7% svansbitna grisar vid slakt. Studie II visade att ökad halmgiva minskade förekomsten av svansskador och initierade mer halminriktade beteenden men hade liten inverkan på hygien. Studie III visade att svanspositionen, det vill säga om grisen har knorr eller hängande svans, vid utfodring korrekt klassificerade 78% av grisarna med sår på svansen. Mindre allvarliga skador, t.ex. svullnad eller bitmärken, upptäcktes inte med hjälp av svanspositionen.

De viktigaste slutsatserna var att ökad halmgiva minskar andelen svansskador samt ökade halminriktade beteenden, utan att påverka hygienen negativt. Därför bör det vara möjligt att använda halm för att öka det undersökande beteendet istället för att svanskupera även i EU.

Nyckelord: gris, storgris, slaktgris, tillväxtgris, svansskada, berikning, svanskupering, intakt svans, boxhygien, grishygien, inhysningsmiljö.

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Dedication

To all the pigs of the world: life will get better. We will not give up!

Kom du sköna nya värld,
Kom till allas hem och härd,
Kom och fyll vår huvudhärd,
Med förströelse
Claes Eriksson

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List of publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Wallgren, T.*, Westin, R., Gunnarsson, S. (2016). A survey of straw use and tail biting in Swedish pig farms rearing undocked pigs. *Acta Veterinaria Scandinavica*, 58 (84).

II Wallgren, T.*, Larsen, A., Lundeheim, N., Westin, R., Gunnarsson, S. (2018). Implication and impact of straw provision on behaviour, lesions and pen hygiene on commercial farms rearing undocked pigs. *Applied Animal Behaviour Science*, 210, 26-37.

III Wallgren, T.*, Lundeheim, N., Gunnarsson, S. Impact of straw on pig and pen hygiene *(manuscript)*

IV Wallgren, T.*, Larsen, A., Gunnarsson, S. (2019). Tail posture as an indicator of tail biting in undocked finishing pigs. *Animals,* 9(1), 18.

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The contribution of Torun Wallgren to the papers included in this thesis was as follows:

I Carried out main analyses and summarised the results. Responsible for writing and completing the manuscript including correspondence with journal.

II Was involved in planning and was responsible for performing the experiment. Carried out main analyses and summarised the results. Responsible for writing and completing the manuscript, including correspondence with journal.

III Was involved in planning and was responsible for performing the experiment. Carried out main analyses and summarised the results. Responsible for writing and completing the manuscript, including correspondence with journal.

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Abbreviations

C	Control
ES	Extra Straw
EU	European Union
FAH	Farm and Animal Health Service
LW	Live weight
SBA	Swedish Board of Agriculture
SFO	Swedish Food Agency

Abbreviations related to legislation

SJVFS 2019:20 (L106)	Statens jordbruksverks föreskrifter och allmänna råd (SJVFS 2019:20) om grishållning inom lantbruket m,m., saknr L106 [Swedish board of Agriculture regulations and general recommendations (SJVFS 2019:20) on pig husbandry in agriculture, Case No. L106.
Dir 2008/120/EC	Council Directive 2008/120/EC of 18 December 2008 laying down minimum standards for the protection of pigs.

1 Background

Pig production is an important part of modern food production in both high and low income countries. Pigs are used for converting (often) lower quality feed into high quality protein (meat) and pig meat can be an important source of nutrients in human diets. Pigs, like humans, are omnivores but have some possibility to break down fibrous feed via microbes in the colon. Pigs are therefore often, at least partly, fed with products that are not fit for, or used for human consumption, such as bi-products from the food industry or low quality cereals. Pig meat has also been considered to have a moderate climate impact, causing lower greenhouse gas emissions than beef production, but higher emissions than chicken production (Sonesson *et al.*, 2009). The highly prolific sows and the high feed conversion ratio make pig production efficient. Swedish pigs, which are among the most efficient in the world, today use 25.4 Mega Joule Net Energy (MJ NE) per kg growth and grow on average 94 g /day in the range 30-115 kg (FAH, 2018; Eriksson, 2016).

According to the Food and Agriculture Organization of the United Nations (FAO) over 1,486 million pigs were produced in the world in 2017 (FAOSTAT, 2018). The majority of these pigs can be found in Asia (59.4%) followed by Europe (21.8%), America (16.2%), Africa (2.0) and Oceania (0.6%). China is the main producer, rearing 702 million pigs for slaughter each year, followed by the United States (124.4 million). The largest pig producing countries in Europe are Germany (58.4 million) and Spain (50.1 million). Sweden runs a small production of pigs in global measures (2.6 million) and stands for about 1% of European pig production. There are around 379 herds with sows and 654 herds with finishing pigs in Sweden with a mean herd size of 165 sows or 825 finishing pigs (SBA, 2018; SBA, 2016). The agricultural business stands for 0.28% of the Swedish BNP (SBA, 2018).

As mentioned, the main purpose for keeping pigs is human consumption. It should be remembered that behind each produced pork chop there is a pig and each pig is an individual. It could be argued that the ethical consideration behind all animal production must be that the animals are provided with an acceptable production environment where they can express species-specific behaviours and as far as possible be protected from disease and discomfort (e.g. Jensen, 2012; Gjerris, 2014). To achieve this, pig production is in most countries regulated by animal protection laws of various levels of stringency. For example, the aim of the Swedish Animal Welfare Legislation (2018:1192) is to 'ensure good animal protection and promote good animal welfare and respect for animals'. Further it states that animals should be kept in such an environment that their welfare is promoted and they should be able to conduct natural behaviour, while abnormal behaviour should be prevented.

When the provided production environment does not enable natural behaviour and the animals are in some way communicating this, for example by showing abnormal behaviour, we have the obligation to improve the production environment, as stated by law. One such example is tail biting, mainly performed by pigs due to lack of occupation/possibility of performing natural behaviour (EFSA, 2008).

Instead of being provided with a better production environment, 90-95% of pigs produced within the European Union are tail docked to reduce tail biting. This is performed even though the Dir 2008/120/EC has condemned routine tail docking since 2003 and despite the fact that tail docking merely removes the symptoms of tail biting but not the underlying cause (EFSA, 2008). The fact is that the Council Directive's suggestion of improved pig environment to reduce tail biting is neglected. Furthermore, the tail docking procedure is commonly executed without any pain relief, which results in acute and sometimes long-term pain (Sandercock *et al.*, 2016; Simonsen *et al.*, 1991). Normally, national legislation (e.g. in Sweden, Finland and Lithuania) or other specific regulations or production schemes are the reasons for rearing pigs with intact tails (Nannoni *et al.*, 2014).

This is the take-off point from which this thesis was developed: how can the pig production environment be improved in order to reduce tail biting, a production disease mainly caused by insufficient housing conditions? As Nannoni *et al.* (2014) put it so well: 'Tail docking is performed because animals are situated in an inadequate environment, thus denied the freedom to express their normal explorative behaviour'.

2 Introduction

2.1 Animal welfare

There are several different definitions of animal welfare. One that is well known is the concept of the five freedoms, stating that animals should be free from suffering in five different aspects: hunger and thirst, discomfort, pain, injury or disease, should be free to express normal behaviour, and should be free from fear and distress (FAWC, 2009). Welfare is further described as an *individual's* attempt to cope with its environment (Broom, 1986) and concerns the feelings and emotions of animals, the animals' ability to function biologically, i.e. produce well, and the naturalness of the animals' life, i.e. ability to behave naturally (Keeling *et al.*, 2011). To assess the welfare of an animal, we must therefore assess all these different aspects (Fraser, 2008).

Even in 1986 it was recognised that the absence of indicators of poor welfare is not enough to claim good welfare (Broom, 1986). Today it is acknowledged that good welfare is predominantly the presence of positive experiences which can be achieved through low or high effort interventions and assessed through a combination of indicators (Broom, 1986). The concept of welfare will however vary between e.g. cultures and hence causes of action may differ between groups of people (Weary & Robbins, 2019).

Tail biting is an unwanted behaviour originating from unfulfilled behavioural needs and is considered negative for welfare and will be further described in the coming chapters. In this thesis, the focus has been mainly on the presence (or absence) of tail damage as an indicator of tail biting. Behaviour and behavioural outcomes (here; tail damage) are both potential welfare indicators but should not be considered as an attempt to assess the overall welfare of pigs, which is a much more complex matter.

2.2 The pig

2.2.1 Natural habitat

Wild boars inhabit different habitats such as forests, swamps and fields (Abaigar *et al.*, 1994; Boitani *et al.*, 1994). The home range consists of resting and feeding areas. Day nesting areas are close to the feeding areas while separate nesting areas are used during the night (Wiepkema, 1986). The resting areas are used consistently while feeding areas are used based on feed availability and disturbances such as hunting (Boitani *et al*., 1994). Dunging in the morning takes place at special dunging areas close to the nesting sites, while dunging during foraging is done without a specific dunging area (Wiepkema, 1986; Stolba & Wood-Gush, 1984). The size of the home range is dependent on resources, disturbances and group size. The seasonal home range of boars is larger compared to that of females, due to the sexual and territorial behaviour of males during mating season (Boitani *et al*., 1994).

2.2.1 Social structure

Wild boars generally live in social groups of adult females and their offspring (Kaminski *et al.*, 2005). The offspring usually remain with the mother but kin-groups of sisters will in some cases, e.g. related to group size, form new groups instead. Males older than one year predominantly live in bachelor groups of young males or solitarily and will mainly court females during mating season (Spinka, 2017).

Wild boar piglets are born once to twice per year in litters of 3-6 piglets. Weaning is a gradual process, occurring at 15-22 weeks of age, where piglets suckle less and subsequently increase feed consumption (Worobec *et al.*, 1999; Jensen & Stangel, 1992). The process is individual and siblings are not necessarily weaned at the same time (Worobec *et al.*, 1999).

2.2.2 Domestication

The pig (*Sus scrofa domesticus*) was domesticated from the Eurasian wild boar (*Sus scrofa*) about 7,000-10,000 years ago (Larson *et al.*, 2007; Giuffra *et al.*, 2000). Domestication is the process by which a population of animals becomes adapted to man and its captive environment (Price, 1984). It is achieved through a combination of genetic changes and environmentally induced development over generations. Pigs and wild boars however still belong to the same genus and wild boars continue to live and thrive in the wild (Price, 1984).

Domestication alters both the behaviour and physical development of the domesticated species compared to its wild ancestor. The behavioural differences consist of quantitative alterations, i.e. levels of conducted behaviour, while the qualitative nature of the responses, i.e. the type of behaviour conducted, remains unchanged (Price, 1999; Price, 1984). A reduced responsiveness to environmental change is considered an adaptation to living in the new 'safe environment' (Price, 1984). Overall, domestic pigs in semi-natural environment express the same behaviours as wild boars (Gustafsson *et al.*, 1999).

2.2.3 Exploratory behaviour

Pigs conduct exploratory behaviour of their surroundings through rooting, sniffing and chewing in order to find food, resting places and familiarise with their environment (Studnitz *et al*., 2007). The direction of the behaviour is steered by motivation. For instance pigs will search for food in locations where they have previously found food whereas they will explore unfamiliar environments if they are satiated (Inglis *et al*., 2001). Pigs kept under semi-natural conditions spend ~60% of their time in exploratory behaviour during daylight hours (Stolba & Wood-Gush, 1989). Around 40% of the exploratory behaviour is rooting, indicating the importance of this specific behaviour (Stolba & Wood-Gush, 1984). Exploratory behaviour is costly; still, pigs will conduct explorative behaviour until another motivation, such as sleep, becomes more pronounced (Studnitz *et al*., 2007). The fact that this costly exploratory behaviour is deeply motivated and performed to such a large extent has led to it being described as a behavioural need for the pig (Studnitz *et al*, 2007; Jensen & Toates, 1993). Animals that cannot fulfil behavioural needs may show signs of suffering such as frustration (Jensen & Toates, 1993). However, due to the flexibility of pigs' behaviour in relation to their surroundings, it is difficult to compare activity budgets or behaviours between different habitats (Boitani *et al.*, 1994).

2.3 Modern pig production

Compared to wild boars, commercially raised pigs experience quite a different environment (Figure 1). Pigs are commonly housed in a confined area (protected from predators and harsh environment), grouped according to age and regularly provided with feed that can be consumed within a short period of time (Hughes & Duncan, 1988). Hence, the animal is challenged to fill available time with a limited number of behaviour patterns, compared to wild animals that allocate the different behaviours within a limited amount of time, making sure to fulfil needs such as feeding and reproducing (Hughes & Duncan, 1988).

2.3.1 Pig housing

During the suckling period, piglets are housed with their mother, who is their main feed and heat source. The piglets are abruptly weaned at ~28 or ~35 days in Sweden or a minimum of 21 days within the EU, through removal of the sow. Weaned pigs are usually moved to a separate grower unit provided with feed and artificial heat. They are kept in the grower unit for approximately 5 weeks, between 10-30 kg live weights (LW). During this period the space requirement ranges from ~0.32-0.56 m^2 in Sweden (SJVFS 2019:20 (L106)) and 0.15-0.3 m^2 within the EU (Dir 2008/120/EC) dependent on pig live weight.

From the grower unit, pigs are moved to the finishing pig unit where they are kept until slaughter at ~110kg LW at around six months of age. During this period the space requirement ranges from 0.56-1.43m^2 in Sweden (SJVFS 2019:20 (L106)) and 0.3-0.65m^2 in the EU (Dir 2008/120/EC) dependent on pig live weight.

In Sweden, pigs are commonly kept in groups of 10-13 in pens consisting of both solid and slatted floors. Systems with larger groups and deep straw bedding exist but are less common; fully slatted floors are banned. Within the EU, pigs are commonly housed in larger groups in fully slatted pens (EFSA, 2007; Hendricks & van de Weerdhof, 1999).

Figure 1. Sketches of the natural environment (here pictured as the entrance to a forest) and captive production environment of pigs (here pictured as pens with partly slatted flooring).

2.3.2 Exploration possibilities

Even though living in confined, safe areas and provided with adequate feed, pigs are still highly motivated to conduct exploratory rooting behaviour (Olczak *et* *al.*, 2015; Studnitz *et al.*, 2007). Compared to natural conditions, where rooting is generally unrestricted, rooting activities under commercial conditions are often fully dependent on the provision of rooting material. In order to meet pigs' explorative needs the Dir 2008/120/EC laying down minimum standards for the protection of pigs states:

> '[…] pigs must have permanent access to a sufficient quantity of material to enable proper investigation and manipulation activities, such as straw, hay, wood, sawdust, mushroom compost, peat or a mixture of such, which does not compromise the health of the animals.'

However, the directive provides no guidance on how to assess permanent access or the fulfilment of explorative needs. Further, provision of the mentioned materials is essentially impossible in fully slatted pens since the material passes through the slats and becomes unavailable for the pigs. Therefore, it can be assumed that this legislation has low compliance within the EU.

Pigs in barren environments have been found to rest more (Olczak *et al.*, 2015). Resting has been considered positive for profitability since low activity levels help to maintain a high growth rate (Olczak *et al.*, 2015). From a welfare perspective, however, high levels of resting/inactiveness can be considered negative as this is an abnormal behaviour. Lack of rooting opportunity may also direct the pigs' exploratory behaviour towards other pigs, causing tail biting (Lahrmann *et al.*, 2015).

2.4 Tail biting

Tail biting is a common issue in modern pig production, reducing health, farm profitability and animal welfare in both the biter and bitten pig (D'Eath *et al.*, 2014; Brunberg *et al.*, 2013; Smulders *et al.*, 2008; Schroder-Petersen & Simonsen, 2001). It is an abnormal behaviour defined as one pig's dental manipulation of another pig's tail (Smulders *et al.*, 2008; Schroder-Petersen & Simonsen, 2001). This definition describes a large variety of behaviours ranging from gentle manipulation to obsessive biting, leading to tail or even rump losses and causing acute, short- and/or long-term pain (Taylor *et al.*, 2010; Schroder-Petersen & Simonsen, 2001; Blackshaw, 1981). Usually, the term 'tail biting' is used to describe visual tail wounds originating from tail-in-mouth behaviour (Bench & Gonyou, 2009). From a production perspective, tail lesions can cause reduced growth rate, abscesses and lead to carcass condemnation at the abattoir, which reduces farmer profit (Kritas & Morrison, 2007; Valros *et al.*, 2004; Wallgren & Lindahl, 1996). Still, the tail lesions identified at slaughter are probably underestimating the true prevalence since only severe tail wounds are detected (Lahrmann *et al.*, 2017; Keeling *et al.*, 2012). On the other hand, it is usually impossible to differentiate tail biting damage from damage caused by e.g. necrosis and tail biting may therefore also be overestimated.

2.4.1 Cause

Tail biting is multifactorial and affected by many different factors such as lack of enrichment, high humidity, temperature, drought, season, climate, feed, health status and disease outbreak (Olczak *et al.*, 2015; D'Eath *et al.*, 2014; Bracke *et al.*, 2013; EFSA, 2007; Schroder-Petersen & Simonsen, 2001). The triggering factor is often difficult to specify and varies between farms and occasions (D'Eath *et al.*, 2014). Lack of long straw has however been identified as the main risk factor for tail biting in modern pig production (EFSA, 2007).

From an animal perspective, tail biting indicates stress often caused by an inadequate environment (Moinard *et al.*, 2003; Schroder-Petersen & Simonsen, 2001). The unsatisfied exploratory behaviour is redirected to available means such as pen mates and fittings (Studnitz *et al.*, 2007). Damaging tail biting does not occur in the wild boar or other *Suidae* while non-damaging tail biting is considered a normal extension of the natural exploratory and foraging behaviour (Taylor *et al.*, 2010). Pigs that perform tail biting also conduct more ear and pen fitting biting, and sometimes perform more belly nosing, compared to non-tail biting pigs (Brunberg *et al.*, 2011).

Due to the behavioural background of tail biting, different types of production systems have different risks associated with the development of the behaviour. The largest risk factors in systems where straw is provided are related to environment, e.g. temperature, ventilation and humidity but also stocking density; while the main risk factor in systems without straw is the lack of enrichment (Taylor *et al.*, 2012). The lowest risk occurs when pigs are reared on straw along with high quality objects and substrates, while pigs with previous experience of straw but currently not provided with adequate rooting materials are at high risk (Taylor *et al.*, 2012).

Tail biting often occurs in outbreaks which can develop rapidly (D'Eath *et al.*, 2014). There is no clear definition of what is considered an outbreak, but it could be defined as the presence of visual lesions in several pigs in a group. Outbreaks may start with one pig playing with another pig’s tail, subsequently escalating to damaging the tail badly and chasing of the bitten animal (Blackshaw, 1981). The strong, but highly individual, attraction to blood is proposed to explain the quick escalation (Fraser, 1987). Also, wounded tails may attract chewing as they are easily damaged, stimulating exploratory behaviour (Feddes & Fraser, 1994).

Further, tail biting is affected by age and weight and thus does not occur at the same levels during the whole lifespan (Scollo *et al.*, 2016; Schroder-Petersen & Simonsen, 2001). High stocking density (>100kg/m^2) increases the risk of tail biting, possibly due to reduced avoidance possibilities (Moinard *et al.*, 2003). Additionally, tail biting is related to competitiveness around feeding and feeding-related issues such as unpredictable feeding times (Scollo *et al.*, 2016; Valros *et al.*, 2016; Taylor *et al.*, 2012; Smulders *et al.*, 2008; Moinard *et al.*, 2003), and the relative importance of enrichment material becoming higher if feeding competition exists (Guy *et al.*, 2013).

It has been suggested that farms with good production performance, e.g. high growth rates, have less tail biting compared to farms with poorer production although causality remains unknown (van Staaveren *et al.*, 2017). Victims of ear or tail biting grow slower compared to other pigs (van Staaveren *et al.*, 2017; Camerlink *et al.*, 2012; Wallgren & Lindahl, 1996). In a study by Camerlink *et al.* (2012) it was found that giving oral manipulation was uncorrelated to growth rate but social nosing was associated with increased growth rate. Correlations between presence of tail biting, respiratory disease and rectal prolapse have also been found (Kritas & Morrison, 2007; Moinard *et al.*, 2003), which implies that tail biting is linked to other health problems, although the causal relationship is still uncertain.

2.4.2 Types of tail biting

Schroder-Petersen and Simonsen (2001) suggested dividing tail biting behaviour into two categories: the pre-injury state (i.e. before a wound is present) and the injury state (i.e. where a wound is present), respectively. However, tail biting is usually not identified until the injury state is reached (Sonoda *et al.*, 2013). Taylor *et al.* (2010) split tail biting into three categories: two-stage tail biting (similar to the definition of Schroder-Petersen and Simonsen (2001)), sudden forceful tail biting, and obsessive tail biting.

Two-stage tail biting originates from unfulfilled foraging and exploratory behaviour, beginning with gentle manipulation and escalating to more damaging biting (Taylor *et al.,* 2010).

Sudden forceful tail biting is described as intense, forceful biting of tails without including the stage of gentle manipulation. It is not easy to distinguish sudden forceful biting from two-stage tail biting via only the outcome, i.e. tail wounds. Sudden forceful biting has been suggested to originate from lack of desired resources, such as food (Taylor *et al.,* 2010; Moinard *et al.,* 2003; van Putten, 1969).

Obsessive tail biting is defined as a large amount of sudden forceful tail biting seemingly performed by animals obsessed with tails rather than resources (Taylor *et al.*, 2010; Moinard *et al.*, 2003; van de Weerd *et al.*, 2005). It may share an origin with sudden forceful biting but the individual is rewarded by accessing tails rather than the initial resource. It occurs not only in relation to scarce resources but appears as an abnormal behaviour, suggesting pathological changes.

It should be possible to prevent two-stage tail biting by providing a suitable rearing environment, e.g. enrichment (Taylor *et al.*, 2010): this is the major concern of this thesis.

2.5 Prevention of tail biting

2.5.1 Tail docking

Tail docking is a procedure whereby the length of the tail is reduced. The procedure can be carried out in a number of ways, most commonly through the use of side-pliers, scissors, scalpel, gas or electrically operated cautery iron (Sutherland, 2015). It causes behavioural and physiological changes indicating acute stress and pain (Sutherland, 2015; Nannoni *et al.*, 2014). The idea is that the reduced tail length attracts less biting and makes the tip more sensitive, making pigs less willing to accept biting (Lerner & Algers, 2013; Simonsen *et al.*, 1991). Apart from the acute pain, tail docking can cause long-term consequences such as the development of neuromas and abscesses (Herskin *et al.*, 2015). Di Giminani *et al.* (2017) used tail amputation to model pain related to docking and biting. They conclude that amputation caused acute and sustained changes of the peripheral mechanical sensitivity such as hyperalgesia, even weeks after the amputation, and that younger pigs were affected for a longer period compared to older pigs. Further, traumatic neuroma development may still be ongoing, months after the docking was performed (Sanderock *et al.*, 2016). Docked pigs also show less exploratory behaviour (Nannoni *et al.*, 2016; Scollo *et al.*, 2013). Based on knowledge about neuroma formations, pain and stress perception, at least some docked pigs will experience long-term pain and be subjected to severe tail damage (Sandercock *et al.*, 2016; Schroder-Pedersen & Simonsen, 2001). Despite these welfare implications tail docking remains the only widely used method to prevent tail biting (Nannoni *et al.*, 2014).

Studies conclude that tail docking reduces the prevalence of tail lesions, but does not eliminate the behaviour (Sutherland, 2015; D'Eath *et al.*, 2014; Sutherland & Tucker, 2011; Moinard *et al.*, 2003). For example, in Ireland tail lesions range from 3.2-70% at batch level despite tail docking (van Staaveren *et al.*, 2017). Further, 50% of Dutch farmers report tail biting issues among their (mainly docked) pigs (Bracke *et al.*, 2013). According to the Dutch farmers, an elimination of tail docking was thought to increase biting further and docking was therefore proposed as the best tail biting prevention method (Bracke *et al.*, 2013). However, Finnish farmers, rearing undocked pigs, do not perceive tail biting as a large issue and most farmers would not go back to tail docking even if allowed (Valros *et al.*, 2016).

Routine tail docking has been banned within the EU since 2003 and before docking is practiced, measures such as altering environment and reducing stocking density should be taken. Nonetheless, around 90% of the EU population of pigs are docked, while the remaining pigs are reared with intact tails mainly due to national legislation (EFSA, 2007). Tail docking is by national law prohibited in Finland, Lithuania and Sweden (Nannoni *et al*., 2014).

It could be concluded that tail docking does not aim to solve the underlying cause of tail biting, but merely the outcome of it, and can hence not be expected to eliminate the redirection of exploratory behaviour towards tails. To further problematise tail docking, 100% of pigs among the docked-tail population are subjected to the acute pain resulting from the docking procedure.

2.5.2 Explorative material

Another approach to handling tail biting is to solve the underlying issue, principally by increasing the possibility of conducting exploratory behaviour. The provision of manipulable material enables the expression of exploratory behaviour, reduces pig and pen fitting manipulation and improves welfare (Lahrmann *et al.*, 2015; Bench & Gonyou, 2006; Schroder-Petersen & Simonsen, 2001).

Important features

Exploratory behaviour in pigs is best stimulated by materials that are complex, changeable, destructive, edible and have odours (Studnitz *et al.*, 2007; Van de Weerd *et al.*, 2003; Feddes & Fraser, 1994). Materials similar to earth, such as peat and mushroom compost, are preferred and resemble what pigs would root in nature (Jensen *et al.*, 2008; Beattie *et al.*, 1998). Enrichment characteristics may also have a synergic effect, and materials possessing several valuable features have an increased value (van de Weerd *et al.*, 2003).

In order to sustain attention over time, provided material should stimulate foraging and explorative behaviour, and not become soiled (van de Weerd *et al.*, 2003). Pigs value destructive chewing more than non-destructive chewing and changeability, and destructibility is vital to maintaining interest over time (Studnitz *et al.,* 2007; Feddes & Fraser, 1994). Long-term interest is also attained by replenishing material (van de Weerd *et al.,* 2003). Further, pigs are tough testers, destroying materials or simply playing with them until they end up out of reach (van de Weerd *et al.,* 2003). Consequently, materials must aim at improving animal welfare at minimum labour and material costs. They must also function well in the production system (Telkanranta *et al.*, 2014).

Pigs synchronise explorative activities and want to interact with objects together (Jensen *et al.*, 2015; Zwicker *et al.,* 2012; Van de Weerd *et al.*, 2003). The possibility of doing so depends on space allowance and the quantity of manipulation material (Jensen *et al.*, 2015) and may be influenced by the social structure of the group (Van de Weerd *et al.*, 2003). A limited amount of material limits access and may cause competition, aggression and/or restlessness among the pigs (Zwicker *et al.*, 2012; van de Weerd *et al.*, 2006).

Straw

Straw is thought to be a good rooting material even though more earth-like materials are often used to a higher extent (Studnitz *et al.*, 2007). When comparing concrete, mushroom compost, peat, sand, sawdust, straw and wood bark, straw was only preferred by pigs compared to concrete (Beattie *et al.*, 1998). Pigs will however show a high motivation to interact with straw (Scollo *et al.,* 2013; Fraser *et al.,* 1991). Straw has also been shown to sustain the pig's interest over time (Van de Weerd *et al.*, 2003). Apart from occupation, straw can allow pigs to improve lying comfort and thermal comfort on concrete floors (Tuyttens, 2005). Moreover, straw is a by-product of crop cereal production and is therefore likely to be available to producers combining pig and crop cereal production.

Straw has been found to decrease inactivity and increase explorative behaviour as well as stimulate play behaviour (Scollo *et al.*, 2013; Studnitz *et al.*, 2007; Bolhuis *et al.*, 2005). Straw access also reduces pig- and pen-directed behaviours such as tail biting (Bodin *et al.*, 2015; Camerlink *et al.*, 2015; Studnitz *et al.*, 2007; Moinard *et al.*, 2003; Hunter *et al.*, 2001; Fraser *et al.*, 1991). Enrichment with straw has in some studies totally prevented tail biting (van de Weerd *et al.*, 2006). Finnish farmers rearing undocked pigs consider straw the most important manipulable material when it comes to preventing tail biting (Valros *et al.*, 2016).

The more straw, the more straw-directed behaviour (Jensen *et al.*, 2015; Studnitz *et al.*, 2007) and the less pig-directed behaviour is performed (Pedersen *et al.*, 2014); but how much straw is enough? According to Bodin *et al.* (2015) a straw ration of 300g/pig/day is not enough to give maximum manipulation of straw while 200g straw/pig/day gave enough to minimise redirected behaviours such as tail biting. Pedersen *et al.* (2014) estimated that 387g straw/pig/day fulfilled pigs' behavioural need to explore while an increased straw ration did not give any biologically relevant reduction in oral manipulation of pen mates, i.e. did not reduce oral manipulation enough to reduce tail damage. Jensen *et al.* (2015) found that more than ~250g straw/pig/day did not increase straw manipulation further.

Straw manipulation is highest one hour after straw allocation and newly provided straw seems particularly interesting to pigs (Jensen *et al.*, 2015; Lahrmann *et al.*, 2015; Scott *et al.*, 2006). Increased pig and pen manipulation has been observed just before allocation of new rooting material, suggesting that exploratory motivation is unfulfilled (Jensen *et al.*, 2010). Daily provision of fresh straw is also important to stimulate exploratory behaviour in deep straw systems (Hunter *et al.*, 2001). However, providing the same amount of straw divided into several servings per day had little impact on straw manipulation and redirected behaviours in a small study conducted by Bodin *et al.* (2015). The way in which straw is provided has been found to have little effect on overall activity levels: for example, although deep straw provides more manipulation and rooting possibilities, it does not alter the overall activity rate compared to the provision of e.g. straw racks (van de Weerd *et al.*, 2006; Fraser *et al.*, 1991). The possibility of simultaneously accessing straw is increased at higher daily straw rations (Jensen *et al.*, 2015).

Straw length has been suggested to affect manipulation qualities, making chopped straw less attractive than intact straw (D'Eath *et al.*, 2014; Day *et al.*, 2008). A short straw length reduces the diversity of expressed behaviour: for example, making pigs lick up rather than root or chew straw (Day *et al.*, 2008). Also, longer straw has been shown to reduce tail biting more efficiently (Day *et al.*, 2008). Other studies did not find any effect of straw length on lesions or explorative behaviour when comparing long straw to straw chopped to a mean length of 5-6 cm (Lahrmann *et al.*, 2015).

Implications of straw usage

One argument for not using straw is the incapability of handling large amounts of straw in the manure handling systems and on slatted floors (Tuyttens, 2005). Long straw causes blockages in the slurry systems and manure to stack up in the pen, causing a poor environment that requires manual cleaning (Lahrmann *et al.*, 2015; D'Eath *et al.*, 2014). Further, fully slatted floors limit the usefulness of straw since it can pass through the slats without the pigs being able to access it (Telkanranta *et al.*, 2014). Chopped straw reduces problems with stacking although it is still able to cause blockage in slurry systems (Lahrmann *et al.*, 2015). It has been suggested that blockage of slurry systems and poor pen hygiene are preventable through controlling the flow of enrichment material by the use of e.g. straw dispensers (Zwicker *et al.*, 2012; van de Weerd *et al.*, 2006).

Taking earlier research into account I conclude that straw usage could largely solve the underlying cause of two-stage tail biting. Straw implementation has, however, largely not taken place in the European production systems which, as mentioned previously, mainly consist of pens with fully slatted floors (EFSA, 2007; Hendricks & van de Weerdhof, 1999) and there is a shortage of practical knowledge about straw management in many European farmers.

2.5.3 Interventions during tail biting outbreaks

Environmental enrichment may also reduce tail biting after the behaviour has been initiated (Bench & Gonyou, 2006). The most common action to limit tail biting outbreaks is however removing the tail biter from the pen after an outbreak has been detected (Valros *et al.*, 2016; Taylor *et al.*, 2010; Hunter *et al.*, 2001). Other actions taken to reduce outbreaks are the addition of objects and materials, such as straw, to the affected pen, as well as reducing stocking density, providing antibiotics to the bitten pig or painting the tail with tar or anti-bite spray (Hunter *et al.*, 2001).

2.5.4 Predicting outbreaks

Prediction of tail biting has the advantage of enabling farmers to impede outbreaks and reduce their impact. Currently, tail biting is usually not detected until severe damage is visible, at which point the elimination of the behaviour is difficult and the removal of animals merely restricts the impact of the outbreak (Taylor *et al.*, 2010).

Explorative behaviour, such as enrichment manipulation, has been used as an indicator of tail biting outbreaks (Larsen *et al.*, 2016). Pens with a high prevalence of tail damage are more active and more engaged in both pig- and pen-directed behaviour (Ursinus *et al.*, 2014). A lowered proportion of time spent sitting or lying was seen four days before visible blood even though no alterations in tail manipulation were observed (Statham *et al.*, 2009). Daily visits to individual automatic feeders may be reduced 6-9 weeks or 2-5 weeks before tail biting at pen-level and pig-level respectively, probably due to altered social dynamics (Wallenbeck & Keeling, 2013). One disadvantage of using behaviour as a predictor is the time-consuming nature of recordings, combined with ambiguous conclusions. There is however large potential in automatically collected data from e.g. feeding automats which vastly reduces data collection efforts (Wallenbeck & Keeling, 2013).

Tail posture has also been suggested as a wounded tail indicator. Feddes and Fraser (1994) suggested the curled tail position hinders other pigs from biting their tail tip while pigs subjected to tail biting have been found to keep their tails hanging or tucked between the hind legs (D'Eath *et al.*, 2014; Statham *et al.*, 2009; Kleinbeck & McGlone, 1993). Hanging tails have been observed in weaners 2-3 days before visible tail wounds (Zonderland *et al.*, 2009). Observing tail posture and analysing data is currently time consuming and therefore difficult to incorporate in current commercial management.

2.6 Rearing pigs with intact tails

Although lack of straw is described as the number one risk factor for tail biting, straw use has not taken place within the EU (EFSA, 2007). A substantial amount of research has been conducted regarding the provision of straw and how far it enables explorative behaviour. Still, the implementation of straw provision instead of tail docking has failed. There is a lack of understanding of how to apply straw provision in commercial production, both in regard to the amount of straw and straw management.

Straw does however not eliminate the risk of tail biting entirely. Hence straw usage alone is not the entire solution, and needs to be combined with e.g. methods to detect tail biting at an early stage, in order to increase preventative measures. In order to increase the implementation of straw usage, apply it in current production systems and enable the rearing of pigs with intact tails, straw usage and management must be investigated in commercial production.

3 Aims

The general aim of this thesis was to investigate the impact of straw on pen management and tail biting in pigs reared with intact tails and to study early detection of tail biting under commercial conditions.

This project was part of the European project FareWellDock that had the general aim of supplying necessary information and quantitative risk assessment and stimulating a non-docking policy in the EU.

The specific aims in the different studies were:

- Study I: to gather information about how Swedish farmers rear pigs with intact tails, how straw is used, and their perception of straw usage and tail biting (Paper I).
- Study II: to investigate the impact of straw on behaviour, lesions and hygiene (Papers II and III).
- Study III: to investigate the relationship between tail posture and tail damage to facilitate early detection of tail biting (Paper IV).

4 Materials and Methods

Information on the full materials and methods is found in the printed papers provided at the end of this thesis (Papers I-IV). The project was conducted on Swedish commercial farms to gather knowledge and information from producers with long experience of rearing pigs with intact tails.

Study I consisted of a telephone survey to Swedish pig producers performed during 2014 and is fully presented in Paper I. Studies II and III consisted of on-farm experiments investigating the impact of straw usage on pig behaviour, lesions and hygiene (Papers II and III) and the correlation between tail posture and tail lesions (Paper IV). Studies I and II investigated grower pigs (from 10-30kg LW, 5-12 weeks of age) and finishing pigs (from 30~115kg LW, 12 weeks to slaughter at six months) separately while Study II investigated finishing pigs only.

4.1 Ethical statement

Study I is based solely on data obtained from telephone interviews with commercial pig producers.

Studies II and III are based on behavioural observations and clinical scoring of pigs in commercial farms where the treatment, increased straw rations (Study II) and different ways of providing straw (Study III) aimed to improve animal welfare. Due to the purpose (improving welfare) and the low severity of these experiments they did not require approval by an ethical committee for animal experiments according to Swedish national legislation (7 chap. 7§ Animal welfare ordinance [2019:66]).

4.2 Study I (Paper I)

4.2.1 Farmers and data records

Study I consisted of a telephone survey with commercial pig farmers in Sweden conducted from July to November 2014. Farmer contact information was supplied by the Swedish Board of Agriculture (SBA) and included farms with ≥50 sows or ≥300 finishing pig places. The farms were categorised as grower farms, finishing pig farms or farrow-to-finish farms (keeping both grower and finishing pigs). The final contact list consisted of 747 grower farms, 892 finishing pig farms and 4618 farrow-to-finish farms. The list provided by SBA was likely not up to date since the number of farms on the list exceeded the number of pig farms in Sweden.

4.2.2 The survey

The survey contained 2 general questions, 60 questions (35 multiple-choice, 25 open-ended) related to grower pigs and 58 questions (29 multiple-choice, 29 open-ended) related to finishing pigs. Farrow-to-finish farmers answered questions regarding both grower and finishing pigs. The survey layout was as follows:

- General questions—e.g. type of production and breed.
- Production information—number of pig places and growth rate.
- Tail biting—e.g. occurrence, suspected causes.
- Straw usage—e.g. ration, frequency of provision.
- Pen conformation—e.g. pen size, type of flooring.
- Feeding system—e.g. type of feed, feeding system.
- Manure handling—e.g. type of system and straw-related issues

4.2.3 Estimation of straw ration

A majority of farmers (72%) reported the amount of straw usage as number of bales used per week or year combined with bale weight. The amount of straw provided per pig/day was subsequently calculated according to the following equations:

$$\frac{\left(\frac{straw\ usage\ per\ week\ (kg)}{number\ of\ grower\ places\ in\ the\ herd}\right)}{7} = \text{straw ration/grower/day (kg)}$$

$$\frac{\left(\frac{straw\ usage\ per\ week\ (kg) * 52 weeks}{number\ of\ finishing\ pigs\ produced\ per\ year}\right)}{99^{1}} = \text{straw ration/finishing pig/day (kg)}$$

4.2.4 Statistical analysis

The information obtained in the survey was recorded in Microsoft Excel and transferred to SAS software ver. 9.4 (SAS Inst. Inc., Cary, NC, USA) for statistical analysis. Descriptive statistics were calculated using frequencies, mean and median values for growers and finishers respectively. Answers from the survey were classified as either continuous (e.g. straw usage), ordinal (e.g. frequency of tail biting) or categorical (e.g. strategies for avoiding tail biting outbreaks). Categorical data was solely presented as frequencies and median/mean when feasible.

Correlations between continuous and ordinal outcomes were analysed using Spearman's rank correlation.

4.3 Study II (Papers II and III)

4.3.1 Animals and housing

Study II was conducted from November 2015 to June 2017 on five commercial farms in the southwest of Sweden. The experiment was conducted during the growing phase on three farms (G1, G2, G4) and during the finishing phase on four farms (F2, F3, F4, F5), studying one batch per age group and farm. On two farms (G/F2, G/F4) the experiment was conducted on the same batch of pigs during both the grower and the finishing pig phase (Table 1).

All pigs within the same batch were raised within the same physical unit. Pens with different pen design or number of pigs compared to the average pen of the unit, e.g. 'sick pens', were excluded from the study. All pigs were kept in pens with partly slatted flooring. Daily supervision, cleaning and provision of fresh wheat straw was carried out by the animal keeper on each individual farm.

[1] According to the Swedish national herd monitoring database (WinPig Slakt), the average number of days spent in the finishing pig unit was 99 days in Sweden in 2014 (FAH, 2015).

4.3.2 Experimental design

Studied pens were allocated into two Treatments; Control (C) or Extra Straw (ES). All pens in each Treatment were located together to facilitate the animal caretakers' work. Apart from straw ration, pens were managed equally on farm level.

C-pens were provided with each farm's normal daily straw ration. ES-pens got a doubled control ration (Table 1). The control ration was determined prior to the start of the experiment by measuring the straw rations usually provided by the animal keeper on each farm. During the study period the daily straw ration was fixed. However, if there was blockage in the slatted flooring (to the extent that for at least 50% of the slatted area was no longer visible) the straw ration could be paused until the blockage was cleared. Possible blockage was recorded by the care-taker daily.

Table 1. *Information about participating farms and treatments in Study II.*

Farm	Age category	No. of pigs in experiment	No. of pigs/pen	Area/pig (m^2)	Straw ration, g/pig		No. of missing daily obs. (%)
					C	ES	
G1	Growers	286	12	0.41	8.3[1]	16.7[1]	0 (0)
					16.7[2]	41.7[2]	
					50.0[3]	83.3[3]	
G2	Growers	427	10-11	0.49-0.54	4.3-4.7	8.5-9.4	1 (3)
F2	Finishers	444	11	0.95	12	24	11[2] (15)
F3	Finishers	195	11	0.88	9.1	18.2	2 (3)
G4	Growers	360	12(9)[4]	0.33-0.45[4]	3.8-5.1[4]	7.6-10.2[4]	2 (5)
F4	Finishers	209	9	1.00	12.2	24.4	10 (14)
F5	Finishers	408	10	0.95	5.8	11.5	14 (21)

1. Provided straw ration day 1-15
2. Provided straw ration day 16-24
3. Provided straw ration day 25-35
4. Three pigs per pen were removed after 5 weeks to comply with national legislation regarding stocking density (SJVFS 2019:20 (L106))

4.3.3 Behavioural observations

Every second week, including the first and last week of the experiment, behaviour recordings were performed in eight fixed focal pens per treatment and farm (16 pens per farm, 48 grower pens and 64 finishing pens in total). Observations were done at pen level over one hour in a 4-minute interval scan sampling, returning to each focal pen every fourth minute (15 records/pen/occasion). Behavioural observations started at least 1 h after provision of the daily straw ration (mean 2.4 ± 1.2 h) according to the ethogram (Table 2). Prior to the behavioural observations, all pigs were in an active state.

4.3.4 Lesion scoring

Scoring of ear and tail lesions was performed in all experimental pens in the first and last week of the experiment. In addition, pigs in focal pens were scored for lesions in connection with the behavioural observations. The scoring was performed through palpation at individual level (Table 3).

Table 2. *Ethogram modified from Jensen and Pedersen (2018). The secondary state was recorded for pigs previously scored as active*.

Behaviour	Description
Primary state, number of pigs	
Inactive	Lying or sitting down
Active	Standing up with the body supported by the legs
Secondary state, number of pigs with their mouth or snout in contact with	
Straw	Straw
Other manipulable materials	Manipulable materials other than straw, if present
Pen	Pen fitting, floor or faeces
Other pigs	Another pig's body (either in the same or in a neighbouring pen
Inactive	Apparently inactive or performing other activity

4.3.5 Scoring of hygiene

Observations of pig and pen hygiene were performed in connection to the behavioural recordings.

Pig hygiene was recorded according to the Welfare Quality protocol applied to growing and finishing pigs (Welfare Quality ®, 2009). All pigs were individually assessed for manure on the body, on the side that was most visible to the observer. Each pig was scored on a three-point scale: 1 if a maximum of 20% of the side of the pig was covered in manure; 2: >20-50% manure coverage; 3: >50 manure coverage.

Pen hygiene was assessed through separate observations of the slatted and solid floor. The solid and slatted parts of the pen were each divided into four parts. For a solid floor area to be considered dirty, at least 50% of the area was wet, covered in faeces or mired straw. For a slatted floor area to be considered as blocked, at least 50% of the slats should be covered to the extent that the gaps between the slats were no longer visible. For every part considered as dirty or blocked the pen was assigned one point subsequently added to receive the final hygiene score. A maximum of four points (all parts ≥50% dirty/blocked) and a minimum of zero points (all parts <50% dirty/blocked) could be received on the solid and slatted part of the pen separately.

The animal caretaker recorded alterations in straw provision and extra cleaning on pen level daily. Prior to the daily straw provision, the animal caretaker scored the amount of unsoiled leftover straw in the pen according to the following scale adapted by Pedersen *et al.* (2014): 0: less than 1 dl straw; 1: 1dl-1L of straw; 2: 1L-10L of straw; 3: >10 L of straw.

Table 3. *Lesion scoring of tail length (L0-L2) and damage (D0-D4) modified from Zonderland et al. (2003) and ear lesions (E0-E4) modified from Telkanranta et al. (2014).*

Score 0	Score 1	Score 2	Score 3	Score 4
Tail length				
L0	L1	L2		
No shortening.	The tail is shortened to a length > 2 cm.	The tail is shortened to a length < 2 cm.		
Tail damage				
D0	D1	D2	D3	D4
No damage	The tail is red and/or swollen	The tail has bite marks, but no missing tissue.	The tail has one or more open wounds.	The tail is swollen and has one or more open wounds.

4.3.6 Statistical analysis

Data was recorded in, or transferred to, Microsoft Excel and statistically analysed using SAS software ver. 9.4 (SAS Inst. Inc., Cary, NC, USA). The number of weeks in production was divided into three equal parts (*Period* 1; 2; 3) to facilitate comparison between farms with different production lengths.

Behaviour was recorded at pen level and analysed as percentage of active pigs performing the studied behaviour (Straw-, Pig- or Pen-directed behaviour) on each observed occasion (combining all 15 scan observations into one mean observation/pen recording occasion).

The lesion scoring was performed at individual pig level. In the analyses, lesions were expressed as binomial traits: either the pig was scored with a lesion of a certain grade or not. For example, L1-2 combined pigs recorded with tail length recorded as 1 or 2 while L2 consisted only of the recordings of pigs with the tail length 2.

To analyse the effect of *Treatment* (C, ES) on lesion scoring and behaviour, analysis of variance was used to construct a statistical model for each trait analysed: Tail length, Tail damage, Activity level, Straw-, Pen- and Pig-directed behaviour. All statistical analyses of lesions scoring were performed with the pig as the experimental unit and analyses including behaviour were performed with the pen as the experimental unit.

Treatment effects were analysed for growers and for finisher pigs separately. The statistical model included the effects of *Treatment* (C, ES), *Farm* (G1, G2, G4, F2, F3, F4, F5) and *Period* (1, 2, 3). *Pen* (within Farm and Treatment) was considered as a random effect, and consideration was taken for repeated observations within *Pen*, *Farm* and *Treatment*. The interactions between *Treatment**Farm*, *Period**Farm* and *Treatment**Period* were tested for significance and were removed from the model if not found to be statistically significant.

The impact of *Farm* and *Treatment* on cleaning of pens was investigated descriptively. The impact of *Treatment* on pen and pig hygiene was investigated through Treatment means at age group level using Fisher’s exact test.

4.4 Study III (Paper IV)

4.4.1 Animals and Housing

The study was carried out on one commercial farrow-to-finish pig farm in the southwest of Sweden from December 2017 to March 2018. One batch of 458 finishing pigs was studied for a total of 102 days. All pigs were undocked and males were surgically castrated with local anaesthesia (0.3-0.5mL/testicel of lidocaine 20mg/mL and adrenalin 0.036 mg/mL (Lidokel-Adrenalin vet ®)).

Studied pigs were allocated to 42 pens, housing 10 (n=4), 11 (n=37) or 12 (n=1) pigs per pen. All pens had a total floor area of 10.49 m^2, consisting of 7.81 m^2 solid and 2.68 m^2 slatted floor, a 3.4 m feeding trough and a nipple drinker above the slats. The pigs were inspected daily by the herd staff and the pens were manually cleaned and provided with fresh chopped straw once a day (~25 L of straw provided on the floor or ~44 L provided in a straw rack; 25 L of straw weighs ~1.8 kg). To keep track of individuals, pigs were marked with spray paint (PORCIMARK marking spray, Kruuse, Denmark) twice a week.

4.4.2 Experimental design and data recording

The tails of the pigs were scored weekly by palpation with regard to tail damage (Table 3).

Tail position was scored on the same day as the lesion scoring by filming at feeding. The tail position (curled/hanging) was subsequently scored from the video recordings. A tail was considered curled if the majority of the tail was curled and pointing upwards in relation to the horizontal extension of the back.

4.4.3 Statistical analyses

Statistical analysis was carried out using the following three software tools: StataIC 15.1 (StataCorp LLC, College Station, TX, USA), MLwiN (Centre for Multilevel Modelling, University of Bristol, Bristol, UK) and SAS software ver. 9.4 (SAS Inst. Inc., Cary, NC, USA). A binomial multivariate regression model (trend model) with tail position (0: hanging tail; 1: curly tail) as outcome was built. The analysis included the following independent variables: *Pen*, *Pig*, *Lame* (yes/no), *Damage* (non-damaged/swollen/bite marks/wound/inflamed wound), *Sex* (gilt/barrow) and *Time* (1-14). Time was standardised using the following equation: $sTime = (\text{Time} - 7.5)/6.5$ to receive values ranging from 0 to 1. The relationship between the data and Time was found not to be linear, and therefore $sTime^2$ was used to allow a better linear fit to the data. All variables were included in the model, which was subsequently reduced by backward selection of the significant variables ($p \leq 0.05$). *sTime* and $sTime^2$ were kept in the model to account for repeated measurements.

Clustering within the pen and pig data was accounted for by including random slopes for *sTime* at Pen and Pig level and for $sTime^2$ at Pen level. The software was unable to fit a random slope for $sTime^2$ at Pen level.

To investigate the possibility of using tail posture as an indicator of tail biting and to estimate the specificity and sensitivity of the method, a receiver operating characteristic (ROC) analysis was conducted between tail posture and tail damage. A curled tail posture was considered to be either present or absent (hanging tail posture). To create the ROC curve, tail position was used to classify tails as Damaged (non-damaged/swollen/bite marks/wound/inflamed wound).

5 Summary of results

In this chapter, a summary of the results from each study is presented. For full details, see Papers I (Study I), II, III (Study II) and IV (Study III).

5.1 Study I (Paper I)

5.1.1 Participating farms

A total of 139 farmers were called and 60 farmers participated in the study, 43% response rate. Of contacted farmers, 20% were not reached, 8% were unwilling to participate (half of them due to lack of time) and 28% did not keep pigs according to the set criteria of the study. Of the participating farms there were 17 grower, 14 finishing pig and 29 farrow-to-finish farms.

5.1.2 Straw and straw usage

All but two farmers reported providing the pigs with straw. Straw was mostly provided daily (76.5% of grower and 82.9% of finishing pig farms) but ranged from twice daily to every second week for partly slatted systems. The amount of straw was estimated to a median ration of 29g/pig/day for growers (range 8-85g/pig/day, n=29) and 50g/pig/day for finishers (range 9-225g/pig/day, n=22) in partly slatted systems. Straw was the only substrate provided in 62.2% of the grower and 64.9% of the finishing pig farms. The remaining farms combined straw with materials such as saw dust, wood shavings or peat, commonly on specific occasions, e.g. to improve poor pen hygiene.

Of the straw-using farmers, 24% would have wanted to increase the straw ration if there were no limitations applying to an increased straw ration. Reported limitations were mainly concerns about blocked slats and manure handling systems, but factors such as cost, pen hygiene and work load were also mentioned.

5.1.3 Occurrence and management of tail biting

Tail biting had been observed by the farmers in 50% of the grower and 88% of the finishing pig farms. On affected farms, tail bitten pigs were commonly seen less than twice a year in grower (78.3%) and 3-6 times a year in finishing pig (37%) farms. In general, one pen in each affected batch had tail bitten pigs. Finishing pig farms reported on average 1.6% (0.1-6.5%) tail bitten pigs (with short tails) scored at the abattoir.

The most common suspected causes of tail biting were salt deficiency and too high stocking density among grower farmers and composition/feed equipment malfunction and unknown causes among finishing pig farmers.

A majority of farmers took immediate action in response to tail biting outbreaks (95%). Identifying and removing the biter and separating the bitten pig were the most common actions against tail biting outbreaks followed by increasing the straw ration, checking ventilation and provision of other manipulable materials or toys. Antibiotic treatment of bitten pigs was practiced among 76% of grower and 92% of finishing pig farms. Analgesia was used as treatment in one grower farm only. Five farms used tar on the bitten pigs' tails.

5.1.4 Associations between straw, tail biting and management

Tail biting frequency (i.e. how often tail biting was observed) was moderately negatively correlated to straw ration in both grower ($r=-0.328$, P 0.01, $n=38$) and finishing pig farms ($r=-0.32$, $P<0.05$ $n=37$). Straw was reported to cause problems in the manure handling system on 56% of the grower and 81% of the finishing pig farms, but never more often than monthly.

5.2 Study II (Papers II and III)

5.2.1 Leftover straw (unpublished)

Growers

The amount of leftover straw in the pen prior to the daily straw allocation ranged between score 1-2 on Farm G1 and G2 and between score 0-2 on Farm G4 (Table 4).

Finishers

The amount of leftover straw in the pen prior to the daily straw allocation ranged between score 0-3 on Farms F2 and F5, from 2-3 on Farm F3 and from score 0-2 on Farm F4 (Table 4).

Table 4. *Scoring[1] of the amount of unsoiled leftover straw prior to the daily straw provision.*

Farm	Control			Extra Straw		
	Score (Mean)	Range	n	Score (Mean)	Range	n
G1	1.0	1-1	48	2.0	2-2	48
G2	1.3	1-2	48	1.2	1-2	44
G4	1.4	1-2	36	1.9	0-2	36
F2	1.1	0-3	137	1.7	0-3	137
F3	2.7	2-3	54	2.8	2-3	45
F4	1.4	0-2	72	1.4	0-2	72
F5	1.3	0-2	108	1.7	0-3	108

[1] Score 0: less than 1 dl straw; Score 1: 1dl-1L of straw; Score 2: 1L-10L of straw; Score 3: >10L of straw.

5.2.2 Behaviour (Paper II)

Growers

The most commonly performed behaviour was manipulating straw (25% of active time) regardless of the size of provided straw ration (Figure 2). Pigs with an increased straw ration had more Straw-directed behaviour and less Pen-directed behaviour compared to pigs with a control straw ration. Furthermore, both Straw- and Pen-directed behaviour were also significantly affected by *Farm*, *Period* and the interaction between *Farm*Treatment* and *Farm*Period*; *Treatment* had a significant effect in Farms G1 and G4, where ES-pigs on average showed more Straw-directed behaviour. In Farm G1, Straw-directed behaviour increased between Period 2 and 3, and in Farm G4 Straw-directed behaviour increased with age (*Period*). Similarly, for Pen-directed behaviour, *Treatment* had a significant effect in Farms G1 and G4 but not in G2. However, in Farms G2 and G4, an increase in Pen-directed behaviour was found to be related to increasing age (*Period*).

Finishers

The most common behaviour was Straw-directed behaviour followed by Pen-directed behaviour (Figure 3). There was a significant effect of *Treatment* on Straw- and Pen-directed behaviour, where the ES-pigs conducted more Straw-directed behaviour and less Pen-directed behaviour compared to the C-pigs. Both *Treatment*Period* and *Farm*Period* interactions were significant in the analysis of Straw- and Pen-directed behaviour respectively. For Straw-directed behaviour, a significant effect was found in Period 2, where ES-pigs had significantly higher Straw-directed behaviour than C-pigs.

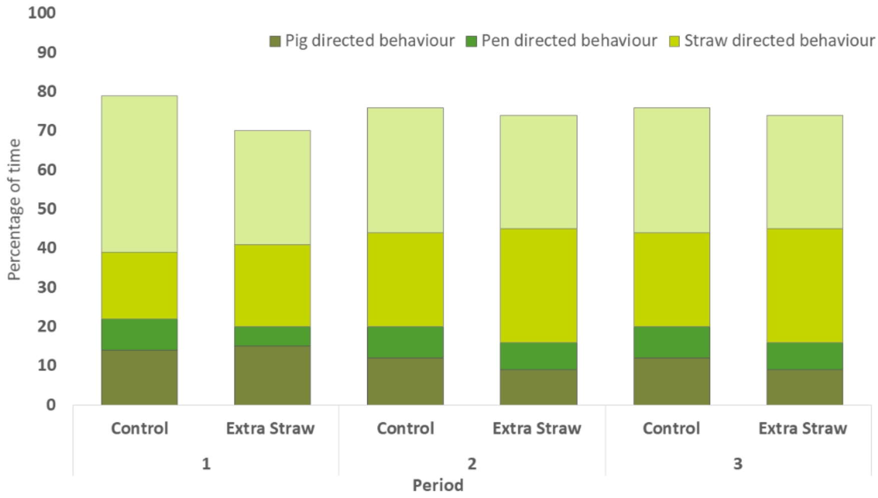

Figure 2. Grower pig behaviour. The full bar indicates the average amount of active behaviour conducted during each Period for each Treatment. The percentage of Pig-, Pen- and Straw-directed behaviour is displayed as a percentage of active behaviour.

Figure 3. Finishing pig behaviour. The full bar indicates the average amount of active behaviour conducted during each Period for each Treatment. The percentage of Pig-, Pen- and Straw-directed behaviour is displayed as a percentage of active behaviour.

5.2.3 Tail lesions (Paper II)

Growers

None of the grower pigs were recorded as having L2 (tail length reduced to less than 2 cm) in Period 3. Tail shortening was seldom recorded in any *Treatment*. Over all *Periods*, 0.2% C and 0.3% ES observations were recorded with a tail length less than 2 cm (L2). The proportion of grower pigs recorded with tail damage (≥D1) increased over time (*Period*) (Figure 4). In Period 3, 39.4% of the C-pigs and 48.5% of the ES-pigs were recorded as free of damage (D0) (Figure 3). Severe damage (≥D2) was more common in C-pigs than in ES-pigs.

On grower level *Treatment* had no significant effect on either tail shortening or tail damage. The low incidence (<1%) of more severe scores (L2, D4) made calculations of any Treatment effects impossible for these scores.

Finishers

Approximately 10% of the finishing pigs had tail shortening (L1-2) in Period 3 (Figure 5). As in the growers, the number of finishers with tail damage increased over time and approximately 50% of the pigs had any type of tail damage (D1-4) in Period 3.

Tail Damage D2-4 were significantly affected by *Treatment* and the interaction *Farm*Period*. The interactions between *Farm*Period* showed that differences change over time. Tail damage D3-4 were significantly affected by *Treatment*, where the ES-pigs had significantly less damage than the C-pigs. In Farm F2, more damage was found in Period 3, whereas in Farm F3, damage fluctuated over time with increased incidence of damage in Period 2 and less damage in Period 3. In Farm F5 difference between *Treatments* was only found in Period 2.

5.2.4 Pig hygiene (Paper III)

Growers

At grower level, 0.8% of the observations on Farm G1 and 1.1% on Farm G2 were considered dirty. The mean Pig Hygiene score was 1.01 on grower level, meaning that in general <20% of the pig was dirty. Dirty pigs (more than 20% of the body surface being soiled) were observed on Farm G1 (0.8% of observations) and on Farm G2 (1.1% of observations) but not on Farm G4.

No significant effect of *Treatment* on pig hygiene was found.

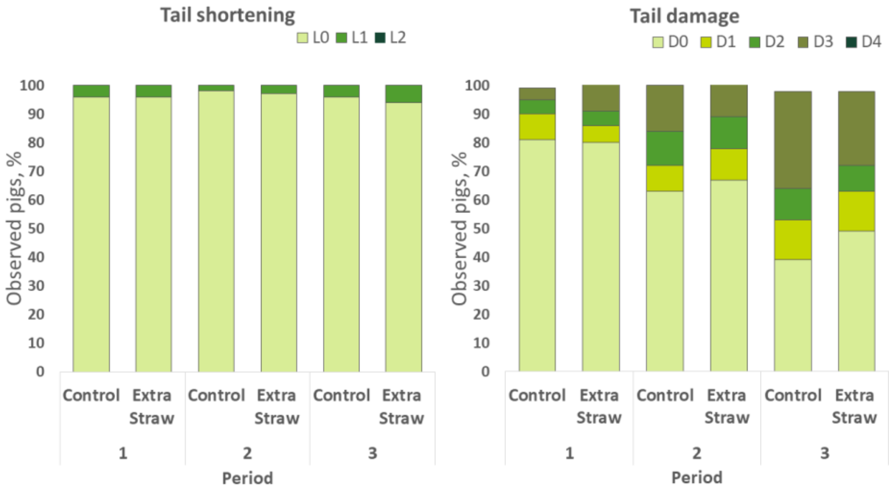

Figure 4. Proportion of tail shortening and tail damage in growers per Period and Treatment.

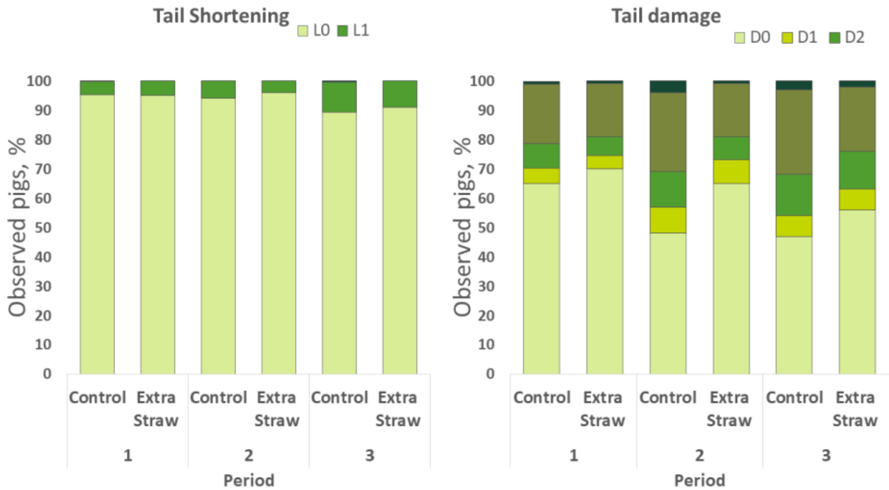

Figure 5. Proportion of tail shortening and tail damage in growers per Period and Treatment.

Finishers

On finishing pig level, 0.9% of the observations on Farm F2, 0.8% on Farm F3, 8.1% on Farm F4 and 3.4% on Farm F5 were considered dirty. Mean Pig Hygiene score was 1.04, ranging from 1.00-1.12, meaning that in general <20% of the area of the pig was dirty.

Treatment had significant effect on pig hygiene on three occasions on Finishing pig farm level. On Farm F4, i.e. the farm providing one of the highest straw rations, ES-pens had cleaner pigs on occasion 4. On Farm F5, providing the lowest straw rations, ES-pigs were cleaner on occasion 6 while C-pigs were cleaner on occasion 10.

5.2.5 Pen hygiene (Paper III)

Growers

The straw provision was not paused due to blocked slats at any time point. Occasional extra cleaning of the pens was conducted on all Farms regardless of Treatment. On Farm G1 ES-pens required more frequent extra cleaning (4% of documented occasions in C-pens, 19% in ES-pens). Farm G4 (C: 31%; ES: 31%) and Farm G2 had approximately the same amount of extra cleaning in C-and ES-pens (0.6% resp. 0.4%).

On the solid floor, 91.6 % of the C and 96.3% of the ES observations were scored as clean (Score 0). The mean score for solid hygiene ranged from 0.00-0.25.

On the slatted floor 85.4 % of the C and 90.7% of the ES observations were scored as clean (score 0). The mean hygiene score of the slatted floor ranged between 0.00-0.56.

Finishers

Farm F2 paused the straw provision due to poor pen hygiene 11% of the observations in both C- and ES-pens. On Farm 3 straw provision was paused 1% in both C- and ES-pens. On Farm 4 straw provision was paused 6 % in both C- and ES-pens. On Farm F5 straw provision was paused 0.3 % in C-pens and 0.08% in ES-pens. Farm F2 did not conduct any extra cleaning and in Farm F5, extra cleaning was seldom performed in any of the Treatments (0.3% of C-pens and 0.4% of ES-pens). Farm F3 conducted extra cleaning on 6% of the occasions in C-pens and 0.2% of ES-pens and F4 in 44% of C-pens and 51% of ES-pens.

On the solid floor, 89.4% of the C and 92.0% of the ES observations were scored as clean (Score 0). The mean score ranged between 0.00 and 0.47.

On the slatted floor 92.5% of the observations in C and 8.4% of the observations in ES were scored as clean (Score 0). The mean score ranged from 0.01-0.84.

5.3 Study III (Paper IV)

5.3.1 Tail posture and damage

A total of 6092 observations (across time) of tail posture were made: 5713 curled and 379 hanging. Of the curled tails, 55.4% were undamaged (D0) and of the hanging tails, 28.8% were undamaged (D0) (Figure 6).

Hanging tails were positively associated with tail damage scores of '*wound*' and '*inflamed wound*' ($p < 0.05$), but not with less severe damage. Pigs with tail damage scored as '*wound*' were 4.2 times more likely to have hanging tails than pigs with non-damaged tails, while pigs with tail damage scored as '*inflamed wounds*' were 14.2 times more likely to have hanging tails than pigs with non-damaged tails. Barrows were 1.6 times ($p < 0.005$) more likely to have hanging tails than gilts.

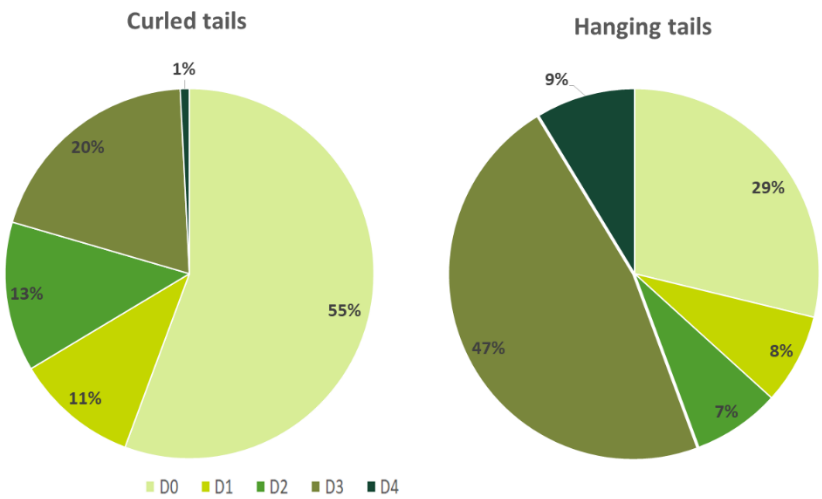

Figure 6. Proportion of scored damage in curled (n=5713) and hanging (n=379) tails scored at feeding.

5.3.2 Evaluation

Tails scored as '*swollen*' had a sensitivity (i.e. the probability that a damaged pig tail was scored as damaged through tail position) of 70.6%, while tails scored as '*inflamed wound*' had a sensitivity of 8.6%. The specificity (i.e. the probability that an undamaged pig tail was classified as undamaged through tail position) increased when increasing the cut-off point of what was considered a damaged tail. When the cut-off point was set to '*inflamed wound*', the specificity was 99.2%, while the specificity was 55.4% if the cut-off point was set to ‘*swollen*’. When setting the cut-off point of when to consider a tail as damaged to ‘*wound*’ or ‘i*nflamed wound*’, the sensitivity was 55.2%, the specificity was 79.7%, and 78.1% of cases were correctly classified.

6 General discussion

6.1 Methodology

Studies conducted under commercial settings differ from studies made under strictly experimental circumstances, where more consistent management and data collection is possible. Instead, on-farm experiments have other advantages. They provide us with the possibility of investigating management and functionality in reality while encountering the difficulties and notions of the farmers' actuality. Hence they allow us to investigate the implementation of the results in the environment where we intend to make use of them.

It is common knowledge that tail biting is largely a sign of poor rearing environment (e.g. EFSA, 2007). Prevention of tail biting through tail docking without improving the environment has been prohibited by European legislation since 2003 (Dir 2008/120/EC). Further, many studies have shown that tail biting can be reduced through implementation of straw provision (Larsen *et al.*, 2018b; D'Eath *et al.*, 2014; Sonoda *et al.*, 2013; Moinard *et al.*, 2003; Hunter *et al.*, 2001). Still, over 90% of the pigs produced within the EU are tail docked to reduce impact of tail biting instead of altering the provided production environment (EFSA, 2007).

Conducting on-farm experiments may enhance the trustworthiness of the research and increase the likelihood of the results being incorporated into commercial farming. In this case, the research concerns the implementation of management techniques to enable the rearing of pigs without the use of tail docking. By conducting the experiments under commercial conditions it is possible to investigate both management effect and effect on management.

To reduce individual farm effect, increase external validity and further increase trustworthiness among farmers, the experiments presented in this thesis were conducted on several farms (Studies I, II and III). Further, several replicates (pens) within each farm increased the internal validity in Studies II and III.

6.1.1 Study I (Paper I)

The aim of this study was to investigate how Swedish farmers rear undocked pigs, and gather information about their management routines and experiences with a special emphasis on straw usage. The results are based on farmers' self-reported perceptions of their management and production, and should hence be interpreted with caution.

One example is the prevalence of tail biting, which was estimated both from abattoir data (in finishing pig farms) and from perceptions of how often tail bitten pigs were seen and how many pens were usually affected.

Studies show that abattoir data generally underestimates the true prevalence of tail lesions, which has also been shown in Sweden (Keeling *et al.*, 2012). To be scored 'tail bitten' according to the Swedish guidelines at least half of the tail should be missing or show evident tail damage, or the carcass should be discarded due to tail lesions (Livsmedelsverket, 2006).

Farmer perception may differ from reality for several reasons. One example could be that the farmer reports only detected outbreaks. Detected outbreaks usually consist of severe tail biting where blood and lesions are detected from outside the pen, and hence less severe biting is missed/not reported (Sonoda *et al.*, 2013). Similarly, it is likely that the amount of tail lesions is underestimated at farm level since tail lesions without tissue loss or blood prevalence are unlikely to be discovered during normal farm routines (Zonderland *et al.*, 2009). Tail damage such as swelling, bite marks or small lesions likely needs palpation or similar to be discovered. In addition 'bitten pigs' were not defined in this study. Nor did we ask the farmers to define bitten pigs themselves, which hindered us from asking questions regarding how farmers themselves defined tail biting. The fact that farmers reported similarly (e.g. similar causes of tail biting outbreaks, similar frequency of tail biting outbreaks) however indicates that the results are comparable and that farmers have similar definitions of tail biting (e.g. close to the definition of the abattoir).

Still, the results of this study should be considered for what they are: farmers' opinions and not absolute facts.

6.1.2 Study II (Papers II and III)

The aim of this study was to investigate straw impact on pig behaviour, lesions, and pig and pen hygiene. The experiment was conducted on three different grower and four different finishing pig farms. The farms differed not only in used straw rations, but also somewhat in pen conformation, feeding regimes as well as herd staff. The impact of all these individual factors was not estimable, although the overall effect of the farms was taken into consideration when analysing the data. The impact of e.g. specific routines on prevalence and severity of tail damage or behaviour was however partly taken into account by the inclusion of several farms in the experiment (for external validation), and the use of several replicates per farm and treatment (for internal validation).

There were missing daily records (of leftover straw and pen cleaning) in all but one farm (G1), ranging from 3-21% of total observations. There were no missing daily observations on the day of scoring. In most cases, missing daily records were related to occasions when someone other than the original animal caretaker was caring for the pigs, e.g. weekends. On these days, different treatment groups likely got a control straw ration which, if anything, could have led to us underestimating the effect of an increased straw ration.

Swedish pigs in commercial production are commonly not individually marked. This was also the case in our study and therefore we were unable to follow individuals over time. Consequently it became impossible to analyse for instance how tail damage or behaviour correlated with each other or how tail damage developed over time on an individual level.

6.1.3 Study III (Paper IV)

Although several studies have found a relationship between tail position and tail biting (D'Eath *et al.*, 2018; Lahrmann *et al.*, 2018; Larsen *et al.*, 2018a; Ursinus *et al.*, 2014; Statham *et al.*, 2009; Zonderland *et al.*, 2009; Kleinbeck & McGlone, 1993) and cannibalism (McGlone *et al.*, 1990) there is still lack of knowledge regarding how pigs use their tails to communicate or express emotion.

Tail movement (lateral swinging or wagging) has been associated with positive emotions (Rius *et al.*, 2018; Reimert *et al.*, 2013; Newberry *et al.*, 1988). Low tail has been associated with negative emotions such as social isolation and unpredictable interventions (Reimert *et al.*, 2013) and tail damage (D'Eath *et al.*, 2018; Zonderland *et al.*, 2009). Tail wagging has however been observed also during e.g. food searching, walking, tactile stimulation as well as cutaneous stimulation (Newberry *et al.*, 1988; Kiley-Wortington, 1976) and tail damage (Zonderland *et al.*, 2009). During our study, tail posture was scored at feeding, simply because of the feasibility of scoring when all the pigs were gathered along the feeding trough. The aim was to develop a method that could also be used in commercial production, although it is unknown how feeding alone affects tail position.

Hanging tails have been shown to predict tail damage up to 2-3 days before actual tail damage is seen, and a tail tucked in between the legs correlates to tail damage the day after the tucked-in tail is seen (Zonderland *et al.*, 2009). During our study the causality of hanging tails was not investigated, and tail posture was not used to predict the exact moment when tail biting or tail damage occurred but only to see whether there was any correlation between them. To be able to draw such conclusions a more comprehensive data collection would have been needed. Such data collection would have had to involve shorter intervals of scoring of tail damage and tail posture as well as continuous sampling of the overall behaviour of the pig.

Further, the fact that tail movements are usually one of the components of the total body posture, and may serve as a sign of communication and not as a single signal needs to be taken into consideration (Kiley-Wortington, 1976). Hence tail movements should be studied in the context of the whole animal posture (Kiley-Wortington, 1976). More research is needed to fully understand how pigs use their tail for communication, and how this influences the relationship between tail posture and tail damage/tail biting.

6.2 Straw provision

6.2.1 Implementation and straw ration

The wide usage of straw in Sweden described in Study I indicates that straw usage is considered feasible and functional under commercial Swedish conditions. Only one grower pig farmer thought that observed tail biting outbreaks were caused by boredom, according to Study I. This result indicates that Swedish farmers are generally satisfied with the provided straw ration and its outcome, i.e. amount of tail biting. This is further strengthened by the fact that few farmers were interested in increasing the provided straw ration even if it was not associated with any negative consequences such as manure handling issues. However, one of the most common measurements when tail biting was seen was provision of extra straw. This indicates that farmers do in fact connect tail biting with lack of occupation.

According to the EU Dir 2008/120/EC, pigs should have ‘permanent access to a sufficient quantity of material to enable proper investigation and manipulation’. Permanent access has previously been defined as the presence of more than one litre of unsoiled straw at all times and was achieved at 80-290g straw/pig per day for pigs of 30-80kg LW (Pedersen *et al.*, 2014). Straw was mainly provided daily in reported median straw rations of 29 g/pig per day for growers and 50 g/pig per day for finishers reared in partly slatted flooring systems. According to Study II, straw rations ranged from 6-83g/pig/day (depending on the farm's normal straw ration).

These results suggest that many Swedish farmers are unable to reach permanent access, as it was defined by Pedersen *et al.* (2014), due to the comparably low straw rations. According to the results from Study II the mean amount of clean straw left in the pen before the daily straw allocation corresponded to at least one litre of straw only in the Extra Straw Treatment on Farm G1 and on Farm F3 regardless of Treatment. Farms G1 and F3 were the farms with the highest straw rations in the study. On the remaining farms, the mean leftover straw score ranged from 1-1.16, indicating that there were between 1dl to 1 litre of straw left in the pen. These results suggest that this definition of permanent access can be obtained at lower straw rations (from 9 g/pig/day) compared to the results from Pedersen *et al.* (2014). Higher straw rations did however lead to numerically larger amounts of straw left in the pen before the daily straw allocation, in all farms but Farm G2. The limit of 1 litre of straw does however need to be validated to make sure that it has a biologically relevant correlation to the behaviour of pigs before being used as an absolute measure of permanent access to straw.

According to Pedersen *et al.* (2014) one litre of straw corresponds to a weight of ∼60 g, whereas 50 g in Study II was roughly estimated to a volume of ∼15 L. The weight-volume of straw largely depends on the storage method, straw length and dry matter content. When reviewing the Swedish agricultural database Agriwise, the weight per litre ranges from 35-200g depending on how the straw has been stored; straw that has been stored loose has the lowest weight-volume (range 35-65g/l) and straw stored as large square bales has the highest weight-volume (range 150-200g/l) (Agriwise, 2015). The reason for the large difference between what was reported in Pedersen *et al.* (2014) and our study may partly depend on different storage methods (which were not described in neither Pedersen *et al.* (2014) or our paper). Further, when the straw ration was measured in Study II the straw was first transferred from storage (commonly large round bale) to a smaller container that was used in the pig stable. During this procedure, the straw is probably loosened and fluffed up and its volume increased. In Study III where straw ration weight were measured directly from the large round bale, the straw weighed ~70g/l which is more comparable to the Study of Pedersen *et al.* (2014). Also the length of the straw likely affects the volume that the straw takes, the longer straw the larger volume. Despite the lower weight-volume in Study II (roughly estimated to 3-4g/l), the volume of the leftover straw measured on pen floor still was found to have increased. Possibly there is an association between weight, length and volume of straw and its value to pigs that is still not understood. To better be able to compare straw rations between different studies, a standardized method to describe the amount of straw including for example straw species, weight, length, volume and preparation needs to be developed.

6.2.2 Impact on behaviour and lesions

The amount of straw needed to reduce the prevalence of tail biting behaviour by fully satisfying the pigs' need to explore has previously been determined to be approximately 400 g straw/pig per day (Bodin *et al.*, 2015; Pedersen *et al.*, 2014). Again, this ration is far greater than provided straw rations reported in Study I and investigated in Study II.

In Study I the number of affected pens during an outbreak was limited: on average 1 pen/outbreak. The amount of severely damaged tails, scored in the abattoir, was quite low (<2%), which indicates an overall sufficient environment where severe tail biting is quite scarce.

In Study II, it was evident that the size of the straw ration affected the conducted behaviour to a higher extent than the prevalence of damage on the tails. Significant treatment effect on tail damage was seen more often in finishing pigs. Overall, the prevalence of tail damage was higher in finishers compared to growers. An effect of *Treatment* on growers was only seen on Farm G1, which also had considerably higher straw rations compared to the other grower farms (Farms G2 and G4). Therefore, the observed altered behaviour at these investigated lower straw rations does not always seem to be enough to reduce the prevalence of lesions. On the other hand, it might also be related to the fact that the provided straw rations are simply too small to induce such behavioural changes. The somewhat limited *Treatment* effect on lesions could depend on the relatively low straw rations provided (dependent on the farm's base straw ration).

Compared to the prevalence of lesions, straw had a larger effect on behaviour. The doubled straw ration investigated in Study II had an effect on Straw- and Pen-directed behaviour on two of the farms at grower level (Farms G1 and G2). Farm G1 had a considerably higher straw ration compared to the other two farms in the study (Farms G2 and G4), while the difference between rations on Farm G2 and G4 was ~1g. The impact of the size of the straw ration on behaviour is hence not the same on all farms and the results imply that rations of around 10 g/pig/day start affecting the behaviour on some farms dependent on the circumstances. The same pattern was found in finishing pigs, where straw provisions of around 10 g/pig/day were enough to change behaviour on some, but not all, farms. It seems that pigs will redirect active behaviour towards straw and away from pen fittings when straw rations are increased, even at levels of around 10–20 g/pig/day. The difference in straw ration (dose) did however not seem to affect conducted Straw-directed behaviour to the same extent as the Pen-directed behaviour, which was reduced more when the provided straw ration was higher.

However, both Straw- and Pen-directed behaviour on both grower- and finisher levels were significantly increased when the straw ration was doubled, implying that the behaviour was positively altered. Still, the alteration was not enough to change the actual outcome of the behaviour, i.e. fully eliminate tail biting and tail lesions.

6.2.3 Practical implications

Straw has been reported to be negative for pen hygiene in partly slatted pens compared to no straw provision in fully slatted pens (Scott *et al.*, 2007a; Scott *et al.*, 2007b; Scott *et al.*, 2006). It could be argued that fully slatted and partly slatted floors are incomparable. The solid part of the slatted floor does indeed get soiled more easily since soiled straw, faeces and similar can pile up. Fully slatted floors are on the other hand designed so that all material will pass through the slats: soiled manure as well as clean straw. Fully slatted floors are less preferable for pig welfare due to the lack of possibility of providing enrichment material to enable natural behaviour. However, the results from this thesis suggest that cleanliness is not an issue in partly slatted pens which are provided with straw. Pigs will naturally want to separate the lying and dunging area (e.g. Wiepkema, 1986; Stolba and Wood-Gush, 1984) and will thus minimize soiling of the lying area as far as possible. There are however few studies investigating the impact of straw on pig and pen hygiene and more research is needed, especially for different housing systems. Further, more research is needed to investigate the impact of straw on manure handling systems in order to facilitate animal- and management-friendly straw provision to pigs. As an example, the dimensions of the pipes in the manure handling systems are not regulated in the EU Directive or in Swedish national legislation and were not assessed in this study. It is however likely that these measures have an impact on the prevalence of the blockage caused by straw in manure handling. Further the pipe diameter might also effect the possibility of spreading of manure on fields and could hence be an interesting area of new research and an important piece to the puzzle regarding straw management.

Straw provision in pig pens has been suggested to cause blockage of the slatted floor and to cause obstructions in the manure handling system (Lahrmann *et al.*, 2015; Sutherland & Tucker, 2011). The results of Study I showed that the frequency of reported problems in the manure handling system was low. The majority of farmers (76%) provided chopped straw, which could explain the low frequency of problems caused by straw in manure handling systems (Guy *et al.*, 2013; Westin *et al.*, 2013). Still, it was perceived that increasing the straw ration would increase blockages in the manure handling and slatted floor.

The results from Study II showed that increased straw rations generally did not increase the need for manual cleaning of the pens, apart from one farm where the blockage was quite high regardless of ration size, probably related to the pen design since it was the only system where the slatted flooring was closest to the alley from where the straw was distributed. The results from Study II showed that neither pig nor pen hygiene was generally negatively affected by the provision of straw, either in the control or extra straw treatment pens. On the contrary, the majority of the pens in this study were scored as not soiled or blocked on the solid or slatted floor regardless of the amount of straw provided and the variability in cleanliness between treatments was minimal.

To a low extent, some animals were considered dirty in Study II. Dirtiness could be a response to poor pen hygiene (where pigs are forced to lie down in e.g. faeces), but it could also indicate wallowing. Wallowing has been defined as 'covering the body in mud or mud-like substances', mainly for the purpose of thermoregulation (Bracke, 2011). Wallowing in excreta, which is the type of wallowing commonly possible in commercial indoor housing, as there is no mud available, evokes a conflict between the need for heat loss and the natural desire not to lie down in faeces (Huynh *et al.*, 2005). Therefore, it could be argued that wallowing is not a hygiene issue caused by e.g. straw provision soiling but rather an indicator of high temperature and/or high humidity which the pigs try to cope with through wallowing. Poor pig hygiene caused by the pigs wallowing might therefore be a sign of poor housing environment rather than a primary effect of the enrichment material causing poor pen hygiene. Possibly, pigs might even try to create a mud pool substitute with the material available, e.g. water, manipulable material and faeces. Furthermore, the space allowance might influence the possibility for thermoregulation by lying down without close body contact with other pigs. At low space allowance, there is simply not enough space for all pigs to lie down without body contact with pen mates. Therefore, the pigs may be forced to lie down on the slatted floor area due to space requirement limitations (Huynh *et al.* 2006). This could explain reduced pig hygiene with increased pig age: as the pigs grow bigger, the stocking density per kg LW increases and the pens get more crowded, subsequently forcing pigs to lie down on the dirty slatted area as well due to lack of available space.

There is however limited research available on the effect of straw on pig hygiene, although the correlation between poor pig hygiene and poor pen hygiene seems inevitable. Further, the behaviour of wallowing needs to be further investigated to understand its relation to traits other than thermoregulation. Not least to understand the motive behind wallowing to evaluate the lack of wallowing opportunities in modern pig production and its relation to welfare.

6.3 Tail damage

6.3.1 Occurrence and characterisation

The amount of pigs with tail damage differed quite substantially between the three different studies in this thesis: from ~2% in Study I to ~50% in Studies II and III. Comparing the prevalence of tail biting between different sources is difficult, partially due to the definition of tail biting, as descriptions may range from swelling to tissue loss between scoring schemes (Keeling *et al.*, 2012; Taylor *et al.*, 2010). This is most likely the main explanation of the differences seen in these three studies. The protocol used in Studies II and III scored tails as damaged on a scale ranging from swelling to inflamed wounds. Damage recorded as swelling (D1) or bite marks (D2) did not involve any punctuation of the skin, which was involved in damage recorded as wounds (D3) or inflamed wounds (D4). The scoring scheme used at Swedish abattoirs, as reported in Study I, scored only severe tail wounds, which are described as 'evident biting wounds or more than half of the tail missing' or 'if the whole carcass has to be discarded due to tail wounds' as tail biting (SFA, 2012; SFA, 2006). Hence, the prevalence of tail biting as scored in Study II and III is likely quite divergent from the amount of tail biting scored at the abattoir in Study I. Very few of the scored lesions from Studies II and III would likely be scored at the abattoir. In Studies II and III pigs with heavily reduced tail length (L2) would probably be scored at the abattoir while most damage that had a score less than D4 would likely not be detected. Compared to Study I, where approximately 2% of the pigs were scored as tail bitten at the abattoir, around 2-3% of finishing pigs were scored as D4 at the end of Study II and 4.5% of the pigs at the end of Study III.

In Study I farmers were asked to estimate how often tail biting was seen in production (commonly never in grower farms and 3-12 times/year in finishing pigs). Also here it is important to remember that milder tail lesions without substantial bloodshed are unlikely to be observed by the farmers since palpation of tails is usually not carried out. Both abattoir and farmer scoring therefore likely underestimate the prevalence of tail lesions compared to a scoring scheme like the one used in Studies II and III, which includes a swollen tail or superficial scratches as the lower limit for bitten tails (Keeling *et al.*, 2012; Valros *et al.*, 2004). A detailed scoring scheme will likely also provide different results depending on how, and with what precision, the assessment is carried out.

Tail biting may also be overestimated through the scoring schemes. For example, in Studies II and III, pigs with a shortened tail at the first observation occasion probably had a shortened tail already when scoring started in the current experiment. The tail shortening could originate from previous tail biting, but could also be congenital, caused by trauma, toxins or necrosis. With regard to tail damage and shortening, it is usually impossible to distinguish between different causes from a fully healed wound, which is why scoring of tail shortening may overestimate the incidence of tail biting behaviour both under experimental and abattoir scoring.

6.3.2 Severity

The scoring scheme used in Studies II and II did not involve any scoring of the magnitude of the damage or lesions. The majority of the scored lesions (D3, D4) were <5mm in diameter and would most probably not have been discovered without the close examination that the scoring scheme involved. Still, 55% of C-pigs and 45% of ES-pigs in grower farms and 50% of C-pigs and 40% of ES-pigs in finishing pig farms in Study II had damaged tails in Period 3. In Study III, 53% of the observations had some sort of tail damage. Of the scored tail damage, ~40-50% was damage without any skin punctuation (D1-2), hence concerning very mild lesions. It could be argued that the majority of the remaining lesions (almost exclusively scored as lesions, D3) were also very mild lesions due to their moderate size. Even lesions scored as D3 would likely not be scored at the abattoir (due to being too small) and would not be found without close examination. Less severe wounds may be of less importance with regard to health reduction and carcass loss and it may be argued that they are negligible. Still, they are a sign of tail biting behaviour, which in turn can be linked to reduced welfare depending on why it occurs e.g. accidental tail-in-mouth behaviour or stress-related behaviour. Smaller lesions can still cause pain, or reduced health and wellbeing and/or production and in this case it is the perception of the bitten pig that determines the effect on the welfare.

In Study II, it was shown that the amount of tail damage was reduced with increased straw rations, but this was only true for the more severe lesions, scored as D3 and D4. Similarly, in Study III, only scores D3 and D4 were linked to a hanging tail posture. This could be a sign that pigs are not significantly bothered by less severe tail damage such as swelling and bite marks are or not affected by the limited straw ration provided (no effect on explorative behaviour). On the other hand, it may also indicate that the studied straw rations did not provide pigs with enough occupation to eliminate tail-in-mouth behaviour, but provided enough occupation to reduce the redirection of exploratory behaviour that leads to severe tail biting.

6.3.3 Suspected causes

Study I showed that suspected causes of tail biting varied between farms and age groups (grower or finishing pigs). This is in accordance with previous studies which conclude that different production systems have different risks for developing tail biting (D'Eath *et al.*, 2016; Taylor *et al.*, 2012). Pigs with permanent access to straw are mainly exposed to climatic risk factors for tail biting such as temperature and air humidity (Taylor *et al.*, 2012). The farmers in Study I mentioned stocking density as the main risk factor in grower units and feed composition/feed equipment as the main risk factor in finishing pig units along with stocking density. This finding is partly in accordance with the perception of Dutch pig farmers (mainly rearing docked pigs), who consider stocking density to be the main risk factor for tail biting, along with stable climate (Bracke *et al.*, 2013). Furthermore, in Studies II and III tail damage increased with time, probably due to less space being available per pig with increased age (e.g. Smulders *et al.*, 2008). Stocking density has been considered to be one of the most common risks associated with tail biting in pigs reared in partly slatted systems with straw (EFSA, 2007). The stocking density at slaughter weight (110 kg LW) in Sweden is ~1m^2 compared to 0.65 according to the EU legislation. In addition, tail biting significantly increases when the feeding space decreases (Smulders *et al.*, 2008) and as the pen facilities remain unchanged, the stocking density will increase in the pens, decreasing feeding space per pig as the pigs grow larger. As discussed earlier, increased stocking density also increases the risk that pigs will be forced to lie on the slatted or soiled part of the pen and therefore become soiled themselves.

6.4 Early detection of tail biting

The results from Study II showed that tail posture at feeding correctly classified damaged tails in 78% of cases when the cut-off point was set to ‘wound’ (D3). The cut-off point was set to ‘wound’ since it was statistically proven to be associated with tail posture by our model, and also the type of damage that we previously found significantly affected by the provided straw ration in Study II. Less severe damage did not affect tail posture.

However, with this method 44.8% of pigs with tail damage will be missed and 20.3% will be misclassified as having wounded tails although they do not. According to Study I, the most common treatment when identifying tail biting was addition of straw or by other means trying to increase exploratory behaviour: these treatments can be considered positive for welfare. However, pigs with wounds that are missed through the assessment of tail position need to be identified through other means such as clinical examination or behavioural deviations prior to outbreaks and need to be investigated through further research.

The misclassification of injured pigs through tail posture was also identified by several previous studies and pigs with hanging tails do not always have tail damage and vice versa (Lahrmann *et al.*, 2018; Larsen *et al.*, 2018a; Statham *et al.*, 2009; Zonderland *et al.*, 2009). Previously, tail position has been shown to indicate tail biting 3 days prior to when actual tail lesions can be observed (Lahrmann *et al.*, 2018; Zonderland *et al.*, 2009). However, due to the experimental setup in Study III we could not investigate this relationship. Weekly recordings of tail position only detect tails where damage is already present. However, most of the wounds detected by tail posture would not be detectable without close examination of the tail, and therefore tail posture could still be useful in commercial production for detecting tail biting before wounds are detectable from outside the pen.

Moreover, we were unable to associate damage that was less severe than 'wound' with tail posture. If we had used shorter observation intervals we might have been able to detect time dependent changes. However, our study was designed to reflect usability for commercial farmers, who do not have the time to clinically observe individual pigs through palpation daily. We propose that the method used in Study III could be incorporated into normal farm routines, for instance when farmers are checking feeding equipment or the health status of pigs.

As suggested by Kleinbeck and McGlone (1993), tail posture might be an indicator of pig comfort. The reason for the large amount of hanging tails observed at the beginning and end of the production period could therefore be related to stress (e.g., due to new environment or new hierarchy), rather than to tail biting. On the other hand, tail biting is also known to occur when stressors such as increased stocking density and new hierarchies arise (Schroder-Petersen & Simonsen, 2001).

The causality behind hanging tails is not evident from this study. Lahrmann *et al.* (2018) noted that the activity of pigs influenced their tail posture, revealing that tail posture could also be a response to emotional states other than e.g., pain or discomfort. For example, pigs engaged in rooting activities were more likely to have hanging tails compared to walking or running pigs. Furthermore, tail posture was more likely to change in a short time after pigs changed activities. As discussed by de Oliveira and Keeling (2018), certain animal postures may not be specific to specific emotional states and may not be possible to assess alone but rather only in combination with whole body posture. They found that there were interactions between tail, ear and neck position and activity in cows, suggesting that cows express themselves differently during different activities (brushing, queuing for milking or feeding). To understand the role of tail posture in the communication of pigs it needs to be investigated further in relation to the whole posture and emotional status of the animal. Only then can we start to understand the causal relationship between tail biting/tail damage and tail posture.

The model used in Paper IV took into account that different pigs might react differently to the same stimuli. The variability was higher at individual level than at pen level, implying that the mix of pen mates might even out differences at the individual level when assessing one pen as the level of investigation. Pain is a subjective experience and this is hence not a surprising finding (Ison *et al.*, 2016). The pain related to tail docking has been investigated by e.g. Di Giminiani *et al* (2017a), Di Giminiani *et al* (2017b), Sandercock *et al* (2016) but the different pain thresholds and the development of long term effects of tail biting need further investigation. Also, pain related to tail biting needs to be investigated further, not the least to understand the pain related to less severe damage such as swelling and tail biting to enable the assessment of welfare related to these types of tail damage.

6.5 Rearing undocked pigs

Already the results from Study I show that it is possible to rear undocked pigs. The fact is that it is already being done! Study I showed that tail biting can be prevented by straw access in undocked pig populations and that daily straw usage is possible in commercial pig production. In Study II we further showed that straw rations did not cause poor pig or pen hygiene. It was also proven that it is possible to rear pigs with considerably small rations of straw without experiencing large issues of tail biting. The larger the straw ration, however, the more explorative behaviour the pigs display, and the less tail damage detected: therefore, larger straw rations likely improve welfare further.

Even when straw is provided, it is unlikely that we will be able to fully eliminate tail biting in commercial pig production. Two-stage tail biting (that has been the main focus of this thesis) could be considered an elongation of pigs' exploratory behaviour and rearing pigs in confined areas will likely lead to a pig tail ending up in another pig's mouth by chance sooner or later, leading to at least swelling and bite marks on the tail. Sudden forceful and obsessive tail biting can also be triggered by other risk factors, such as problems with feed or feeding systems which will almost inevitably occur from time to time. The impact of tail biting can however be reduced through early detection which enables farmers to decrease or even prevent tail biting outbreaks and their consequences. Checking tail position at feeding could be incorporated into normal farm routines and could be used as an early indicator of tail biting as shown in Study III, and followed by improving the environment etc. as shown in Study I and II.

Another way to decrease tail biting outbreaks due to e.g. feeding dysfunction could be to enhance pigs' capability to cope with new or uncontrolled situations. For example, it has been proposed that the nervous system needs to be used in order to thrive and that early experiences set the foundation for how the brain is used later in life (Rosenzweig & Bennett, 1996). Individuals with a greater range of experiences during early life profit better from new experiences in adulthood (Hebb *et al.*, 1994). Therefore, improvement of (as in increased variability) early rearing environment could possibly prepare pigs to cope with changes later in life and needs further investigation.

The rearing of pigs with intact tails is however not solely solved through the use of straw or other manipulable material. Tail biting is a multifactorial problem and factors other than lack of occupational material such as stocking density, feeding regime, genetics and climate etc. may also contribute to its development (Smulders *et al.*, 2008) as was reported in Studies I, II and III. As previously mentioned, different production systems have different risks for developing tail biting (D'Eath *et al.*, 2016; Taylor *et al.*, 2012). Moreover, the participating farms in Study II had small differences in health status, stocking density, management, and climate etc. All these are factors that could affect tail biting and occurrence of lesions. It is therefore likely that the provision of extra straw did not have the same effects in all farms, although the management, stocking densities, genetics and group sizes were very similar. Factors such as health status and heat/cold stress are however considered to be less likely to increase the risk for developing tail biting compared to lack of straw (EFSA, 2007). The different farm preconditions in this study also reflect the diverse preconditions for pig production within the EU, where different commercial farms have different preconditions and thereby risks for tail biting.

At least a few notes should nevertheless be mentioned in relation to the rearing of undocked pigs in countries such as Sweden compared to the EU standards, which likely have an impact on the rearing successful of undocked pigs.

- The lower maximum stocking density compared to the EU. Increased stocking density is associated with an increase in other pen-related risk factors for tail biting and affects the possibility of interacting with provided manipulable materials.
- The ban of fully slatted floors, which ease straw provision and manipulation. Straw can also be used in fully slatted flooring systems given that the pigs can make use of the straw before it passes through the slats.
- The small group size. One of the benefits of the small group size is that when there is an outbreak, only a limited number of pigs can be affected. Further, it is easier to identify, and remove, the biting pig.
- A good health status, including strict all-in-all out systems and managing pigs with a very low use of antibiotics which demands good pig management skills. This health status is likely also linked to the higher weaning age compared to the EU, which enables weaning of larger and more mature piglets that cope well with the stress of weaning.
- Last but not least: the absolute ban of docking. The fact that most EU-countries do not implement the EU Directive enables the violation of the prohibition of tail docking. This also likely increases the difficulty of ending tail docking and exacerbates the idea that rearing pigs with intact tails is impossible. Think of Roger Bannister![2]

[2] Roger Bannister was the first man to run an English mile in under four minutes, something that was believed to be impossible. The record was broken after 46 days and has now been done by hundreds of men.

7 Main conclusions

Swedish farmers, rearing pigs with intact tails

- Commonly provided the pigs with straw daily
- Did not consider tail biting to be a large issue
- Had approximately 2% of the pigs scored as tail bitten at the abattoir.

Increased straw ratio

- Reduced the amount of tail lesions
- Reduced the amount of Pen-directed behaviour (unwanted explorative behaviour)
- Increased the amount of Straw-directed behaviour (wanted explorative behaviour)
- Was not associated with poor pig hygiene
- Was not associated with poor pen hygiene
- Was not associated with increased pen cleaning

A hanging tail at feeding

- Is an indicator of tail lesions
- Is a feasible method of early detection of tail biting in commercial production

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Popular science summary

Pigs in their natural environment explore their surroundings through rooting, sniffing and chewing in order to find food, resting places and familiarise themselves with their environment. Pigs kept under semi-natural conditions spend ~60% of their active time exploring, mainly through rooting. Even though pigs in intensive production live in confined, safe areas and are provided with adequate feed they are still highly motivated to conduct exploratory behaviour. Compared to natural conditions, where rooting is generally unrestricted, rooting under commercial conditions is often fully dependent on the provision of rooting material. In order to meet pigs' explorative needs the EU Council Directive 2008/120/EC, laying down minimum standards for the protection of pigs, states that pigs should have permanent access to a sufficient amount of material, such as straw, to enable proper investigation and manipulation activities.

Lack of rooting opportunities may direct pigs' exploratory behaviour towards other pigs, causing tail biting. Tail biting is an abnormal behaviour defined as one pig's dental manipulation of another pig's tail. This definition describes a large variety of behaviours ranging from gentle manipulation to excessive biting, and leading to tail or even rump losses, causing acute, long- and short-term pain. Tail biting is a common issue in modern pig production, reducing health, farm profitability and animal welfare in both the bitten and biting pig.

Due to the behavioural background of tail biting, different types of production systems have different risks associated with the development of the behaviour. The largest risk factors in systems where straw is provided are related to environment, e.g. temperature, ventilation and humidity but also stocking density, while the main risk factor in systems without straw is lack of enrichment. The lowest risk occurs when pigs are reared on straw along with other high quality objects and substrates.

However, instead of being provided with a better production environment, >90% of the pigs produced within the European Union are tail docked to reduce tail biting, even though the Council Directive 2008/120/EC condemns routine tail docking. Tail docking is a procedure where part of the tail is removed in piglets, in order to create a more sensitive tip of the tail. This makes pigs less willing to allow other pigs to chew on their tail later on, and it is thought that a shorter tail is less attractive to chew on. The docking procedure is commonly executed without any pain relief and results in acute and sometimes long-term pain. Tail docking may remove the symptoms of tail biting but not the underlying cause. Therefore, the Council Directive advices solving the underlying issue through improved pig environment to reduce tail biting before tail docking is implemented. This should principally be done through increasing opportunities to conduct exploratory behaviour. One argument for not using enrichment material such as straw instead of docking is the difficulty of handling large amounts of straw in the manure handling systems and on slatted floors. It is thought that straw causes blockages in the slurry systems and causes manure to pile up in the pen, causing a poor environment that requires manual cleaning. A few EU countries however, e.g. Sweden, Finland and Lithuania, have prohibited tail docking by national legislation and therefore rear undocked pigs.

The overall aim of this thesis was to investigate how straw can be managed to rear pigs with intact tails and its effect on behaviour and hygiene and whether tail posture can be used as a sign for the early detection of tail biting. The thesis is based on two studies (Study I and II) investigating straw usage and tail biting and one study (Study III) aiming to develop a method for early detection of tail biting. The aim of Study I was to gather information about how Swedish farmers rear pigs with intact tails and how straw is used through a telephone survey. The aim of Study II was to investigate the impact of straw on behaviour, lesions and pen management (such as pig and pen hygiene as well as pen cleaning). The study was conducted on five commercial Swedish farms raising undocked pigs where the farms' normal straw ration was doubled to facilitate the investigation of increased straw ration impact on behaviour, lesions, hygiene and management. The aim of Study III was to investigate the relationship between tail posture (hanging or curled) and tail damage to facilitate early detection of tail biting. Early detection of tail biting, i.e. before visible wounds appear, could increase the likelihood that an outbreak is prevented through provision of extra care, e.g. extra straw. The tail posture was scored at feeding to facilitate easy incorporation of this method into normal farm routines.

The results from Study I revealed that all Swedish farmers provide their pigs with some sort of manipulable material, and that 99% of them use straw. Tail biting had occurred in 50% of the grower and 88% of the finishing pig farms. The estimated median straw ratio was 29 gram/pig/day in grower and 50 gram/pig/day in finishing pig farms. The amount of tail biting recorded at the abattoir was on average 1.7%. Despite the fact that 44% of grower farms and

19% of finishing pig farms never having any problems in the manure handling system caused by straw, 76% reported being unwilling to increase straw ration due to perceived consequences such as poor pen hygiene and blockage of the manure handling system.

The results from Study II showed that increased straw ration decreased the presence of tail wounds. Increased straw ration initiated more straw-directed behaviour while decreasing the amount of pen-directed behaviour. Regardless of the size of the straw ration, the most common behaviour was straw-directed, indicating the relative importunateness of this investigative behaviour. The amount of tail damage increased over time, regardless of size of straw ration and at the end of the production period, around 50% of the pigs with extra straw and 60% of the pigs with control ration had some sort of tail damage. It should however be noted that the majority of the recorded tail damage was so small (<5mm) that it would likely not have been discovered without close examination. Increased straw ration had little or no effect on pen or pig hygiene, indicating that this is likely not as a big problem as producers may perceive.

Tail posture (hanging or curled) at feeding was used to correctly classify tail damage in 78% of the cases where tail damage was defined as wound on tail (regardless of size). A hanging tail were more often subjected to tail damage compared to a curled tail. Less severe tail damage, such as swelling or bite marks, did not significantly affect the tail posture. It was concluded that tail posture could be used as an indicator of tail biting at feeding in commercial herds, although it should not be the only measure as it will miss early signs such as swelling and bite marks as well as misclassifying a certain number of pigs. The false positive misclassifications are however commonly treated with e.g. provision of extra straw to reduce tail biting and are therefore not associated with any negative consequences.

The main conclusions of this thesis are that increased straw rations reduce tail damage as well as pen-directed behaviours. Rather, the provision of straw increases straw-directed behaviours, while not affecting pig and pen hygiene negatively. Hence, by providing straw, it should be possible to rear pigs with intact tails without the use of tail docking.

Populärvetenskaplig sammanfattning

Grisar utforskar sin omgivning genom att böka, sniffa och tugga för att hitta mat, viloplatser och bekanta sig med sin miljö. Grisar som hålls under semi-naturliga förhållanden spenderar ~60% av sin aktiva tid med att utforska sin omgivning, främst genom att böka. Trots att grisar i intensiv produktion lever i begränsade utrymmen, förses med foder och skyddas från yttre faror är de fortfarande mycket motiverade att utföra samma typ av undersökande beteende som under naturliga förhållanden. Under kommersiella förhållanden är dock grisarna ofta helt beroende av att förses material som de kan undersöka för att utforskande beteende skall kunna utföras. För att uppfylla grisarnas undersökande behov anges i EU-rådets direktiv att grisar ska ha permanent tillgång till tillräcklig mängd material, till exempel halm, som de kan undersöka och sysselsätta sig med.

Får grisar inte utlopp för sitt undersökande beteende kan beteendet omdirigeras till att undersöka andra grisar och leda till svansbitning. Svansbitning är ett onormalt beteende som innebär att en gris tuggar på en annan gris svans och innefattar allt från skonsam manipulation till orsakandet av skador så svåra att delar av svansen eller bakdelen avlägsnas. Beteendet kan orsaka såväl akut som lång- och kortvarig smärta och är ett allvarligt problem i modern grisproduktion. Svansbitning försämrar hälsostatusen, lönsamheten och djurvälfärden både för den bitna och den bitande grisen.

I stället för att minska risken för svansbitning genom att skapa en bättre produktionsmiljö kuperas svansarna på >90% av de grisar som produceras inom EU. Detta görs trots att det inom EU är förbjudet med rutinmässig svanskupering. Under kuperingen klipps en del av svansen av under grisens första levnadsvecka. Detta skapar en kortare svans som blir mer känslig för beröring. Detta gör att grisen senare i livet blir mindre benägen att tillåta andra grisar att tugga på svansen samtidigt som en kortare svans anses mindre attraktiv att tugga på. Kuperingen utförs vanligen utan smärtlindring och ger akut och ibland långvarig smärta. Några EU-länder, t.ex. Sverige, Finland och Litauen, har förbjudit kupering genom nationell lagstiftning och föder därför upp grisar med intakt svans. I Sverige minskar man istället risken för svansbitning genom att förse grisarna med halm för att på så sätt stimulera det undersökande beteendet. Ett argument för att inte förse grisarna med exempelvis halm istället för att kupera har varit att halm orsakar stopp i utgödslingssystemen och skapar dålig boxhygien vilket kräver manuell rengöring.

Det övergripande syftet med denna avhandling var att undersöka hur halm kan användas för att föda upp grisar utan att svanskupera och halmmängdens effekt på beteende och hygien samt om svansposition kan användas för tidig upptäckt av svansbitning. Resultaten baseras på tre praktiska studier. Syftet med Studie I var att samla information om svenska bönders erfarenheter av att föda upp grisar med intakta svansar och hur halm används i praktiken. Syftet med Studie II var att undersöka hur en ökad halmgiva inverkar på beteende, svansskador och hygien. Studien genomfördes på fem kommersiella svenska gårdar där respektive gårds normala halmgiva jämfördes med en fördubblad giva (8-80g/gris/dag i försöksboxar jämfört med 4-50g/gris/dag i kontrollboxar beroende på gård och undersökt tidsperiod). Syftet med Studie III var att undersöka förhållandet mellan grisens svansposition (knorr eller hängande) och svansbitning för att underlätta tidig upptäckt av svansbitning. Tidig upptäckt av svansbitning, d.v.s. innan synliga sår uppstår, kan öka sannolikheten att ett svansbitningsutbrott kan hävas genom extra vård, t.ex. ökad sysselsättning (halmgiva).

Resultaten från Studie I visade att samtliga intervjuade gav sina grisar något slags manipulerbart material och att 99% använde halm. Den beräknade halmgivan var 29g/gris/dag hos tillväxt- (5-10 veckor gamla grisar) och 50g/gris/dag i storgrisbesättningar (10-25 veckor gamla grisar). Svansbitning hade observerats vid något tillfälle i 50% av tillväxt- och 88% av storgrisbesättningarna. Mängden svansbitning som registrerats vid slakteriet var i genomsnitt 1,7%. Trots att 44% av tillväxt- och 19% av storgrisbesättningarna aldrig haft problem orsakat av halm i gödselhanteringssystemet, rapporterade 76% att de inte ville öka halmgivorna då de var oroliga att de skulle skapa problem med utgödslingssystemet eller boxhygien.

Studie II visade att ökad halmgiva minskade förekomsten av svansskador och beteende riktat mot boxinredning (oönskat beteende) samt ökade mängden halminriktat (önskat) beteende. Oavsett storleken på halmgivan var det vanligaste förekommande beteendet halmriktat, vilket indikerar att det undersökande beteendet är viktigt för grisen. Mängden svansskador ökade över tid, oavsett halmgivans storlek och i slutet av produktionsperioden hade omkring 50% av grisarna med extra halm och 60% av grisarna med vanlig halmgiva någon form av svansskada. Det bör dock noteras att majoriteten av de registrerade svansskadorna var så små (<5 mm) att de sannolikt inte skulle ha upptäckts utan noggrann undersökning. Ökad halmgiva hade liten eller ingen effekt på gris- och boxhygien.

Studie III visade att svanspositionen vid utfodring korrekt klassificerade sårskador på svansen i 78% av fallen, där grisar med hängande svans oftare hade svansskador. Mindre allvarliga svansskador, såsom svullnad eller bettmärken, hade emellertid inte signifikant påverkan på svanspositionen. Svansposition skulle kunna användas som en indikator för svansbitning i kommersiella besättningar, även om det bör kombineras med andra åtgärder för att kunna identifiera tidigare tecken på svansbitning såsom svullnad och bettmärken. De falskt positiva svansbitna grisarna behandlas dock vanligtvis med en ökad halmgiva och är därför inte förknippat med några negativa konsekvenser.

De huvudsakliga slutsatserna av denna avhandling är att ökade halmgivor reducerar svansskador samt boxinriktade beteenden. Istället ökar halminriktade-beteenden (önskat undersökande beteende) med ökade halmgivor. Det påverkar heller inte gris och boxhygienen negativt inom de halmgivor som testats. Därför bör det vara möjligt att föda upp grisar med intakt svans utan svanskupering även i andra länder.

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