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REVIEW ARTICLE

Tail docking in pigs: a review on its short- and long-term consequences and effectiveness in preventing tail biting

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Abstract

In spite of European legislation attempting to limit this practice, tail docking is nowadays the only preventive measure against tail biting which is widely adopted by farmers. Docking consists in amputating, usually without anaesthesia or analgesia, the distal part of the tail, in order to reduce its attractiveness and to sensitize it, increasing avoidance behaviour in the bitten pig. Tail docking results in both acute and chronic effects on pig welfare, and its effectiveness in preventing tail biting is limited, since it reduces the symptoms of a behavioural disorder, but does not address the underlying causes. The aim of the present paper is to review the available literature on the effects of tail docking on swine welfare. Although from a practical standpoint the welfare risks arising from tail docking may appear to be negligible compared to those arising during and after tail biting outbreaks, it should be considered that, apart from acute physiological and behavioural responses, tail docking may also elicit long-term effects on weight gain, tail stump sensitivity and animal freedom to express their normal behaviour. Such chronic effects have been poorly investigated so far. Besides, studies evaluating the effectiveness of anaesthetics or analgesic treatments are often conflicting. Within this framework, further research is recommended in order to reduce the acute and chronic pain and discomfort experienced by the animals, until preventive measures (*e.g.,* environmental enrichment, stocking densities) are broadly adopted to prevent tail biting.

Introduction

Tail biting has been identified as an important and undesirable behaviour in growing pigs (Stafford, 2010), which causes substantial loss to producers due to deteriorating body conditions in affected animals (Kritas and Morrison, 2007). It has implications of poor animal welfare conditions (Heinonen *et al.,* 2010) for both the individuals actively expressing this abnormal behaviour and the victims of this activity (Edwards, 2006; Mills *et al.*, 2010) and reduces also the economic profitability of this sector (Zonderland *et al.,* 2010). It has been generally accepted that the aetiology is of a multi-factorial nature (Breuer *et al.,* 2005; Rodenburg and Koene, 2007; Sutherland *et al.,* 2009), some being internal, individual factors and others being external, environmental factors. The term tail biting has been used to describe a wide range of behaviours in pigs, and tailoring the appropriate solution to tackle different types of tail-biting is often challenging (Taylor *et al.*, 2010).

Even though literature extensively dealt with tail biting causes and possible solutions, tail docking is nowadays the only preventive measure widely adopted by farmers against tail biting (Schrøder-Petersen and Simonsen, 2001; Moinard *et al.,* 2003). This process is done by amputating, usually without anaesthesia or analgesia, the distal part of the tail (Schrøder-Petersen and Simonsen, 2001), to shorten it and to sensitize it by inducing hyperalgesia and allodynia in the tail tip to promote avoidance of the bitten pig (Arey, 1991; Simonsen *et al.,* 1991; EFSA, 2007), but also to remove the tuft of hair at the tip which may be attractive to other pigs (Simonsen *et al.,* 1991). Under common intensive farming conditions, tail docking generally reduces the frequency of tail biting (Hunter *et al*., 2001; Sutherland *et al*., 2008, 2009, Scollo *et al*., 2013), but does not completely eliminate the problem, especially when underlying causes for the tail biting problem remain unresolved (EFSA, 2007). It is also worth noting that the functional approach to animal welfare, which states that welfare and distress are antithetic, links the achievement of high productivity standards with, among others, the absence of lesions (Scipioni *et al*., 2009). Tail docking represents, *per se*, a kind of lesion, which is paradoxically aimed to avoid more severe situations. As such, tail docking is seen negatively by European consumers, which list the absence of mutilations among the very important factors for animal protection (Martelli, 2009; based on EC data).

The acute welfare risks from tail docking may seem to be much less than the long-term welfare risks from tail biting. However, the balance between the welfare effects of tail biting and tail docking heavily depends both on the effectiveness of tail docking in reducing the tail biting behaviour and on the extent (severity and duration) of acute and chronic pain arising from tail docking.

The efficacy of tail docking to reduce the frequency of tail biting is very difficult to estimate, since it depends on the level of tail biting in control undocked pigs. However, comparisons between the two populations should be made carefully since the systems in which docked and undocked pigs are kept are not equivalent, undocked pigs generally living in systems where hazards for tail biting are less prevalent (*e.g.*, more often having access to enrichment materials such as straw and additional space) (EFSA, 2007; Taylor *et al*., 2010). As concerns the pain arising from tail docking, literature extensively addressed the acute behavioural and physiological response to tail docking, but rarely took into account its chronic effects (Sandercock *et al*., 2011; Strobel and Hawkins, 2012; Zhou *et al.,* 2013). The present paper aims to review the available literature on tail docking in order to evaluate the diffusion of the practice in the European countries, its consequences in terms of animal welfare and its effectiveness in preventing tail biting outbreaks.

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Current legislation on tail docking

Council Directive 2008/120/EC states that all procedures intended as an intervention carried out for other than therapeutic or diagnostic purposes and resulting in damage to or the loss of a sensitive part of the body or the alteration of bone structure shall be prohibited. However, some exceptions are recognized, including reduction of corner teeth of piglets, docking of a part of a tail, castration of male pigs. Since these procedures are likely to cause obvious immediate pain and some prolonged pain to pigs, according to the cited directive neither tail-docking nor reduction of corner teeth must be carried out routinely, but only where there is evidence that injuries to sows' teats or to other pigs' ears or tails have occurred. Besides, before carrying out these procedures, other measures shall be taken to prevent tail-biting and other vices, therefore issues related to inadequate environmental conditions or management systems, including environmental enrichment and stocking densities, should be addressed. Furthermore, these procedures shall only be carried out by a veterinarian or a person trained and experienced in performing the applied techniques with appropriate means and under hygienic conditions. If castration or docking of tails is practiced after the seventh day of life, it shall only be performed under anaesthetic and additional prolonged analgesia by a veterinarian (European Commission, 2008).

Current legislation clearly states that tail docking should not be performed on a routine basis in countries belonging to the EU. Some countries (Austria, Denmark, Finland, Lithuania, Slovenia and Sweden have specific legislation further limiting this practice (EFSA, 2007; Table 1). In Finland, Lithuania and Sweden tail docking is prohibited, unless motivated from a medical veterinary perspective.

Prevalence of tail-biting lesions and tail docking in EU countries

A summary of information collected from surveys (questionnaires, sent by EFSA to national experts in different countries) indicates that the percentage of undocked pigs in the surveyed countries varied widely, from <1% to 100%, the prevalence of undocked pigs in the EU being currently very low (5-10%) (EFSA, 2007; Figure 1). The prevalence of tail bitten pigs also varied widely and was often unknown in these surveys. In Table 2, a summary of the available scientific literature estimating the prevalence of tail biting lesions in different European countries is given. Prevalence level can vary greatly depending on the population studied (in a pen, building, farm, abattoir, or national herd level), location of study (farm, abattoir) and level of tail inspection (scientific studies or routine meat inspection data). Such differences in prevalence reporting clearly make cross-study comparisons difficult. For example, according to Taylor *et al.* (2010), prevalence reports focusing on individual pigs can mask the skewed distribution of tail-biting across farms.

Harley *et al.* (2012) evaluated the prevalence of tail biting as a welfare surveillance tool in the Republic and Northern Ireland. According to their observation, the tail of over 99% of the study pigs were docked. In their study, almost 60% of the pigs inspected had detectable tail lesions. However, only 1% of pigs were found to have severe tail lesions.

Meat inspection offers good opportunities to assess the welfare status of individual animals at their farm origin, giving the opportunity to assess systematically the presence of macroscopic lesions caused by unsuitable rearing environments, anomalous animal behaviour or health conditions. Nevertheless, there are some risks of misreporting. When tail biting lesions are recorded at the slaughterplant, under-reporting may occur because only the more severe cases are recorded. Besides, the low prevalence of tail biting recorded at the slaughterhouse is likely due to the absence of information on the number of animals early culled at the farm during the fattening period (Taylor *et al*., 2010). Busch *et al.* (2004) showed that tail damage, estimated by clinical examination of the herd on the farm, was two times more prevalent than detected by carcass inspection at the abattoirs. Conversely, mild or healed tail wounds (which may represent previously more severe lesions at an advanced stage of healing) are rarely assessed and may in some cases be indistinguishable from docked tails (Taylor *et al*., 2010). According to Harley *et al.* (2012), this may lead to an overestimation of the prevalence of tail docking.

Tail docking: operative procedures

Tail docking usually takes place in the first few days of life along with iron administration, teeth resection, identification, and castration (Marchant-Forde *et al.,* 2009). The procedure is usually carried out by the farmer or his employees and can be performed with teeth clippers, cutting pliers, scissors, a scalpel blade, and a gas or electrical cautery iron (Sutherland and Tucker, 2011). If traditionally tail docking was done by using slide cutter clippers, recently the use of heated clippers has become more widespread aiming to cauterize

Table 1. Countries where European legislation on tail docking is further restricted by national legislation (data taken from EFSA, 2007).

Country	Limits	Legislative act
Denmark	- between days 2 and 4 of life - documented damage to tails in the heard when tail docking is not performed - tail should be docked as little as possible (not more than ½ of the tail) - if performed after the 4th day of life, piglets should be given long-lasting analgesia	BEK no. 324, 6 May 2003
Sweden	- not allowed (it does not appear on the list of surgical interventions allowed for medical reasons)	SFS 1988:534 Paragraphs 2,4,10
Finland	- forbidden as an act causing needless pain to the animal	2002:0910
Lithuania	- totally banned	?
Switzerland	- removed from the list of mutilations that can be performed without anaesthesia	Animal Protection Ordinance, 2001
Norway	- amputation of tails for medical reasons can only be performed by veterinarians using anaesthesia and prolonged analgesia. As a consequence, it is not carried out any more	Regulation for Housing of Swine of 2003, Paragraph 10

the wound during the process thus improving the well-being of the piglet in reducing the risk of secondary infection (Marchant-Forde *et al.,* 2009). However, some Authors suggested that cautery may delay wound healing, which could possibly lead to chronic infections (Graham *et al.,* 1997; Sutherland *et al.*, 2009). As a general rule, no anaesthetic or analgesic treatments are performed to reduce the pain evoked by tail docking. When scissors or wire cutters are used, they are usually dipped in an antiseptic for disinfection, but usually no antiseptic is applied on the tail before or after docking (EFSA, 2007). The tail length which should remain after docking should be sufficient to cover the vulva in females, and of equivalent length in males (Sutherland and Tucker, 2011). In practice, the length of the tail that is removed by docking is variable: from only the tip of the tail to up to ¾ of the tail, or more. Similarly, the length of the tail stump can vary considerably and may depend on the sex and purpose of the animals (the tail stump is normally longer in females that are raised for reproduction) and on the prevalence of tail biting in the farm (when tail biting is frequent, farmers tend to dock tails more severely) (EFSA, 2007). Currently, there is limited literature comparing the stress response caused by different methods of tail docking in pigs (Sutherland and Tucker, 2011), while such a response has been more extensively assessed in lambs. According to Graham *et al.* (1997), tail docking lambs using the rubber ring method resulted in a marked stress response, whereas using a heated docking iron produced a response similar to that of control-handled lambs. Similarly, Prunier *et al.* (2005) showed that at 1 day of age stress response did not differ between pigs tail docked using a cautery and control-handled pigs. However, behavioural responses were shown to be greater in tail-docked pigs compared with control-handled pigs for up to 1 min after tail docking (Noonan *et al.*, 1994). Sutherland *et al.* (2008) compared tail docking by cautery iron and blunt trauma cutters at approximately 6 days of age, and suggested that tail docking using a heated cautery may reduce the acute physiological stress response as compared with conventional tail docking using blunt trauma cutting, although behavioural responses were similar between the two procedures. In contrast, Marchant-Forde *et al.* (2009) found that docking using a cautery iron tended to increase the number of squeals during the docking procedure compared with docking using cutting pliers, and explained this difference as partly due to the fact that tail docking using a cautery iron took significantly longer, thereby exposing the piglets to handling of longer duration.

Research describing the efficacy of local or general anaesthesia to alleviate pain caused by tail docking in pigs is also limited. The main disadvantage of using local anaesthesia is the necessity to repeatedly handle the animal, possibly leading to increased stress experience. Furthermore, the prolonged recovery period from general anaesthesia could increase the risk of piglets being crushed by the sow and reduce feeding opportunities (Sutherland and Tucker, 2011). The same Authors evaluated the effects of different anaesthesia treatments (local anaesthesia injected immediately before docking, short-acting or long-acting local anaesthesia applied topically to the tail wound, and general anaesthesia with carbon dioxide gas). According to their results, none of the proposed methods was effective at significantly changing the physiological or behavioural response to tail docking, highlighting the necessity to find practical on-farm methods to reduce the pain caused by docking in pigs, until this practice can be abolished. Contrarily to the above, Prunier *et al.* (2001) studied the effects of a cold analgesic spray in attenuating the physiological and behavioural responses of piglets to tail docking, and observed it was effective in reducing the behavioural response during and immediately after the procedure. Similarly, the use of a wound spray with povidone iodine and lidocaine has been shown to reduce behavior associated with pain due to tail docking and bleeding, and to improve healing, while doing nothing at processing might increase the rate of infections and abscesses and slow the healing process (Strobel and Hawkins, 2012).

Responses to tail docking

Acute responses to tail docking

Tail docking causes acute trauma and pain (Sutherland *et al.,* 2008). Different authors have used various parameters and physiological indicators to measure the stress response to this procedure.

Cortisol

Prunier *et al.* (2005) measured the plasma patterns of stress indicators (cortisol, ACTH, glucose and lactate) in 1-day old piglets that were submitted to tail docking (using heated cautery clippers), sham-cut or non-handled. The Authors observed no effect of the experimental procedure on blood parameters. Even though the experimental data were too scarce to lead to a definite conclusion, the authors formulated three different and independent hypotheses to explain these results, including the possibility that the pituitary-adrenocortical axis might be not responsive to stress in 1-day-old pigs, that the nociceptive stimuli due to tail docking might be not sufficient to elicit a physiological stress response, and on the contrary that the manipulation of the animals associated with blood sampling may have masked the effects of the experimental procedures. Sutherland *et al.* (2008) performed a similar experiment using 6-day-old piglets. They were allocated to one of two treatments: docked (with blunt trauma cutting or hot iron cautery) at a length of 2 cm or non-docked (sham-cut). Cortisol concentrations at 60 min after the procedure were significantly higher in the blunt trauma than in the iron cautery or non-docked

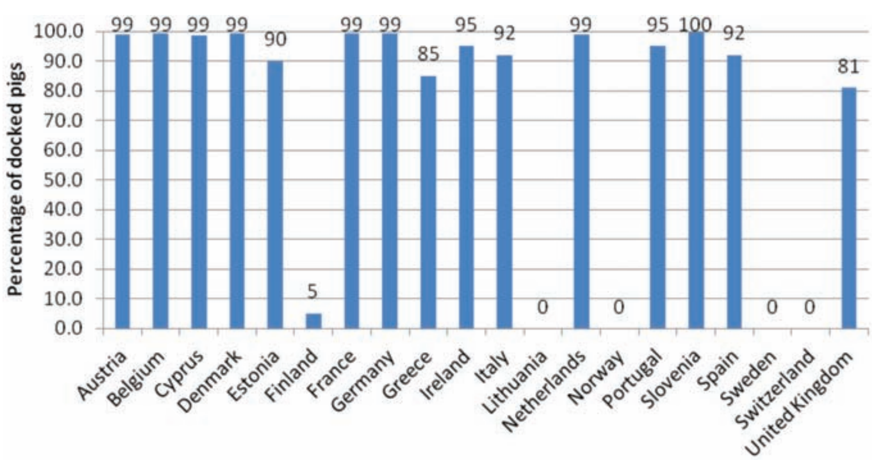

Figure 1. Percentage of docked pigs in some European countries (adapted from EFSA, 2007).

group. Interestingly, the cortisol response to tail docking was similar between hot iron cautery and sham-cut piglets, indicating that the stress experienced by piglets during handling might *per se* mask the response to tail docking by hot iron cautery. Nonetheless, based on their findings, the Authors concluded that blunt trauma cutting caused a greater acute cortisol response to piglets, being the most stressful among the treatments studied. Marchant-Forde *et al.* (2009) measured cortisol variations after tail docking comparing side-cutter pliers and gas heated cautery clippers in 2, 3, and 8 days old piglets. Blood samples were taken at 45 min, 4 h, 48 h, 1 wk and 2 wk post-procedure and assayed for cortisol and beta-endorphins. According to their results, there was no effect of treatment on either cortisol or β-endorphin concentration post-procedure.

Table 2. Prevalence of tail biting: comparison between EFSA survey (EFSA, 2007) and scientific literature (Taylor *et al.*, 2010)

Country	EFSA survey: % of tail bitten pigs (EFSA, 2007)	Location	Type of data collection	Scientific literature % of tail bitten pigs	Prevalence level	Number of pigs in study	Reference
Austria	30 of farms with bitten pigs 20 to 30 of bitten pigs in those affected farms	-	-	-	-	-	-
Belgium	2-5°	Farm	Scientific study	2.12%	Pigs	38,559	Smulders *et al.* (2008)
		Farm	Scientific study	14.3%	Pen	38,559	Smulders *et al.* (2008)
Cyprus	1-2°	-	-	-	-	-	-
Denmark	1.2 to 3.1	Farm	Clinical exam	Mean 1.2%	Pigs	151,000	Busch *et al.* (2004)
		Abattoir	Meat inspection data	Mean 0.62%	Pigs	151,000	Busch *et al.* (2004)
		Farm	Scientific study	1.26%	Pigs	154,347	Petersen *et al.* (2008)
England	0.9	Farm	Specialist visit	in the last 3 months 1.2%; slatted systems 2%; on straw 0.4%	Pigs	400,000	NADIS (2013)
		Abattoir	Scientific study	4.27%	Pigs	62,971	Hunter *et al.* (1999)
Estonia	1°	-	-	-	-	-	-
Finland	<5 (up to 30 for the whole life span, considering minor lesions) °	Abattoir	Scientific study	34.6%	Pigs	10,852	Valros *et al.* (2004)
		Farm	Specialist visit	8%	Pigs <25 kg	16,000	Tiilikainen (2000)
Ireland	3°	Abattoir	Scientific study (Republic and Northern Ireland)	58.1% detectable lesions 1.03% severe lesions	Pigs	35,288	Harley *et al.* (2012)
Italy	Not assessed	Farms	Scientific study	0.05% (weaning units); 0.34% (fattening units); 0.15% (total)	Pigs (mostly tail-docked)	79,780 heavy pigs (30 farms)	Scollo *et al.* (2013)
Latvia	50 (mainly in big, intensive standard commercial farms) °	-	-	-	-	-	-
Netherlands	1°	Abattoir	Meat inspection data	<1%	Pigs	550,000	Elbers *et al.* (1992)
Portugal	5-50°	-	-	-	-	-	-
Slovenia	<1°	-	-	-	-	-	-
Sweden	1.3-1.5	Abattoir	Routine	1-2%	Pigs	Swedish national herd	Holmgren and Lundeheim (2004)
		Farm	Animal Health Service	2.7%	Pigs	233 fattening barns	Holmgren and Lundeheim (2004)
		Abattoir	Routine inspection	1.9%	Pigs	15,914	Keeling and Larsen (2004)
		Abattoir	Scientific unit	6.2% and 7.2%	Pigs	7682 + 8232 (15,914)	Keeling and Larsen (2004)
		Abattoir	Scientific unit	7.0 -7.2% (injury or shortening)	Pigs	15,086	Keeling *et al.* (2012)
Norway (non UE country)	1-2°	Abattoir	Meat inspection data	2.3%	Pigs	255,000	Flesjå and Ulvesaeter (1979)
Switzerland (non UE country)	0.6 to 1.6	Farm	Scientific Study	Traditional farms: 35% (pigs) - 8% (groups); *animal friendly* farms: 5% (pigs); 0.6% (groups)	Pigs/groups	84 farms	Cagienard *et al.* (2005)

°Figures based on EFSA's experts opinion. France, Germany and Spain were not assessed by EFSA nor specific further data were found in recent literature.

Haematology

Sutherland *et al.* (2008) examined haematological values in animals docked using blunt trauma cutters and cautery iron. Total WBC (white blood cells) counts declined in both procedures when compared to their controls (sham-docked) at 30 min post docking, but returned to baseline values 30 min later. The controls showed no variations in total WBC during the observation period. The authors assumed that the changes in this value were due to a result of stress-induced leucocyte trafficking. More recently, Sutherland *et al.* (2009) found no difference leukocyte counts, differentials, and neutrophiles-to lymphocyte ratios of pigs treated with hot iron cautery, cold blunt trauma cutting, or sham-docked (controls) at 3 or 7 weeks post-treatment.

Other blood parameters

C-reactive protein along with haptoglobin has been demonstrated by Eckersall *et al.* (1996) as a good indicator for the identification of inflammatory lesions in pigs. Sutherland *et al.* (2009) measured C-reactive protein to evaluate the acute phase response in 6-day-old piglets that underwent hot cautery and blunt trauma tail docking comparing them to controls (no treatment). Two blood samples were taken: the first at 3 weeks and the second at 7 weeks of age. At 3 weeks no difference was recorded among the treatments, but at 7 weeks the control pigs showed higher levels of this indicator than the tail docked pigs. Furthermore, the Authors observed that acute phase protein concentrations were positively correlated with the severity of the tail-bit lesions, which was higher in control than in docked pigs. The overall findings suggest therefore that docking reduced tail biting, thus inflammations as indicated by lower C-reactive protein levels. Torrey *et al.* (2009) measured IgG, IgA, and IFN-γ that are considered general indicators of colostrum intake and passive transfer of immunoglobulins. The authors recorded results that corroborated those previously observed in tilapia, showing decreased plasma immunoglobulins 1 to 5 days after a stressor (Chen *et al.,* 2002). However, the differences recorded were not highly significant among the treatment groups (no handling, sham processed, and tail docking with ear notching) to elucidate the influence of these procedures on colostral IgG decline. Prunier *et al.* (2005) measured glucose and lactate concentrations to determine the changes these parameters may undergo during husbandry procedures. Catecholamines are known to stimulate glycogen mobilization, which results in glucose and lactate release. According to their results, neither tail docking nor tooth resection had marked effects on plasma cortisol, ACTH, glucose, and lactate. As mentioned above, Marchant-Forde *et al.* (2009) evaluated β-endorphin concentrations post procedure and found that there was no effect of treatment on this indicator.

Behavioural responses

Behavioural observation of individual piglets after tail docking was carried out by Sutherland *et al.* (2008). Hot cautery docked pigs spent more time sitting than cold blunt trauma cut pigs up to 15 min after tail docking, probably to relieve the sensation caused by the procedure or to protect the wounded site. Tail docked piglets (both blunt trauma and hot cautery docking) spent significantly more time scooting than their controls between 31 and 45 min post tail docking, but not afterwards (scooting was defined in the ethogram as: caudal part of body being dragged across the ground), regardless of the tail docking method. This behaviour was assumed to be performed to relieve themselves of the discomfort caused by tail docking since it is not part of the pigs' natural behaviour and was not recorded in any of the groups prior to the procedures and in their controls. However, based on the finding that at 90 min post-procedure cortisol concentrations were similar among treatments (hot cautery, cold blunt and control), the authors suggested that the transient pain and stress experienced by tail-docked animals was minimal 90 min after the procedure. Marchant-Forde *et al.* (2009) observed the behavioural responses of piglets during tail docking procedures. The authors observed two characteristic movements: the first being leg kicks and the second being escape attempts (piglets often carried out a bout of sequential kicks in attempt to escape, followed by a pause). The authors found that in both treatments (hot cautery and cold blunt trauma) escape attempts were significantly higher (almost twice the occurrences) than in sham-handled piglets. Torrey *et al.* (2009) observed the immediate effects of processing at two different ages (1 and 3 days old) on the behaviour of piglets. The processing consisted in tail docking using side cutter pliers, sham-processing or no treatment (controls). Some differences were observed in the behaviour of piglets immediately after treatments were applied. Processed piglets jammed their tail between their legs more often than sham handled or control piglets and tended also to tremble more after the procedures. Piglets processed on day 1 trembled significantly more than any piglet on day 3. General behaviour (suckling, lying alone, playing, or sitting) in the 10 min immediately after processing did not differ between sham-processed and processed piglets. No difference between treatments or day of treatment was observed with respect to nursing bouts and suckling behaviour performed between nursing bouts.

Vocalization

Some authors in the past such as White *et al.* (1995), Weary *et al.* (1998) and Horn *et al.* (1999), have suggested that high frequency vocalizations, and overall greater vocalization frequency are indicative of pain and stress in piglets. When evaluating this parameter Torrey *et al.* (2009) and Marchant-Forde *et al.* (2009) considered frequency and peak amplitude as the characteristics that should be elaborated. The second group of Authors found that pigs undergoing hot iron cautery docking emitted more squeals per second, and these calls had higher mean and peak frequencies than their controls. Calls from piglets undergoing cold treatment had higher peak frequencies than those from the control groups, but no other differences were found. The authors postulated that during the procedure the hot iron may accidentally come into contact with the tail before the docking bringing forth burns, and therefore amplifying the vocal response. Torrey *et al.* (2009) also found that during treatments, docked and ear-notched piglets vocalized at a greater average frequency and produced higher frequency vocalizations (higher than 100 Hz) than sham-processed, thus concluding that tail docking and ear notching are both painful procedures for piglets.

Conclusions on acute response to tail docking

Tail docking causes acute stress and pain, regardless of the method used. A number of different studies reached the same conclusion using different welfare indicators, such as cortisol concentrations (Sutherland *et al.,* 2009; Marchant-Forde *et al.,* 2009), haematological values (Sutherland *et al.,* 2008, 2009), behavioural responses (Sutherland *et al.,* 2008; Marchant-Forde *et al.,* 2009; Torrey *et al.,* 2009) and vocalizations (Marchant-Forde *et al.,* 2009; Torrey *et al.,* 2009). However, pain duration was generally reported as minimal (Sutherland *et al.,* 2008; Torrey *et al.*, 2009) and stress response is usually lower in intensity when compared to castration (Prunier *et al.,* 2001, 2005).

Long-term effects of tail docking

Little work has addressed the chronic effects of tail docking on animal welfare. This lack of scientific studies is probably due to the difficulties in correctly evaluating chronic pain and chronic stress in domestic animals. These conditions may not be apparent to the observer, since the commonly used behavioural and physiological variables are usually more helpful in detecting acute rather than chronic conditions (Anil *et al.*, 2002). Indeed, chronic stress has major consequences on animal welfare, and a long-lasting situation in which the animal cannot restore its homeostasis may lead to chronic stress symptoms with a prepathological or even pathological character (Wiepkema and Koolhaas, 1993). Responses to chronic pain may include alterations and cautious behaviour in movements and posture, avoidance of pain-aggravating stimuli, seeking of pain-relieving factors and environments, self-care of a painful region (licking or grooming), and signs of stress. During chronic stress, undesirable effects on health, reproduction, growth and behaviour may also occur.

Weight gain

Marchant-Forde *et al.* (2009) evaluated the effect that tail docking procedures had on growth rate. Piglets were weighed immediately before tail docking and then at 24 h, 48 h, and at two weeks post-procedure. The authors reported that the hot cautery docking had a negative influence on growth rate up to 14 d post-procedure, resulting in significantly lighter piglets when compared to the blunt-cut and the sham-cut treatments. Similarly, Zhou *et al.* (2013) observed that teeth clipping and tail docking reduced average daily gain up to 70 d of age, resulting in lighter body weight when compared with sham-processed pigs.

Contrarily to the above, previous studies by Prunier *et al.* (2001), did not observe any difference in growth rate during the first week post-procedure. Sutherland *et al.* (2009) also reported a different effect of treatments on live weight. According to their results, the duration of perpetrating tail-biting behaviour was negatively correlated with the live weight of pigs and the average daily gain of pigs from weaning until the end of the study. Besides, tail-biting lesions were greater in pigs tail docked at a longer length compared with conventionally short tails. Pigs live weight and average daily gain did not differ among treatments (cautery, blunt trauma or sham-cut), at weaning but did show significant differences at 7 weeks of age, when cautery-cut and blunt-trauma cut pigs had higher bodyweights than sham-cut pigs. A possible explanation of this result might be the fact that 30% of tail-biting behaviour occurred while pigs were standing at the feeder. Competition for feeder space may lead to smaller, lower ranking pigs performing tail-biting behaviour, reducing their feed intake and average daily weight gain. Taylor *et al.* (2010) extensively reviewed how individuals that become obsessive tail-biters are likely to be significantly smaller. Such an effect makes tail biting a welfare issue not only for the victims, but also for the pigs perpetrating tail-biting, and results in reduced growth rates not only of the bitten pigs (because of pain, distress and infection) but also of the biter pigs (because of competition for feeder space), increasing the economic losses for producers. According to Sinislao *et al.* (2012), the average daily gain in tail biting victims is reduced by 1 to 3%, although no differences with respect to food conversion rate or red meat percentage were observed in their study.

Chronic pain

Simonsen *et al.* (1991) and Done *et al.* (2003) suggested that the end of the amputated tail includes regressive changes of the peripheral nerves and formation of neuromas. This would justify the increased sensitivity to pain and possibly cause spontaneous pain, but at the same time would exercise a positive effect since the victim pigs would be additionally motivated to move, preventing further tail biting and potential injury (Sutherland *et al.,* 2009). In 2010, Herskin *et al.* confirmed the relationship between tail docking and the formation of neuromas in the tail tip, and found results suggesting that the formation of neuromas increases with increased docking length, observing that pigs where 75% of the tail was removed had a higher occurrence of neuroma tissue when compared with pigs in which 50% or 25% of the tail was removed (100, 79 and 41% of tails presenting neuroma tissue, respectively). The existence of changes in the sensitivity of pig tail after docking has not been demonstrated so far. However, Eicher *et al.* (2006) observed in heifers' docked tail an increased sensitivity to heat and cold. Di Giminiani *et al.* (2011) recently proposed the use of an electronic Von Frey anesthesiometer directed at the mid-section of the tail to assess the mechanical pain sensitivity in the tails of growing pigs. Similar studies (Sandercock *et al.,* 2011) conducted stimulating the tail root showed no alterations in mechanical nociceptive thresholds in tail-docked pigs, *i.e.* no evidence of chronic hyperalgesia.

Infection

Another problem that could arise from tail docking and may determine prolonged pain is infection. The tissue lesion due to tail docking may constitute a route for bacterial entry and hence favour local or systemic infection (EFSA, 2007). According to Graham *et al.* (1997), there are some evidences that lesions produced by thermal cautery in lambs delay healing, therefore chronic infection is possible to develop. On the other hand, Sutherland *et al.* (2008) observed small or no differences in wound healing between piglets that were tail-docked using cautery iron or blunt trauma cutters.

Infection is considered to be a very rare sequel to docking and much more common in tail bitten animals. Spinal abscesses can be secondary to the primary lesion at the tail, as a result of tail-biting or unhygienic tail docking (Huey *et al.,* 1996). However, experimental evidence regarding this possible consequence is scarce. According to Riising *et al.* (1976), tail docking and tooth clipping increase the incidence of fatal streptococcal infections in suckling piglets. More recently Strom (1996) suggested that tail docking, together with tooth clipping and castration increases the risk of arthritis in piglets.

Communication

Apart from somatic implications that may arise from tail docking, there is another aspect that must be considered, that being the role of the tail in the pig's life. Houpt (2005) suggests that pigs use their tail to communicate and the tail itself can be used by humans as a valuable, if crude, diagnostic tool. The pig's tail is elevated and curled when greeting, competing, chasing, courting, mounting; it straightens when the pig is asleep or dozing, isolated, ill or frightened; it twitches when the skin is being irritated. It is clear that tail docked pigs are denied the freedom of expressing their normal behaviour since the tail is a tool of intraspecific communication and interaction. Furthermore, McGlone *et al.* (1990) observed that tail postures seemed correlated with outbreaks of cannibalism. With tails tucked between their legs after an outbreak of tail biting, pigs showed an apparent chronic fear response. Also, tails being down and between their legs may provide some protection from being bitten.

Behaviour redirection

The motivation for tail biting is considered to be an extent of normal foraging activity (Taylor *et al.,* 2010), and certain individuals direct it towards the tails of pen mates as a misdirected explorative behaviour when reared in barren environments (Newberry and Wood-Gush, 1988). Fraser and Broom (1990) suggested that, in farms where tail docking is a routine practice, pigs tend to redirect tail biting behaviour to other parts of their pen-mates body such as ears and legs. To our knowledge, only a few studies have investigated the relationships between different abnormal behaviours and suggested that ear biting is linked to tail biting (Beattie *et al.*, 2005; Brunberg *et al.*, 2011). Goossens *et al*. (2008) observed that ear-biting behaviour occurred more often when tails were docked more shortly. Schrøder-Petersen and Simonsen (2001) have extensively reviewed how the two behavioural alterations have common underlying causes and often develop together.

Conclusions on long-term response to tail docking

Tail docking may have long-term consequences on the welfare of pigs, determining long-term pain and stress, limiting the capability of pigs to communicate and redirecting the biting behaviour to other body parts such as ears and legs. To date, little research has addressed chronic pain due to surgery in farm animals. Therefore further studies, involving more effective and practical ways of identifying and reducing post-operative and chronic pain are needed (Walker *et al.*, 2011).

The effectiveness of tail docking in preventing tail biting

Ample evidence for the benefits of tail docking has been provided (*e.g*., Hunter *et al.*, 2001; Sutherland *et al.*, 2009). As reviewed by Sonoda *et al.* (2013), short-docked tails are less likely to be bitten, either because they are less attractive or because it is extremely difficult for the tail biter to get hold of the tail when there are only a few centimeters left. Overall, most of these studies indicate that the incidence of tail-biting behaviour was greater in pigs with intact or long tails compared with pigs with tails docked shorter, leading to the conclusion that tail docking is effective in reducing tail biting. Scollo *et al.* (2013) observed that undocked heavy pigs showed lower cortisol levels when compared to docked pigs. This finding was associated with a higher risk of tail biting up to week 9, but lower risk of tail lesions at week 14.

However, Moinard *et al.* (2003) highlighted another important aspect. Their survey confirmed the results from Chambers *et al.* (1995) that tail docking is positively associated with tail biting. The most likely explanation for this finding is that tail docking is widely used as a supposedly curative solution on farms with a tail-biting problem. The Authors also suggested that it is likely that a farmer's response to tail biting is to cut the tails shorter. Therefore, pigs with intact tails are mainly found on farms with good conditions (as regards tail biting problems), whereas docking is widely performed on more problematic farms (EFSA, 2007). Tail docking is indeed suitable to prevent the symptoms of a behavioural disorder, but it does not resolve the underlying causes of this detrimental abnormal behaviour of pigs kept in intensive housing systems (Sonoda *et al.*, 2013). Tail biting should therefore be looked at as an indicator of an inadequate environment (Shrøder-Petersen and Simonsen, 2001) and, also according to current legislation, the appropriate environmental modifications and enrichment strategies should be adopted before resorting to tail docking on a routine basis.

Conclusions

Tail biting is performed because animals are situated in an inadequate environment, thus denied the freedom to express their normal explorative behaviour. Even though tail docking does not resolve the underlying causes of tail biting and may not be effective by itself in eliminating the detrimental behaviour, it is still considered the effective practice in the control of tail biting. However, it is clear that tail docked pigs experience pain, injury, fear and distress, and can be denied the freedom to express their normal behaviour since the missing tail is a tool of communication and interaction among them. The long-term benefits of tail docking might appear to outweigh the acute stress and pain caused by applying this procedure and to be more important than the consequences of tail biting on the welfare of the biter and the victim pigs, and this is the reason why, in spite of European legislation limiting this practice, tail docking is still widespread. However, until root causes of tail biting are understood and preventive measures are broadly adopted to abolish it, we can reasonably expect that tail docking will continue to be widely practiced. Within this framework, further research is recommended in order to improve pain alleviation during and after tail docking and to promptly detect and intervene on chronic pain and stress signs.

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