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Minimising pain in farm animals: the 3S approach – 'Suppress, Substitute, Soothe'

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Recently, the French National Institute for Agricultural Research appointed an expert committee to review the issue of pain in food-producing farm animals. To minimise pain, the authors developed a '3S' approach accounting for 'Suppress, Substitute and Soothe' by analogy with the '3Rs' approach of 'Reduction, Refinement and Replacement' applied in the context of animal experimentation. Thus, when addressing the matter of pain, the following steps and solutions could be assessed, in the light of their feasibility (technical constraints, logistics and regulations), acceptability (societal and financial aspects) and availability. The first solution is to suppress *any source of pain that brings no obvious advantage to the animals or the producers, as well as sources of pain for which potential benefits are largely exceeded by the negative effects. For instance, tail docking of cattle has recently been eliminated. Genetic selection on the basis of resistance criteria (as e.g. for lameness in cattle and poultry) or reduction of undesirable traits (e.g. boar taint in pigs) may also reduce painful conditions or procedures. The second solution is to* substitute *a technique causing pain by another less-painful method. For example, if dehorning cattle is unavoidable, it is preferable to perform it at a very young age, cauterising the horn bud. Animal management and constraint systems should be designed to reduce the risk for injury and bruising. Lastly, in situations where pain is known to be present, because of animal management procedures such as dehorning or castration, or because of pathology, for example lameness, systemic or local pharmacological treatments should be used to* soothe *pain. These treatments should take into account the duration of pain, which, in the case of some management procedures or diseases, may persist for longer periods. The administration of pain medication may require the intervention of veterinarians, but exemptions exist where breeders are allowed to use local anaesthesia (e.g. castration and dehorning in Switzerland). Extension of such exemptions, national or European legislation on pain management, or the introduction of animal welfare codes by retailers into their meat products may help further developments. In addition, veterinarians and farmers should be given the necessary tools and information to take into account animal pain in their management decisions.*

Keywords: pain, pain management, farm animals, review

Implications

The authors develop in this review an original approach integrating available knowledge in the literature in order to minimise pain in farm animals. Thus, the authors propose an approach named the '3S', accounting for 'Suppress, Substitute and Soothe' taking into account their feasibility, acceptability and availability. The first proposal is to *suppress* any source of pain that brings no obvious advantage to the animals and the producers. The second proposal is to *substitute* a technique causing pain by another less-painful method. Lastly, in situations where a painful technique cannot be avoided, treatments should be used to *soothe* pain.

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Introduction

Over the last decades, animal production science supported the modernisation of food animal husbandry in order to improve its efficacy and meet economical aims. In the mean time, society became progressively aware of and more concerned about animal suffering. Today, when animals are being increasingly bred to produce food in large amounts, the demand for a better respect of animal well-being continues to grow. One important aspect of animal well-being is the avoidance of pain. 'Freedom from pain, injury and disease' for breeding animals was early recognised by the *Farm Animal Welfare Advisory Committee* in 1967 as one of the five minimal requirements to guarantee animal welfare, known as the 'Five Freedoms' (Brambell, 1965).

The ability of feeling pain is now well recognised in most if not all farm animal species and defined in terms of an aversive sensory and emotional experience (Molony and Kent, 1997). Pain activates numerous physiological reactions initially, in evolutionary terms, targeting a protective function in a wild environment. In a controlled and protected environment like a breeding farm, pain and especially chronic pain often induces negative effects on well-being and behaviour, as well as on production criteria like growth and reproduction. However, the main obstacle in avoiding pain inflicted on-farm animal species is the difficulty in recognising and quantifying it (Le Neindre *et al*., 2009). Pain intensity is by definition an individual entity and needs to be evaluated using different criteria, as described in non-communicating humans (Herr *et al*., 2010). In addition, the evaluation of pain in farm animals is particularly challenging because of their behaviour tending to hide signs of weakness (Anil *et al*., 2002). This is probably the main reason why the existence and degree of pain have been underestimated in farm animals. Finally, it is sometimes difficult to evaluate the pain status of each individual in a barn (e.g. poultry, swine) or to treat pain in a single individual without disturbing the whole group of animals. The degree to which farm animals can feel pain must be addressed, but this requires a specific approach. A similar situation has been known in laboratory animals used for experimentation. Today, the concepts of Replacement, Reduction and Refinement, called the '3Rs' (Russell and Burch, 1959), are mandatory concerns in the design of an animal experiment to ensure that all means are used to minimise unnecessary pain and distress (Flecknell, 2002). Of course, these principles cover more largely the issue of animal welfare and ethical considerations, help in particular to have a structured approach to minimise pain in animals and to direct further research. Banner (1995) provided the first ethical frame work to deal with welfare issue considering the ethical implications of the emerging technologies in the breeding of farm animals. Mellor and collaborators stated recently that there is no doubt that significant pain is caused by many common husbandry procedures in farm animals, and humans therefore have an ethical obligation to avoid or to minimise the pain they cause (Mellor *et al*., 2008). The authors propose to challenge the necessity of common practices and to weigh benefits and advantages of painful procedures. Fisher and collaborators also proposed to avoid certain procedures by breeding animals that do not require them or to replace them by management strategies or with non-painful strategies, for example, non-surgical alternatives (Mellor *et al*., 2008). More recently, following the demand of the Ministry of Agriculture, the French National Institute for Agricultural Research (INRA) appointed an expert committee to produce a comprehensive review of pain in food-producing farm animals with the aim to find solutions. The review proposes a three-step approach. First, every effort should be made to *Suppress* the procedures or environments that are a source of pain; if this is not possible, to *Substitute* such procedures by others causing no or less pain and distress, and finally to *Soothe* pain when it cannot be avoided (Le Neindre *et al*., 2009). These three different and consecutive steps can be summarised under the '3S' approach: 'Suppress, Substitute and Soothe pain'.

This approach was used to review existing practical solutions and structure the search for new solutions to eliminate or alleviate pain in farm animals. Solutions to suppress and replace the use of animals for the production of food, although of indisputable value, were not treated in the review.

The present review presents the '3S' approach and develops a few examples to limit sources of pain. In addition, the need for further research, as well as particular limitations, and leverages of food-production environment (e.g. economical, legislative and technical constraints) are described.

Suppress the procedures that are a source of pain in farm animals but not indispensable

In some situations, the painful procedure can simply be suppressed

The first step in attempting to reduce pain and pain sources in farm animals is to identify procedures that are known to be both painful and of little use – these can be simply suppressed without negative consequences. A good example is the suppression of tail docking in dairy cows. The main justifications were to reduce faecal contamination of the udder and potential bacterial contamination and consequently mastitis to limit the transmission of zoonotic bacteria (such as leptospira) during milking and lastly to prevent environmental soiling and improve comfort of farmers due to tail switching. It has recently been confirmed that cows with an undocked tail neither present an increased risk for contamination with leptospirosis or a dirty udder nor do they produce milk of lower quality (Stull *et al*., 2002). The practice of tail docking could thus be suppressed without negative consequences (Tucker *et al*., 2001). Therefore, in the United States of America, California passed a regulation banning routine tail docking in dairy cattle and similar actions have been proposed in other states. Other countries, such as Australia, have also banned tail docking. In some European countries, this procedure is not yet banned by regulation but is scarcely implemented in routine practice. The routine of tail docking in draft horses takes place in another context. The procedure is more linked to habits based on cultural (aesthetics and increased value) and technical objectives

(Lefebvre *et al.*, 2007) than to concerns on production quality or animal health. In this case, there may be more reluctance from defenders to give up tail docking, but laws prohibiting tail docking and the discrediting of horses with a docked tail in shows and sales from professional organisations encourages its disappearance (Lefebvre *et al.*, 2007). Additional arguments can also be found when the procedure can be proven to have further disadvantages than evoking pain. For example, the absence of the tail was reported to decrease significantly the animal's natural ability to remove insects (Stull *et al.*, 2002). A similar ethical framework was already used to banish the tail docking in dog (Morton, 1992).

The suppression of certain painful procedures may need the implementation of additional measures

Before suppressing painful procedures, some additional measures may need to be implemented. Since the 1970s and the use of slatted floor, tail docking of piglets has been generalised in order to reduce tail biting. Abattoir surveys in the United Kingdom showed an increase of tail docking from 35% in 1972/1973 (Penny and Hill, 1974) to 81% in 1997 (Hunter *et al.*, 1999). Nowadays, more than 90% of the pigs are tail docked in the countries of the European Union (EU; EFSA, 2007b). Even though some data are conflicting, it is recognised that tail docking does reduce the risk of tail biting (EFSA, 2007b). Most arguments supporting this assertion come from anecdotal observations in commercial farms showing that tail biting was solved, at least in part, by tail docking. There are also data based on observations in commercial abattoirs (Penny and Hill, 1974; Hunter *et al.*, 1999 and 2001), as well as results from controlled experiments (Krider *et al.*, 1975; McGlone *et al.*, 1992), reporting a clear reduction of tail biting when tail docking is performed. However, two UK studies demonstrated the opposite in a survey (Chambers *et al.*, 1995), as well as certain farm recordings (Moinard *et al.*, 2003), probably because tail docking was used in order to solve other problems in the farms. Another very efficient way to reduce the occurrence of tail biting is rearing pigs on straw bedding (EFSA, 2007a). It seems that providing small amounts of long straw on the floor is efficient (Zonderland *et al.*, 2008) as environment enrichment strategies. However, providing straw is not possible in most Western Europe pig farms where animals are reared on slatted floor. Therefore, unless housing systems are fundamentally modified, it is not possible to suppress tail docking in pigs without taking the risk of increasing the prevalence of tail biting.

In some instances, the painful procedure could be implemented not as a routine but only when necessary

The practice of cutting piglets' teeth is common. It aims at reducing skin lesions due to biting and injuries at the udder, as well as improving maternal behaviour of sows. During and shortly after tooth clipping or grinding, piglets show some behavioural defence movements (Noonan *et al.*, 1994; Bataille *et al.*, 2002), suggesting that these procedures evoke moderate pain, but no immediate hormonal stress response could be observed (Bataille *et al.*, 2002; Prunier *et al.*, 2005). However, a high incidence of severe tooth lesions (fractures, abscess, necrosis, inflammation) was observed after tooth grinding or clipping (Hay *et al.*, 2004). These injuries are thought to be painful. In parallel, teeth shortening has been shown to reduce effectively skin lesions from biting, but to be without effect on udder injuries (Gallois *et al.*, 2005) or on maternal behaviour (Prunier *et al.*, 2004). These data suggest that teeth shortening should not be practised routinely but rather as a solution when injuries appear and when other reasons (such as insufficient milk production) are excluded. In organic farms, cutting teeth routinely is not allowed.

Controlled genetic selection can offer solutions to decrease the incidence of painful situations in farm animals

Genetic selection of farm animals may lead to some changes that could either increase or reduce the potential for conditions that lead to pain. Several cases can be distinguished: problems directly related to the selection traits, problems that are undesired consequences of selection and specific issues in which genetics may help.

An example of the first case is the stress syndrome in pigs (Backstrom and Kauffman, 1995). This syndrome is triggered by an acute stress or exposure to halogenated anaesthetic agents such as halothane. It leads to rapid death preceded by tachycardia, hyperventilation, hyperthermia, muscular rigidity and acidosis. It results from a defect of calcium recapture because of a point mutation in the gene coding for the sequence of a calcium channel, known as ryanodine receptor, in the sarcoplastic reticulum of skeletal muscle (Fujii *et al.*, 1991). The vulnerability of muscle cells is revealed by the increased plasma levels of intracellular enzymes such as creatine kinase, especially in response to stress, such as the transport of the animals to the slaughterhouse (Perez *et al.*, 2002). In pigs that carry the mutation, slaughter stress may increase the frequency of pre-slaughter deaths (Murray and Johnson, 1998; Ritter *et al.*, 2008) or lead to the production of unpalatable meat known as pale, soft and exudative because of a fast early *postmortem* pH decline and increased muscle temperature after death (Monin *et al.*, 1999). Some breeds like the Pietrain pig, with a well-developed musculature, have a high frequency of the pathological mutation, which can be explained by the fact that the mutated gene increases meat yield (Larzul *et al.*, 1997). The elucidation of the causal mutation in 1991 (Fujii *et al.*, 1991), probably the first example of molecular genetics to become operative in animal production, allowed for the selection of animals devoid of the sensitivity allele (NN). Although genetic selection has been efficiently applied in some production systems (Ritter *et al.*, 2008), the use of a terminal Pietrain sire in which the stress sensitivity allele is maintained at the homozygous state (nn) is a common practice, giving heterozygous (Nn) terminal (commercial) products (Mérour *et al.*, 2009). Heterozygous carriers have an intermediate position relative to homozygous carriers and non-carriers, with respect to growth and meat quality (Fernandez *et al.*, 2002). This practice is supported by the advantage conferred by the mutated gene on pork production (mainly increase of growth rate, feed efficiency and carcass lean yield), despite the negative effects on meat quality and stress vulnerability (Larzul *et al*., 1997; Mérour *et al*., 2009; D'Eath *et al*., 2010). This example raises the question of the balance between ethical and economical aspects of genetic selection and illustrates the resistance to implement scientific knowledge that is not directly related to production traits. However, it is worth noting that even non-carrying Pietrain pigs show a peculiar muscle weakness manifested by increased plasma concentrations of creatine kinase, typical of a myopathic condition (Foury *et al*., 2007), and a large proportion of these animals are also halothane sensitive. It is not established whether this condition is painful by itself, but it may increase stress-induced physical discomfort in the animals (Allison *et al*., 2005 and 2006). It is further worth noting that during slaughter, irrespectively of specific genotypes, selection for improved production may have negative consequences for animal health. For example, moving market-weight pigs of modern breeds over 47 m increases by two-fold the incidence of cardio-vascular problems compared with distances of 4 to 24 m (Ritter *et al*., 2008).

Similar examples can be found in cattle. Cattle of the Pyrenaica breed are genetically predisposed to muscular dystrophy and showed high creatine kinase levels when walked towards their summer pasture in the mountains (Garcia-Belenguer *et al*., 1996). Other cattle breeds present difficulties to give birth by natural ways. For example, more than 90% of Belgian Blue calves are born by the caesarean section (Hanzen *et al*., 1994). Caesarean section may be considered as an appropriate alternative to reduce pain and health risks caused by the birth of inadequately big-sized calves (Webster, 2002). However, caesarean section should be performed with adequate analgesia techniques (local anaesthesia and anti-inflammatory drugs), which appears to be the case in only 15.8% in France and 37.7% over Europe, with more than 1% of veterinarians performing caesarean section without any form of post-surgery analgesia (Guatteo *et al*., 2008). In addition to pain-related questions, the need to perform nearly systematically caesarean section raises the much broader issue of the acceptability of the maintenance of a breed that is unable to reproduce naturally (Webster, 2002; Larrère and Larrère, 2004). Some consider that the selection of animals unable to reproduce naturally infringes on their dignity (Buhk, 1999).

The above examples illustrate the need to address the question of the acceptability of the genetic selection for production traits that at the same time create biological weaknesses from other points of view (Buhk, 1999; Larrère and Larrère, 2004). The economic pressure on genetic selection is high. Recent work on cattle showed a direct relationship between market price and genetic traits (Mc Hugh *et al*., 2011). However, other examples show that negative consequences of genetic selection may be corrected for. For instance, in cattle of the Charolais breed, a specific effort was made to reduce surgical deliveries by introducing calving ability into their genetic selection index. Consequently, a positive trend towards easy calving was observed, and today 92% of calving processes are considered as easy (http://www.charolaise.fr/herd_book_charolais_chiffres.htm). Facilitated natural calving implies the selection for smaller calves at birth and an enlarged pelvis of the mother (Coopman *et al*., 2004; Mounier *et al*., 2007).

The second case concerns unwanted secondary consequences of genetic selection on other traits. One example is the effect of genetic selection on 'robustness', defined as 'the ability to combine a high production potential with resilience to stressors, allowing for unproblematic expression of a high production potential in a wide variety of environmental conditions' (Knap, 2005). Generally, increased robustness is difficult to associate with improved production levels. For example, local breeds, well adapted to their (potentially harsh) environment, have usually low absolute levels of production, although they may be high relative to the environmental constraints. Conversely, genetically selected, highly productive stocks frequently show signs of reduced robustness (Rauw *et al*., 1998; Knap and Rauw, 2008; Siegel *et al*., 2008; Star *et al*., 2008; Veerkamp *et al*., 2008). Reduced robustness may be associated with increased pain and reduced animal welfare, due to, for example, increased lameness and susceptibility to other diseases, reduced survival of newborns and lower functional longevity. The trade-off between productivity and robustness is predicted by the resource allocation theory (Beilharz, 1998; Glazier, 2008): the energetic resources of an individual are limited and their allocation across metabolic functions is optimised towards the best adaptation of the individual to its environment (=fitness). Genetic selection for production traits logically redirects resources towards these production traits, at the expense of other traits (such as robustness traits). When resources are not sufficient to support full expression of the production potential, the interaction between the selected genotype × restrictive environment may reduce the resilience of the animal. Genetic selection may further cause problems when characteristics that are not directly related to the selected traits are not sufficiently taken into account. For instance, in several species (pig, poultry), the increased frequency of painful limb disorders may be a consequence of the selection for high growth rate (Julian, 1998). Locomotor problems such as the twisted leg syndrome in broiler chickens (Le Bihan-Duval *et al*., 1996) or dyschondroplasia (or osteochondrosis) in broilers (Sheridan *et al*., 1978) and pigs (Yazdi *et al*., 2000; Fukawa and Kusuhara, 2001; Storskrubb *et al*., 2010) are highly heritable and could be efficiently decreased through genetic selection. Therefore, deterioration in traits such as leg soundness, mortality rates at various stages of the animal's life and functional longevity may be avoided by including them in breeding goals and selection criteria, as shown by existing breeding programmes (Knap, 2008). Finally, there are several perspectives to improve general robustness and resilience to environmental diversity by genetic selection (Bodin *et al*., 2010; Mormède *et al*., 2011). Particularly, the discovery of molecular bases for genetic variation of complex traits will possibly reveal DNA polymorphisms that may be used for genomic selection.

Finally, genetic selection may help reduce or suppress various sources of pain, such as dehorning of cattle, harmful behaviours like aggression and various forms of heterophagy (e.g. feather pecking, caudophagy), as well as diseases. At least three genetic loci influence the presence of horns, the polled locus (on BTA1) being the most important with two alleles, P (dominant; polled or absence of horns) and p (recessive; horned; Prayaga, 2007). The existence of a genetic basis for polledness has long been suspected. Some breeds are completely polled (e.g. Aberdeen Angus or Hereford), whereas other breeds have a substantial proportion of polled animals (e.g. Norwegian red). In most breeds, a few polled bulls are available (e.g. Holstein, Charolais, German Fleckvieh), allowing increasing polledness via selective breeding. However, these animals did not usually reach the best levels of production typical of their breed and some risk existed of inbreeding, because of the limited number of polled bulls.

Diseases are a major source of pain in animals, and although pathogens are the main source of diseases the role of genetic factors in vulnerability or resistance to disease is well documented (Mirkena *et al*., 2010). The effects of genetic factors may be related to non-specific influences on neuroendocrine stress responses or to innate immunity and adaptive immunity mechanisms (Gross, 1976; Salak-Johnson and McGlone, 2007; Minozzi *et al*., 2008; Clapperton *et al*., 2009). Two examples of frequently occurring pain-inducing diseases will illustrate the perspectives opened up by genetic selection. First, footrot is a bacterial disease responsible for lameness in lambs and mature sheep. It is a major welfare problem in sheep and causes important economic losses. The influence of genetic factors on resistance to the disease has been demonstrated and several attempts to breed sheep with increased resistance to the disease were successful. Molecular genetics found that this resistance depended on the DQA2 gene of the major histocompatibility complex. Today a test for selection at the molecular level is now commercially available allowing the selection without the need to monitor the phenotypic (clinical) expression of the disease in the flock (Hickford *et al*., 2004; Bishop and Morris, 2007; Mirkena *et al*., 2010). Second, mastitis is an inflammation of the mammary gland resulting from bacterial infections. Sub-clinical mastitis is generally diagnosed by an increase in somatic cell counts (SCC) in the milk. Although heritability for mastitis ($\sim$0.04) and SCC (0.11) in dairy cattle is low, the genetic correlation between the two is high ($\sim$0.70), so that SCC can be conveniently used in selection index to reduce the incidence of mastitis in cows (Mrode *et al*., 1998; Heringstad *et al*., 2000; Colleau and Regaldo, 2001; Willam *et al*., 2002) and ewes (Barillet *et al*., 2001; Rupp *et al*., 2003). These examples show the potential of genetic selection and significant progress may be made by the exploration of the molecular polymorphism responsible for these genetic effects on susceptibility to disease.

Behaviour is a frequent source of painful conditions in farm animals. The most obvious of these is aggressive behaviour. Aggressive behaviour may be a normal form of social behaviour but can induce pain due to skin damage and intense stress, and may also affect negatively carcass grading and meat quality (D'Eath *et al*., 2010). Aggressive behaviour is principally observed when animals from different origins are mixed such as at the time of weaning or before slaughter in pigs. Skin and muscular-skeletal system damage are used as a proxy to evaluate the intensity of aggressive behaviour (Turner *et al*., 2006a), which is influenced by a large range of environmental factors (Guàrdia *et al*., 2009), but also by genetic factors (Turner *et al*., 2006b, 2008 and 2009), raising the possibility that phenotypic selection may be efficient to reduce excessive aggressive interactions (Turner *et al*., 2010). A large corpus of knowledge is available from human and laboratory animal studies on the molecular bases of genetic variation in aggressive tendencies (Maxson and Canastar, 2007). Several other forms of harmful behaviour are influenced by genetic factors (e.g. feather pecking and cannibalism in poultry (Craig and Muir, 1996; Buitenhuis *et al*., 2009), tail biting in pigs (Breuer *et al*., 2005)), although in most cases the aetiology is complex, and more research is necessary to allow their introduction in genetic selection schemes.

The first question before implementing a painful procedure in farm animals, especially for routine use, is to question its relevance. Nevertheless, when suppression of the painful procedure is considered unconceivable because of both its need and the absence of alternative solutions (including genetic selection), the question should be: which approach allows minimising the pain associated with this procedure? The first option is to choose the least painful procedure.

Substitute the painful procedure by the least painful procedure

Feather pecking is a commonly observed behavioural disorder in poultry that consists of pecking and damaging the feathers of other birds. If not controlled, this behaviour most often results in severe damage of the plumage, wounding and death (Hughes, 1982 and 1985), which can result in mortality rates up to 20% and occasionally over 50%. Being a 'multi-factorial' disorder (Hughes and Duncan, 1972; Blokhuis, 1989), various causal factors relative to the rearing environment and genetic characteristics were reported (Sharma *et al*., 1999). Debeaking or beak trimming may reduce feather pecking but result in both acute and chronic nociceptive stimuli and potentially stress and frustration. The beak is a highly specialised organ involved in various vital activities: drinking and feeding, including food selection, as well as grooming behaviour, plumage cleaning, transport of material and defence and attack (Megret *et al*., 1999; Cheng, 2006). The peripheral part of the beak is constituted of keratinised tissues, whereas its central part is ossified and surrounded by innervated tissues containing mechanical and thermal nociceptors. The presence and distribution of these receptors are not uniform between the lower and upper mandibles, or across species. The short-term neurological consequences of debeaking were shown by recordings of the electric activity of sensory fibres innervating the lower part of the beak in chicken (Gentle, 1991). Discharges were observed during the 4 h following hot-iron beak trimming. After this initial phase, there is a period of relative electrophysiological and behavioural insensitivity (24 to 48 h). Another indicator of acute stress resulting from the procedure is the increased variation of the heart rhythm, with the exception of 1-day-old chicks (Glatz and Lunam, 1994). Apart from these acute effects, the long-term neurological consequences of debeaking are the risks for neuroma formation resulting from the uncontrolled extensive regrowth of the schwann cells and nerve fibres. In chickens, the risk increases with the size of the section and age at which it is performed ($<$4 weeks, $\geqslant$4 weeks; Breward and Gentle, 1985). Moreover, these effects are not systematically reported probably because of the differences in the procedures used, the age at which it is carried out (at time of hatching or before 10 days), the degree of amputation (debeaking or beak trimming $<$1/3), the technique used (cauterising, beak-trimming techniques, hot blades or the infra-red radiation technique) and the implementation of specific managing measures (e.g. water dispenser for a few days post-operatively). For example, Gentle *et al.* (1997) and Lunam (2005) showed that beak trimming of the upper beak ($<$50%) at 1 or 2 days of age, rather than at 10 days of age, did not induce neuroma formation (at 70 days of age) and it also induced less immediate behavioural changes. However, although beak trimming at a very young age may be preferable from the point of view of nociception, re-trimming at a later age may be necessary in some poultry species or breeds, with negative consequences for animal welfare (Rochard *et al.*, 2008).

Another example is the disbudding and/or dehorning cattle, which are often part of routine procedures, especially in dairy cattle. Dehorning refers to the removal of horns and is most frequently used in adult cattle, whereas disbudding involves the removal of horn buds and mainly concerns young calves. One of the main reasons for the procedure is to increase security during handling and transport both for humans and for the cattle. In addition, dehorning/disbudding may decrease interference from dominant animals at feeding time. Finally, carcass wastage due to bruising is twice as high in horned compared with dehorned cattle (Goonewardene *et al.*, 1999). In this example, the procedure is painful, but refraining from it may also cause pain. In this case, the question of pain management is central and the challenge is to determine which method to dehorn and/or disbud cattle is least painful. The most frequent procedure, at least in dairy herds, is disbudding, and can be achieved using different techniques: cauterisation, rubbing or covering the horn buds with chemical substances or amputation with a scoop. On the basis of a review of the available literature, Stafford and Mellor (2005) stated that disbudding at a young age should be preferred to dehorning in adults. Among several disbudding methods, it is recommended to use the cauterisation method, as it produces lower stress responses, and to debud as early as possible, preferably before 3 weeks of age (Sylvester *et al.*, 1998; Stilwell *et al.*, 2004; Stilwell *et al.*, 2007).

Castration of male calves reared for beef production is also a common procedure. Methods of physical castration involve surgical removal of the testes, or damaging the testicles by interruption of its blood supply using a castration clamp (Burdizzo castration), rubber ring or latex band (Kent *et al.*, 1996). For all techniques and at all ages, castration is believed to be painful (Molony *et al.*, 1993; Robertson *et al.*, 1994) with acute (Stafford *et al.*, 2002; Ting *et al.*, 2004), as well as longer-lasting components (Ting *et al.*, 2003a and 2003b; Thuer *et al.*, 2007). The castration clamp method (Burdizzo) appears to induce the least acute and longer-lasting pain responses in calves (Stafford *et al.*, 2002) and is recommended for use, although producers sometimes refuse to use it because of the higher probability of failure. The age of the animal also plays a role in the pain response to castration, with less pronounced pain responses in younger compared with older calves. Thus, following castration, the cortisol increase was lower in calves of 6 rather than 42 days of age (Robertson *et al.*, 1994), and increases in plasma cortisol, acute-phase proteins and scrotal swelling were less pronounced in calves of 1.5 rather than 5.5 months of age (Ting *et al.*, 2005). Even if the Burdizzo method in very young calves is recommended, castration is a painful procedure and requires additional pain medication (Robertson *et al.*, 1994). Immuno-castration using vaccination, as already used in South America could also be an alternative.

Although such routine procedures are known to be painful, few studies have compared the pain associated with the different methods that can be used. To minimise pain related to routine procedure, further research into the development of alternative methods is needed. However, using the least painful procedure does not usually mean total alleviation of pain, additional pain management is required. In other words, pain has to be soothed.

Soothe pain caused by procedures considered unavoidable

When painful procedures are considered unavoidable for efficient animal husbandry, the associated pain needs to be alleviated with appropriate treatments. The present section will develop only the pharmacological treatment of pain. However, such treatment may require to be associated with appropriate management such as the isolation of the treated animal in a nursery room allowing it to remain undisturbed, to increase its resting time and to facilitate its access to water and food, as well as the avoidance of stress or coercion to move (Anderson and Muir, 2005).

Pharmacological treatment of pain is well described in pets but also in cattle. It is generally recommended to administer analgesics before and after any noxious intervention (e.g. surgical procedure) whenever possible, and to treat pain each time it can be recognised (Anderson and Muir, 2005; Levionnois and Guatteo, 2008). The main treatments used are local or regional anaesthesia and non-steroidal anti-inflammatory drugs; however, in some circumstances other analgesics or sedatives may be indicated. For instance, local anaesthesia was found efficient to treat pain due to castration in many species. Desensitisation of the spermatic cord or intratesticular injection was also efficient to reduce pain during and shortly after castration in calves (Mellema *et al.*, 2007) and stallions (Haga *et al.*, 2006). In piglets, several techniques for the use of local anaesthetics were described to provide short-term analgesia (White *et al.*, 1995; Haga and Ranheim, 2005; Ranheim *et al.*, 2005; Haga *et al.*, 2006; von Borell *et al.*, 2009). Before disbudding calves and dehorning in cattle and goats, it is recommended to sedate the animal (McMeekan *et al.*, 1999; Stafford *et al.*, 2003; Stewart *et al.*, 2009) and to administer a local anaesthetic (Lepkova *et al.*, 2007). Nevertheless, sedated calves could be unable to react to pain due to strong muscular relaxant effect of xylazine (Stilwell *et al.*, 2010). Although loco-regional techniques desensitise the tissue during the procedure and reduce subsequent pain, anti-inflammatory drugs allow additional benefits counteracting the longer-lasting pain induced by inflammatory reactions. The association of a non-steroidal anti-inflammatory agent with a local anaesthetic has been proven effective in surgical contexts (Ting *et al.*, 2003a and 2003b; Anderson and Muir, 2005; Stilwell *et al.*, 2008). Pain may also be induced by many diseases. Such pain can often be significantly reduced by administration of anti-inflammatory drugs as was shown for lameness (Desrochers, 2004), mastitis (Erskine *et al.*, 2003) and abdominal pain.

Unfortunately, some surveys reveal that the use of analgesic drugs is not as widespread as it should be. In Switzerland, 15% of veterinarians neither used local anaesthetics nor sedation for the castration of calves (Boesch *et al.*, 2006). In Canada, 8% and 40% of veterinarians never used local anaesthetics or sedative drugs when dehorning calves, respectively (Misch *et al.*, 2007). In a European survey, veterinarians used local anaesthetics in only 70% of castration or dehorning procedures, and administered non-steroidal anti-inflammatory drugs in only 50% of the cases of severe foot pain and 38% of caesarean sections (Guatteo *et al.*, 2008). Furthermore, some routine procedures like castration or dehorning are also performed frequently by farmers, and more than 60% of them declared that they never use any analgesic treatment to soothe pain (Boesch *et al.*, 2006; Misch *et al.*, 2007; Guatteo *et al.*, 2008).

In addition to historical and cultural reasons, the use of analgesics in production animals is limited by economical, practical and legislative issues. Concerted actions between scientists, politicians and stakeholders of the production chain are needed to find solutions and generalise the treatment of pain in farm animals. One problem could be the concern of consumers regarding drug residues. This could be solved if the pharmacological products are delivered with clear information relative to their use, allowing better acceptance by the consumer. This principle is used by organic production systems, even though the primary objective of those systems is to avoid pharmacological treatments as much as possible.

Sometimes, it is difficult to relieve pain. As pain is an individual condition, it is sometimes impossible to recognise pain and treat it individually in a larger group of animals. Farmers would need to observe animals easily and without disturbing them, to isolate and treat them individually or, even better, to avoid isolation stress, in small groups. The use of analgesics, like the administration of local anaesthesia, should also be facilitated. In some countries, only veterinarians are allowed to administer them, increasing the cost and reducing the practicability. In other countries, such as Switzerland, a licence is delivered to farmers who have followed a specific training course.

Finally, the legislation on the use of pharmacologically active substances in production animals is restrictive. It is strictly limited to the licence of a given drug to be used in a given species and in specific circumstances. In addition, although in most countries non-steroidal anti-inflammatory drugs exist for many species, their use for post-operative farm animal analgesia is not an indication. Local anaesthetics are not allowed in all countries. As the development and licensing of new drugs is a long and complicated procedure, it is important that existing drugs are optimally used. Today, there is an urgent need to facilitate and rationalise the use of analgesics in production animals as part of everyday practice.

A case study of the 3S integrated approach: castration of piglets

Approximately 80% of the 250 million male piglets that are reared yearly in the EU countries are castrated surgically (Fredriksen *et al.*, 2009). In many countries, pigs for meat production are usually slaughtered at 100 to 115 kg live weight at an age of 150 to 160 days when testes are well developed and secrete sex steroids. Male pigs are castrated first to improve meat quality by avoiding boar taint, a specific odour and taste unpleasant for the consumer, occurring in a certain percentage of the carcasses of entire males and, second, to facilitate management by reducing behavioural problems like mounting and aggression (EFSA, 2004b). Although castration may be legally performed by the farmer without anaesthesia and analgesia until 7 days of age (directive 2001/93/EC), available evidence shows that surgical castration at any age is painful (Prunier *et al.*, 2006; von Borell *et al.*, 2009). To improve the problem, three main alternatives can be considered (PIGCAS, 2008):

- Rearing entire males (*Suppress*). Rearing entire males has advantages in terms of work load, pain, animal health and feed efficiency, but may also cause problems as indicated above (EFSA, 2004a; von Borell *et al.*, 2009; Zamaratskaia and Squires, 2009). Rearing entire males is systematically applied in United Kingdom and Ireland or at a very large scale in some southern countries like Spain and Portugal (Fredriksen *et al.*, 2008). To reduce the risk of boar taint, pigs are slaughtered at a slightly lower weight than in other European countries. Another solution may be the genetic selection of animals with low levels of boar taint, which would help generalise the production of entire males (EFSA, 2004a; von Borell *et al.*, 2009; Zamaratskaia and Squires, 2009). This solution seems possible but is expected to need several years of study and development, given the complexity of the mechanisms that are involved and the possible negative side effects on reproductive performance.

- Performing immunological castration by vaccinating male pigs against GnRH, a hormone stimulating testicular activity, 4 to 6 weeks before slaughter (*Substitute*). A vaccine (Improvac®) involving two subcutaneous injections is already available for farmers in Europe. Immuno-castration has a cost that can be partly or totally compensated by a reduction of feed costs and a potentially higher price for leaner carcasses. There is a risk of self-injection even if devices have been developed to protect the operator. The development of immuno-castration might also be hindered by the possible rejection by consumers as demonstrated in a prospective survey in Switzerland (Huber-Eicher and Spring, 2008) but not in Sweden (Lagerkvist *et al*., 2006) or Belgium (Vanhonacker *et al*., 2009).
- Performing surgical castration in anaesthetised animals associated with the use of analgesic drugs to relieve pain during castration and the following hours (*Soothe*). This technique is already applied in commercial farms in Norway (local anaesthesia with lidocaine in most cases (Fredriksen and Nafstad, 2006), in Switzerland (general anaesthesia with isofluorane; Schulz *et al*., 2007) and in the Netherlands (general anaesthesia with CO_2; Gerritzen *et al*., 2009). Performing surgical castration with anaesthesia and analgesia has a cost that can be very high, especially if a veterinarian is required (de Roest *et al*., 2009), which is compulsory in some countries (Norway for example). Other drawbacks are that the pain may not be totally removed and that anaesthesia can be stressful (Prunier *et al*., 2006; von Borell *et al*., 2009).

In summary, all the existing solutions are open to further improvement. Further developments may be expected, taking into account market opportunities and constraints, new knowledge regarding the role of genetics and rearing techniques in boar taint reduction, boar taint detection at slaughter plants and also new ways of administering anaesthetics.

Case study 2: beak trimming

Partial amputation of the beak or beak trimming is the most common method to prevent or reduce feather pecking. Prevalence of feather pecking depends not only on species but also on genotypes or breeds within poultry species. For example, feather pecking is mostly seen in white egg-laying hens, turkeys and Muscovy ducks. Risk increases further with age, and consequently beak trimming is extensively used in breeding flocks with longer lifespan (revived by Hughes and Gentle, 1995; Fiks van Niekerk and de Jong, 2007). To improve the situation, three main alternatives can be considered:

- *Suppression* of beak trimming can sometimes be considered; for instance, several Northern European countries banned it. Some, as the Netherlands, do have a ban but associated with a long-term derogation. In any case, these countries produce only few turkeys and Muscovy ducks facilitating the implementation of the ban. In addition, they produce laying hens of the Leghorn breed, which displays much lower levels of feather pecking disorders than brown egg-laying hens. Possibly, in future, genetic selection may provide a solution, as the expression of feather pecking prevalence is heritable. Several experimental divergent selection programmes successfully reduced the phenomenon (Craig and Muir, 1996; Muir, 1996; Kjaer *et al*., 2001; Chapuis *et al*., 2003). However, today, non-feather pecking lines are not yet available for most commercial production systems as the expression results from complex social interactions. Further studies are needed.
- *Substitution* of earlier beak trimming by more modern techniques is at least a partial improvement. The beak-trimming procedures consist of removing the end part of the beak, using various techniques and tools such as small clippers, scissors or hot blades. The latter are preferential as they ensure simultaneously cutting and cauterisation. In addition, the proportion of the beak that is removed and the age of the birds when it is applied may also vary. In the early development of the laying hen industry, it was common practice to carry out beak trimming on older birds (~16 to 18 weeks), but this practice was discontinued when experiments showed that this could cause neuroma formation and hypothetically phantom limb pain (see also above Breward and Gentle, 1985; Duncan *et al*., 1989; Gentle *et al*., 1990; Gentle, 1991; Gentle *et al*., 1997). Applying the beak-trimming procedure to younger birds (<10 days) appeared to avoid the long-term chronic impact that can occur in the stump of the beak when older birds are beak trimmed (Breward and Gentle, 1985; Duncan *et al*., 1989; Gentle *et al*., 1990; Gentle, 1991). Currently, there is much interest in the use of a novel infra-red beak treatment as an alternative to hot-blade beak trimming. The procedure (carried out on 1-day-old chicks) involves focussing a high intensity infra-red beam at the tip of the beak, which penetrates the hard outer horn and damages a clearly demarcated zone of the underlying dermis and sub-dermal tissues. One to three weeks later, the tissue behind the damaged area heals and the beak tip is lost. During treatment, the chick's head is firmly retained in a rubber holder that prevents movement of its head, enabling precise and reliable treatment of the beak. The technique minimises operator error and inconsistency, although it still requires the chick to be restrained, and subsequently leaves the chick with a shortened beak (FAWC, 2007). The use of this procedure is expanding rapidly, although specific equipments have to be set up according to species, or even breeds. Applied to 1-day-old Muscovy ducks, the use of the infra-red technique reduced feather pecking throughout the production life, in contrast to manual beak trimming using scissors (Rochard *et al*., 2008).
- *Soothing* nociceptive stimuli induced by practices considered unavoidable may be difficult in birds, because of their anatomical and physiological differences compared

with mammals. Today, we lack knowledge and analgesics for the use in birds. For example, their use has been described for mass sterilisation in pigeon and explored for broiler caponisation; however, negative side effects were observed and the method cannot be recommended presently (Martrenchar *et al*., 2001).

In summary, the efficiency of strategies to *soothe* nociceptive stimuli and stress in birds remains difficult. Significant progress was made by the *substitution* of earlier by earlier and better beak-trimming techniques (hot-blade and more recently infra-red laser) involving its application to very young birds, and the use of hot-blade and more recently the infra-red laser beam technique. *Suppression* of beak trimming induced impacts may be most easily obtained using genetic selection programmes. The identification of genetic markers (quantitative trait locus, single nucleotide polymorphism) combined with the new tools such as genomic selection may provide ways to minimise feather pecking.

Discussion

In commercial farms, pain management is frequently restricted to the treatment of pain, whereas the relevance or the necessity of painful procedures is rarely addressed. The objective of the 3S approach presented in this paper is to propose a structured and standardised strategy to reduce pain due to husbandry procedures. In some cases, depending on the definition of the procedure used, different interpretations of the 3S are possible. For example, regarding castration of pigs, the use of vaccination could be considered both as a 'suppress' solution (no surgical castration) or a 'substitute' solution (less-painful procedure than surgical castration, but still castration). However, in both cases, the 3S approach will help construct a strategy and be beneficial to the animal, which is its goal. Overall, the objective of the approach is to improve animal husbandry conditions or at least help identifying research priorities.

To allow a full implementation of the 3S approach it will be necessary to increase our knowledge on pain in farm animals:

- More work is necessary to develop tools to identify pain and to evaluate its intensity and type, depending on the nature of the painful stimulus, the animal species, the developmental stage and genetic predisposition to pain for instance. The availability of a pain scale is a prerequisite to evaluate the acceptability of a procedure and possibly consider its *suppression*, or its *substitution* by another procedure, or to evaluate the efficiency of strategies to *soothe* pain.
- Further research is needed on pain mechanisms across farm animal species and their phylogenetic bases. It is known that the peripheral components of nociception are widely present in various animal phyla. Although the emotional components of pain are increasingly studied in humans, little is known for non-human mammals and even less for birds and fish (see Le Neindre *et al*., 2009 for an extensive discussion and bibliography). A cross-phyla analysis is critical to avoid or limit excessive anthropomorphic interpretation of clinical signs that may be related to pain (Rose, 2002 and 2007).
- Other investigations should involve the careful analysis of the interaction between the animal characteristics and the environment in the development of pain. In several cases, like lameness, production diseases, disease susceptibility and behavioural deviations, the painful condition results from a complex interaction between the environment and the animal that has been more strongly selected for production than for robustness traits. The development of genetic strategies to improve these so-called functional traits is of primary importance to the reduction of pain in farm animals.

Alleviating pain in farm animals may have financial costs during the implementation step when adaptations of the production system are needed, or more durably, in the case of large-scale use of analgesics or local anaesthesia for instance. However, many studies have shown that reducing pain after some procedure is economically beneficial. For instance, a review by Bretschneider (2005) indicates that weight loss increases quadratically as the age of castration is increased, regardless of the method used. Therefore, although controlling pain could look like economically disadvantageous (increased treatment costs), there are many studies proving it to be economically sound (decreased loss of income). Recent history has shown that in-depth changes in production systems to improve animal welfare are possible. The European Community has played an active role in the application of increased consideration of animal well-being from a holistic point of view. For example, the European legislation has imposed minimal animal welfare standards relative to domestic markets, slaughter procedures and international trade. In the same way, to reduce pain inflicted on farm animals, legislation may facilitate the use of pharmacological substances in animal production or impose modifications of production systems to take into account animal pain. It is expected that in the near future the European Network of Reference Centres for the protection and welfare of animals will be developed, with the objective to label products on the basis of the welfare of animals in production units and throughout the food chain (http://ec.europa.eu/food/animal/welfare/farm/docs/options_animal_welfare_labelling_report_en.pdf). Several initiatives may contribute to this goal, including the Welfare Quality® project that was designed to develop European standards for on-farm welfare assessment and product information systems and practical strategies to improve animal welfare (www.welfarequality.net). Similarly, the new European council regulation on animal protection at the time of killing implements an animal reference centre or network in each Member State to facilitate the exchange of new knowledge and techniques (Council Regulation (EC) No. 1099/200).

In addition, voluntary schemes involving farmers could be encouraged by public authorities (in line with agri-environmental schemes in Europe). Such schemes have a cost and could be financed either by public finances or by increased market value through labelling systems. This would allow farmers to include pain management in their rearing practices. The enforcement can be managed either by public authorities (as is the case for animal welfare) or by private firms through private standards. Such standards are flexible tools and are increasingly being developed by retailers to control quality specifications with which their suppliers have to comply with. At the present time, these specifications target mainly food safety and sometimes social or environmental aspects of production or animal welfare (Fulponi, 2006). It would be interesting to consider the inclusion of pain alleviation in such schemes.

A crucial question is whether pain management does increase the market value of animal products to compensate possible increases in production costs. Improved pain management would need to be part of consumer expectations. Today, these expectations are hard to predict. Each example presented in the present paper was specific for a species and a procedure and may impact different consumers in different ways. For instance, piglet castration deals with pork taste and animal pain due to castration. Immuno-castration may avoid surgical castration but raises the question of the acceptability of biotechnology and possibly increased product prices. Lagerkvist *et al.* (2006) and Huber-Eicher and Spring (2008) have studied attitudes of Swedish and Swiss consumers, respectively, to these questions. The Swedish survey shows that consumers are willing to pay on average 21% more for pork from immuno-castrated pigs. Results of the Swiss survey show that nearly half of the consumers rejected the idea of eating meat from immuno-castrated boars, whereas more than 80% accepted the idea of castration under analgesia. These different results reflect undoubtedly cultural differences, but may also be partly explained by differences in the survey procedures; for example, in contrast to the Swiss survey, the Swedish survey did not include the option 'castration with analgesia'.

Another crucial aspect is adult, continuing education, extension and field outreach relative to pain management for farmers and practitioners or technicians involved in the use of painful procedures. Several studies have described the perception and attitudes of farmers and practitioners regarding the use of local anaesthetics, for example, in the case of dehorning calves. Although both groups recognised pain management as the most common reason for use of local anaesthetics, time, cost and lack of information or skills were put forward as the most common reasons for the lack of their use (Hoe and Ruegg, 2006; Misch *et al.*, 2007). Producers who used local anaesthetics were 6.5 times more likely to involve the veterinarian in their dehorning decisions, whereas 13% of the producers were unaware of the options for pain management. The results suggest (i) that more efforts need to be taken in order to disseminate up-to-date knowledge on pain management to veterinarians and farmers and (ii) that veterinarians should take the initiative to inform their clients on the various options available for pain management (Misch *et al.*, 2007; Laven *et al.*, 2008).

The 'suppress–substitute–soothe' approach should be systematically applied to each potentially painful situation. The alternatives or solutions provided by this step-by-step analysis will be mostly specific for a given procedure and species. For example, dehorning and castration in calves and piglets should be considered independently, while taking into account the specificity of each production system, and the feasibility and the societal acceptability of the possible solutions. The main aim of this approach is to provide solutions instead of considering pain as a fatality. Finally, the 3S approach allows reconsidering constantly each painful condition or procedure in the light of its relevance, the optimal condition (at a given time) of its use, but also identifying the research questions that need to be addressed.

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