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Applied Animal Behaviour Science 92 (2005) 261–282
APPLIED ANIMAL BEHAVIOUR SCIENCE
www.elsevier.com/locate/applanim

The importance of straw for pig and cattle welfare: A review

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Available online 14 June 2005

Abstract

The provision of straw in animal production systems is widely presumed to be beneficial for the welfare of the animals. The aim of this paper is to review the scientific basis of this assumption for pigs and cattle. As there are important disadvantages (cost, labour, hygiene and incompatibility with manure drainage systems) associated with the use of straw, studies investigating whether there are suitable alternatives to straw that fulfil the same welfare functions are also reviewed.

It is concluded that straw has many positive effects on the welfare of pigs. Bedding improves the physical comfort of the floor, and—unless temperatures are high—straw enables pigs to somewhat control their microclimate thereby increasing thermal comfort. Straw also functions as an important stimulus and outlet for exploration, foraging, rooting and chewing behaviours. Pigs that are feed restricted or housed in barren environments, in particular, can be strongly motivated to express these behaviours and the inability to do so may result in behavioural problems or anomalies. In addition, it has been demonstrated that preparturient sows are highly motivated to obtain nesting material and that straw can have a beneficial effect on maternal behaviour after farrowing. Although there may be superior alternatives for each of these functions of straw separately, it remains unlikely that these alternatives can adequately replace the total combination of these functions and also offer advantages regarding hygiene, environment, labour and economics.

The importance of straw for the welfare of cattle mainly concerns floor-comfort. However, it appears that the provisioning of (high quality) synthetic lying mats, perhaps in combination with soft walking floors, may provide floor-comfort equal to that of straw. Although the consumption of straw reduces feeding motivation, and hence, the development of oral stereotypies, the behavioural function of straw is less for cattle compared to pigs. Moreover, it is possible to compose more appropriate roughage-feeds that better fulfil the behavioural as well as the dietary needs of cattle.

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0168-1591/$ – see front matter
doi:10.1016/j.applanim.2005.05.007

For both pigs and cattle, there is weak evidence that concrete flooring rather than straw is a risk factor for increased overall morbidity and mortality. However, the relation between straw and health is complex, equivocal and disease specific.

Keywords: Bedding; Housing; Comfort; Floor; Lying area; Leg injuries

1. Introduction

In Europe, animal farming systems using straw have a welfare-friendly image. What *appears to be* good welfare, however, does not necessarily *mean* good animal welfare. The answer to the question whether straw is favourable to animal welfare should be based on scientific research. The aim of this contribution is to analyse scientific literature regarding the implications of providing straw on pig and cattle welfare.

Evaluating the welfare relevance of straw from scientific literature is far from easy for several reasons viz.: (1) the composition, structure, quality and quantity of straw can be very varied; (2) there is hardly any consensus amongst scientists about the definition of animal welfare or on the way it can be assessed; (3) most studies do not specifically investigate the welfare impact of straw but discuss this item as one of many aspects of animal housing or animal management; (4) the importance of straw may vary with the age of the animals and their housing conditions and management.

With these caveats in mind, I review the effect of straw on the welfare of pigs and cattle with respect to the following categories (adapted from Fraser, 1985): (1) *comfort requirements*, provided by the texture and the draining and (thermal) insulating properties of straw; (2) *behavioural needs*, since straw can be used for expressing behaviours that they are strongly motivated to perform; (3) *nutritional requirements*, since the lack of bulk feed can be compensated by the intake of straw. In addition to the above functions, the effect of straw on (4) *hygiene and health* is also discussed.

The use of straw has considerable disadvantages as well. These include for example, higher production costs (e.g. due to the cost of straw itself, increased labour, and/or facilities to store straw) and incompatibility with slatted flooring and liquid manure handling systems. Moreover, organic bedding such as straw provides ideal conditions for the growth of many bacteria and pathogens. In this paper, it is also investigated therefore whether there are suitable alternatives to straw that fulfil the same welfare functions.

2. Pigs

The provision of straw is generally considered to improve the comfort and welfare of pigs (Arey, 1993). Although the influences of straw are complex and depend largely on pig breed, management and housing (Schouten, 1986; Edwards and Furniss, 1988), experts on pig welfare assign considerable importance to the availability of a substrate such as straw in their welfare assessments of housing systems (Anonymous, 2001; Spoolder et al., 2003). Also, many quality assurance schemes for pork such as Freedom Food (RSPCA, UK)

prescribe a production system with compulsory provision of straw or other rooting substrates. The cost of rearing pigs in such straw-based systems is (slightly) greater than in slatted systems because the lower building costs do not outweigh the extra costs of straw and labour (Gourmelen et al., 2000; Bornett et al., 2003). Moreover, small increases in production costs may have large effects on farmer incomes (Den Ouden, 1996). The EU's Scientific Veterinary Committee (SVC, 1997), therefore, concluded that the provision of straw is a relatively expensive way to improve pig welfare (with the exception of countries where labour and straw are cheap).

2.1. Comfort requirements

As pigs spend ca. 80% of their time lying (Marx and Mertz, 1989; Ekkel et al., 2003), adequate lying comfort is important for their welfare. Straw tends to ease the effects of stress resulting from concrete floors (Warnier and Zayan, 1985). A series of multiple choice tests demonstrated that piglets prefer insulating floor types to bare floors made of metal or wire mesh (Marx and Schuster, 1986). Beattie et al. (1998) reported that pigs given the choice between various floor substrates spent most of their time on peat, mushroom compost and sawdust, subsequently on sand, whereas bark and straw scored only better than concrete. The authors tentatively concluded that pigs are attracted by substrates with a similar texture to earth.

The preference for particular floor characteristics or bedding materials depends, however, on the thermal conditions inside the pig house (Morrison et al., 1987). Weaners prefer to lie on straw in a cold environment but choose bare floors at higher temperatures (Fraser, 1985; Marx and Mertz, 1989). On hot summer days deep-bedded houses may therefore lead to problems if pigs have no provisions to cool off. The preferred floor temperature may also vary according to the pigs' age (Geers et al., 1990) or the reproductive stage of sows (Phillips et al., 2000).

Installing mats in farrowing crates with slatted floors reduces the likelihood of slipping, improves the comfort of sows, and encourages the use of the heat pad by piglets (Boyle et al., 2000). Hence, mats may improve the welfare of pigs in farrowing crates but further research is required into less abrasive materials since piglets appear to have an increased risk of skin injuries with mats. Gravås (1979) indicated that piglets housed on concrete floors showed a similar prevalence of lesions to the carpus as piglets on rubber mats, but the wounds on the mats were deeper and larger. A thin layer of wood shavings has also been associated with an increased risk of forelimb skin abrasions among piglets, whereas the presence of straw has been linked to a reduced prevalence of sole bruising (Mouttotou and Hatchell, 1999). These authors concluded that straw is a suitable and resilient substrate for piglets to move and rest on; it maximises floor contact and reduces loading on the hooves.

Group housed sows show a significant preference for lying areas covered with soft mats compared to concrete floors (Tuyttens et al., 2004). It seems possible, therefore, that at least the floor comfort provided by straw might be fulfilled by synthetic mats. Such mats might overcome some of the disadvantages of the use of straw. However, neither the health consequences, the long-term durability, nor the relative preference for mats versus straw have been tested. Moreover such insulating mats provide pigs with fewer possibilities to control their own micro-climate as compared to loose bedding materials and might be

avoided by pigs when temperatures are high. Finally, such mats would have to be combined with other enrichment in order to accommodate other functions of straw such as recreation and nutrition.

In short, unless temperature is high, straw is clearly preferable and more comfortable to pigs than bare concrete floors. However, other floor substrates such as peat and compost that better resemble natural lying surfaces seem even more attractive to pigs than straw. Synthetic lying mats should also be investigated as an alternative and hygienic lying surface that might provide adequate floor comfort without complicating manure handling or increasing labour demand.

2.2. Behavioural needs

Numerous studies have shown that the enrichment of a barren housing environment with straw, peat, extra space, etc. has a favourable effect on pig behaviour. Hirt and Wechsler (1994) compared the behavioural diversity—a measure of the quality of housing from a welfare point of view—of fattening pigs in three housing systems: a strawless pen with an unstructured outside yard, an open front deep litter pen and a straw-bedded pen with an enriched outside yard. Behavioural diversity was highest in the straw-bedded pen with the enriched outside yard and lowest in the strawless pen. In another study, the provision of extra space and a rack with peat and straw resulted in less tail-biting, aggression and anti-social behaviour on the one hand and increased activity, explorative and playing behaviour on the other hand (Beattie et al., 1995). Moreover, these pigs were more open to learning particular tasks than those kept in intensive, bare confinement conditions (Sneddon et al., 2000). Other studies demonstrated similar behavioural advantages of housing systems for weaned piglets on straw versus piglets in strawless pens (Sebestik et al., 1984; McKinnon et al., 1989).

Kelly et al. (2000) compared the behaviour of weaned pigs in three different housing systems: deep-straw, Straw-Flow® (i.e. pen with strawed sloped floor), and flatdecks. Compared to pigs in flatdecks, pigs housed in both straw-bedded systems showed behavioural patterns indicative of increased welfare. Supplies of merely 50 g of straw per pig per day in the Straw-Flow® pen resulted in marked differences in behaviour (more straw-directed behaviour and less pig/pen-directed behaviour) as compared to pigs in flatdecks. Pigs in deep-straw pens received 4.4 times as much straw as pigs in Straw-Flow® pens and spent an even greater percentage of their time in straw-directed activities, rooting, chewing and playing. Behaviour directed towards the pen or group mates, however, did not differ between both housing systems. The researchers concluded that even a small quantity of straw sufficed to keep the pigs busy for most of the time and to provide welfare benefits. However, the increase in straw-directed activities and play suggested that deep-straw did provide welfare benefits over and above those of Straw-Flow®. Arey (1993) and Day et al. (2002) also reported a tendency for straw-directed behaviour to increase with the quantity of straw provided.

Scientific literature clearly demonstrates that oral behaviour of pigs housed in a barren environment devoid of manipulable substrates is often directed to pen fittings or pen-mates (Ruiterkamp, 1987; McKinnon et al., 1989). Environmental enrichment tends to reduce such undesirable behaviour. However, the above-mentioned studies and

numerous others do not allow these effects to be attributed to straw as its influence cannot be separated from other resources provided such as extra space (e.g. Buré, 1981; Ruiterkamp, 1986) or another type of housing (e.g. van Putten and Dammers, 1976; Arellano et al., 1992).

The number of studies in which the effects of straw alone have been investigated is much smaller. Fraser et al. (1991), for example, investigated the effects of straw on the behaviour of weaned piglets housed in raised decks under constant conditions (ad lib feeding, comfortable temperature and stocking density). Straw supplied in large quantities as bedding or in small quantities in a rack resulted in less rooting and chewing behaviours directed to pen-mates. The researchers concluded that for growing pigs with adequate space, feed and thermal comfort, the main function of straw consists of providing a stimulus and outlet for exploratory and manipulative behaviour involving the snout and the mouth, which could otherwise be directed to other objects in the pen or to pen-mates. That such a provision can reduce undesirable behaviour such as aggression, tail biting and stereotypy has been confirmed by numerous studies (Fraser, 1975; Burbidge et al., 1994; Spoolder et al., 1995).

However, the relationship between straw and undesirable social behaviour is complex. According to a British epidemiological study, the provision of a small quantity of straw reduced the likelihood of tail biting, presumably because a regular supply of small quantities of straw is more attractive to pigs than a deep bed system where straw is in constant large supply, but is less frequently replenished and perhaps contaminated with excreta (Hunter et al., 2001). On the other hand, the attraction of limited amounts of fresh straw may become a cause of aggressive competition over a limited resource (Morgan et al., 1998). The use of straw as a bedding substrate where animals are floor-fed has also been shown to exacerbate levels of aggression (Whittaker et al., 1999). Limited availability of straw in a rack did not suffice to completely eliminate the problem of vulva biting in houses equipped with electronic feed stations (Krause et al., 1997). Andersen and Bøe (1999) reported that the provision of straw may not be an important element in reducing aggression within stable groups of loose-housed sows. According to Arey and Franklin (1995), the provision of straw in group housing systems did not lead to a reduction of fighting in newly mixed groups either. The relation between straw and undesirable behaviour is further complicated by the level of feed restriction. Straw has a greater impact on aggression among pigs with restricted feeding than with pigs fed ad libitum (Kelley et al., 1980). Moreover, research by Olsen (2001) demonstrated that both oral behaviour towards group mates and equipment and skin injuries can be reduced among pigs by further environmental enrichment (access to other roughages and shelter) even though they were already provided with an outside run and ample straw and space.

Other substrates can be used as a stimulus and outlet for oral behaviours. A trough filled with earth for example, can reduce the frequency of passive lying down, aggressive behaviour and ear and tail biting (Wood-Gush and Beilharz, 1983; Appleby and Wood-Gush, 1988). However earth, just as straw, may block slurry evacuation channels. Supplying pigs in batteries with peat on a large tray may equally help to reduce abnormal behaviour but without blocking slurry evacuation channels (Buré et al., 1983). Durrell et al. (1997) reached a similar conclusion for sows: enriching sow pens with spent mushroom

compost on suspended racks reduced aggressive behaviour, injuries, floor sniffing and lying down with open eyes. The authors considered this solution inexpensive, practical, and that pigs may prefer such a substrate to high quality barley straw (Sneddon and Beattie, 1995).

An alternative method that is perhaps acceptable to both pig and producer consists of enriching the environment of the pigs with ''toys'' that they can bite, chew or nibble. Access to such toys has been shown to reduce aggressive behaviour amongst group mates (Blackshaw et al., 1997), excitability and fear of humans (Grandin et al., 1987; Pearce et al., 1989). However, it appears difficult to find toys which ''entertain'' pigs for the same length of time as straw does. Pigs in cages provided with chains and belts spent only 0.1% of their time with these objects whereas pigs in a deep bed pen spent over 5% of the observation time with straw (Britton et al., 1993). Pigs appear to have a preference for toys in which they can easily bite and chew. Studies have shown that they prefer a piece of cloth instead of a chain or a rubber hose (Grandin and Curtis, 1984), a rubber dog instead of a nylon rope with knots, or a rubber hose or a chain (Apple and Craig, 1992). Recently, van de Weerd et al. (2003) tested 74 different enrichment objects for pigs. Long straw in a box was the fourth most popular object at the fifth day of exposure. Overall, destructible and ingestible objects that stimulate foraging and explorative behaviour best kept the pigs' interest sustained.

Young et al. (1994) developed a device, the ''Edinburgh Foodball'', which better allowed sows to express foraging behaviour. When rooted, the device delivers small food rewards randomly, in space, time and quantity. Food-deprived gilts interacted with this device over long periods of time and preferentially directed their rooting activities at the foodball instead of straw. Furthermore, sows provided with such a foodball showed a similar foraging and activity time budget to that observed in free-range pigs which is often regarded as an indicator of good welfare.

There is also mounting evidence that straw is important for nest building behaviour by sows. Shortly before parturition the female pig is strongly motivated to build a nest. Sows have a strong preference to farrow in a bedded lying place and are prepared to gather large amounts of straw to build a nest (Arey et al., 1991). Although such observations indicate that the availability of nest building materials is important for preparturient sows, their preference for a particular product such as straw does not suffice as evidence for a real need or necessity for this product (Duncan, 1978). Arey (1992) investigated, therefore, the intensity of the motivation of sows for straw by means of operant conditioning techniques. These experiments clearly demonstrated that pregnant sows have a strong demand for straw on the day before farrowing. The demand for straw then approached the demand of an essential commodity such as food. However, the sows' preference to farrow in a bedded area depends on the amount of straw that is provided (Arey et al., 1989).

In one study, sows housed on straw during pregnancy produced more milk and heavier piglets than sows without straw (Højgaard-Olsen and Nielsen, 1966). Despite the fact that some researchers did not find a link between straw and suckling behaviour (Lammers and de Lange, 1986; Edwards and Furniss, 1988), others reported that the presence of straw in the farrowing/lactating environment exerts a favourable influence on the maternal behaviour of sows: they performed more rapid suckling grunts during nursing (which are

associated with oxytocin release and milk let down, Algers et al., 1990), more post-suckling slow grunts, more piglet-oriented vocalisations and investigations, they were more responsive to the distress vocalisations of their piglets, and they showed a shorter latency to recognition of their own piglets during a separation test (Cronin and van Amerongen, 1991; Cronin and Smith, 1992; Herskin et al., 1998). Such improved maternal behaviour did not consistently contribute to piglet survival.

In (semi-)natural environments sows use a variety of materials such as grass, straw, twigs and branches for nest building (Jensen, 1986). Damm et al. (2000) reported that when sows had access to straw and branches more structured and functional nests could be built than when only straw was provided. Nests made of straw and branches might therefore be more effective in reducing the motivation for nest building prior to the onset of parturition. Less satisfactory nests made of only straw might not induce sufficient feed-back such that some sows remain motivated to nest build for longer and are more restless during farowing.

To conclude, straw is a suitable environmental enrichment for pigs providing them a stimulus and outlet for exploratory and manipulative oral behaviours, which often—but not always—leads to a reduction in undesirable behaviour. Superior or more attractive enrichment devices are few and are, like straw, destructible objects that stimulate foraging and explorative behaviour. In addition, straw allows sows to build a nest (which they are strongly motivated to do just before parturition) and can favourably influence their maternal behaviour.

2.3. Nutritional requirements

Straw can also be a source of food, especially in restrictively-fed pigs, such as pregnant sows on a concentrated diet (Edwards, 1990). The provision of straw may buffer the adverse effects of a low food level on weight and back fat gain in group-housed sows (Spoolder, 1998). Straw may not only increase satiety but also the total time spent processing and ingesting food. According to Lawrence and Terlouw (1993), feed restriction and the impossibility to demonstrate foraging behaviour are considered as the main reasons for the development of oral stereotypic behaviour among sows. There could be two strategies to prevent the development of these stereotypies: by offering sows a sufficiently enriched environment in which they can express foraging behaviour or by reducing the sow's motivation to eat. The importance of straw as foraging substrate was discussed in the previous section. As concerns the second strategy, it has been demonstrated that the administration of copious feed rich in various fibres decreases the frequency of abnormal oral behaviours (e.g. stereotypic and adjunctive behaviours) while increasing the rest time (Robert et al., 1993; Brouns et al., 1994; Bergeron et al., 2000). The influence of straw on the motivation to eat appears to be marginal as the mixing of feed with straw does not discourage pigs to work for food (Lawrence et al., 1989; Lawrence and Illius, 1989) and does not sufficiently reduce voluntary feed intake (Brouns et al., 1995). Experiments with operant conditioning have shown that other feedstuffs rich in fibres (e.g. mixtures of sunflower meal, wheat bran, sugar beet pulp, soybean hulls, oat hulls, and corn gluten feed), however, are able to reduce the pig's motivation for eating (Day et al., 1996; Robert et al., 1997; Ramonet et al., 1999), and hence are for this particular aspect superior to straw.

Hence, there are fibre-rich feedstuffs that are superior to straw in reducing restrictively-fed pigs' motivation to eat and, consequently, in reducing the development of oral stereotypies.

2.4. Hygiene and health

Scientific literature concerning the relation between the use of straw in pig husbandry, hygiene in the animal house, and pig health is limited and equivocal. The few studies that have been published are mainly of epidemiological origin. They need to be interpreted with caution as particular effects of straw may be confused with other aspects of housing and management.

It is often assumed that straw has a detrimental influence on animal house hygiene and encourages the carry-over of diseases. Although generally pigs tend to keep their lying area free from excrement (Whatson, 1985), the use of straw bedding increases the likelihood of pigs coming in contact with manure and becoming infected with parasites as compared with slatted floors where the manure disappears below floor level. From a study by Davies and Morrow (1997), it indeed appeared that the prevalence of salmonella in manure from fattening pigs was lower with than without slatted floors. The use of straw has been identified as a risk factor for infections with *Yersinia enterocolitica* (Skjerve and Lium, 1998) and with the helminth *Oesophagostomum* (Roepstorff and Jorsal, 1990).

On the other hand, the prevalence of movement disorders, claw damage and other leg injuries is higher on concrete floors without bedding (Brennan and Aherne, 1987; Andersen and Bøe, 1999). This could explain why the prevalence of bursitis with slaughter pigs and injured knees with piglets is less when straw is used (Mouttotou and Hatchell, 1998, 1999). Straw will generally reduce the risk of leg and foot injuries, which provide an easy entrance for germs. But, unless the upper layer of the straw bedding is kept fresh and dry, the strength of the horn will decrease because of the higher water content (Kroneman et al., 1993). Furthermore, slatted floors may be more stressful to pigs and indirectly, through a reduction in resistance, lead to an increased infection risk (Straw, 1986; Flori et al., 1995). This hypothesis may explain the lower risk for influenza A infections (Ewald et al., 1994) and stomach and intestine disorders (Christensen et al., 1995; Smith and McOrist, 1998) found in straw systems compared to slatted floors. This is supported by a recent Danish study (Stege et al., 2001) on 79 pig farms where 20 samples were taken and analysed for *Lawsonia intracellularis*, *Brachyspira hyodysenteriae*, *Serpulina intermedia*, *Brachyspira innocens*, *Brachyspira pilosicoli* and *Escherichia coli*. Supplying straw to weaned pigs was associated with a lower prevalence of *S. intermedia*, *B. innocens* and *B. pilosicoli*.

Not only the morbidity, but also the mortality of pigs (Hoogerbrugge, 1987) and piglets (van Veen et al., 1985) is increased when they are housed on slats compared with straw. A survey of 44 farms to investigate the influence of housing conditions on the culling percentage of sows also indicated a higher culling percentage in strawless houses than in houses where straw was provided (Tuinte, 1971 cited in Maton et al., 1985).

To conclude, the relation between the use of straw and pig health is equivocal: some diseases/injuries are more prevalent in strawed housing systems while the opposite is the case for other diseases/injuries.

3. Cattle

Although perhaps not as prominently as for pigs, the provision of straw is also included as an important criterion in resource-based cattle welfare assessment schemes, such as the ANI 35 L/2000 (Bartussek et al., 2000). It is discussed below whether straw serves the same welfare functions for cattle as for pigs. In its comprehensive review on the welfare of cattle kept for beef production, the Scientific Committee on Animal Health and Animal Welfare (SCAHAW, 2001) recommended *inter alia* that: (1) fully slatted floors should not be used; (2) a solid lying area with bedding is provided; and (3) a minimum of 10% long fibre roughage is provided in the diet. These recommendations illustrate that the possible welfare functions of straw for cattle concern mainly floor comfort and fulfilling nutritional requirements for normal rumen function and at the same time behavioural needs related to foraging/eating. As, contrary to pigs, there is little evidence that straw is important for fulfilling other behavioural needs, both functions (nutritional requirements and behavioural needs) are discussed together for cattle.

There is a lack of published data on the costs of building, and of keeping cattle in, modern straw-based systems versus other housing systems. Boussery and Sonck (2002) compared the construction costs of a cubicle house and a littered loose house with slatted feeding area for herds of 60–120 dairy cattle. The cost per cow was estimated to be on average 15.5% lower for the cubicle house than the partly littered loose house. The latter housing type required much more space mainly for the storage of straw. However, the stocking density was also much lower in the partly littered loose house than in the cubicle house. In addition to the increased construction costs, straw-based systems are also expensive to run in countries where straw and labour are costly (Maton et al., 1985; Sonck, 1993).

3.1. Comfort requirements

Despite the fact that slatted floors have been used for many years in intensive cattle husbandry, there are many welfare concerns (SCAHAW, 2001). Numerous studies on cattle indicate that floor comfort is superior on straw than on slatted floors, with regards to both lying and walking/standing.

Cattle clearly prefer a soft lying place rather than a hard one (Natzke et al., 1982; Herlin, 1997). For example, cattle kept on concrete floors tended to lie down or stand up less frequently and displayed more abnormal movements during these transitions than animals kept on straw (Graf, 1979; Andreae and Smidt, 1982). Besides the number of lying periods, the total lying time was also reduced on concrete (Graf, 1984), or the duration of individual lying bouts was longer which may increase the likelihood of skin damage (Ladewig, 1987). Lying periods and intentions to lie down were also more frequently interrupted with cattle on slatted floors and they hesitated more before lying down (Andreae and Smidt, 1982; Ladewig, 1987). Lying down was accompanied with a greater increase of plasma cortisol concentration in bulls in slatted cubicle houses compared to bulls in littered loose houses (Schlichting et al., 1983). Bulls housed on straw tended to slip less frequently and were more active than bulls on concrete slatted floors (Ruis-Heutinck et al., 1999). Cows on slatted floors moreover displayed less oestrous behaviour, were less fertile, and produced less milk in the first lactation than cows on straw (Beneke, 1985; Mogensen et al., 1999).

Synthetic mats may be a suitable substitute to avoid or reduce the use of straw. Haley et al. (2001) showed that mats improved lying comfort and facilitated lying down and standing up as compared to concrete flooring. A preference test by O'Connell et al. (1992) demonstrated that the addition of mats in cubicles increased their occupancy over standard cubicles with concrete floors. Cramer et al. (1974) found, however, that cows prefered deep-bedded stalls with earth bases followed, in order, by rubber mats, indoor-outdoor carpet and concrete stalls. Manninen et al. (2002) tested the relative preference of dairy cows for three floor types in an uninsulated loose house: concrete with a large quantity of straw, soft rubber mat with a thin layer of straw, or 2–3 mm sand without straw. The cows avoided and laid down for the least time on sand. The cows preferred straw only above mats with straw in winter but not in summer. Generalising the results of such studies should be done with caution as the preference of cows can strongly differ depending on the type of lying mat (Sonck et al., 1999) and on the quantity of straw (Jensen et al., 1988). Sand reduces hock injuries (Weary and Taszkun, 2000), has good hygienic properties (Britten, 1994; Niles, 1994), and does not make it more difficult to get up or lay down compared to no bedding (Ekelund et al., 1998), but the preference of cattle for other bedding materials (e.g. sawdust) over sand has been confirmed by Tucker et al. (2000). However, additional experience with sand may improve acceptance of this surface (Tucker et al., 2003).

Wechsler et al. (2000) reported that although the lying behaviour of cows housed in cubicles with synthetic mats versus compact mattresses of straw or cow dung is identical, cows on synthetic mats had more minor injuries to the tarsal joint. Buchwalder et al. (2000) compared the following lying area surfaces in cubicle houses: compact straw mattresses, loose straw bedding, soft synthetic mats and conventional rubber mats. There were no differences in total daily lying-down time. The authors nevertheless concluded that loose straw beds and conventional rubber mats were of inferior quality as a lying area surface for dairy cows, as the duration of the lying down movements was prolonged and leg injuries were more frequent than with straw mattresses or soft lying mats. Weary and Taszkun (2000) reported that most skin lesions to the tarsal joints of dairy cows were found on farms using soft lying mats. The least lesions were found when sand was used as a lying bed material. The incidence and seriousness of the injuries amongst cows housed on sawdust was intermediate. According to the investigators the high incidence of injuries with cows housed on lying mattresses could not be attributed to the abrasive lying surface but might be due to the heat caused by friction between the legs and the mattress that reduced the strength of the skin.

Floor comfort in the lying areas has received a lot of attention, but walking comfort in the passageways is also of major importance. The combination of a rubber mat provided with a little bedding (finely chopped straw or wood shavings), and a rubber-covered slatted floor at the rear side, appears to be comfortable (Hultgren, 2001) as well as hygienic (Hultgren and Bergsten, 2001). Soft covers (e.g. rubber linings) on slatted floors or rubber mats on full concrete floors can, like straw, reduce the likelihood of slippage and abnormal movements during standing-up and lying-down (Koberg and Irps, 1989; Wee et al., 1989). Benz (2003) reported that cows on soft walking floors were more active, had a greater step length (equalling the step length on pasture) and appeared more confident when walking and cleaning parts of their body. Soft walking floors have also been reported to reduce lesions to hooves and joints (Wee et al., 1989; Ruis et al., 1999), to reduce physiological

signs of stress (Hänninen et al., 2003) and to have favourable effects on some production parameters (Irps, 1987).

To summarise, there is ample evidence that straw bedding provides better floor comfort to cattle than concrete floors without bedding. However, suitable alternatives to reduce or perhaps eliminate the use of bedding are available. Some synthetic and organic lying mats seem to provide equal lying comfort as straw does, although more work is required to determine how specific surface characteristics (e.g. softness, stability, friction, abrasiveness) or the use of extra bedding could reduce injuries and increase floor comfort. Such mats could be combined with rubber-lined slatted floors to provide walking comfort in passageways.

3.2. Behavioural needs and nutritional requirements

As grazing herbivores, cattle have evolved into a species that spends a substantial amount of time foraging and feeding. Under natural conditions they may graze 7–9 h daily while they need nearly the same amount of time for ruminating the ingested feed (Hafez and Bouissou, 1975). According to Redbo (1992), there could be a pre-programmed minimum duration of time spent feeding that cattle require in order to receive sufficient negative feedback on feeding motivation. Similar to pigs, a short duration of feeding may thwart feeding motivation and trigger oral stereotypies.

This was illustrated in the experiment by Redbo and Nordblad (1997) who investigated the effect of a 3-week roughage removal in heifers that at other times were fed a diet with free access to long straw. In comparison with periods during which straw was available ad libitum, the frequency of eating and ruminating behaviour dropped markedly whereas the number of animals with stereotypic behaviour (tongue-rolling, bar-biting and chain-chewing) increased when only a combination of silage and concentrates was administered. The authors therefore recommended that roughage be made available to cattle continuously. Oral stereotypies were indeed less frequently observed with cattle fed ad libitum than with animals on restricted rations (Redbo et al., 1996).

Providing straw can also have a favourable influence on the functioning of the rumen when the ration contains insufficient structure. As a result of increasing milk production, the energy content of the dairy cattle ration must be continuously increased. Administering a higher quality but less structured ration can lead to acidification of the rumen (acidosis). The administration of straw offers no complete guarantee against disorders of the rumen since not all cows are able to control their energy and roughage intake optimally (Geerts et al., 2002).

Veal calves receiving a strict all-liquid diet show some physiological abnormalities (e.g. impaired fermentation due to a poor development of the papillae in the rumen) and are unable to carry out normal activities such as masticating and ruminating (Broom, 1991). As a result they may develop abnormal oral behaviour such as tongue rolling (van Putten, 1982; Sambraus, 1985). According to Egger (1995), the demands for roughage by veal calves receiving liquid feed can be satisfied by providing them straw on a daily basis. On the other hand, supplying roughage to calves has been shown to be associated with lesions on the abomesum (Welchman and Baust, 1987). Straw alone appears to be an unsuitable solid feed for young veal calves (Toullec, 1991). Some of these physiological problems do

not occur when dry feed supplements of straw-cereal pellets are supplied (Morisse et al., 1999).

It can be concluded that straw has been shown to increase eating and ruminating behaviour and to reduce oral stereotypies. However, it seems likely that there are superior roughage feeds that better fulfil the nutritional and behavioural requirements of cattle. Contrary to pigs, there do not seem to be other behavioural needs for which the presence of straw is important.

3.3. Hygiene and health

The type of floor and/or bedding may not only have an influence on the incidence of leg lesions but also on other pathologies, mortality and hygiene. However, as is the case for pigs, the relationship between straw, hygiene and health is equivocal.

According to van Putten (1982), the advantage of straw as an insulating material in intensive veal calf farms is countered by poor hygiene. Webster et al. (1985) confirmed that veal calves reared in groups in straw yards were usually dirtier than calves housed in individual crates. Westendorp and Hakvoort (1977) found sawdust to be the best material for keeping cows in cubicles clean, followed by woodshavings and chopped straw. The poorest results were obtained with shredded paper. Other experiments, however, showed no differences in cleanliness between sawdust and shredded paper (O'Connell and Meaney, 1997). Using shredded paper as bedding material in animal houses poses some questions in connection with possible chemical contamination of milk.

Important functions of straw are the encapsulating of dung and the absorption of urine, milk and other fluids. The absorbing properties of chopped straw are better than those of long straw, and of sawdust better than those of wood shavings (Wassink, 1990; Langley, 1998). However, sawdust from hardwood and wood shavings might contain sharp particles that can give rise to irritations and wounds (Wassink, 1990).

In vitro studies have shown that bedding materials that are primarily organic contain the essential nutrients required for the development of prominent mastitis-causing bacteria such as coliforms and streptococci (Zehner et al., 1986). In these studies five types of bedding materials were compared under strictly controlled conditions as growth media for *Escherichia coli*, *Streptococcus uberis* and *Klebsiella pneumoniae*. These pathogens showed maximum growth in recycled dried manure followed by straw and wood shavings. Growth was the least with paper and sawdust originating from softwood. Inorganic bedding materials such as sand also showed low numbers of bacteria. Bacterial counts in bedding materials on commercial dairies confirm that inorganic bedding decreases teat-end exposure to environmental mastitis pathogens (Hogan et al., 1989). Hence, it is not surprising that many dairy farmers are reducing their use of organic bedding material in order to lower the incidence of mastitis (Elbers et al., 1998).

However, the relationship between straw and the incidence of mastitis is not as clear as often assumed. Firstly, transfer of bacteria to the teats is also influenced by the degree of adhesion of litter to the teats (Hogan et al., 1989). This is closely linked to particle size of the material. Sawdust and chopped straw adhere more easily to the teats than long straw. This could explain why the risk of mastitis was higher among farms with a solid manure system if chopped straw or sawdust bedding was used compared to long straw (Oltenacu

et al., 1990). Secondly, there also are reports suggesting a favourable effect of straw on the clinical condition of udders and teats (Matzke et al., 1992; Ekesbo, 1996). Stanchion barns with hard lying places were associated with an increased risk for teat tramping and udder injuries among dairy cows whereas the use of a sufficient quantity of straw reduced this risk (Karlsson and Gustafsson, 1977). Maton et al. (1985) also confirmed that the risk for teat trauma was higher in stanchion barns with slatted floors than in littered stanchion barns. Furthermore teat lesions are well-known predisposing factors in the development of infections, and in particular, for mastitis. According to a large-scale Swedish study, the risks for udder injuries and mastitis among tied cows were 1.3 and 1.2 times higher, respectively, on farms with liquid manure systems than on farms with solid manure systems (Oltenacu et al., 1990).

Leg lesions and lameness are also major problems in the intensive cattle industry (Murphy et al., 1987). Claw horn lesions are a major cause of lameness. The incidence of such lesions was higher for cows housed on hard concrete floors (Bergsten and Frank, 1996; Faull et al., 1996), and for cows housed in cubicles than for cows in straw yards (Livesey et al., 1998). Conditions in straw yards are less conducive to hoof wear: cattle spend more time lying down and the floor surface is dry and resilient (Phillips and Schofield, 1994). The greater heel depth provided by straw gives cattle a firmer structure with which to cushion impact during locomotion. By contrast in the cubicle house, long periods of standing combined with a wet floor lead to softening of the horn, and the hard and abrasive surface leads to erosion of the soft tissue. This results in a greater incidence of (Phillips and Schofield, 1994), or more severe and persistent (Webster, 2001) lesions among cattle housed in cubicles.

Data provided by Maton et al. (1985) indicated, however, that the lowest incidence of claw lesions was found in stanchion barns with slatted floors. This is probably due to the fact that, in this type of housing, the claws are in contact with moist manure less often. Claw injuries were also observed less frequently when calves were kept on wooden slats (23%) than on solid concrete floors with straw (71%) (Dammrich, 1983). This was attributed to the lower quantity of moisture in the horny material of the hooves of calves kept on slats which, in turn, has a positive influence on the resistance of the claws against infections.

According to Wierenga (1987) animals housed on hard floors such as concrete are more careful when lying down and standing up to avoid accidents. This could lead to a less than optimal load on the joints and consequently to injuries. These injuries can also occur when animals slip, or try to avoid slipping, on a floor with insufficient grip.

Hannan and Murphy (1983) compared the incidence of other diseases among young bulls kept on slatted floors versus on straw. The incidence of five disease-classes (acute stress of the rumen, injury, abscess formation, respiratory disease, other diseases) did not differ significantly between housing types. Three classes of disease (eye disease, skin disease and enteritis) occurred more frequent on slatted floors, while two classes of disease (lameness and clinical parasitism) occurred more frequently on straw yards. Overall morbidity was twice as high among bulls kept on slatted floors than in those kept on straw yards. However, mortality as a result of natural causes (i.e. not culled) was higher on straw yards (0.21%) than on slatted floors (0.12%). Necrosis of the tail tip was also more frequently found on slatted floors than on other types of floors (Metzner et al., 1994; Schrader et al., 2001).

Other figures on overall morbidity/mortality are scant. Brandsma (1982) reported that cattle herdsmen with cows held in stanchion barns with slatted floors called the veterinarian 1.88 times/cow/year compared with 1.75 times/cow/year for cows kept in littered stanchion barns. In a French study (ITEB, 1983), the effect of floor type on total mortality (i.e. natural mortality and culling) of bull calves was compared among 16 herds on deep bedding (728 animals), 10 herds on slatted floors (1084 animals) and 6 herds on littered sloped floors (276 animals). Total mortality was lower on floor types with straw (deep bedding: 1.95%, littered sloped floor: 4.32%) than on slatted floors (5.99%).

In short, the relation between straw and health is complex and equivocal. Straw may not be the best bedding material to keep cattle clean and is a good growth medium for many pathogens. Nevertheless, there is no straightforward relation with the incidence of diseases such as mastitis. Perhaps overall morbidity and mortality appear higher among cattle kept on slatted floors than on straw yards, but the evidence is weak.

4. General conclusion

The welfare-friendly image of farm animal housing systems using straw is largely supported by the scientific literature. This is particularly the case for pig housing systems. For pigs, straw has a wide variety of effects, most of which are positive for their behaviour and welfare. Compared to uncovered floors, straw improves floor comfort (less slippery and hard) and, except in high temperatures, increases the thermal comfort by an improved controllability of the microclimate by the pigs themselves. Straw also has an important ''recreational function'' (sensu Fraser, 1985) and is used as a substrate for the expression of various behaviour patterns such as exploring, rooting, foraging and chewing. The motivation to express these behaviours is thwarted in feed restricted and barren housed pigs. Although the underlying mechanism may not be fully understood, such conditions are associated with behavioural problems such as aggression and stereotypies. Moreover, it has been demonstrated that the sows' demand for nesting materials such as straw is very strong immediately before parturition and that straw can have a favourable influence on maternal behaviour after farrowing. Therefore, the importance allocated to the provision of a substrate such as straw in pig welfare assessment protocols and quality assurance schemes seems justified.

However, the use of straw in pig production systems has important disadvantages as well. These include the incompatibility with slatted floors and liquid manure handling systems, the extra costs of straw and labour, and concerns about increased health risks. The latter was not supported (nor refuted) by this review as the relation between straw and health appears to be disease specific.

Because of these disadvantages, the provision of straw is far from being universally adopted and the search for alternative types of environmental enrichment should continue. It remains important, of course, to compare the possible health risks of these alternatives with those of straw. Almost all of the functions of straw with regard to improving welfare can be fulfilled as well or better by alternative substrates or materials (e.g. spent mushroom compost for floor comfort, the 'Edinburgh Foodball' for the expression of foraging behaviour, or special fibre-rich feedstuffs for reducing feeding motivation). However, an

advantage of straw is that it has been shown to serve *all* of these functions simultaneously (depending of course on how it is provided), while many alternatives serve only one (e.g. toys for the expression of foraging behaviour) or a few functions (e.g. peat for floor comfort and the expression of foraging behaviour). Alternatives should continue to be investigated to determine whether one or some combination of them can be used to provide the same benefits of straw while at the same time offering advantages in relation to hygiene and health, environment, labour and economic aspects.

For cattle, the benefits of providing straw to improve welfare are less varied and mainly concern floor comfort. Although straw has been shown to increase eating and ruminating behaviour and to reduce oral stereotypies by reducing feeding motivation, the recreational value of straw is more restricted for cattle than for pigs. Indeed, straw does not seem to fulfill other behavioural needs in cattle.

The economic disadvantages of providing straw to cattle appear greater than for pigs. In pig production, the extra costs for straw and labour were somewhat compensated by the lower construction costs for straw-based housing systems. For cattle housing systems, however, the limited information that is available suggests that construction costs for straw-based systems are much higher than for non straw-based systems.

Therefore, the use of alternative materials to straw seems more feasible for cattle than for pigs. Already, synthetic lying mats are commonly used in the cattle industry and research has confirmed that at least some of these mats provide equal lying comfort as straw does. Whether or not these lying mats ought to be provided with some sort of litter, and how floor comfort and thermal comfort can be optimised without increasing the risk for leg injuries, teat tramping or other health problems remain to be investigated further. Recently, research has suggested that the use of more natural compact organic mattresses of straw and/or dung may also be superior to loose straw as lying area surface. Such lying mats may be combined with soft walking floors (e.g. slats with rubber linings), which are also commercially available, in order to improve walking comfort in the passageways. Finally, suitable roughage feeds for cattle exist that better fulfil the behavioural as well as the nutritional needs of cattle than loose straw does. Hence, if these alternatives are provided, it seems that the use of straw can be reduced or even eliminated without compromising the welfare of cattle.

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