APPENDIX 22

ALCASDE

Alternatives to Castration and Dehorning

D.2.2.1. Report on the assessment of dehorning and the keeping of horned dairy and beef cattle

SP2: Alternatives to dehorning: To develop and promote alternatives to the dehorning of cattle.

WP2.2: Assessment of benefits and drawbacks of dehorning and alternatives to dehorning in dairy and beef cattle.

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U. Knierim, N. Irrgang, B.A. Roth, T. Gorniak University of Kassel, Germany

Table of contents

1. Introduction

Dehorning is a frequently applied procedure that eases the management of cattle, but is also critical in terms of animal welfare as it violates the integrity of the animals and causes stress and pain. This report will review reasons for disbudding and dehorning and the different common dehorning methods including the use of drugs during the procedure and its benefits for stress- and pain alleviation. It will further summarise information on the possible effects of dehorning on the development of the animals by discussing the significance of horns for the behaviour and physiology of cattle. In terms of the development of alternatives to dehorning it will provide an overview over the state of knowledge concerning requirements for the successful keeping of fully horned cattle.

2. The horn - development and anatomy

Horns are the pairs of hard, bonelike, permanent growths projecting from the heads of cattle. The horn itself consists of dense keratin and elongates from its base. Variations in level of nutrition of the animal are reflected in variations in rapidity of horn growth, resulting in a series of rings on the horn, which may reflect seasonal stress, notably the stress of calving in cows. The age of the animal may be estimated by counting the rings of the horns (Gottschalk et al., 1992).
The horn bud starts to form during the first two months of life. The horn is produced at the corium, the area of cells located at the junction of the horn and skin. If the horn but not the corium is removed, the horn will resume growing. In calves up to about 2 months of age, the horn bud is free-floating in the skin layer above the skull. As the calf grows older, the horn bud attaches to the skull, more precisely to the periosteum of the frontal bone overlying the frontal sinus. A small horn then starts to grow. Once the horn bud attaches to the skull, the horn core becomes a bony extension of the skull, and the hollow centre of the horn core opens directly into the frontal sinuses of the skull (Parsons & Jensen, 2006).

3. Disbudding and dehorning

Disbudding means the removal of the horn buds of the calf at an early age (up to 2 or 3 months) when the horn itself is not yet developed (Rosenberger, 1970). It is carried out using a hot iron, caustic paste or by surgical removal with tube, scoop or curved knife.
Dehorning is used in animals older than 2 or 3 month and implies the removal of the horns by means of cup and scoop type dehorners, electrical or wire saw or shears.
While it seems logical to speak of disbudding only as long as the horn bud is flee-floating, and of dehorning from the moment on when the bud attaches to the skull, in the literature and everyday language the distinction is not made that precisely. Often dehorning is more related to adult cattle and disbudding to calves of sometimes older age than 2 months. Addi-

tionally, dehorning is used as a generic term that includes disbudding and dehorning.

3.1. Reasons for the dehorning of cattle

Dehorned cattle are considered less dangerous for stockpeople's on-the-job safety. Normal head movements of the animal, e.g. to chase away flies, can hurt unwary stockmen accidentally and purposefully conducted attacks of horned animals can cause much more harm as if done by hornless animals. Hornless cattle are also considered to be less aggressive or having a calmer temperament (Sambraus, 1978; Goonewardene et al., 1999). According to farmers' reports horned cattle seem to be more self-confident and ready to defend themselves in unpleasant situation, e.g. when they have to be restraint for injections or other treatments. For these reasons veterinarians as well as cattle dealers and cattle drivers often prefer to handle dehorned cattle (see Deliverable 2.1.2.: Analysis of attitudes of farmers towards dehorning). However, almost no scientific evidence on behavioural differences between horned and hornless cattle during handling is available. Tulloh (1961) assessed temperament of horned, dehorned and polled beef cattle during handling, although partly there was a confounding between breeds, sex and horn status. Nevertheless, he concluded that there were no significant differences in temperament scores between horned and hornless animals.
Another reason for dehorning is to reduce social stress (Oester, 1977), bruises and injuries caused by horn thrusts amongst the animals, which can occur especially when kept in loose housing, and during transport and lairage. The range of horn inflicted damage may vary from minor skin lesions to serious injuries (Menke, 1996) which are especially problematic when udder or vulva are affected. Horn thrusts in the udder can result in the occurrence of visible blood in the milk, which also has economical implications, because the milk cannot be sold before it is free of blood again, and the affected cow may need medical treatment. Forceful thrusts in the trunk can even result in a rupture of the abdominal wall or abortion (Rosenberger, 1970).
In terms of economics, it is commonly assumed that the adjustment of the housing system and management to the special needs of horned cattle implies higher investment and labour costs. Additionally, in regions with specialised leather goods industry even smaller skin lesions can reduce the sale value of the leather (Buchner et al., no year). Scratches on the skin can occur especially during crowding, e.g. on transport (Shaw et al., 1976; Wythes et al., 1979). Farmers may also suffer financial penalties on sale of horned cattle (LfL, 2009) or have no access to certain cattle markets (see Deliverable 2.1.1.: Quantitative survey of current dehorning practices).

3.2. Methods of disbudding

The objective of all methods of disbudding is to destroy the small ring of skin encircling the horn bud. Horn tissue is formed from specialized cells located in this area. To be successful, these methods should be used before significant horn growth occurs (Parsons & Jensen, 2006). Chemical and hot-iron disbudding methods destroy the horn-producing cells, whereas physical methods excise them (Vickers et al., 2005).

3.2.1. Disbudding with hot iron - cautery

Various hot iron dehorning tools are available. Furthermore, they may be heated by butane gas, 12- or 24-volt electric current (Fig. 1). However, from farmers' discussion forums in the internet it appears that also less adequate tools such as soldering-irons are used. According to Stafford and Mellor (2005) hot iron disbudding can be applied up to an age of 2 months, but Rosenberger (1970) recommends it only up to an age of six weeks in order to achieve satisfactory results, namely to avoid the growth of scurs (little crippled horns). For the disbudding procedure the calf should be restrained firmly in a feeding rack or a "restraint box". The free ending of the iron burning device has a little cavity (cup shaped) which fits around the bud. The iron should be heated to a dull red, pressed onto the area around the bud, and slowly rotated with moderate pressure for about 10 seconds up to 3 minutes to destroy the horn-forming tissue (Rosenberger, 1970; Laden et al., 1985; Gottschalk et al., 1992; Wohlt et al., 1994; McMeekan et al., 1998b; Parsons & Jensen, 2006; Stilwell et al., 2007). If the burning device is not hot enough, the burning time can last much longer. The iron should burn through the full thickness of the skin and the core of the bud has to turn brown (Gottschalk et al., 1992). By destroying the vessels, which surround the bud, further growth of the horns is inhibited. While Gottschalk et al. (1992) do not give an exact age limit, they point out that in younger calves the burning of the surrounding vessels is sufficient, whereas the whole bud should be removed by levering it out from the side when the horn is further developed. The heat of the burning device is supposed to close the damaged blood vessels and, thus, no bleeding should occur if properly done. The cauterization also minimizes the risk of infection (Parsons & Jensen, 2006).

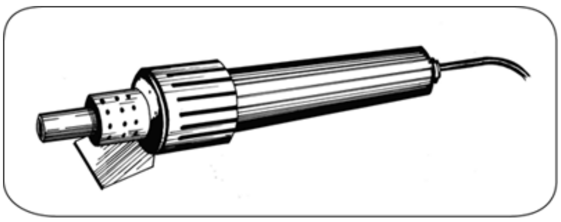

Figure 1: An electric hot-iron dehorner (from Anderson, 2009)

3.2.2. Disbudding with caustic paste

Various chemicals are used for the procedure such as potassium hydroxide, sodium hydroxide, or fluids or pastes that contain nitric acid, trichloroacetic acid, antimony trichloride or zinc oxide. A common mixture is composed of 28 % antimony trichloride, 7 % salicylic acid and 65 % collodion (Rosenberger, 1970).
The optimal age to ensure success of disbudding with caustic paste is between 8 and 14 days, but sometimes it is used up to an age of 3 to 4 weeks, especially in female calves (Gottschalk et al., 1992). If applied on

calves over 14 days scurs may grow, because the effect of the caustics might be insufficient (Rosenberger, 1970).
Before application the area around the buds should be shaved. Then the buds are moistened with some drops of water. The buds and the areas around them get rubbed in under only little pressure with the caustic paste until the skin turns reddish and the dabbed area becomes scarified and wrinkled, which can need about 1 to 1.5 minutes depending on the development of the calf (Gottschalk et al., 1992). The caustic paste remains on the bud until the destroyed tissue gets rejected, which takes 4 to 6 weeks. As long as the active chemical is in contact with the tissue, damage continues (Yano et al., 1993). Calves treated with caustic paste must be protected from rain for a few days after the treatment to prevent the caustic from washing onto the face area and causing chemical burns e.g. on the eyes. Overdosage of the caustics can lead to necroses affecting even the frontal bones of the skull (Rosenberger, 1970). There is also a risk in suckling calves to rub the caustic paste on the udders of their dams during suckling or other herd-mates and causing chemical burns on them as well (Parsons & Jensen, 2006).

3.2.3. Disbudding with scoop, tube or knife - surgical removal of the horn producing area

This method surgically removes the horn and a small ring of skin encircling it. The surgical removal of the bud can be carried out up to an age of 2 to 3 month. There are different devices to conduct the procedure, e.g. tube (Fig. 2), scoop (Fig. 3), Roberts device or curved knife.
The area around the buds should be shaved and fumigated. Application of antiseptics to the calf's skin before dehorning is of little benefit unless the hair is shaved and the area washed with soap before the antiseptic is applied (Parsons & Jensen, 2006). The sharp end of the scoop or tube is placed over the bud and rotated to isolate the central core of the buds. The cutting edge is then used as a gouge to get the punched part completely loose by abrasing the underside (Rosenberger, 1970). Possibly occurring bleeding can be stopped by cauterisation or ligature. The remaining wound should be disinfected and should heal within 3 to 4 weeks (Gottschalk et al., 1992). Another method is the use of a curved knife similar to a furrier's knife (but without a hook on the end). The knife is drawn through the skin towards and through the horn, slicing off the horn. This will remove an elliptical piece of skin with the horn in the centre. To ensure that no horn-forming tissue is left, the ring of hair around the bud has to be removed completely. The most common mistake when disbudding with a knife is to remove an incomplete ring of hair around the horn bud. To prevent scurs, a second cut will be needed to remove all horn-forming tissue (Parsons & Jensen, 2006).

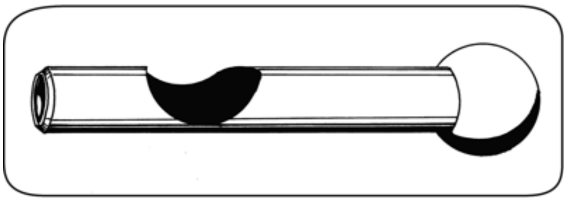

Figure 2: A dehorning spoon or tube (from Anderson, 2009)

3.3. Dehorning

In calves where horn growth already started, shears (Fig. 4), tube or scoop are used to remove the horns and to inhibit their further growth by cutting off a ring of skin of at least 1 cm around the base of the horns. Cup and scoop type dehorners are operating with a scissor-like movement. The scoop type dehorner is consisting of two interlocking semicircular blades attached to leverage handles (Fig. 3). It amputates the horn, adjacent skin and some underlying bone by closing the blades whilst pressing them down vertically on the horn as the operator spreads the leverage arms (Parsons & Jensen, 2006).

In adult cattle or cattle older than 6 months, the bony horn core has to be cut. Various special tools for the amputation of the grown horn are available, e.g. the keystone dehorner (a guillotine type instrument with detachable blades, which has long handles and is capable of chopping off the largest cow horns and most bull horns, Fig. 4); electrical saw or wire saw. The bone tissue should be cut and not just crushed or cracked. To avoid crushing or cracking the bones of the skull, wire saws should usually be used when mature animals are dehorned. If crushing or cracking of bone occurs, e.g. caused by a sudden defence reaction of the animal during dehorning with electrical saw with stiff blade, infection is more likely to occur (Parsons & Jensen, 2006). From the 7th or 8th month onwards, pneumatisation of the bony horn core (development of the cornual sinus) begins which implies that the sinus gets opened during the amputation. Dehorning then leaves an open hole that reaches down into the sinuses of the head. On the residual wound surface sulfonamid paste or antibiotic ointment should be applied (Rosenberger, 1970). Hay or other food particles should be prevented from being thrown on the head of freshly dehorned cattle at feeding time. Therefore, the open hole into the head can/should be covered with gauze or cotton to keep out debris (e.g. dusty, hay or insects). Recently dehorned cattle should also be protected from rain and dust storms until the open sinus has completely healed, which will last about 4 to 8 weeks. If a sinusitis occurs, the sinus must be flushed with disinfectants (Rosenberger, 1970). To avoid infections caused by flies and maggots in the wound, dehorning should be done under cool and dry weather conditions. In wet weather the healing rate is decreased, and the risk of infections is increased. Once an infection is established, it may results in a serious, long-term sinus infection (Parsons & Jensen, 2006). Chronic sinusitis is a frequent complication of dehorning (Ward & Rebhun, 1992, cited from American Veterinary Medical Association, 2007). Also haemorrhage can become a concern in dehorning older calves and adult animals. If not controlled, it can result in severe weight loss or death. Bleeding of the two or three main arteries that supply the horn area should be stopped. Arteries can be pulled and twisted until they break under the subcutaneous tissues, which will then provide pressure and a base for clot formation. Other possibilities to stop bleeding are cauterization with a hot iron, or a string can be tied around the horn base to apply pressure for 24 hours. Blood stopper chemicals should not be placed down into an open sinus as that may result in serious complications (Parsons & Jensen, 2006).

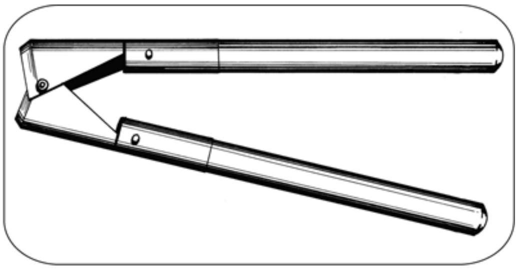

Figure 3: A Barnes-type dehorner scoop / gauge (from Anderson, 2009)

Figure 4: Dehorning cup/guillotine shears / keystone dehorner (from Anderson, 2009)

3.4. Pain and distress during disbudding and dehorning

Disbudding and dehorning cause tissue damage which results in activation and release of intracellular contents from damaged cells, inflammatory cells and nerve fibres (Anderson & Muir, 2005, cited from American Veterinary Medical Association, 2007). Most probably these processes will lead to similar experiences of pain as they would in human beings. Not only the anatomy of the nervous system and physiological response are similar (Weary et al., 2006), but also information processing in the brain appears comparable as has been shown in chickens by Gentle (2001). Therefore, the various kinds of tissue damage and their possible consequences on pain experience will briefly be discussed. Additionally, studies on physiological and behavioural responses towards different disbudding or dehorning procedures that indicate pain and distress will be reviewed.

Physiological indicators include responses of the sympathetic-adrenomedullary system, such as changes in heart rate or in plasma catecholamine concentrations, and responses of the hypothalamic-pituitary-adrenocortical system, namely changes in concentrations of cortisol, adrenocorticotropic hormone (ACTH) and corticotrophin releasing factor. Indicators relating to the sympathetic-adrenomedullary system may be useful for comparing the experience of cattle immediately after dehorning. Changes in plasma cortisol concentrations over time have been used more frequently than any other single parameter to measure pain-induced distress. Generally the cortisol response can be divided in 2 major phases. The first peak in plasma cortisol concentrations is probably due to the nociceptor impulse barrage caused by horn amputation and the plateau and decline to pre-treatment levels may represent a phase where inflamma-

tion-related pain and its resolution dominate the response (McMeekan et al., 1998b).
Behavioural indicators of the calf's pain during the disbudding procedure are struggling behaviours like scurrying, urging forward, head jerking and rearing. A further sign of discomfort is quick tail wagging. After unsuccessful defence reactions some calves just drop themselves down (Taschke, 1995; Graf & Senn, 1999). Postoperative behaviours indicating pain and distress are restlessness (frequent standing up and lying down), repeated shaking of the head, ear flicking, tail flicking, hind leg kicking, scratching the lesion with the hind foot, reduction of social behaviours, head rubbing, backwards movements, neck extension, reduced lying and reduced exploratory behaviour, avoiding of head pushing against pen mates, reduced feeding time or standing indifferently with lowered head (Taschke, 1995; Morisse et al., 1995; Graf & Senn, 1999; Faulkner & Weary, 2000). Behavioural responses may be modified by age, breed, previous experiences, temperament etc. (Stilwell et al., 2007). For instance, especially younger calves may respond to intense pain merely by becoming apathetic which comprises inert lying with head on flank and showing little response to stimuli such as those resulting from other calves (Stilwell et al., 2009). It is a general problem in the interpretation of behavioural indicators that a low overt response does not necessarily mean absence of suffering. Especially in prey species such as cattle low overt responsiveness has evolved as a way of concealing vulnerability towards potential predators (Broom, 2001). Very subtle signs (e.g. inert lying or shallow respiration) may be of crucial importance also in older cattle (Sanford et al., 1989).
Decreases in individual animal performance after disbudding/dehorning are likely related to physiological or pathological as well as behavioural responses that may be associated with pain.

3.4.1. Hot iron disbudding

Hot iron disbudding causes third-degree burns in the zone of direct contact. This means charring and extreme damage of the epidermis that reaches down to the subcutaneous tissue and often also to the skull bone. The surrounding tissue exhibits first- and second-degree burns (Taschke, 1995). The first- and second-degree burns develop an infection, which leads to a sensitization of the nociceptors, i.e. experience of pain (Taschke, 1995).
The cortisol response to hot iron disbudding lasts about 1-4 hours (Petrie et al., 1996; Grøndahl-Nielsen et al., 1999; Faulkner and Weary, 2000). A sharp rise is followed by a rapid decline to pre-treatment levels and no plateau phase occurs. Only Morisse et al. (1995) found significantly higher plasma cortisol concentrations than in control animals until at least 24 hours when they took their last blood sample. However, even when cortisol levels returned earlier to control values, indications of pain or distress were still noticeable. In the study of Grøndahl-Nielsen et al. (1999) heart rates were increased until 3.5 hours after hot iron disbudding whereas cortisol levels already declined after 1 hour. Faulkner and Weary (2000) found behavioural signs of pain (head jerks, ear flicking) during the complete 24 hours of observation time (peak at 6 hours), whereas cortisol re-

sponses normally reached pre-treatment levels 4 hours after the procedure.
Plasma cortisol concentrations appear not to be influenced by the type of hot iron disbudder. Dehorning with a conventional electrical dehorner (applied for 1 to 2 min) or a Buddex (applied for 10 seconds) resulted in similar cortisol responses (Wohlt et al., 1994).

3.4.2. Caustic paste disbudding

Caustic paste disbudding causes chemical burn of underlying tissue. The active ingredient used for paste disbudding is a strong alkali, which firstly withdraws water from inside the effected cells, causing intracellular dehydration. Secondly, saponification of subcutaneous fat causes the fatty tissue to lose its function, with increased damage due to the heat of reaction. Thirdly, the reaction with protein forms alkaline-proteinate, which is soluble and contains OH ions, the latter causing further chemical reactions which initiate deeper injury of the tissue. Alkaline injuries are more progressive, compared with acid, and the necrotic tissue becomes moist (Yano et al., 1993). Histopathological findings after alkali burns in pigs have revealed full-thickness epidermal necrosis and superficial dermal necrosis (Cowart et al., 2000). The pain caused by alkali is described by humans as “itching pain” or “marked pain” (Ma et al., 2007, cited from Stilwell et al., 2009). Malenfant et al. (1996) found that 36 % of chemical burn patients complained about pain whereas 71 % of them experienced paraesthetic sensations.
Disbudding with caustic paste causes an increase in plasma cortisol level for 1 hour, reaches the highest level at 60 minutes after disbudding and returns to basal levels within 4 hours to 24 hours after treatment (Morisse et al., 1995; Stilwell et al., 2009).

3.4.3. Surgical disbudding or dehorning

After surgical dehorning (applied at an age of 3 to 6 months), plasma cortisol concentrations increased rapidly and markedly 30 to 60 minutes after dehorning, declined slightly, plateau levelled for 3 to 4 hours, and then returned to baseline values approximately 6 to 9 hours after the procedure (Sylvester et al. 1998b, McMeekan et al., 1997). A new smaller, but significant rise of plasma cortisol levels occurred at 13 to 15 hours after dehorning, returned to pre-treatment level again and did not rise above until at least 24 hours after dehorning when the last blood sample was taken (Sutherland et al., 2002b).
The cortisol response is not influenced by the tool used for the procedure (scoop, shears, saw or embryotomy wire). Consequently pain and stress appear to be similar, although the remaining wounds are of different depth (Sylvester et al. 1998b). Stilwell et al. (2007) suggest, that the marked responses during the first hour after treatment may be limited by a "ceiling effect" that is described as the maximum hormonal level possibly attained after a negative experience (Molony and Kent, 1997; Molony et al., 2002). Indeed, cortisol responses in the first hour after amputation dehorning are similar to those following ACTH injection, indicating that dehorning causes maximum cortisol secretion during this period (Sylvester el al. 1998b). This physiological limitation should be taken in ac-

count. Thus, the following cortisol decrease may as well be due to exhaustion of the system and not necessarily to pain reduction. Interestingly, in the study of Stilwell et al. (2007) also the pain related behaviour showed a wavering pattern, that was not found in hot iron- or caustic paste disbudded calves: a decrease at 3 hours compared with the level at 1 hour and a new, very pronounced increase at 6 hours. The behavioural responses also indicated that severe pain was still present despite the decrease in cortisol levels.
In surgical dehorning of mature cattle it has been found in Brahman steers that the size of the opening of the frontal sinus was inversely related to their liveweight gains in the month following dehorning (Winks et al., 1977). Steers with suppurating wounds and small sinus openings also gained less weight than steers with small openings that have healed (Winks et al., 1977).

3.4.4. Comparison of methods and conclusions on pain caused by disbudding or dehorning

Although in legal standards disbudding at different ages is usually treated differently, e.g. in terms of anaesthesia requirements (see chapter Legislation in Deliverable 2.1.1.) suggesting that pain perception is more pronounced at older ages, there are no scientific investigations available comparing indications of pain at different ages. However, when looking at different studies that used calves between 6 weeks and 6 months of age, plasma cortisol responses to different disbudding or dehorning procedures show very similar patterns (Petrie et al., 1996; McMeekan et al., 1997, 1998a, b; Sylvester et al., 1998a, b) suggesting that noteworthy age related differences in pain perception do not exist. However, when comparing disbudding and dehorning, effects due to type and size of the imposed wounds may become important. In terms of animal performance, for instance Laden et al. (1985) and Grøndahl-Nielsen et al. (1999) did not find any short- or long-term effects of hot iron disbudding on food intake and growth rate in 4 to 6 and 8 week old calves. On the contrary, after surgical dehorning in Brahman crossbred steers aged 4, 9, 19 and 30 months, weight gains were significantly reduced, especially during the first 2 to 6 weeks (Loxton et al., 1982). In mature steers (Winks et al., 1977) and in Canadian feedlot cattle in winter, negative weight effects were still evident after 106 days (Goonewardene & Hand, 1991).
Duration and level of cortisol responses differ, however, according to the methods applied. The cortisol response to hot iron disbudding is significantly lower and shorter than that to surgical dehorning. This suggests that scoop dehorning may be more painful (Petrie et al., 1996; Stafford & Mellor, 2005). Also in calves disbudded with caustic paste Morisse et al. (1995) and Stilwell et al. (2007) found higher cortisol responses than in calves disbudded with hot iron. While for surgical disbudding/dehorning there is some evidence that additional cauterization may help to decrease postoperative pain (Petrie et al., 1996; Sylvester et al., 1998a; Sutherland et al. 2002b), reduction of the acute cortisol reponse is insufficient to recommend it to general use. Moreover, struggling and other escape behaviours during cautery indicate that it is itself an aversive experience (Stafford & Mellor, 2005).

In fact, in terms of behavioural responses during the procedure itself, hot iron disbudding elicits most struggling compared to the other methods (Stilwell et al., 2007). Stilwell et al. (2007) suggest that the difference to scoop disbudding or dehorning is mainly due to the shorter time scoop dehorning takes and the aversiveness of the contact with the extremely hot iron. Struggling in caustic paste disbudded calves is minimal and does not differ from sham disbudded calves (Stilwell et al., 2007), because caustic activity and consequently pain take a short time to come into effect (Stilwell et al., 2007 & 2009). Immediately after disbudding Morisse et al. (1995) found no difference in pain related behaviours between hot iron and caustic paste disbudded calves. Stilwell et al. (2007) conclude on the basis of their behavioural observations that in the first and third hour after treatment all three methods cause probably similar pain, but that at 6 hours pain seems to be much more severe in the scoop dehorned than in hot iron or caustic paste disbudded animals. Also when comparing responses over a 24 hour period after disbudding, scoop dehorned calves showed higher incidences of pain related behaviours than caustic paste and hot iron disbudded calves. Between the latter no significant difference was found, although the kind of behaviour was slightly different. Caustic paste disbudded calves showed more restlessness (transitions from lying to standing) and inert lying and less active behaviours like head shaking and head rubbing (Stilwell et al., 2007). However, it has also to be taken into account that the ages of the calves were different in the different treatments (about 117 days old in scoop dehorned, 98 days old in hot iron disbudded and 25 days old in caustic paste disbudded calves).

Thus, although according to Choiniere (1989, cited from Taschke, 1995) tissue damage due to burns can be expected to be perceived more painful than those from cuts, there are clear physiological and behavioural indications that altogether least pain will be imposed by hot iron disbudding and most by surgical disbudding or dehorning.

In general, it needs to be stressed that the studies cited cover only periods of at most 36 hours in physiological and 24 hours in behavioural investigations. Since pain related behaviour was still evident at 24 hours (Faulkner & Weary, 2000; Stilwell et al., 2007), it cannot conclusively be clarified how long the disbudding or dehorning pain persists. For example, Stafford (unpublished data, cited from Stafford & Mellor, 2005) found dehorned calves grazing and ruminating less between 24 and 48 hours after dehorning, which suggests that there is chronic pain, even if not sufficient to stimulate a significant rise in plasma cortisol concentration. In principle, it can also not be ruled out that as a long-term consequence of disbudding or dehorning neuromas may develop from the remaining stumps of damaged nerves. Neuromas may give rise to abnormal spontaneous nervous activity that is perceived as pain in the removed tissue (Breward & Gentle, 1985). Neuroma development has been found in docked tails of piglets (Simonsen et al., 1991), lambs (French & Morgan, 1992) and fattening cattle (Winterling & Graf, 1994) as well as in beak-trimmed laying hens (Breward & Gentle, 1985). However, in laying hens it appears that the risk of neuroma persistence rises with increasing age of the animals when the mutilation is carried out (Glatz, 2000). Regarding dehorning or disbudding there is a complete lack of investigations and therefore evidence on actual risks that such long-term pain may be present.

3.4.5. Distress of Handling

Restraint, firm handling of the buds without actual amputation and blood sampling by venepuncture with or without injection of a local anaesthetic, showed only transient and moderate rises of plasma cortisol levels during 20 to 40 minutes after the onset of handling and blood sampling (McMeekan et al., 1998a; Graf & Senn, 1999). Wohlt et al. (1994) found in control calves, which were handled and restraint as for dehorning without being actually dehorned, cortisol responses of one third to a quarter of that after actual dehorning, which were resolved 5 hours earlier than after actual dehorning. In contrast, Sutherland et al. (2002b) did not find any significant influence of handling and blood sampling (venepuncture from the jugular vein) on plasma cortisol change, nor did Stilwell et al. (2009) found an effect of handling on plasma cortisol level or behaviour. This means that behavioural and physiological responses will in part be due to the mere handling and this part will vary according to individual differences and circumstances. However, it can be expected that in relation to the responses triggered by the actual mutilation they are of minor extent.

3.5. Stress and pain alleviation during disbudding or dehorning

3.5.1. Sedation

In order to ease the disbudding/dehorning procedure and decrease handling stress for the animals sometimes sedatives are administered (see Deliverables 2.1.1. and 2.1.2.). However, it is a rather frequent misconception in practice that this treatment should provide anaesthesia as well. Grøndahl-Nielsen et al. (1999) showed that sedation with xylazine (combined with butorphanol), used in different groups of calves before sham disbudding or hot iron disbudding, reduced the physical activity in calves during hot iron disbudding, but that sedation without anaesthesia was not effective in reducing the cortisol response to disbudding, and only slightly reduced vigorous head jerks during disbudding compared to non-sedated animals. However, sedation made the administration of local anaesthetic easier and thus eliminated the need for physical restraint during the administration of the local anaesthetic and during dehorning.

3.5.2. Local anaesthesia

The cornual nerve, a branch of the Trigeminal nerve (cranial nerve V), provides sensation to the skin of the horn/bud region. Injection of a local anaesthetic around the cornual nerve, as it traverses the frontal crest, desensitizes this region (Frandson et al., 2003). Partly different results regarding local anaesthesia effects on physiological and behavioural pain indications towards disbudding/dehorning have been obtained in different experimental investigations (Morisse et al., 1995; Petrie et al., 1996; Mc Meekan et al. 1998a, b; Sylvester et al., 1998b; Grøndahl-Nielsen et al., 1999; Graf & Senn, 1999; Sutherland et al., 2002b; Sylvester et al., 2004; Vickers et al., 2005; Stilwell et al., 2009). They may partly be due to different disbudding methods applied in calves of different ages (caustics: 10 to 35 days, hot iron: 10 days to 8 weeks, scoop disbudding: 6 weeks, scoop dehorning: 3 to 6 months) and different implementations of local anaesthesia, e.g. as regards applied volumes of the anaesthetic. For instance, Morisse et al. (1995) observed an incomplete to lacking effectiveness of anaesthesia during caustic and hot iron disbudding in 40 % of animals that still attempted to escape the operation while 60 % remained motionless showing no evidence of pain. Also Vickers et al. (2005) did not find a significant reduction of behavioural indicators of distress despite application of a local anaesthetic prior to disbudding with caustic paste. They presumed that the basic pH of the caustic paste negatively affected the action of the local anaesthetic. However, volumes of the anaesthetic used (1.5 ml lidocaine to block the cornual nerve and 3 ml s.c. at the base of the horn) might have been insufficient, as Stilwell et al. (2009) concluded from their study that even 5 ml of 2 % lidocaine injected around the cornual nerve was efficient in reducing, but not preventing cortisol rise and pain-related behaviours. Also in the study of Morisse et al. (1995) under field conditions only volumes of 4 ml were used which in some calves might have been insufficient. They, however, considered other factors such as poor handling of calves or individual differences in the neural topography of the horn area as potential causes. Weary (2000) warns that differences in the behavioural response between treated and untreated calves can be sufficiently subtle so that it is difficult for observers to be certain if adequate nerve blockage was achieved. Therefore, efficacy of the anaesthesia should always be controlled before disbudding by testing sensitivity of the skin around the horn bud by pricking (Waiblinger, 2001; DEFRA, 2003; Stilwell et al., 2009). This also means that the person doing the disbudding or dehorning should always allow enough time for the anaesthetic to numb the area before they begin (DEFRA, 2003).

Despite single studies that did not find indications of pain release through local anaesthesia (e.g. Petrie et al., 1996, for hot iron disbudding), Stafford and Mellor (2005) concluded in their review that in principle a cornual nerve blockade using lignocaine reduces immediate behavioural pain responses like escape behaviour seen during the disbudding/dehorning procedure and eliminates the plasma cortisol response for the duration of its action. However, calves disbudded using a local anaesthetic still require restraint, because calves respond to both, the pain of the procedure and to the physical restraint. The injection of the anaesthetic provokes transient stress and pain, not primarily due to the puncture itself, but presumably due to the pressure caused by the injected volumes (Graf & Senn, 1999). However the slight rise of cortisol concentration and defence actions often ceased already during the injection, because anaesthetisia rapidly takes effect (Graf & Senn, 1999). Nonetheless, calves must also be restrained while the local anaesthetic is administered, as well as during the actual dehorning. This leads to the suggestion that not only local anaesthetics but also sedation should be applied, and in addition analgesia with a non-steroidal anti-inflammatory drug (Stafford & Mellor, 2005) as will be discussed below.

3.5.3. Nonsteroidal anti-inflammatories

Local anaesthesia does not provide an adequate post-operative pain relief. After the anaesthetic effect has worn off, an increase in plasma cortisol concentration occurs (Sutherland et al., 2002b; Stilwell et al., 2009), which may last on high levels for about 5 hours (Sutherland et al., 2002b). Faulkner and Weary (2000) found a surge in pain related behaviours 3 to 12 hours after hot iron disbudding of calves treated with local anaesthesia. The most popular local anaesthetic, lignocaine or lidocaine, is effective for only about 2 hours after administration, bupivacaine for 4 hours (Stafford & Mellor, 2005). This is reflected by calves treated with anaesthesics showing significantly higher cortisol concentrations up to 24 hours post hot iron disbudding than anaesthetised not disbudded calves (Morisse et al., 1995). Recent studies indicate that calves treated with local anaesthetics actually have higher plasma cortisol levels than untreated animals after the local anaesthetic loses its effectiveness (McMeekan et al., 1998a; b; Graf & Senn, 1999). After scoop dehorning even extending the local anaesthesia to 8 hours by giving bupivacaine a second time 4 hours after disbudding, did not abolish the cortisol response (McMeekan et al., 1998a). On the contrary, the plasma cortisol concentration increased sharply at 8.3 hours after dehorning when the anaesthetic effect had ended and increased steadily until the last sampling at 9.3 hours after dehorning. Concentrations were then higher than in animals dehorned without anaesthetic treatment (McMeekan et al., 1998a). McMeekan et al. (1998b) assumed that local anaesthesia might indirectly enhance inflammatory pain in dehorned calves, because cortisol is a potent anti-inflammatory substance in mammals, but is markedly reduced during the period of local anaesthesia. Thus, the prevention of the usual large cortisol response during the nerve-blockade could lead to unimpeded progression of inflammatory reactions in the amputation wounds (McMeekan et al. 1998a). Another explanation may be that calves not given local anaesthesia may become habituated to the noxious sensory input originating from the wounds, so that they may still experience nociceptor input, but this does not elicit such a large cortisol response anymore due to feedback mechanism in the hypothalamic-pituitary-adrenocortical-system that tend to lead back to homeostasis. The importance of novelty in axis activation has been noted in numerous studies (Mason, 1968, cited from McMeekan et al., 1998a). As described in chapter 3.4.2. the return of cortisol levels to pre-treatment values may not in any case indicate an actual relief of pain.

In any case, administration of nonsteroidal anti-inflammatories (NSAIDs), e.g. ketoprofen (phenylbutazone is ineffective according to Sutherland et al., 2002a), is a good option to prolong postoperative analgesia (McMeekan et al., 1998a; Faulkner & Weary, 2000; Stafford & Mellor, 2005). Oral administration of ketoprofen in the milk 2 hours before and 2 and 7 hours after hot iron disbudding of 4 to 8 week old calves (combined with xylazine and lidocaine injections), significantly reduced head shaking 3 to 12 hours after disbudding and ear flicking 3 to 24 hours after disbudding compared to control animals only treated with xylazine and lidocaine. Additionally, ketoprofen treated calves tended to gain more weight during the total observation time of 24 hours after disbudding compared to control animals (Faulkner & Weary, 2000). However, calves thus treated with

ketoprofen showed still some head shaking and ear flicking. Furthermore, the treatment did not reduce the frequency of head rubbing at all, whereas the frequency of pain related behaviours in sham disbudded control calves were near zero (Faulkner & Weary, 2000). McMeekan et al., (1998b) found that plasma cortisol and behavioural responses were kept close to baseline levels in the hours that follow dehorning, although there was a small but significant increase of cortisol concentration 30 minutes after dehorning.
It is important to note that ketoprofen will have little effect on the pain caused by the amputation itself, as its action is on the inflammatory pain that starts not until 2 hours after disbudding/dehorning. On this line, ketoprofen alone (injected intrajugularly 15 to 20 minutes before scoop disbudding) did not significantly reduce the initial peak in plasma cortisol concentration during the first 1 to 3 hours after disbudding compared to animals disbudded without ketoprofen, whereas the plasma cortisol concentration returned earlier to pre-treatment levels at about 2 hours rather than 8 hours after disbudding (McMeekan et al., 1998b). However, in calves younger than 2 weeks and disbudded by hot iron, intramuscular administration of ketoprofen in addition to lidocaine produced a reduction in cortisol concentration already within the first 3 hours after disbudding, but did not affect later cortisol responses up to 8 hours post disbudding compared to animals solely treated with lidocaine (Milligan et al., 2004). The authors assume that the potentially beneficial effect of using a non-steroidal anti-inflammatory drug increases with the size of the horn buds removed, as the amount of tissue damage and postoperative inflammatory pain should increase accordingly.

3.5.4. Conclusion

Whatever method of disbudding/dehorning is used, the procedure causes distress and pain in the treated animals, which should be alleviated as far as possible, preferably by a combination of sedation, local anaesthesia and anti-inflammatory treatment. Sedation allows an easier administration of the local anaesthetic without major struggling of the animal. The combination of a sedative and local anaesthetic allows disbudding/dehorning without immediate pain and stress response, and the addition of a non-steroidal anti-inflammatory drug reduces the pain related responses during the hours following disbudding/dehorning. Efficacy of local anaesthesia should be individually controlled.

4. Possible long-term impacts of dehorning derived from the significance of horns for cattle

4.1. Functions of horns

In cattle, both male and females of horned breeds have horns. Polledness did not occur naturally during evolution. All polled breeds existing nowadays evolved from human breeding efforts (Epstein, 1971, cited from Menke, 1996). Hypotheses on the evolutionary function of horns in female ungulates were reviewed by Roberts (1996). They include that horns may provide advantages concerning predator defence or in resource competition. Estes (1991) formulated the hypothesis that male mimicry in female bovids serves the mother to protect their male offspring against the aggression of dominant males, which leads to a prolonged presence of the sons in the natal herd and home range. This is adaptive because the survival and reproductive success of male offspring and the mother's own genetic fitness are all enhanced. Additionally, for male ungulates there are indications that horns serve as honest signals of genetic quality in female choice of mating partners (Estes, 1991).

In terms of behaviour, the presence of horns will likely affect quality and quantity of social interactions as well as social relationships in a herd which will be discussed in more detail below. Additionally, horns may be used during self-grooming of body regions, which were otherwise out of reach. Taschke (1995) found in mature cows observed 24 hours before dehorning that 27.5 % of all self-grooming occurrences were carried out with the help of the horns. In the first 3 hours after dehorning the cows showed an “imaginary horn rubbing”, but after a short period they stopped that and repeatedly showed standing with lowered head.

Cows appear to be well aware of their horns. For example, Menke (1996) reports that horned cows can access even very narrow feeding racks without jolting by tilting their heads. According to oral reports of some farmers some horned cows are even able to deliberately open closed feeding racks with the tips of their horns.

In terms of functions for human purposes, farmers in earlier times favoured cattle with horns over hornless cattle because they were used as drought animals and the horns served to attach the harness (Rosenberger & Robeis, 2005). Even today, horns are partly used for tying catte (see Deliverable 2.1.2.).

4.2. Relevance of horns for social behaviour within the herd

In general, literature explicitly dealing with horned animals is relatively scarce which is even more applies to comparisons between horned and dehorned herds. Often, it is not even stated in social behaviour studies whether animals were horned or not. It had, therefore, to be assumed that animals were dehorned if not stated otherwise.

Contrary to frequent expectations that horned cattle would be more aggressive than dehorned ones (Sambraus, 1978), Menke (1996) argues that due the more aversive experience when e.g. butted by a horned cow, in fact threats without physical interaction were likely more effective and physical agonistic interactions less frequent in horned than in hornless herds. Also Graf (1974) noticed that chasing up lying cows was effective from a greater distance when the actor was horned instead of dehorned. He concluded that horned animals are receiving more respect from their conspecifics than hornless. The maintenance of dominance relationships largely by threat signals and withdrawal and only seldomly by physical interactions reflects the typical situation in well established groups on pasture (Bouissou, 1972; Reinhardt et al., 1986). To which degree this is obtained under housing conditions presumably will not only depend on the presence of horns, but also on a multitude of animal related as well as housing and management related factors (see Table 1). Many farmers state that different breeds and also different breeding lines within one breed imply different potentials for intraspecific aggression (and also for aggression against humans, Boivin et al., 1994). For instance, Saler groups showed more non-agonistic interactions than Friesian groups (Le Neindre & Sourd, 1984), and Plusquellec & Bouissou (2001) found the breed Ehringer, selected for fight and dominance ability, less aggressive in undisturbed groups as well as more tolerant in a food competition test than the breed Brown Swiss (Brune des Alpes). Unfortunately, no comparative studies on horned and dehorned herds under comparable conditions regarding proportions of physical and non-physical agonistic interactions are available. In any case, they would be difficult to implement as threats may be very subtle signals that are difficult to observe reliably on group level (Winckler et al., 2002). Moreover, sufficient control of the possibly confounding factors displayed in Table 1 would be needed.

Table 1 Factors influencing the quality and quantity of agonistic behaviour in cattle

Factor	References
Presence or absence of horns	Graf, 1974
Herd composition, frequency of regrouping, mixing unfamiliar animals	Boe & Farevik, 2003; Menke, 1996
Group rearing of calves (early social environment & social experience)	Boe & Farevik, 2003
Method of integration of new cows into the herd	Menke, 1996; Boe & Farevik, 2003
Separation time of dry/calving cows from the herd	Waiblinger, 1996
Measures to avoid disturbances by cows in oestrus	Menke, 1996
Locking the feeding rack during feeding	Waiblinger, 1996
Problem solving management	Waiblinger, 1996
Human-animal-relationship (frequency and quality of contact, friendly approach/contact)	Waiblinger, 1996
stockperson character and attitude towards the cows	Waiblinger, 1996
Frequency of personnel change	Menke, 1996
Frequency of brushing the cows	Waiblinger, 1996
Number of different milkers	Menke, 1996
Herd size	Reviewed by Boe & Farevik, 2003
Design of housing facilities (structured versus unstructured lying area, feeding rack)	Menke, 1996
Space allowance per cow	Wierenga, 1990; Metz & Mekking, 1984; Menke et al., 1999
Provision of an outdoor run	Menke, 1996; Schneider et al., 2008
Animal characteristics (breed, temperament, breeding line)	Le Neindre & Sourd, 1984; Boivin et al., 1994; Plusquellec & Bouissou, 2001

To compare horned and dehorned herds with respect to frequencies of physical agonistic interactions is similarly difficult. Such a comparison is only available from Graf (1974) for horned and dehorned cows at pasture. His results confirm the hypothesis of lower frequencies of physical agonistic interactions in horned cows (0.67 pushes/animal*hour versus 2.64 pushes in dehorned cows). Menke et al. (1999), though acknowledging the limitations due to confounding factors and differences in timing and methods of observations, tried to evaluate their results of observations in 35 horned dairy cow herds in relation to other studies with dehorned herds. They found that the average level of 0.25 physical interactions per animal and hour in the horned herds was lower throughout than the results from dehorned herds that ranged from 0.33 to 4.6 interactions/animal and hour (Collis et al., 1979; Andreae et al., 1985; Menke, 1996; Jonasen, 1991).
Menke et al. (1999) further hypothesized that lower frequencies of physical agonistic behaviour in horned herds will have positive effects on the stability of the social structure of the herd. For example, older horned cows might be able to stay high in rank despite loosing weight and physical strength. For example, Reinhardt (1980) reported from a semi-wild herd of Zebu cattle from older high-ranking cows that they had lower body weight, but longer horns than younger low-ranking cows. Kimstedt (1974), on the other hand, observed in one commercial dairy herd, that was dehorned, no consistent shift in ranks after dehorning. However, observation time was probably too short to detect real long-term effects on the social order of the herd. Nevertheless, also Bouissou (1972) mentioned that dehorning high ranking animals does not necessarily change rank order. This obviously depends on whether they get involved in fighting or not. If it comes to fighting with horned animals, they will most probably loose (Sambraus, 1978). Bouissou (1972) additionally concluded from her investigations that live weight in pairs of horned animals is even more influential regarding dominance than in dehorned ones. However, again this may only apply if it comes to fighting. It is conceivable that during head to head pushing horns can fulfil their function of hooking the animals together (Sambraus, 1978), and consequently body weight will more heavily influence fighting force. In general, evidence on influencing factors of social rank in horned and dehorned cows are rather contradictory anyway, due to the complex interactions of aspects listed in Table 1 as well as cattle age, weight, size, and so on (Schein & Fohrman, 1955; Wagnon et al., 1966; Bouissou, 1972; Collis, 1976; Stricklin et al., 1980; Beilharz & Zeeb, 1982). However, for herds with horned and dehorned cows it can be expected that the presence of horns will often overrule other influencing factors and put horned cattle at an advantage (Bouissou, 1972; Beilharz & Zeeb, 1982).
Largely independent from rank or other influencing factors it is expected that horned animals attempt to maintain much greater inter-individual distances than dehorned ones which makes the keeping of horned cattle under restricted space conditions more difficult (Sambraus, 1978). However, scientific studies on spacing behaviour comparing horned and hornless cattle are lacking. Possibly, the difference between horned and dehorned animals lies in the consequences when desired distances between individuals are not kept, rather than in the desired distances themselves. In goats, Aschwanden et al. (2008) in an experimental study could

not detect any influence of the presence of horns on social distances. It would be worthwhile to undertake similar studies in cattle.
When it comes to physical agonistic interactions in horned herds, the risk for overt injury due to the interactions is higher than in hornless herds. Menke et al. (1999) found a mean of 13.6 supposedly horn-inflicted lesions per cow in the 35 investigated dairy farms. Though the majority of these lesions were superficial scratches, the large variation from 1 to 63.5 injuries per average cow may indicate distinct problems on certain farms. The welfare evaluation of injury levels is difficult because injuries (bruises) in hornless cattle due to agonistic interactions may exist as well, but will mostly not be visible. The only studies investigating bruises in horned and hornless cattle were related to the situation during transport and at the abattoir. Here Shaw et al. (1976) and Meischke et al. (1974) found that groups of horned animals or groups of horned and hornless animals had a higher mean weight of bruised tissue trimmed from the carcass than hornless. The studies allowed no distinction between bruises caused during housing and afterwards, and varying transport conditions (e.g. durations between 1 and 10 days) were not controlled for. Furthermore, bruising during transport and lairage can occur due to fighting as well as to falling or collisions with equipment or other animals (Tarrant, 1990). It remains that injury risks are higher in horned cattle. However, there is insufficient knowledge about the pain associated with the different lesions. Similarly, it is not known if the decreased risk of injury also decreases social stress in hornless cattle. The opposite hypothesis would be that the improved housing and management conditions are not only necessary to successfully keep horned cattle, but are additionally beneficial by decreasing the social stress which is imposed on hornless cattle under standard housing and management conditions. These questions deserve further investigation in the future.

4.3. Potential physiological effects of horns or absence of horns

In the ancient world Goddesses and Gods representing fertility and vitality were often associated with horns or horned cows or bulls (Cooper, 1978 cited from Menke, 1996). Also among cattle breeders the relation of superior production traits to the presence of horns appears to be a regular perception (Koots & Crow, 1989). It was for instance reported that a Swedish polled breed exhibited more fertility related problems than horned breeds (Venge, 1959, cited from Menke, 1996). Although this is more a reservation towards polled cattle rather than towards dehorning, some breeders also appreciate the presence of horns in breeding animals for selection purposes. Indeed, in wild bovids, here African buffalo, Ezenwa & Jolles (2008) showed that horn size in males and females is an indicator of health, especially with regard to parasitic burden and immune function. They concluded that in sexual selection horns may serve as honest signals of individual health and genetic quality.
Some farmers state that dehorned and polled cows tend to have more digestive problems (Stranzinger, 1984, cited from Menke, 1996) and more lameness problems (Pilz, 2006). Often these farmers have an anthroposophic background. Rudolf Steiner, the founder of the anthroposophic movement, postulated that horns and digestion are closely related

(Spengler Neff, 1997). Arguments commonly put forward in favour of this connection are based on several empirical observations, which to our knowledge, however, have not been scientifically investigated yet. For instance, it is claimed that horns get warm during rumination. Furthermore, it appears that cattle breeds or bovids living in environments providing low energy forage (e.g. in the savannah or steppe) tend to have larger horns than those having rich diets available (e.g. in middle or northern European flat areas). However, another possible function of horns in thermoregulation may also play a role, as cattle breeds originating from hot climates often have especially large horns. Because the core of the horn is part of the sinus, horns may contribute to nasal heat exchange, which is found in a range of large mammals. This is a mechanism to considerably reduce water loss through cooling of the air during exhalation in giraffes, waterbucks, goats and cows (Langman et al., 1979).
It is further claimed that the presence of horns affects milk quality. Using qualitative methods such as copper chloride biocrystallization or the capillary dynamolysis method (Steigbildmethode) differences between milk from horned and dehorned have been described (Wohlers, 2003; Baars et al., 2005), and it was claimed that these differences indicate a lack of vitality of dehorned cows (Anon., 2009). However, the methods applied are still in the process of scientific validation (e.g. Wohlers et al., 2007). Another aspect of milk quality currently under investigation is based on reports of some consumers that milk from horned cows show hypoallergic effects (Kusche & Baars, 2007).

4.4. Potential effects of dehorning on the human-animal relationship

Waiblinger (1996) found in 35 horned herds that the proportion of dehorned animals in the herd correlated negatively with the avoidance distance towards humans, i.e. the more cows of a herd were dehorned, the shyer the animals were. One of the possible explanations is dehorned cattle becoming more fearful of humans due to the possibly traumatic experience of disbudding/dehorning. This hypothesis has not rigorously been investigated yet. Enhanced fearfulness of humans enhances the likelihood of attacks as has been shown under range conditions (Boivin et al., 1994, Le Neindre et al., 1996). Therefore, this aspect deserves more investigation in the future.

5. Requirements for the keeping of fully horned cattle

Usually the keeping of horned cattle in tying systems is not seen as especially problematic except possibly in terms of human safety and with regard to later transport. The performance of physical agonistic behaviour is largely prevented in tie stalls (EFSA, 2009) and thereby risks of injuries are diminished. This is reflected by a considerably lower proportion of dehorned cattle in tying systems (see Deliverable 2.1.1: Quantitative survey of current dehorning practices). However, increasingly loose housing systems are the dominating ones (see Deliverable 2.1.1: Quantitative survey of current dehorning practices). The EU regulation on organic agriculture (2008) even bans tying systems for larger organic herds with a transition period terminating in 2013. Due to increased injury risks in loose housing it is mostly recommended to dehorn or disbud the animals (e.g., Fluch, 1986). For fattening bulls the Council of Europe Recommendation Concerning Cattle (1988) states that "group-housing of horned bulls or bringing together horned and dehorned bulls together should be avoided." If, alternatively, it is decided to leave the cattle horned, it is commonly supposed that they can only successfully be kept in loose housing under improved housing and management conditions. This reflects farmers' experiences (Schneider et al., 2009) while almost no published scientific evidence from experimental studies on this issue is available.

Detailed recommendations concerning improved housing and management conditions for horned cattle to our knowledge can only be found in German language, from Austria, Germany and Switzerland (Menke & Waiblinger, 1999; Rist, 2002; Fürschuss et al., 2004; Eilers et al., 2005; Schneider, 2008). These recommendations again are mainly based on practical experiences and opinions, and only to a very small degree on results from experimental or epidemiological studies. Where such evidence is available, it will be mentioned in the following. Furthermore, the existing recommendations relate to dairy cows, and not to suckler herds or beef bulls, although it appears valid to transpose general principles. Very rarely, specific requirements for horned beef cattle are addressed at specific points in general recommendations (see below).

In some countries (e.g., Austria, Switzerland) there are legal minimum standards regarding space allowances or resource availability for cattle. Although according to the Council of Europe Recommendation Concerning Cattle (1988) "space allowances for cattle housed in groups should be calculated … taking into account the presence or absence of horns …" these minimum standards do not differentiate between horned and hornless cattle. The same is true for the numerous official or unofficial welfare recommendations on housing and management conditions for cattle with some exceptions: For instance, the recommendation of the Danish Agricultural Advisory Center (2002) states that for horned beef cattle feeding area width and resting area should be increased up to 20 % depending on breed and temperament. Also in the recommendations of the Lower Saxonian Rural Ministry (2007) some differentiations regarding horned and dehorned dairy cows can be found.

In the following we will provide an overview over those areas that in the different specific recommendations are highlighted as crucial for the successful keeping of horned dairy cows. We will compare the recommendations with each other and, exemplarily, with some official general standards or recommendations. Aspects where no differentiation in relation to the presence or absence of horns can be detected will not be tackled. Finally we will conclude on the state of established practical experience and scientific knowledge as well as on future research needs concerning the alternative of keeping cattle with horns.

5.1. Housing conditions

There is general agreement (Menke & Waiblinger, 1999; Eilers et al., 2005; Schneider, 2008) that with respect to housing conditions the design and dimensions of feeding places, of passageways, space allowances in general and availability of cubicles, if applicable, are of special impor-

tance. The underlying aim is to avoid or reduce competitive situations, taking into account the assumed greater avoidance distances in horned cattle (Menke & Waiblinger, 1999; Eilers et al., 2005; Schneider, 2008). For example, Menke and Waiblinger (1999) recommend that population density should be 10-20 % under the allowed maximum. In fact, a negative correlation between general space allowance per cow and agonistic behaviours and skin injuries caused by horns was found by Menke et al. (1999) in an epidemiological study including 35 horned dairy herds in loose housing. Another aspect generally regarded as crucial is the prevention of bottleneck and dead-end situations (Menke & Waiblinger, 1999; Rist, 2002; Eilers et al., 2005; Schneider, 2008). Additionally, Schneider (2008) states that a clear view in all directions is important for the animals in order to allow adequate responses to other cows. She further recommends that pen equipment such as drinking troughs, salt blocks, concentrate feeders or brushes are placed in such a way that there is a minimum free space of 3 m from at least three sides.
An overview over the different minimum recommendations for horned dairy cows in relation to legal minimum standards or official recommendations is provided in Table 2.

5.1.1. Feeding area

Most authors recommend the use of a feeding rack with a self-locking mechanism, because fixation of the cows during main feeding periods ensures undisturbed feeding for low and high ranking animals (Menke & Waiblinger, 1999; Eilers et al., 2005; Schneider, 2008). Menke & Waiblinger (1999) and Schneider (2008) advise against feeding gates that do not open to the top because the possibility to enter and leave the feeding rack fast and safely is not provided. Minimum recommendations concerning feeding place width vary from 75 cm up to 100 cm per animal (Table 2). Schneider (2008) additionally points out that requirements for bulls might be even higher, because horns in male cattle often grow outwards/vertically. Also for the alley width behind feeding places different minimum recommendations are given, ranging from 3.50 m to 5.00 m (Table 2).
In order to avoid frequent regroupings of the herd according to performance level which lead to increased agonistic interactions, Menke & Waiblinger (1999) suggest to use selection gates towards different feeding areas where different energy levels are fed.
Eilers et al. (2005) and Schneider (2008) additionally make recommendations on minimum numbers of drinking troughs (1 trough per 10 animals). Menke & Waiblinger (1999) mention that it may be advantageous to provide water troughs directly at the feeding rack (2 animals/trough) so that water is available during fixation.
Generally concentrate feeders are seen as a potentially problematic resource regarding increased risks for horn-related injuries, especially at udder and vulva. The advice is to provide enhanced protection for the cows in the feeding station by prolonged walls at the rear or, better, an enclosing mechanism (Menke & Waiblinger, 1999; Eilers et al., 2005; Schneider, 2008). Only Menke and Waiblinger (1999) provide recommen-

dations for minimum dimensions of concentrate feeders (80 cm wide and 240 cm long).

5.1.2. Activity / walking area

Minimum recommendations concerning alley widths between cubicles and one-way-alleys vary from 2.50 m to 4.00 m, and 0.80 to 1.00 m, respectively (Table 2). Menke and Waiblinger (1999) and Schneider (2008) additionally point at the beneficial effects of an outdoor run that provides supplemental withdrawal space. In fact, Menke (1996) showed experimentally on 5 commercial farms with deep litter or flow straw pens that an outdoor run that is additionally open during the night reduced the frequency of agonistic interactions. In another experimental study on an experimental farm Schneider et al. (2008) found in tendency less interactions and injuries when a larger outdoor run (9 m^2/cow) was accessible in comparison to a smaller (4.5 m^2) or no outdoor run. The attractiveness of the outdoor run should furthermore be enhanced by factors such as permanent access, feeding racks, drinking troughs or brushes (Schneider, 2008).

5.1.3. Lying area

Basically, there are two types of lying areas: the unstructured and the structured type. Schneider (2008) argues that unstructured lying areas provide the possibility to flee fast, but at the same time lying animals can easier be attacked. Lying, lying down and standing up can be performed unhindered. In structured lying areas, i.e. cubicles, the cows are better protected, but when attacked, usually have to retreat in direction of the attacking cow, that is to the rear of the cubicle. Therefore, Eilers et al. (2005) and Schneider (2008) recommend provision of cubicles with the possibility to flee forward. At the same time, it is assumed that horned cows need a considerably larger front head lunge area (get-up-zone) of up to 100 cm (Fürschuss et al., 2004; Schneider, 2008). This explains the higher cubicle lengths recommended for horned cows of 2.85 m to 3.00 m (Table 2). Additionally, Menke and Waiblinger (1999) advised against cubicles on a raised base because they assumed a higher risk for pushes against the udder of the lying cow. Regarding the unstructured lying area space requirements proposed range from 4 to 12 m^2, partly depending on the type of litter system (Table 2). Schneider et al. (2008) found in a small experimental study on an experimental farm with a two floor deep litter system in tendency less interactions and less injuries with larger space allowances (8 m^2/cow vs. 4.5 m^2).

5.1.4. Milking parlour and waiting area

Schneider (2008) and Menke and Waiblinger (1999) recommend to use milking parlours with single stalls where the cows are safe from threatening and aggressive behaviour of other cows. Tandem und butterfly milking parlours are recommended. They strongly advise against veterinary treatments in the parlour as aversive experiences might cause refusal to enter (Menke & Waiblinger, 1999), and against feeding of concentrate

during milking because it might increase agitation in the waiting area (Schneider, 2008).
Only Schneider (2008) gives recommendations regarding the waiting area. She proposes that square shapes of this area are preferable over tubular shapes because they provide more withdrawal space. She stresses the importance of a good view over the whole waiting area that allows the stockperson to take appropriate action in case of aggressive behaviour. For small herds Schneider (2008) even sees the alternative to guide the cows individually or in small groups in the milking parlour which however is associated with a higher workload.

5.2. Management

Menke and Waiblinger (1999) as well as Schneider (2008) emphasise that management is a key factor of success in keeping horned cows in loose housing systems, namely the feeding and social herd management as well as the problem solving ability of the farmer (e.g., immediate repair of defective feeding racks, solutions to problems from single aggressive cows). For the latter, Menke et al. (1999) in their epidemiological study found significant effects on the frequency of aggressive behaviour and injuries caused by horns.

5.2.1. Feeding management

As already stated above, a fixation of the cows during main feeding periods is recommended in order to reduce agonistic interactions during feeding. However, it is an open question for how long cows should be fixed. According to Schneider (2008) the duration of fixation at the feeding rack needs to be determined for each farm individually. Menke (1996) investigated this issue experimentally in five horned commercial herds. Although not analysed statistically, he found that in three of the investigated herds longer fixation time (3 hours vs. 0.5 hours) led to less agonistic interactions, but the opposite in the other two. He deduced from his observations that in the latter cases increased competition around the drinkers arose, because cows were very thirsty after the long fixation time.

5.2.2. Social herd management

Schneider (2008) argues that a high average age is associated with reduced agonistic interactions in the herd as it means reduced introductions of young animals into the herd. Furthermore, Menke and Waiblinger (1999) and Schneider (2008) agree that the introduction of new herd members needs special attention. Menke et al. (1999) in their epidemiological study found significantly fewer injuries in herds where the farmer habituated new animals gradually to the herd and paid attention to the social behaviour during integration (Menke et al., 1999). In a small experimental study including horned commercial herds Menke (1996) further observed that the integration of one new herd member compared to a group of new members led to significantly fewer agonistic interactions in herd members and integrated animals. However, this was only a very small study and Schneider (2008) on the contrary recommends to introduce small groups instead of single animals based on reports of farmers

(Schneider et al. 2009). Both recommendations (Menke & Waiblinger, 1999; Schneider, 2008) regard it advantageous, if possible, to introduce new herd members on pasture where there is ample space available.
Cows in oestrus may lead to considerable disturbances and increased agonistic interactions in the herd. Menke et al. (1999) showed that measures such as removing cows in oestrus for a short time from the herd was significantly related to less agonistic behaviour. In this connection Schneider (2008) suggests that a bull running with the herd has calming effects on the cows.
Finally, the importance of breeding selection against aggressiveness, e.g. by removing aggressive animals from the herd that are responsible for a considerable amount of injuries, is stressed in both recommendations (Menke & Waiblinger, 1999; Schneider, 2008).

5.2.3. Manipulations of the horns

There are possibilities to modify the horns in order to reduce the risk of injuries (Menke & Waiblinger, 1999; Schneider, 2008). One possibility is to cut or grind off the tips of the horns in order to make the horn tips round (Menke & Waiblinger, 1999; Schneider, 2008). Another possibility is to cover the horn tips of more aggressive cows with soft protectors (Schneider, 2008).

5.3. Handling

The same recommendations for handling horned and dehorned cows apply, but their consideration is regarded even more important in horned cows. They include to be assertive and calm in all situations (Menke & Waiblinger, 1999; Schneider, 2008). A clear communication with the animals and predictability of the stockman are assumed to reduce anxious behaviour and are therefore advised (Menke & Waiblinger, 1999; Schneider, 2008). In general, a good human-animal relationship, preferably from birth on, should be aimed at (Menke & Waiblinger, 1999; Eilers et al., 2005; Schneider, 2008). On this line Menke et al. (1999) found in their epidemiological study a significant negative relation between the frequency of agonistic behaviours and the ability of the stockperson to identify individual cows and the frequency of personnel changes. Therefore, it is recommended to have as little personnel changes as possible (Menke & Waiblinger, 1999; Schneider, 2008).

5.4. Transport and slaughter

No specific recommendations for the transport and slaughter of horned cattle can be found.

Table 2: Overview over minimum standards or recommendations regarding crucial aspects for the keeping of (horned) dairy cattle

	Legal minimum standards		Official minimum recommendations		Specific minimum recommendations for horned dairy cows					
	Austrian animal husbandry regulation (2004)	Swiss animal welfare regulation (2008)[1]	Danish Agricultural Advisory Center (2002)[2]	Germany: Lower Saxonian Rural Ministry (2007)[3]	Germany: Lower Saxonian Rural Ministry (2007)[3]	Menke & Waiblinger (1999)	Rist (2002)[4]	Fürschuss et al. (2004)[5]	Eilers et al. (2005)	Schneider (2008)
Feeding place width (per animal)	40-75 cm (body weight 150 - over 650 kg)	65-78 cm	70 cm	70-75 cm		75 cm	80-90 cm	80-90 cm	80-90 cm	85-100 cm
Alley width behind feeding place	3.20 m	2.90-3.30 m	3.20 m	3.50 m (4.00 m recommended)		3.50 m		4.00 m	4.50 m	5.00 m
Animal/feeding-place ratio	2.5:1 if food provision is ad libitum			1:1 (in larger groups 1.2-1.5:1)		1:1	1:1.1-1.2		1:1.1-1.2	1:1-1.1
Concentrate feeder				1 station/25 cows		Width: 0.80 m, length: 2.40 m				
Animal/water troughs ratio			6:1						10:1	10:1
Alley width between cubicles	2.50 m	2.20-2.60 m	2.40 m (1.80 m for crossovers)	2.50 m (3.00 m recommended; one-way: 1.0-1.2 m)	3.5 m	2.50 m (one-way-alleys: 0.8-1.0 m)	4.00 m	4.00 m (one-way-alleys: 1.0 m)	4.00 m	4.00 m, (crossovers: 3.00 m, one-way-alleys: 1.0 m)
Cubicle length (wall-facing)	1.90-2.60 m (body weight 300 – over 700 kg)	2.30-2.60 m	2.60 m	2.50-2.80 m (incl. 80 cm get-up-zone)			3.00 m (incl. 60 cm get-up-zone)	2.85 m (incl. 80-100 cm get-up-zone)	3.00 m	3.00 m (incl. 100 cm get-up-zone)

[1] for cows with height at withers of 125 – 145 ± 5 cm; [2] for cows of 700 kg body weight/large breeds; [3] for new buildings; [4] for cows of 500-650 kg body weight; [5] for cows with height at withers 135 ± 5 cm resp. 650 kg body weight

Table 2 (continued): Overview over minimum standards or recommendations regarding crucial aspects for the keeping of (horned) dairy cattle

	Legal minimum standards		Official minimum recommendations		Specific minimum recommendations for horned dairy cows					
	Austrian animal husbandry regulation (2004)	Swiss animal welfare regulation (2008)[1]	Danish Agricultural Advisory Center (2002)[2]	Germany: Germany: Lower Saxonian Rural Ministry (2007)[3]	Germany: Germany: Lower Saxonian Rural Ministry (2007)[3]	Menke & Waiblinger (1999)	Rist (2002)[4]	Fürschuss et al. (2004)[5]	Eilers et al. (2005)	Schneider (2008)
Cubicle length (double rows)	1.70-2.40 m (body weight 300 – over 700 kg)	2.00-2.35 m	2.45 m	2.40-2.70 m			2.40 m	2.85 m (incl. 80-100 cm get-up-zone)	2.70 m	2.50 m
Animal/cubicle ratio		1:1		1:1		1:1	1:1.1-1.2		1:1.1-1.2	1:1.1-1.2
Lying area per animal (unstructured area)		4.00-5.00 m^2	6.50 m^2	One floor deep litter: 6-8 m^2 two floor deep litter: 4.5-5 m^2; one floor straw flow: 5 m^2, two floor straw flow: 4-4.5 m^2	One floor deep litter: 12 m^2; two floor deep litter: 7-9 m2; one floor straw flow: 5 m^2, two floor straw flow: 4-4.5 m^2		8.00 m^2	7.00 m^2	8.00 m^2	8.00 m^2
Outdoor run: area per animal			5.00 m^2	3.00 m^2			15.00 m^2	12.00 m^2-15.00 m^2	12.00 m^2	4.50 m^2

[1] for cows with height at withers of 125 – 145 ± 5 cm; [2] for cows of 700 kg body weight/large breeds; [3] for new buildings; [4] for cows of 500-650 kg body weight; [5] for cows with height at withers 135 ± 5 cm resp. 650 kg body weight

5.5. Discussion and conclusions

The specific recommendations for the housing and management of horned dairy cows indeed include quite a number of higher minimum standards than usually to be found for hornless cows (for housing see the comparison in Table 2). However, the risk areas identified are of similar relevance for horned and hornless cattle. For example, high competition, particularly in the feeding area, frequent social change or lack of withdrawal space may impair welfare in dehorned cattle as well. It is not known yet, if horned cows truly show higher inter-individual distances than hornless cows and, therefore, have higher space requirements. Alternatively, the difference may mainly lie in the more visible consequences of agonistic interactions, namely horn-inflicted scratches and wounds, whereas possible bruises in hornless cattle are difficult to detect. No studies that may answer these questions are available yet. Additional to the risks of injury due to social interactions, there are clear risks of horn injuries due to inadequate equipment (e.g. the feeding rack) that need to be avoided. Especially regarding certain dimensions of the housing environment there is a certain variation in the recommendations for horned dairy cows. Partly, they may be time related, as 9 years lie between the oldest and youngest recommendation, and cows have grown larger in the meantime. However, due to the very limited scientific evidence on the effects of different dimensions on the welfare of horned dairy cows, future research in this area would be needed. The same is true for certain management measures such as a welfare-friendly introduction of new herd members.

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