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Preventive measure against possible BSE-hazard: Irreversible electrical cattle stunning - a review

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ABSTRACT

During stunning the entrance of the bolt into the cranial cavity results in massive brain tissue damage. There is a risk of brain tissue particles being transferred via the blood flow in the minor blood circulation system. This can lead to contamination of blood, lungs and heart with the BSE agent. Tissues of CNS carry almost all of the infectivity in cattle sub-clinically and clinically affected by BSE. The approved rapid post-mortem tests cannot identify BSE-infected animals early in the incubation period. Thus it is not inconceivable that an animal with a negative rapid test result could, if stunned by a method that produced emboli, still have BSE-infected emboli dispersed through the venous blood stream, the lungs and the heart. Two systems for electrical stunning of cattle are presented. The replacement of the penetrative stunning method with cardiac arrest stunning, in regions where the BSE is present, will prevent the risk of dissemination of brain particles into the blood and carcass.

Key words: bovine spongiform encephalopathy (BSE), variant Creutzfeldt-Jakob disease (vCJD), dissemination of brain particles, stunning methods and BSE risks, irreversible electrical stunning

Introduction

After the outbreak of the bovine spongiform encephalopathy (BSE) contamination of beef by tissues of the central nervous system (CNS) due to slaughter technology causes some concern considering the potential health hazard by food-borne exposure to the

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infectious agent of BSE (LUECKER et al., 2002). Particular risks are associated with those elements of the bovine CNS which are most closely linked with BSE (brain and spinal cord) and their potential for contamination of abattoir workers, carcass and the abattoir environment during slaughter of BSE- infected animals (PRENDERGAST et al., 2003). Due to concerns about a link between variant Creutzfeldt-Jakob disease in humans and similar prion protein-induced disease in cattle, i.e., BSE, strict controls are in place to exclude BSE-positive animals and/or specified risk materials (SRM), including bovine CNS tissue, from the human food chain (DALY et al., 2002). These tissues comprise the skull (including the brain and eyes), the tonsils, the vertebral column excluding the vertebrae of the tail and the transverse processes of the lumbar vertebrae, also including dorsal root ganglia and spinal cord, of bovine animals aged over 12 months, and the intestines from the duodenum to the rectum and the mesentery of bovine animals of all ages. In addition to the above mentioned SRM the following tissues must be designated as SRM in the United Kingdom of Great Britain and Northern Ireland and in Portugal, with the exception of the Autonomous Region of the Azores: the entire head excluding the tongue, including the brain, eyes, trigeminal ganglia and tonsils; the thymus, the spleen and the spinal cord of bovine animals aged over 6 months (REGULATION (EC) No 270/2002). Nevertheless, because of the open scientific questions regarding the transmission and spread of the BSE prion in cattle, the German Federal Institute for Health Protection of Consumers and Veterinary Medicine (BgVV) [Bundesinstitut für gesundheitlichen Verbraucherschutz und Veterinärmedizin] recommends that the definition of specific body parts as SRM should in future be applied, for precautionary reasons, without age restriction to all cattle and in all countries in which BSE cases have occurred (BgVV, 2001d).

Despite the rigorous application of current SRM control policies and the prohibition of pithing, traditional slaughter technology, especially captive bolt stunning, head handling and carcass splitting continue to present significant opportunities for CNS material including BSE prion present in the CNS of any sub-clinically infected cattle to contaminate meat entering the human food chain, abattoir equipment, surfaces and operatives and should therefore be replaced by safer techniques (ANIL et al., 1999, 2002; BAUER et al., 1997; BgVV 2001a, 2001b, 2001c, 2001d, 2001e, 2001f, 2001g, 2001h, 2002; BUNCIC et al., 2002; DALY et al., 2002; ELLERBROEK and SCHUETT-ABRAHAM, 2002; GARLAND et al., 1996; HELPS et al., 2002; HORLACHER et al., 2002; LOVE et al., 2000; LUECKER et al., 2002; SCHMIDT et al., 1999; PRENDERGAST et al., 2003; RAMANTANIS 2002a, 2002b, 2003; SCHUETT-ABRAHAM, 2002b; SCHWAEGELE et al., 2002; SSC 2001a, 2001b, 2002; TROEGER 2001, 2002a, 2002b, TROEGER et. al., 2002). Therefore, the risk of meat contamination by CNS particles when applying certain slaughtering methods is of great concern in relation to the potential health hazard for consumers posed by food-borne exposure to the infectious agent of BSE and because of the suggested link between BSE and vCJD.

Stunning of animals

The stunning of animals is applied to induce a state of unconsciousness and insensibility of sufficient duration to ensure that the animal does not recover until killed by bleeding out. A second reason for stunning is to produce sufficient immobility to facilitate the initiation of exsanguinations. Bleeding out must be accomplished after stunning without delay. According to current legislation (DIRECTIVE 93/119/EC) cattle must be stunned before slaughter. Animals must be restrained in an appropriate manner, so as to spare them any avoidable pain, suffering, agitation, injury or contusions. The animals' legs must not be tied and animals must not be suspended before stunning or killing. Currently permitted stunning and killing methods are: A. Stunning 1) captive bolt pistol, 2) concussion, 3) electronarcosis and 4) exposure to carbon dioxide and B. Killing 1) Free bullet pistol or rifle, 2) electrocution and 3) exposure to carbon dioxide. (ANNEX C, 93/119 /EC). However, in practice exposure to carbon dioxide is inappropriate and is not used to stun ruminant species. Mechanical stunning is either non-penetrative or penetrative. Non-penetrative stunners have a "mushroom-headed" bolt, which impacts with the skull but does not enter the brain, causing the stun due to concussive forces alone. Penetrative stunners cause insensibility due to the concussive blow of the skull, and the physical damage resulting from the entry of the bolt into the brain. Captive bolt penetrative stunning is widely used in cattle. Explosive cartridges and compressed air have been used to drive bolts through the skull of cattle. Where slaughter lines move rapidly, the use of the cartridge-driven pistol causes unacceptable delay. To overcome these difficulties the pneumatic stunner has been devised. A version of the pneumatic stunner with a hollow bolt, injects, after the bolt has been shot into the head, highly compressed air in the cranial cavity, largely destroying the brain and sometimes the spinal cord. This makes pithing unnecessary. It is noted that some of these stunning devices have side ports, which vent air at 180 pounds per square inch into the cranial vault (BAUER et al., 1997). The combination of the captive bolt pistol, driven by explosive cartridges or compressed air and pithing, or the sole use of the pneumatic stunner with a hollow bolt that injects highly compressed air in the cranial cavity, cause death to the animal, even without the subsequent bleeding out (BgVV, 2001a). Pithing is not recommended for hygienic reasons independent of BSE risks (MACKEY and DERICK, 1979). The injection of high-pressure air into the brain produces a significant blowback of brain tissue. This produces a smearing of the head of the animal with liquefied brain. The use of this stunner for a second time, following an initial ineffective stun, leads to a massive quantity of liquefied brain matter exiting from the original bolt hole, thus heavily exposing abattoir workers to this material. It has also been reported that operators and the slaughter premises very quickly become contaminated with this material (SCVM, 1998). Both pithing and the injection of air into the cranial cavity were prohibited by the Commission Decision 2000/418/EC. A 2001 survey demonstrated that no American Meat Institute member used air-injected pneumatic cattle stunning devices. In addition, stunner manufacturers in the USA ceased producing air-injected pneumatic devices in 1997 (SMITH, 2002).

Risk of dissemination of CNS particles into and/or onto the carcass and within the abattoir environment

The entrance of the bolt into the cranial cavity results in massive brain tissue damage with bleeding and, in some cases, brain tissue emerges from the hole made by the bolt. Some of this may be maintained within the air-filled sinuses of the frontal bones but some may escape to the exterior, including the trough where the blood is collected. If a second shot is required to effectively stun an animal (a not uncommon event) the force of penetration through a second hole may cause a significant release of brain material through the first hole (SSC, 2001a). Penetrative captive pistols are not sterilized between successive animals normally, and it is unlikely that it would have been practical under commercial conditions. When a healthy animal that nevertheless has infectivity in the brain is stunned using a penetrative method there is the possibility that any infectivity that contaminates the bolt of the gun could be introduced into one or more animals sequentially stunned with the same gun (SSC, 2001b).

Other agents, i.e. bacteria, have been already reported as being transferred by this route. Inoculation of the brain of lambs through the stun hole immediately after being stunned by a cartridge-operated, penetrative captive bolt pistol with marker organisms showed that the marker organisms can be recovered from the blood, liver, lungs, spleen, lymph nodes, deep muscles and the carcass surface (BUNCIC et al., 2002). When the pistol, which had been used to stun one brain-inoculated lamb, was used to stun consecutive, non-inoculated lambs, the marker organisms were found in stun wounds, in blood and on carcass surface of the consecutively stunned animals. Overall, the results of their study indicated that penetrative stunning of food animals could carry risks of internal and/or external microbial contamination of edible tissues and organs. Therefore, the risk of spreading harmful agents (not only limited to the BSE agent but including other pathogens as well) between animals via penetrative stunning has to be considered as significant. The use of non-penetrative stunning methods largely eliminates the problem of cross-contamination of other cattle from the stunning gun (SSC, 2001a). DALY et al. (2002) used a marker organism to model the effects of commercial captive bolt stunning procedures on the movement of mobilized CNS material within slaughtered animals and the abattoir environment. The marker organism was detected in the slaughter environment immediately after stunning and in the abattoir environment at each subsequent stage of the slaughter-dressing process. It was also detected on the hands of operatives; on slaughter equipment, and in samples of blood, organs, and musculature of inoculated animals. The study demonstrated that material presented in, or introduced into, the CNS of cattle during commercial captive bolt stunning may become widely dispersed across the many animate and inanimate elements of the slaughter-dressing environment and within derived carcasses, including meat entering the human food chain.

With regard to the possible transferring of prions due to the stunning procedure PRENDERGAST et al. (2003) detected CNS proteins on the captive bolt gun (CBG), the receiving platform for stunned animals and in material leaking from the CBG apertures of the bovine heads. The authors reported that contamination of the CBG is particularly undesirable since, once contaminated, it has the potential to spread CNS material from animal to animal and thus transfer any prions present in one animal into other animals. The release of CNS proteins from the aperture made by the CBG during the post-stunning processing demonstrates the potential for the prion to leak onto the slaughterhouse floor, with subsequent dissemination to other areas of the abattoir by movement of personnel, equipment, etc. These observations confirm the significant risks of direct and indirect dissemination of brain tissue, during and immediately after stunning.

As the heart continues to pump for several minutes following the entrance of the bolt (ANIL et al., 1999), there is a risk of brain tissue particles being transferred via the (venal) blood flow in the minor blood circulation system. This can lead to a contamination of blood, lungs and heart with the BSE agent (TROEGER, 2001). In humans it is well recognized that severe penetrating injuries to the brain and head trauma can cause such severe brain damage that cerebral emboli are produced which most frequently are found in the lung at autopsy (SSC, 2001a). Commenting on the implications of stunning with air-injected pneumatic devices BAUER et al. (1997) hypothesized that brain tissue is "blown" through the foramen magnum, enters the anterior vena cava (via the external jugular or costocervical vein), travels to the right auricle of the heart and either enters the lungs via the right ventricle of the hurt/main pulmonary artery or retrograde out the right auricle into the posterior vena cava and subsequently to the veins of the liver and kidney. Embolic brain tissue could also enter the musculature of the diaphragm via the phrenic veins, which enter the posterior vena cava between the right auricle and the hepatic veins. Emboli could also travel to the musculature of the rear legs via the iliac veins. Regarding the possible dissemination of CNS tissue to the edible parts of the carcass after the use of a pneumatically operated air injection and/or conventional captive bolt pistol with subsequent pithing, ANIL et al. (1999) reported that some of the emboli were smaller than the calibre of most capillaries and it is likely that some of the embolic tissue can pass through the pulmonary capillary bed and through the left side of the heart to the visceral and other edible parts. Although no evidence of emboli in the arterial blood was found, probably due to the small size of blood samples and restricted timing of the sampling, ANIL et al. (2002) concluded that more detailed investigations are required to determine whether or not emboli can reach the systematic arterial circulation and the edible parts of the carcass. Skin, hair and bone could also be carried into the vasculature with the brain tissue subsequent to the stunning process (BAUER et al., 1997). There are data that also without pithing, brain material is detached in the trajectory of a penetrative captive bolt. The estimated amounts are in the range of 10-35 g of brain material (SSC, 2001b). When a penetrative cartridge-operated conventional captive bolt pistol is used (cow puncher, Accles and Shelvoke) an average of 10 g of brain tissue (out of a total of 450 g) can be dislodged. This figure represents, approximately, the maximum potential load of prion-contaminated tissue that might be disseminated haematogenously as a result of using a captive bolt gun on an animal with BSE (ANIL et al., 2002). Since less than 1 g of infected brain is sufficient to infect a cow by the oral route (SCVM, 1998) and since the minimum infectious dose of BSE for humans is not known (SSC, 1999), the risk of the introduction of CNS material into other tissues by the use of penetrative stunning, should be seriously considered. This risk of contamination has been proved in several scientific studies. The frequency with which CNS tissue enters the bloodstream depends on the method of stunning. In the USA, GARLAND et al. (1996) found visible pieces of brain tissue in the pulmonary arteries of 2.5 to 5 per cent of cattle examined after being stunned with a pneumatically activated, penetrating captive bolt pistol, that introduced air intracranially. BAUER et al. (1997) documented the finding of brain macroemboli in the pulmonary arteries of cattle after stunning with a pneumatic-actuated penetrating captive bolt stunning device. The application of pneumatic-powered air injection stunners (PPAISs), pneumatic-powered stunners (PPSs), and cartridge-fired stunners (CFSs) in commercial beef slaughter plants was evaluated in 15 beef slaughter plants in the USA by SCHMIDT et al. (1999) in order to determine the extent of dissemination of central nervous system tissue. In eight plants where PPAISs were used, 33% of hearts examined (n = 1,050) contained large clots in the right ventricles. In the four plants where CFSs were used, 1% of the hearts (n = 480) contained detectable clots. In three plants where the newly modified PPSs were used, 12% of the hearts (n = 450) contained detectable clots. Large segments of spinal cord were detected and confirmed histologically from two hearts in a plant that used a PPAIS. Most of the material was found in a single right ventricle and was composed of 10 to 13 cm segments of spinal cord. ANIL et al. (1999) reported that the frequency of occurrence of neural emboli in 15 cattle was 33% after powered air injection stunning, about 6% (1 of 16) of cattle after conventional cartridge-operated captive bolt pistol with subsequent pithing; but no evidence of embolism was found in 15 cattle stunned with a non-penetrating captive bolt or in 14 cattle stunned with a conventional penetrating captive bolt pistol without pithing. Regarding the dilution of the brain tissue in the blood, the report by ANIL et al. (1999) shows clearly that contamination occurs within the first 40 seconds after stunning the animal. After that, the levels become insignificant. But it is considered unlikely that in the majority of cattle sticking is accomplished within 20-40 seconds of stunning. Intervals between stunning and sticking of about 1 minute in total have been observed under field conditions (SSC, 2001a). In Germany, a total duration of 60 seconds is indicated in the legislation (TIERSCHLV, 1997). According to the Humane Slaughter Association (HSA) it is more likely to exceed one minute (HSA, 1995). Thus, in the event that sticking is not completed within 40 seconds of stunning, the majority of cerebral emboli will already have traversed the heart or be trapped in the heart or lungs, which accords with the findings in practice (GARLAND et al., 1996; SCHMIDT et al., 1999). HORLACHER et al. (2002) examined the lungs of 323 cattle after stunning with a cartridge-driven captive bolt without pithing. Sixty per cent of the lungs contained emboli (in total, 358 emboli found in 194 lungs), which were tested with immunochemistry as well as immunohistochemistry to detect CNS. The results of their study suggest that contamination of the lung with CNS cannot be excluded. However, the incidence appears to be very low. Since the lungs of cattle are usually not consumed the authors concluded that the human exposure risk following the consumption of a contaminated lung is considered slight. LUECKER et al. (2002) examined the lungs and hearts of 726 animals stunned with a cartridge-driven captive bolt. Forty-eight of them contained a total of 58 emboli-like particles in lungs and/or right ventricles. The incidence of the emboli-like particles was found to be slightly higher in animals slaughtered without pithing (5.9%) than animals slaughtered with pithing (4.1%). Overall, the results showed that CNS contamination of bovine carcasses could not be excluded by current slaughter technology. However, it was noted that the additional human BSE-exposure risk could be judged to be at least minor when considering the extent of contamination, dilution effects and BSE-testing.

Tissues of CNS carry almost all of the infectivity in cattle sub-clinically and clinically affected by the BSE. In naturally occurring BSE in cattle, the age at which brain material may contain infectivity is unknown and it is not possible to predict with certainty when a natural case of BSE will show infectivity in the brain. The limited available data from experimental oral infection of cattle suggest that infectivity would become detectable in the central nervous system only at a late stage of the incubation time, some months before clinical onset (SSC, 2001b). The approved rapid post-mortem tests, which are mandatory for all over 30 (24)-month-old bovines, cannot identify BSE infected animals early in the incubation period, but they are able to prove the presence of the BSE agent close to the end of the incubation period for animals that are already clinically ill (SPECIAL REPORT, 2001) or just before the outbreak of the illness [some months before clinical onset, (SCHUETT-ABRAHAM, 2002a); at the earliest six months before the outbreak of the clinical disease (ELLERBROEK and SCHUETT-ABRAHAM, 2002)] and the brains of which might be already highly infectious (SCHUETT-ABRAHAM, 2002b). These tests cannot identify pre-clinical cases at earlier stages of incubation (Fig. 1). They are approved for use on animals over 30 months old, and may not be reliable for animals under that age (SPECIAL REPORT, 2001). Furthermore, the current rapid post-mortem tests detect PrP^{Sc}, not infectivity. Detection of PrP^{Sc} by any method is considered as evidence for the presence of infectivity. But absence of detectable PrP^{Sc} does not necessarily provide evidence of absence of infectivity. A negative PrP^{Sc} test result, including that from a rapid test, does not mean that the animal, or even the brain, is devoid of infectivity, whether it is currently detectable or not (SSC,

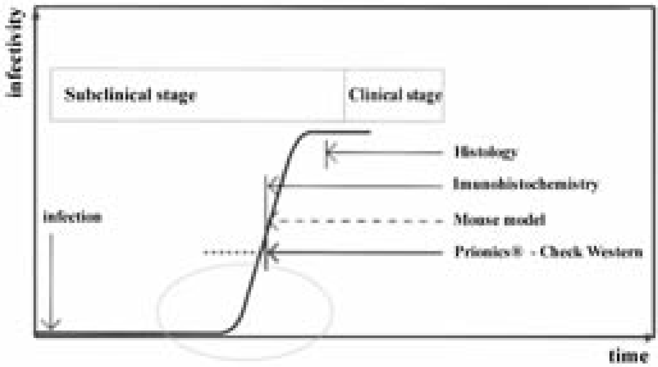

Fig. 1. Comparing sensitivity of Prionics® -Check Western with conventional reference methods. The encircled part in the infection curve during the subclinical stage cannot be identified (Prionics® - Check Western, catalogue No. 3184986, modified)

2001b). Thus, it is not inconceivable that an animal with a negative rapid test result could, if stunned by a method that produced emboli, still have BSE-infected emboli dispersed through the venous blood stream, the lungs and the heart, as described previously. There is no current method of estimating the magnitude of this risk. It would certainly be lower when methods other than penetrating methods and pithing are used (SSC, 2001a).

According to the scientific opinion on stunning methods and BSE risks adopted by the SSC of the EC in January 2002, if brain damage occurs and if brain particles are disseminated in the blood, the tissues and organs likely to be contaminated with the risk material, irrespective of the type of the penetrative stunning, in decreasing order of risk are: blood, pulmonary arteries, lung, right atrium and ventricle of the heart. The level of risk will vary according to the specific equipment used, the depth and velocity of penetration, the amount of brain material damaged, the location of the stun, the possibility of re-stunning, etc. The ranking order of stunning methods in terms of decreasing risk for causing contamination is: 1. Pneumatic stunner that injects air. 2. Pneumatic stunner that does not inject air. 3. Captive bolt stunner with pithing. 4. Captive bolt stunner without pithing. Negligible or absent risk can be expected from: Non-penetrative stunner and electro-narcosis (SSC, 2002).

As far as the level of risk to consumer health is concerned, the SSC adopted that the risk of contamination of tissues and organs with BSE-infectivity from CNS material as a consequence of the stunning method used for cattle slaughtering depends on three factors: a) the amount of BSE-infectivity in the brain of the slaughtered animal; b) the extend of brain damage, and c) the dissemination of brain particles in the animal's body. As far as the amount of BSE-infectivity in the brain is concerned, the question of the importance of the stunning method used becomes clearly irrelevant if cattle brains can be assumed to be free of BSE-infectivity, as is the case for all cattle from geographical BSE risk (GBR) I countries or all cattle under one year of age regardless of the GBR level of the country of origin. Moreover, when applied to cattle that have been passed as BSE-free at a rapid post-mortem test, or to cattle below 30 months of age, penetrative stunning methods other than stunning with a pneumatic gun that injects air, or any other stunning method accompanied by pithing, are likely to result in a much lower or no significant risk of contamination with the BSE-agent (SSC, 2002). By the above mentioned statement the SSC tends to assume that if the infection is transferred to other tissues in the animal, which may then be consumed, then a risk must be taken into account. However, no action is demanded, apart from the condemnation of the BSE-positive carcass, assuming that the BSE post-mortem rapid tests as being adequate to avoid the risk as a result of the emboli (PRIONDATA.ORG).

Nevertheless, animals older than 1 year, but less than 30 months, infected at birth, showed some level of infectivity (SSC, 1999) and BSE cases with clinical symptoms were found in Germany even in animals aged less than 30 months (ELLERBROEK and SCHUETT-ABRAHAM, 2002) and during 1986-2002 at least 18 cases of BSE in animals aged less than 30 months were reported in Great Britain - the youngest animal was only 20 months old (DEFRA). Additionally, as is mentioned above, the currently available BSE rapid tests detect infection only at an advanced stage of incubation. Currently, one cannot reliably say how long after a BSE infection BSE-prions will be detected in the brains of infected animals (ELLERBROEK and SCHUETT-ABRAHAM, 2002). Thus, in regard to the level of risk to consumer health (much lower or no significant risk) the above mentioned limit of 30 months set by the SSC may underestimate the presence of subclinical BSE cases, which may not be subjected in the rapid post-mortem BSE test according to EC Regulation 270/2002. Consequently, blood, heart, lungs, viscera, and other edible parts of the carcass of BSE- negative cattle, or even animals less than 30 months of age, may pose a definite risk to consumers as a result of the dissemination of embolic brain tissue (RAMANTANIS, 2002b).

Moreover, the histopathological examination of the typical BSE case is based on detection of the characteristic vacuolation affecting the grey matter of the brain. This vacuolation is orderly and usually distributed in a symmetrical bilateral fashion at the obex (PHILLIPS et. al., 2000). All fast post-mortem methods use the obex region for test performance. A low degree of heterogeneity of PrP^{Sc} concentration was detected in locations more distant from the obex, resulting in considerable low readings of positive BSE cases at the clinical stage (REPORT, 2002). In contrast, atypical BSE cases reported recently in Italy, France and Japan showed a different pattern of regional distribution and topology of brain PrP^{Sc} accumulation (BIACABE et al., 2004; CASALONE et al., 2004; YAMAKAWA et al., 2003). In addition, the Hiroshima and Ibaraki cases in Japan were aged only 21 and 23 months old, respectively. These cases were screened at the abattoir. It is noted that since

October 18, 2001 the BSE post-mortem examination for all cattle slaughtered has been compulsory in Japan (YAMAKAWA et al., 2003). Had such cases been presented for slaughter in the EU they would not have been tested according to the present legislation. Further, being that the infectivity in the atypical cases not largely confined in the obex region, the entry of the bolt in the frontal areas of the brain may result in much higher possibility of meat and organs contamination with the brain particles derived from that area.

Finally, as far as both the extent of brain damage and the dissemination of brain particles in the animal body are concerned, the SSC, stressing the relatively high risk of brain damage and disseminating infectivity resulting from stunning with a pneumatic gun that injects air under pressure and any stunning method accompanied by pithing, adopted the view that there is no clear-cut evidence of such a risk from other penetrative stunning methods, although on the basis of limited and preliminary data such a risk cannot be excluded for any form of penetrative stunning.

For reasons of precautionary health protection the BgVV suggests that the whole head (SCHUETT-ABRAHAM, 2002b), heart, lungs and blood following stunning by a penetrative captive bolt pistol without pithing should be designated as SRM and therefore be excluded from the food chain. If this is not possible, then an alternative stunning method, i.e. electric stunning, should be used. (BgVV, 2001b). Since 1998 the same Federal Institute has repeatedly proposed, in regions where BSE is present, the imminent replacement of the penetrative stunning method with cardiac arrest stunning, so that the transfer of risk material could be avoided (BgVV, 2001a).

Irreversible electrical stunning

In principle, systems for electrical stunning are available, but they have to be modified to suit European requirements (beef races, slaughtering capacities, animal protection) (TROEGER, 2001). The use of an irreversible, head to body electrical stun incorporating cardiac fibrillation and spinal discharge will prevent the risk of recovery, but maintain an intact but still carcass that is safe to handle (WOTTON et al., 2000) and above all the risk of dissemination of brain particles into the blood and carcass will be absent (RAMANTANIS, 2002b).

Irreversible electrical stunning for cattle was first developed in New Zealand during the 1980s. Since the summer of 2001 the first cardiac arrest stunning unit adapted to European requirements has been operational in continental Europe (ANONYMOUS, 2002). At least 4 standard units (Beef stunner) have so far been in commercial use in the UK (ANONYMOUS, 2000). At the time of stunning (and killing), adult cattle must be confined in a stunning pen. The cardiac arrest stun of cattle is performed in three sequential cycles (LEE, personal communication; GILBERT, 1993; WOTTON et al., 2000): First, a head-only cycle, to stun the animal; secondly, a cardiac cycle, to induce ventricular fibrillation (cardiac arrest), and thirdly, a spinal discharge cycle, to reduce convulsions after death (Fig. 2). The standard model of the beef stunner is a stand-alone cattle-stunning box with a pneumatically operated head restraint through a neck yoke and a chin lift. Electrical contact with the brisket is made through an electrode that is applied pneumatically between the animal's forelegs. Water is applied to the nose, neck and brisket electrodes to increase conductivity. The stunner delivers a current at 550 V, 50 Hz, sinusoidal AC, via a choke which limits the current to a maximum of about 3.5A, from a nose-contacting plate to three electrodes sequentially: firstly, a neck yoke applied for 3 seconds; secondly, a brisket electrode applied for 15 seconds, and thirdly, the rear of the Beef Stunner box applied for 4 seconds. It is essential that, during use, the electrodes are regularly inspected and kept in a clean state in order to ensure efficient operation. WOTTON et al. (2000) examined the electrical characteristics necessary to induce an effective and immediate stun and subsequently to produce a cardiac arrest in adult cattle. An effective and immediate stun was produced when ≥1.15 As sinusoidal AC at 50 Hz was applied between the nose and neck electrodes for less than 1 second. However, when applied for 3 seconds, head-only currents of >0.46 A sinusoidal AC at 50 Hz were sufficient to induce epileptiform activity in the brain. The induction of effective head-only electrical stunning resulted in an average interval of 50 seconds before the return of rhythmic breathing movements, and positive corneal and palpebral reflexes. The cardiac arrest cycle successfully induced ventricular fibrillation when >1.51 A sinusoidal AC at 50 Hz was applied for 5 seconds between the nose and brisket electrodes.

In Germany, a multifunctional stunning box developed in 2001 delivers a current from a nose contacting plate to, firstly, two neck electrodes, applied for a minimum of 4 seconds, and secondly a brisket electrode applied for 14-16 seconds (3.0-3.5 A, 50 Hz),

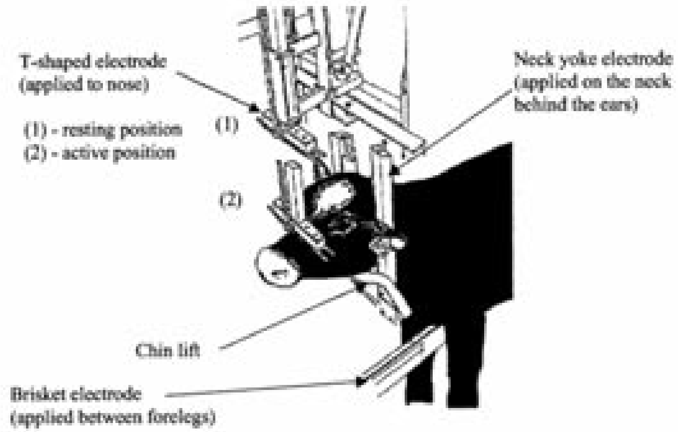

Fig. 2. Electrical stunning and killing of adult cattle (Code of practice, 2001)

inducing ventricular fibrillation (Fig. 3). At the end of the stunning current flow the box is rotated by approx. 20º at the side and the sticking takes place in the box, where the cattle still remains in an upright position. The sticking can be accomplished within 10 seconds of the end of the current flow. After the torrent of blood has ended the box is turned to the side, either by 90º to fasten the looped chains and pull the animal out upwards, or by 120º to allow the cattle to slide onto a receiving grate or a conveyor belt. Through a stunning

Fig. 3. Internal view of the stunning box (in animal direction): Breast and abdomen support bars (with cardio-electrode) and head fixing slide (green) in stunning position; muzzle electrode (centre back) (With the permission of BANSS, Biedenkopf, Germany)

transformer a constant current is applied (adjustable between 2.5 and 3.5 A). The current frequency can be selected between 10 and 990 Hz, as well as the duration of the stunning current flow. The individual parameters can each be selected separately for the "neck" and "heart" current paths.

The stunning box offers the following interesting characteristics: a) Form and positioning of the electrodes; the neck electrodes sit at points in the immediate vicinity of the target organ (CNS) in the area of the first cervical vertebra. This enables a high local current density to be achieved. The breast electrode is also positioned close to the target organ. Neither the electrodes nor the cattle are moistened. b) Breast and abdomen support bars: these enable the animal to be kept in an upright position, even while the stunning current is flowing and during the sticking. This counteracts mechanical damage to the slaughtered carcass due to the animal uncontrollably collapsing or tonic-clonic convaltions. c) Possibility of immediate bleeding after the end of the current flow; apart from a possible positive effect on the degree of bleeding, this ensures above all, that reflex movements during the further course of the slaughtering process are largely prevented.

As a result of the electrical current the ATP reserves of the muscles are mostly exhausted and the formation of new ATP is largely diminished due to the lack of oxygen (bleeding), so that insufficient energy is available for the muscle contractions (TROEGER, 2002a; SCHMIDT, personal communication). Since January 2003 the first unit has been operational in a slaughterhouse in Germany (SCHMIDT, personal communication). The stunning box fulfils the requirements of German legislation concerning occupational safety and animal protection aspects (MOJE, 2003). In a study of the quality parameters of the carcass and meat SCHNURR (2003) did not detect any broken bones and also noticed that the blood splash was minimum and that the glycolytic rate was fast. Furthermore, he observed a positive tendency as far as meat colour and tenderness were concerned, but also indications of elevated drip loss. He concluded that the irreversible electrical stunning in cattle is an acceptable procedure.

According to UK regulations the stunning and killing of adult cattle is brought about by passing a current of 2.5 A for 3 seconds through the head using nose-to-neck electrodes, followed sequentially by a current of 2.5 A for 14 seconds via neck and brisket electrodes to induce cardiac arrest and death (CODE OF PRACTICE, 2001). The German Animal Welfare at Slaughter Regulation (TIERSCHLV, 1997) in compliance with Directive 93/119/EC permits electrocution as the only electrical method allowed for pre-slaughter stunning of cattle over 6 months old. The irreversible electrical stunning of cattle over 6 months is brought about by passing a minimum current of 2.5 A, that has to be reached in less than 1 second, for a minimum of 4 seconds through the head, followed sequentially by passing a current for a minimum of 8 seconds, through the brisket to induce cardiac fibrillation.

Conclusions

Current penetrative stunning practice in traditional slaughter technology continues to present significant opportunities for CNS material, including BSE prion present in the CNS of any sub-clinically infected cattle, to contaminate blood, lungs, heart, viscera and other edible parts of the carcass, abattoir equipment and the environment and should therefore be replaced by safer techniques.

The replacement of the penetrative stunning method with cardiac arrest stunning in regions where the BSE is present would prevent the risk of dissemination of brain particles into the blood and carcass and the environment during and immediately after stunning. Furthermore, it would minimize the release of CNS material during the early stages of processing, and at the time of head handling and harvesting cheek meat, resulting in significantly less direct and indirect contamination of carcass meat, operatives and abattoir equipment and the environment.

The number of SRM tissues has been rising steadily. Both pithing and the injection of air into the cranial cavity have been prohibited in all member states of the EU since 1 January 2001. It could be the first step before prohibition of the penetrative stunning method for ruminants. Federal agencies and independent researches have been continuously raising the spectre of the widespread dissemination of SRM material during current slaughter practices. We should consider alternative methods of cattle stunning in order to forestall the situation.

(Footnotes)
Part of this paper was presented by S. B. Ramantanis at the 27th World Veterinary Congress, September 25-29, 2002, Tunis, Tunisia with the title "Alternative method of cattle stunning. Is it a necessity?" Further details and new information on the topic have since been added.

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RAMANTANIS, S. B., M. HADŽIOSMANOVIĆ, Đ. STUBIČAN: Mjere sprečavanja opasnosti od GSE-a: ireverzibilno električno omamljivanje goveda. Vet. arhiv 75, 83-100, 2005.

SAŽETAK

Omamljivanje klinom dovodi do teškog oštećenja moždanog tkiva. Postoji rizik da se čestice moždanog tkiva krvnom strujom prenesu u manji cirkulacijski sustav. To može uzrokovati kontaminaciju krvi, pluća i srca s uzročnikom GSE. Tkivo središnjeg živčanog sustava je izvor infekcije u supklinički i klinički oboljelih goveda od GSE. Primjenom brzih postmortalnih testova u inkubaciji ne mogu se identificirati inficirane životinje u ranom inkubacijskom periodu. Stoga postoji mogućnost da u životinja s negativnim rezultatom brzog testa, ukoliko se omamljuju uz mogućnost nastajanja embolije, nastali inficirani embolusi mogu proširiti uzročnika venskom cirkulacijom do pluća i srca. Budući da postoje dva načina električnog omamljivanja goveda, isključivanje prodorne metode omamljivanja primjenom klina koja uključuje srčani zastoj u područjima gdje ima GSE spriječio bi se rizik širenja čestica moždanog tkiva u druge organe.

Ključne riječi: goveđa spongiforma encefalopatija (GSE), varijanta Creutzfeldt-Jakobove bolesti (vCJB), širenje moždanih čestica, metoda ubijanja i GSE rizik, ireverzibilno električno omamljivanje