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SLAUGHTERING METHOD AND ANIMAL WELFARE

Klaus Troeger

Institute for Technology, Federal Centre for Meat Research, Kulmbach, Germany

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Abstract:
The animal protection aspects of slaughtering, i.e. handling, transportation, driving to the stunning place, stunning and bleeding become of increasing importance for meat consumers and the acceptance of meat in general. In many countries, the procedures of slaughter are regulated by law. European law stipulates pre-slaughter stunning. Also the requirements for the movement and lairaging of animals in slaughterhouses, for restraint of animals before stunning, for stunning or killing as well as for bleeding are layed down in the Council Directive 93/119/EC.

The handling, restraint and stunning methods must be continuously upgraded according to the current scientific knowledge to improve welfare. Actually, the following guidelines for animal welfare conforming slaughter and killing procedures, under consideration of meat quality aspects too, can be given: Generally irrevesible stunning methods, such as cardiac arrest stunning with an electric current or longer exposure to gas mixtures are preferred from the animals welfare point of view but also because of meat quality reasons. Electrical stunning: For pigs a two-step cardiac arrest stunning system with first a constant current ($\geq$ 1.3 amps) through the head and second a head-to-body current (c. 1.0 amp, 50 – 60 hz) is highly recommended. Concerning CO_2 anesthesia of pigs, if high CO_2 concentrations (> 80 %) and appropriate exposure times (> 70 sec, c. 5 min for an irreversiblle stun) are used the method can be consi-dered as an acceptable pre-slaughter stunning method. Concerning captive-bolt-stunning, animals should be rendered unconscious in a single shot to the head and the bolt should damage the brain. Bleeding should occur as soon as possible after shooting. Appropriate cartridges should be used. Concussion stunning, which is a nonpenetrative, percussive stunning method by a "mushroom head" is not an acceptable method of pre-slaughter stunning. For ritual slaughter, restraint devices must be appropriate and operated correctly. Suspending a consious animal is strictly rejected and forbidden according to european law (exception: poultry, rabbits). The use of upright restraint devices is strongly recommended. Concerning the act of throat cutting without prior stunning the animal welfare concern depends also on the details of performance (kosher, halal slaughter). A short-time pre-throat cutting electrical stunnig is authorized by Muslim religious authorities.
Finally, exsanguination is of very high importance from the animal welfare point of view. Incomplete and inadequate sticking can lead to recovering of animals in the slaughter line while further slaughter procedures are carried out. Therefore, control mechanisms to evaluate the effectiveness of sticking must be installed. After incision of the blood vessels, no further dressing procedures nor any electrical stimulation may be performed on the animals before they are dead (no brain stem reflexes).

Introduction:
The following expression of Jeremy Bentham „the question is not, can they *reason*? nor can they *talk*? but, can they *suffer*? (BENTHAM, 1789) starts a new era of ethics in dealing with animals. Today, it is generally accepted, that animals should not suffer, because in this point they are comparable to humans (RUH, 1997). Meat consumers, especially young people in largely urbanized regions of developed countries, are increasingly demanding that animals be reared, handled, transported and slaughtered using humane practices (APPLEBY & HUGHES, 1997). Concerning slaughter, that means, that stunning should render animals insensible to pain to ensure that they do not suffer needlessly during slaughter.

Because of animal welfare reasons by european law all animals must be stunned before they are slaughtered. The Council Directive 93/119/EC lays down standards on the protection of animals at the time of slaughter or killing. Article 13 of the Directive requires the Commission to make reports setting out the latest available scientific information on stunning and killing procedures. Such a report was finished in 1996 by a working group of the Scientific Veterinary Committee (N.N., 1996). In the introduction of the report, the following points of general importance were considered:

- Pre-slaughter handling: Appropriate for the stunning method used; it should be upgraded according to the current knowledge to improve welfare
- Stunning with a minimum of excitement
- Duration of stunning: Stunning method should render animals unconscious until death supervenes through bleeding
- Irreversible stunning methods, such as cardiac arrest stunning with an electric current or longer exposure to gas mixtures are preferred from the animals welfare point of view but also because of meat quality reasons
- Personnel involved in pre-slaughter handling, stunning and killing should be trained and certified
- Stunning or killing equipment should bei maintained in a good state of repair

These points are not only relevant to animal welfare but also to meat quality.

Electrical stunning

Electrical stunning is important first of all for slaughtering pigs and poultry. In some countries like New Zealand, electrical stunning of cattle also is very widespread.

The aim of the stunning process is primarily not to immobilize the animals for an easier handling but to render them immediately unconscious. With many electrical stunning methods in this regard problems are prevalent. The main reasons are that the basic electrical principles like Ohm's Law are unknown or ignored (Tab. 1). According to results of HOENDERKEN (1978), for achieving an effective stun of pigs within 1 sec in 95 % under practical conditions, an electric current of 1.25 amps is necessary.

Electrical stunning of pigs, not in accordance with animal welfare requirements, is quite often observed in practice. One of the drawbacks is, that a part of the manual or automatically stunned pigs show signs of recovery during bleeding. On the other hand there is the possibility, that the animals experiences an unacceptable long time of current flow, before they get unconscious because of insuffcent technical equipment or mishandling by workers. From human experiments with current safety switches and voltages up to 200 volts physiological reactions of test persons are known (BIEGELMEIER, 1986). The lower limit of feeling pain is at a specific energy of current flow between 50 and 100 amps^2 sec x 10^{-6}. A flow of 500 amps^2 sec x 10^{-6} is felt as inbearable (for instance 175 V, current flow time 26.6 ms, current flow through body 0.128 amps, equal to 525 amps^2 sec x 10^{-6}). Even higher energy is often used for stunning purpose without the guarantee, that animals render unconscious immediately. Recent investigations in order to find the best parameters of stunning according to animal welfare are based primarily on sine wave alternating current with a frequency between 50 and 60 hz. On this basis, animal welfare observing electrical stunning of pigs was found to require a minimal current of 1.25 amps, which should be reached within **1 sec**. This duration requirement however appears **not acceptable** according to the facts mentioned above.

BERGHAUS & TROEGER (1998) found, that an effective stun (epileptic fit) of pigs can be induced within a minimum current flow time of **0.3 sec**, using a 50, 500 or 800 hz constant stunning current of 1.3 amps through the head . Therefore this time requirement is appropriate for animal welfare conforming electrical stunning.

GRANDIN & SMITH(1999) reported, in most U.S. plants, a single current is passed from head to body. GRANDIN (1997) recommends, that when a single current is passed from head to body the first 1 second should be a minimum of 1.25 amps at 50 to 60 hz. Research is still needed to find out how long really is the minimum current flow time needed when placing electrodes head-to-body to reach an effective stun. If time is longer compared to head-only stunning, the single head-to-body-current-methods should be judged to be not humane.

The producers of stunning equipment are changing some mechanical and electrical parameters empirically like shape of electrodes, stunning current, frequency or wavefoms to minimize carcass damages such as broken bones and blood splash, not knowing how these technical modifications influence welfare concerns (Tab. 1, 2). In the following is given an overview of the development of stunning devices for pigs.

Tab. 1: Examples of the application of Ohm's law when stunning sheep

Condition of animal	Dry and in full fleece	Recently sheared, young, thin, wet skin
Voltage applied (V)	200 V	200 V
Resistance across head (R)	1,000 Ω	150 Ω
I = V / R	0,2 A	1.3 A
Result	Ineffective stun	Effective stun

Source: Human Slaughter Association, U.K., 1994

The manual use of tongs with different shaped electrodes for head-only stunning is still very widespread in smaller shlaughterhouses. To reach an immediate unconsciousness with this method, two conditions are needed: 1. **Correct positioning of tongs**: the brain must lie across the shortest distance between the two electrodes. 2. **Higher stunning voltages** (if no constant current equipment is used) at the beginning, to overcome quickly the resistance of the pig skin, so that the required amount of current can flow. Investigations (TROEGER & WOLTERSDORF, 1989) have shown, that the current of 1.25 amps or more needed to achieve immediate unconsciousness can only be reached quickly by using a stunning voltage of **at least 250 V** and postioning the electrodes at precisely the right place (e. g. at both sides at the base of the ear). Only in this case manual electrical stunning with 250 V is acceptable from the welfare point of view.

For higher capacity slaughterhouses (up to 600 hog/h) automatic high voltage stunning was and sometimes still is the usual method (V-restrainer). Those high-voltage-systems are in use since more than 25 years in Germany and the disadvantages, combined with this method, have resulted in a change to CO_2-stunning in much of these plants. High-voltage stunning in a V-restrainer is not up-to-date and brings severe problems with meat quality, one is blood splash on the loins. Also from the point of view of animal protection, the system is not without problems. Because of operating faults there are individual cases which do not meet animal protection requirements. The dimensions of stunning device are arranged to suit a normal hog of between 80 and 120 kg liveweight. In many plants however the occasional lighter pigs are also put through this equipment. Because they are smaller, these animals, with their heads down, miss the stunning fork and the electrodes then come into contact with the back or loin area. This is an extreme fault and must be avoided by separating smaller animals in the lairage.

Tab. 2: Electrical stunning methods (head-only-systems)

	manual	automatically
current flow	head bilateral	head bilateral
restraining device	box, pen	V-restrainer
voltage (V)	250 – 400	450 – 700
amperage (amps)[a)]	≥ 1,3	5 – 15
frequency (hz)	50 - 500	50 – 100
charge[b] (amps x sec)	10 – 15	10 – 20
applicator	tongs, fork	fork

[a)] when using apparatus with constant voltage, amperage depends on resistance
[b)] relevant to meat quality

Further development leaded to **two-step cardiac arrest systems**, both manual and automatic once. Additionally, stunning currents at **higher frequencies** were used to minimize blood splash in muscles and broken bones. ANIL & McKINSTRY (1992) reported, that by using frequencies of about 1600 hz the stunning effect is reduced (shorter time to recovery). At the moment, producers of electrical stunning equipment offer apparatus with stunning frequencies up to about 800 hz. BERGHAUS & TROEGER (1998) found, that the duration of epileptic states and time to recovery were not shorter with a stunning current at 500 and 800 hz compared to a 50 hz stunning current. DALY & SIMMONS (1994) found, that a current level of 0.75 amps produced unconsciousness in 100 % of animals when using 50 hz, and this threshold remained adequate until the frequency exceeded 3000 hz.

Actual manual systems work with (pneumatic) tongs, which are placed on both sides on the base of the ear. After a constant current flow (1.4, 1.5 amps) with 500 hz for 3 or 4 seconds through the head, a third electrode is placed (pneumatically) behind the elbow on left side of the breast and a head-to-body current with 50 – 100 hz (1.0 amp) for 3 sec follows. The slaughter capacity of the system is about 200 pigs per hour.

Tab. 3: Irreversible electrical stunning methods (cardiac-arrest-systems)

	manual	automatic
current flow	head bilateral, followed by head- to body or body to body or only head to body	head bilateral, followed by head to body
restraining device	box, pen	conveyor belt restrainer
voltage (V)	220 – 400 80 – 120 [a)]	230 – 270 100 – 150 [a)]
amperage (amps)[1)]	≥ 1,3 ≥ 1,0 [a)]	ca. 1,7 - 2,6 ca. 1,0 - 1,7 [a)]
frequency (hz) [2)]	50 - ca. 1000	800
charge[3] (amps x sec)	ca. 4 – 5 ca. 3 [a)]	ca. 6 ca. 3 [a)]
applicator	tongs, fork; heart electrode [a)]	pneumatic head electrodes, pneumatic heart electrode[a)]

[1)] when using apparatus with constant voltage, amperage depends on resistance
[2)] for inducing cardiac ventricular fibrillation: 50 – 60 hz
[3)] relevant to meat quality

[a)] only for inducing cardiac ventricular fibrillation (by 3. electrode) after current flow through the head

Improvements are also seen in **automatic electrical stunning** devices. The Midas-system of Stork Company, Netherlands, incorporated a new conveyor belt transport system; the pig rides on this belt with the feet hanging down on both sides and becomes in this position relatively relaxed. This is a good condition for an effective stun.

The Midas-System has a capacity of 200 – 600 hogs/hour, the Synchro-System up to 1100. It is not a high voltage system. Nevertheless the current flow time is with 2.5 sec comparable to high voltage systems, but the electric charge (amps x sec) is very much lower. This is an advantage for meat quality. The induction of cardiac ventricular fibrillation is carried out by an automatic breast electrode, so the animals show only little or no clonic phase convulsions. Stunning currents are registrated on PC; also for veterinary animal welfare supervision, the cases where 1.3 amps were not reached within 1 sec are registrated. After a current flow of about 0.7 sec through the head the third electrode is contacted pneumatically with the left side of the breast and an additional current flows head-to-body.

Welfare aspects of the Midas-stunning-device were evaluated by WENZLAWOWICZ et al. (1998) under practical conditions on 6056 pigs in three european plants. Current flow was registered and video analyses of head electrode placement and movements of the pigs after stunning were made. Reflex activity (eye reflexes, nose pinch) 40 to 60 seconds after stunning and cardiac arrest (electrocardiogram) were tested. The incidence of correct stunning was 99.1 %. With sufficient electrode-body-contact (incidence: 98,8 %) 1.3 amps were achieved after 440 ms at the latest. Deficient stunning was caused by disadvantageous fixation so that the head could not be caught correctly (welfare relevant: 0.7 % of the pigs). It is concluded that both technical improvements and mainly reduction of the strain during lining up are necessary. Lastly is summerized that effective cardiac arrest and relatively low reflex activity confirm a good stunning. Stumming-effectiveness seems a progress compared to conventional stunning facilities especially at higher line speed.

The factors, which are important when using electrical stunning systems for pigs from an animal welfare point of view, are summerized in Tab. 4.

Requirements for a humane **electrical stunning of poultry** were given by SCHÜTT-ABRAHAM (1996). Poultry is usually stunned in a water bath stunner to which a constant voltage is applied. Loss of consciousness until death by bleeding is only ensured if the electrical head-to-body stunning (in addition to causing an epileptic fit) leads also to ventricular fibrillation in at least 90 % of the birds. For this minimal effective currents (I_{eff}) of 0.12 amps (chickens), 0,13 amps (ducks, geese) or 0,15 amps (turkeys) resp. are required per bird with curents not substantially deviating from sinus 50 hz. Therefore the voltage has to be set in a way that the total current measured equals the number of simultaneously immersed birds multiplied by the minimum current per bird.

Tab. 4: Electrical stunning: Important factors for animal welfare

factors	criteria
♦ minimum of excitement and physical strain	internal muscle temperature (ham) 45 min p.m. ≤ 40,5°C
♦ immediate unconsciousness	no vocalization (squealing) if the stunning current is interrupted after 0,3 seconds
♦ **two-step cardiac arrest system** – constant current (≥1,3 amps) through the head, followed by – head-to-body current (0.9 – 1,0 amps, 50 - 60 hz)	- little or none clonic phase convulsions - death within 60 sec (no eye reactions, dilatation of the pupils)
♦ horizontal bleeding table	conveying still muscles are relaxed (1,5 - 2 min)
♦ short stun-to-stick-intervall	- horizontal bleeding: < 10 sec
♦ effective sticking	- amount of blood > 3 litres/pig, - insignificant rest blood in vessels

In addition the following requirements have to be met by devices for stunning poultry:
- stunning transformers must deliver sufficient voltage to guarantee the required total current even under full load of the slaughter chain;
- stunning devices should be equipped with a volt- and amperemeter showing the correct amount of effective current even if currents deviate from sinus 50 hz to make proper supervision of stunning conditions possible at all times;
- water baths for poultry must be adequate in size and depth to ensure smooth passage of the birds as well as immersion of their heads. The contact between feet and shackle must be optimized by wetting the legs;
- entrances to water bath stunners must be constructed in a way to prevent premature shocks to the birds, e.g. due to overflowing water;
- the live electrode must extend to length of the water bath to ensure even voltage distribution within the water;
- the water bath has to be long enough to ensure even at the hightest processing speed that each bird will receive the stunning current for at least 4 seconds.

Carbon dioxide stunning

The two most commonly used methods for commercial pre-slaughter stunning of pigs are electrical stunning and CO_2 anesthesia. While the electric current used in electrial stunning produces an epileptiform activity in the brain leading to unconsciousness, CO_2-stunning results in a lowering of blood pH which leads to loss of consciousness (EISELE et al., 1967). This chemical change in the blood needs some time, which also depends on the concentration of the CO_2-atmosphere the animal is exposed to.

Commercially carbon dioxide stunning is at present used first of all for pigs, but also turkeys and chickens already are stunned or killed with CO_2. Experiences showed that pigs should be immersed in maximum concentration of carbon dioxide as fast as possible to reduce reaction to the gas and time to loss of consciousness (TROEGER & WOLTERSDORF, 1991).

There are two main types of carbon dioxide stunning or killing systems, a dip-left system, where pigs are lowered continuously into the gas and the paternoster system, where pigs are lowered successively into the gas with stops as pigs enter or leave the equipment. The paternoster system is most commonly used. The maximum gas concentration, number of gondolas and through time vary widely depending on slaughter rate. The latest development is an automatic danish system for groupwise CO_2-stunning up to 800 hog/hour. This system has the advantage, that lining up and restraint of animals is not necessary (BARTON GADE & CHRISTENSEN, 1999).

Adequate stunning can be achieved by using high CO_2 concentrations (>80 %) and longer exposure times (>70 sec). Exposure times that result in killing are not known precisely but lie around 5 minutes with 90 % CO_2.

The welfare implications of carbon dioxide stunning is still under debate. Some studies have shown that the majority of pigs will avoid an atmosphere of high concentrations of carbon dioxide (CANTIENI, 1976; RAJ & GREGORY, 1995). This aversion was found to be greater than the motiviation to obtain a reward in the carbon dioxide atmopshere, even after 24 h fasting (RAJ & GREGORY, 1995). On the other side, exposure to CO_2 was less avesive than were electrical shocks. Aversion was measured by determining the time required to enter and re-enter a coequipment after being exposed to the gas or to an electrical shock (JONGMAN et al., 1998). Scientist have also interpreted the increasse in rate and depth of respiration that occurs during the inhalation of carbon dioxide as respiratory discomfort (RAJ & GREGORY, 1995) and in humans, this is interpreted as dyspnia or breathlessness (GREGORY et al., 1990; STARK et al., 1981). Animal welfarists are concerned that the increased rate and depth of breathing would last until loss of unconsciousness occurs with the gas, and this can be as long as 38 seconds (HOENDERKEN et al., 1979). However, other studies showed that pigs react sometimes very little to exposure to high concentrations of carbon dioxide provided that exposure is rapid (TROEGER & WOLTERSDSORF, 1991). Other scientists consider the faster and deeper respiration as an advantage because it facilitates the uptake of the gas and this can shorten the time to loss of consciousness (FORSLID, 1992). Overall it can be concludedd that CO_2 anesthesia of pigs can be considered as an acceptable pre-slaughter stunning method.

Alternative gas mixtures for stunning

In contrast to stunning of pigs with CO_2, the animals show no adversive reactions when exposed to gas mixtures of either 90 % argon in air 0r 60 % argon and 30 % CO_2 in air.The phase before unconsciousness happens without stress (RAJ & GREGORY, 1996). The practicability of these gas mixtures under commercial conditions was still tested in the United Kingdom. Since the alternative gas mixtures are also heaver than air (in density), they can be contained in a pit or a tunnel system. Argon, being an inert gas, is odourless and tasteless and it does not induce sense of breathlessness before loss of consciousness occurs.

The use of alternative gas mixtures eliminates the welfare concerns associated with the induction of anaesthesia with a high concentration of carbon dioxide. The main purpuse of using these gas mixtures for stunning or killing poultry is to spare the birds the stress associated with the uncrating and shackling of live birds. If the birds were killed whilst they are still in their transport containers the uncrating, shackling and neck cutting can be performed on the relaxed carcasses. When tipped out of their transport module on to a conveyor belt poultry shall also be conveyed into the chamber. This would at least help to avoid the stress associated with live bird shackling.

Killing of birds rather than stunning is recommended. A minimum of 2 minute exposure is required to kill quails, chickens and turkeys with the alternative gas mixtures. SCHÜTT-ABRAHAM (1996) said, that for killing turkeys by an argon-induced hypoxia an exposure of 3 minutes is necessary. Water fowl can also be killed with a 3 minute exposure to alternative gas mixtures.

It is concluded that alternative gas mixtures are ideally suited for stunning or killing poultry either in their transport containers or on a conveyor belt. This will eliminate some of the stress associated with the live bird handling at processing plants. Poultry should be immersed into the recommended gas mixtures as soon as possible (N. N., 1996).

Captive-bolt stunning

This method is widely used for cattle, calves, small ruminants, horses and rabbits. A cartridge, compressed air or for small animals like rabbits a spring under tension have been used to drive bolts through the skull. The bolt should damage the brain. Decisive for an effective stun is the right positioning of the captive-bolt stunner. For cattle, the most effective position for captive-bolt placement, to induce instantaneous insensibility, is in the middle of the forehead (DALY & WHITTINGTON, 1989). It is estimated, that 5 – 6 % of cattle captive bolt stunning is not applied correctly (DRAWER & WOLTERING, 1990). Inadequate facilities for the presentation of heads of animals to the operator is considered to be the major cause of this potential problem. The use of a mechanical head restraint will improve the accuracy of captive-bolt stunning, but it can increase stress if it is improperly used (EWBANK & PARKER, 1992). After the animals head is restrained, it should be stunned as quick as possible (within a few seconds).

Another common cause of low efficacy of captive-bolt stunning is poor maintenance of the captive-bolt stunner (GRANDIN, 1998). Captive-bolt stunners must be cleaned and serviced, following the manufacturer's recommendations, to maintain maximum hitting power and to prevent misfiring or partial-firing. High bolt velocity causes a concussion that induces instantaneous insensibility (DALY & WHITTINGTON, 1989; BLACKMORE, 1985). Each plant should develop a system of verified maintenance for captive-bolt stunners. Pneumatic-powered captive-bolt stunners must be operated at the air pressure recommended by the manufacturer.

The following types of captive-bolt stunners are in common use in commercial beef slaughter plants: Pneumatic-powered stunners, pneumatic-powered air injection stunners and cartridge-fired stunners (SCHMIDT, 1999). A common mistake to render animals insensible with one captive-bolt shot is also an inappropriate cartridge or a to low air pressure.

Measures are needed to rationalise the colour coding of cartridges according to the amount of gun powder contents (1 grain = 0.065 g) and its suitability for stunning particular species. At present, only one manufacturer in Europe discloses the technical details.

The force delivered by the cartridges can be determined by firing the captive bolt using cartridges through a lead cylinder (6 cm diameter, 7 cm length and 2500 g weight; lead content should be 99.9 %) and measuring the depth of penetration of the bolt. The suitability of cartridges for stunning various animals can then be set using the following guidelines:

Depth of penetration in lead	Suitable for stunning
9 mm	light (< 150 kg body weight) animal
14 mm	heavy (> 150 kg body weight) animals

When air pressure is used to drive the bolt, according to the manufacturer, the pressure required for light weight animals (sheep, goats, calves) is 9 bar and for heavy weight animals (cattle, horses) is 12 bar (N. N., 1996).

It is concluded that animals should be rendered unconscious in a single shot to the head and the bolt should damage the brain. Bleeding should occur as soon as possible after shooting. Appropriate cartridges should be used.

Concussion stunning

Concussion stunning is a nonpenetrative, percussive stunning method where a controlled obtuse blow is delivered to the head by a „mushroom head" fitted to a captive-bolt or, for smaller animals, by a manual blow. The „mushroom" is a metal convex disc approximately 4 cm in diameter and the impact is applied to the frontal region of the head. This „mushroom head" is used almost only on adult cattle, especially in cases of ritual slaughter. In Germany the method is forbidden because of animal welfare reasons. The method is not commonly used. The prevalence of miss-stunning under abattoir conditions is a major concern (N. N., 1996).

It is concluded that concussion stunning by a „mushroom head" is not an acceptable method of pre-slaughter stunning . For ritual slaughter, a short-time electrical stunning (head-only method) is recommended (NOWAK & RATH, 1990). Small batches of poultry or rabbits may be stunned with non-mechanically operated instrument.

Waterjet stunning

Waterjet stunning is the use of a high pressure waterjet with 2500 – 3500 bar and an injection time 20 – 100 msec (SCHATZMANN et al., 1990) for stunning/killing of slaughter pigs. The method is in an experimental phase.

Experiments to explore waterjet suitability were conducted under laboratory conditions with post-mortem material (pig heads) and live slaughter pigs (SCHATZMANN et al., 1990; LAMBOOIJ, 1991). Immediate unconsciousness, as determined by electroencephalogram, was initiated by a rapid penetration of the skin and skull (LAMBOOIJ, 1991). Destruction of the brain tissue occured in 0.2 – 0.4 sec. A problem associated with the waterjets is convulsions, which may appear after the use of this stunning method.

LAMBOOIJ & SCHATZMANN (1994) concluded that waterjet stunning with immobilization by an electric current during bleeding appears to be a humane and suitable method to stun pigs in a slaughterhouse. But further research concerning alternative restraining methods during stunning and alternative electrical currents for immobilization (low or high frequencies) is needed to improve the total meat quality.

Exsanguination

Because electrical stunning and CO_2 anesthesia are reversible as a rule prompt and accurate (effective) sticking is of high importance from the animal welfare point of view. Incomplete and inadequate sticking occures when pigs are kicking excessively post-stun, or when sticking results in a small wound that impedes bleed out, or, in some instances, by the inexperience of the operatives (ANIL et al., 1997). The consequence can be, that animals regain consciousness in the slaughter line while further slaughter procedures (e.g. scalding) are carried out. To avoid this extreme mistreatment of animals, control mechanisms must be installed. Guidelines therefore were given by ANIL et al. (1997): Observations made in the sticking area can provide evidence as to whether recovery from the stun is likely to occur before death supervenes. The sticking procedure should be closely examined, modified and regularly monitored so as to minimize the chance of recovery. Animals should be observed for signs of rhythmic breathing movements (not occasional gasps) throughout the stun/kill process. This should be carried out by observing the nostrils and abdominal movements of the animal. Animals categorised as ineffectively stunned should be immediately stunned with a mechanical stunning system. In this event the stun/kill operation should be discontinued so that the cause can be investigated and remedial action taken to prevent further occurrences. The sticking procedure should be examined by a licenced slaughterman, in order to minimize any delay between stunning and sticking and to ensure an adequate gash (wound) length and subsequent rapid loss of blood. Animals should be followed on the bleeding line and checked for signs of recovery. Other useful examinations include the return of the corneal reflex and responsiveness of an animal to a painful stimulus. The corneal reflex can be elicited by touching the eyeball, however,,it is not as reliable an indicator of the start of recovery as the return of rhythmic breathing movements. Both rhythmic breathing and the corneal reflex are brain stem reflexes, which when present indicate a functioning brain stem.

Requirements for bleeding of slaughter animals were found in Council Directive 93/119/EC, Annex D:

1. For animals which have been stunned, bleeding must be startet as soon as possible after stunning (german legislation $\leq$20 sec) and be carried out in such a way as to bring about rapid, profuse and complete bleeding. In any event, the bleeding must be carried out before the animal regains consciousness.
2. All animals which have been stunned must be bled by incising at least one of the carotid arteries or the vessels from which the arise.
   After incision of the blood vessels, no further dressing procedures nor any electrial stimulation may be performed on the animals before the bleeding has ended.
3. Where one person is responsible for the stunning, shackling, hoisting and bleeding of animals, that person must carry out those operations consecutively on one animal before carrying them out on another animal.
4. Manual back-up must be available where poultry is bled by means of automatic neck-cutters so that, in the event of a breakdown, birds may be slaughtered immediately.

Ritual slaughter

Ritual slaughter is performed by a throat cut, which severs all soft tissues of the throat (muscles, blood vessels, oesophagus, trachea, nervs) without pre-slaughter stunning. It is necessary to distinguish between kosher (Jewish) slaughter and halal (Muslim) slaughter. For kosher slaughter, there exists exact rules for the slaughter process, the instruments used and the qualification of the slaughterman. A straight, razor-sharp knife („Chalaf") that is twice the width of the throat is required, and the cut must be made in a single continous motion. For halal slaughter, no special knife-design is required.

GRANDIN (1993, 1994) observed the reactions of hundreds of cattle and calves during kosher slaughter and reported that there was a slight quiver when the knife first contacted the throat. This reaction was slighter as the reaction caused by invasion of the cattles flight zone by touching its head. By contrast, halal slaughter performed with short knives and multiple hacking cuts results in vigorous reactions of cattle (GRANDIN & SMITH, 1999). Throat-cutting without stunning does not induce instantaneous unconsciousness. DEVINE et al. (1986) found, that sheep become insensible (i.e. EEG < 10 µV) at 8 –22 sec, but the calf EEG did not fall below 10 µV until 79 sec after the throat cut. the throat is required, and the cut must be made in a single continous motion. For halal slaughter, no special knife-design is required.

From the animal welfare point of view, the method of restraint before cutting the throat is of concern. According to the Council Directive 93/119/EC in the European Community it is not allowed to suspend animals before stunning or killing (exception: poultry, rabbits). In the guidelines for ritual slaughter, published by the American Meat Institute (GRANDIN, 1997), the use of upright restraint devices (pen, conveyor restrainer systems) is strongly recommended. This method of restraint meets very well also the requirements of european legislation: „In the case of ritual slaughter, restraint of bovine animals before slaughter using a mechanical method intended to avoid any pain, suffering or agitation and any injuries or contusions to the animals is obligatory." (Council Directive 93/119/EC. Annex B). The „Weinberg device", where the cattle is turned to the back before throat cutting, may induce more excitement than the use of upright restraint devices.

According to german legislation, an exception of the obligatory pre-slaughter stunning is only given for kosher slaughter. In agreement with Muslim religious autorities, certain stunning methods are practiced since several years before halal slaughter. For cattle, short-time electrical stunning is used immediately before throat cutting (NOWAK & RATH, 1990). The temples are moistened and tongs are placed on both sides of the head (240 V, 2 sec).

It is concluded, that by ritual slaughter restraint devices must be appropriate and operated correctly. Concerning the act of throat cutting without prior stunning the animal welfare concern depends also on the details of performance.

Assessment of stunning effectiveness

Following a successful electrical stunning application the physical signs of epileptiform activity should be evident (ANIL at al., 1997). Cessation of rhythmic breathing, salivation and limb rigidity are the first signs to be recognised in a recumbent animal. After 10 to 20 seconds the tonic phase ceases and kicking movements (clonic phase) follow for about 30 seconds (BERGHAUS & TROEGER, 1998).

When cattle or sheep are shot with a captive bolt, the animal should instantly drop to the floor, or, in a conveyor restrainer, the head should drop down after a spasm for a few seconds (GRANDIN & SMITH, 1999). Eyes should be stare and motionless, breathing should be stopped and after suspending the animals the tongue is hanging straight down.

Signs of an ineffective stun are first of all

- vocalization either at the beginning, during or after stunning,

- rhythmic breathing (not occasional gasps)
- the attempt to raise the head,
- a righting reflex,
- controlled movements of the eyes.

Conclusions:

Meat consumers are increasingly demanding that animals be reared, handled, transported and slaughtered using humane practices. Concerning slaughter, that means first of all the use of appropriate pre-slaughter stunning methods. A humane slaughter of livestock is not only desirable because of ethical reasons but also because of meat quality reasons.

The most widespread stunning method is electrical stunning. For pigs a two-step cardiac arrest stunning system with first a constant current ($\geq$ 1.3 amps) through the head and second a head-to-body current (c. 1.0 amp, 50 – 60 hz) is highly recommended. Concerning CO_2 anesthesia of pigs, the welfare implications are still under debate. If high CO_2 concentrations (> 80 %) and appropriate exposure times (> 70 sec, c. 5 min for an irreversible stun) are used the method can be considered as an acceptable pre-slaughter stunning method. Concerning captive-bolt-stunning, it is concluded that animals should be rendered unconscious in a single shot to the head and the bolt should damage the brain. Bleeding should occur as soon as possible after shooting. Appropriate cartridges should be used. Concussion stunning, which is a nonpenetrative, percussive stunning method by a „mushroom head" is not an acceptable method of pre-slaughter stunning. Concerning waterjet stunning, LAMBOOIJ & SCHATZMANN (1994) concluded that waterjet stunning with immobilization by an electric current during bleeding appears to be a humane and suitable method to stun pigs in a slaughterhouse. For ritual slaughter it is concluded, that restraint devices must be appropriate and operated correctly. Concerning the act of throat cutting without prior stunning the animal welfare concern depends also on the details of performance. Throat-cutting without stunning does not induce instantaneous unconsciousness.

Finally, exsanguination is of very high importance from the animal welfare point of view. Incomplete and inadequate sticking can lead to recovering of animals in the slaughter line while further slaughter procedures are carried out. Therefore, control mechanisms to evaluate the effectiveness of sticking must be installed. After incision of the blood vessels, no further dressing procedures nor any electrical stimulation may be performed on the animals before they are dead (no brain stem reflexes).

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