# Opinion of the Scientific Panel on Animal Health and Welfare on a request from the Commission related to welfare aspects of the main systems of stunning and killing the main commercial species of animals[1]

**(Question N° EFSA-Q-2003-093)**

**Adopted on the 15th of June 2004**

## SUMMARY OF OPINION

The EFSA Scientific Panel on Animal Health and Welfare was asked by the Commission services to report on the welfare aspects of the main systems of stunning and killing in the main commercial species of animals with consideration of Directive 93/119/EC. Species referred to in the present opinion are: cattle, sheep, pigs, poultry, horses and farmed fish. Welfare aspects of the systems for stunning other species, such as rabbits, deer, ratites or goats, have not been included in the present opinion.

Stunning before slaughter is a statutory requirement in the EU (with exceptions in some Member States for religious slaughter) to induce unconsciousness and insensibility (inability to perceive stimuli) in animals, so that slaughter can be performed without avoidable fear, anxiety, pain, suffering and distress.

This Scientific opinion is a scientific assessment of the welfare during stunning and killing adopted by the EFSA AHAW Panel based on the data of the Scientific Report. In drafting this Scientific Opinion, the panel did not consider ethical, socio-economic, cultural or religious aspects of this topic. Considering the mandate, the present opinion concentrates on the welfare of the animals concerned at the point of application of the stunning and stun / killing techniques and does not consider in detail other preceding or subsequent procedures, although it is recognised that, for instance, transport to the slaughterhouse, lairage conditions, pre-slaughter handling and restraint prior to stunning may cause serious welfare problems. Scientific data on other issues such as food safety, BSE (bovine spongiform encephalopathy), human operator safety, economic impact are not reviewed in this opinion.

This opinion considers the main stunning and stun / killing methods under commercial slaughterhouse and under farm conditions in Europe. Killing of animals without stunning and stun / killing methods for disease control are also considered.

Stunning methods induce temporary loss of consciousness and rely solely on prompt and accurate sticking procedures to facilitate bleeding and to cause death. Sticking involves the severing of major blood vessels e.g. neck cutting or chest sticking. If unbled, even the adequately stunned animal has a potential to regain brain and body functions. Stun / killing methods induce unconsciousness and death either simultaneously or sequentially.

Procedures appropriate to cattle, sheep, pigs, chickens, turkeys, farmed fish and horses and their related minimum requirements such that unconsciousness and insensibility are induced and poor welfare is minimised, are recommended.

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An understanding of the states of unconsciousness and insensibility and the measures to assess these permit evaluation of the effectiveness of the different methods applied. Efficient stunning methods disrupt the neurons or neurotransmitter regulatory mechanisms in the brain, causing a long-lasting depolarised neuronal state that renders animals unconscious and insensible. Indeed, most of the known or established stunning methods also induce high degrees of electrical synchronisation in the brain leading to a quiescent or isoelectric electroencephalogram. During and immediately after stunning, depending on the method and species involved, animals show typical behaviour patterns and physical reflexes, which can help to monitor the effectiveness of stunning under commercial conditions. In general, vocalisation in animals during the induction of unconsciousness with any stunning method is indicative of pain or suffering (however, absence of vocalisation does not guarantee absence of pain or suffering). Under practical conditions, eye reflexes and reactions to painful stimuli should always be investigated and evaluated, in combination with the resumption of normal rhythmic breathing and righting reflexes, to assess stunning effectiveness.

The duration of unconsciousness and insensibility varies between methods, species and animals. The stun-stick interval should be sufficiently short to induce death through blood loss before the animal recovers from the stun. Sticking procedures vary between species; however, the supply of oxygenated blood to the brain should be stopped as rapidly as possible.

Stun / killing methods, which induce unconsciousness and death either simultaneously or sequentially, do not rely on bleeding to cause death and therefore should be preferred when available and proven to be effective.

In all the stunning and stun / killing methods (excluding gas mixtures), animals should be restrained appropriately and heads properly presented to the operator for effective application of the procedure(s).

Due to the serious animal welfare concerns associated with slaughter without stunning, pre-cut stunning should always be performed.

As a general rule, each method should be applied only once, i.e. animals should be rendered unconscious and insensible by a stunning or stun / killing method or device applied for the first time. In the event of a failure (unsuccessful stun), the animal should be killed immediately by an appropriate backup killing method.

It is important that all operators involved with stunning and slaughter are competent, properly trained and have a positive attitude towards the welfare of the animals.

All the equipment used for stunning or stun / killing should be maintained in good working conditions and recorded evidence of parameters applied, maintenance and rectified defects should be kept.

There are no ideal methods for the stunning and killing of farm animals for commercial slaughter or disease control purposes and it is therefore necessary to select those procedures whose proper application have most advantages in terms of animal welfare. Bad practice increases the disadvantages of any method.

The penetrating captive bolt, if applied properly, can render sheep and cattle insensible with minimal effects on welfare. Captive bolt usage is appropriate for some pigs, but there can be problems if it is used for boars and old sows. Captive bolt has the disadvantage that there is no automated method for practical use available today and depends essentially on the education and skill of the person who performs the stunning.

Gas stunning has a high potential for humane stunning or stun / killing if non-aversive gases or gas mixtures are used. It requires sophisticated technical equipment. The animals are exposed to a moderate handling stress only.

Electrical stunning can immediately cause unconsciousness and makes the animal insensible. It requires high standards of technical equipment and skilled people to perform and monitor the stun and a system to record the stunning details such as voltage, current and frequency of the current for each individual stun. For automated applications the animal has to be restrained. There is still a lack of knowledge about mechanisms of brain function during application of electrical currents to the head.

There is an urgent need for further detailed investigations of the mechanisms and effects of the different stunning methods, their technical and organisational performance in practice and improved and continuing education of the staff to ensure good animal welfare.

**Key words :** cattle, sheep, pigs, poultry, horses, fish, animal welfare, stunning, killing, slaughterhouses, disease control, consciousness, mechanical stunning methods, mechanical stun / killing methods, electrical stunning methods, electrical stun / killing methods, gas stunning methods, gas stun / killing methods, controlled atmospheres, waterjet stun / killing method, microwave irradiation, needle bolts, percussive stunning, mechanical spiking, asphyxia, thermal shock, salt bath, ammonia solution, decapitation, exsanguinations, anaesthesia, slow live chilling, shooting, electric harpoon, barbituric acid derivates, T61, chloral hydrate, magnesium sulphate, potassium chloride, biosecurity.

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## BACKGROUND

The EFSA Scientific Panel on Animal Health and Welfare (AHAW) was asked by the Commission services to report on the welfare aspects of the main systems of stunning and killing the main commercial species of animals with consideration of Directive 93/119/EC.

The mandate was accepted by the AHAW Panel at the first Plenary meeting, in 2003. It was decided to establish a Working Group of AHAW experts chaired by one Panel member. Therefore the Panel entrusted a Scientific Report to a working group under the Chairmanship of Dr. H. Blokhuis.

This opinion has been adopted by the Plenary Meeting of the AHAW Panel on the 15th of June 2004 and the relevant conclusions and recommendations are based on the Scientific Report separately published on the EFSA web site www.efsa.eu.int, which was drafted by the Working Group and accepted by the Panel.

## TERMS OF REFERENCE

The EFSA Panel on Animal Health and Welfare was asked to report on the welfare aspects of the main systems of stunning and killing the main commercial species of animals.

For each stunning and killing method commonly used, the following three areas are covered:

- The minimal conditions by which the method is likely to be efficient from the animal welfare point of view in field conditions,
- The criteria or procedures to check that the stunning and the killing method is properly used,

- The advantages and disadvantages of the method used, taking into account the commercial and field conditions.

Two separate contexts are considered: stunning and killing methods used in slaughterhouses and those used for disease control measures.

Species referred to in the present opinion are: cattle, sheep, pigs, poultry, horses and farmed fish. Welfare aspects of the systems for stunning other species have not been included in the present opinion.

## ASSESSMENT

A full assessment can be found in the Scientific Report published in the EFSA web site www.efsa.eu.int, which was drafted by a Working Group set up by the AHAW Panel. The Scientific Report is considered as the basis for the discussion to establish the conclusions and recommendations by the AHAW Panel, as expressed in this opinion.

## CONCLUSIONS AND RECOMMENDATIONS

The Scientific Panel on Animal Health and Welfare concludes on the welfare aspects of the main systems of stunning and killing the main commercial species of animals as follows:

# 1. GENERAL

### 1.1. CONCLUSIONS

Most animals which are slaughtered in the EU for human consumption are killed by cutting major blood vessels in the neck or thorax so that rapid blood loss occurs. If not stunned, the animal becomes unconscious only after a certain degree of blood loss has occurred whilst after greater blood loss, death will ensue. The animals which are slaughtered have systems for detecting and feeling pain and, as a result of the cut and the blood loss, if not stunned, their welfare will be poor because of pain, fear and other adverse effects. The cuts which are used in order that rapid bleeding occurs involve substantial tissue damage in areas well supplied with pain receptors. The rapid decrease in blood pressure which follows the blood loss is readily detected by the conscious animal and elicits fear and panic. Poor welfare also results when conscious animals inhale blood because of bleeding into the trachea. Without stunning, the time between cutting through the major blood vessels and insensibility, as deduced from behavioural and brain response, is up to 20 seconds in sheep, up to 25 seconds in pigs, up to 2 minutes in cattle, up to $2^1/_2$ or more minutes in poultry, and sometimes 15 minutes or more in fish.

In general, stunning methods induce temporary loss of consciousness and rely on prompt and accurate sticking procedures (bleeding out) to cause death. The duration of unconsciousness and insensibility varies between methods, species and animals.

Effective stun / kill methods on the other hand, which induce unconsciousness and death either simultaneously or sequentially, do not rely on bleeding to cause death.

Restraint of animals, needed to ensure proper application of mechanical or electrical stunning or stun / killing methods, can be one of the most stressful and painful stages of the slaughtering process. Therefore, the ability to move animals in groups with less handling and restraint is an advantage on welfare grounds of all gas stunning or stun / killing systems as compared with mechanical or electrical methods.

While carbon dioxide ($CO_2$) has many advantages, aversion (a tendency to show behaviour to avoid or withdraw from a situation which is associated with a noxious stimulus) to this gas at

some level (usually above 20%) is clearly a welfare problem. Depending on how one interprets an animal's behaviour it is difficult to quote a level from the published work that will apply to all pigs and poultry. However, it is likely that levels above 30% in pigs and turkeys and 25% in chickens are at the very least unpleasant and that higher levels are aversive.

### 1.2. RECOMMENDATIONS

Due to the serious animal welfare concerns associated with slaughter without stunning, all animals which are slaughtered should be adequately stunned in a humane way, whenever possible, so as to avoid poor welfare in the period before unconsciousness ensues. Effective stun / killing methods, when available and reliable, are preferred from an animal welfare point of view.

In all the stunning and stun / killing methods, animals should be restrained appropriately and heads properly presented to the operator for effective application of procedure(s) (excluding gas mixtures).

The stun-stick interval should be sufficiently short to induce death through blood loss before the animal recovers from the stun.

Sticking procedures vary between species. However, supply of oxygenated blood to the brain should be stopped as rapidly as possible.

No carcass processing or electrical stimulation to improve meat quality should commence until the animal is dead.

All operators involved with stunning and slaughter should be properly trained, their skills and knowledge examined, in particular in the field of welfare, and the person should be certified to be competent and should have a positive attitude towards improving animal welfare. They should also attend retraining courses and their ability to implement new knowledge and acquire new skills should be assessed as new technologies evolve.

All the equipment used for stunning or stun / killing should be maintained in good working conditions. Recorded evidence of maintenance and rectified defects should be kept.

#### 1.2.1. Mechanical methods

When using captive bolt guns, colour codes indicating cartridge strength should be harmonised across manufacturers. Colour codes should be the same for the same species and age group (e.g. red for cows and horses, black for bulls).

Open cartridges should not be used as they can easily absorb moisture and lose their function. All captive bolt equipment, including cartridges, should be stored in appropriate conditions in abattoirs.

Bolt velocity should be measured regularly according to the manufacturers' specifications and appropriate field devices made available to ensure proper use in the field.

#### 1.2.2. Electrical methods

All stunning and stun / kill electrical parameters should be based on sound science.

Electrical stunning tongs should be placed on the head such that they span the brain. Electrical stun / killing tongs (one cycle method) should be placed on the head and body such that they span the brain and the heart.

Electrical stunning and stun / killing devices should supply constant currents and should also be fitted with an acoustic or optic signal to indicate: (a) an interrupted stun, (b) excessively short stun duration or (c) increase in total electrical resistance in the pathway (due to dirt, fleece or carbonisation), which could lead to failure. This would facilitate effective monitoring of

electrical stunning and stun / killing methods under commercial conditions. Electrical stunning and stun / kill devices should indicate that the recommended voltage and current have been delivered during the stun or signal if this is not the case. The voltage and current measuring devices should be appropriate to the waveform and frequency of the current used in the stunner. A calibrated volt and/or current meter appropriate to the waveform and frequency of the current should be used to verify the output of the stunner. The sampling rate of the meter needs to be fast enough and appropriate to the electrical parameters.

The details of electrical stunning parameters, such as waveform, frequency and the output voltage and current in appropriate units (average or root mean square) need to be recorded and readily available for internal or external audit and to verify that correct parameters are applied, thus ensuring that a current of sufficient magnitude beyond that recommended to induce generalised epilepsy is applied.

Monitoring of electrical stunning and stun / killing efficiency should be improved by evaluating the stunners in designated laboratories, using established neurophysiological criteria, prior to installation and delivery of a certificate (kite mark).

### 1.2.3. Gas methods

Gas concentrations and exposure times need to be monitored and records kept. They should be readily available for internal or external audit and to verify that the recommended methods are used.

### 1.2.4. Backup stunning methods

As a general rule, each method should be applied only once, i.e. animals should be rendered unconscious and insensible by a stunning or stun / killing method or device applied for the first time. In the event of a failure (unsuccessful stun), the animal should be killed immediately by an appropriate backup killing method. Two consecutive failures to stun with any specific device should warrant immediate investigation and the fault should be rectified before starting stunning procedures again.

## 1.3. FUTURE RESEARCH

### 1.3.1. High research priorities

#### a) Restraint systems

For both mechanical and electrical stunning or stun / killing methods, there is an urgent need to develop appropriate restraint systems.

#### b) Mechanical methods

A field tool to measure the velocity and power of the **penetrating captive bolt** under practical conditions should be developed. Such a device should be available for all captive bolt guns.

The appropriate length, diameter, shape and velocity of the penetrating captive bolt to be used for stunning or killing should be determined for each species to ensure immediate onset of unconsciousness or death.

#### c) Electrical methods

There is an urgent need to revise and scrutinise the electrical methods. The interactive effects of various electrical parameters on onset and duration of unconsciousness and insensibility (current strength, duration, wave forms and frequency) should be determined for the different species, using neurophysiological evidence (electroencephalogram and evoked potentials) rather than induction of seizures. It is necessary, for welfare reasons, to make sure that the total electrical current which is applied reaches immediately the respective centres of the brain

to perform a proper and immediate stun. The timing of sticking techniques should also be incorporated in these investigations.

For control purposes, there is a need to develop monitoring systems to register all relevant electrical variables such as strength of current, voltage and frequency, under practical conditions.

Successful induction of cardiac ventricular fibrillation during electrical stun / killing would depend upon the delivery of sufficient electrical current to the myocardium. The amount of current delivered will depend upon the voltage and total impedance in the pathway (between the electrodes). Research should be carried out to determine the effects of such variables during the induction of cardiac ventricular fibrillation.

**d) Gas methods**

Aversion to gas mixtures and the mental state of animals during the induction of unconsciousness with gas mixtures need further evaluation to develop humane mixtures and to facilitate better understanding and determination of suffering in animals.

### 1.3.2. Other future research

Research is needed to reveal the diversity of spinal reflexes and spinal automatisms and the times they occur after the application of stun / killing methods in animals.

Methods to establish times of "sensibility" post stunning or at slaughter in relation to the time of onset of the full effects of "sticking" need to be studied. Development of a chest sticking technique simultaneously cutting skin and vessels would make it easier and more rapid. The differential effects of severing the external jugular veins alone or in conjunction with the common carotid arteries as part of the sticking procedure in relevant species need to be investigated.

The implications for good animal welfare of the most efficient methods for achieving rapid exsanguination should be established.

Systems of killing "fallen animals" that facilitate sampling the brain stem for subsequent testing for TSEs (Transmissible Spongiform Encephalopathies) should be investigated for cattle and sheep.

**a) Mechanical methods**

The **non-penetrating captive bolt** is considered unreliable and consequently is not currently used in most abattoirs and needs extensive modification if efficiency is to be improved. Non-penetrating captive bolt stunning, which is ineffective in its current form, might be improved by changing shape of the bolt, force of the impact, in relation to skull characteristics (e.g. to avoid bone crushing) and a combination of different stunning methods. The possibility and efficiency of applying a rapid killing method (possible chest sticking) after the non-penetrating stun should be studied

**b) Combined methods**

Research and development so far have focused on using a single method or procedure to stun / kill animals. Each of them has their own animal welfare advantages and disadvantages. The use of a combination of established or novel methods to stun / kill animals need to be evaluated. When investigating such combinations, their practicability should be kept in mind.

# 2. METHODS FOR STUNNING AND STUN / KILLING CATTLE

Two main methods exist to stun adult cattle and calves: mechanical stunning (captive bolt) and electrical stunning. In captive bolt stunning of adult cattle and calves, the penetrating captive bolt is the most commonly used method.

## 2.1. MECHANICAL STUNNING METHODS

### 2.1.1. Conclusions

**Penetrating captive bolt** stunning has several animal welfare advantages over non-penetrating captive bolt stunning (success rate, duration of unconsciousness) and, if properly used, results in an effective stun. However, field observations indicate that 4% of stuns can be improper, often due to insufficient head restraint, wrong position of the operator, inadequate maintenance of the gun or bad quality of the cartridges.

Insufficient data are available on the effectiveness of **non-penetrating captive bolt** stunning in different age/weight groups of animals. It is however unlikely that the existing method is suitable for all types of cattle, because of varying characteristics of the skull depending on breed, age and sex (different skull shapes, local deformation of skulls in young calves, inadequate concussion in mature bulls).

From an animal welfare point of view, the best method currently available for stunning cattle and calves is the **penetrating captive bolt**.

### 2.1.2. Recommendations

**The penetrating captive bolt** should be used for cattle and calves. The **non-penetrating captive bolt** stunning method available at present is unreliable and should not be used.

## 2.2. ELECTRICAL STUNNING OR STUN / KILLING METHODS

### 2.2.1. Conclusions

Electrical stunning can be applied manually to young calves. If the system is properly maintained and used, unconsciousness can be reliably induced. It also can be manually applied to adult cattle that are calm or restrained.

Electrically induced head-only stuns may not last long enough to allow normal killing by bleeding. Cardiac ventricular fibrillation or immediate sticking while the animal is restrained will prevent recovery during bleeding (electrical stun / killing). The heart can resume normal functioning if an animal is manipulated too soon after application of the stun / killing method.

Electrical stunning and stun / killing induces tonic / clonic seizures, making prompt and accurate sticking difficult. In some parts of the world, electro-immobilisation (low voltage spinal discharge) is applied following the stun to prevent the movements. However, electro-immobilisation will mask the signs of consciousness in inadequately and poorly stunned animals and will cause pain to such animals. Alternative systems exist which allow electrical stunning and immediate sticking within the restraining pen before development of tonic / clonic seizures.

### 2.2.2. Recommendations

Manual application of electrical stunning may be used with very low throughput rates. For less calm animals or at higher throughput rates, automated systems should be used.

For head-only electrical stunning, a minimum current of 1 second, > 1.28 A[2] (200 V[3], 50 Hz[4]) can be used to effectively stun adult cattle, and 1 second, 1.25 A (150 V, 50 Hz) to stun calves (6 months) when applied on the temporal region of the skull.

Either animals have to be chest stuck within 23 seconds (adult cattle) or 12 seconds (calves), or ventricular fibrillation has to be induced.

In adult cattle, ventricular fibrillation can be induced in an automatic stunning system by a head-brisket discharge (5 seconds, 1.5 A (175 V, 50 Hz)) or by placing manually electrodes across the chest (25 seconds, 1.8-2.8 A or 5-10 seconds, 2.3-3.5 A (250 V, 50 Hz)).

In calves, ventricular fibrillation can be induced using withers-to-back (1-2 seconds, current not reported, 600 V, 50 Hz), head-to-back (5 seconds, 0.9 A, 300 V, 50 Hz) or head-to-leg (5 seconds, 0.5-2.0 A, 400 V, 50 Hz) application of electrical current.

Manipulation of the carcasses for hoisting and sticking should be delayed for 30 to 60 seconds to avoid that the heart resumes normal functioning.

### 2.2.3. High research priorities

More information is needed on electrical parameters (duration of application, current type and strength) and electrode placements to be used to induce loss of consciousness and cardiac fibrillation in adult cattle and calves.

The depth and duration of unconsciousness and insensibility induced with various electrical parameters need to be clearly established in cattle. The return of possible signs of consciousness such as breathing in adult cattle subjected to electrical stun / killing needs further investigation in order to determine whether they do indicate return of consciousness and/or sensitivity. If so, the method should be improved to ensure unconsciousness until death.

There is a need to develop systems allowing sticking in an electrical stunning box to allow immediate sticking after stunning, before clonic convulsions start. As the animals would lose blood very quickly, cardiac ventricular fibrillation or gentle handling after a stun / killing procedure would be unnecessary.

## 3. METHODS FOR STUNNING AND STUN / KILLING SHEEP

Mechanical methods (penetrating captive-bolt) and electrical methods are the most common methods for stunning sheep under slaughterhouse conditions.

### 3.1. MECHANICAL STUNNING METHODS

### 3.1.1. Conclusions

**The use of the penetrating captive-bolt** leads to an immediate loss of consciousness, when the devices are properly maintained and used in properly restrained animals.

The effectiveness of the **non-penetrating captive bolt** under slaughterhouse conditions is not known.

### 3.1.2. Recommendations

**The penetrating captive-bolt** should be used for stunning sheep under slaughterhouse conditions. **Non-penetrating captive bolts** should not be used because no investigations exist for adult sheep to prove that it is suitable for them.

[2] A : ampere
[3] V : volts
[4] Hz : hertz

It is important to sever both common carotids to facilitate rapid bleeding and shorten time to death, and therefore to reduce the likelihood of recovering consciousness before death.

### 3.1.3. High research priorities

Methods for restraining single sheep with minimal stress to the animal prior to the use of the penetrating captive bolt should be developed.

## 3.2. ELECTRICAL STUNNING OR STUN / KILLING METHODS

### 3.2.1. Conclusions

Electrical resistance in sheep varies according to age, breed, and the extent of wool cover.

Electrical stunning leads to an immediate loss of consciousness when the devices are properly maintained and used in properly restrained animals. Electrical stunning of unrestrained sheep in a pen can cause incomplete stunning or painful electric shocks and thus poor welfare.

Electrical stunning in sheep has the disadvantage that maintenance of good electrical contact is not easy due to the small size of the animal's head and insulation resulting from the wool. Poor electrical contact with consequent carbonizing of electrodes or wool would increase electrical resistance of the stunning electrodes. Electrodes fitted with pins penetrate the wool cover better and help to achieve more effective stunning. Wetting of electrodes or wool at the site of tong placement helps to reduce electrical resistance.

### 3.2.2. Recommendations

**Head-only electrical stunning** should be induced using a minimum of 1.0 A (root mean square or average) during a minimum of 2 seconds on restrained sheep only, sticking should then be performed within 8 seconds.

**Head-to-back stun / killing (one cycle method)** should only be used in a restrainer. For effective use, a minimum of 1.0 A (AC[5] 50 Hz) for a minimum of 3 seconds should be applied. Sticking should then be performed without unnecessary delay.

**The two cycle stun / killing method** (for killing under disease control situation) should be performed using a minimum of 1.0 A (AC 50Hz) for a minimum of 2 seconds for the first cycle, and 4.0 seconds for the second cycle.

In animals with wool at the site of tong placement, electrodes should be fitted with pins or wetted to reduce electrical resistance.

### 3.3.3. High research priorities

To improve electrical stunning under slaughterhouse conditions, methods to maintain good electrical contact and low-stress devices for restraining single sheep should be developed. The effect of water used for wetting the fleece on stunning effectiveness is not fully understood.

[5] AC: alternating current

# 4. METHODS FOR STUNNING AND STUN / KILLING PIGS

Two main methods exist to stun or stun / kill pigs: electrical stunning or stun / killing and gas stunning with $CO_2$. Electrical stunning or stun / killing is the most commonly used method in Europe, but as many pigs are stunned with electricity as with $CO_2$.

## 4.1. MECHANICAL STUNNING METHODS

### 4.1.1. Conclusions

Only **penetrating captive bolts** can be used on pigs (**non-penetrating bolts** are not used). Stunning of pigs under slaughterhouse conditions with a penetrating captive bolt is mainly restricted to casualty slaughter and is not used routinely. However, it is widely used as a back-up method when other methods fail. When properly used, it leads to an immediate loss of consciousness. The welfare concerns are that accurate shooting is difficult and it may not be effective in mature sows and boars.

### 4.1.2. Recommendations

The captive bolt should be fired perpendicular to the frontal bone surface.

### 4.1.3. Other future research

There is a need to develop and evaluate a captive bolt gun that would effectively stun / kill pigs, including breeding sows and boars.

The feasibility and effectiveness of pithing pigs to kill them after shooting with penetrating captive bolt need to be evaluated. If this is not possible, then the effectiveness of administration of a neurotoxin (e.g. potassium chloride) through the bolt wound to chemically destroy the brain should be evaluated.

## 4.2. ELECTRICAL STUNNING AND STUN / KILLING METHODS

### 4.2.1. Conclusions

When properly used, electrical stunning leads to an immediate loss of consciousness.

In electrical stunning, serious welfare concerns are related to the introduction of an animal into the restrainer as well as being restrained in poorly designed systems or in high throughput slaughterhouses. Restraint in V-shaped restrainers can be extremely stressful for pigs. Band restrainers appeared to cause less stress.

A major risk with electrical stunning, especially with unrestrained pigs, is improper manual placement of electrodes which can cause incomplete stunning and painful electric shocks and thus result in poor welfare. Automated electrical systems using V-shaped restrainers may fail to induce effective stunning in all animals, due to incorrect electrode placement related to varying animal size or to bad design of the system. Automated electrical stunning systems using chest belt conveyors have a high stunning efficiency due to the use of photo sensors to improve placement of electrodes and accurate positioning of the animals head.

Electrical stun / killing, which induces cardiac ventricular fibrillation, should ensure that no pigs regain consciousness during bleeding. However, impacts during shackling and hoisting could resuscitate the heart.

### 4.2.2. Recommendations

When electrical stunning is used, guiding and handling equipment should be designed to facilitate introduction of pigs into the restrainer, in order to minimize stress. Low stress

restraining devices should be used to reduce movements caused by stress. Band restrainers should preferably be used. .

Correct placement of the electrodes should be ensured in all the electrical methods. In the automated systems, the placement of the electrodes should be adapted to the size of the pigs.

For **electrical head-only stunning**, a minimum current of 1.3 A (root mean square or average) should be applied across the brain for at least 1 second to induce immediate loss of consciousness. Sticking should then be performed within 15 seconds after end of the stun.

For **the one cycle electrical head-to-back stun / killing method**, a minimum current of 1.3 A (root mean square or average) using 50 Hz sine wave AC should be applied for at least 1 second to induce immediate loss of consciousness and cardiac ventricular fibrillation.

For the **two cycle electrical stun / killing method**, a minimum current of 1.3 A (root mean square or average) should be applied across the brain for at least 1 second to induce immediate loss of consciousness, followed by a minimum current of 1 A (root mean square or average) using 50 Hz sine wave AC spanning the heart for at least 1 second to induce cardiac ventricular fibrillation. When using this method for manual stun / killing, the recommended minimum currents should be applied for at least 3 seconds. The method should ensure that the current reaches the brain before or at the same time as it reaches the heart, lest the conscious animal be killed by cardiac arrest, an inhumane method.

Following electrical stun / killing of pigs, the stun-stick interval is not critical, providing that subsequent forceful handling of the animal is avoided as this could resuscitate the heart before sticking or during bleeding.

### 4.2.3. High research priorities

The technical reference data for electrical stunning such as 1.3 A are either rather old or worked out under experimental laboratory conditions. There is a need to verify these data under commercial conditions.

Contradictory results in the duration of an electrical stun using different frequencies and waveform currents have been found in pigs. The depth and duration of unconsciousness and insensibility induced with various electrical waveforms, frequencies and amount of current need to be clearly established using well defined criteria such as quantitative electroencephalogram and/or evoked potentials in the brain.

Stunning of pigs with an electric current is expected to increase the brain extra cellular levels of GABA (gamma amino butyric acid), as happens in sheep. It is not known how long the GABA level remains elevated and what are its animal welfare implications. This needs to be evaluated using a combination of neurochemical and neurophysiological techniques.

## 4.3. GAS STUNNING AND STUN / KILLING METHODS

### 4.3.1. Conclusions

In $CO_2$ stunning, loss of sensibility and consciousness is not immediate but immersion of pigs into 80 to 90% $CO_2$ usually leads to the induction of unconsciousness within 30 seconds. At a given high concentration of $CO_2$ (80% by volume in air) and using increasing exposure times, the duration of unconsciousness increases and the stun-stick interval can be increased proportionally without animals recovering consciousness. However, at concentrations above 30% $CO_2$, the gas is known to be aversive and cause hyperventilation and irritation of the mucous membranes that can be painful, and elicits hyperventilation and gasping before loss of consciousness.

Hypoxic stunning induced with 90% argon in air is less aversive than hypercapnic hypoxia induced with 30% $CO_2$ in argon or nitrogen or stunning with 80-90% $CO_2$ in air.

At the exposure time of 3 minutes, the duration of unconsciousness induced with 30% $CO_2$ and 60% argon in air is short (<50 seconds). Exposure times of 7 minutes will be necessary to stun / kill pigs with this gas mixture.

At the exposure time of 3 minutes, the duration of unconsciousness induced with 90% argon or nitrogen in air is short (<50 seconds). Exposure times of longer than 7 minutes will be necessary to stun / kill pigs with argon-induced hypoxia, but it is not known how long an exposure time is needed to achieve killing of all pigs.

To overcome practical problems due to this short stun-stick interval, inducing cardiac ventricular fibrillation with an electric current might be a viable option.

### 4.3.2. Recommendations

Ideally, gas stunning and stun / killing systems should incorporate some general animal welfare principles. Pigs should be maintained in a stable social group with the minimum of restraint (group stunning).

Pre-slaughter handling facilities used for loading animals into cradles should be designed to minimise stress.

All pigs should be rendered rapidly unconscious in the gas. An irreversible state of unconsciousness should be reached in all pigs prior to sticking.

There should be adequate monitoring of gas concentrations of the system and efficient evacuation in the event of any system failure.

The gas used to induce unconsciousness should be non-aversive. In this regard, the use of argon, nitrogen or mixtures of these gases seems to have animal welfare advantages, because hypoxia induced with these gas mixtures is not aversive to pigs.

Stunning in gas mixtures containing low oxygen concentrations should be done with: (a) a mixture of 30% $CO_2$ and 60% argon or nitrogen in air, or (b) with 90% argon or nitrogen (or other inert gas) in air. In both cases, the maximum residual concentration of oxygen should be 2% by volume. Pigs should be immersed into these recommended gas concentrations within 10 seconds from leaving the atmospheric air and they should be exposed to gas mixtures for a minimum of 3 minutes under situations where death will be achieved through bleeding.

After stunning with hypoxic gas mixtures, pigs should be bled out as fast as possible. Considering the duration of unconsciousness given above (see 4.2.1.), the recommended stun-to-stick interval are:

- After exposure to 30% $CO_2$ and 60% argon or 90% argon in air:
    - for 3 minutes exposure: the stun-to-stick interval should not exceed 25 seconds,
    - for 5 minutes exposure: the stun-to-stick interval should not exceed 45 seconds.
- After exposure to 30% $CO_2$ and 60% argon for 7 minutes: the stun-to-stick interval is not critical (as all the pigs are dead).
- After exposure to 90% argon for 7 minutes: the stun-to-stick interval should be kept short i.e. less than 60 seconds.

However, the prolonged exposure times and relatively short stun-to-stick intervals mentioned above may not be commercially feasible where high throughput rates are required. Therefore, potential alternatives have been proposed. For example, stunning of pigs with 30% $CO_2$ and 60% argon in air or with 90% argon in air, and then inducing cardiac ventricular fibrillation with an electric current to kill them prior to shackling, hoisting and bleeding. In this regard, exposure of pigs to the novel and humane gas mixtures has been reported to induce isoelectric electroencephalograms within 90 seconds. Therefore, induction of ventricular fibrillation

immediately (e.g. within 10 seconds) after 90 seconds exposure could be an option; but it may not be practically possible to induce ventricular fibrillation in all the pigs under group stunning situations (e.g. five pigs). Under these circumstances, exposure times should be prolonged such that the last animal within a group will remain unconscious until the induction of ventricular fibrillation.

The times recommended previously for exposure to novel and humane gas mixtures and stun-to-stick intervals could be used to provide guidelines. For example, ventricular fibrillation should be induced within 25 and 45 seconds after 3 and 5 minutes exposure, respectively, to these gas mixtures.

#### 4.3.3. Future research

#### a) High research priorities

Further research is needed to develop humane gas mixtures and to determine stress levels of pigs during the induction stage of gas stunning before loss of consciousness.

Further research and development should aim to evaluate and, if relevant, to develop stun / killing systems based on the induction of hypoxia.

In humans, inhalation of high concentration of $CO_2$ for a short time or prolonged inhalation of a low concentration of $CO_2$ induces breathlessness. Breathlessness can be determined from the increases in intrathoracic / diaphragmatic pressures. Similar techniques could be employed to ascertain whether pigs experience breathlessness during stunning with this gas.

#### b) Other future research

Exposure of pigs to $CO_2$ has been reported to increase the extra cellular levels of GABA in the brain. Since GABA is an inhibitory amino acid neurotransmitter and hence would prevent induction of epilepsy in the brain, it is believed that electrical stunning may not be appropriate to re-stun pigs showing signs of recovery of consciousness after $CO_2$ stunning. This needs to be scientifically investigated.

### 4.4. OTHER METHODS

#### 4.4.1. Conclusions

The use of the **waterjet stun / kill method** and **microwave irradiation** have been tested experimentally and have not been further developed due to disadvantages on animal welfare, operative health and safety grounds.

#### 4.4.2. Other future research

**Combined methods** needs to be evaluated as it may be possible to develop equipment for pigs to induce unconsciousness and insensibility with non-aversive gas mixtures and then to subsequently kill them with electric current.

### 4.5. Other future research for all methods where pigs are stuck

There appears to be a potential conflict between the size of the sticking wound and chances of carcass contamination during scalding (welfare vs. hygiene), which needs to be evaluated and resolved.

# 5. METHODS FOR STUNNING AND STUN / KILLING POULTRY SPECIES (CHICKENS AND TURKEYS)

Electrical and gas methods are the most common methods for stunning and stun /killing poultry under slaughterhouse conditions.

Since welfare is poor when the shackling line and water bath electrical stunning method is used, and birds are occasionally not stunned before slaughter, the method should be replaced as soon as possible. At present, the inert gas stun / killing method is the best alternative.

## 5.1. MECHANICAL STUN / KILLING METHODS

### 5.1.1. Conclusions

Captive bolts are normally used for stun / killing birds and as a backup method when other methods fail. Shooting of poultry with existing captive bolts, both penetrating and non-penetrating guns, results in severe skull fractures and structural damage to the brain leading to death. A commercially available captive bolt (Humane Poultry Killer) fitted with a plastic percussive head is widely used to kill poultry on farm and as a backup method in processing plants. When penetrating captive bolts are used, the bolt diameter, velocity and penetration depth are critical to achieving a humane stun / kill.

During restraint of birds using shackles before mechanical stun / killing, there is a potential in a significant number of animals for dislocations and fractures to occur before being stunned.

### 5.1.2. Recommendations

Birds should be restrained to facilitate accurate placement and effective shooting. The methods for shackling birds should be such that it minimises the potential for joint dislocations and fractures through careful handling and good shackle design.

Captive bolts should be fired perpendicular to the frontal bone surface.

The bolt diameter should be a minimum of 6mm and deliver an impact energy of 21 Joules and, in any case, appropriate to the species of poultry to destroy the skull and brain.

### 5.1.3. High research priorities

Research is needed to develop better restraining mechanisms.

## 5.2. ELECTRICAL STUNNING AND STUN / KILLING METHODS

### 5.2.1. Conclusions

**Stunning methods** used for poultry are head-only electrical stunning and water baths electrical stunning (involving high frequency (>100Hz) electric currents). The duration of unconsciousness decreases with increasing frequency, e.g. above 200Hz, of the stunning current applied head-only or in a water bath.

Electrical water bath involving 50 to 60Hz sine wave alternating currents is used as a **stun / killing method.**

**Electrical stunning and electrical stun / killing using water baths** require extremely stressful handling and shackling of live poultry. The pain and distress associated with inversion (hanging upside down) and shackling (compression of metatarsal bones) induces wing flapping in the majority of birds, and there is a potential in a significant number of animals for dislocations and fractures to occur.

Allowing certain time intervals (e.g. 12 and 20 seconds in chicken and turkey, respectively) between shackling and water bath stunning or stun / killing, provision of breast comforters up to the entrance to the water baths and dim light in the area of shackling and stunning or stun / killing have a calming effect on birds and reduces the prevalence and duration of wing flapping.

Wing flapping at the entrance to the water baths predisposes birds to receive electric shocks prior to be stunned, those pre-stun electric shocks are extremely painful and distressing to the birds. Owing to large wingspans in turkeys, their wings hang lower than their heads and therefore the leading wings normally make contact with the electrified water baths before the heads are fully immersed.

The amount of current delivered to individual birds in a multiple-bird water bath stunning or stun / killing system varies according to the electrical resistance or impedance of individual birds in the bath and cannot be controlled without the implementation of constant current stunners.

**Electrical stun / killing technique (experimental), using dry electrode**s, performed on poultry restrained in conveyors avoids the poor welfare that results from shackling when using electrical stun / kill in a water bath. However, the minimum currents necessary to effectively stun / kill have been established only for chickens and need to be determined for turkeys.

Electrical stun / killing methods involving dry electrodes or water baths are better than electrical stunning on bird welfare grounds because the stun-to-neck cutting interval and the blood vessels severed at slaughter are not critical, and also because in water bath stunning systems, (a) delivery of effective current to all the birds could not be guaranteed due to the reason that current flow through individual birds in a multiple bird water bath stunner varies inversely according to the electrical impedance of birds (in the circuit or pathway), (b) effectiveness of stunning decreases with increasing electrical frequencies that do not induce ventricular fibrillation, (c) mechanical neck cutting may not be effective in severing all the major blood vessels in the necks of all birds to prevent return of consciousness during bleeding, and (d) under commercial conditions, birds showing signs of consciousness during bleeding could not be accessed safely and swiftly to apply a backup stunning or killing method.

### 5.2.2. Recommendations

Recommendation of one effective minimum current for all the electrical waveforms and frequencies used under commercial conditions is not feasible and it could not possibly ensure good welfare in the birds. Therefore, based on the available scientific information (in chickens), certain minimum currents are recommended for different ranges of electrical frequencies.

Stunning procedures should be followed within 20 seconds by severance of all the major blood vessels in the neck, including both common carotid arteries, to avoid recovery of consciousness during bleeding and all the birds should be dead when entering scald tanks.

**For head-only electrical stunning**, the size, shape and design should be appropriate to the species such that they facilitate effective application of the stun and deliver recommended currents within a second of stun application. Birds should be restrained suitably to facilitate uninterrupted and effective application of the stun. Head-only electrical stunning electrodes should be placed on either side of the head such that they span the brain. Minimum root mean square or average currents of 240 and 400 mA should be applied for a minimum of seven seconds to chickens and turkeys, respectively, when using a constant voltage stunner supplied with 50 to 60 Hz sine wave AC. When using constant current stunners delivering sine wave AC, the following minimum currents should be applied for a minimum of one second.

Table 1. Minimum currents to apply for a minimum of one second when using constant current stunners delivering sine wave AC

| Sine wave AC frequency (Hz) | Minimum root mean square current (mA) |
|---|---|
| 50 | 100 |
| > 50 and up to 400 | 150 |
| > 400 and up to 1500 | 200 |

To facilitate effective monitoring and auditing, **electrical water bath** stunners should be fitted with visible and audible alarm systems to warn when the supply voltage falls below the levels that would be necessary to deliver the minimum recommended currents.
The size and shape of the metal shackles should be appropriate to the size of legs of poultry, such that secure electrical contact is provided without causing avoidable pain. Wetting shackles prior to hanging live birds reduce electrical resistance and improve contact between legs and shackle.

The methods of shackling birds should be such that it minimises the potential for joint dislocation and fractures through careful handling and good shackle design. Shackle lines should not have bends and dips that induce wing flapping. There should be a sufficient delay between shackling and stunning to provide time for the birds to stop wing flapping. The minimum shackle duration should be 12 and 20 seconds in chickens and turkeys, respectively. Poultry should be hung on the shackle line by both legs for a time as short as possible. The maximum time interval between shackling and stunning should not exceed one minute.

Runts (smaller than average birds), which are likely to miss the water bath stunner, and injured birds that are in pain should not be shackled. Instead, they should be killed using an appropriate killing method (e.g. captive bolt).

Lighting conditions during shackling of live poultry should be controlled to reduce wing flapping. Breast comforting plates that help to calm the birds should be used from the point of shackling until the birds enter the water bath stunner.

Pre-stun electric shocks occurring at the entrance to the electrified water bath should be avoided by providing an electrically insulated entry ramp to the bath and avoiding overflow of water at the entrance, for example.

The height of the water bath should be adjusted according to the size of poultry to ensure at least complete immersion of the birds' heads in the water or, preferably, immersion of the birds up to the base of the wings. Food-grade salt, at least 0.1% weight / volume, should be added to the fresh water bath to improve electrical conductivity, where appropriate. The electrodes in water bath stunners should extend to the full length of the water bath.

During stunning, there should be secure and uninterrupted contact between the shackle and the earth (rubbing) bar.

Electrical water baths for stunning or stun / killing poultry should be supplied with constant current, rather than constant voltage, source and each bird in the water bath should receive the recommended minimum amount of current.

The voltage supplied to the water bath stunning systems should be sufficient to deliver the following minimum recommended root mean square or average currents (mA) to each of the birds in the water bath (table 2).

Table 2. Minimum recommended root mean square or average currents (mA) delivered to birds in water bath stunning systems

| Frequency (Hz) | Chickens | Turkeys |
|---|---|---|
| Up to 200 Hz | 100 | 250 |
| 200 to 400 Hz | 150 | 400 |
| 400 to 1500 Hz | 200 | 400 |

When using pulsed DC the mark:space ratio (which is the duration for which current remains ON and OFF within each cycle (Hz)) should be 1:1.

In the event of line breakdown or a delay in stunning the birds, access should be available to unshackle the birds that have not reached the water-bath and have not been stunned, and bleed those birds that have been stunned and remain in the water-bath.

Recommendations for electrical stunning in water baths apply also to electrical stun / killing in water baths, except for the minimum currents. Minimum root mean square or average currents of 150 and 250mA delivered with a 50 to 60Hz sine wave AC should be applied for a minimum of one second to chickens and turkeys, respectively.

Since stunning and stun / killing using a shackling line and water bath causes very poor welfare in the birds, these systems should be replaced as soon as possible by a system causing less stress and pain such as those using non-aversive gases. If this is not feasible, application of electrical stun / killing technique to poultry restrained in conveyors should be considered.

However **Electrical stun / killing using dry electrodes** is not used commercially, the technique is available for processors (especially small and on farm processors) and its use should be encouraged.

Birds should be restrained suitably to facilitate uninterrupted application of the stunning and killing current cycles. Birds should be stunned head-only first, immediately followed by a head-to-body current application. Good electrical contact should be maintained during stunning and killing. The body electrodes should span the heart.

When using a constant voltage stunner, a minimum root mean square current of 240mA of 50Hz sine wave AC should be applied for at least 5 seconds across the head to stun and another one seconds across the body to stun / kill chickens uninterruptedly. When using a constant current stunner, a minimum root mean square current of 150mA of 50 Hz sine wave AC should be applied for at least one second across the head to stun and one additional second across the body to kill chickens uninterruptedly.

No birds shall survive the application of any electrical stun / killing method or show signs of recovery of consciousness during bleeding.

### 5.2.3. Future research

#### a) High research priorities

If the use of shackles is to continue, research is needed to develop better shackling mechanisms for birds and to develop alternative systems of restraint.

Evaluation and development of electrical stun/ kill techniques that do not involve shackling of conscious turkeys are needed. In that scope, devices that stun / kill turkeys restrained in conveyors using dry electrodes need to be investigated. This will eliminate the need to shackle conscious birds, especially heavy turkeys, and avoid the associated pain and distress.

The minimum currents necessary to achieve effective stunning and killing need to be established. The impact of electrical stunning (head-only or water bath) current waveform, frequency and the amount of current on the depth and duration of unconsciousness induced in poultry need to be clearly established using neuro-physiological parameters to understand the effect of these variables.

The time to cessation of wing flapping from the moment of hanging turkeys on a moving shackle line under commercial conditions needs to be determined to specify a minimum shackling duration for this species (there is only one survey study available for turkeys comparing to broilers for which many reports exist).

The prevalence of pre-stun electric shocks occurring prior to electrical water bath stunning of chickens under commercial conditions is not known and needs to be determined.

The prevalence of alive and conscious poultry (chickens and turkeys) entering scald tanks under commercial processing conditions needs to be determined and methods found to prevent it.

### b) Other future research

The previously reported times to onset of brain death after cutting common carotid arteries and external jugular veins (or combination of blood vessels) in the necks of turkeys and chickens, as determined from the loss of visual evoked potentials in anesthetised and mechanically ventilated birds, appear to be longer than the time normally needed to reach the scald tanks under commercial processing conditions. Poultry are known to defecate as they enter scald tanks and it is not certain whether this potential hygiene problem is an indicator of a serious welfare problem, i.e. birds entering scald tanks before the onset of brain death and hence defecating in the scald tanks.

Further investigations involving electrical stunning and slaughter procedures are needed to establish the cumulative impact of stunning and slaughter on the time to onset of brain death and recommend bleed out times that are appropriate to the species of bird.

## 5.3. GAS STUNNING OR STUN / KILLING METHODS

### 5.3.1. Conclusions

The balance of evidence suggests that controlled atmospheres containing concentrations of more than 30% $CO_2$ are aversive and may cause pain and respiratory distress before loss of consciousness. Hypoxia induced with argon and / or nitrogen with less than 2% by volume of oxygen is not aversive to poultry.

A controlled atmosphere containing 30% or less by volume of $CO_2$ in argon and / or nitrogen with less than 2% by volume of oxygen seems to be adequate for stun / killing poultry. In addition an alternative system anaesthetising birds with an atmosphere of 30 to 40% $CO_2$ (with $O_2$ and $N_2$) for 1 minute, followed by 2 minutes in 80% $CO_2$ or more to cause death, is being evaluated.

The exposure times necessary to effectively stun poultry with any gas mixtures, without killing some birds and / or inadequately stunning some other birds, are not known. The duration of unconsciousness induced with the known gas mixtures are very short and therefore, it will be difficult to avoid return of consciousness either prior to or during bleeding. Birds showing signs of consciousness following stunning need to be effectively re-stunned, preferably using captive bolts, instead of neck dislocation.

### 5.3.2. Recommendations

In the absence of sound scientific evidence concerning the depth and duration of unconsciousness induced with gas mixtures, minimum conditions **for stunning** poultry could not be defined.

When using gas mixtures **for stun / killing**, live poultry should only be conveyed into the gas mixtures either in transport crates or on conveyor belts. Birds should reach the recommended gas mixtures within 10 seconds of leaving atmospheric air.

Under no circumstances should gases at freezing temperatures enter the chamber. Appropriate gas concentrations should be monitored continuously at bird level inside the chamber.

The recommended gas mixtures are: (a) a minimum of 2 minutes exposure to argon, nitrogen or other inert gases, or any mixture of these gases, in atmospheric air with a maximum of 2% oxygen by volume; (b) a minimum of 2 minutes exposure to any mixture of argon, nitrogen, or other inert gases with atmospheric air and $CO_2$ provided that the $CO_2$ concentration does not exceed 30% by volume and the oxygen concentration does not exceed 2% by volume.

All the birds should be killed by the gas mixtures and under no circumstances should they show signs of recovery of consciousness once they had been through the chamber.

Stun / killing poultry in transport crates using hypoxia and shackling of relaxed carcasses would result in best welfare since it would not only eliminate live bird handling and shackling at the processing plants but also effectively kill all the birds. In this regard, the use of hypoxia (less than 2% by volume of oxygen) induced by argon, nitrogen, inert gases or mixtures of these may be the best option from an animal welfare point of view.

#### 5.3.3. High research priorities

Stunning of poultry with gas mixtures needs further investigation to determine more humane gas mixtures as well as the duration of unconsciousness, appropriate stun-to-neck cutting interval, blood vessels to be severed and the time to onset of brain death.

Gas stunning mixtures should be improved and validated so they can be quickly and widely used in slaughterhouse, thus decreasing distress and pain due to shackling.

Bleeding techniques that do not need shackling of gas-stunned birds need to be evaluated and developed.

### 5.4. OTHER METHODS

#### 5.4.1. Conclusions

The use of **needle bolts** for poultry or **microwave irradiation** have been tested experimentally but have not been further developed due to disadvantages on animal welfare and operative health and safety grounds.

#### 5.4.2. Recommendation

**Needle bolts** or **microwave irradiation** should not be used for poultry.

## 6. METHODS FOR STUNNING AND STUN / KILLING HORSES

Penetrating captive bolt stunning is the most common used method in European abattoirs. When performed correctly, captive bolt and free bullet can be effective methods for respectively stunning and killing horses and for both methods, loss of consciousness is immediate.

### 6.1. PENETRATING CAPTIVE BOLT STUNNING

#### 6.1.1. Conclusions

Although scientific investigations in mechanisms and effectiveness of captive bolt stunning in horses were not available for the scientific report, practical information and experience

indicates that the method may work well under slaughterhouse conditions, if the equipment is well maintained.

#### 6.1.2. Other future research

Pre-slaughter handling, mechanisms and effectiveness of captive bolt stunning and bleeding in horses should be scientifically evaluated.

### 6.2. FREE BULLETS FOR KILLING

#### 6.2.1. Conclusions

The use of free bullets can be necessary in excited and uncontrollable horses.

#### 6.2.2. Recommendations

This method cannot be used in confined spaces and requires personnel trained in the use of firearms.

## 7. METHODS FOR STUNNING AND STUN / KILLING FARMED FISH

### 7.1. CONCLUSIONS

Many existing commercial killing methods expose fish to substantial suffering over a prolonged period of time. For some species, existing methods, whilst capable of killing fish humanely, are not doing so because operators don't have the knowledge to evaluate them.

In practice, **percussive stunning** tends to be a stun / killing method. It has the capacity to cause a humane death in many moderately sized species (0.2 to 14kg) if correctly applied.

Only **mechanical spiking methods** can be considered humane. **Non mechanical methods** are difficult to standardise and even mechanical methods require considerable skill to apply.

**Electrical methods** can be stunning or stun / killing methods, depending on the electrical parameters applied. Evidence indicates that electrical stunning systems do not induce a sufficiently long period of insensibility to ensure the fish dies before recovery of consciousness. Electrical stun / killing systems can be humane if the correct parameters are used but might cause substantial suffering when incorrectly applied.

Fish find **$CO_2$ narcosis** very aversive. It can be a stunning or a stun / killing method. But in commercial practice, it is usually a sedation method only because of the short exposure times used.

**Shooting and electric harpoon** for farmed tuna, **hydraulic shock and hypoxic stunning** have poor welfare implications.

**Asphyxia, asphyxia in ice / thermal shock, salt bath, ammonia solution, electro-immobilisation / electrostimulation / physical exhaustion using electrical shocks, decapitation** and **bleeding out / exsanguination** are not humane methods for killing fish

**Sedation / anaesthesia prior to slaughter** reduces the stress associated with handling if used correctly but it is not possible to use currently available anaesthetic or sedative for any fish that might enter the food chain. Pre-slaughter sedation by slow live chilling is not a humane method to sedate or kill fish.

### 7.2. RECOMMENDATIONS

Many fish killing process are designed for commercial efficiency rather than welfare priorities. Criteria for humane application of percussive stunning, spiking and electrical stunning should be made available to the industry.

For **percussive stunning and spiking**, the species for which the method is appropriate, the force that should be applied and the correct target area should be specified. Mechanical percussive stunning devices should be regularly tested for correct function and efficiency.

For **electrical stunning**, species for which the method is appropriate, the stunning current, voltage and exposure time and method that ensures immediate and sustained insensibility should be specified. With development, electrical stun / kill systems are likely to be the most appropriate method for humanely killing many small farmed species of fish for which there is currently no other satisfactory method available.

**$CO_2$ Narcosis, asphyxia, asphyxia in ice/thermal shock, salt bath, ammonia solution, electro-immobilisation/electrostimulation/physical exhaustion using electrical shocks and decapitation** should not be used to kill fish because they cause avoidable suffering before death.

Fish should not be **cooled on ice in air or water** as a means of removing muscular activity or killing.

In all cases, it should be mandatory that a stunning / killing step is incorporated before exsanguinations or any processing of fish commences e.g. gutting, desliming, etc

### 7.3. FUTURE RESEARCH

There is a major lack of knowledge of many aspects of stunning and killing in fish.

There is a need to develop (a) techniques to facilitate handling and restraint of fish, (b) methods that ensure immediate unconsciousness in all species of fish currently farmed and, (c) for all stunning methods, to evaluate methods for killing fish before recovery from the stun.

Existing equipment and procedures should be evaluated and certified to ensure that they effectively and humanely stun or stun / kill fish.

For many species, there is not a commercially acceptable method that can kill fish humanely. The development of humane slaughter methods should be an integral part of developing any new species for fish farming.

#### 7.3.1. High research priorities

The parameters required to stun and/or stun / kill fish by means of electric current should be investigated in all appropriate farmed species (<10kg). The relationship between required exposure duration, required electric field strength, electrical frequency and water conductivity should be identified for the induction of both insensibility and death. The mechanism of death in fish exposed to electrical stunning parameters should be identified. The relationship between the above electrical parameters and carcass quality should be examined. Apparatus for electrical stunning of smaller farmed sea fish (sea bass, sea bream) should be developed.

The welfare implications of electric harpoon or shooting in the case of farmed tuna should be investigated.

The welfare implications of hydraulic shock and hypoxic stunning should be assessed by measurement of brain function in combination with observation of behaviour.

#### 7.3.2. Other future research

Mechanical devices such as captive bolt pistols should be developed for all species for which they would be of value. The humaneness of percussive killing should be investigated in each farmed species of fish. Mechanical devices for percussive killing of fish larger than those currently killed by this method should be investigated.

There is also a need to investigate ways to humanely kill fish taken from the water with a hook, a line or a net.

# 8. KILLING FOR DISEASE CONTROL

Previous conclusions for various stun / kill methods and species of animals should also be considered in this section.

For disease control purpose, a stun / kill rather than a "stun and bleed" method is normally required on the grounds of biosecurity, efficiency of operation and disposal of potentially infective materials.

There is a need to survey the common on farm killing practices during disease outbreaks in European countries, assessing practicability and animal welfare implications. Research to define optimal practices for emergency killing on farm as well as animals' handling and restraint systems for the various killing methods is urgently required to improve animal welfare, while maintaining biosecurity aspects. On farm non-invasive killing methods should be developed, especially if samples of CNS (central nervous system) tissue are required.

## 8.1. MECHANICAL METHODS

### 8.1.1. Conclusions

**Free bullet** fired to the brain is effective for on-farm killing of cattle, sheep, pigs and horses, due to massive brain destruction that causes immediate unconsciousness and death. It is suitable for animals that are difficult to handle and restrain.

**Penetrating captive bolt** are used to kill on farm cattle, calves, sheep, pigs, horses and poultry. It induces death in poultry but may only stun rather than kill large animals. Pithing should be performed immediately after shooting to ensure death, except where a pneumatic gun that injects air into the brain is used. Disposable pithing rods that would plug into the bolthole are commercially available however their effectiveness has not been validated. Adequate restraint of the animal is necessary to enable accurate delivery of the shot and this may limit its practical application on farms.

**Percussive blow** applied manually to the head is only suitable as a killing method for small number of poultry, piglets and lambs and should not be used on calves. It may not always cause death. Operator fatigue is an important factor in this method. Restraint of the animal is necessary and may be stressful.

**Neck dislocation** may not concuss poultry and it is therefore uncertain whether it causes immediate unconsciousness.

**Mechanical maceration** of chicks up to 72 hours old and embryonated eggs in a high-speed grinder fitted with rotating blades (6000 or more revolution per minute) results in immediate death.

### 8.1.2. Recommendations

**Free bullets** are only recommended to kill on farm cattle, calves, sheep, pigs and horses when other methods cannot be applied. The cartridge, calibre and type of bullet should be appropriate for the species and age. An animal should be killed by a single shot to a recommended anatomical position. While with increasing distance the chance of failure to shoot accurately with free bullet increases, a telescopic device and/or infrared targeting systems would help to improve precision. The ammunition should be appropriate to the species of the animals and distance of shooting.

The animals should be restrained wherever possible and/or sedated if necessary prior to killing with **penetrating captive bolts**. Pithing should be performed in large animals after shooting to ensure death. Precautions should be taken to avoid the spread the body fluids and tissues, e.g. brain tissue and blood, that has leaked from the hole.

A **percussive blow** to the head of piglets and lambs should not be used because it is not always effective.

**Cervical dislocation or decapitation** should be preformed after the birds have been stunned by some other means.

### 8.1.3. Future research

#### a) High research priorities

Requirements to induce death of all the animals by using penetrating captive bolt should be determined (kinetic energy, bolt diameter, penetration depth, type of pistol).

The susceptibility to infection in relation to the body fluids and brain tissues coming from the cranial hole after the use of free bullets or penetrating captive bolt should be determined.

#### b) Other future research

The minimal velocity of the impact to induce effective non-penetrating captive bolt stunning in each type of animal should be determined, taking into account the type of captive bolt. The duration of unconsciousness after such stunning methods should be specified.

## 8.2. ELECTRICAL METHODS

### 8.2.1. Conclusions

Electrical stun / kill methods are effective and non-invasive to kill large animals and poultry on-farm (various mobile systems are available for poultry). However, it is worth noting that induction of ventricular fibrillation in piglets and lambs may not be successful; these two species need prolonged current application across the heart.

Particular restraint of animal is needed to facilitate proper application of the electrodes, which can be distressing.

### 8.2.2. Recommendations

Electrical stun / killing methods are recommended, as they are non-invasive, to kill on farm calves, sheep, pigs and poultry.

In large animals, the appropriate current regarding species and ages should be applied for at least 10 seconds on the head and 45 seconds across the heart in order to ensure the death of all animals. The animals should be suitably restrained to ensure the correct placement of the tongs. Electrical methods are not recommended for killing piglets and lambs, as they may not cause ventricular fibrillation.

For poultry, the length of the water bath should be sufficient to provide a minimum of 10 seconds current application. Birds should be monitored during the following 10 minutes to ensure that death has occurred.

## 8.3. GAS METHODS

### 8.3.1. Conclusions

Killing of poultry and piglets with **controlled atmospheres** are non-invasive methods that permit the euthanasia of animals in groups, minimising stress caused by handling and restraint procedures.

Killing of all pigs in a group can be achieved with exposure to 90% $CO_2$ for 5.5 minutes although this gas is very aversive it may be the most practical. Exposure times of 7 minutes will be necessary to kill pigs in a mixture of 30% $CO_2$ and 60% argon. Exposure times of longer than 7

minutes will be necessary to kill pigs in 90% argon, but it is not known how long exposure time is needed to achieve killing of all pigs

**Carbon monoxide** is suitable for killing piglets and poultry, inducing a rapid loss of consciousness and death, provided that the gas source is pure and not obtained from outlet gases.

**Hydrogen cyanide** gas is not suitable for killing poultry because it may cause respiratory distress and convulsions prior to loss of consciousness.

### 8.3.2. Recommendations

**Controlled atmospheres** for killing can be used in poultry and piglets. Animals should be introduced into the chamber only after it has been filled with the required gas (mixture) concentration and they should remain in this atmosphere until they are dead. Chambers should not be overcrowded and measures should be taken to avoid animals climbing on top of each other when entering the chamber. Poultry should not be thrown in the chamber, bedding should also be added. Compressed gases, especially $CO_2$, should be vaporised prior to filling the chamber.

Only **carbon monoxide** administered from a pure source (not from outlet gases) should be used to kill piglets. Animals should be exposed to between 4% and 6% of CO by volume in air for a minimum of 6 minutes. Carbon monoxide should however be administered at a low flow rate as high flow rates induce severe convulsions, which can occur before loss of consciousness. As carbon monoxide is extremely noxious, personnel should be informed of the danger and suitably protected.

Exposure to **hydrogen cyanide** is not recommended to kill poultry as it causes respiratory difficulties before the onset of unconsciousness and is dangerous to humans.

### 8.3.3. High research priorities

Optimal gas euthanasia concentration and exposure time should be defined.

## 8.4. OTHER METHODS

### 8.4.1. Conclusions

**Intravenous administration of barbituric acid derivates overdose**, usually results in death. Restraint is necessary for intravenous administration which could be distressing. It passes the placental barrier, killing the unborn foetus. Other routes of administration can be painful and/or difficult to achieve or take longer time to induce unconsciousness and death.

When barbiturates cannot be used, **T61** may be a suitable substitute. T61 is a mixture of three drugs: hypnotic agent (Embutramide, 200mg/ml), curariform drug (Mebezonium iodide, 50mg/ml) and local anaesthetic (Tetracaine hydrochloride, 5mg/ml). However, accidental injection of T61 outside the vein or intravenous injection at a rapid rate have been known to cause signs of pain in some animals. T61 does not cross the placental barrier. As T61 contains a neuromuscular blocking agent, there is a possibility that an animal may not be unconscious at the time of muscle paralysis causing some fear.

**Killing of live fish** in emergency is best achieved by euthanasia using overdose of anaesthetic. A variety of anaesthetics is used, but the most common would be methane tricaine sulphonate or benzocaine. Euthanasia is not a medicinal function so, medicines legislation would not apply, but welfare and environmental requirements still have to be observed and no fish killed by chemical euthanasia can be allowed to enter the food chain. Under emergency circumstances, such as slaughter under notifiable disease legislation, when stocks slaughtered may be allowed to enter the food chain, **$CO_2$ narcosis**, followed by slaughter under strict containment, while highly aversive, is used.

### 8.4.2. Recommendations

**Intravenous lethal injection of barbiturates** may be recommended to kill large animals and poultry. It should be the first choice for pregnant animals, since the drug crosses the placenta and will also kill the foetus.

**T61, chloral hydrate, magnesium sulphate and potassium chloride** are not recommended for killing conscious animals.

**Killing of fish** in emergency should be achieved by euthanasia using overdose of anaesthetic. Appropriate methods of electrical killing may also be used. When possible however, in such circumstances, careful transport of fish for slaughter in a processing plant under strict containment would be the preferred option.

### 8.4.3. Future research

The perception of the foetus to adverse effects during killing of pregnant animals may need to be studied further.

## DOCUMENTATION PROVIDED TO EFSA

Letter, 19 May 2003 with ref. SANCO.C.2 RT/mcd D(2003) 112-320517, from Mr Robert J. COLEMAN from the Health & Consumer Protection Directorate-General transferring pending scientific questions to the European Food Safety Authority.

## REFERENCES

All references are available in the Scientific Report on welfare aspects of the main systems of stunning and killing the main commercial species of animals.

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