

**EFFECT OF PERIHARVEST HANDLING ON WELFARE
STATUS OF SLAUGHTER PIGS AND INTRINSIC PORK
QUALITY.
REVIEW OF RECENT FINDINGS**

**EFFECTUL MANIPULĂRII ÎNAINTE DE SACRIFICARE
ASUPRA BUNĂSTĂRII SUINELOR DESTINATE
ABATORIZĂRII ȘI A CALITĂȚII CARCASELOR**

SZÜCS E.*, CEUSTERMANS A.***, VAN DE PERRE V.***, GEERS R,**

*Faculty of Agricultural and Environmental Sciences, Szent István University, Gödöllő,
Hungary*

*Laboratory for Quality Care in Animal Production, Zootechnical Centre, Katholieke
Universiteit Leuven, Lovenjoel, Belgium*

There is a growing concern of consumers that the meat producing animals are bred, reared, handled and slaughtered in ways that are sympathetic to their welfare status. Good animal welfare is generally considered as a primary requirement and EU and national legislation is in force throughout the total production chain and everyday practice is above the minimum threshold level required. The relative importance of stress during animal production and in the immediate pre-slaughter period as a major determinant of ultimate meat quality has long been recognized. Good welfare may result in better product quality is a powerful additional commercial incentive to improve the way we rear, handle and slaughter animals. In the ante mortem period, good welfare usually results from careful handling of animals that reduces stress and trauma. In contrast, poor ante mortem handling leads to stress and results in poorer meat quality. Critical points within the pre-slaughter period are (a) loading, (b) transport, (c) lairage, (d) stunning

Key words: fattening pigs, periharvest handling, loading, transport, lairage, stunning, meat quality.

Introduction

Meat has been used for food since the beginning of recorded time. Pork is recorded as food as early as 3400 B.C. in Egypt and 2900 B.C in China. The time being, livestock industry is highly intensive, specialized and scientific. The status of animals has been the object of philosophical concern for a very long time. Recently, animal welfare has been a growing issue among consumers and society and ultimately public attitudes determine the demand of market for animal

products, thus, producers have to have interest in remaining informed about welfare animal issues and recent scientific research (Szücs, 1999). In particular, there is concern in many countries about the effects of transport, lairage, slaughter and associated handling on the welfare of animals. A single enterprise may be involved not only in primary production, but in slaughter, processing and distribution within the total production chain. For this reason interest of animal agriculture has been directed towards risk factors and points influencing product quality and safety. Quality and safety of foods of animal origin are strongly dependent on animal welfare. The direct relationship of animal welfare and primary production of food of animal origin seems to be obvious and has been elucidated in research for long time. Thus, that there is a growing concern of consumers that the meat producing animals are bred, reared, handled and slaughtered in ways that are sympathetic to their welfare status. Good animal welfare is generally considered as a primary requirement and EU and national legislation is in force throughout the total production chain and everyday practice is above the minimum threshold level required. Summing up comprehensive research studies Grandin (1997, 1998, 2000) and Grandin and Smith (2005) stated that understanding of the behaviour of livestock will facilitate handling, reduce stress, and improve both handler safety and animal welfare. Large animals can seriously injure handlers and/or themselves if they become excited or agitated. Reducing stress on animals has been demonstrated to improve productivity and prevent physiological changes that could confound research results. Recent studies have shown the adverse effects of stress on animals. Transportation and restraint stress reduced the immune function. Interactions among welfare status, environmental effects and intrinsic pork quality in pigs have been studied by Szücs *et al.* (2007). The stress imposed by transit had a greater detrimental effect on the animal's physiology than the stress of feed and water deprivation for the same length of time. As far as the effect of transport, lairage and pre-slaughter handling on welfare related meat quality is concerned, guidelines for treatment of animals and handling facilities, vehicles during transport and lairage prior to slaughter have been recommended. The most critical points within the pre-slaughter period are (a) loading, (b) transport, (c) lairage, (d) stunning.

Results and Discussions

(a) Loading

One of the rules included in codes of practice and legislation is that pigs should be fasted prior to slaughter at reasonable intervals and given drinking water *ad libitum*. When fasting is not used, swine submitted to intensive handling may develop hyperthermia. Fasting for at least 12 hours before loading decreases the risk of mortality during transport. In this situation, fasting is a necessary stress for the well-being of the pig. An extended fasting period, longer than 24 hours, causes a carcass weight loss of approximately 100 g/h. This is why it is important to have a system of drinkers at the processing plant aiming at re-hydrating the pigs after

unloading, especially during hot weather (one drinker/20 pigs). Studies on this subject measure the real efficacy of drinker systems and determine the number of water points needed taking into account the stocking density of lairage areas at the processing plant (Chevillon, 2000b). Currently, a feed withdrawal is recommended in practice. The risk of contamination of the pig's body surface is higher when the animals are transported as the stress of transport promotes the proliferation of species of *Salmonella* bacteria in the gut and their excretion into the environment. The puncture of a full stomach at evisceration is another source of carcass contamination. Food withdrawal either of 16 h or 22-28 h is recommended to have complete gastric emptying and minimize the risk of faecal contamination. Pre-slaughter fasting per se has only small effects on meat quality (Tarrant, 1989), but when combined to other pre-slaughter stressors it can be detrimental. Pre-slaughter feed restriction may cause losses with respect to carcass and meat quality in pigs (Beattie *et al.*, 1999). Very low initial pH can be measured in the loin of pigs that were not fasted and were transported to slaughter immediately after the arrival at the abattoir. Long fasting periods, when associated to long transports or lairage, would tend to decrease the incidence of PSE meat and increase the prevalence of DFD character due to muscle glycogen depletion, especially in muscles supporting the animal's posture and weight.

Removing pigs from the pens and moving them to the loading area submits them to stress and forced handling. There is a change in the heart rate, which goes from about 90 heart beats/min in a pig at rest in the finishing pen to 210-220 hbm (Chevillon, 2000a). Pigs must be removed from their home pens and moved gently, after their last meal or 7-8 hours after it, and, if possible, at the coolest hours of the day. Mixing pigs with unacquainted pen-mates induces high levels of aggression aiming at a new social rank. Fighting leads to increased skin damage score on the carcass and meat quality defects (Warris and Brown, 1985; Karlsson and Lundstrom, 1992). However, in practice, pigs are often mixed prior to loading in order to obtain groups of uniform weight and to adjust the group size to that of the lorry compartments. Installation of mobile dividing gates on the lorry deck is a practical solution to eliminate mixing of unfamiliar pigs.

Loading pigs onto the lorry is considered the most critical stage of transport because of the strong human-animal interaction and change of environment. Loading duration must be as short as possible. In the example presented in Fig 1 210 pigs were loaded in 50 minutes, or less than 25 minutes to load 100 pigs (Chevillon, 2000b). As a general rule, 100 pigs must be loaded in less than 30 minutes. Maximum transport density should be 2.5 pigs/m² and the number of pigs per compartment should not exceed 20. Trucks should have compartments with an individual capacity of 12-15 pigs. Showering the pigs inside the truck for five minutes after loading helps to decrease the risk of hyperthermia (Colleu and Chevillon, 1999). The ventilation openings in the truck must be regulated to maximum opening during loading. In hot weather, an increase in the environmental temperature, CO₂ and humidity was observed when the truck was not moving with

pigs which did not rest and were disturbed (active, ears standing and a tendency to huddling) at loading (Chevillon, 2000a).

The transfer from the familiar fattening pen to the novelty of the lorry interior and the abattoir area combined with the strong physical, activity induced by forced walking through alleys or sloped ramps, make pigs nervous and not easy to handle. However, pigs move easily through a ramp where they walk up side by side (Grandin and Smith, 2005). The use of a lift makes pigs easier to handle and prevent the handlers to restrain them. Lorries equipped with hydraulic tail-gate lifts proved to increase the number of transport handled with boards and limited the use of electric prods and sticks (Chambers and Grandin, 1991).

The electric prod is a lightweight, hand held, livestock goad. It can be powered by "C" cell, or 9 Volt battery and delivers a 5,000-6,000 Volt shock between two contact points at the end of the prod. The shock is low in amperage and is said to be similar to the jolt delivered by an electric fence. Deliver only a brief shock, do not hold the prod to the animals hide and shock repeatedly, and use only on the hip, flank or shoulder, never where the skin is thin or moist such as near the anus or mouth or eyes (Grandin and Smith, 2005). The use of the prod has animal welfare implications. Keeping animals calm throughout the slaughter process enables the slaughter to be quicker, quieter and less stressful for animals and handlers alike. The easy availability, which causes an excessive use of electric prods to handle pigs, is the single most important factor that compromises the attitude of the stockperson towards pigs. Brundige *et al.* (1998) demonstrated that pigs loaded using an electric prod show significant higher behavioural and physiological responses indicative of stress when compared with pigs loaded using a hurdle. When the electric prod was used, pigs vocalized, lost their balance and tried to jump out of the loading area. Salivary cortisol, heart rate and body temperature is significantly higher in pigs loaded using an electric prod when compared to pigs loaded using a hurdle (Zanella and Duran, 2000).

When using ramps the angle should not exceed 20° and should be of step type and covered by rubber to prevent pigs from slipping and producing noise (Christensen and Barton-Gade, 1996). In order to avoid delays in the loading procedures, pigs should be encouraged to move forward by pushing the group from behind with boards. The use of goads is not allowed by European legislation, and must be very limited (shocks lasting < 2 sec) and that of sticks/hoses must be avoided given their detrimental effects on the welfare with increased heart rate, carcass bruises and low meat quality with blood spots (van Putten and Elshof, 1978; Geverink *et al.*, 1996; Nanni Costa *et al.*, 1996). Recent research showed that a shock with an electric prod is more aversive than inhaling 90% CO₂ (Jongman *et al.*, 2000). However, the use of these handling systems is quite common at this stage and it would basically reflect the poor truck design using ramp instead of lift (Driessen and Geers, 2000) and the inexperience of the handlers (Faucitano, 2000).

(b) Transport

Long term observations by Smith *et al.* (2004) concluded that there are two aspects contributing to the most serious animal welfare problems during transport: (a) loading unfit animals onto a vehicle; and (b) a lack of financial accountability for injuries, bruises and other losses that occur during transport procedures. The worst abuses occur when weak, emaciated or severely lame animals are transported. Downer animals not able to walk should be euthanised on the farm. Homozygous positive pigs for stress gene are also not fit for long journeys because they are prone to death. Observations indicate that the worst abuses occur when the people either handling or transporting the animals are not held accountable for losses. For this reason it is strongly recommended that insurance programs and transport contracts be structured to reward both drivers and handlers for reductions in bruises, injuries and associated trim losses. The most contentious issue in livestock transport is the length of time between rest stops especially at intercontinental transportation. The stress of loading and unloading the animals, plus the increased total time for the journey must be balanced against the benefit of the rest stop. Pigs will lie down after a few hours. Interrupting land transport after 8 or 10 hours to unload animals for food, water and rest is counter productive, especially if animals are not severely overcrowded. Longer transport of livestock is acceptable if animals are loaded at lower densities. Visual examination should be made of all stock at least every 6 hours. When livestock are loaded very tightly, they do not hold each other up, but rather, the trip becomes a constant struggle greatly accelerating fatigue. To prevent stressors that impact stock during transportation, recommendations should be followed as follows: (a) due to the fact that the most deleterious stressors associated with transportation are handling, loading/unloading, mixing of unfamiliar individuals, and environmental stress such as heat and cold. (b) Therefore, the most effective means of decreasing transportation stress would be to design trucks and loading equipment to allow the easiest transition for stock to move on and off transportation vehicles. (c) In addition, education and enforcement of premier management practices associated with livestock handling are imperative. (d) Recommendations relative to transportation during environmental extremes need to be closely followed and supplementary precautions should be considered such as providing water to stock during long periods of transportation and during exposure to hot and humid conditions. For animals transportation is a novel situation and as such it is capable of provoking apprehension and several new potentially stressful conditions including unfamiliar noises and smells, vibrations and sudden speed changes of the lorry, variation of environmental temperature and lower individual social territory. Effects of extreme temperature conditions was analysed by Ábrahám *et al.* (2002) on mortality rates in slaughter pigs during transport. The aim was to establish effects of daily minimum temperature (T_{\min}) on transport loss in pigs. The results of the regression analyses reveal a close, quadratic relationship between T_{\min} and mortality rate (MR) in stress-susceptible pigs. A lower association was established

for both stress resistant populations. Below 0 C°, the MR increases at a faster rate, than that of above 10 C° within the range of 2.5-4.5 %, and 25-3 %, respectively.

Vehicle design. To optimise transport conditions the vehicle should have a covered deck, an effective ventilation system with adjustable openings on the sides from the driver's cabin, an hydraulic upper deck, mobile compartment dividers and a non-skid rubber surface on the floor assisting decrease noise as well. In addition, a lorry has to be equipped with a built in sprinkling equipment (Christensen and Barton-Gade, 1996). Sides and ceiling must be insulated and light reflecting in order to protect pigs from outside weather variations. In practice choice of either mechanical natural ventilation depends on climate.

It has been evidenced that the deck and transport compartment environment have an impact on welfare, skin blemish and meat quality. Pigs transported in the front and rear compartments produced poor meat quality (PSE or DFD) and have higher lactate levels compared to pigs travelling in central pens (Guise and Penny, 1989; Barton-Gade *et al.*, 1996). Moreover, pigs transported in lower decks can either show a greater PSE-incidence, particularly when the pen is poorly ventilated (Guise and Penny, 1992), or a tendency to DFD meat, which is possibly due to the effects of physical stress caused by the necessity to keep the standing position in order to cope with the high level of vibrations (Barton-Gade *et al.*, 1996). Skin damage score is also higher in these pigs as standing pigs are more subjected to fall or trampling and thus can be injured during transport (Barton-Gade *et al.*, 1996). Finally, the lower deck effect has an impact on the pig's welfare during transport. Pigs transported on the lower deck have higher body temperature and blood cortisol levels and show a higher degree of dehydration (Barton-Gade *et al.*, 1996). Anyway, a lorry of double-decker type height allows the handler to enter and off-load without stressing the animals.

Stocking density. Choosing the appropriate space allowance during transport has become a compromise: argues towards increasing stocking density are under economic pressure. The more pigs are transported the lower the unit costs. To increase maximum profit high stocking density may result in higher profit from a single journey. On the other hand, animal welfare and mortality have to be a compromise because either too low or too high stocking densities may result in losses in welfare level and higher mortality rate. The current legislation in Europe specifies that the loading density for pigs of around 100 kg should not exceed 235 kg/m² (0.425 m²/100 kg) and that a maximum increase of 20% (0.510 m²/100 kg or 196 kg/m²) may also be required depending on the meteorological conditions and journey time. However, these recommendations are hardly met in practice as the chosen densities are adjusted to the different transport conditions (weather, road type, distances, pig's breed and size) among different countries. In most EU countries, stocking densities range from 0.35 to 0.39 m²/100 kg and go up to 0.43-0.50 m²/100 kg. Based on the measurements of the space needed for sternal recumbency, it is now suggested that the minimum space required is equivalent to about 250 kg/m² for normal slaughter pigs of 90-100 kg live weight (Warriss, 1998).

Transport time and distance. Transport distances are dependent of the availability of animals in the region around the abattoir. However journey times are likely to increase with the concentration of the slaughtering industry into fewer and larger plants for economic reasons (Warriss, 1994). The majority of pigs in EU member states travelled less than 2 h with average distances of 100 km or less. Transit duration has a variable effect on pork quality. Shorter transport (<1 h) may be more detrimental than larger ones as pigs must be given time to recover from the stress of loading (Bradshaw *et al.*, 1996) and to acclimate to the stress of transport (Stephens and Perry, 1990). The recommendation in the EU on pig transport is that minimum transport times should be aimed for and a maximum acceptable journey limit might be 3 h (Warriss, 1996). However, it seems that a total journey time between 8 and 16 h under good conditions, even without access to water, appears to be acceptable from the animal welfare point of view (Brown *et al.*, 1999). In case of long journeys, transport can be prolonged up to 24 h, provided that transport conditions (ventilation and density) are good and water is available. After 24 h pigs must be unloaded, allowed to rest for 24 h and provided with food before continuing the journey.

Unloading. Animals should be unloaded from the lorry after arrival as soon as possible. If delay may unavoidable animals have to be provided with adequate ventilation. Although unloading is considered less stressful than loading, carcass bruising and injuries due to rough handling are unavoidable unless appropriate equipment is provided. Problems can be caused by the lack of sheltered quays because when animals are subjected to wind, rain and sunlight they balk and may refuse to exit the lorry. On arrival, a "booking-in" schedule, which is a strict coordination of truck arrivals with the predicted number of pigs in lairage, lairage capacity and speed of operation, would help to reduce waiting times (Jones, 1999). Unloading is considered less stressful than loading, increased carcass bruising and injuries due to rough handling are unavoidable at this stage unless appropriate equipment is provided. The use of an hydraulic lift to unload pigs increases the easiness of handling and shortens the off-load time. Steep ramps less than 15-20° are not recommended (Jones, 1999). Pigs have difficulties in descending a slope and are often pushed forward by rough handling (sticks, electric goads and kicks) and driver vocalisation (Faucitano, 2001). Damage to the surface of the carcass after dehairing is a serious commercial problem, since it decreases the grade and subsequently the value of the carcass. In many countries, the incidence of skin damage on the carcass has not been considered to be a problem with high priority, as it seems to be easily solved by just trimming off the skin. However, the presence of an haematoma in the underlying tissue and its negative influence on meat quality must be taken into account. Some EU countries are aiming at reducing the incidence of blemished carcasses in order to safeguard the image of the national pork sector for both domestic and exporting markets. Major factors responsible for the incidence of skin damage on the carcass are fighting among mixed groups of pigs and poor handling during the preslaughter stages. Recognition of the economical impact of these two factors on the slaughter pigs may lead to more

welfare-friendly handling systems and to reduction in the practice of pre-slaughter mixing of animals.

(c) Lairage

As a rule abattoirs are equipped with slip-resistant off-loading ramps making unloading of animals easy preventing them from injuries. No electric prods are allowed to use at unloading of vehicles and lairage. At unloading injuries have to be detected. After inspection animals have to be moved into pens. After unloading, pigs need a minimum of two hours to recover from the stress and activity resulting from transport. The duration of rest is essential for their recovery, even if the journey was a short one. Different from the example presented, where the average heart rate was around 130 hbm, taking into account the total transport period (3 hours), averages close to 150 hbm are frequently observed in short journeys (30 minutes). Showering the pigs at unloading for 10-20 minutes, depending on the season, reduces the body's surface temperature in 3-4 °C. Showering limits the risk of hyperthermia during hot weather and consequently the mortality rate in lairage pens is reduced. However, intermittent and short distance showers are detrimental, as they prevent pigs from resting and lying down. A quick shower during the night when pigs arrive the night before slaughter may be needed to avoid skin reddening. The pen capacity must not exceed 40 pigs. The optimum size of lairage pens is of 15-20 pigs, the equivalent to a truck compartment, limiting the mixture of animals during unloading, thus reducing aggression and fights. Density may not exceed 2 pigs/m² or may not be below 1 pig/m². When a lot of space is available, fighting increases, as well as the severity of the aggressions. In long lairage times (a night of 6-8 hours), it is common to see some heart beat peaks corresponding to frequent fights among unfamiliar pigs (Driessen and Geers, 2000). In addition to creating a reservoir of animals aimed at maintaining the constant speed of the slaughter line, the function of lairage is to allow animals to recover from the stress of transport and unloading as stated above. High-stress lairage systems can lead to high lactate and CPK levels in the blood and a more than two-fold higher incidence of PSE meat (Warriss *et al.*, 1994). Besides this inadequate treatment of slaughter pigs in this stage, lack of environmental control may result in additional stress leading to further economic losses due to death up to 0.57% mortality rate and poor meat quality. There is some indication that the way animals are housed and treated already during the fattening period has an influence on subsequent behaviour in the slaughterhouse and final meat quality. D'Souza *et al.* (1995) stated that pigs negatively treated with electroshocks already on the farm some weeks before slaughter showed a lower muscle glycogen content at 5 and 40 minutes post-slaughter and a lower ultimate pH in the loin. Although there was no interaction between on-farm and abattoir handling, pigs that were both on-farm and at the abattoir negatively handled had a higher drip loss and a higher incidence of PSE. Experiments about pre-slaughter treatment and its consequences for the welfare and the meat quality of the animals reveal that pigs frequently handled on-farm or grown in a 'richer' (in terms of space) environment were much easier to move out

of their pen and at the slaughterhouse (Geverink *et al.*, 1998). The workload for the stockmen was considerably reduced while meat quality, on the other hand, was only slightly different with even a negative tendency for the handled pigs. This may be due to the higher glycogen content present in the muscle cells at slaughter which could be converted to lactate. Animals experienced less stress and therefore had higher energy reserves at slaughter. Pre-slaughter treatment (e.g. feed withdrawal time) possibly has to be adapted to overcome this effect.

Lairage time. Under normal conditions of ambient temperature and humidity a resting time of 2-3 hours in lairage pens is usually regarded as a fair compromise between animal welfare, skin blemish score, meat quality and abattoir economics (Warris *et al.*, 1998). In practice, the resting times applied are varying from 1 to 15 hours depending on the abattoir size, availability of pigs for slaughter, transport time, handling procedures and environmental conditions (Gispert *et al.*, 2000). No or short (below 30 minutes) resting times lead to high incidence of PSE meat (Fortin, 1989; Eikelenboom *et al.*, 1991). A longer lairage time proved to reduce the incidence of PSE meat but increase DFD meat due to increased glycogen depletion from the muscles (Gispert *et al.*, 2000). Both during transport and lairage, mixing of unfamiliar pigs should be avoided since fighting and social stress in general lead to both more PSE and DFD (Karlsson and Lundström 1992). Consequently, a short lairage time of approximately 2 hours at the slaughterhouse allows the animal to recover from transport stress and may improve both animal welfare and meat quality. Optimal feed withdrawal times are suggested to be in between 16 to 24 hours (Eikelenboom *et al.* 1991) or 12 to 18 hours. If feed deprivation is too long (e.g. with overnight lairage), energy reserves are empty and there is not enough glycogen left to assure a sufficient pH decline and meat tends to become DFD (Gispert *et al.* 2000). Biochemical analyses were made in blood samples collected from slaughter pigs before lairage as animals were unloaded from the lorry in the abattoir, and another one during bleeding was made by Abraham *et al.* (2004, 2005, 2006). The objective was to investigate the effect of lairage time (1 vs. 16 hour) and the way of driving animals to stunning (with or without using an electric goad/prod), the stress response and meat quality, especially pH and colour, under commercial conditions. Lairage time did not seem to influence the stress level of animals. Glucose and lactic acid levels equally increased significantly during lairage and stunning. In another experiment blood samples were taken one hour prior to slaughter, and another one during bleeding to analyse cortisol, lactic acid, glucose, NEFA and MDA concentration in blood plasma. The stunning per se caused heavy distress to pigs. Driving animals up to stunning and stunning itself changed more or less significantly in all of the parameters analysed, however, no significant differences were established in any of the meat quality traits.

Handling in lairage. The benefit of providing pigs with a resting time between transport and slaughter can be lost if pigs are subjected to poor handling and stressful environmental conditions i.e. climate and noise in lairage. Handling problems are caused by inappropriate corridors, races and pen design,

discontinuities in the floor texture and colour, air drafts and lighting (Grandin, 1998). Although mixing unfamiliar pigs in lairage is a very common practice in commercial conditions, it must be always discouraged as it leads to fighting which prevents pigs from resting, increases skin damages and promotes the development of PSE/DFD meat (Brown *et al.*, 1999; Gispert *et al.*, 2000). Lairage temperatures and humidity of 15-18 °C and 59-65 %, respectively, are considered as optimal to limit the physical stress, the lactate level in blood, and to decrease the occurrence of PSE meat. Spraying pigs with cold water (9-10 °C) possesses three distinct advantages: (1) it cools the pigs, (2) reducing of the cardiovascular system, and (3) improving meat quality. Showering the animals regularly during lairage has especially during the hot season a beneficial effect on aggressive behaviour and welfare of the animals. The room with pens must be well-ventilated. All pens have to be equipped with drinking water supply. In addition, the lairage has to be equipped with a misting system to cool and calm down pigs in hot weather. Misting results in better welfare status and improves meat quality. In the lairage the pigs are showered with water. The temperature of shower water is 19 till 20 °C (Driessen and Geers, 2000). Showering reduces the muscle temperature. Pigs with low muscle temperature always produce good (non-PSE) meat. Pigs with a high temperature may produce meat of either good or poor quality. Before slaughter, showering the animals for ½ hour decreases muscle temperature and may lead to a better meat quality in the loin. This drop of temperature is sufficient to reduce the initial rate of myosin denaturation by 35 % resulting in reduction in drip loss (Offer, 1991). In winter, care has to be taken that the animals do not become chilled as this is experienced as stress and leads to inferior meat quality (Long and Tarrant, 1990; Warris, 1994; 1998). In addition showering calms the pigs, reducing aggressive behaviour in lairage and facilitating greater ease of handling upon entrance into the stunning chute (Weeding *et al.*, 1993), reduces smells, cleans the pigs, limiting bacterial contaminations of water in the scalding tank (Tarrant, 1989) and increases the efficiency of electrical stunning by lowering skin impedance. Although it is generally accepted that the shower regime should be intermittent and not longer than 30 min in order to get the greatest cooling effect and reduce activity and aggression (Weeding *et al.*, 1993; Jones, 1999), there is no agreement on the time and number of applications. The movement of pigs to the stunning point is very stressful because they are handled fast and in small groups. Under these conditions, behavioural reactions are very intense as squealing, huddling, escape reactions. Welfare can be correlated to acidity (pH) measurement of the muscle 25-30 minutes after stunning. The level of stress during pre-stunning influences the velocity of transformation of glycogen into lactic acid. The higher the stress and disturbance of the pigs a few minutes prior to stunning, the faster the transformation. Under stress hyperthermia is frequent, and therefore a rapid decline in pH causes muscle protein denaturation and leads to PSE meat. Hambrecht (2005) stated the well known fact that forced moving of the pigs to the stunning area causes stress which may lead to a higher risk of PSE (Barton-Gade, 1997). The standard tool used to handle pigs is a board, made of plastic or wood. When

pigs refuse to move and impair the movement of the group, other tools may be used. The electric prod is used along with the board. Sticks and rigid tubes must not be used because they may cause deep bruising if improperly used. Vocalizations (shouts) and hand clapping cause fear in pigs, reducing their movement. So, as the animal refuses to move, the handler must physically intervene on the back or on the hind of the animal (Chevillon, 2000b). To move the pigs to stunning, no electric goads should be used and pigs should be given enough time to move. The latter is at high slaughter speeds impossible because the line speed exceeds the natural slow walk of the pigs. Many plants in the U.S. are dividing lines that handle 1000 pigs per hours into two lines that run at 600 or less (Grandin, 1998). Experience shows that even at line speeds around 500, considerable 'force' has to be applied to make the pigs move fast enough. The design of the lairage pens and the races towards the stunning area is crucial and improvements may make moving the pigs a lot easier. Pigs resist lining up in single file races as opposed to cattle for example. Furthermore, slick floors, air hissing, air drafts blowing down towards the animals and moving from light to dark areas are all examples of factors that impede animal movement (Grandin, 1997). Facilitating easy pig moving means a reduction in stress (both for the animals and the personnel) and may therefore improve sensory and technological meat quality, not to speak of welfare aspects. Between pigs of the same farm in spite of the same genetic background there still exists considerable variation in sensory and technological meat quality. Experiences gained reveal that the day of slaughter has a large impact on final quality even when feed withdrawal, transport and lairage time were standardised. It is during the last minutes of the pig's life that quality may be deteriorated despite all previous efforts to produce optimal quality. The analysis of the heart rate of pigs in the lairage pens and while moving to the stunning point clearly shows that their disturbance reaches its peak at this point. The pigs are in panic, and this panic is intensified by the impossibility to escape.

(d) Stunning

The competence of the operators, and the appropriateness and effectiveness of the method used for stunning are the responsibility of the management of the slaughterhouse, and should be checked regularly by a competent authority (<http://www.oie.int>). Persons carrying out stunning should be properly trained and competent, and should ensure that

- the animal is adequately restrained
- animals in restraint are stunned as soon as possible
- the equipment used for stunning is maintained and operated properly in accordance with the manufacturer's recommendations, in particular with regard to the species and size of the animal
- the instrument is applied correctly
- stunned animals are bled out (slaughtered) as soon as possible
- do not stun animals when slaughter is likely to be delayed.

In addition, such persons should be able to recognise when an animal is not correctly stunned and should take appropriate action.

Stunning is mandatory before bleeding in order to reduce the animal's activity, pain and suffering during slaughter according to EU Directive 91/119/EEC. The immobilization of pigs before slaughter is also mandatory. As a rule three different stunning methods are used and are presented in order of importance as follows: (1) electric stunning; (2) carbonic gas (carbon dioxide) stunning, and (3) captive bolt stunning (compressed air pistol is used only for emergency slaughter). The aim is to immobilize pigs prior to sticking. Both as far as welfare and quality aspects are concerned, stunning as well plays an important role. It is commonly agreed that quality of stunning, whether gas or electricity is used, depends on the correct application and that both systems show some advantages and disadvantages. With electrical stunning, the correct application such as the voltage used and the positioning of the tong is crucial. With CO₂-stunning, there surely occur less blood splashes in muscles and subcutaneous tissue as well as less bone fractures in the forelegs and the vertebral column caused by excessive contractions of the muscles subsequent to electrical stunning (Barton-Gade, 1997). The way of restraining the pigs has also an influence on the amount of stress, both methods are not optimal in that respects, though. Restraining the pigs in conveyors for electrical stunning is both for the pig and the staff handling the pigs very unpleasant. Gas stunning, on the other hand, is a discontinuous process (stop and go in the dip lift system) which interrupts the moving of the pigs. Both systems are likely to cause considerable stress in the animal but most research favours gas stunning both concerning welfare and meat quality. Henckel *et al.* (1998) for example found that drip loss almost doubled (4.4 vs. 8.5 %) when comparing gas with electrical stunning. However, pigs were for 10 seconds manually stunned with electrical tong which in no way is to compare with modern electrical stunning systems. Drip loss levels found in own experiments with electrical stunning were far lower than the levels found in the aforementioned study with electrical stunned pigs and resembled the values of the gas stunned pigs. Research of Cannon *et al.* (2000) showed a higher drip loss for electrical stunned pigs, too, but stress susceptible animals seemed to be more affected than others. In well-treated animals free of the halothane gene, no difference in drip loss can be seen. Their experiment is a very nice example for the interaction of genotype, pre-slaughter handling and stunning method.

Electric stunning. Before stunning by electric current it is necessary to immobilize the animal inside the pen or inside a restrainer. The action of isolating and restraining individual animals results in stress and excitement because they are separated from the group. In the most common V restraining system the animals are restrained by the sides. The time spent in the restrainer has to be as short as possible. The aim of electric stunning is rendering the animal instantaneously unconscious under determined conditions: minimum electric current of 1.25 A released in less than one second; electrodes must be placed close to the brain eye to eye or eye to ear. In classic electric stunning systems with two electrodes, voltage over 300 V and sufficient power (>0.9 KVA) can reach 1.25 A in less than one

second. Whatever stunning system used, parameters must be continuously observed to assure animal welfare (Ramantanis, 1999; Troeger, 1998). Classic stunning systems with two electrodes placed on the head may cause meat quality problems. These systems use high voltage (>300 V) and a V restrainer, resulting in 50% of residual blood in deboned cuts. The system which causes less blood splashing in deboned cuts is CO₂ stunning (15% of the cuts, and only 0.5% require trimming). 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 stunning.

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 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.

CO₂ stunning is characterized by sequential placement of one or two pigs inside a cage immersed in a well containing CO₂ at 75 % for 30-40 sec. In this system, pigs are frequently kept in long and narrow walkways, in single or double line, for more than 3 minutes. This causes intensive stress during handling because pigs are aversive to being confined and they will squeal and try to escape. In such situations it is unavoidable to use electric prod to make animals move. The loss of consciousness is not instantaneous as it is the case with electric stunning (Chevillon, 2000b). In Denmark, a new CO₂ stunning system is based on moving and stunning groups of 4-5 pigs at the same time. There is less suffering (absence of panic and squeals). A 400-800 pigs/h line speed can be obtained with this system (Christensen, 1999). This handling system promotes better working conditions, easier handling, as well as better animal welfare. The use of CO₂ stunning leaves some questions on animal welfare because stunning is not instantaneous. This is because CO₂ stunning has 3 different stages (Barton Gade, 1999):

- *Analgesia*: initiated when the animals enter the CO₂ tunnel, and it is characterized by CO₂ inhalation;
- *Excitation*: when sudden contraction movements and rarely screams are observed;
- *Anaesthesia*: when the animal is rendered totally unconscious.

The first stage lasts 14-20 seconds, whereas the second lasts for 7-20 seconds.

The loss of consciousness is not instantaneous, as in electric stunning. The speed in entering the cages and the CO₂ concentration currently used must be evaluated and investigated in order to accelerate gas inhalation and to reduce the excitation stage. This new CO₂ stunning system in groups represents an important advance in animal welfare and also in working conditions for the handlers who move the pigs from the lairage up to the stunning point. Under animal welfare standpoint, the comparison of the two systems (electric and CO₂ stunning) shows an advantage of the new CO₂ stunning system, specially while moving the pigs, which are no longer moved individually, but in groups (Chevillon, 2000b). New electric stunning systems may reduce stress in the restrainer because the pig is carried by the abdomen, and no longer 'crushed' on the sides. However, some questions still remain: what is the impact of CO₂ stunning on pig welfare? Are the analgesia (CO₂ inhalation) and excitation stages stressful for pigs? Is the pig still conscious at this stage?

Conclusions and Implications

(a) Loading animals onto vehicle is considered the most critical stage of transport because of the strong human-animal interaction and the change of environment. For this reason, duration of loading must be as short as possible.

(b) Recommendation for good handling of farm animals are: (1) move small groups, (2) do not overcrowd the collecting yard, (3) handlers should be aware of basic concepts of flight zone and point of balance, (4) facilities must have non-slip flooring and (5) keep animals calm. To achieve comfort of animals, transport vehicles have to be equipped with appropriate loading facilities, non-slip floors and good ventilation. Vehicles must not be overloaded. During transport the lorry has to be driven with considerate speed and unnecessary stops have to be avoided. Before leaving the farm all animals have to be checked if they are suitable for transport.

(c) To prevent hyperthermia in warm weather, the holding area must be ventilated by fixed or mobile fans or by incorporating evaporative cooling systems. Lairage has to be equipped with a misting system to cool and calm down animals in hot weather. Spraying animals, especially pigs with cold water (9-10 °C) has the following advantages: (1) cooling the body of animals, (2) reducing aggressive behaviour, (3) improving welfare status, (4) reducing the load on the cardiovascular system and (5) improving meat quality.

(d) Stunning methods induce temporary loss of consciousness and rely solely on prompt and accurate sticking procedures to facilitate bleeding and to cause death. Stunning is mandatory before bleeding in order to reduce the animal's activity, pain and suffering during slaughter. Persons carrying out stunning should be properly trained and competent, and should ensure that (1) the animal is adequately restrained; (2) animals in restraint are stunned as soon as possible; (3) the equipment used for stunning is maintained/operated properly for the species and size of the animal; (4) the instrument is applied correctly; (5) stunned animals are bled out as soon as possible; (6) do not stun animals when slaughter is to be delayed.

Bibliography

1. **Ábrahám, Cs., K., Balogh, M., Weber, J., Seenger, M., Mézes, H., Fébel, E., Szücs, K., Ender** (2005)- Lairage time is a compromise. Effect of preslaughter handling on stress response and meat quality of pigs. *Fleischwirtschaft International*. 2, 10
2. **Ábrahám, Cs., K., Ender, K., Balogh, M., Weber, Seenger, J., M., Mézes, H., Fébel, E., Szücs** (2006)- Behandlung vor der Schlachtung - Einfluss auf die Stressreaktionen und die Fleischqualität von Schweinen. *Fleischwirtschaft*, 86, 103
3. **Ábrahám, Cs., G., Holló, M., Weber, K., Balogh, M., Mézes, H., Fébel, M., Vada-Kovács, E., Szücs** (2004)- Investigation on physiological parameters indicating stress status in slaughter pigs during transport and lairage. 50th International Congress of Meat Science and Technology, Helsinki, Finland, 8-13 August 2004
4. **Ábrahám, Cs., Zs., Lakos, J., Mika, M., Miskucz, E., Szücs** (2002)- Effects of extreme temperature conditions on mortality rates in slaughter pigs during transport. 24th Biennial Conference with the International Society for Animal Hygiene, 7-11 July, 2002. Adelaide, South Australia. *Animal Production in Australia*. 24, 269
5. **Barton-Gade, P. A.** (1997)- *Manipulating Pig Production VI*, 100.
6. **Barton-Gade, P. A.** (1999)- Preliminary observations of pig behaviour on immersion in high concentrations of CO₂ gas. *Colloquia International "Stunning systems for pigs and animal welfare"*, 25-27/08/1999.
7. **Barton-Gade, P. A., L., Christensen, S. N., Brown, P. D., Warriss** (1996)- Effect of tier and ventilation during transport on blood parameters and meat quality in slaughter pigs. *Proc. EU-seminar "New Information on Welfare and Meat Quality of Pigs as Related to Handling, Transport and Lairage Conditions"*, Landbauforschung Völkenrode, Mariensee, Germany. Sonderheft 166, 101-116 pp.
8. **Beattie, V. E., R. N., Waetherup, B. W., Moss** (1999)- The effect of feed restriction prior to slaughter on performance and meat quality of pigs. *Proc. Brit. Soc. Anim. Sci. Penicuik, Midlothian, UK*, 11
9. **Bradshaw, R. H., R. F., Parrott, J. A., Goodle, D. M., Lloyd, , R. G., Rodwayand, D. M., Broom** (1996)- Effects of mixing and duration of journey on the welfare of pigs during transport. *Proc. EU-Seminar "New Information on Welfare and Meat Quality of Pigs as Related to Handling, Transport and Lairage Conditions"*. Landbauforschung, Völkenrode, Sonderheft 166, Mariensee Germany, 95

10. **Brown, S. N., T. G., Knowles, J. E., Edwards, P. D., Warris** (1999)- Relationship between food deprivation before transport and aggression in pigs held in lairage before slaughter. *Vet. Rec.*, 145,630
11. **Brundige, L., T., Oleas, M., Doumit, A. J., Zanella** (1998)- Loading techniques and their effect on behavioural and physiological responses of market weight pigs. *J. Anim. Sci.*, 76 Suppl. (1) 99
12. **Chambers, Ph. G., T., Grandin** (1991)- Guidelines for Humane Handling, Transport and Slaughter of Livestock. Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific, RAP Publication 2001/4
13. **Channon, H. A.** (2000)- Halothane genotype, pre-slaughter handling and stunning method all influence pork quality. *Meat Sci.*, 56, 291
14. **Chevillon, P.** (2000a)- Bien-être des porcs lors de operations de pré-abattage et d'anesthésie. Proc. 8th Journées des Sciences du Muscle et Technologies de la Viande, France
15. **Chevillon, P.** (2000b)- Pig welfare during pre-slaughter and stunning. I Conferência Virtual Internacional sobre Qualidade de Carne Suína 16 de novembro a 16 de dezembro de 2000 - Via Internet. 1
<http://www.cnpsa.embrapa.br/pork/programa.html> (3110.2005)
16. **Christensen, L.** (1999)- A new system for considerate treatment of pigs during division and group wise CO2 stunning. Colloquia international "Stunning systems for pigs and animal welfare", 25-27/08/1999.
17. **Christensen, L., P. A., Barton-Gade** (1996)- Design of experimental vehicle for transport of pigs and some preliminary results of environmental measurements. Proc. EU-Seminar "New information on Welfare and Meat Quality of pigs as related to Handling, Transport and Lairage Conditions. Landbauforschung Völkenrode, Sonderheft 166. Mariensee, Germany. 47
18. **Driessen, B., R., Geers** (2000)- Stress during transport and quality of pork. An European view. I Conferência Virtual Internacional sobre Qualidade de Carne Suína 16 de novembro a 16 de dezembro de 2000 - Via Internet. 1
19. **D'Souza, D. N., F. R., Dunshea, B. J., Leury, R. D., Warner** (1995): Manipulating Pig Production, V. 258
20. **Eikelenboom, G., J. H., Hoving-Bolink, W., Sybesma** (1991)- Effect of feed withdrawal before delivery on pork quality and carcass yield. *Meat Sci.*, 29, 25
21. **Faucitano, L.** (2001)- Causes of skin damage to pig carcasses. *Can. J. Anim. Sci.*, 81, 39
22. **Fortin, A.** (1989)- Pre-slaughter management of pigs and its influence on the quality (PSE/DFD) of pork. Proc. 35th ICoMST, Copenhagen, Denmark, 981
23. **Geverink, N. A., A., Kappers, E., Van de Burgwal, E., Lambooij, J. H., Blokhuis, V. M., Wiegant** (1998)- Effects of regular moving and handling on the behavioural and physiological responses of pigs to pre-slaughter treatment and consequences for meat quality. *J. Anim. Sci.*, 76, 2080

24. **Geverink, N. A., B., Engel, E., Lambooj, V. M., Wiegant** (1996)- Observations on behaviour and skin damage of slaughter pigs and treatment during lairage. *Appl. Anim. Behav. Sci.* 50, 1
25. **Gispert, M., L., Faucitano, M. A., Oliver, M. D., Guardia, C., Coli, K., Siggens, K., Harvey, A., Diestre** (2000)- A survey of pre-slaughter conditions, halothane gene frequency, and carcass and meat quality in five Spanish pig commercial abattoirs. *Meat Sci.* 55, 97
26. **Grandin, T.** (1997)- *Assessment of Stress During Handling and Transport.* *J. Anim. Sci.* 75, 249
27. **Grandin, T.** (1998)- *Introduction: Management and economic factors of handling and transport.* In: "Livestock Handling and Transport", CAB Int., 1
28. **Grandin, T.** (2000)- *Livestock handling and transport.* 2nd edition, Wallingford, Oxon, UK: CABI Publishing: Oxon.
29. **Grandin, T., G., Smith** (2005)- *Animal welfare and humane slaughter.* <http://www.grandin.com/references/humane.slaughter.html> (08.11.2005)
30. **Guisse, H. J., R. H. C., Penny** (1989): Factors influencing the welfare and carcass and meat quality of pigs. 1. The effects of stocking density in transport and the use of electric goads. *Anim. Prod.* 49, 511
31. **Hambrecht, E.** (2005)- Key Factors for Meat Quality. <http://www.hypor.com/sitemap.php> (31.10.2005)
32. **Henckel, P., M. Andersson, S. Holst** (1998) – Influence of stunning method on pH-decrease and meat quality. *Proc 44th International Congress of Food Science and Technology, Spain*, p 1068-1069
33. **Jones, T.** (1999)- An investigation and assessment of the handling system of twelve abattoirs in Great Britain and four Italy. In: *Improved handling systems for pigs at slaughter*" PhD Thesis, Royal Veterinary College, University of London, UK
34. **Jongman, E. C., J. L., Barnett, P. H., Hemsworth** (2000)- The aversiveness of carbon dioxide stunning in pigs and a comparison of the CO2 stunner crate vs. the V-restrainer. *Appl. Anim. Behav. Sci.* 67, 67
35. **Karlsson, A., K., Lundstrom** (1992)- Meat quality in pigs reared in groups kept as a unit during the fattening period and slaughter. *Anim. Prod.* 54, 421
36. **Long, V. P. and Tarrant, P. V.** (1990): The effect of the pre-slaughter showering and post-slaughter rapid chilling on meat quality in intact pork sides. *Meat. Sci.* 27, 1818
37. **Nanni, Costa L., D. P., Lo Fiego, A., de Grossi, V., Russo** (1996)- Effect of loading method, stocking density and temperature on carcass and meat quality in heavy pigs. *Proc EU Seminar "New information on welfare and meat quality of pigs as related to handling, transport and lairage conditions"*, Landbauforschung Völkenrode, Germany, 83
38. **Putten van, P., W. J., Elshof** (1978)- Observations on the effect of transport on well-being and lean quality of slaughter pigs. *Anim. Reg. St.* 1, 247
39. **Ramantanis, S. B.** (1999)- Stunning Technology. In "Meat and Meat Products Technology". E. PE. A. BC., Athens. 362

40. **Stephens, D. B., G. C., Perry** (1990)- The effect of restraints, handling, simulated and real transport in the pig. *Appl. Anim. Behav. Sci.* 28, 41
41. **Szücs, E.** (1999)- Gondolatok az állattermék-előállítás néhány etikai, etológiai kérdéséhez (Considerations to ethics and ethology of animal production). *Állattenyésztés és Takarmányozás* (Hungarian Journal of Animal Production). Herceghalom, 48, 541
42. **Szücs, E., R. Geers, T. Jezierski, E. Sossidou** (2007)- Livestock production systems: Welfare, environment and product quality. Pigs. (In: *Farm Animal Welfare, Environment & Food Quality Interaction Studies. Part B.*, Eds.: Sossidou, E. and E. Szücs, WELFOOD Edition, Thessaloniki, 73. (ISBN978-960-89849-0-5))
43. **Tarrant, P. V.** (1989)- The effects of handling, transport, slaughter and chilling on meat quality and yield of pigs. In: "Manipulating Pig Production- II" (J. L. Barnett and D. P. Eds), Warnibee, Victoria, Australia
44. **Troeger, K.** (1998)- Fleischgewinnung und -behandlung. In: Brandscheid, W., Honikel, K., Lengerken, G., and Troeger, K. (Eds) *Qualität von Fleisch und Fleischwaren* (Bd.1). Deutscher Fachverlag
45. **Warriss, P. D.** (1994)- Ante mortem handling of pigs. In: "Principles of pig science" ed: D. J. A. Cole, T. J. Wiseman and M. A. Varley. Nottingham University Press, UK 425
46. **Warriss, P. D.** (1998)- Choosing appropriate space allowances for slaughter pigs transported by road: a review. *Vet. Rec.* 142, 449
47. **Warriss, P. D.** (1996)- Guidelines for the handling of pigs ante mortem. Proc. EU-seminar "New Information on Welfare and Meat Quality of Pigs as Related to Handling, Transport and Lairage Conditions", Landbauforschung Völkenrode, Mariensee, Germany. Sonderheft, 166, 217
48. **Warriss, P. D., S. N., Brown** (1994)- A survey of mortality in slaughter pigs during transport and lairage. *Vet. Record.* 134, 513
49. **Warriss, P. D., S. N., Brown** (1985)- The physiological responses of fighting between pigs and the consequences for meat quality. *J. Sci. Fd. Agric.*, 36, 87
50. **Warriss, F. D., S., Brown, J., Edwards, T., Knowles** (1998)- Effect of lairage time on levels of stress and meat quality in pigs. *Anim. Sci.*, 66, 255
51. **Weeding, C. M., H. J., Guise, R. H. C., Penny** (1993)- Factors influencing the welfare and carcass and meat quality in pigs. *Anim. Prod.*, 56, 151
52. **Zanella, A.J., O., Duran** (2000)- Pig welfare during loading and transportation: a North American Perspective. I Conferência Virtual Internacional sobre Qualidade de Carne Suína 16 de novembro a 16 de dezembro de 2000 - Via Internet, 1

*This research has been supported by the Pilot, Project HU 2004-L-B-PP-170001 "Promoting Quality Assurance in Animal welfare * Environment * Food Quality Interaction Studies Through Upgraded e-Learning" within the framework of the*