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Short-term stress: the case of transport and slaughter

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ABSTRACT

Short-term stressors such as transport and slaughter include psychological and physical stimuli that might be aversive for the animals. Restraint, manipulation and sudden change lead to fear, or psychological stress, while hunger, thirst, fatigue, injury and extreme thermal conditions are considered as physical stresses. Animal responses to these stimuli include behavioural and physiological changes devoted to coping with adverse situations. If the recovery or the adaptation fails, the consequences can be extremely serious, ranging from weight loss and death to impaired carcass and meat quality. As the stress during transport and slaughter is unavoidable, only the knowledge of the physiological and behavioural needs of the animals during all procedures from pre-transport handling to stunning, together with the correct use of the facilities for handling and transportation, can minimize the intensity and the duration of stress. The final goal is to improve transport and slaughter conditions for the animal and, as a consequence, animal welfare and meat quality.

Key words: Acute stress, Transport, Slaughter, Carcass bruises, Meat quality.

RIASSUNTO

IMPORTANZA E CONSEGUENZE DEGLI STRESS ACUTI: IL CASO DEL TRASPORTO E DELLA MACELLAZIONE

Le principali cause di stress acuto negli animali d'allevamento sono costituite dalla manipolazione, dalla costrizione, dalla movimentazione e dal contatto con ambienti nuovi e situazioni sconosciute. La risposta dell'animale non è facilmente prevedibile perché dipende da molti fattori, in particolare dalla percezione che ha di tali situazioni, dall'immediatezza con cui queste si manifestano e dalle precedenti esperienze che ha potuto fare. Il trasporto e la macellazione, operazioni che necessariamente fanno parte del ciclo d'allevamento, includono inevitabilmente i fattori di stress sopra elencati nonché situazioni che, per ovvi motivi, non possono essere state sperimentate in precedenza. La risposta agli stress acuti connessi al trasporto e alla macellazione si manifesta sia a livello fisiologico che comportamentale e, spesso, può esercitare un effetto negativo sulla qualità della carcassa e della carne. La presenza di lesioni sulle carcasse

e l'alterazione dei processi post-mortali a livello muscolare sono i danni più frequenti che un inadeguato svolgimento del trasporto e della macellazione possono causare. La conoscenza delle esigenze fisiologiche e comportamentali degli animali in tutte le fasi comprese tra il carico in azienda e lo stordimento, nonché l'utilizzo di mezzi ed attrezzature pienamente adeguate a tali esigenze, possono ridurre la risposta agli inevitabili fattori di stress e migliorare, nel contempo, le condizioni alle quali sono sottoposti gli animali e la qualità delle loro produzioni.

Parole chiave: *Stress acuto, Trasporto, Macellazione, Lesioni carcassa, Qualità carne.*

Introduction

As respects animals, the term “stress” is defined as a constellation of events including a stimulus (stressor), a reaction at the level of nervous system due to the stimulus (stress perception) and a physiological activation of the “fight or flight” system (stress response) (McEwen, 2002). A stressor is not always harmful; it can be considered harmful only by assessing the way in which the animal is able to cope with it and to regain the previous homeostasis (von Borrell, 2001). Thus, the stress does not always have unfavourable consequences and often its positive effects in terms of adaptation and health are neglected. According to McEwen (2002), stress can be harmful when it is long lasting and the animal is unable to successfully cope with it. Thus, the stress can be classified on the basis of its duration. Acute or short stress lasts minutes, hours or a few days while chronic stress persists for months or years. Most frequently, the transport of animals takes from a few hours to two or three days to be carried out, while the slaughter usually occurs as soon as possible after arrival at the slaughterhouse; therefore, these operations are considered events capable of generating acute stress. Chronic stress during transport could be hypothesised for long lasting shipments overseas that can require several weeks.

This article briefly reviews the assessment of acute stress in ruminants and in pigs during road transport and at slaughter, while summarising consequences on animal

welfare and meat quality and indicating possible preventive measures.

The assessment of acute stress

Transport is a complex series of operations which includes handling, loading, journey, unloading at the farm or at the abattoir, and, in this latter circumstance, time spent in lairage pens. Slaughtering includes handling in the resting area, driving of animals to the stunning area and application of an appropriate stunning method. During all these practices, animals experience different stressors which can be classified as “physical” and “psychological” (Grandin, 1997). The physical stressors include removal of feed and water, extreme thermal conditions, extreme variations in light and noise, and muscular exertion related to handling at the farm and at the plant (loading and unloading included), to maintaining the standing position in the truck (depending on driving quality and type of road) and to reacting to new social conditions (aggressive interaction, mount, fight, flight, etc.). The psychological stressors include unaccustomed handling and restraint as well as the exposition to new conditions in terms of social group, personnel, smells, and noises. Both physical and psychological stressors experienced during transport and slaughter lead to adaptive responses at the physiological and behavioural levels. Therefore, the assessment of acute stress during transport and slaughter has to include physiological and behavioural measurements. However,

the complexity and the number of the operations involved in transport and slaughter make the assessment of stress quite difficult thereby requiring an approach which takes into account all the problems of welfare measurements as reviewed by Mason and Mendl (1993).

The physiological indicators commonly used for the stress evaluation during transport have been listed by Knowles and Warriss (2007). Summarizing, deprivation of food leads to a reduction of immediately available energy, such as glucose, and mobilization of body fat, with a consequent increase in Free Fatty Acids (FFA) and ketones such as β -hydroxybutyrate. Fasting also increases the catabolism resulting in an increased level of plasma urea. Dehydration increases the plasmatic levels of haematocrit, albumin and total protein and the value of the osmolality while the physical exertion increases creatin kinase and lactate plasmatic levels. Fear increases cortisol and Packed Cell Volume (PCV) and, in association with physical exertion, leads to an increase in heart and respiratory rates. The motion sickness, related to the driving style, increases vasopressin. Variations in body and skin temperature are also related to transport stress. With regard to the measurement of body temperature, the renewed interest in Infrared Thermography (IRT) is highlighted as it may be applied where the temperature of live animals or carcasses is difficult to measure under certain housing conditions or in situations occurring during commercial slaughter. Several studies have been carried out to measure the surface temperature of pigs to evaluate the effects of environmental conditions (Loughmiller *et al.*, 2001; Warriss *et al.*, 2006b) and to predict the pork quality of pigs immediately before they are slaughtered (Garipey *et al.*, 1989; Schaeffer *et al.*, 1989).

As highlighted by Broom (2007), the

physiological measures can be interpreted correctly only if their basal level and their fluctuation over time are ascertained. In general, these indicators show a variation during transport due to an adaptation to the stress inducing conditions. The variations of cortisol and creatin kinase describe this situation well. The levels of the former increase during the first period of transport, as a consequence of the physical effort and of the psychological stress due to the loading and to the novelty of the situation. Subsequently it decreases as the journey proceeds. This variation has been observed in calves (Lensink *et al.*, 2001), in slaughter cattle (Warriss *et al.*, 1995), in sheep (Broom *et al.*, 1996) and in pigs (Zanella and Duran, 2000). On the other hand, creatin kinase enzyme increases its levels during the journey as a consequence of a progressive physical exertion due to the effort to maintain equilibrium on the floor decks and to the difficulty or low tendency to lay down (Knowles and Warriss, 2000). Accordingly, in correlation to the increase in the transport time, the levels of FFA, B-hydroxy-butyrate and PCV rise as consequence of progressive deficit of energy and hydration (Warriss *et al.*, 1995; Marahrens *et al.*, 2003).

The inappropriate behaviour of the stockmen during handling and driving of animals could be a significant factor in acute stress. Electric prods, often used without need and criteria in animal driving, increase the level of plasmatic cortisol. Thus, the stress linked to the pain is added to that related to loading or unloading. In this condition the body temperature and the heart and respiratory rates increase (Knowles and Warriss, 2007).

At the end of the journey, the animals to be slaughtered are either directly driven to the stunning cage or kept in lairage in order to recover from the stress of transport. Resting pens have to be appropriate in size in order to maintain the separation of the groups

unloaded from the vehicles, and adequate in design in order to easily drive the animals to the stunning cage (Grandin, 2007b). Mixing unfamiliar animals in lairage can result in well-known detrimental effects on welfare, carcass and meat quality. The mixing increases the level of cortisol both in cattle (Mohan Raj *et al.*, 1992) and in pigs (Fernandez *et al.*, 1994). Moreover, the fighting causes bruises and skin blemishes that reduce the quality of lean meat. The optimal lairage time is one of the most discussed aspects because, as pointed out by Warriss (2003), it is largely controlled by the slaughter plant instead of the transport time, which is mainly related to the location of the production unit. It is not easy to identify optimum lairage duration at the abattoir in order to recover from the physical and psychological stress caused by the previous transportation and to optimise the meat quality. For cattle, as reviewed by Knowles (1999), there is the tendency to kill the animals as soon as they leave the lorry to avoid dark cutting beef and bruising on carcasses. Nevertheless, the immediate slaughter does not appear to be a favourable practice for reducing bruising, especially when the supply of the slaughter chain requires quickly driving animals to the stunning trap. If the holding time spent in lairage pens and in the race loading to the trap is reduced from 25 and 30 min to less than 10 min and 15 min, respectively, the incidence of bruises increases in calf and bull carcasses, confirming that to drive animals in a hurry is a risk factor in the occurrence of bruising (Nanni Costa *et al.*, 2005). However, after a long transport, adequate lairage time is necessary for recovering from the stress of the journey. Knowles *et al.* (1999) report that a resting time of 24 h, with feed and water available, makes it possible to recover from the stress caused by a journey time from 14 to 36h, while Gallo *et al.* (2003) found that a prolonged lairage over 16h leads to

an increase in ultimate pH and dark-cutter carcasses. Similar negative results on beef quality were recently found by Liotta *et al.* (2007) prolonging the resting time over 36 hours after long journeys. The effects of lairage times and slaughter conditions on pig welfare have been recently reviewed by Warriss (2003). He suggests an optimal resting period ranging from 1 to 3 hours and indicates that shorter lairage times are associated with PSE meat and longer lairage times are associated with DFD defect, skin blemishes and lower carcass yield. Warriss *et al.* (1998) showed that kreatin kinase and lactate levels increase significantly from 1 to 3h of resting while they decrease after overnight lairage. Instead, the cortisol decreases progressively from 1h to 3h and overnight. In general, a prolonged lairage time reduces both physiological and physical stress but also increases the risk of aggressive behaviour and consequent skin blemishes (Nanni Costa *et al.*, 2002).

Behavioural measures can be useful to assess short-term stress of animals and might improve the comprehension of the physiological measures. The conditions of transport and lairage reduce the behavioural repertory shown at the farm and what is possible to observe is mainly related to the reaction to physical and psychological stressors. In fact, at the start of transport procedures the animals are suddenly moved from the farm box into a closed vehicle which is reached by physical and psychological exertion. During loading, as a reaction to the new situation and unknown races, high frequency of balking and reversal occurrences could be observed in both cattle (Maria *et al.*, 2004; Nanni Costa *et al.*, 2006) and pigs (Nanni Costa *et al.*, 2007). At loading and inside the vehicle, the animals maintain their flocking behaviour (Gonjou, 2000) and this makes it difficult if there is a need to isolate and to drive a single head from the group.

Bulls are social animals and tend to jump over the partitions trying to rejoin the other group members. Moreover, the pigs, after being loaded into the truck, show an explorative behaviour in order to find a place where they can rest or lie down (Broom, 2007).

During the journey, the animals typically lie down on the floor of the vehicle, however, that depends on the duration of travel and the loading density. Cattle prefer to stand during transport but on long journeys they were observed beginning to lie down after 16 hours (Tarrant *et al.*, 1992) or after 24 hours of transport (Knowles, 1999). During the resting period after a long journey, transported cattle lie down longer than normal (Knowles *et al.*, 1999). For young calves, the time spent lying decreases with increasing age (Eicher, 2001). Sheep tend to lie down in increasing numbers during the first 5 to 10 hours of the journey (Knowles, 1998), while pigs start to lie down quite early - about 30 minutes after the departure - and the majority are lying down after 3 hours of transport (Guise *et al.*, 1998). An adequate stocking density is essential to guarantee the space for the animal to lie down and stand up. Thus, standing animals in a vehicle at the end of a long journey could be a sign of inadequate conditions of transport.

Restlessness and positioning while standing are important behavioural occurrences for young and mature cattle in moving vehicles (Tarrant and Grading, 2000; Eicher, 2001). The most common position assumed during the journey is either perpendicular or parallel to the direction of motion because they improve the security of balance. Restlessness is indicated by the frequency of changes in position and it was found to increase according to social regrouping (Kenny and Tarrant, 1987), to heat stress (Nanni Costa *et al.*, 2003), and driving events such as cornering. Tarrant and Grandin (2000) stated that braking, gear changing and cor-

nering are responsible for 80% of the loss of balance in the moving vehicle. With regards to the non invasive measures of behaviour that it is possible to record in the vehicle during transport, it could be interesting to examine them using techniques like the fractal method which showed promising results when applied to the assessment of stress in farm animals (Alados *et al.*, 1996; Maria *et al.*, 2004).

The consequences of the acute stress

If the pre-slaughter procedures are not carried out in such a way as to reduce unavoidable stress as much as possible, the consequences could be extremely serious: mortality, loss of weight, morbidity and, for the animal destined to the slaughterhouse, impaired carcass and meat quality.

Despite the relevance of deaths occurring during the journey and lairage for the identification of critical points, the respective figures are rare. For cattle, it is generally considered low (Knowles, 1999) and the transporters organisation estimated the mortality rate around 0.01% (UNICEB, 2002). Also for young calves less than 1 month old the mortality during transport is low but this rate increases following transport as a consequence of diseases (Knowles and Warriss, 2007). More information is available for pigs. Warriss (1996) reports on national short term (<8h) transportation between different EU countries a range from 0.03% to 0.16%. More recently, the figures from Denmark from the early 1990s to 2002 show a reduction in mortality rate from 0.040% to 0.012%. (Christensen, 2005). According to Knowles (1998), the mortality rate for the slaughter sheep during road transport ranges from 0.02% to 1.63%, this latter figure referring to harsher transport conditions.

The loss of live weight and carcass yield during transport, as consequence of with-

drawal of food and water, represent an economic loss. In cattle, over the first 18-24 hours, the loss is around 7% with a range of variation included from 3% to 11% (Knowles and Warriss, 2007), while the loss of carcass weight ranges from less than 1% to 8% (Knowles, 1999). The range of weight loss in pigs, even in short term transport, is between 4% and the 6% (Lambooi, 2000). As reported by Knowles (1998), in sheep the loss of weight after a journey of 15 hours is 7% and increases to 8% when the journey is prolonged to 24 hours.

Bruising can occur during each pre-slaughter operation including loading at the farm, transportation, and unloading and resting at the abattoir. Bruises also reflect poor handling practices because they can be produced by impact against the handling facilities and by violent contact with prods or sticks used improperly by the handlers (Grandin, 2007b). Carcass injuries result in an economic loss to the meat industry; the overall cost of carcass bruising is caused by loss of edible parts, labour costs to trim out the bruising and general carcass value depreciation. The estimation of the cost of bruises for the Italian beef industry amounts to about 1.5 million euros per year (Nanni Costa *et al.*, 2001). Similar estimates in the UK, USA and Canada showed losses of around 2.6 million, 95.4 million and 3.6 million euros per year, respectively (McNally and Warriss, 1996; Boleman *et al.*, 1998; Van Donkersgoed *et al.*, 2001). The incidence of bruised pig carcasses was found to be 4% in the UK (Warriss, 1984) and 1.5% in Spain (Gispert *et al.*, 2000), while the presence of damaged shoulders and hams ranged from 1% to 2% in the USA (Morgan *et al.*, 1994). In sheep carcasses, Knowles (1998) indicated an incidence of bruising varying from 0.03% to 1.25%.

Acute stress experienced during the transport and the handling before stunning

leads to a direct and indirect modification of the post mortem processes in the muscles with consequences for the meat quality. As previously reported, these operations increase the body temperature and if it remains high until the moment of stunning, due to animal excitation or warm environmental conditions, the consequence is a fast rate of acidification with possible negative effects on meat quality, such as lower water retention and paler colour. This is particularly evident in pigs where the single or double presence of the allele Hal⁺ of the Halothane gene, which is responsible for the Porcine Stress Syndrome, leads to the PSE (Pale, Soft, Exudative) meat defect. Obviously, the incidence of this defect is related to the presence of the Hal allele but not exclusively because a rapid drop in pH in muscles can be associated with short lairage (Warriss, 2003) or a stress that occurred just before stunning (van der Wal *et al.*, 1999). For these reasons, in the industrial slaughterhouses the showering during the resting period is largely used to reduce the body temperature (Knowles *et al.*, 1998).

In cattle, and to a lesser extent in pigs, the acute stress related to transport and pre-slaughter handling might reduce the glycogen content in the muscles. Intense physical activity related to the mounting behaviour in cattle or to the mixing of unfamiliar animals leads to a depletion of glycogen reserves *in vivo* and to an insufficient meat acidification *post mortem* (ultimate pH>6.00). The consequence is the Dark Cutting Beef (DCB) defect in beef and the Dark Firm Dry (DFD) defect in pork. The incidence of DCB, according to the category of cattle, ranged from 1.4% to 8.0% in the UK (Brown *et al.*, 1990), from 2.4% to 4.3% in Sweden (Fabiasson *et al.*, 1984), from 0.45% to 1.5% in Canada (Jones and Tong, 1989) and from 1.0% to 4.7% in Italy (Nanni Costa *et al.*, 2001). Smith *et al.* (1995) estimated a

loss per year of 6 US dollars for each head harvested in the USA.

The presence of the DFD defect in sheep transported in Europe has not been raised in the scientific literature (Knowles, 1998) while in Australia, where the journey by road can be very long, Morris (1994) observed an incidence of 15% of lamb carcasses with ultimate pH higher than 6.00. DFD occurrence in pork is associated with a prolonged resting period or with a fight as a consequence of mixing unfamiliar pigs in lairage, as reviewed by Warriss (2003).

Preventive measures

The consequences of the acute stress during transport and slaughter should be minimized by acting on the education of people, on equipment and on preparation of animals for the travel. The education includes training, evaluation of knowledge achieved and skills certification for the people involved, as planned, for instance, by the Reg. UE 1/2005 for truck drivers engaged in long transport (>8 hours) (European Council, 2005). The latter have to follow special training courses which include several items related to the human-animal relationship, such as animal behaviour, practical aspects of animal handling and the impact of driving behaviour on the welfare of the transported animals and on the quality of meat (Reg. UE 1/2005, Annex 4), in order to achieve the certificate of competence without which they are not allowed to transport animals for long journeys. Also the codes of practices offer strong support for education because they have a significant impact on the ways in which people manage animals. Their application not only ensures compliance with the minimum welfare requirements but increases in the personnel the awareness that appropriate treatments avoid unnecessary suffering and improve the safety of the working environ-

ment. The most effective of these codes are retailer codes of practice, since retail companies need to protect their reputation (Broom, 2005). The application of the code of practice often includes audit programmes which encourage suppliers to continuously improve. As shown by Grandin (2007a), the improvement of handling and stunning practices after the audit programmes can be extremely relevant. Moreover, some incentives to education on handling practices could be greatly effective in reducing stress during transport and the ante mortem period, i.e. monitoring procedures at the slaughterhouse, rewards for low mortality rates and financial accountability for bruises (Grandin, 2003).

Improved equipment should minimise the decline in the well being of animals during transport. The modern vehicles used for journeys exceeding 8h are designed to reduce as much as possible the negative effects resulting from extreme environmental conditions, uncomfortable vibration and water deprivation. Insulation and ventilation of vehicles have to guarantee comfort in extreme thermal conditions. Mechanical ventilation is indeed beneficial, especially when the vehicle is not in motion, in providing air movement around the animals. Nevertheless, as suggested by Kettlewell *et al.* (2005) this system has to be designed to guarantee appropriate ventilation for the needs of livestock rather than to merely meet the perceived legal requirements. Otherwise, natural ventilation plays an essential role in assuring air movement through the vehicle in motion. As recently highlighted by Warriss *et al.* (2006a), exclusive fan-assisted ventilation is not able to reduce the body temperature of pigs, at list during short journeys. Vibration is one of the factors involved in transport stress (Grandin, 1997). Vibration of the transport vehicle is believed to be one of the stressors linked to development of "shipping fever" in calves

and travel sickness in pigs. Air suspensions on all axles are recommended in order to reduce vibration and to guarantee comfort during transport (Singh and Marcondes, 1992; Randall *et al.*, 1996).

EU Council Regulation (EC) No. 1/2005 requires that for journeys exceeding 8 hours a rest period of at least 1 hour must be given for watering and feeding after 9 hours of journey for unweaned calves, lambs, kids and piglets and after 14 hours for the other categories of cattle, sheep and goat. After, they may be transported for an additional 9 hours and 14 hours, respectively. In addition to the low propensity to drink water on board (Knowles *et al.*, 1999), the presence of unusual drinking devices can make the consumption difficult. In order to facilitate water assumption, some modern vehicles are already equipped with troughs and bowls which can be extended on the deck and, after use, embedded in the wall.

Pigs may be transported for a maximum period of 24h and, during the journey, they must have continuous access to water. Mist-ing produced through the drinking devices is considered a reliable treatment to cool pigs during transport reducing mortality in hot weather (SCAHAW, 2002). However, despite the interest in misting for reducing thermal stress, there are not yet any studies to demonstrate its effects and/or its optimal usage.

The stress due to transport and ante mortem handling can be attenuated by preparing the animal for the journey using a nutrimental supplementation. This interesting approach was intensively reviewed by Schaefer *et al.* (2001) who emphasised that the modification of the diet immediately before transport offers the potential to reduce stress and improve carcass yield and meat quality. For this purpose, the provision of small quantities of energy, electrolytes, amino acids, trace nutrients and nutrient complexes could be offered either before or after

transport. Notably, oral electrolyte therapy improved water retention showing a positive effect in reducing live weight loss, carcass shrinkage and dark-cutting beef. Beneficial effects of electrolytes in combination with carbohydrates and amino acids were also found on beef cattle and pig carcasses.

Conclusions

The acute stress induced by the transport and by the pre-slaughter procedures is substantially unavoidable but that does not mean that those operations cannot be improved. The use of reliable indicators to assess the physiological and the psychological state of the animals can make it possible to better understand the stress caused by the transport. Moreover, the response to the transport and handling conditions by the animals become more effective depending on how much the physiological, behavioural and environmental needs of the animal are taken into consideration. In practice, that means avoiding the use of electric prods (with the only exception being for worker safety), preventing thirst and hunger during travel through effective access to water and feed, and eliminating extreme environmental conditions by improving the environmental control in the truck and in the resting pens. This may be not sufficient if the education of the handlers is neglected; training and skills certification as well as a repartition of responsibility among the subjects involved in the animal transport chain are equally essential to improving the conditions of transported animals and the quality of their products.

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