Stressor factors in the transport of weaned piglets: a review

P. Roldan-Santiago[1], R. Martinez-Rodriguez[2], A. Yanez-Pizana[1], M.E. Trujillo-Ortega[2], M. Sanchez-Hernandez[2], E. Perez-Pedraza[2], D. Mota-Rojas[1]

[1]Metropolitan Autonomous University-Xochimilco, Stress Physiology and Farm Animal Welfare, Department of Animal Production and Agriculture, Mexico D.F., Mexico
[2]National Autonomous University of Mexico, UNAM, Department of Animal Medicine and Production: Swine, FMVZ and CEIEPP, Mexico D.F., Mexico

ABSTRACT: The transport of weaned piglets is considered an important stress factor since the conditions involved in shipping affect the animals' health and welfare. The principal stressor factors that piglets experience during transport include: mixing with unfamiliar animals, overcrowding, heat, cold, temperature fluctuations, vibrations, and noise. It is well known that all these factors contribute to raising the level of stress caused by the weaning process; however, the additional effects attributable to transport immediately after weaning impact the physiology, metabolism and behaviour of piglets, predisposing them to delayed growth. For this reason, animal transport must be well-planned and take into account such aspects as preparation of the piglets, choosing the best route and vehicle type, assuring adequate vehicle design and maintenance, and providing sufficient space. Also important for assuring the welfare of the piglets during transport are sufficient rest time, appropriate access to food and water, defined measures for monitoring the animals during the trip, implementing means of disease control, and establishing the steps to be followed in case of an emergency.

Keywords: stress; physiology; piglets; animal welfare; immune system

Contents

1. Introduction

Transport is considered a key stress factor that affects farm animals because it can have detrimental effects on their health and welfare (von Borell and Schaffer 2005). Today, for commercial and sanitary reasons, soon after weaning piglets must be shipped from one site to another, where they will continue their growth process. The objectives of this transfer are to reduce vertical disease transference and optimise the piglets' growth potential (Wamnes et al. 2008). However, it has been postulated recently that several factors related to transport increase stress levels that have cumulative effects on piglets. Therefore, transport-induced stress added to that caused by the weaning process itself has harmful consequences for the welfare of piglets (Berry and Lewis 2001; Wamnes et al.

2008). Given these circumstances, and depending on whether transport occurs under experimental or commercial conditions, piglets can be exposed to diverse stress factors during shipping. These may include: mixing with unfamiliar animals (Berry and Lewis 2001), movement inside the vehicle, loading density (Perremans et al. 2001), trip duration, temperature inside the vehicle, environmental conditions during the journey, fasting, and noise. To give but one example, the new sounds that the animals are exposed to may activate their defence mechanisms, thus causing them to intensify their physical activity as they struggle to escape (Lewis and Berry 2006). Similarly, mixing with other animals can lead to the formation of hierarchies, a process that entails aggressive behaviour and fighting among piglets (Villarroel et al. 2011). In this vein, several studies of the transport of growing pigs and those beyond the growth stage have demonstrated that shipping (simulated or real) can cause increases in blood levels of cortisol and creatine phosphokinase (CPK), two substances whose hormones are commonly associated with responses to stressful stimuli (Bradshaw et al. 1996a,b; Hicks et al. 1998) and have been shown to cause behavioural changes (Hicks et al. 1998), fatigue (Lambooy 1988) and weight loss in animals of as much as 7% (Prandl 1994). Trip duration is another determining factor in this process, since prolonged transport periods mean greater food and water deprivation (Berry and Lewis 2001); simultaneously, fatigue becomes more frequent (Becerril-Herrera et al. 2010; Mota-Rojas et al. 2012a,c). Another element that can affect animal health and welfare during transport is loading density, especially in the case of recently-weaned piglets (Lewis et al. 2012). In adult pigs, high loading densities have been associated with elevated mortality rates (Warriss 1998). Recent studies in pigs weaned and transported for 60 min in summer have reported lower indices of immunological alterations and physical damage when transported in spaces that average 0.06 and 0.07 m^2/pig, compared to spaces of just 0.05 m^2/animal. This finding suggests that a minimum space of 0.06 m^2/pig is optimal (Sutherland et al. 2009a). Meanwhile, another series of recent studies has used physiometabolic indicators of stress (pH, partial carbon dioxide pressure, partial oxygen pressure, sodium, calcium, glucose, lactate and blood hematocrit) in piglets weaned at different ages (15, 21 and 28 days) to evaluate the effect of weaning followed by transport. Observations showed that the piglets weaned and shipped at an early age (two weeks) suffer significant metabolic, hydric and gas exchange imbalances that affect their welfare (Roldan-Santiago et al. 2011b). Finally, regardless of age, subjecting piglets to transport has been shown to be an extremely stressful experience, as just a one-hour trip is sufficient for them to begin to suffer physiometabolic imbalances (Roldan-Santiago et al. 2011a). It is in this context that the present review analyses and discusses the principal stress factors that affect the physiology, metabolism and behaviour of recently-weaned piglets during transport.

2. Transport of weaned piglets

Transport in general is a stressful activity for piglets, an experience that commonly has repercussions for both their physiology and behaviour. This is especially true of early-weaned piglets (14 to 19 days) (Stephens and Perry 1990; Warriss 1998; Lewis and Berry 2006). However, the responses to stress caused by transporting weaned piglets have been little studied (Lewis and Berry 2006), although it is known that during the weaning process piglets confront a whole series of diverse, abrupt changes. Piglets weaned at four weeks of age must change from a purely liquid diet to a solid one, an adaptation that often results in no food ingestion during the first 24 or 48 h post-separation (Bruininx et al. 2002; Dybkjaer et al. 2006). On this issue, various authors have pointed out that transport immediately after weaning can exacerbate this period of fasting and lead to a higher risk of diarrhoea and delayed growth (McCracken et al. 1995; Berry and Lewis 2001).

Another well-known fact is that piglets shipped immediately after weaning at 17 days, and for different transport times (20 min vs. 12 or 24 h), suffer weight loss (0.4 ± 0.1 kg; $P < 0.01$) regardless of trip duration (Wamnes et al. 2006). In their 2001 study, Berry and Lewis confined groups of 17-day-old piglets in wooden crates measuring 1.2 × 1.2 × 1 m (i.e., a vital space per piglet of 0.18–0.36 m^2) provided with straw bedding, and then simulated transport at distinct trip times (0–24 h) and temperatures (20–35 °C). Their observations revealed a significant effect of trip duration and temperature on weight loss: the piglets subjected to 6 h of transport at a temperature of 20 °C had an average weight loss of 0.45 kg, while those transported for 24 h at a temperature of 35 °C suffered a substantially greater weight loss of 0.63 kg ($P < 0.001$). These findings suggest that prolonged confinement added to higher ambient temperatures increases weight loss in piglets. Moreover, in a later study under the same trip conditions, these authors found a significant increase in water consumption after 24 h of transport compared to piglets shipped for 6 and 12 h (Lewis and Berry 2006). In relation to these results, Bergeron and Lewis (1997) reported that pigs may lose up to 12.7% of their body weight through dehydration. Furthermore, Lambooy (1988) points out that transport periods longer than 12 h lead to greater weight loss due to a prolonged period of food and water deprivation; conditions that propitiate a state of fatigue in piglets.

3. Duration of transport

Transport time affects the welfare of piglets (Hambrecht et al. 2005), a fact that may be reflected in their behaviour. Piglets that remain in a supine position for long periods are manifesting a behaviour that can be associated with the fatigue they experience during transport (Wamnes et al. 2008). Lewis and Berry (2006) found that during the first 12 h of shipping, 36% of piglets stay standing, while 60% lie down. These behavioural patterns were seen to increase with greater transport times, for in the ensuing 12 h, 91.6% of the pigs were prostrate, while the percentage of animals that remained standing fell to just 7.4%. This suggests that part of the increase in adopting a supine posture after 12 h of transport is attributable not just to fatigue, but also to thermoregulation (overcrowding). The mixing of unfamiliar animals that occurs during transport is another factor that causes stress (Edwards 2002; Ekkel et al. 2003; Mota-Rojas et al. 2009, 2011b, 2012b,c; Becerril-Herrera et al. 2010). Experiments have shown that mixing provokes an increase in the number of fights among piglets, an additional factor that could contribute to the onset of fatigue (see Berry and Lewis 2001). In other research, prostration has been identified as a behaviour that indicates "stress" (Dybkjaer et al. 2006). This type of conduct has been observed more frequently during the first 12 h of transport (2.8%) than in the following 12 h (0.3%) (Lewis and Berry 2006), and is also observed more often during the first day that piglets spend in weaning corrals (0.49%), though it decreases (0.29%) on the second and third days that the piglet stays in that area (Lewis et al. 2012). On the basis of these findings, the authors posit that the increase in prostration, the reduced number of piglets that sit, and the establishment of new hierarchies may be signals indicating that the piglets have become habituated to some of the elements of the shipping environment (Berry and Lewis 2001).

With regard to the frequency of water consumption, it has been observed that this index is higher on the first day after transport and increases with trip duration (control group: 2.4%; 6 h: 2.7%; 12 h: 3.0%; 24 h: 3.7%) (Lewis and Berry 2006). In a simulated transport model, piglets shipped for 24 h, regardless of temperature (20 °C, 30 °C, 35 °C), presented higher hematocrit values (41.1%) than the control group (0 h of transport: 39%); these results reflect the extreme dehydration that piglets may suffer during transport (Berry and Lewis 2001).

4. Temperature during transport

It is widely believed that trip temperature and duration are the two main factors that affect the early response of recently-weaned piglets to transport (Berry and Lewis 2001). Both summer heat and winter cold can increase the level of stress that piglets experience in the vehicle and, therefore, negatively affect their behaviour and welfare after the stressful weaning process. Temperature significantly exacerbates the stress that piglets suffer during transport and may increase the risk of dehydration (Wamnes et al. 2008). Indeed, temperature has adverse effects whether it is too low or too high. In Canada a comfortable temperature for weaned piglets (weighing 4–7 kg) of 24–34 °C has been suggested (CARC, 1993). During transport, however, the temperature inside the vehicle can vary rapidly, especially in winter if it is not equipped with a heating system (Grandin 2008). In their study, Berry and Lewis (2001) assessed the effect of trip duration and temperature on weaned piglets. Their results report greater weight loss in animals shipped for 24 h at temperatures of 30–35 °C, and in piglets shipped for 6 h but at a temperature of 20 °C. In addition, the season of the year can affect piglet behaviour during transport, as it has been observed that the number of piglets that fight inside the truck in the summer (39) is greater than in wintertime (just 3). This finding might indicate that in winter thermoregulation takes priority for the piglets, while certain social behaviours –like establishing hierarchies – take a back seat (Lewis and Berry 2006;

Lewis et al. 2012). In this regard, Lewis (2008) mentions that the average body temperature measured on the surface of the ear in summer (36.2 °C) was significantly higher than the temperatures measured in autumn (27.0 °C) and winter (23.1 °C). The rectal temperatures recorded were also higher in summer (39.2 °C) than in autumn (38.7 °C) or winter (38.6 °C). These differences between ear and rectal temperatures suggest that there is a demand for physiological mechanisms that function to maintain body temperature. In another study, Berry and Lewis (2001) simulated the transport of piglets on a 24-h trip at a constant temperature of 35 °C. They observed a reduction in food consumption (0.26 kg) during the three days after weaning, compared to groups with 0 h (0.43 kg) and 6 h (0.49 kg) of transport. In that same study, the authors mention that the differences between the treatment groups (temperature and duration) remained evident for seven days after transport. Food consumption was measured as follows: piglets with 0 h of transport, 3.32 kg; those with 6 h of transport, 3.27 kg; and after 24 h of transport, 2.61 kg. However, at 14 days post-transport these differences had disappeared ($P > 0.05$) (0 h: 14.12; 6 h: 13.43; and 24 h: 12.47 kg). Lewis et al. (2012) weaned and shipped piglets in three seasons (summer, autumn, winter) using four different trip times (0, 6, 12 and 24 h). According to their observations, 17 piglets (5.9%) were classified as showing little activity, and those same animals had not recovered their weight at seven days post-weaning. Similar findings were seen more often after transport in winter. Preliminary observations of these piglets showed that they were apparently healthy animals that had not learned to eat sufficient food to satisfy their physiological needs. These piglets represent an important area of concern in terms of welfare due to this prolonged pattern of low food consumption, especially after wintertime transport.

5. Loading density

Loading density is another important aspect of animal transport, for it has been shown that both too little and too much vital space per animal can compromise health and welfare (Hay et al. 2001; Kanitz et al. 2002). For this reason, the space requirement during transport is not only a problem of animal health but also a welfare concern throughout the pork industry. High densities have been associated with elevated mortality rates in pigs shipped to the slaughterhouse (Warriss 1998). Also, Gade and Christensen (1998) found that losses (dead and non-ambulatory pigs) during shipping were twice as high under conditions of low loading density (0.4 m^2/pig) compared to high densities (0.5 m^2/pig) in the trucks. Their figures were 0.88 vs. 0.36% of total losses, respectively. Studies have also demonstrated that loading density affects some physiological variables that serve to assess the degree of stress and fatigue that pigs suffer during transport; including lactate dehydrogenase and creatine phosphokinase concentrations. It is in this regard that Kim et al. (2004) report lower concentrations of lactate dehydrogenase in pigs shipped at low densities (0.31 m^2/100 kg) compared to medium (0.35 m^2) and high densities (0.39 m^2). Other research has pointed out that creatine kinase levels are higher in pigs transported at densities below 0.5 m^2/100 kg (Gade and Christensen 1998; Warriss 1998; Lewis 2008). Lewis and Berry (2006), meanwhile, found that pigs that are weaned and shipped in a vital space of 0.06 m^2/animal spend 55.3% of their time in a prostrate position and 40.5% on foot during transport. Kim et al. (2004) observed that time spent standing during transport was lower in piglets under conditions of low density (0.39 m^2/100 kg) compared to medium (0.35 m^2) and high density (0.31 m^2). However, Gade and Christensen (1998) found that providing more space to the pigs did not result in a larger number of prostrate animals; to the contrary, they observed continuous disturbances by other pigs at loading densities of 0.42 m^2/100 kg and of 0.5 m^2/100 kg. Those pigs experienced greater difficulty in maintaining their balance. In this respect, Sutherland et al. (2009a) report that piglets with 0.06 m^2/animal of space spend more time on foot (2.6%) during transport compared to piglets shipped at 0.07 m^2/animal (1.3%). They suggest that limiting the amount of space available results in the piglets reposing one on top of another, and that as this behaviour becomes more frequent both the number of lesions and the degree of distress will increase. Thus it may be that shipping weaned piglets at a vital space of 0.07 m^2/animal is preferable to transport under more restrictive conditions (0.06 m^2/pig).

One of the alterations related to the stress that weaned piglets suffer during transport is an elevated proportion of neutrophils: i.e., lymphocytes and higher cortisol concentrations. In their study, Sutherland et al. (2009b) transported 100 recently-weaned piglets for 112 min at different loading densities (0.05, 0.06 and 0.07 m^2/pig). They found that the concentrations of creatine-kinase (CK), aspartate aminotransferase (AST) and urea rose in the weaned pigs after shipping, regardless of loading density. During post-transport, the concentrations of CK and urea reached the upper limit or were slightly above the normal range, though AST was within the normal range for weaned piglets. In these circumstances, muscle fibres release CK and AST into the bloodstream in response to exercise or tissue damage; thus, their presence is a good marker of muscle activity or of tissue damage in pigs (Fabrega et al. 2002; Yu et al. 2009; van der Meulen et al. 2010). In another study, Sutherland et al. (2009b) found high concentrations of total proteins and albumin, suggesting that the pigs suffered mild dehydration as a consequence of transport. However, hematocrit and body weight did not decrease significantly after shipping, indicating that these pigs experienced only mild dehydration after the 112-min transport period. It is important to remember that these results may differ in piglets that are weaned and transported in the summer, in warm weather conditions, or for longer trip times, since hematocrit increased and the piglets experienced weight loss after weaning and transport for 60 min at an average temperature of 28 °C. In the aforementioned experiment, the piglets transported at densities of 0.05 m^2/animal spent less time lying down than those shipped at densities of 0.06 and 0.07 m^2/animal between 30 and 60 min post-transport; a finding that suggests that the pigs transported at a density of 0.05 m^2/pig were more restless than those shipped at densities of 0.06 or 0.07 m^2/animal (Sutherland et al. 2009a). Additionally, Lewis and Berry (2006) found that early-weaned piglets transported for 0–6 h at a space of 0.06 m^2/pig rested 71% of the time and stood for 26.5% of the transport period in summer, while the studies conducted by Sutherland et al. (2009a) report that piglets weaned and transported for 60 min with a vital space of 0.06 m^2/animal sat 68% of the time and lay down for 19%. Of course, the differences between these two studies may be attributable to the different transport times involved.

Sutherland et al. (2009b) also report that piglets spent the final 30 min of the 112-min trip in inactive conducts (prostrate/piled). They offer two possible explanations for this: first, that these behaviours mean that the piglets had adapted to the transport conditions; second, that they were suffering from exhaustion. Fatigue can be provoked by several of the stress factors to which piglets are exposed during transport, such as unloading and mixing with unfamiliar piglets, among others. In other studies, the early weaning of piglets shipped for 0–6 h in winter (–2.8 °C to 3.2 °C) at a loading density of 0.06 m^2/animal spent about the same amount of time resting as on foot (Lewis and Berry 2006). However, since it is known that piglets often present behavioural changes, the crowding they manifest at times may be a means of regulating their temperature since their bodies have little hair and, more importantly, their levels of body fat are low. Thus, while the observed increase in supine postures may be a marker of exhaustion, it could also be related to thermoregulation by piglets due to temperature reductions inside the transport vehicle (Sutherland et al. 2009b).

On this topic, studies conducted with adult pigs have found that the animals are more likely to lie down during the final hours of a long highway journey (Grandin, 1997; Becerril-Herrera et al. 2010; Mota-Rojas et al. 2012b). This coincides with recent results from Mota-Rojas et al. (2006), who evaluated the position upon arrival of three groups of pigs that had been transported for periods of 8, 16 and 24 h. They observed that as trip time increased the number of animals that arrived in a prostate position also rose. Moreover, the number of male animals that arrived in that posture was statistically different ($P < 0.001$) from the number of females shipped in the same period. Also, Gallo et al. (2000) point out that as travel time increases the animals tire, tend to lie down, and may become more prone to falling; therefore, it is important to make detailed observations of behaviour using video recording during the journey. Combined with the physiological parameters of stress, this will facilitate interpretations of the effects of transport on animals.

6. Vehicle vibration

Vibration inside the vehicle is bothersome for pigs and can provoke vomiting during transport (Bradshaw et al. 1996b). Vibration, as one aspect of movement, can be characterised by direction (horizontal, vertical) acceleration, and frequency. A relationship has been established between these factors and the subjective degree of comfort or discomfort that humans experience using diverse measures of vibration (Randall 1992). Those studies suggest that vibration may be an even more aggravating element than the noise associated with transport (Stephens and Perry 1990).

The vehicles used to move farm animals are rarely designed to reduce vibration, so animals may be subjected to a magnitude of shaking even higher than that felt by the driver. In this regard, Perremans et al. (2001) observed that low frequency vibration (2–4 Hz) causes greater stress than higher frequencies (8–18 Hz), because when exposed to low-frequency vibrations the animals spent 10 times less time in prostrate postures. Also, their cortisol levels were higher when the vibrations at frequencies of 4, 8 and 18 Hz ended. In these conditions, the increased sensitivity of the piglets to higher frequencies at the end of the experiment could be explained by the agitation of the vehicle's floor: that is, although the degree of displacement was minimal, the frequency of movement was excessive. This shaking action could cause the piglets' viscera and muscles to vibrate, and this would propitiate a state of fatigue. In contrast, the sinusoidal nature of movement at lower frequencies results in relatively large, regular displacements to which the animals might be able to acclimatise themselves. Hence, their initial response could diminish as they become accustomed to such movements. In an earlier study, Perremans et al. (1998) recommended eliminating low frequency vibrations and high accelerations, since they cause the animals' heartbeat to increase during transport. Similar results regarding vibration conditions were observed during the transport of pigs to slaughterhouses (Randall et al. 1997).

Perremans et al. (2001) report finding an increase in the blood concentrations of ACTH and cortisol at 10 and 30 min, respectively, after the piglets began to experience vibration, regardless of frequency. Stephens and Perry (1990) also analysed piglets' responses to different vibration frequencies and found that vibrations function as an aversive stimulus since the animals learn to support or balance themselves in such a way that they cease to feel the vibrations.

In their research on piglets, Peeters et al. (2005) set out to examine the effects of complementing the diet with magnesium, tryptophan, vitamin E or vitamin C before a simulated transport experiment. They subjected 126 piglets to vibrations in a transport simulator (8 Hz, 3 m/s) for 2 h and then let them rest for the same interval. The cortisol concentrations in the saliva (collected before and after recovery) of the animals that received vitamin E were lower. Those animals also had lower concentrations of lactate before the vibrations began. Stable concentrations of lactate and creatine kinase (CK) in the piglets that received the vitamin E complement were clearly evident, while the other treatments reduced lactate by at least 4 mg/dl, or increased CK by at least 500 IU/l. In addition, there was a relation between the loss of CK and damage to the membrane of the muscle tissue. Thus, the authors affirm that vitamin E stabilises the membrane, especially in situations of stress. Finally, vibration can be considered a stress factor with a high emotional impact, since the animals clearly manifest more intense fear as the frequency of the vibrations increases (Perremans et al. 2001). Despite these indications, however, additional studies designed specifically to study this relationship are needed.

7. Piglet behaviour during transport

Knowledge of the basic behaviour and physiological responses of animals during transport is required to define the minimum requirements of space and optimum environmental conditions for shipping. There is evidence that traveling in a moving vehicle provokes greater stress than if the pigs are simply loaded onto a truck for the same period of time while the vehicle is parked (Lewis 2008). After a trip of 25 min, or an identical waiting period with the truck parked, Geverink et al. (1998) reported that, upon unloading, the adult pigs that had travelled were less active and spent less time exploring their surroundings than those that had not been moved. In another finding, cortisol levels in the saliva were significantly higher in the group that was shipped. Lysine-vasopressin values have also been associated with malaise during transport, suggesting that it may also be a valid marker of the welfare of transported pigs (Bradshaw et al. 1996a).

Earlier studies have documented that early weaning causes diminished food ingestion, weight loss (Lewis and Berry 2006), an increase in oral/nasal behaviours (Schmolke et al. 2004), and more frequent vocalisations (Weary et al. 2008). In a recent study of transported piglets, Lewis and Berry (2006) observed a higher frequency of water consumption on the first day post-trip (control group (0 h): 2.4%; 6 h: 2.7%; 12 h: 3.0%; 24 h: 3.7%). These results show that the piglets were thirsty and that the increase in this behaviour (drinking water) post-travel was an attempt to compensate for the water lost during transport. This increase showed a linear tendency in relation to trip duration.

8. Immunological alterations during transport

The factors that contribute to triggering stress in transported piglets are very similar to those that appear during the transport of adult pigs to the slaughterhouse for sacrifice (Mota-Rojas et al. 2006, 2009, 2011a; Becerril-Herrera et al. 2010; Martinez-Rodriguez et al. 2011). In this respect, findings include increased heartbeat, high concentrations of catecholamines and cortisol and greater cell volume. The increase of catecholamines causes splenic contractions that produce a higher percentage of erythrocytes. This explains, in part, the dehydration seen in the animals after transport (Becerril-Herrera et al. 2010). For all these reasons, assessments of animal responses to stress have used both physiological and behavioural parameters. Regarding the former, blood concentrations of cortisol, lactate, glucose, vasopressin and catecholamines (Hicks et al. 1998; Fischer 1996; Gallo et al. 2001; Davis et al. 2006; Edwards et al. 2010) are those most often employed; however, in the case of cortisol one must keep in mind that concentrations can vary widely and its half-life is very short, factors that can lead to contradictory results (Mota-Rojas et al. 2011a). Other means of evaluating stress have involved such markers as analysing cell packs, leucocyte counts and ketone bodies, or evaluations of enzymes like lactate dehydrogenase and creatine phosphokinase (Becerril-Herrera et al. 2010). Yet other studies have explored the use of respiratory rates together with body temperature (Knowles 1999).

Evaluating the acid-base balance is another useful tool for determining responses to stress during animal handling (Becerril-Herrera et al. 2010; Roldan-Santiago et al. 2011a,b; Trujillo-Ortega et al. 2011; Mota-Rojas et al. 2011b, 2012a,d). Hamilton et al. (2004) assessed the effect of handling intensity on the acid-base response in adult hogs. Their results show that pigs handled with greater intensity present higher lactate levels, lower levels of pH and HCO_3, and excess base.

More recently, Mota-Rojas et al. (2012a) and Becerril-Herrera et al. (2010) have demonstrated the usefulness of determining the variables associated with the acid-base balance, including lactate, pH, glucose and blood gases (pCO_2 and pO_2) for evaluating stress and animal welfare in adult pigs that are shipped to abattoirs for sacrifice. In the results of the latest research, transport caused a reduction and increase in pH and lactate blood, respectively, as well as decreases in blood gases. However, scientific literature showing the results associated with the effect of transport-induced stress on physiometabolic changes in weaned pigs is still scarce.

9. Conclusions

Transporting piglets contributes to increasing the levels of stress caused originally by weaning, mainly because during the weaning process piglets not only confront the separation from their mother and litter mates, but also experience changes in their physical environment and handling to which they are not accustomed. Therefore, when in addition to all these changes the piglets are also shipped to another site to continue their growth process, the level of stress they suffer increases, and the physiological, metabolic and behavioural repercussions become more severe since the animal must deal with a whole series of new stressor factors during transport. The principal conditions that piglets experience when shipped include mixing with unfamiliar animals, overcrowding, heat, cold, temperature fluctuations, vibration, noise, and trip duration.

Mixing with unfamiliar animals during transport provokes aggression and fighting among the piglets, and this has repercussions for their food consumption, growth and gastrointestinal health; for example, a piglet can lose up to 12.7% of its body weight due to transport-induced dehydration. Temperature and trip duration can also affect the early immunological response of piglets, so it is critical to assure a comfortable temperature inside the transport vehicle. Studies have shown that an interior temperature range of 24–34 °C is recommendable. Also to be taken into account is that as trip duration increases piglets will become more prone to suffering extreme dehydration, with hematocrit values falling to levels as low as 40%. Thus, prolonged transport periods coupled with increased food and water deprivation result in more frequent episodes of fatigue. With regard to the factor of loading density, it has been shown that both too little and too much vital space compromise the health and welfare of pigs. Low densities of 0.04 m^2/piglet, for example, can produce mortality rates of 0.88% during transport. In contrast, a vital space of 0.06 m^2/pig results in fewer immunological alterations and reduces physical damage, so this amount is considered the minimum recommended space for shipping piglets. With respect to the vibration caused by the vehicle during trips, it is important to remember that low frequency vibrations of 2–4 HZ provoke greater stress than high frequency vibrations of 8–18 Hz. On the basis of all the findings reviewed in this paper, the recommendation is to maintain the piglets under optimal environmental conditions by taking into account all the following factors: climate type, season of the year, temperature, ventilation, humidity, type of road, trip duration, and loading density on the transport vehicle. The goal of considering all these elements is to reduce as much as possible the levels of stress that each condition can cause and, therefore, improve the welfare of recently-weaned piglets during transport.

10. Acknowledgements

This study is part of the M.Sc. thesis of Patricia Roldan-Santiago, a graduate student in the program of Production Sciences and Animal Health at the Faculty of Veterinary Medicine and Animal Husbandry at the Universidad Nacional Autónoma de México (UNAM) in Mexico City. The research was funded by CONACYT scholarship No. 423262. Prof. Daniel Mota-Rojas and PhD. María E. Trujillo-Ortega, were supported, as members, by the Sistema Nacional de Investigadores (SNI) in Mexico.

11. REFERENCES

Becerril-Herrera M, Alonso-Spilsbury M, Tujillo-Ortega ME, Guerrero-Legarreta I, Ramirez-Necoechea R, Roldan-Santiago P, Perez-Sato M, Soni-Guillermo E, Mota-Rojas D (2010): Changes in blood constituents of swine transported for 8 or 16 h to an Abattoir. Meat Science 86, 945–948.

Bergeron R, Lewis NJ (1997): Farm animal transportation, health and welfare (in Franch). Cahiers Agricultures 8, 437–444.

Berry RJ, Lewis NJ (2001): The effect of duration and temperature of simulated transport on the performance of early-weaned piglets. Canadian Journal of Animal Science 81, 199–204.

Bradshaw RH, Parrott RF, Forsling ML, Goode JA, Lloyd DM, Rodway RG, Broom DM (1996a): Stress and travel sickness in pigs: Effects of road transport on plasma concentrations of cortisol, beta-endorphin and lysine vasopressin. Animal Science 63, 507–516.

Bradshaw RH, Parrott RF, Goode JA, Lloyd DM, Rodway RG, Broom DM (1996b): Behavioural and hormonal responses of pigs during transport: Effect of mixing and duration of journey. Animal Science 62, 547–554.

Bruininx E, Heetkamp MJ, Van Den Bogaart A, Van Der Peet-Schwering CM, Beynen AC, Everts H, Den Hartog LA, Schrama JW (2002): A prolonged photoperiod improves feed intake and energy metabolism of weanling pigs. Journal of Animal Science 80, 1736–1745.

CARC (1993): Recommended code of practice for the care and handling of farm animals: Pigs, addendum early weaned piglets. Canadian Pork Council, Ottawa, Ontario.

Davis ME, Sears SC, Apple JK, Maxwell CV, Johnson ZB (2006): Effect of weaning age and commingling after the nursery phase of pigs in a wean-to-finish facility on growth, and humoral and behavioral indicators of well-being. Journal of Animal Science 84, 743–756.

Dybkjaer L, Jacobsen AP, Togersen FA, Poulsen HD (2006): Eating and drinking activity of newly weaned piglets: Effects of individual characteristics, social mixing, and addition of extra zinc to the feed. Journal of Animal Science 84, 702–711.

Edwards LN, Grandin T, Engle TE, Porter SP, Ritter MJ, Sosnicki AA, Anderson DB (2010): Use of exsanguination blood lactate to assess the quality of pre-slaughter pig handling. Meat Science 86, 384–390.

Edwards SA (2002): Perinatal mortality in the pig: environmental or physiological solutions? Livestock Production Science 78, 3–12.

Ekkel ED, Spoolder HA, Hulsegge I, Hopster H (2003): Lying characteristics as determinants for space requirements in pigs. Applied Animal Behaviour Science 80, 19–30.

Fabrega E, Manteca X, Font J, Gispert M, Carrion D, Velarde A, Ruiz-de-la-Torre JL, Diestre A (2002): Effects of halothane gene and pre-slaughter treatment on meat quality and welfare from two pig crosses. Meat Science 62, 463–472.

Fischer K (1996): Transport of slaughter animals – Effects, weaknesses measures. Fleischwirtschaft 76, 521–526.

Gade PB, Christensen L (1998): Effect of different stocking densities during transport on welfare and meat quality in Danish slaughter pigs. Meat Science 48, 237–247.

Gallo C, Perez S, Sanhueza C, Gasic J (2000): Effects of transport time of steers before slaughter on behaviour, weight loss and some carcass characteristics. Archivos de Medicina Veterinaria 32, 157–170.

Gallo C, Espinosa M, Sanhueza C, Gasic J (2001): Effects of trailer transportation during 36 hours with and without rest, on the live weight and some carcass traits in bovines, on the live weight and some carcass traits in bovines. Archivos de Medicina Veterinaria 33, 43–53.

Geverink NA, Kappers A, van de Burgwal JA, Lambooij E, Blokhuis HJ, Wiegant VM (1998): Effects of regular moving and handling on the behavioral and physiological responses of pigs to preslaughter treatment and consequences for subsequent meat quality. Journal of Animal Science 76, 2080–2085.

Grandin T (1997): Assessment of stress during handling and transport. Journal of Animal Science 75, 249–257.

Grandin T (2008): Safe handling of large animals: Part II. Irish Veterinary Journal 61, 758–763.

Hambrecht E, Eissen JJ, Newman DJ, Smits CH, den Hartog LA, Verstegen MW (2005): Negative effects of stress immediately before slaughter on pork quality are aggravated by suboptimal transport and lairage conditions. Journal of Animal Science 83, 440–448.

Hamilton DN, Ellis M, Bertol TM, Miller KD (2004): Effects of handling intensity and live weight on blood acid-base status in finishing ‘pigs. Journal of Animal Science 82, 2405–2409.

Hay M, Orgeur P, Levy F, Le Dividich J, Concordet D, Nowak R, Schaal B, Mormede P (2001): Neuroendocrine consequences of very early weaning in swine. Physiology and Behavior 72, 263–269.

Hicks TA, McGlone JJ, Whisnant CS, Kattesh HG, Norman RL (1998): Behavioral, endocrine, immune, and performance measures for pigs exposed to acute stress. Journal of Animal Science 76, 474–483.

Kanitz E, Tuchscherer M, Tuchscherer A, Stabenow B, Manteuffel G (2002): Neuroendocrine and immune responses to acute endotoxemia in suckling and weaned piglets. Biology of the Neonate 81, 203–209.

Kim DH, Woo JH, Lee CY (2004): Effects of stocking density and transportation time of market pigs on their behaviour, plasma concentrations of glucose and stress-associated enzymes and carcass quality. Asian-Australasian Journal of Animal Sciences 17, 116–121.

Knowles TG (1999): A review of the road transport of cattle. Veterinary Record 144, 197–201.

Lambooy E (1988): Road transport of pigs over a long-distance – some aspects of behavior, temperature and humidity during transport and some effects of the last 2 factors. Animal Production 46, 257–263.

Lewis NJ, Berry RJ (2006): Effects of season on the behaviour of early-weaned piglets during and immediately following transport. Applied Animal Behaviour Science 100, 182–192.

Lewis NJ (2008): Transport of early weaned piglets. Applied Animal Behaviour Science 110, 128–135.

Lewis MC, Inman CF, Patel D, Schmidt B, Mulder I, Miller B, Gill BP, Pluske J, Kelly D, Stokes CR, Bailey M (2012): Direct experimental evidence that early-life farm environment influences regulation of immune responses. Pediatric Allergy and Immunology 23, 265–269.

Martinez-Rodriguez R, Roldan-Santiago P, Flores-Peinado S, Ramirez-Telles JA, Mora-Medina P, Trujillo-Ortega ME, Gonzalez-Lozano M, Becerril-Herrera M, Sanchez-Hernandez M, Mota-Rojas D (2011): Deterioration of pork quality due to the effects of acute ante mortem stress: An overview. Asian Journal of Animal and Veterinary Advances 6, 1170–1184.

McCracken BA, Gaskins HR, Ruwekaiser PJ, Klasing KC, Jewell DE (1995): Diet-dependent and diet-independent metabolic responses underlie growth stasis of pigs at weaning. Journal of Nutrition 125, 2838–2845.

Mota-Rojas D, Becerril M, Lemus C, Sanchez P, Gonzalez M, Olmos SA, Ramirez R, Alonso-Spilsbury M (2006): Effects of mid-summer transport duration on pre- and post-slaughter performance and pork quality in Mexico. Meat Science 73, 404–412.

Mota-Rojas D, Becerril Herrera M, Trujillo-Ortega ME, Alonso-Spilsbury M, Flores-Peinado SC, Guerrero-Legarreta I (2009): Effects of pre-slaughter transport, lairage and sex on pig chemical serologic profiles. Journal of Animal and Veterinary Advances 8, 246–250.

Mota-Rojas D, Orozco-Gregorio H, Gonzalez-Lozano M, Roldan-Santiago P, Martinez-Rodriguez R, Sanchez-Hernandez M, Trujillo-Ortega ME (2011a): Therapeutic approaches in animals to reduce the impact of stress during transport to the slaughterhouse: a review. International Journal of Pharmacology 7, 568–578.

Mota-Rojas D, Orozco-Gregorio H, Villanueva-Garcia D, Bonilla-Jaime H, Suarez-Bonilla X, Hernandez-Gonzalez R, Roldan-Santiago P, Trujillo-Ortega ME (2011b): Foetal and neonatal energy metabolism in pigs and humans: a review. Veterinarni Medicina 56, 215–225.

Mota-Rojas D, Becerril-Herrera M, Roldan-Santiago P, Alonso-Spilsbury M, Flores-Peinado S, Ramirez-Necoechea R, Ramirez-Telles JA, Mora-Medina P, Perez M, Molina E, Soni E, Trujillo-Ortega ME (2012a): Effects of long distance transportation and CO_2 stunning on critical blood values in pigs. Meat Science 90, 893–898.

Mota-Rojas D, Bolanos-Lopez D, Concepcion-Mendez M, Ramirez-Telles J, Roldan-Santiago P, Flores-Peinado S, Mora-Medina P (2012b): Stunning swine with CO_2 gas: Controversies related to animal welfare. International Journal of Pharmacology 8, 141–151.

Mota-Rojas D, Martinez-Burnes J, Villanueva-Garcia D, Roldan-Santiago P, Trujillo-Ortega ME, Orozco-Gregorio H, Bonilla-Jaime H, Lopez-Mayagoitia A (2012c): Animal welfare in the newborn piglet: a review. Veterinarni Medicina 57, 338–349.

Mota-Rojas D, Villanueva-Garcia D, Hernández-Gonzalez R, Roldan-Santiago P, Martinez-Rodriguez R, Mora-Medina P, Gonzalez-Meneses B, Sanchez-Hernandez M, Trujillo-Ortega ME (2012d): Assessment of the vitality of the newborn: An overview. Scientific Research and Essays 7, 712–718.

Peeters E, Neyt A, Beckerst F, De Smet S, Aubert AE, Geers R (2005): Influence of supplemental magnesium, tryptophan, vitamin C, and vitamin E on stress responses of pigs to vibration. Journal of Animal Science 83, 1568–1580.

Perremans S, Randall JM, Allegaert L, Stiles MA, Rombouts G, Geers R (1998): Influence of vertical vibration on heart rate of pigs. Journal of Animal Science 76, 416–420.

Perremans S, Randall JM, Rombouts G, Decuypere E, Geers R (2001): Effect of whole-body vibration in the vertical axis on cortisol and adrenocorticotropic hormone levels in piglets. Journal of Animal Science 79, 975–981.

Prandl O, Fischer A, Schmidhofer T, Sinell HJ (eds.) (1994): Technology and Meat Hygiene (in Spanish). 1st ed. Acribia, Zaragoza, Spain. 655 pp.

Randall JM (1992): Human subjective response to lorry vibration – implications for farm animal transport. Journal of Agricultural Engineering Research 52, 295–307.

Randall JM, Duggan JA, Alami MA, White RP (1997): Frequency weightings for the aversion of broiler chickens to horizontal and vertical vibration. Journal of Agricultural Engineering Research 68, 387–397.

Roldan-Santiago P, Mota-Rojas D, Trujillo-Ortega ME, Hernandez-Gonzalez R, Martinez-Rodriguez R, Sanchez-Hernandez M (2011a): Stress of weaning piglets 21 days: responses fisiometabolicas. Acontecer Porcino 106, 42–48.

Roldan-Santiago P, Gonzalez-Lozano M, Flores-Peinado SC, Camacho-Morfin D, Concepcion-Mendez M, Morfin-Loyden L, Mora-Medina P, Ramirez-Necoechea R, Cardona AL, Mota-Rojas D (2011b): Physiological response and welfare of ducks during slaughter. Asian Journal of Animal and Veterinary Advances 6, 1256–1263.

Schmolke SA, Li YZ, Gonyou HW (2004): Effects of group size on social behavior following regrouping of growing-finishing pigs. Applied Animal Behaviour Science 88, 27–38.

Stephens DB, Perry G (1990): The effects of restraint, handling, simulated and real transport in the pig (with reference to man and other species). Applied Animal Behaviour Science 28, 41–55.

Sutherland MA, Krebs N, Smith JS, Dailey JW, Carroll JA, McGlone JJ (2009a): The effect of three space allowances on the physiology and behavior of weaned pigs during transportation. Livestock Science 126, 183–188.

Sutherland MA, McDonald A, McGlone JJ (2009b): Effects of variations in the environment, length of journey and type of trailer on the mortality and morbidity of pigs being transported to slaughter. Veterinary Record 165, 13–18.

Trujillo-Ortega ME, Mota-Rojas D, Juarez O, Villanueva-Garcia D, Roldan-Santiago P, Becerril-Herrera M, Hernandez-Gonzalez R, Mora-Medina P, Alonso-Spilsbury M, Rosales AM, Martinez-Rodriguez R, Ramirez-Necoechea R (2011): Porcine neonates failing vitality score: physio-metabolic profile and latency to the first teat contact. Czech Journal of Animal Science 56, 499–508.

van der Meulen J, Koopmans SJ, Dekker RA, Hoogendoorn A (2010): Increasing weaning age of piglets from 4 to 7 weeks reduces stress, increases post-weaning feed intake but does not improve intestinal functionality. Animal 4, 1653–1661.

Villarroel M, Barreiro P, Kettlewell P, Farish M, Mitchell M (2011): Time derivatives in air temperature and enthalpy as non-invasive welfare indicators during long distance animal transport. Biosystems Engineering 110, 253–260.

von Borell E, Schaffer D (2005): Legal requirements and assessment of stress and welfare during transportation and pre-slaughter handling of pigs. Livestock Production Science 97, 81–87.

Wamnes S, Lewis NJ, Berry RJ (2006): The performance of early-weaned piglets following transport: Effect of season and weaning weight. Canadian Journal of Animal Science 86, 337–343.

Wamnes S, Lewis NJ, Berry RJ (2008): The behaviour of early-weaned piglets following transport: Effect of season and weaning weight. Canadian Journal of Animal Science 88, 357–367.

Warriss PD (1998): Choosing appropriate space allowances for slaughter pigs transported by road: a review. Veterinary Record 142, 449–454.
Weary DM, Jasper J, Hotzel MJ (2008): Understanding weaning distress. Applied Animal Behaviour Science 110, 24–41.
Yu J, Tang S, Bao E, Zhang M, Hao Q, Yue Z (2009): The effect of transportation on the expression of heat shock proteins and meat quality of M. longissimus dorsi in pigs. Meat Science 83, 474–478.

Received: 2013–05–07
Accepted after corrections: 2013–05–20

Corresponding Author:

Daniel Mota-Rojas, Metropolitan Autonomous University-Xochimilco, Department of Animal Production and Agriculture, Mexico D.F., Mexico
Tel. +5255 5483 7535, E-mail: dmota100@yahoo.com.mx