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Effects of Pre-Slaughter Transport, Lairage and Sex on Pig Chemical Serologic Profiles

[1]D. Mota-Rojas, [2]M. Becerril Herrera, [3]M.E. Trujillo-Ortega,
[4]M. Alonso-Spilsbury, [4]S.C. Flores-Peinado and [5]I. Guerrero-Legarreta
[1]Department of Animal Production and Agriculture,
Universidad Autónoma Metropolitana, Campus Xochimilco, México, D.F
[2]Eiah-Benemérita Universidad Autónoma de Puebla, Teziutlán, Puebla, México
[3]Department of Animal Medicine and Production: Swine,
Facultad de Medicina Veterinariay Zootecnia, UNAM, México, DF, México
[4]Taller de Carnes, Facultad de Estudios Superiores Cuautitlán,
Campo 4, UNAM, Cuautitlán Izcalli, México
[5]Laboratorio Bioquímica de Macromoléculas, Departamento de Biotecnología,
Universidad Autónoma Metropolitana-Iztapalapa, México D.F

Abstract: The aim of this research was to study the effects of pre-slaughter transport and lairage on the chemical serologic profile of swine, as well as its relationship with qualitative aspects of meat: pH, color and temperature. Forty eight Pietrain x Landrace pigs were monitored (24 females and 24 barrows). They were transported on straw bedding trucks without stops during 2 h and deprived of feed and water. Blood samples were taken before loading, at arrival to the slaughterhouse, after lairage and during bleeding (20 sec after they were electrically stunned). At arrival to the slaughterhouse pigs were randomly distributed in 4 groups: Rested (n = 24) non-rested (n = 24) these groups were also divided by sex. Blood samples were taken form groups 1 and 2 and the animals sent directly to the slaughter pens, whereas groups 3 and 4, after blood sampling, were taken to lairage pens. Glucose and Creatine Kinase (CK) showed a high increase in blood concentration, associated to an increase in muscular activity and a decrease in globulins concentration as a consequence of stress and immunosuppression. Hyperglycemia and lactic acidosis detected in animals without rest were statistically different ($p<0.05$) compared to the group that rested. Bicarbonate level significantly decreased ($p<0.05$) in non-rested animals as compared to rested animals. Results indicated that animals without rest before slaughter can show hemodynamic and metabolic alterations that lead to hyperglycemia, lactic acidosis and an abrupt descent of pH, altering the carcass color.

Key words: Pigs, transport, lairage, pork quality, CK

INTRODUCTION

Information from chemical-serological profile is used to determine infectious and non infectious processes, as well as stress disorders (Clemens *et al*., 1989). Transport is stressful for pigs, decreasing animal welfare and meat quality (Warriss *et al*., 1998; Mota-Rojas *et al*., 2006; Becerril-Herrera *et al*., 2007, 2008). Tadich *et al*. (2000) evaluated several blood variables as stress indicators in bovine livestock during transport: Creatine Phosphokinase (CPK) lactate and cortisol, among others.

Conversely to other species, some pre-slaughter and post-slaughter factors affect both carcass and meat quality in different animals (Maldonado *et al*., 2007; Guerrero *et al*., 2007; Averós *et al*., 2008). Grandin (1997) reported that animal loading and unloading cause acute stress in pigs. Trip duration from the farm to the slaughterhouse usually has a negative effect on meat quality (Warris, 2000; Mota-Rojas *et al*., 2006). Long periods increase stress indicators such as: Cortisol, creatine kinase and lactate (Grandin, 2000).

The objective of this research, was to study the effect of pre-slaughter transport and lairage on serological profile of swine and its relationship to qualitative aspects of meat such as pH, color and temperature.

MATERIALS AND METHODS

Animals: The study was carried out in municipal abattoir in Central Mexico during late Winter (12-16°C average

Corresponding Author: Daniel Mota Rojas, Department of Animal Production and Agriculture, Universidad Autónoma Metropolitana, Campus Xochimilco, Calzada del Hueso 1100. Col, Villa Quietud, 04960, México D.F, México

temperature) in 48 Pietrain x Landrace finalized pigs (24 females and 24 barrows). Transport was carried out in trucks with straw bedding, according to the Animal Care Regulations in Mexico (Official Mexican Regulation NOM-024-ZOO, 1995). During transportation, animals were deprived from feed and water and loaded at 0.35 m^2/100 kg space allowance. The trip was carried out from 8-10 a.m., traveling 118 km at 60 km h^{-1} average speed.

Treatments: On arrival to the slaughterhouse, pigs were distributed at random in 4 groups: Rested (n = 24) and non-rested (n = 24) each group was divided in females and males. Group 1 (rested females) and 2 (rested males) were bled and sent to slaughter pens. Group 3 (non-rested females) and 4 (non-rested males) taken after bleeding to the lairage pen; the animals were rested under a sheds, 1.5 m^2/animal? space allowance, for 5 h. There were provided with water *ad libitum* but deprived from feed. To trance the carcasses, animals were taken to the slaughter pens according to their identification number, following the same slaughtering process. Pigs were slaughtered following Mexican regulations for commercial practice in municipal abattoirs (Official Mexican Regulation NOM-033-ZOO, 1995).

Blood samples were taken from all animals before departure, on arrival to the slaughterhouse, after lairage and during bleeding (20 sec after stunning). The samples were taken from the jugular vein in less than 30 sec and centrifuged at 2500 rpm for 10 min. The obtained serum was refrigerated at 2°C and taken to our laboratory for serological analysis.

Carcass pH and temperature determination (45 min): pH after 45 min postmortem (pH_{45}) was measured using a penetration potentiometer (HI8314, membrane pHmeter, 115 V/60 Hz. Cod. 1.1176, Hanna Instruments) and carcass temperature using a digital thermometer (model CT561C/F, Citizen) both in the *Longissimus dorsi* muscle.

Color measurement: Color was measured on *L. dorsi* cut immediately after pH and temperature measurements. The meat was also classified using a subjective color scale, according to the (NPPC, 1991) consisting in 5 color levels: Pale, slightly pink, grayish pink, light red and dark red.

Data analysis: Samples were completely randomized design, according to the following model:

$$Y_{ij} = \mu + \iota_i + \xi_{ij}$$

where:

Y_{ij} = Response variable (weight at birth)
μ = General mean
ι_i = Effect of the treatment
ξ_{ij} = Random error

Blood analysis results were analyzed using Or-Mann Whitney test and meat quality traits by Tukey test ($p<0.05$) both statistical analysis were carried out using a SAS (1999) program for personal computers.

RESULTS AND DISCUSSION

Serological profile values before and after transportation are shown in Table 1. Transport was found to the mains factor affecting these profile; significant differences were observed ($p<0.05$) in all variable comparing before and after transport. Glucose and Creatine Kinase (CK) showed an increase in blood concentration, associated to an increase in muscular activity; decrease in globulin concentration was a result of stress and immunosuppression. It is mainly produced in striated muscle cells, being one of the main enzymes for clinical evaluation. When a skeletal muscle, including cardiac muscle, is damaged or destroyed, CK difusses out of the cell, rendering high CK level in blood that quickly returns to normal after muscular damage has been caused (Kaneko *et al*., 1997).

Some cellular enzymes, such as Dehydrogenase Lactate (DHL) and CK, diffuse to the blood stream as a result of tissue damage or muscular effort (Pollard *et al*., 2002).

Serological profile values in pre slaughtering rested and non-rested animals are shown in Table 2. Significant differences were found in all values between rested and non-rested animals ($p<0.05$) except for phosphorus; no significant differences were found between sex within pre-slaughter resting. Higher concentrations of glucose, lactate, creatinine and albumin were observed in non-rested animals; most variables were within normal values

Table 1: Plasma profile before and after transportation

Compound	Before transport	After transport
Glucose (mg dL^{-1})	90.25±1.05^b	150.54±3.83^a
Lactate (mmol L^{-1})	5.10±0.21^b	24.67±0.53^a
Blood pH	7.34±0.01^a	7.03±0.01^b
Urea (mmol L^{-1})	3.21±0.03^b	4.69±0.03^a
Creatinine (µmol L^{-1})	105.84±0.38^b	142.37±0.56^a
Total bilirrubine (µmol L^{-1})	1.70±0.04^b	2.82±0.02^a
Asparto-amino transferase (AST) U L^{-1}	20.79±0.50^b	34.50±0.50^a
Creatinakinase (CK) U L^{-1}	465.62±5.82^b	794.83±9.57^a
Albumin g L^{-1}	24.08±0.45^b	35.12±0.30^a
Globulins g L^{-1}	20.54±0.41^b	26.60±0.30^a
Calcium (mmol L^{-1})	2.47±0.01^b	2.71±0.01^a
Phosphorus (mmol L^{-1})	2.13±0.005^b	2.45±0.01^a
Potasium (mmol L^{-1})	4.62±0.02^b	5.35±0.009^a
Bicarbonate (mmol L^{-1})	25.09±0.10^b	30.57±0.15^a

*The first blood sample was taken at the pens, before moving the pigs to the trucks. The second sample was collected immediately on arrival at the abattoir. ^{a,b}Means with different literals in rows are different ($p<0.05$) to the U-Mann Whitney test

Table 2: Serological profile values in pre slaughtering rested and non-rested pigs

	Rested (n = 24)		Non-rested (n = 24)	
Compound	Females	Males	Females	Males
Glucose (mg dL^{-1})	108.16±2.80^{b}	99.50±3.03^{b}	160.83±8.61^{a}	157.66±8.25^{a}
Lactate (mmol L^{-1})	14.53±0.29^{b}	15.38±0.60^{b}	25.58±0.48^{a}	26.36±0.42^{a}
Blood pH	7.21±0.01^{a}	7.26±0.02^{a}	6.97±0.03^{b}	7.0±0.02^{b}
Urea (mmol L^{-1})	4.31±0.02^{b}	4.28±0.02^{b}	4.78±0.11^{a}	4.61±0.01^{a}
Creatinine (μmol L^{-1})	103.18±0.84^{b}	106.33±1.20^{b}	144.06±0.98^{a}	140.85±0.70^{a}
Total bilirrubine (μmol L^{-1})	2.51±0.04^{b}	2.30±0.03^{b}	2.85±0.07^{a}	2.83±0.06^{a}
Asparto-amino Transferase (AST) U L^{-1}	40.33±0.49^{a}	40.33±0.66^{a}	34.0±1.15^{b}	35.0±0.85^{b}
Creatinakinase (CK) U L^{-1}	903.33±4.35^{a}	899.50±6.27^{a}	802.67±7.48^{b}	799.0±17.99^{b}
Albumin g L^{-1}	27.66±0.42^{b}	27.50±0.61^{b}	34.66±0.88^{a}	35.33±0.55^{a}
Globulins g L^{-1}	30.0±0.63^{a}	29.50±0.42^{a}	26.83±0.70^{b}	25.66±0.49^{b}
Calcium (mmol L^{-1})	2.50±0.04^{b}	2.49±0.02^{b}	2.73±0.02^{a}	2.70±0.007^{a}
Phosphorus (mmol L^{-1})	2.47±0.17^{a}	2.30±0.01^{a}	2.43±0.01^{a}	2.43±0.02^{a}
Potasium (mmol L^{-1})	5.67±0.03^{a}	5.63±0.03^{a}	5.36±0.01^{b}	5.30±0.02^{b}
Bicarbonate (mmol L^{-1})	31.68±0.18^{a}	31.83±0.19^{a}	29.93±0.35^{b}	30.51±0.19^{b}

*Blood sampling was taken before animals were housed at the lairage boxes. ^{a,b}Means with different literals in rows are different ($p<0.05$) to the U-Mann Whitney test

Table 3: Plasma profile values during bleeding in rested and non-rested males and females pigs

	Rested (n = 24)		Non-rested (n = 24)	
Compound	Females	Males	Females	Males
Glucose (mg dL^{-1})	135.50±2.8^{b}	136.83±4.81^{b}	203.33±7.37^{a}	220.66±6.60^{a}
Lactate (mmol L^{-1})	17.06±0.29^{b}	18.03±1.02^{b}	27.31±0.44^{a}	28.80±0.91^{a}
Blood pH	7.13±0.03^{a}	7.09±0.02^{a}	6.93±0.04^{b}	6.99±0.04^{AB}
Urea (mmol L^{-1})	6.41±0.07^{b}	6.50±0.11^{b}	7.13±0.13^{a}	7.31±0.07^{a}
Creatinine (μmol L^{-1})	95.25±0.43^{a}	96.07±0.95^{a}	100.13±2.57^{a}	85.05±14.80^{a}
Total bilirrubine (μmol L^{-1})	6.11±0.14^{b}	6.25±0.11^{b}	6.61±0.21^{b}	7.28±0.14^{a}
Asparto-amino transferase (AST) U L^{-1}	81.50±1.66^{b}	80.33±1.72^{b}	94.66±2.59^{a}	98.0±0.57^{a}
Creatinakinase (CK) U L^{-1}	5351.0±205.27^{b}	5512.7±54.89^{b}	6076.0±41.06^{a}	6112.0±16.90^{a}
Albumin g L^{-1}	35.16±0.47^{b}	33.83±0.79^{b}	42.33±0.42^{a}	42.16±0.30^{a}
Globulins g L^{-1}	34.50±0.42^{a}	34.16±0.60^{a}	30.0±0.63^{b}	29.16±0.79^{b}
Calcium (mmol L^{-1})	2.87±0.04^{b}	2.88±0.02^{b}	3.05±0.04^{a}	2.97±0.02^{AB}
Phosphorus (mmol L^{-1})	3.40±0.01^{c}	3.43±0.01^{c}	3.60±0.01^{b}	3.70±0.01^{a}
Potasium (mmol L^{-1})	6.02±0.35^{a}	5.61±0.03^{a}	5.42±0.007^{a}	5.34±0.02^{a}
Bicarbonate (mmol L^{-1})	19.03±0.50^{a}	19.16±0.32^{a}	16.10±0.09^{b}	16.25±0.14^{b}

*Blood sample was collected during bleeding after electric stunning. ^{a,b,c} Means with different literals in rows are different ($p<0.05$) to the U-Mann Whitney test

for rested animals. Increase of total protein was mainly due to dehydration causing hemoconcentration as a result of vomits or diarrheas and secondly, although it can be also causes by globulin increase, in the absence of dehydration, due to considtions such as advanced hepatic illnesses (cirrhosis) chronic infections and possible neoplasia.

Significant differences were observed for serological profile values during bleeding in rested and non-rested males and females animals are shown (Table 3). Although, pH and phosphorus level varied with sex, pH of non-rested males was more alkaline (6.99) than in non-rested females (6.93) phosphorus level was statistically different in non-rested males (3.7) than in females (3.6) and to rested animals (3.43 in males and 3.40 in females). Increase in phosphorus level was due to carbohydrate metabolism.

Pollard *et al.* (2002) demonstrated that CK level depends on type and duration of transport, whereas Kaneko *et al.* (1997) found that vitamin E and selenium deficiency or both resulted in an increase in CK levels in pigs, although this was not found in PSE pork.

Hiperglucemia and lactacidemia observed in non-rested animals was significantly different ($p<0.05$) to the rested group. Lactoacidemia results from rapid energy production, mainly via glycolysis and is an indication of stress (Trujillo-Ortega *et al.*, 2007; Orozco-Gregorio *et al.*, 2008). It is worth mentioning that bicarbonate levels was significantly reduced (16 mmol L^{-1}) ($p<0.05$) in the non-rested group, but not in rested animals (19 mmol L^{-1}). Acidosis in stressed animals is a mechanism to reestablish normal pH, using bicarbonate present in the system (HCO_3^-) which acts as a buffer, reestablishing the lost acid-base balance (Alonso-Spilsbury *et al.*, 2005).

Blood temperature during exsanguinations was significantly higher in non-rested females (39.86°C) ($p>0.05$) as compared to males and rested animals, as shown in Table 4; no significant difference was observed between rested males and females.

No differences were observed in hot carcass pH in non-rested males and females; conversely, differences were observed between males and females in rested animals. Resting was a determinant factor in meat color;

Table 4: Carcass variables in rested and non-rested pigs

	Rested n = 24		Non-rested n = 24	
Variable	Females	Males	Females	Males
Blood temperature during exsanguination*	39.02±0.03^{c}	39.15±0.01^{c}	39.86±0.04^{b}	40.39±0.19^{a}
Hot carcass temperature at 45 min	38.93±0.05^{c}	39.01±0.04^{c}	39.94±0.08^{b}	40.48±0.21^{a}
Hot carcass pH 45 min	6.20±0.01^{a}	6.11±0.006^{b}	6.01±0.02^{c}	5.94±0.02^{c}
Cold carcass pH (after 24 h refrigeration)	5.54±0.01^{a}	5.53±0.01^{b}	5.56±0.02^{b}	5.63±0.01^{a}
Meat color	3.0±0.0^{a}	2.83±1.66^{a}	2.50±0.22^{ab}	1.83±0.30^{b}

*Sample temperature of blood was taken during bleeding shortly after electrical stunning. ^{a,b,c} Means with different literals in rows are different ($p<0.05$) to the U-Mann Whitney test

bright-red color is observed in rested animals, although no significant differences was due to sex. Less desirable, brown coloration was observed in meat from non-rested males; resting resulted in significant differences for males, as well as for females.

Schäfer *et al.* (2002) found that the metabolic processes and environmental factors immediately before and after death affect pH and temperature during the 1st 2 post-mortem hours, being critical for the subsequent water drip loss in meat.

Prolonged journeys in crowded trucks affect meat quality due to glycogen decrease, causing exhaustion in animals (Averós *et al.*, 2008). When pigs are subjected to acute stress (8 h transport) the incidence of pale coloration (similar to PSE condition) was higher, occurring mostly in males (Mota-Rojas *et al.*, 2006). On the other hand, when pigs were subjected to a chronic or prolonged stress, incidence of dark colored carcasses, similar to DFD meat was higher (Becerril-Herrera *et al.*, 2007).

Gallo *et al.* (2003) also demonstrated that heifer meat color is influenced by muscle glycogen level before slaughtering, affecting postmortem pH decrease as well as final pH. Nevertheless, Brown *et al.* (1999) found progressive pH increase in pig *Longissimus dorsi* after a prolonged journey (24 h).

Gallo *et al.* (2000) reported high pH_{45} variation and color among individuals, concluding that some animals are more susceptible; these authors recommended more studied on traveling time using higher population numbers under stress conditions in order to determine whether time of transportation or transport conditions are the leading factors for carcass characteristic alterations.

CONCLUSION

Variation in chemical profile variables was mainly a consequence of the unfavorable conditions of animal welfare, together with the organism own control mechanisms to maintain homeostasis. Results of this study indicate that pigs non-rested pigs before slaughtering presented hemodynamic and metabolic alterations leading to hyperglycemia, lactoacidemia and fast pH decrease, leading to meat coloration alteration.

REFERENCES

Alonso-Spilsbury, M., D. Mota-Rojas, D. Villanueva-García, J. Martínez-Burnes, H.G. Orozco, R. Ramírez-Necoechea, A. López and M.E. Trujillo-Ortega, 2005. Perinatal asphyxia pathophysiology in foetal and human neonate: A Review. Anim. Reprod. Sci., 90: 1-30. DOI: 10.1016/j.anireprosci.2005.01.007.

Averós, X., T.G. Knowles, S.N. Brown, P.D. Warriss and L.F. Gosálvez, 2008. Factors affecting the mortality of pigs being transported to slaughter. Vet. Rec., 163: 386-390. http://veterinaryrecord.bvapublications.com/cgi/reprint/163/13/386.

Becerril-Herrera, M., D. Mota-Rojas, I. Guerrero-Legarreta, M. González-Lozano, P. Sánchez-Aparicio, C. Lemus-Flores, S. Flores-Peinado, R. Ramírez-Necoechea and M. Alonso-Spilsbury, 2007. Effects of additional space during transport on pre-slaughter traits of pigs. J. Biol. Sci., 7 (7): 1112-1120. http://www.ansijournals.com/jbs/ 2007/1112-1120.pdf.

Becerril-Herrera, M., M. Alonso-Spilsbury, C. Lemus-Flores, I. Guerrero-Legarreta, A. Olmos-Hernández, R. Ramírez-Necoechea and D. Mota-Rojas, 2008. CO_2 stunning may compromise swine welfare compared with electrical stunning. Meat Sci., 81: 233-237. DOI: 10.1016/j.meatsci.2008.07.025.

Brown, S.N., T.G. Knowles, J.E. Edwards and P.D. Warriss, 1999. Behavioural and physiological responses of pigs to being transported for up to 24 h followed by 6 h recovery in lairage. Vet. Rec., 145 (15): 421-426. http://veterinaryrecord.bvapublications.com/cgi/reprint/145/15/421.

Clemens, E.T., B.D. Schultz, M.C. Brumm, G.W. Jesse and H.F. Mayes, 1989. Serum chemical profile of feeder pigs, as influenced by market stress and feeding regimen. Am. J. Vet. Res., 50 (7): 1114-1117. http://www.ncbi.nlm.nih.gov/pubmed/2774336.

Gallo, C., S. Pérez, C. Sanhueza and J. Gasic, 2000. Effects of transport time of steers before slaughter on behaviour, weight loss and some carcass characteristics. Arch. Med. Vet., 32 (2): 157-170. http://www.scielo.cl/scielo.php?pid=S0301-732X2000000200003&script=sci_arttext.

Gallo, C., G. Lizondo and T.G. Knowles, 2003. Effects of journey and lairage time on steers transported to slaughter in Chile. Vet. Rec., 152 (12): 361-364. http://www.scielo.cl/scielo.php?pid=S0301-732X2000000200003&script=sci_arttext.

Grandin, T., 2000. Livestock Handling and Transport. 2nd Edn. U.K. CABI Publ., pp: 464. ISBN: 978085-1994093.

Grandin, T., 1997. Assessment of stress during handling and transport. J. Anim. Sci., 75: 249-257. PMID: 9027573. http://jas.fass.org/cgi/reprint/75/1/249.

Guerrero, M.Y., S. Flores-Peinado, M. Becerril-Herrera, A. Cardona-Lejia, M. Alonso-Spilsbury, M. Zamora-Fonseca, J. Toca, R. Ramírez, J. Toca and D. Mota-Rojas, 2007. Insensibilization of California breed rabbits and it's effect on sanguineous pH, temperature, glucose levels, creatine kinase and slaughter performance. J. Anim. Vet. Adv., 6 (3): 410-415. http://www.medwelljournals.com/fulltext/ java/2007/410-415.pdf.

Kaneko, J.J., J.W. Harvey and M.L. Bruss, 1997. Clinical biochemistry of domestic animals. USA: Academic Press. 5th Edn., pp: 294.

Maldonado, M.J., D. Mota-Rojas, M. Becerril-Herrera, S. Flores-Peinado, D. Camacho-Morfín, A. Cardona-Leija, R. Ramírez-Necoechea, L. Morfín-Loyden, M. González-Lozano, M.E. Pereda-Solís and M. Alonso-Spilsbury, 2007. Broiler Welfare Evaluation Through 2 Stunning Methods: Effects on Critical Blood Variables and Carcass Yield. J. Anim. Vet. Adv., 6 (12): 1469-1473. http://www.medwelljournals.com/fulltext/java/2007/1469-1473.pdf.

Mota-Rojas, D., M. Becerril-Herrera, C. Lemus, P. Sánchez, M. González, A. Olmos, R. Ramírez and M. Alonso-Spilsbury, 2006. Effects of mid-summer transport duration on pre-and post-slaughter performance and pork quality in Mexico. Meat Sci., 73: 404-412. DOI: 10.1016/j.meatsci.2005.11.012.

NPPC, National Pork Producer Council, 1991. Procedures to evaluate market hogs. Bulletin Des Moines, IA. pp: 11-16. http://www.nppc.org.

Official Mexican Regulation NOM-024-Z00, 1995. Especificaciones y características zoosanitarias para el transporte de animales, sus productos y subproductos, productos químicos, farmacéuticos, biológicos y alimenticios para uso en animales o consumo por éstos. Diario Oficial de la Federación, 10-16-95. http://www.sagarpa.gob.mx/dlg/hidalgo/sagarpahidalgo/ganaderia/NOM-024-ZOO-1995.pdf.

Official Mexican Regulation NOM-033-ZOO, 1995. Sacrificio humanitario de los animales domésticos y silvestres. Diario Oficial de la Federación 16 de julio de. http://www.economia.gob.mx/work/normas/noms/ 1996/033-zoo.pdf.

Orozco-Gregorio, H., D. Mota-Rojas, M. Alonso-Spilsbury, A. Olmos, R. Ramírez, Y. Velazquez, A. Nava-Ocampo, R. Hernández-González, M.E. Trujillo-Ortega and D. Villanueva-García, 2008. Short-term neurophysiologic consequences of intrapartum asphyxia in piglets born by spontaneous parturition. Int. J. Neurosci., 118: 1299-1315. DOI: 10.10 80/00207450701872846.

Pollard, J.C., R.P. Littlejohn, G.W. Asher, A.J.T. Pearse, J.M. Stevenson-Barry, S.K. Mcgregor, T.R. Manley, S.J. Duncan, C.M. Sutton, K.L. Pllock and J. Prescott, 2002. A comparison of biochemical and meat quality variables in red deer (Cervus elaphus) following either slaughter plant. Meat Sci., 60: 85-94. DOI: 10.1016/ S0309-1740(01)00110-3.

SAS, 1999. SAS/STAT Guide for Personal Computers. Version 8 SAS Institute Inc. Cary, NC. USA. http://www.uwm.edu/IMT/Computing/sasdoc8/sashtml/common/images/copyrite.htm.

Schäfer, A., K. Rosenvold, P.P. Purslow, H.J. Andersen and P. Henckel, 2002. Physiological and structural events post mortem of importance for drip loss in pork. Meat Sci., 61: 355-366. DOI: 10.1016/S0309-1740(01) 00205-4.

Tadich, N., C. Gallo and M. Alvarado, 2000. Effects on cattle of transportation by road up to 36 h with and without a rest on some blood variables indicator of stress. Arch. Med. Vet., 32 (2): 171-183. http://www.produccionbovina.com/etologia_y_bienestar/bienestar_en_bovinos/13-stres.pdf.

Trujillo-Ortega, M.E., D. Mota-Rojas, A. Olmos, M. Alonso-Spilsbury, M.M. González, M.H. Orozco, R. Ramírez and A.A. Nava, 2007. A study of piglets born by spontaneous parturition under uncontrolled conditions: Could this be a naturalistic model for the study of intrapartum asphyxia? Acta Biomed., 78: 29-35. http://www.actabiomedica.it/data/2007/1_2007/ trujillo_ortega.pdf.

Warriss, P.D., S.N. Brown, P.P. Barton, C. Gade, L. Santos, N. Costa, E. Lambooij and R. Geers, 1998. An analysis of data relating to pig carcass quality and indices of stress collected in the European Union. Meat Sci., 49 (2): 137-144. DOI: 10.1016/S0309-1740(97)00133-2.

Warriss, P.D., 2000. Meat science: An Introductory Text. 1st Edn. Wallingford. Oxon, U.K. CABI Publ., pp: 310. ISBN-10: 0851994245.