aJava

Asian Journal of Animal and Veterinary Advances

Academic
Journals Inc.

www.academicjournals.com

Asian Journal of Animal and Veterinary Advances 6 (12): 1256-1263, 2011
ISSN 1683-9919 / DOI: 10.3923/ajava.2011.1256.1263

Physiological Response and Welfare of Ducks During Slaughter

[1]P. Roldan-Santiago, [1]M. González-Lozano, [2]S.C. Flores-Peinado, [2]D. Camacho-Morfín, [3]M. Concepción-Méndez, [2]L. Morfín-Loyden, [2]P. Mora-Medina, [1]R. Ramírez-Necoechea, [2]A.L. Cardona and [1]D. Mota-Rojas

[1]Department of Animal Production and Agriculture, Universidad Autónoma Metropolitana, Campus Xochimilco, Stress Physiology and Farm Animal Welfare, México, D.F. México

[2]Departament of Ciencias Pecuarias, Facultad de Estudios Superiores Cuautitlán, Universidad Nacional Autónoma de México, Cuautitlán Izcalli, Estado de México

[3]Facultad de Ciencias Naturales, Universidad Autónoma de Querétaro, Licenciatura en Medicina Veterinaria y Zootecnia, Juriquilla, Santa Rosa Jauregui, Querétaro, Mexico

Corresponding Author: D. Mota-Rojas, Stress Physiology and Farm Animal Welfare, Universidad Autónoma Metropolitana, Calz, del Hueso 1100, Col, Villa Quietud, México D.F. México

ABSTRACT

This study was undertaken with the goal of assessing the responses to stress in ducks slaughtered by two different methods on the basis of measuring the critical blood variables of 90 White Peking ducks (*Anas platyrhynchos*) with a mean weight of 2200±30 g. Reference values were established by taking samples from 30 ducks at rest; another 30 birds were stunned electrically; while 30 more were slaughtered by decapitation without prior stunning. The physiometabolic profile assessed included the following critical blood variables. Results revealed statistically significant differences ($p<0.05$) between lactate concentrations (72.13±21.71; 57.87±19.60; 57.31±25.91) and pCO_2 (44.27±8.31; 32.27±4.31; 31.52±4.38) and between the reference values and the levels obtained from the groups of ducks sacrificed using the different methods. The metabolic adjustments that occurred in these White Peking ducks at the time of sacrifice depended on the slaughtering process itself, regardless of stunning method. The birds that were slaughtered presented low values of Ca^{++} and lactate, two indicators of agony, sensibility to pain and stress that affect animal welfare. The values of CO_2 and blood lactate statistically decreased when compared with baseline. The behavior of this physiometabolic profile in the duck is completely different from pork, lamb or beef. A better understanding of the physiometabolic processes of ducks will allow us to improve handling, prevent stress and comply with the Mexican Norms for humane treatment and prevention of pain during the slaughtering of animals.

Key words: Animal welfare, ducks, electric stunning, pre-mortem stress, gasometry

INTRODUCTION

Currently many researchers studying stress in animals from different approaches (Olmos-Hernandez *et al*., 2008; Vahdatpour *et al*., 2009; Konca *et al*., 2009; Sattari *et al*., 2009; Ceylan *et al*., 2009; Dehghan *et al*., 2010; Yildirim and Yurekli, 2010; Hamidi *et al*., 2010; Ince *et al*., 2010; Mota-Rojas *et al*., 2011a, b). Currently, duck meat is one option for obtaining low-cost proteins of animal origin that can be produced on a large scale to obtain a wide variety

of processed products (Hird *et al*., 2005). However, the stress mechanisms triggered during slaughter in this species have physiological repercussions on the animals' homeostasis that directly affect their welfare. This is important because the main objective of ensuring animal welfare is to eliminate fear and pain during the animal's life. On this point, Manteca (2007) mentioned that during slaughter, animals are exposed to new experiences that inevitably cause fear. Thus, one of the most important aspects of ante-mortem handling that must be assessed to improve animal welfare is stunning.

Pre-slaughter stunning induces a state of unconsciousness that inhibits activation of the eyelids and the somato-sensorial system (Heath, 1984). The ideal stunning method is one that guarantees the best conditions of animal welfare (i.e., produces minimal phases of pain and excitation), while minimizing problems with final product quality and assuring safe conditions for operators, all at a minimum economic cost (Ingling and Kuenzel, 1978; Manteca, 2007). In this regard, Mexico has established the "Official Mexican Norms" (NOM-033-ZOO, 1995) that oblige processors to stun birds prior to slaughter in order to ensure a humanitarian form of slaughter. Also, the scientific literature states that the correct application of some stunning method in birds reduces brusque movements such as fluttering and violent contractions during bleeding (McNeal *et al*., 2003; McNeal and Fletcher, 2003). But stunning methods have effects on post-mortem metabolic indexes (glycolysis, accumulation of lactic acid, depletion of ATP) that, over time, will also have repercussions on meat quality in the canal (McNeal and Fletcher, 2003).

Our accumulated knowledge of the metabolic profile and blood gas exchanges in slaughter animals provides an understanding of the repercussions of the ante-mortem stressors (Mota-Rojas *et al*., 2006, 2008; Gonzalez *et al*., 2007). Maintaining high standards of animal welfare during transportation and slaughter requires the appropriate equipment and supervision of employees. Besides, animals should be unconscious at the time of slaughter in order to avoid pain and stress during the procedure (Becerril-Herrera *et al*., 2009, 2010; Mota-Rojas *et al*., 2009). However, analyses of the physiometabolic indicators or blood profiles of ducks destined for human consumption are few, despite the fact that these elements are deemed indicators of stress in animals taken to slaughter and are closely related to animal welfare (Omojola, 2007).

Therefore, the principal objective of this research was to assess the welfare of ducks sacrificed by two different methods of slaughter and the effects of those processes on gas exchanges, energy metabolism and acid-base and mineral imbalances.

MATERIALS AND METHODS

Population and lodging: This study was conducted (2009) at the Centro de Enseñanza de la Facultad de Estudios Superiores Cuautitlán, Universidad Nacional Autónoma de México (FES-C, UNAM), located in Cuautitlán, State of Mexico. A total population of 300 ducks housed in a production facility at the FES-C, UNAM included 90 birds of the White Peking breed (*Anas platyrhynchos*) with a mean weight of 2200±30 g. All the ducks were fed a diet with the following nutritional components: 18 PC, 6 fat, 5 fiber, 6 ash, 12 moisture and 53% Nitrogen Free Extract (NFE). The ambient conditions in the facility where the ducks were kept during fattening were: temperature 18.5°C, wind velocity 6.7 m s^{-1} and light intensity 1 lux.

Groups: Dividing the groups for the study reflected the method of sacrifice used, as the aim was to compare the effects of two processes on the critical blood variables that are indicators of animal

welfare. Of the total of 300 ducks at the production facility, 90 were selected at random: 30 were used to take the reference values; 30 others were sacrificed after electrical stunning; and the other 30 were slaughtered by decapitation with no prior electrical stunning. The experiment was conducted in accordance with the guidelines for the ethical use of experimental animals (Sherwin *et al*., 2003).

Prior to the slaughtering process, blood samples were taken from 30 randomly chosen ducks to obtain reference values. Samples were extracted inside the production facility where the ducks were housed and were then processed, taking into account that the birds were at rest and had suffered only minimal handling. During the extraction of the reference samples, the ducks were blindfolded with a dark-colored band, taking care not to interfere with their breathing and adhering to a time parameter of less than 30 sec of immobilization so as to avoid causing stress while the sample was obtained through a puncture in the radial vein.

Once the reference values were obtained, the birds in the two groups destined to be slaughtered by the two different methods were transferred from the production facility to the meat-processing area at the Faculty of Higher Studies of Cuautitlan, located at a distance of approximately 100 m (330 f). Those ducks were moved individually and were also blindfolded, as described above, in order to keep them calm and avoid causing stress. When the ducks arrived at the meat-processing area each bird's weight was recorded and they were placed in lairage corrals in groups of 10, where they remained for 1 h until slaughtering began.

Slaughtering and sample analysis

With electric stunning: For the birds destined to be sacrificed after electric stunning, the method involved applying a voltage of 150 mA for 5 sec. The negative electrode was placed first and then the positive electrode, to avoid any deviation to ground and causing stress in the ducks.

Without electric stunning: Both the rear extremities and wings of the ducks were restrained to prevent them from making brusque movements when sacrificed. Only the ducks in this group had their wings so restrained.

In both groups, slaughtering was done by sectioning the carotid artery and jugular veins; care was taken not to affect the atlanto-occipital articulation.

Immediately after slaughter, blood samples were collected in 5 mL containers previously heparinized to preclude any modification of the values of the blood gases and metabolites. Once obtained, each sample was placed in a blood gas and electrolyte parameter analyzer (GEM Premier 3000, Instrumentation, Laboratory Diagnostics USA/Italy). The physiometabolic profile took into account the following critical blood variables: hematocrit (%), glucose (mg dL^{-1}), electrolytes [Na^+, K^+ and Ca^{++} (mmol L^{-1})]; lactate levels (mg dL^{-1}); partial carbon dioxide pressure [pCO_2 (mmHg)] and oxygen [pO_2 (mmHg)].

Statistical analysis: The variables pertaining to the acid-base balance, energy metabolism and blood gases were analyzed statistically utilizing a totally random design. The reference values of the ducks slaughtered was compared using the two methods of sacrifice (with and without, prior electric stunning). The mathematical model used was as follows:

$$Yij = \mu + \iota\, i + \xi ij,\ i = 1, 2, 3\ \text{Groups},\ j = 1, 2, 3 \ldots \text{Repetitions}$$

Where:
Yij = Variable response (weight at slaughter)
μ = General mean
ιi = Group effect
ξij = Random error

Results were analyzed using a computerized program for statistical analysis (SAS, 2004), according to the model proposed and the following procedures:

- To determine the existence of statistical differences among the means of the variables evaluated, a Tukey test was used ($p<0.05$)
- The variable of blood pH was analyzed using a Kruskal-Walllis test and is shown as Mean±ranges (SAS, 2004)

RESULTS

There is statistical evidence to support the affirmation that the metabolic alterations that occurred in the White Peking ducks (*Anas platyrhynchos*) at the time of slaughter depended on the method of sacrifice used, regardless of stunning. The most significant differences were observed upon comparing the results from the reference group with those of the groups of ducks sacrificed with and without, electric stunning (Table 1). Temperature was different only in the birds sacrificed without prior stunning when compared to that of the ducks in the reference group ($p<0.05$) while comparisons of the data on the temperatures of the groups slaughtered using two different methods showed no differences (Table 1). The values of glucose, calcium and potassium were not statistically different ($p>0.05$) between ducks slaughtered by electrical stunning versus non-stunned. The percentage of hematocrit was not changed according to the method of stunning. The sodium level falls significantly ($p<0.05$) in both groups of ducks regardless of method of slaughter (Table 1). Blood pH and pO_2 revealed an increase at the moment of slaughter for both methods of slaughter, compared to the reference group ($p<0.05$). The levels of blood pCO_2, Na^+ and lactate presented reductions at the time of slaughter for both groups that were sacrificed, compared to the reference values ($p<0.05$). The pCO_2 values were approximately 12 mmHg lower in the ducks that were sacrificed, while the values for lactate were approximately 14 mg dL^{-1} higher in the ducks in the reference group ($p<0.05$) (Fig. 1).

Table 1: Blood electrolytes and metabolites of White Peking ducks (*Anas platyrhynchos*) upon slaughtering, after electric stunning and after decapitation only

Parameter	*Reference values (n = 30)	With prior electric stunning (n = 30)	Without stunning (n = 30)
Temperature (°C)	33.73±1.80^a	33.04±2.25^{ab}	32.33±2.22^b
Na^+ (mmol L^{-1})	144.20±3.99^a	140.20±2.91^b	140.28±3.28^b
K^+ (mmol L^{-1})	6.12±0.58^a	6.20±0.45^a	5.73±0.98^a
Ca^{++} (mmol L^{-1})	1.27±0.05^a	1.28±0.05^a	1.28±0.04^a
Glucose (mg dL^{-1})	203.67±13.53^a	201.43±22.86^a	199.52±14.40^a
Hematocrit (%)	44.00±2.91^a	44.30±2.93^a	44.41±3.49^a

*The reference values correspond to ducks at rest with access to water and food, housed at a production facility. Different litters in the same row indicate differences between groups according to the Tukey test ($p<0.05$). Values are presented as Mean±SD

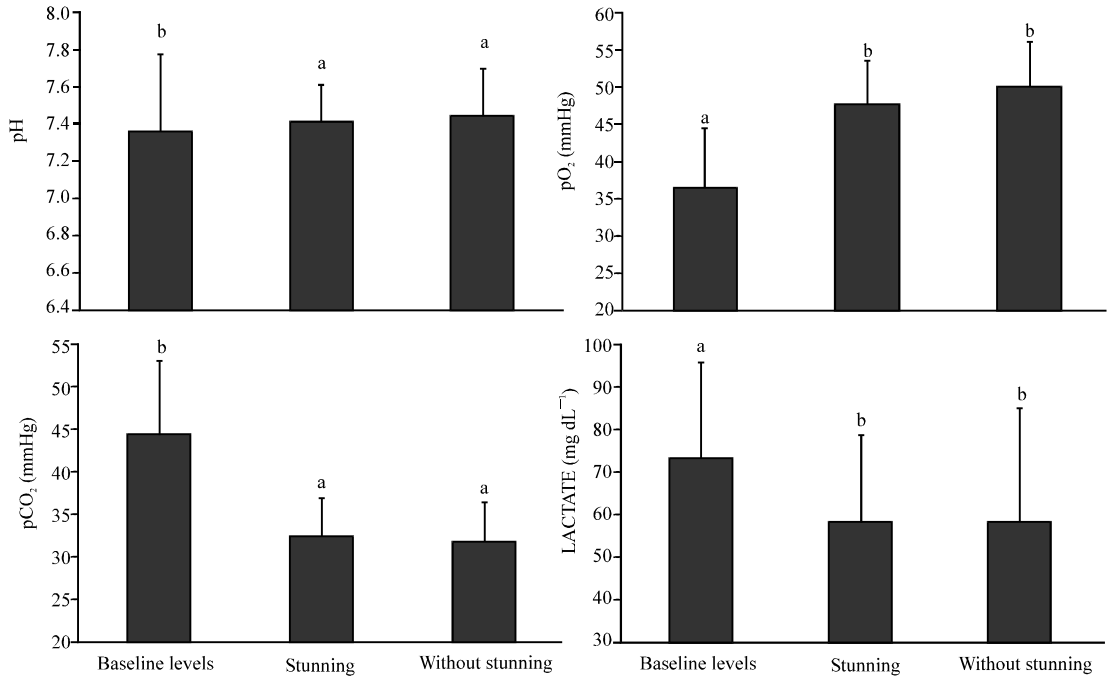

Fig. 1: Variables from the biochemical blood profile (pH, pO_2, pCO_2 and lactate) of a group of ducks first rendered unconscious by electric stunning and a group slaughtered without stunning (decapitation only). Different letter between bars show significant differences between the groups ($p<0.05$)

DISCUSSION

In this study, the birds that were slaughtered had low Ca^{++} and lactate values, two important indicators of agony, sensitivity to pain and, according to more recent studies, also stress. It appears that the metabolic adjustments that took place in the White Peking ducks (*Anas platyrhynchos*) at the time of slaughter depend on the method of sacrifice used, regardless of stunning. Although, no differences were observed in the physiometabolic variables of the birds sacrificed using the two different methods, results from the group that was electrically stunned prior to sacrifice show that the time required for slaughtering decreased, as the volume and velocity of bleeding increased. During the slaughtering procedures involving the two different methods of sacrifice, care was taken to assure an adequate immobilization of the birds so as to prevent any stress-related response during slaughtering and death. These measures not only made the bleeding process safer for the operators, they also reduced the incidence of injuries to the ducks, such as bone fractures and bruising.

pH, pCO_2 and temperature: In this study, blood pH increased at the moment of slaughtering under both conditions of sacrifice, compared to the group that supplied the reference values. It is well known that blood pH reflects states of respiratory and metabolic alkalosis or acidosis and that alterations of this parameter are explained by the proportion of CO_2 in the animal's organism at the time of sacrifice. We observed that the birds that were electrically stunned showed a close relation among the variables, such that the increase in the pH values corresponded to a reduced level of

pCO_2, suggesting that the birds' responses as reflected in these variables were of a compensatory type. Qiao *et al.* (2001) affirm that pH is a fundamental component of the metabolism of birds and can be used to predict or ascertain post-mortem meat quality in the canal; but the factor of pH has other implications for the homeostasis of the organism. Despite the increase in the concentrations of hydrogen ions caused by the formation of carbon dioxide (CO_2) that results from the gas exchanges, blood plasma pH should remain constant, since enzymatic activity and metabolic processes require controlling pH within very narrow limits (Franson, 1995). Therefore, because pH is so closely related to pCO_2, both procedures employed -i.e., slaughtering with and without, prior electric stunning-drastically reduced pCO_2 when compared to the reference group.

This study also revealed a tendency towards a temperature reduction in the ducks that were sacrificed using the two methods tested and between the ducks sacrificed without prior stunning (only decapitation) and those of the birds in the reference group. In ducks, temperature decreases are regulated by processes of radiation, conduction, convection and evaporation (Sturkie, 2000; Quintana, 2006). Because these birds have no sweat glands, they can shed heat by short-wave radiation through the skin, but the primary mechanism they use is panting, which allows liquids from the lungs to evaporate and thus results in a loss of body temperature. The small, excess quantities of oxygen combine with hemoglobin to form oxyhemoglobin, but the increase of pCO_2 produces a more acidic environment that propitiates the liberation of oxygen from the hemoglobin.

The elevated pO_2 values seen at the moment of slaughter in this study may indicate a compensatory mechanism in the ducks. In this regard, it is important to recall that panting is related to hyperventilation in birds, one result of which is a higher concentration of blood oxygen.

Lactate: With respect to lactate, we observed a decrease of this value in the ducks at the time of slaughter. Gonzalez *et al.* (2007) and Maldonado *et al.* (2007) mentioned that the reduction in post-sacrifice lactate levels is due to the fact that in stressful situations ducks utilize lactate as an alternative source of energy, instead of increasing lactate levels as occurs in mammals. On this issue, Sturkie (2000) affirmed that birds that suffer a process of oxygen deprivation followed by an increase of lactic acid in the blood and a reduction of the buffering capacity of bicarbonate (HCO_3) experience an increase in carbon dioxide (CO_2) that provokes changes and modifications in pH. The critical blood variables evaluated in this study allowed us to observe the metabolic modifications that took place in the ducks due to the effect of the slaughtering process. Thus, the blood metabolic profile opens up the possibility of implementing methods that procure animal welfare. Today, lactate is considered a key variable or indicator in assessments of animal welfare in several species (Becerril-Herrera *et al.*, 2009, 2010; Edwards *et al.*, 2010); thus, in the specific case of ducks it must be taken into account in all assessments, as was the case in this study.

CONCLUSION

It appears that the metabolic adjustments that take place in White Peking ducks (*Anas platyrhynchos*) at the moment of slaughter depend on the sacrificing process used, regardless of stunning method. The ducks that were slaughtered presented low Ca^{++} and lactate values, two key indicators of agony, sensitivity to pain and stress that are directly related to animal welfare. A better understanding of the physiometabolic processes of ducks will allow us to improve handling, prevent stress and comply with the Mexican Norms for humane treatment and prevention of pain during the slaughtering of animals.

REFERENCES

Becerril-Herrera, M., M. Alonso-Spilsbury, C. Lemus-Flores, I. Guerrero-Legarreta, A. Olmos-Hernandez, R. Ramirez-Necoechea and D. Mota-Rojas, 2009. CO_2 stunning may compromise swine welfare compared with electrical stunning. Meat Sci., 81: 233-237.

Becerril-Herrera, M., M. Alonso-Spilsbury, M.E. Trujillo-Ortega, I. Guerrero-Legarreta and R. Ramirez-Necoechea *et al.*, 2010. Changes in blood constituents of swine transported for 8 or 16 h to an Abattoir. Meat Sci., 86: 945-948.

Ceylan, E., S. Dede, Y. Deger and I. Yoruk, 2009. Investigation of the effects of carrying heavy load on prooxidation/antioxidant status and vitamin D_3 in healthy horses. Asian J. Anim. Vet. Adv., 4: 41-46.

Dehghan, A., M. Arabi, S. Nahid and M. Aminlari, 2010. Changes of serum reduced and oxidized glutathione in heat stressed ram. Asian J. Anim. Vet. Adv., 5: 472-477.

Edwards, L.N., T. Grandin, T.E. Engle, S.P. Porter, M.J. Ritter, A.A. Sosnicki and D.B. Anderson, 2010. Use of exsanguination blood lactate to assess the quality of pre-slaughter pig handling. Meat Sci., 86: 384-390.

Franson, R.D., 1995. Anatomy and Physiology of Domestic Animals. Interamericana-McGraw-Hill, New York. .

Gonzalez, V.A., G.E. Rojas, A.E. Aguilera, S.C. Flores-Peinado and C. Lemus-Flores *et al.*, 2007. Effect of heat stress during transport and rest before slaughter, on the metabolic profile, blood gases and meat quality of quail. Int. J. Poult. Sci., 6: 397-402.

Hamidi, H., R. Jahanian and J. Pourreza, 2010. Effect of dietary betaine on performance, immunocompetence and gut contents osmolarity of broilers challenged with a mixed coccidial infection. Asian J. Anim. Vet. Adv., 5: 193-201.

Heath, G.B.S., 1984. The slaughter of broiler chickens. Poult. Sci., 40: 151-159.

Hird, H., J. Chisholm and J. Brown, 2005. The detection of commercial duck species in food using a single probe-multiple species-specific primer real-time PCR assay. Eur. Food Res. Technol., 221: 559-563.

Ince, S., I. Kucukkurt, I. Aytekin and E. Bacak, 2010. Short-term effect of deltamethrin treatment on oxidative stress biomarkers in anatolian water buffaloes. Asian J. Anim. Vet. Adv., 5: 266-270.

Ingling, A.L. and W.J. Kuenzel, 1978. Electrical terminology, measurements and units associated with the stunning technique in poultry processing plants. Poult. Sci., 57: 127-133.

Konca, Y., F. Kirkpinar, S. Mert and S. Yurtseven, 2009. Effects of dietary ascorbic acid supplementation on growth performance, carcass, bone quality and blood parameters in broilers during natural summer temperature. Asian J. Anim. Vet. Adv., 4: 139-147.

Maldonado, M.J., D. Mota-Rojas, M. Becerril-Herrera, S.C. Flores-Peinado and D. Camacho-Morfín *et al.*, 2007. Broiler welfare evaluation through two stunning methods: Effects on critical blood variables and carcass yield. J. Anim. Vet. Adv. 6: 1469-1473.

Manteca, V.X., 2007. Critical points in managing ante-mortem in pigs. Effect of Stunning on the Welfare and Quality. Facultad de Veterinaria, Montevideo. Uruguay.

McNeal, W.D. and D.L. Fletcher, 2003. Effects of high frequency electrical stunning and decapitation on early rigor development and meat quality of broiler breast meat. Poult. Sci., 82: 1352-1355.

McNeal, W.D., D.L. Fletcher and R.J. Buhr, 2003. Effects of stunning and decapitation on broiler activity during bleeding, blood loss, carcass and breast meat quality. Poult. Sci., 82: 163-168.

Mota-Rojas, D., M. Becerril, C. Lemus, P. Sanchez and M. Gonzalez *et al.*, 2006. Effects of mid-summer transport duration on pre-and post-slaughter performance and pork quality in Mexico. Meat Sci., 73: 404-412.

Mota-Rojas, D., M.J. Maldonado, M.H. Becerril, S.C.P. Flores and M. Gonzalez-Lozano *et al.*, 2008. Welfare at slaughter of broiler chickens: A review. Int. J. Poult. Sci., 7: 1-5.

Mota-Rojas, D., M.B. Herrera, M.E. Trujillo-Ortega, M. Alonso-Spilsbury, S.C. Flores-Peinado and I. Guerrero-Legarreta, 2009. Effects of pre-slaughter transport, lairage and sex on pig chemical serologic profiles. J. Anim. Vet. Adv., 8: 246-250.

Mota-Rojas, D., H. Orozco-Gregorio, D. Villanueva-Garcia, H. Bonilla-Jaime and X. Suarez-Bonilla *et al.*, 2011a. Foetal and neonatal energy metabolism in pigs and humans: A review. Vet. Med., 56: 215-225.

Mota-Rojas, D., H. Orozco-Gregorio, M. Gonzalez-Lozano, P. Roldan-Santiago, R. Martinez-Rodriguez, M. Sanchez-Hernandez and M.E. Trujillo-Ortega, 2011b. Therapeutic approaches in animals to reduce the impact of stress during transport to the slaughterhouse: A review. Int. J. Pharmacol., 7: 568-578.

NOM-033-ZOO, 1995. Norma oficial Mexicana, Humanitarian slaughter of domestic and wild animals. (Sacrificio humanitario de los animales domesticos y silvestres). July 7th, 1995 En El Diario Oficial de la Federacion, Mexico.

Olmos-Hernandez, A., M.E. Trujillo-Ortega, M. Alonso-Spilsbury, R. Ramirez-Necoechea and D. Mota-Rojas, 2008. Foetal monitoring, uterine dynamics and reproductive performance in spontaneous farrowing sows. J. Applied Anim. Res., 33: 181-185.

Omojola, A.B., 2007. Carcass and organoleptic characteristics of duck meat as influenced by breed and sex. Int. J. Poult. Sci., 6: 329-334.

Qiao, M., D.L. Fletcher, D.P. Smith and J.K. Northcutt, 2001. The effect of broiler breast meat color on pH, moisture, water-holding capacity and emulsification capacity. Poult. Sci., 80: 676-680.

Quintana, J.A., 2006. Management of Most Common Domestic Fowl. 3rd Edn., Trillas Publication, Mexico.

SAS, 2004. SAS Institute User's Guide. Version 9.2, SAS Institute, Inc., Cary, NC., USA.

Sattari, A., S.S. Mirzargar, A. Abrishamifar, R. Lourakzadegan, A. Bahonar, H.E. Mousavi and A. Niasari, 2009. Comparison of electroanesthesia with chemical anesthesia (MS222 and Clove Oil) in rainbow trout (*Oncorhynchus mykiss*) using plasma cortisol and glucose responses as physiological stress indicators. Asian J. Anim. Vet. Adv., 4: 306-313.

Sherwin, C.M., S.B. Christiansen, I.J. Duncan, H.W. Erhard and D.C. Lay *et al.*, 2003. Guidelines for the ethical use of animals in applied ethology studies. Applied Anim. Behav. Sci., 81: 291-305.

Sturkie, P.D., 2000. Transport of Blood Gases. In: Avian Physiology, Whittow, G.C. (Ed.), Academic Press, New York, pp. 208-250..

Vahdatpour, T., K. Nazer Adl, Y.E. Nezhad, N.M. Sis, S.R. Riyazi and S. Vahdatpour, 2009. Effects of corticosterone intake as stress-alternative hormone on broiler chickens: Performance and blood parameters. Asian J. Anim. Vet. Adv., 4: 16-21.

Yildirim, N.C. and M. Yurekli, 2010. Stress-induced changes in tyrosine hydroxylase enzyme activity and adrenomedullin levels in rat hypothalamus, adrenal medulla and heart tissues. Asian J. Anim. Vet. Adv., 5: 339-345.