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A Review: Influences of Pre-slaughter Stress on Poultry Meat Quality

Md. Shawkat Ali, Geun-Ho Kang[1] and Seon Tea Joo*
Division of Applied Life Science, Graduate School, Gyeongsang National University
Jinju, Gyeongnam 660-701, Korea

ABSTRACT: Pre-slaughter conditions affect poultry meat quality. Therefore, stresses before slaughter like heat stress, struggle and shackling on the shackle line, crating and transport and feed withdrawal are very important for the poultry industry in respect of quality as well as welfare of the birds. However, exposure to heat in oxidative stress can in turn lead to cytotoxicity in meat type birds. Chickens exposed to heat stress before slaughter showed the lowest ultimate pH and birds shackled for a longer time the highest. The abdominal fat content was higher in heat stressed birds. Struggling on the shackle line hastened the initial rate of the pH drop and increased the redness of breast meat. Again, with increasing struggling activity, lactate concentration in breast muscle of chicken increased. Paler meat was found in birds that were transported for a longer time than in those after a small journey or not transported. The pre-slaughter and eviscerated weights were decreased as the length of feed withdrawal period increased. (**Key Words :** Pre-slaughter Stress, Poultry Meat Quality)

INTRODUCTION

It is important to recognize that any of the environmental stress factors discussed can result in changes in the metabolites of muscle. These changes, in turn, are responsible for differences in the ultimate properties of meat. The nature of the changes depends upon the severity of the stress, and the level of the animal's stress resistance at the time of death. In poultry, the quality of meat products results from complex interactions between the genotype and the environment, more especially the stresses undergone before slaughter (Berri, 2000; Debut et al., 2003).

Pre-slaughter stressed animals have usually high temperatures, rapid glycolysis (pH drop), and early onset of rigor mortis in their muscles. Although the postmortem changes are rapid, some degree of ante-mortem muscle temperature rise, lactic acid buildup, and depletion of ATP also occurs. This combination of conditions results in an exaggeration of the muscle-to-meat transformation (rapid pH decline and an elevated carcass temperature resulting in protein denaturation) that normally occur. Muscles from pre-slaughter stressed birds usually become pale, soft, and moist or exudative (PSE) after a normal 18 to 24 h chilling period condition. This condition most often results lower possessing yields, increased cooking losses, and reduced juiciness (Aberly et al., 2001).

Ante-mortem stress, including heat-stress (Babji et al., 1982), struggle before slaughter (Ngoka and Froning, 1982; Papinaho et al., 1995), have shown to accelerate glycogen depletion, increase the rate of pH decline, and possibly results in tough meat. Again, Glycogen deficiency usually occurs when animal survive stress, such that associated with fatigue, exercise, fasting, excitement, fighting or electrical shock but are slaughtered before they have sufficient time to replenish their muscle glycogen stores. Muscle glycogen deficiency in these birds' results in limited glycolysis in the muscles after death and results in a high ultimate pH. As a consequence of a high ultimate pH, changes in muscle color that otherwise occur during the post-mortem transformation of muscle to meat, do not occur. The pre-slaughter stresses normally occur in poultry meat processing industry are heat stress, pre-slaughter shackling, struggle, crating and transportation and feed withdrawal.

* Corresponding Author: Seon-Tea Joo. Tel: +82-55-751-5511, Fax: +82-55-756-7171, E-mail: stjoo@gnu.ac.kr
[1] Poultry Science Division, National Institute of Animal Science, RDA, Korea.
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DISCUSION

Heat stress before slaughter

Heat stress is a major concern for poultry, especially in the hot regions of the world becau se of the resulting poor growth performance, immunosuppression, and high mortality. Exposure to acute heat stress is likely to lead to various metabolic changes in poultry meat. An early reaction to high ambient temperature is the increased body temperature (Sandercock et al., 1999). Furthermore, according to Edens (1978), chicken exposed to high environmental temperatures (43°C) showed a rising plasma corticosterone concentration early in the heating episode (before 90 min), afterwards a significant fall signifying the Acute Adrenal Cortical Insufficiency (AACI) syndrome. As reported by Edens and Siegel (1976) or Edens (1978), this syndrome is associated with a loss of plasma glucose, cholesterol, total calcium and inorganic phosphate and decreased plasma sodium to potassium ratio. Debut et al. (2005) stated that acute heat stress affected blood Ca^{2+} and Na^{+} concentration and increased glycaemia and glycolytic potential of thigh muscle also agreed the previous results.

Heat stress increases oxygen radicals, possibly by the disruption of the electron transport assemblies of the membrane (Ando et al., 1997). Heat-induced reactive oxygen species (ROS) formation may be the factor that causes molecular changes in DNA, proteins, lipids and other biological molecules (Bruskov et al., 2002). ROS play an important role in many biological systems, including the body's response to infection, heavy metal and ethanol toxicity, and other conditions (Donati et al., 1990). However, several studies have suggested that exposure to heat results in oxidative stress, which in turn can lead to cytotoxicity (Bernabucci et al., 2002). It was found that significantly enhanced superoxide production in heat stress-treated skeletal muscle mitochondria of meat type chickens, whereas no such increase was observed in laying chickens. The enhancement of superoxide production in meat type chicken was associated with heat-induced increments in rectal and muscle temperatures, leading to significant body weight loss. In contrast, the layer chicken showed no increase in temperatures, although there is a slight decrease in body weight gain (Mujahid et al., 2005). Heat stress increases oxygen radicals, possibly by the disruption of the electron transport assemblies of the membrane (Ando et al., 1997). However, in former study both meat and laying type chicken were exposed to heat stress at 34°C. Therefore, it is likely that increase of mitochondrial heat induced reactive oxygen species (ROS) production was affected directly by increase body temperature rather than the environmental temperature. However it cannot be ruled out that laying-type chickens have a unique regulatory mechanism allowing the suppression of ROS production under heat stress conditions or there is a possibility that laying-type chickens are inherently immune to or better adapted to the higher production of ROS.

Chicken exposed to heat stress before slaughter showed the lowest ultimate pH and the birds shackled for a longer time the highest, same trend also found in glycolytic potential at 3 minutes of postmortem with the birds (Rammouz et al., 2004). This decline in pH is a result of glycolysis and ATP hydrolysis (Van Hoof, 1979). Acute heat stress was chosen as pre-slaughter treatments as this is commonly practiced and has a negative impact on animal welfare (Gregory, 1994; Kannan et al., 1997) and meat quality (Kannan et al., 1997; Debut et al., 2003). Environmental regimen was a highly significant source of variability for chilled carcass weight change; the cyclic heat-stressed broiler carcasses gained more weight than the thermoneutral (control) broiler carcasses during ice-water chilling. Oven-cooked fillet yield was significantly affected by environmental regimen; fillets from cyclic heat-stressed broilers had lower yields than thermoneutral (control) broiler fillets (Whiting et al., 1991). The abdominal fat content was significantly higher under heat stress and the meat quality showed no dependence on the climatic conditions. However, the effect of heat stress was not uniform in the fatty acid pattern and the sum of saturated fatty acid was increased under heat stress (Amad et al., 1992). Although, Shim et al.(2006) stated that heat stress resulted in a significant reduction in total lipid and triglyceride levels, but also increased the levels of total cholesterol in the liver of broiler chicken ($p<0.05$).

Struggle and shackling on the shackle line during processing

Hanging operations could induce severe struggling (straightening up, wing flapping and vocalization) on the shackle line (Gregory and Bell, 1987), increase plasma corticosterone (Kannan et al., 1997; Debut et al., 2005) and affect muscle peri-mortem metabolism and some meat attributes (Debut et al., 2003). According to the last study, struggling on the shackle line hastened the initial rate of the pH drop and increased the redness of breast meat. Furthermore, the behavioral response to shackling varied between chicken types, the slow-growing line being more reactive than the fast-growing line.

Most of the studies of struggling on the shackling line have been investigated in the context of animal welfare (Gregory and Bell, 1987; Gregory, 1994; Sparrey and Kettlewell, 1994). Kannan and Mench (1996) reported that hanging broilers in an inverted position is experienced as a stressful event which leads to an increase in plasma corticosterone concentration. Debut et al. (2005) and Kannan et al. (1997) found that increasing the shackling time led to higher plasma conticosterone in chicken. Vigorous wing flapping can be seen as an escape behavior and an indicator of discomfort (Sparrey and Kettlewell, 1994). Reaction of hanging has been already shown to be intensified by environmental factors such as rough hanging, noise, bright light, unsuitable shackles or separation from familiar counterparts (Gregory and Bell, 1987). Debut et al. (2005) confirmed that the lactate concentration in breast muscle of chicken at 15 min post mortem increased with struggling activity. Similar results also found in chicken (Papinaho et al., 1995) and turkey (Ngoka and Froning, 1982). Debut et al. (2005) also stated that breast muscle was more sensitive to struggling activity than thigh muscle in which lactate concentration was barely affected. This could be related to the glycolytic status of the breast muscle and it association with wing flapping activity.

Crating and transport

Crating causes an increase in plasma corticosterone levels in broilers (Kannan and Mench, 1996). The duration of crating (Kannan and Mench, 1996) and the method of crating (Duncan, 1989) can also influence the stress response shown by the bird. Although catching, crating, and loading are the procedures that are most likely to cause plysical injuries, transportation has also been reported to be stressful to broilers. Duncan (1989), for example, found that birds that were crated and transported on a vehicle for 40 min had higher plasma corticosterone concentrations than birds that were crated and loaded onto the vehicle but not transported. Further, Cashman et al. (1989) reported that fear levels in birds were mainly determined by transportation and not just by catching and loading. Ehinger (1977) found that broiler meat tenderness and water holding capacity were reduced after 2 h of transportation but improved after 4 h of transportation. Cashman (1987) assessed the ultimate pH, color, and water holding capacity of broiler meat, and found that meat was paler in birds that underwent a commercial 2-h journey than in birds that were crated for only 10 min and not transported. These reports suggest that transport stress can influence the color and texture of broiler meat.

Feed withdrawal

Feed is normally withdrawn for several hours before catching in order to reduce the danger of carcass contamination. Total feed withdrawal times of 8 to 10 h prior to slaughter are recommended (Wabeck, 1972), although in practice longer periods sometimes occur. Feed withdrawal affects a lot of metabolic processes. Feed deprivation causes a shift from anabolism to catabolism, from lipogenesis to lipolysis, and a reduced metabolic rate. A study by Murray and Rosenberg (1953) revealed that the plasma glucose concentration of fasted chickens declined rapidly until a new equilibrium was reached and become stabilized after 3 h of fasting for at least 16 h. Warriss et al. (1988) stated that live glycogen depleted to negligible amounts after feed withdrawal of 6 h.

Feed withdrawal induces behavioral and physiological responses, indicating that broilers probably suffer from stress (Freeman, 1984). An increase in corticosterone concentrations has been shown in broilers after a feed and water withdrawal of 24 h (Knowles et al., 1995). Also in growing broiler breeders, feed restriction leads to plasma corticosterone increases (De Jong et al., 2003). Withdrawal of feed before catching is likely to increase corticosterone as well (Nijdam et al., 2005).

Feed withdrawal before slaughter allows emptying of the digestive system and reduces the likelihood of faecal contamination during processing. The preslaughter and eviscerated weights were decreased as the length of feed withdrawal period increased (Veerkamp, 1978; Bartov, 1992). Food withdrawal periods of up to 24 h did not affect the fat content in meat (Ang and Hamm, 1985; Bartov, 1992), the relative size of abdominal fat pad or the composition of fatty acids in their meats (Bartov, 1992).

Dietary protein content, or energy-to-protein ratio, besides it determinant effect on weight gain and feed efficiency of broiler chicks, has a marked effect on the quality of their carcasses (yield of edible meat, and carcass fat content). Diet lower than protein recommended reduced the yield of meat (Moran et al., 1992) and increased fattening (Bartov and Bornstein, 1976; Moran et al., 1992). The increased fattening was accompanied by increased saturation of carcass fat (Marion and Woodroof, 1966; Bartov and Bornstein, 1976). Increased fattening was also observed when chickens were fed on diets in crumbled or pelleted form (Marks and Pesti, 1984; Plavnik et al., 1997).

CONCLUSION

The conditions before slaughter affect meat quality parameters, and these conditions are not only important in respect of quality but also important as welfare of the birds. Better understanding of these factors will help the modern poultry industry peoples to obtain good quality products.

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REFERENCES

Aberle, E. D., J. C. Forrest, D. E. Gerrard, E. W. Mills, H. B. Hedrick, M. D. Judge and R. A. Merkel. 2001. Principles of Meat Science (4th edition). Kendall/Hunt Publishing Company, 4050 Westmark Drive, Dubuque, Iowa, USA. p. 94.

Amad, A., J. Poetschke, I. Muller and L. Chhum Pith. 1992. Differentiation of fattening and slaughtering performance and carcass quality of broiler genotypes with and without the dwarf factor and fast or slow feathering under heat stress. Beitr Trop Landwirtsch Veterinarmed, 30:407-425.

Ando, M., K. Katagiri, S. Yamamoto, K. Wakamatsu, I. Kawahara, S. Asanuma, M. Usuda and K. Sasaki. 1997. Age related effects of heat stress on protective enzymes for peroxides and microsomal monooxygenase in rat liver. Environmental Health Prospectives 105:726-733.

Ang, C. Y. W. and D. Hamm. 1985. Influence of length of feed withdrawal times on proximate composition and levels of selected vitamins and minerals in broiler breast meat. Poult. Sci. 64:1491-1493.

Babji, A. S., G. W. Froning and D. A. Ngoka. 1982. The effect of preslaughter environmental temperature in the presence of electrolyte treatment on turkey meat quality. Poult. Sci. 61:2385-2389.

Bartov, I. 1992. Effect of feed withdrawal on yield, fat content and fatty acid composition of various tissues in broilers. Proceedings of the 19th World's Poultry Congress, Amsterdam, Vol. 3. pp. 195-199.

Bartov, I. and S. Bornstein. 1976. Effects of degree of fatness in broilers on other carcass characteristics: Relationship between fatness and composition of carcass fat. Br. Poult. Sci. 17:17-27.

Bernabucci, U., B. Ronchi, N. Lacetera and A. Nardone. 2002. Markers of oxidative status in plasma and erythrocytes of transition dairy cows during hot season. J. Dairy Sci. 85:2173-2179.

Berri, C. 2000. Variability of sensory and lipid oxidation in broilers exposed to high temperature at an early age. Br. Poult. Sci. 41:489-493.

Bruskov, V. I., L. V. Malakhova, Z. K. Masalimov and A. V. Chernikov. 2002. Heat-induced formation of reactive oxygen species and 8-oxoguanine, a biomarker of damage to DNA. Nucleic Acids Research 30:1354-1363.

Cashman, P. J. 1987. An assessment of the fair levels of broilers during transit. M. Sc. Thesis, University of Bristol, Bristol, UK.

Cashman, P. J., C. J. Nicole and R. B. Jones. 1989. Effects of transportation on the tonic immobility fear reactions of broilers. Br. Poult. Sci. 30:211-222.

Debut, M., C. Berri, E. Baeza, N. Sellier, C. Arnould, D. Guemene, N. Jehl, B. Boutten, Y. Jego, C. Beaumont and E. Le Bihan-Duval. 2003. Variations of chicken technological meat quality in relation to genotype and preslaughter stress conditions. Poult. Sci. 82:1829-1834.

Debut, M., C. Berri, C. Arnould, D. Guemené, V. Santé-Lhoutellier, E. Baéza, N. Jehl, Y. Jégo, C. Beaumont and E. Le Bihan-Duval. 2005. Behavioural and physiological responses of three chicken breeds to pre-slaughter shackling and acute heat stress. Br. Poult. Sci. 46:527-535.

De Jones, I. C., A. S. van Voorst and H. J. Blokhuis. 2003. Parameters for quantification of hunger in broiler breeders. Physiology and Behavior 78:773-783.

Donati, Y. R. A., D. O. Slosman and B. S. Polla. 1990. Oxidative injury and the heat shock response. Biochem. Pharmacol. 40:2571-2577.

Duncan, I. J. H. 1989. The assessment of welfare during the handling and transport of broilers. Pages 93-107 in: Proceedings of the 3rd European Symposium of Poultry Welfare (Ed. J. M. Faure and A. D. Mills). World's Poultry Science Association, Tours, France.

Edens, F. W. 1978. Adrenal cortical insufficiency in young chickens exposed to a high ambient temperature. Poult. Sci. 57:1746-1750.

Edens, F. W. and H. S. Siegel. 1976. Modification of corticosterone and glucose responses by sympatholic agents in young chickens during acute heat exposure. Poult. Sci. 55:1704-1712.

Ehinger, F. 1977. The influence of starvation and transportation on carcass quality of broilers (Ed. S. Scholtyssek). The quality of poultry meat, pp. 117-124 (Munich, Germany, European Poultry Federation).

Freeman, B. M., P. J. Kettlewell, A. C. C. Manning and P. S. Berri. 1984. Stress of transportation of broilers. Vet. Res. 114:286-287.

Gregory, N. G. 1994. Preslaughter, handling, stunning and slaughter. Meat Sci. 36:45-56.

Gregory, N. G. and J. C. Bell. 1987. Duration of wing flapping in chicken shackled before slaughter. Vet. Rec. 121:567-569.

Kannan, G. and J. A. Mench. 1996. Influence of different handling methods and crating periods on plasma corticosterone levels in broilers. Br. Poult. Sci. 37:21-31.

Kannan, G., J. L. Heath, C. J. Wabeck and J. A. Mench. 1997. Shackling of broilers: effects on stress responses and breast meat quality. Br. Poult. Sci. 38:323-332.

Knowles, T. G., P. D. Warriss, S. N. Brown, J. E. Edwards and M. A. Mitchell. 1995. Responses of broilers to deprivation of food and water for 24 hours. Br. Vet. J. 151:197-202.

Marion, J. E. and J. G. Woodroof. 1966. Composition and stability of broiler carcasses as affected by dietary protein and fat. Poult. Sci. 45:241-247.

Marks, H. L. and G. M. Pesti. 1984. The roles of protein level and diet form in water consumption and abdominal fat pad deposition of broilers. Poult. Sci. 63:1617-1625.

Moran, E. T., R. D. Bushong and S. F. Bilgili. 1992. Reducing dietary crude protein for broilers while satisfying amino acid requirements by least-cost formulation: Live performance, litter composition, and yield of fast-food carcass cuts at six weeks. Poult. Sci. 71:1687-1694.

Mujahid, A., Y. Yoshiki, Y. Abika and M. Toyomizu. 2005. Superoxide radical production in chicken skeletal muscle induced by acute heat stress. Poult. Sci. 84:307-314.

Murray, H. C. and M. M. Rosenberg. 1953. Studies on blood sugar and glucogen levels in chickens. Poult. Sci. 32:805-811.

Ngoka, D. A. and G. W. Froning. 1982. Effect of free struggle and preslaughter excitement on color of turkey breast. Poult. Sci. 61:2291-2293.

Nijdam, E., E. Delezie, E. Lambooij, M. J. A. Nabuurs, E. Decuypere and J. A. Stegeman. 2005. Feed withdrawal of broilers before transport changes plasma hormone and metabolite concentrations. Poult. Sci. 84:1146-1152.

Papinaho, P. A., D. L. Fletcher and R. J. Buhr. 1995. Effect of electrical stunning amperage and peri-mortem struggle on broiler breast rigor development and meat quality. Poult. Sci. 74:1533-1539.

Plavnik, I., E. Wax, D. Sklan and S. Hurwitz. 1997. The response of broiler chickens and turkey poults to steam-peleted diet supplemented with fat and carcohydrates. Poult. Sci. 76:1006-1013.

Rammouz, R. El., C. Berri, E. Le. Bihan-Duval, R. Babile and X. Fernandez. 2004. Breed differences in the biochemical determinism of ultimate pH in breast muscles of broiler chickens-A key role of AMP deaminase? Poult. Sci. 83:1445-1451.

Sandercock, D. A., R. R. Hunter, G. R. Nute, P. M. Hocking and M. A. Mitchell. 1999. Physiological responses to acute heat stress in broilers: implications for meat quality? Proceedings of the 14th European Symposium on the Quality of Poultry Meat, Bolonga, pp. 271-276.

Shim, K. S., K. T. Hwang, M. W. Son and G. H. Park. 2006. Lipid metabolism and peroxidation in broiler chicks under chronic heat stress. Asian-Aust. J. Anim. Sci. 19:1206-1211.

Sparrey, J. M. and P. J. Kettlewell. 1994. Shackling of poultry: is it a welfare problem? World's Poult. Sci. J. 50:167-176.

Van Hoof, J. 1979. Influence of ante- and peri-mortem factors on biochemical and physical characteristics of turkey breast muscle. Vet. Q. 1:29-36.

Veerkamp, C. H. 1978. The influence of fasting and transport on yields of broilers. Poult. Sci. 57:634-638.

Wabeck, C. J. 1972. Feed and water withdrawal time relationship to processing yield and potential fecal contamination of broilers. Poult. Sci. 51:1119-1121.

Warriss, P. D., S. C. Kestin, S. N. Brown and E. A. Bevis. 1988. Depletion of glycogen reserves in fasting broiler chickens. Br. Poult. Sci. 29:149-154.

Whiting, T. S., L. D. Andrews, M. H. Adams and L. Stamps. 1991. Effects of sodium bicarbonate and potassium chloride drinking water supplementation. 2. Meat and carcass characteristics of broilers grown under thermoneutral and cyclic heat-stress conditions. Poult. Sci. 70:60-66.