

The Effects of Electrical Water Bath Stunning on Meat Quality of Broiler Produced in Accordance with Turkish Slaughter Procedures

Tuğba Gezgin^{1*}, Mustafa Karakaya²

ABSTRACT: This study assessed the effects of electrical water bath stunning process on the meat quality of broilers processed in a commercial slaughterhouse in Turkey. Twenty-five live broilers were electrically stunned while twenty-five live broilers were not. Electrical stunning (30 V, 30 mA, 220 Hz alternative current) was applied for 17 seconds (s) in a water bath. The percentage of the blood loss was determined at 150 s after slaughter. The electrical stunning significantly decreased the percentage of the blood loss in broilers ($P \leq 0.01$). conversely, higher pH values were observed at 15 min and 24 h post-mortem (PM) in muscle samples from broilers slaughtered following stunning compared to un-stunned controls ($P \leq 0.01$). Electrical stunning had no significant effect on L^* a^* and b^* colour values ($P \geq 0.05$). The Water Holding Capacity (WHC) of meat taken from stunned broilers was significantly higher than those of the control birds. ($P \leq 0.01$). Texture analysis revealed greater toughness and firmness values in the meat of stunned broilers ($P \geq 0.05$).

Keywords: Meat quality, Electrical stunning, Texture

Received: 28/09/2016

Accepted: 08/12/2016

Türk Kesim Usullerine Uygun Olarak Üretilen Broiler Et Kalitesi Üzerine Su Banyosunda Elektrikle Bayılma İşleminin Etkisi

ÖZ: Bu çalışma ile Türkiye'de ticari bir kesimhanede üretilen etlik piliçlerin et kalitesi üzerine su banyosunda bayılma işleminin etkileri belirlenmiştir. 25 adet broilere su banyosunda elektrik ile bayılma işlemi uygulanırken, 25 adet etlik piliçlere bayılma işlemi uygulanmamıştır. Bayılma işlemi, su banyosunda (30 V, 30 mA, 220 Hz AA) 17 saniye (sn) 'de gerçekleştirilmiştir. Kan kaybı yüzdesi kesimden sonra 150. sn' de ölçülmüştür. Elektrikle bayılma işlemi kan kaybını önemli derecede düşürmüştür ($P \leq 0.01$). Postmortem (PM) zamanının 15. dk ile 24. saatinde bayılmayı müteakip kesim işlemi yapılan broilerlerden elde edile kas örneklerinde, bayılmadan kesilen kontrol örneklerine göre, daha yüksek pH değerleri gözlemlenmiştir ($P \leq 0.01$). Elektrikle bayılma işleminin L^* a^* ve b^* renk değerlerine önemli derecede etkisi bulunmamıştır ($P \geq 0.05$). Bayılarak kesilen broilerlerden elde edilen örneklerin su tutma kapasitesi, kontrol örneklerine göre daha yüksek bulunmuştur ($P \leq 0.01$). Bayılarak kesilen broilerlerden elde edilen et örneklerinde daha yüksek sertlik (Toughness (Kg.s)) ve sıklık (Firmness (Kg)) değerleri elde edilmiştir ($P \geq 0.05$).

Anahtar kelimler: Et kalitesi, Elektrikle bayılma, Tekstür

GİRİŞ

Regardless of differences in cultural, religious or regulatory practices directing the slaughter of poultry, the application of electrical stunning principles in slaughter plants and the effects of stun killing on end-product quality are of concern to meat processors worldwide (1). In Europe, where applying electrical stunning with a minimum current of 100 mA with frequencies changing proportionally with the magnitude of the current, it is a legal obligation to irreversibly and immediately stun the bird according to the Council of the European Union regulation of 24 September 2009 (EC Regulation No: 1099/2009) on the protection of animals at the time of killing (Official Journal of the European Union 2009). In the United States, where an electric current with a high frequency and low amperage is commonly used in the electrical water bath stunning process to keep animals immobilized to attain good product quality at the following proper slaughter, meat quality is considered as essential

as animal welfare (2). It is well-known that animal welfare standards are becoming increasingly important, even if there exist different opinions concerning the definition of acceptable animal welfare, which are largely due to cultural, ethical or religious differences (3). The Muslim faiths have certain conditions for religiously-acceptable animal slaughter, according to the Quranic verses and hadith (Sayings of the Prophet Muhammad). Specifically, animals must be slaughtered by an adult who is either a Muslim or a People of the Book. At the time of slaughter, the name of Allah must be spoken (The Holy Quran: The Table Spread Chapter, Verse No 3, 5) and slaughter must occur in the best manner possible, with a very sharp knife, easing the slaughter (in order to reduce the animals' pain) and by cutting the throat in a manner inducing rapid and complete bleeding, resulting in the quickest death (Riyad-us-Saliheen Hadith No: 640)(4). Some promoters and defenders of ritual Islamic slaughter put forward that the

#This study is a part of PhD thesis of Tuğba Gezgin.

¹Konya Food Control Laboratory Directorate, Toprak Sarnıç Mah. Karacığancami Sok. No: 1/A Meram, Konya, Turkey

²Department of Food Engineering, Faculty of Agriculture, Selçuk University, Konya, Turkey

*Corresponding Author: Tuğba Gezgin, e-mail: tugba.gezgin@tarim.gov.tr

stunning method can obstruct removal of the blood from carcass after slaughter due to neurological, muscular and cardiovascular changes (5). Chickens are known to lose nearly 50% of the total blood, approximately 4% of live weight, immediately after slaughter (6). The literature is equivocal regarding the stun method and its effect on blood loss: while some report that stunning caused a decrease in blood loss (7, 8, 9), several others report no effect (10, 11, 12). Moreover, it was reported that the lower blood loss was observed in un-stunned and electrically stunned broilers when high currents (60 to 125 mA) and high voltage (80 and 100 V) were employed (13). Further, it has been suggested that electrical stunning only affects the rate of early blood loss and had little effect on the ultimate carcass blood loss (14). The difference between the conclusions of the above-mentioned research may be due to the variety of the stunning procedures employed.

In Turkey, approximately 98% of the population is Muslim (15). Most Turkish consumers, then, require that their meat be prepared in the halal fashion, in keeping with the requirements of their faith. In Turkey, using electrical water bath stunning during the broiler slaughter process is deemed easier by the processors, but its effects on meat quality have come into question. In fact, considerable research evaluating the effects of electrical water bath stunning on broiler breast meat quality worldwide was previously carried out (16, 17). However, due to differences in the way electrical shock is employed stemming from differing religious, cultural and regulatory practices (1), these reports do not necessarily reflect the effect of stunning on the quality of broiler meat consumed in Turkey. Moreover, although electrically stunning of broilers in a water bath has long been used by processors to ease the killing process, an official guideline recommending the use of electric water bath stunning in Turkey is lacking. While a Turkish animal welfare regulation entitled "The regulation about general rules related to welfare of farm animals" (18) includes the sanctions concerning animal welfare (including: control, recording, movement freedom, in-house settings, mechanical equipment and feeding of farm animals), it doesn't address animal welfare at the slaughter of broilers. As such, individual Turkish poultry plants determine the parameters of stunning based on their own in-house research based on three criteria important to Turkish consumers: product quality, animal welfare and halal food. In Turkey, the slaughter of broilers is generally done by hand, following the mentioning of the name of Allah, in compliance with the Islamic rituals (19). Mechanical cutting is generally not preferred during the slaughter process by the producers because, in terms of the halal issue, the meat of the broiler slaughtered by hand is found to be more reliable by Turkish consumers (20), compared with the meat of a broiler slaughtered mechanically. Owing to the lack of a standard to be employed by all Turkish white meat producers at the slaughter of poultry, there is uncertainty among consumers about whether the white meat product they consume is produced in accordance with halal slaughter, animal welfare and meat quality (19). It is reported that various stunning methods and electrical parameters have different effects on post-mortem (PM) rigor development and subsequent meat quality (21). Berri et al. (22), concluded that ante mortem struggling and glycogen concentration in muscle tissue at death were the key factors associated with the onset and extent of PM pH

decline. In the same way, it was confirmed that when animals survive stress associated with exercise, fasting or electrical shock, muscle glycogen deficiency occurs, and result in limited glycolysis and high ultimate pH (pHu)(23). Conversely, it was also reported that electrical stunning had no significant effect on the pHu values of broiler breast meat (17, 24). To our knowledge, there is no scientific study on the bleeding efficiency and meat quality of broilers processed utilizing Turkish slaughter procedures. Therefore, this study aims to define the effect of the electrical stunning process using the procedure most commonly used by Turkish meat producers on the bleeding efficiency and meat quality of broilers.

MATERIAL and METHODS

This study was carried out in a commercial plant (Bolu, Turkey) with required permission to work under the "Regulation for Welfare and Protection of Animals used for Experimental and other Scientific Purposes" (published in the official gazette, 13.12.2011 date, 28141 number) with the approval of Local Ethics Committee of Animal Experiments. Broilers were raised under standard conditions and transported to the slaughterhouse the day before slaughter. 50 broilers (Ross 308 strain, 40-45 day-old and 2500-3000 g weight) of mixed sex were randomly assigned to either the treatment or control groups (n=25/group). Birds were deprived of feed and water in the hencoop for 12 h prior to slaughter. At the time of slaughter, broilers were individually weighed and hung on a shackle line upside-down. The broilers were subjected to either pre-slaughter water bath electrical stunning (Marel, Stork; USA) with an alternative current of 30 mA, 220 Hz, 30 V for 17 s or slaughter without stunning as a control group. In the stunned group, the foot of the birds were sprayed with 1% (w/v) saline solution to ensure the proper conduction of the electric current from the shackle to the foot. The birds were then submerged in a 1% saline water bath until the heads were 0.5 cm below the surface of the solution. Immediately after stunning (or hanging for controls), the broilers were slaughtered by severing both the carotid artery and jugular vein using a unilateral neck cut. The slaughter of all the broilers was carried out manually using a sharp knife in compliance with Islamic rituals.

Broilers were allowed to bleed for 150 s and reweighed to determine the percentage of blood loss (14). After bleeding, the pectoralis major muscle from both left and right sides was separated and kept in the cold room (0-4°C) for the determination of pH, colour, texture and water holding capacity (WHC) (Table 1). pH, color, toughness and firmness measurements were conducted in duplicate using both the right and left breast meat samples separately. 15 min and 24 h PM, pH and color values were measured on each of the 100 pectoralis major samples obtained from stunned or un-stunned broilers. pH value was measured according to the Turkish Standard TS 3136 ISO 2917 (25) using a pH meter calibrated at pHs 4.0 and 7.0 prior to use. Colour values were measured on the outside of the skinless breast fillets at the thick anterior region using a Minolta CR 400 (Osaka, Japan). Colour values of the samples were evaluated using the criteria of the CIELab (Commission Internationale de l'éclairage) method (L^* = lightness, a^* = redness, and b^* = yellowness), which takes three dimensional colour measurements (26).

Table 1 The details of the sample experimental design

Parameters	Replicate number	n	150 s	15. min	24.h	48.h
Blood Loss (%)	1	25	√			
pH	2	25		√	√	
Color (L*, a*, b*)	2	25		√	√	
Toughness (Kg.s)	2	25			√	
Firmness (Kg.s)	2	25			√	
WHC (% w/w)	2	6				√

√: Time of the experiment

Table 2 The effects of electrical stunning process on percentage of blood loss and broiler breast meat pH, CIELAB colour (lightness = L*, redness = a* and yellowness = b*), WHC (water holding capacity), toughness (kg.s) and firmness (kg) values*

Parameters	Electrically stunned broilers	Non-stunned broilers	P
Blood Loss (%)	3.62 ± 0.01	3.89 ± 0.01	0.0001
pH _{15min}	6.52 ± 0.020	6.15 ± 0.018	0.0001
pH _{24 h}	6.17 ± 0.017	6.11 ± 0.013	0.009
L* _{15 min}	46.02 ± 0.32	46.54 ± 0.45	0.426 (n.s.)
a* _{15 min}	2.93 ± 0.16	2.92 ± 0.17	0.990 (n.s.)
b* _{15 min}	1.63 ± 0.14	1.34 ± 0.15	0.767 (n.s.)
L* _{24 h}	46.62 ± 0.34	47.07 ± 0.34	0.148 (n.s.)
a* _{24 h}	2.87 ± 0.12	3.05 ± 0.14	0.320 (n.s.)
b* _{24 h}	1.17 ± 0.11	1.23 ± 0.12	0.576 (n.s.)
WHC (mL/100 g)	50.94 ± 2.4	35.94 ± 0.97	0.0001
Textural attributes			
Toughness (Kg.s)	10.59 ± 0.38	7.79 ± 0.39	0.01
Firmness (Kg)	1.096 ± 0.03	0.881 ± 0.03	0.03

*: means ± SEM, n.s.: non significant

At 24 h PM, pectoralis major samples were subjected to texture analysis. Briefly, samples were cut from the interior layer of the breasts, approximately 3-4 cm³ as described by De Huidobro et al. (27) and were analyzed to determine the toughness and firmness values of samples using a TA.HDPlus texture analyzer (Stable Micro Systems, Godalming, Surrey, UK) fitted with a Warner-Bratzler knife. The following parameters were used: pre-test speed: 3 mm/s, test speed: 1mm/s, post-test speed: 3 mm/s, with a down stroke distance of 30 mm (which can vary between 25-35 mm according to the cutting of meat on the cell) and samples were analyzed in duplicate. At 48 h PM, the WHC of samples was determined according to the method proffered by Wardlaw et al. (28) using 6 parallel measurements per sample, replicating twice. Following the addition of 12 mL of 0.6 M Sodium chloride to 8 g of minced broiler breast meat measured out in cellulose nitrate test tubes, tubes were thoroughly shaken and then placed in a water bath for 15 min at 5°C and centrifuged at 10000 rpm at 4°C (Nüve, NF800R). Following centrifugation, the volume of supernatant was determined and used in the formula set out by Wardlaw et al. (28):

$$\text{WHC} = (12 - \text{SV}) * 100 / 8 \quad (1)$$

WHV= Water Holding Capacity (mL/100 g)
SV = Supernatant volume

Statistical analysis

All the data were analyzed statistically using the General Linear Model Procedure and means were differentiated using Tukey's Post hoc test option of one-way ANOVA- on the MINITAB (Windows Release 12.1 MINITAB 2000) program.

RESULTS and DISCUSSION

In this study, the electrical stunning process significantly affected the percentage blood loss for a bleeding time of 150 s ($P \leq 0.01$). Although low voltage stunning did not cause cardiac arrest, the percentage of the blood loss was reduced significantly nonetheless. The effect of electrical stunning on blood loss of broilers allowed to bleed for 150 s is shown in Table 2. Sayda et al. (29), who explored the effect of Islamic slaughter method and electrical stunning applied with 110 V in a water bath on the quality of broiler meat, concluded that pre-slaughter stunning caused less bleeding. Additionally, blood loss values for no stunning controls and low voltage stunning were reported as 3.7% and to be significantly greater than high current stunning blood loss values in the research carried out by Craig et al. (30). These results also support the findings of this research. It has been postulated that reduction of the percentage of the blood loss in the stunned birds may be caused by the inhibition of the drainage of the blood from vessels resulting from sustained contractions in the stunned birds' muscle.

The results of pH and color values of stunned and un-stunned broilers are summarized in Table 2. At 15 min PM, electrical stunning significantly increased the pH values of samples ($P \leq 0.01$; Table 2.). Our findings are compatible with previous reports revealing that electrical stunning increases the onset pH of rigor mortis which may be the result of immobilization of birds, delaying the depletion of glycogen, thereby causing the reduction in the lactic acid production (17, 8; 31).

In this study, at 24 h PM, mean pH values of pectoralis major samples obtained from stunned broilers were found to be higher than those of the control group ($P \leq 0.01$). We also found that electrical stunning increased pHu values of samples at 24 h PM, which may have resulted from limited

glycolytic activity in the muscles during the slaughter process. Slaughter method had no significant effect on muscle colour coordinates (Table 2) ($P \geq 0.05$). But, it had a slight effect on the lightness and redness of broiler breast meat. The results of the pH, color and the percentage of blood loss reported in this study coincide with the results of a previous study which found that the stunning of rabbits resulted in less bleeding, higher muscle pH and, although not statistically significant, caused slightly lighter carcass color (32). Despite the pHu results, finding no significant difference in meat color may have been due to other physiological factors that could affect the color tone of the meat (for example, degree of stress of the animal).

WHC of breast meat from stunned broilers was significantly higher than that of the controls ($P \leq 0.01$; Table 2). Interestingly, Huang et al. (33) indicated that no stun and middle voltage stun (50 V, 50 Hz, constant voltage) treatments reduced meat WHC when compared with low voltage stun (15 V, 750 Hz) and high voltage stun (100 V, 50 Hz) which might have been caused by the combination of low pH and high temperature PM. Taken together with our pHu results, it is unsurprising that WHC is increased given that the relationship between pH and water holding capacity was previously established (34, 35). As with pH and WHC, both toughness and firmness values of breast meat from electrically stunned broilers were significantly higher than those of the controls ($P \leq 0.01$ and 0.05 , respectively). These results are incompatible with the previous research in which it was reported that breast meat obtained from electrically stunned birds was more tender than the breast meat obtained from un-stunned controls (16) and that stunning had no effect on the tenderness of breast meat (24; 31). This difference may have been caused by the variety of stunning procedures employed in the above-mentioned studies in terms of pHu which would have limited proteolytic activity. While the muscles are changing to meat, it is known that muscle pH plays a very important role in activating proteolytic enzymes (36, 37, 38). Higher muscle pH may have caused a delay in mechanisms underlying the transformation of muscle to meat. Examining the results of our texture analysis using the table sorting method based on the degree of tenderness proposed by Lyon and Lyon (39), it can be concluded that the breast meat samples were slightly tender-slightly tough and slightly-moderately tough for controls and stunned broilers, respectively. Smith et al. (40) noted that early boning of breast fillets yielded tough meat. In addition, Lyon and Lyon (41) found Warner-Bratzler Shear Force means of 10.12 kg of force and 9.53 kg of force for the right and left intact breast meat, respectively, deboned at 2 h PM. Therefore, early removal of breast fillets from carcasses may have resulted in tough meat in our study as well.

CONCLUSIONS

The electrical stunning procedure (low voltage, low amperage, medium frequency with long time) most commonly used in Turkey during broiler slaughter significantly affects the onset pH of rigor mortis, as well as the pHu, tenderness and water holding capacity of broiler breast meat. It is thought that keeping the broilers from struggling by immobilizing them with the aid of electrical stunning may have resulted in higher ultimate pH in the muscles of stunned broilers stemming from the reduction of glycogen metabolism. Meat texture with higher hardness, firmness, pHu and greater WHC were found for

those birds subjected to the stunning treatment. Thus, broiler breast meat obtained from stunned broilers is more suitable for processing into sausage and salami production owing to its higher pHu and WHC. Finally, further research is needed to investigate the differences between several electrical stunning procedures used in Turkish poultry processing plants, to allow for the preparation of Turkish animal welfare standards during the slaughter of poultry, taking into account both meat quality and halal slaughter procedures.

ACKNOWLEDGEMENTS

This study was conducted with the financial support of Selçuk University Scientific Research Projects Foundation. Project number: 11201079.

REFERENCES

1. **Bilgili, S.F.** 1999. Recent advances in electrical stunning. *Poultry Science*, 78(2), 282-286.
2. **FAO.** 2016. Food and Agriculture Organization of The United Nations, http://www.fao.org/fileadmin/user_upload/animalwelfare/HSUS--The%20Welfare%20of%20Birds%20at%20Slaughter.pdf (June.24, 2016).
3. **Girasole, M., Chirollo, C., Ceruso, M., Vollano, L., Chianese, A., Cortsi, L.M.** 2015. Optimization of stunning electrical parameters to improve animal welfare in a poultry slaughterhouse. *Italian Journal of Food Safety*, 4(3): 175-178.
4. **Riaz, M.N., Chaudry, M.M.** (Eds) 2003. Comparison of Kosher, Halal and Vegetarian. *Halal Food Production*. p. 159, CRC Press, LLC: London.
5. **Anil, M.H., Yesildere, T., Aksu, H., Matur, E., McKinstry, J.L., Weaver, H.R., Erdogan, O., Hughes, S., Mason, C.** 2006. Comparison of Halal slaughter with captive bolt stunning and neck cutting in cattle: exsanguination and quality parameters. *Animal Welfare*, 15(4), 325-330.
6. **Newell, G.W., Shaffner, C.S.** 1950. Blood loss by chickens during killing. *Poultry Science*, 29, 271-275.
7. **Schutt-Abraham, H., Woruth, J., Fessel, J.** 1983. Electrical stunning of poultry in view of animal welfare and meat production. "Ed. G Eikelenboom" *Stunning of Animals for Slaughter*, Proceedings of a seminar in the CEC programme of coordination of research on animal welfare, p. 187-196, Martinus Nijhoff Publishers, Boston, MA.
8. **Murphy, B.D., Hasiak, R.J., Sebranek, J.G.** 1988. Effect of antemortem electrical stunning on functional properties of turkey muscle. *Poultry Science*, 67(7), 1062-1068.
9. **Papinaho, P.A. and Fletcher, D.L.** 1995. Effects of electrical stunning duration on postmortem rigor development and broiler breast meat tenderness. *Journal of Muscle Foods*, 6(1), 1-8.
10. **Heath, G.B., Watt, D.J., Waite, P.R., Meakins, P.A.** 1983. Further observations on the slaughter of poultry. *British Veterinary Journal*, 139(4), 285-290.
11. **Griffiths, G.L., McGrath, M., Softly, A., Jones, C.** 1985. Blood content of broiler chicken carcasses prepared by different slaughter methods. *Veterinary Record*, 117(15), 382-385.
12. **Dickens, J.A. and Lyon, C.E.** 1993. Effect of two stunning voltages on blood loss and objective texture of meat deboned at various post-mortem times. *Poultry Science*, 72(3), 589-593.

13. **Contreras, C.C. and Beraquet, N.J.** 2001. Electrical stunning, hot boning and quality of chicken breast meat. *Poultry Science*, 80(4), 501-507.
14. **Craig, E.W. and Fletcher, D.L.** 1997. A comparison of high current and low voltage electrical stunning systems on broiler breast rigor development and meat quality. *Poultry Science*, 76(8), 1178-1181.
15. **PRC.** 2016. Pew Research Center, <http://www.pewforum.org/2012/12/18/table-religious-composition-by-country-in-percentages/> (June.24, 2016).
16. **Lee, Y.B., Hargus, G.L., Webb, J.E., Rickansrud, D.A., Hagberg, E.C.** 1979. Effect of electrical stunning on postmortem biochemical changes and tenderness in broiler breast muscle. *Journal of Food Science*, 44(4), 1121-1122.
17. **Thomson, J.E., Lyon, C.E., Hamm, D., Dickens, J.A., Fletcher, D.L., Shackelford, A.D.** 1986. Effects of electrical stunning and hot deboning on broiler breast meat quality. *Poultry Science*, 65(9), 1715-1719.
18. **ONRT.** 2014. Official Newspaper of The Republic of Turkey 'The regulation about general rules related to welfare of farm animals.' In Newspaper No: 22.11.2014/29183.
19. **Gezgin, T. and Karakaya, M.** 2016. Avrupa Birliği ve Türkiye'de kanatlı eti üretiminde elektro şok uygulaması .(In Turkish). *Gıda ve Yem Bilimi Teknolojisi Dergisi*, 16,45-50.
20. **GIMDES.** 2016. Gıda ve İhtiyaç Maddeleri Denetleme ve Sertifikalama Araştırmaları Derneği <http://www.gimdes.org/makine-ile-tavuk-kesimi.html> (June.24, 2016).
21. **Lamboij, E.** 2014. Electrical Stunning. "Eds C Devine, M Dikeman" *Encyclopedia of Meat Sciences*. (2nd ed.): pp 1342-1348, Academic Press, London.
22. **Berri, C., Debut, M., Santé-Lhoutellier, V., Arnould, C., Boutten, B., Sellier, N., Baéza, E., Jehl N., Jégo, Y., Duclos, M.J., Le Bihan-Duval, E.** 2005. Variations in chicken breast meat quality: Implications of struggle and muscle glycogen content at death. *British Poultry Science*, 46(5), 572-579.
23. **Ali, M.S., Kang, G.H., Joo, S.T.** 2008. A Review: Influences of pre-slaughter stress on poultry meat quality. *Asian-Australasian Journal of Animal Sciences*, 21(6), 912 – 916.
24. **Papinaho, P.A., Fletcher, D.L., Buhr, R.J.** 1995. Effect of electrical stunning amperage and perimortem struggle on broiler breast rigor development and meat quality. *Poultry Science*, 74(9), 1533-1539.
25. **TST.** 2002. Turkish Standards Institute, TS Meat and meat products – Determination of pH – Reference Method. TS 3136 ISO 2917. Turkish Standards Institute, Ankara, Turkey.
26. **CIE.** 1986. Commission Internationale de l'éclairage 1986. *Colorimetry* (2nd ed). Vienna, CIE Publication No: 15.2.
27. **de Huidobro, F.R., Miguel, E., Blásquez, B., Onega, E.** 2005. *A comparison between two methods (Warner-Bratzler and texture profile analysis) for testing either raw or cooked meat.* *Meat Science*, 69(3), 527-536.
28. **Wardlaw, F.B., McCaskill, L.H., Acton, J.C.** 1973. Effects of postmortem changes on poultry meat loaf properties. *Journal of Food Science*, 38(3), 421-423. URL Cited
29. **Sayda, A.M.A., Abdalla, H.O., Mahgoub, I.M.** 2011. Effect of slaughtering method on the keeping quality of broiler chickens' meat. *Egyptian Poultry Science*, 31, 727-736.
30. **Craig, E.W., Fletcher, D.L., Papinaho, P.A.** 1999. The effects of antemortem electrical stunning and postmortem electrical stimulation on biochemical and textural properties of broiler breast meat. *Poultry Science*, 78(3), 490-494.
31. **Alvarado, C.Z. and Sams, A.R.** 2000. Rigor mortis development in turkey breast muscle and the effect of electrical stunning. *Poultry Science*, 79(11), 1694-1698.
32. **Lopez, M., Carrilho, M.C., Campo, M.M., Lafuente, R.** 2008. Halal slaughter and electrical stunning in rabbits: effect on welfare and muscle characteristics. The 9th World Rabbit Congress, 2008, Verona, Italy. pp. 1201-1206.
33. **Huang, J.C., Huang, M., Yang, J., Wang, P., Xu, X.L., Zhou, G.H.** 2014. The effects of electrical stunning methods on broiler meat quality: Effect on stress, glycolysis, water distribution, and myofibrillar ultrastructures. *Poultry Science*, 93(8), 2087-2095
34. **Judge, M.D., Aberle, E.D., Forrest, J.C., Hedrick, H.B., Merkel, R.A.** 1989. *Principles of Meat Science*. Kendall E. D. Hunt Publishing, Dubuque, IA.
35. **Qiao, M., Fletcher, D.L., Smith, D.P., Northcutt, J.K.** 2001. The effect of broiler breast meat color on pH, moisture, water-holding capacity and emulsification capacity. *Poultry Science*, 80(5), 676-680.
36. **Sams, A.R. and Janky, D.M.** 1991. Characterization of rigor mortis development in four broiler muscles. *Poultry Science*, 70, 1003-1009.
37. **Koohmaraie, M.** 1994. Muscle proteinases and meat aging. *Meat Science*, 36, 93-104.
38. **Schreurs, F.J.G.** 2000. Post-mortem changes in chicken muscle. *Worlds Poultry Science*, 56(4), 319-346.
39. **Lyon, C.E. and Lyon, B.G.** 1990. The relationship of objective shear values and sensory tests to changes in tenderness of broiler breast meat. *Poultry Science*, 69, 1420-1427.
40. **Smith, D.P., Fletcher, D.L., Papa, C.M.** 1992. Duckling and chicken processing yields and breast meat tenderness. *Poultry Science*, 71(1), 197-202.
41. **Lyon, B.G. and Lyon, C.E.** 1996. Texture evaluations of cooked, diced broiler breast samples by sensory and mechanical methods. *Poultry Science*, 75(6), 812-819.