

pH and Colour Characteristics of Carcasses of Broilers Fed with Dietary Probiotics and Slaughtered at Different Ages

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ABSTRACT : The objective of the present experiment was to determine the effects of slaughtering at different ages and the use of a commercial probiotic (115-Biogallinox) in broiler diets on the color properties of carcasses, during the first 24 h following slaughter. Ross 308 male broiler chickens obtained from a commercial hatchery were raised to either 35 or 42 days of age. Chickens were fed with different levels of probiotic (P₀: 0.0%, P₁: 0.1% and P₂: 0.2%) containing *Saccharomyces cerevisiae* during the experimental period. At the end of the trial all birds were slaughtered and then stored at 3°C for 24 h. The pH and skin colour of carcasses were determined 1, 3, 7, 10, 13, 17 and 24 h after slaughter. Although the use of probiotic and post-mortem ageing time affected the pH (p<0.01), it was not affected by slaughter age (35 and 42 days) (p>0.05). The highest pH values occurred in carcasses of broilers fed 0.2% probiotic. The pH values of carcasses decreased with post-mortem ageing time (p<0.01). Main factors (treatment, slaughter age and post-mortem ageing time) had an effect on colour (L*, a* and b*) values (p<0.01). L* values of 42d-old slaughter and P2 group were lower than those of 35d-old slaughter and other probiotic groups. The a* and b* values of 35d-old slaughter were lower than those of 42d-old slaughter. The a* and b* values increased during post-mortem ageing (p<0.01). It was determined that changing of the colour traits of broiler carcasses was correlated with probiotic, pH and post-mortem ageing time. Also, it was observed that darkness of carcass colour increased as time progressed. (*Asian-Aust. J. Anim. Sci.* 2006. Vol 19, No. 4 : 605-610)

Key Words : Broiler, Probiotic, Slaughter Age, Broiler Carcass Colour, pH

INTRODUCTION

The broiler industry is constantly searching for ways to improve its product and quality in order to meet the demands of an increasingly discriminating consuming public. In this regard, numerous references exist on increasing poultry meat yields and improving carcass quality. For this reason, many ingredients have been used in broiler diets, in recent years. It is reported that additional benefits can be gained by supplementing broiler diets, particularly using of probiotics as feed additives. Probiotics are used to get rid of abnormalities in the gastrointestinal tract produced by stress and therefore normalize the gut activity (Kutlu and Görgülü, 2001). Manipulation of gut bacteria and gut ecology for improving animal production is still at challenging stage, and the possible application of molecular breeding of gut bacteria to the host animals with significance in their health and nutrition (Kobayashi et al., 2004). The findings of Huang et al. (2004) indicated that the probiotic cultures improved performance enhanced resistance to *E. coli* infection, and improved microbial balance in the gastrointestinal tract. Karaoğlu and Durdağ (2005) reported that the use of probiotic at different levels (0 g probiotic/kg feed, 1 g probiotic/kg feed and 2 g probiotic/kg feed) did not significantly affect the

performance of broilers, but the lower level conditions (1 g probiotic/kg feed) it seems to have minimal influence on performance and carcass traits, and the feeding period had significant effect on the final body weight, daily weight gain, feed efficiency, carcass weights and carcass yields for different feeding periods (35, 42 and 49 day). On the other hand, Aksu et al. (2005) observed that the use of probiotic in broiler diets improved meat quality during storage. Similarly, the use of 0.1% probiotic (*Saccharomyces cerevisiae*) in broiler diets for 49 days decreased carcass pH value, and increased color values (L*, a* and b*) during the 24-h period after slaughter (Karaoğlu et al., 2004).

As presented above there are many researches on the effects of using of probiotics on the growth performance (Erdoğan, 1999; Satbir and Sharma, 1999; Richter et al., 1999; Kumprechtová et al., 2000; Midilli and Tuncer, 2001; Banday and Risam, 2001). But there is a limited information interested in the effect of probiotic on the colour of carcass from broilers fed and slaughtered (Karaoğlu et al., 2004). The colour and variations in colour are important quality attributes that affect selection and acceptability of many foods. The colour of carcass skin affects acceptability of broiler carcasses and its products. Broiler skin and meat colour are also affected by numerous factors such as live production, slaughter, processing, handling, and packaging (Froning, 1995; Fletcher, 1989, 1999; Petracci and Fletcher, 2002).

Thus, this is the first time a probiotic-supplemented diets have been tested for the colour properties of carcasses from broilers fed with probiotic-added diets up to 35 or 42

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Table 1. Composition of basal diets (%)

	Starter diet	Finisher diet
Ingredients and composition (%)		
Ground corn	46.29	46.23
Soybean meal (48% CP)	22.14	21.00
Full-fat-soy	12.50	10.00
Ground wheat	10.00	10.00
Fish meal	4.00	2.50
DCP	1.67	1.73
Ground limestone	0.59	1.30
Salt (NaCl)	0.25	0.26
Soya oil	1.58	3.31
Poultry fat	-	1.50
Lysine	1.2	1
DL-methionine	0.24	0.25
TSAA	0.90	0.75
Choline chloride	0.04	0.04
Trace mineral premix ¹	0.30	0.30
Vitamin premix ²	0.50	0.50
Cocciostat	0.10	0.10
Lasolocyde	-	0.10
Analysis (%) ³		
Dry matter	94.00	93.00
Crude protein	22.00	20.00
ME kcal/kg	3,000	3,100

¹ Trace mineral mixture provides in milligrams per kg of diet: Mn, 70; Zn, 50; Fe, 30; Cu, 5, Se, 0.3.

² Vitamin mixture provides per kg of diet: vitamin A 8,000 IU; cholecalciferol 1,000 IU; α -tocopheryl acetate 15 mg/kg; menadione 3 mg/kg; riboflavin 5 mg/kg; niacin 40 mg/kg; thiamin 2 mg/kg; folic acide 0.6 mg/kg; vitamin B₁₂ 15 μ g/kg.

³ Calculated by AOAC (1984).

days. The main purpose of the present study was to examine the effects of by using different levels (0.0%, 0.1% and 0.2%) of commercial probiotic (*115-Biogallinox*) in broiler diets and slaughter age on the pH and carcasses colour traits during post-mortem aging time.

MATERIAL AND METHODS

Chicks and diets

One-day-old male broiler chicks (*Ross-308*) obtained from a commercial broiler breeder flock (KÖY-TÜR) were used in the current study. All birds were housed in batteries from 1 to 21 days and in grower broiler pens from 21 to either 35 or 42 days in the Application and Research Farm of the Agricultural Faculty, Ataturk University. A total 240 chicks were weighed and distributed randomly into three dietary treatment groups were replicated eight times per treatment, comprising of 10 birds each replicate. All chicks were fed *ad libitum* in three dietary groups for either 35 or 42 days. Broilers were fed the same basal diets in all groups. The basal diet was formulated to meet the nutritional requirements of the broiler chicken (NRC, 1994). Also, birds were fed a starter diet from day 1 to 21, and a finisher diet to either 35 or 42 days. The probiotic was added and

mixed to basal diets. Feed composition used in trial is shown Table 1, and its composition was analyzed by the AOAC (1984).

The experimental groups consisting three dietary treatments were: P₀ fed basal broiler diet containing no probiotics (0 g probiotic kg⁻¹ feed), P₁ fed basal diet plus 0.1% probiotic (1 g probiotic kg⁻¹ feed) and P₂ fed basal diet plus 0.2% probiotic (2 g probiotic kg⁻¹ feed). *115-Biogallinox* (Techniques et Biochimie Appliquees, 116-118 Avenue Beaurepaire, 94100 Saint Maur des Fosses, France) used as a probiotic source contained *Saccharomyces cerevisiae* (4×10⁸ cfu g⁻¹).

All birds were individually weighed at the end of the experimental period, 35 and 42 days of age. Then one bird was randomly chosen from each subgroups. Total 48 birds were selected (P₀: 8, P₁: 8, P₂: 8, total 24 birds for the first slaughter and P₀: 8, P₁: 8, P₂: 8, total 24 birds for the second slaughter). Prior to slaughtering the birds were held without feed for 10 h, electrically stunned, slaughtered by neck cut, bled for 120 s and semi-scalded 54°C for 30 s before mechanical plucking in a rotary drum plucker. The birds were eviscerated manually, washed and allowed to drain 10 min. (Yalcin et al., 1999). After eviscerating, carcasses were stored at 3±0.5°C for 24 h. At various times of this period (1, 3, 7, 10, 13, 17 and 24 h) skin color and pH values were determined in carcasses.

Color measurement

The colour measurements were carried out using a tristimulus colorimeter (Minolta Chroma Meter Measuring Head CR-200, Minolta, Osaka, Japan) and this was used to objectively measure CIE Lab values (L* measures relative lightness, a* relative redness and b* relative yellowness). Before each measurement, the apparatus was standardized against a white tile. The colour values were measured four times on the surface of each carcasses at for 1, 3, 7, 10, 12, 17 and 24 h of chill storage at 3±0.5°C. Colorimeters readings (L*, a* and b*) were always measured from the same points on carcass surfaces (back, breast, leg) for all the carcasses.

pH analyses

The pH value was measured by direct probe of pH meter (SCHOTT L 6880, Lab Star pH). pH measurements were determined by thrusting probe pH meter into breast and leg muscles.

Statistics

A statistical analysis were performed according to 2 (day)×3 (diet)×8 (post-mortem hour) factorial plan for slaughter, group and replicate (pens) factors and the post-mortem aging time factor was measured on the same experimental units repeatedly. It was used in the analysis of

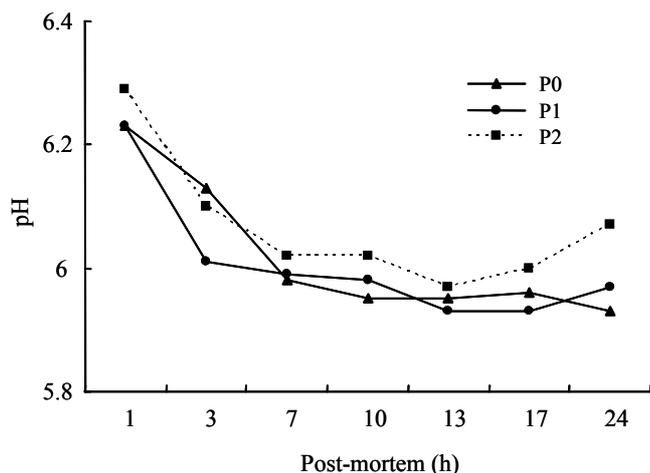


Figure 1. Effect of probiotic on pH changes in carcasses during 24-h post mortem.

variance with SPSS a using the General Linear Models (SPSS, 1996). Means were separated using Duncan’s multiple range test, and the results were shown as mean values±standard deviation in tables. Significant interactions were shown in figures.

RESULTS AND DISCUSSION

The results of the pH and L*, a* and b* values determined in this study were shown in Table 2. The use of probiotic affected pH values during the post-mortem aging time (p<0.01), while the slaughter ages didn’t influence (p>0.05). It was observed that pH values significantly

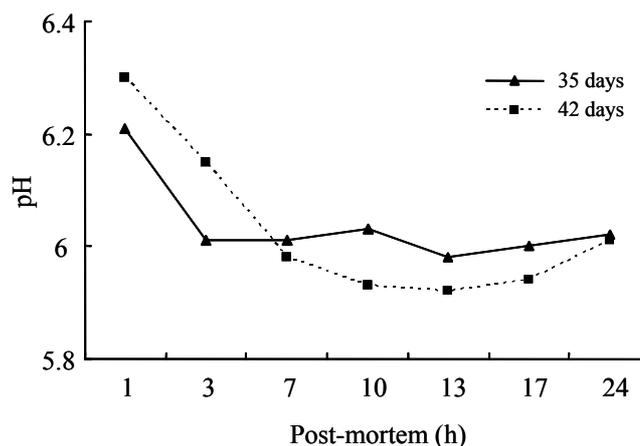


Figure 2. Effect of the slaughter age and post-mortem duration on pH value of carcasses.

decreased during post-mortem (p<0.01) and the lowest pH value occurred at 13th hours (p<0.05). The effect of interaction of treatment by post-mortem on the pH values was significant (p<0.01). Both immediately after slaughtering and at the end of the 24 h the highest pH value were found in P₂ group (p<0.05) (Figure 1).

In addition, the most dramatic pH decreasing of all the treatment groups occurred in the first 7 h. The slaughter age x post-mortem aging time interaction on the pH values was significant (p<0.01) (Figure 2). In point of the initial values (first 1 h), although they were differed 35-d-old slaughter from 42-d-old slaughter, it was observed that the means determined at the end of the 24 h were very similar. pH

Table 2. The effect of slaughter age, probiotic and post-mortem hour on the pH, L*, a* and b* values of broiler carcasses

	pH	L*	a*	b*
Slaughter age (days)				
35	6.03±0.16	65.89±3.21 ^a	1.88±1.34 ^b	9.09±5.72 ^b
42	6.03±0.18	63.48±4.89 ^b	3.34±2.28 ^a	10.76±5.87 ^a
Significance	NS	**	**	**
Diet				
P ₀	6.02±0.17 ^b	65.16±4.58 ^a	2.86±2.14 ^a	8.63±5.72 ^b
P ₁	6.01±0.17 ^b	65.21±3.88 ^a	2.38±1.82 ^b	10.49±5.16 ^a
P ₂	6.07±0.16 ^a	63.69±4.27 ^b	2.59±2.03 ^{ab}	10.64±5.87 ^a
Significance	**	**	**	**
Post-mortem (h)				
1	6.25±0.12 ^a	65.72±3.83 ^a	1.63±0.94 ^e	6.04±3.84 ^d
3	6.08±0.16 ^b	64.17±3.18 ^b	1.77±1.42 ^e	6.24±4.25 ^d
7	6.00±0.15 ^c	63.50±5.03 ^b	2.24±1.58 ^d	8.54±4.38 ^c
10	5.98±0.13 ^{cd}	63.59±5.06 ^b	2.52±1.96 ^{cd}	9.46±4.79 ^c
13	5.95±0.13 ^d	64.24±3.66 ^b	2.93±2.30 ^{bc}	11.37±5.25 ^b
17	5.98±0.14 ^{cd}	65.48±4.24 ^a	3.95±2.45 ^a	14.34±4.40 ^a
24	5.97±0.16 ^{cd}	66.09±4.11 ^a	3.28±1.95 ^b	13.48±5.36 ^a
Significance	**	**	**	**

** p<0.01, NS: non significant.

P₀: probiotic 0.0%, P₁: probiotic 0.1%, P₂: probiotic 0.2%.

± Standard deviation.

^{a-c} Any two means in the same column having the same letters in the same sections are not significantly different at p<0.05.

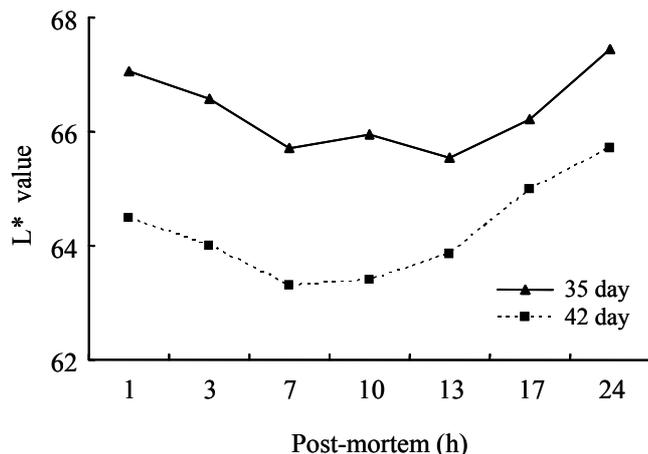


Figure 3. Effect of post-mortem duration and slaughter age on L* value of carcasses.

quickly declined until 3 h of 35-d-old, and by 7 h of 42-d-old slaughter ($p < 0.05$). However, pH values after 7 h were higher at 35-d-old slaughter than those of 42 days (Figure 2).

Karaoğlu et al. (2004) determined that pH values were low in broiler carcasses during post-mortem. Also, Yang and Chen (1993) reported that pH value was 6.23 and increased by storage, and L*, a* and b* values were affected by storage, and meat colour traits were highly correlated with pH values. There is high correlation between muscle ultimate pH and meat colour, and particularly for lightness. It is also well known that darkly coloured muscle is associated with high muscle pH (Livingston and Brown, 1981). Therefore, a high-pH of muscles have darker colour than those of a low-pH (Allen et al., 1997; Fletcher et al., 2000). As pH increased the L* value decreased, i.e. while darkness of meat increased the lightness declined. Yang and Chen (1993) determined that as pH inclined by storage a* value decreased and external colour values (L*, a* and b*) of broiler meats stored at 3°C were 65.55, 1.63 and 16.55, respectively. Castellini et al. (2002) reported that pH value can vary between 5.96 and 6.18 in fresh broiler muscle. Qiao et al. (2002) also determined that mean pH values of broiler breast meat as 5.96 ± 0.03 .

L* values were found lower for slaughter at 42 days of age ($p < 0.01$). It can be influenced by increasing a* and b* values. Because, when a* and b* values increased L* value declined and the colour gradually darkened. The lowest L* values were obtained during 3-17 h of post-mortem ($p < 0.05$) (Table 2). In addition, this value has changed depending on slaughter age ($p < 0.01$). The results related to L* values during post-mortem indicated similar trends with respect to both slaughter times. L* values of birds slaughtered at 42 d of age were noted to have significantly ($p < 0.05$) lower than those of slaughtered at 35-d-old both

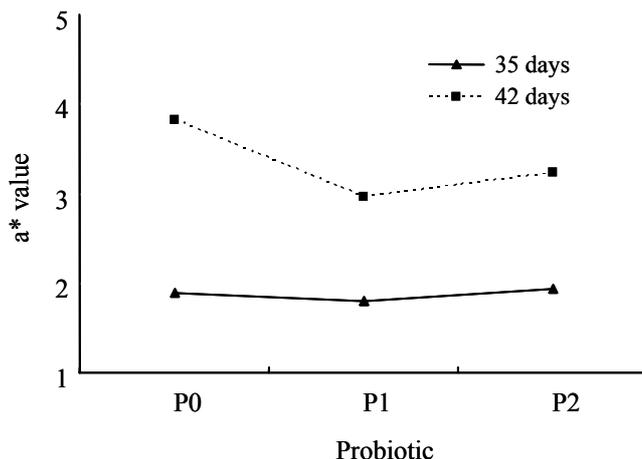


Figure 4. The effect of the interaction of probiotic by slaughter age on a* value of carcasses.

immediately after slaughter and at the end of the 24 h; i.e. L* values decreased by aging of the bird indicating a darkening of color. L* values of both slaughters (35 and 42 d) were found to exhibit a downward trend until 7 h of 24-h-period ($p < 0.05$) (Figure 3).

On the other hand, the diet containing the level of 0.2% probiotic (P2) significantly diminished the L* values ($p < 0.05$) and no significant differences were found between the level of 0.1% probiotic (P1) and control (P0) groups ($p > 0.05$). In that study, Karaoğlu et al. (2004) reported that L* values gradually increased after slaughter and these values relating 1 and 24 h of post-mortem were 63.22 ± 2.87 and 69.11 ± 1.54 , respectively. The difference among durations was significant. Also the same researchers (unpublished data) reported that the L* values of carcasses of broilers fed with a horn hydrolysate-supplemented diet and slaughtered at 49 days of age were 63.50 and 66.37 at 1 and 24 h of post-mortem. Petracci and Fletcher (2002) indicated that L* values of the skin of broiler carcass increased during post-mortem.

The results obtained herein showed that the changes in a* value during post-mortem were significantly influenced by treatment, slaughter age and storage periods. a* value was higher at 42 days ($p < 0.01$) (Table 2). The birds fed with level of 0.1% probiotic (P1) also had the lowest a* value among treatment groups ($p < 0.05$) (Table 2).

Figure 4 depicts that the treatment \times slaughter age interaction significantly affected a* value ($p < 0.01$). In contrast to L*, a* value of 42-d-old slaughter were higher, and this value also higher in control group than probiotic-treated groups ($p < 0.05$). P1 had lower a* value at 42 d, among treatment groups ($p < 0.05$). Under conditions of the study these observations were noted: a* value indicating redness in skin may be due to slaughter age of the bird, and the effect of the use probiotic on a* value may be increase with aging time, either. Because, as many researchers stated

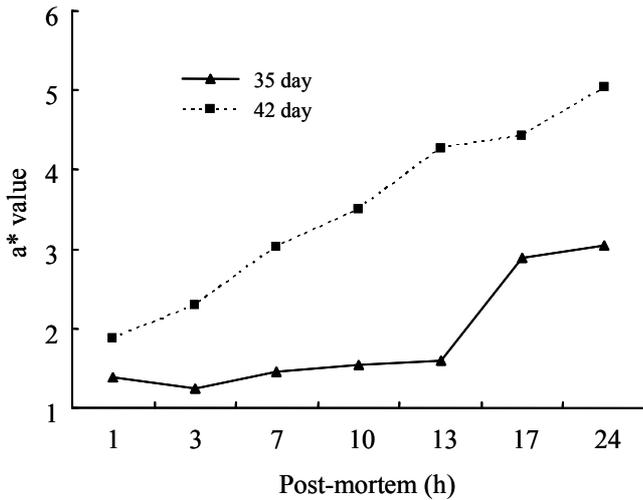


Figure 5. Effect of post-mortem duration and slaughter age on a* value of carcasses.

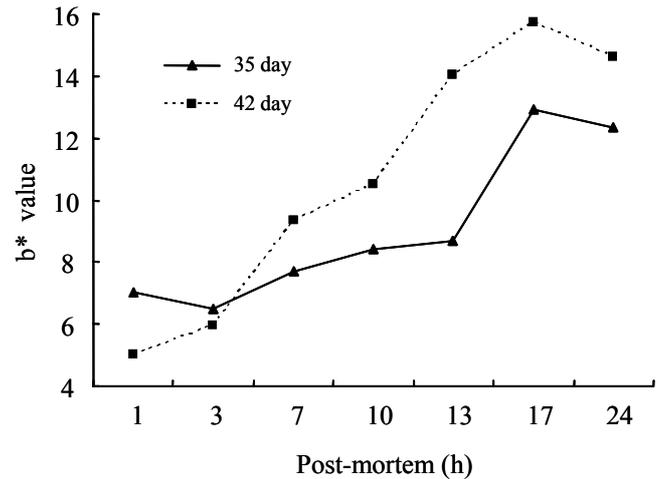


Figure 7. Effect of post-mortem duration and slaughter age on b* value of carcasses.

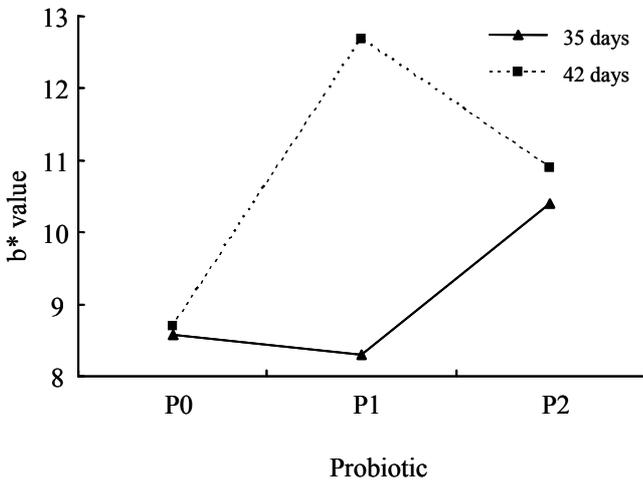


Figure 6. The effect of the interaction of probiotic by slaughter age on b* value of carcasses.

the age has reportedly influenced the myoglobin content of other species (American Meat Institute Foundation, 1960). Results of our experiment show clearly that the use of the probiotic in broiler diets prevented the increase of a* value indicating redness ($p < 0.05$). On the other hand, it was observed that a* value increased during post-mortem ($p < 0.01$) and reached its highest value at 17 h ($p < 0.05$).

Figure 5 illustrates that the interaction of slaughter age \times postmortem aging time affected a* value and the highest a* value occurred from 42-d-old slaughtering, and linearly increased during the 24 h ($p < 0.05$). As to 35-d-old slaughter; there was no change up to 13 h, but then inclined ($p < 0.05$). However, at the end of the storage a* value belonging to 35-d-old was lower approximately 2 units than 42 days ($p < 0.05$) (Figure 5). Petracci and Fletcher (2002) indicated that changing of a* values in the skin of broiler carcass was not significant. In contrast to, Karaoğlu et al.

(2005) determined that a* values of carcasses in broiler slaughtered at 49 days of age were 0.90 ± 0.59 and 2.18 ± 1.34 , for 1 and 24 h of post-mortem. Karaoğlu et al. (2004) found that a* value of carcasses of broilers slaughtered at 7 week of age was 0.94 at first h of post-mortem, and as time goes on it increased to 2.56 at the end of the 24 h. Also the difference both among the various time of post-mortem and treatment groups was significant.

Slaughter age significantly affected b* value ($p < 0.01$) and it was higher for 42-d-old slaughtering ($p < 0.05$). The use of probiotic in broiler diets increased b* values ($p < 0.01$). b* values of control groups of both slaughter were very similar. There were significant differences between treated-probiotic groups ($p < 0.01$). The highest b* values was encountered in P2 at 35-d-old slaughter, while P1 group at slaughtered 42 d of age ($p < 0.05$). Generally, significant differences in b* value were observed in P1 group when compared with slaughter ages ($p < 0.01$) (Figure 6).

This value significantly increased as time passed during post-mortem ($p < 0.05$) (Table 2). It may be due to the moisture loss of skin, and depending on this the carcasses darkened with increased b* value after slaughtering ($p < 0.05$). Also, as investigated Figure 7 the slaughter age \times post-mortem interaction had significant effect on b* value ($p < 0.01$). Although b* values of first h of post-mortem were lower for 42-d-old slaughter than those of 35-d-old slaughter, with respect to 24 h b* values of 35-d-old slaughter were lower ($p < 0.05$).

While there was no significant change up to 13 h at 35-d- slaughter, a given increasing in b* value occurred until 17 h at 42 d slaughter ($p < 0.05$). A study performed by Altan et al. (2001) showed that pH, L*, a* and b* values were 6.00, 60.64, 0.42 and 12.26 in breast skin and 6.11, 60.57, 0.45 and 8.86 in leg skin of *Ross* broiler. Karaoğlu et al. (2004)

observed that probiotic-treated diets significantly affected b^* values of broiler carcass skin, slaughtered at 7 wk of age, and these values ranged from 12.55 ± 5.28 to 22.35 ± 2.53 , from 1 to 24 h of post-mortem, and differences were highly significant. In that study, it was indicated that b^* values of carcasses in broiler slaughtered at 49 days of age were 11.76 ± 6.71 and 18.79 ± 3.94 , at 1 and 24 h of post-mortem.

From the results, it can be concluded that the use of probiotic in broiler diets had significant effect on the pH and carcass colour traits. It is known that pH plays an important role in the carcass colour traits. Also, different slaughter ages affected colour values except for pH. Therefore, the effectiveness of probiotic supplements, especially of the level of 0.1%, in improving the carcass color traits during post-mortem suggests that it is recommendable to add probiotics to broiler diets for the ultimate carcass colour affecting acceptability of consumer.

REFERENCES

- Aksu, M. İ., M. Karaoğlu, N. Esenbuğa, M. Kaya, M. Macit and H. W. Ockerman. 2005. Effect of dietary probiotic on some quality characteristics of raw broiler drumsticks and breast meat. *J. Muscle Food*, 85(4):306-317.
- Allen, C. D., S. M. Russell and D. L. Fletcher. 1997. The Relationship of broiler breast meat colour and pH to shelf-life and odor development. *Poult. Sci.* 76:1042-1046.
- Altan, A., H. Bayraktar and A. Öneç. 2001. The effects of heat stress on colour and pH of broiler meat. *J. Anim. Prod. (Turkish Anim. Sci. Assoc.)*. 42(2):1-8.
- American Meat Institute Foundation. 1960. *The Science of Meat and Meat Products*. W.H. Freeman and Co., San Francisco, California. USA.
- AOAC. 1984. *Official methods of analysis of the Association of Official Analytical Chemist*. 14th ed., The William Byrd. Press, Inc., Richmond, Virginia.
- Banday, M. T. and K. S. Risam. 2001. Growth performance and carcass characteristics of broiler chicken fed with probiotics. *Indian J. Poult. Sci.* 36(3):252-255.
- Castellini, C., C. Mugnai and A. Dal Basco. 2002. Effect of organic production system on broiler carcass and meat quality. *Meat Sci.* 60:219-225.
- Erdoğan, Z. 1999. The use of antibiotics and probiotics in broiler diets. *J. Lalahan Anim. Sci. Res. Inst. (Lalahan Hayvancılık Araştırma Enstitüsü Dergisi)*. 39(2):57-69.
- Fletcher, D. L. 1989. Factors influencing pigmentation in poultry. *Crit. Rev. Poult. Biol.* 2:149-170.
- Fletcher, D. L. 1999. *Poultry Meat Color*. In: *Poultry Meat Science* (Ed. R. I. Richardson and G. G. Mead) CABI Publishing. USA. pp. 159-175.
- Fletcher, D. L., M. Qiao and D. P. Smith. 2000. The relationship of raw broiler breast meat colour and pH to cooked meat colour and pH. *Poult. Sci.* 79:784-788.
- Froning, G. W. 1995. Color of poultry meat. *Poult. Avian Biol. Rev.* 6:83-93.
- Huang, C., S. Qiao, D. Li, X. Piao and J. Ren. 2004. Effects of *Lactobacilli* on the performance, diarrhea incidence, VFA concentration and gastrointestinal microbial flora of weaning pigs. *Asian-Aust. J. Anim. Sci.* 17(3):401-409.
- Karaoğlu, M., M. İ. Aksu, N. Esenbuğa, M. Kaya, M. Macit and H. Durdağ. 2004. Effect of dietary probiotic on the pH and colour characteristics of carcasses, breast fillets and drumsticks of broilers. *Anim. Sci.* 78(2):253-259.
- Karaoğlu, M. and H. Durdağ. 2005. The influence of dietary probiotic (*Saccharomyces Cerevisiae*) supplementation and different slaughter age on the performance, slaughter and carcass properties of broilers. *Int. J. Poult. Sci.* 4(5):309-316.
- Karaoğlu, M., M. İ. Aksu, N. Esenbuğa, M. Kaya, M. Macit and E. B. Kurbanoglu. 2005. Effect of dietary ram horn hydrolysate (RHH) on the pH and color characteristics of carcasses, breast fillets and drumsticks of broilers. *Int. J. Food Prop.* (In press).
- Kobayashi, Y., S. Koike, H. Taguchi, H. Itabashi, D. K. Kam and J. K. Ha. 2004. Recent advances in gut microbiology and their possible contribution to animal health and production, a review. *Asian-Aust. J. Anim. Sci.* 17(6):877-884.
- Kumprechtová, D., P. Zobağ and I. Kumprecht. 2000. The effect of *Saccharomyces cerevisia* Sc47 on chicken broiler performance and nitrogen output. *Czech J. Anim. Sci.* 45(4):169-177.
- Kutlu, H. R. and M. Görgülü. 2001. The alternatives for antibiotics-growth factors used in poultry diets as feed additives. *Yem Magazin Dergisi* (in Turkish). 27:45-51.
- Livingston, D. J. and W. D. Brown. 1981. The chemistry of myoglobin and its reactions. *Food Technol.* 35:244-252.
- Midilli, M. and S. D. Tuncer. 2001. The effects of enzyme and probiotic supplementation to diets on broiler performance. *Turk. J. Vet. Anim. Sci.* 25(6):895-903.
- NRC. 1994. *National Research Council Nutrient Requirements of Poultry*. 9th rev. Ed. National Academy Press, Washington, DC.
- Petracci, M. and D. L. Fletcher. 2002. Broiler skin and meat color changes during storage. *Poult. Sci.* 81:1589-1597.
- Qiao, M., D. L. Fletcher, J. K. Northcutt and D. P. Smith. 2002. The relationship between raw broiler breast meat color and composition. *Poult. Sci.* 81:422-427.
- Richter, G., I. Kühn and H. Köhler. 1999. Test of Toyocerin in broiler fattenings (Prüfung von Toyocerin in der Broilermast). In *vitamine und Zusatzstoffe in der Ernährung von Mensch und Tier: 7. Symposium Jena/Thüringen*, 22. und 23. September, Germany.
- Satbir, S. and V. P. Sharma. 1999. Performance of broiler chicks under different energy and probiotic levels during summer season. *Indian J. Poult. Sci.* 34(1):34-37.
- SPSS. 1996. *SPSS for Windows Release 10.01*, SPSS Inc.
- Yalcin, S., S. Ozkan, Z. Acikgoz and K. Ozkan. 1999. Effect of dietary methionine on performance, carcass characteristics and breast meat composition of heterozygous naked neck (Na/na+) birds under spring and summer conditions. *Br. Poult. Sci.* 40:688-694.
- Yang, C. C. and T. C. Chen. 1993. Effects of Refrigerated Storage, pH Adjustment, and Marinade on Color of Raw and Microwave Cooked Chicken Meat. *Poult. Sci.* 72:355-362.