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EFFECT OF DIFFERENT DIETARY SUPPLEMENTS ON SELECTED QUALITY INDICATORS OF CHICKEN MEAT

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ABSTRACT

The aim of the study was to evaluate the effect of different feed additives (bee pollen extract, propolis extract, and probiotic) on meat quality of broiler chickens. A total of 180 one day-old broiler chicks of mixed sex (Ross 308) were randomly divided into 3 groups. Dietary treatments were as follows: basal diet, free of supplements (control group; C); basal diet plus 400 mg bee pollen extract per 1 kg of feed mixtures and 3.3 g probiotic preparation added to drinking water (group E1); basal diet plus 400 mg propolis extract per 1 kg of feed mixtures and 3.3 g probiotic preparation added to drinking water (group E2). In the experiment, the probiotic preparation based on *Lactobacillus fermentum* (1.10^9 CFU.g^{-1} of bearing medium) was used. Fattening period lasted for 42 days. Feed mixtures were produced without any antibiotic preparations and coccidiostatics. Meat quality was evaluated by following technological properties: cooling, freezing and roasting loss; colour parameters based on CIELab system; and shear force. Both dietary supplementations led to decrease in cooling ($p \leq 0.05$) and freezing ($p \geq 0.05$) losses compared with control. On the contrary, the supplemented diet tended to increase roasting losses ($p \leq 0.05$) and shear force values in thigh muscle ($p \leq 0.05$). Significantly higher L* values ($p \leq 0.05$) in breast and thigh muscles, as well as the b* values in thigh muscle, were found when broiler chickens were fed the supplements, especially bee pollen extract and probiotics. In addition, the supplements improve redness (a*) of meat. The redness of breast muscle appeared to be the most affected ($p \geq 0.05$) by propolis extract plus probiotics supplementation, while thigh muscle had the highest value ($p \leq 0.05$) in bee pollen extract plus probiotics supplemented group. These findings suggested that the supplements have a beneficial effect on quality of chicken meat due to positive changes in most of quality indicators investigated in the study.

Keywords: chicken meat; loss; colour; shear force; dietary supplement

INTRODUCTION

Worldwide, chicken meat continues to be the most popular poultry meat, representing about 85% of total poultry meat output **(Soriano-Santos, 2010)**. The poultry market has grown substantially due to various marketing practices, such as selling individual cuts. Another reason for the increased popularity of poultry is its low fat and cholesterol contents. Poultry products are especially lean compared to other animal products, such as pork or beef. Consumer interest in natural or organic products is increasing at a fast rate and has contributed to the increase in poultry consumption. Many poultry producers have met consumer needs by producing antibiotic- and hormone-free meat **(Padilla, 2010; Lázaro et al., 2015)**.

There are many criteria that drive a consumer decision to purchase certain products, including appearance, taste, aroma, and texture **(Akiba et al., 2001; Padilla, 2010; An et al., 2013)**. Water-holding capacity, colour, pH, tenderness, and sensory acceptability are commonly used in order to evaluate chicken meat quality because consumers prefer meat that is juicy, tender, and not pale **(Schilling et al., 2010; Miezeliene et al., 2011)**.

Colour and appearance of fresh meat are presumed to be indicators of meat freshness and quality. Chicken muscle colour is affected by a variety of factors, including age, environment, diet, and feed withdrawal. The colour of raw muscle is due to the light-scattering properties **(Brewer, 2010)** andranges from pink to red due to hemoglobin and myoglobin within the muscle **(Padilla, 2010)**. One of the important factors affecting meat colour is the pH of the meat. Broilers produced by organic methods had a lower pH and a lower water-holding capacity, which may have been responsible for producing meat that appeared more yellow as well as less red than broilers produced bya traditional system **(Castellini et al., 2002)**.

Tenderness involves all the mouth feel characteristics perceived kinesthetically: those perceived prior to mastication (particle size, oiliness), during mastication (tenderness, juiciness), and after mastication (fibrous residue, mouth coating) **(Brewer, 2010)**. In general, consumers rate tenderness as the major factor that determines the eating quality of meat **(Brewer and Novakofski, 2008)**.

Carcass chilling time is important processing procedure that influences the quality of meat. Slow, inadequate

chilling decreases the pH of the meat from lactic acid build up and begins to denature proteins within the muscle. This defect, known as pale, soft, and exudative (PSE) meat, is a growing problem in the poultry industry **(Padilla, 2010; Bowker et al., 2014)**.

The defect PSE affects colour negatively, as well as meat texture and integrity. Meat quality as well as water-holding capacity begins to decline, which can make meat tough. To minimize the occurrence of PSE, the temperature of the carcass should be less than 25 °C by 60 min *post mortem* **(Alvarado and Sams, 2002)**.

In order to eliminate the use of antibiotics as growth promoters, search of effective alternatives is a very important task in poultry industry **(Fasina and Olowo, 2013; Cai et al., 2015)**. Plant-derived substances received considerable interest because of their antioxidant and antimicrobial effects reported in many studies. Bee pollen is a natural product, which is collected from plants by honey bees **(Attia et al., 2014)**. The pollen is rich in proteins, essential amino acids, oils, fatty acids, minerals, enzymes and co-enzymes, carbohydrates and flavonoids, carotenoids and phytosterols **(El-Asely et al., 2014)**. Propolis is a natural resinous product produced by honey bees from the gum of various plants and trees, and is used in the beehive as a protective barrier against their enemies **(Duman and Özpolat, 2015)**. It contains amino acids, minerals, ethanol, vitamin A and E, B complex vitamins, and flavonoids and has strong antimicrobial properties **(Aygun et al., 2012; Da Silva Frozza et al., 2013)**.

Among the possible alternatives, probiotics are considered a promising alternative to antibiotics, as well. Probiotic is defined as a live microbial feed supplement that beneficially affects the host animal by improving the intestinal microbial balance **(Daneshmand et al., 2015)**. Application of probiotics can prevent the occurence of diseases, replace or reduce the use of antibiotics, stimulate the immune system, inhibit the inflammatory processes **(Vidová et al., 2013)**. Various studies have reported a wide variety of health-promoting properties influencing the host intestinal balance **(Shim et al., 2012; Blajman et al., 2015)**, as well as quality of chicken eggs **(Angelovičová et al., 2013)** and chicken meat **(Bobko et al., 2015)**.

In the previous study **(Haščík et al., 2015)**, we reported debatable effects of bee pollen, propolis and probiotics on technological properties of chicken meat, since the results observed in the study were not satisfactory. For this reason, we have decided to investigate whether the effect of the natural feed supplements will be more obvious when administered in combination, namely the bee pollen extract with probiotic preparation and the propolis extract with probiotic preparation.

Thus, the objective of the present study includes assessment of influence of the natural supplements in the combination on quality of chicken meat by determination of selected technological properties of chicken meat, namely cooling, freezing and roasting loss, colour and shear force.

MATERIAL AND METHODOLOGY

Chickens and dietary treatments

The experiment was carried out in test poultry station of Slovak University of Agriculture in Nitra. A total of 180 one day-old broiler chicks of mixed sex (Ross 308) were randomly divided into 3 groups, namely, control (C) and experimental (E1, E2) of 60 pcs chickens. The experiment lasted for 42 days. The chickens were bred on breed litter (wood shavings), in a temperature-controlled room; ambient temperature in test poultry station was maintained at 33 °C during the first week and gradually decreased by 2 °C, and finally fixed at 19 °C thereafter. Throughout the entire experimental period, the broilers were provided with *ad libitum* access to feed and water and were kept under constant light regime.

Table 1 lists the basal diet formulated according to nutrient requirements of broilers. The broiler chickens were fed a starter diet (HYD-01) from the 1st to the 21st day and grower diet (HYD-02) from the 22nd to the 42nd day. The feed mixtures both starter and grower were produced without any antibiotic preparations and coccidiostatics.

The dietary treatments were as follows: basal diet without any supplementation (C; control group), basal diet plus 400 mg bee pollen extract per 1 kg of feed mixtures and 3.3 g probiotic preparation added to drinking water (group E1), basal diet plus 400 mg propolis extract per 1 kg of feed mixtures and 3.3 g probiotic preparation added to drinking water (group E2). Besides, the groups were kept under the same conditions.

In the experiment, the probiotic preparation based on *Lactobacillus fermentum* (1.10^9 CFU.g^{-1} of bearing medium) was used.

Bee pollen and propolis had origin in the Slovak Republic. The extracts were prepared from minced bee pollen and propolis in the conditions of the 80% ethanol in the 500 cm^3 flasks, according to **Krell (1996)**. The extraction was accomplished in a water bath at 80 °C for one hour. After that, the extracts were cooled and centrifuged. The obtained supernatants were evaporated in a rotary vacuum evaporator at bath temperature 40 – 50 °C and weighed. Residues in an amount of 40 g were dissolved in 1000 cm^3 of 80% ethanol and used for 100 kg of the feed mixtures.

Slaughter and measurements

At the end of the experiment (42 days of age), 120 broiler chickens, randomly selected from each group (n = 40), were slaughtered at the experimental slaughterhouse of Slovak University of Agriculture in Nitra.

After evisceration, the carcasses were kept at approximately 18 °C for 1 h *post mortem* and thereafter longitudinally divided into two parts. After that, the half-carcasses were weight and stored at 4 °C until 24 h *post mortem*, when the first measurements were done. The left half-carcass was used in order to determinate the technological properties as described below, whereas the right one was assigned to different analysis.

Table 1 Composition of basal diet and nutrient content.

Ingredients (%)	Starter (HYD-01) (day of age 1 – 21)	Grower (HYD-02) (day of age 22 – 42)
Wheat	34.00	37.00
Maize	33.92	37.52
Soybean meal (48% N)	23.00	18.00
Fish meal (71% N)	5.00	3.00
Dried blood	-	1.00
Fodder lime	1.00	0.95
Monocalcium phosphate	0.80	0.70
Fodder salt	0.10	0.10
Sodium bicarbonate	0.15	0.20
Lysine	0.13	0.08
Methionine	0.18	0.20
Clinacox 0.5%[1]	0.02	-
Sacox 12%[2]	-	0.05
Bergafat (palm kernel oil)	1.20	0.70
Euromix BR 0.5%[3]	0.50	0.50
Nutrient content [g.kg^{-1}]		
Linoleic acid	13.53	14.05
ME$_N$ [MJ.kg^{-1}]	12.07	12.16
Fibre	30.50	29.67
Crude protein	212.40	191.61
Ash	27.00	20.90
Ca	8.22	7.18
P	6.55	5.86
Na	1.77	1.70

[1] Active ingredient: each kg contains 5 g of diclazuril; [2] Active ingredient: each kg contains 120 g of salinomycin; [3] Active substances per kilogram of premix: vitamin A 2,500,000 IU; vitamin E 20,000 mg; vitamin D_3 800,000 IU; niacin 12,000 mg; D-pantothenic acid 3,000 mg; riboflavin 1,800 mg; pyridoxine 1,200 mg; thiamine 600 mg; menadione 800 mg; ascorbic acid 20,000 mg; folic acid 400 mg; biotin 40 mg; kobalamin 8.0 mg; choline 100,000 mg; betaine 50,000 mg; Mn 20,000 mg; Zn 16,000 mg; Fe 14,000 mg; Cu 2,400 mg; Co 80 mg; I 200 mg; Se 50 mg.

After 24 h, the colour of breast (*Musculus pectoralis major*) and thigh muscle (*Musculus biceps femoris*) from the left half-carcass (n = 10) was assessed using a Minolta CM 2600d spectrophotometer (Konica Minolta, Japan) and reported in the CIE system values of lightness (L*), redness (a*) and yellowness (b*). Lightness (L*) is the amount of incident light that a surface reflects; positive a* values represent the red colour and negative a* values represent the green one; positive b* values represent yellow and negative b* values represent blue. Colour measurements were taken at three locations on each sample and averaged. All the colour readings were taken on skinless meat, in an area free of obvious colour defects (over scald, bruises, and blood accumulation).

The cooling loss was determined in whole left half-carcass as the percentage of weight loss over a 24 h period, by calculating the weight differences before and after cooling.

Afterwards, the same half-carcasses were stored at -18 °C for 3 months prior to next analysis. Thereafter, the samples were thawed. After thawing was completed, the weight of the samples was obtained. To determine the freezing loss (%), the weight differences before and after freezing process were calculated (n = 10). All the weight measurements were performed using the precision balance Kern 440 (Kern and Sohn, Germany) with accuracy of 0.01 g.

The heat treatment of samples was carried out in oven (Gorenje B 3300 E) at 200 °C for 60 minutes. After allowing the samples to cool at room temperature, the samples were weighed so as to calculate the percentage of roasting losses. The roasting loss was expressed as the percent weight reduction of the heat-treated sample compared to the raw sample (n = 10).

The samples that were used for roasting loss determination were also used for shear force determination. Results for tenderness of breast (*Musculus pectoralis major*) and thigh muscle (*Musculus biceps femoris*) have been expressed as shear force (kg.cm^{-2}) (five measurements were performed on each sample to obtain an average value). First, the five cores with the same size (2.0 cm wide, 5.0 cm long and 1.5 cm high) were removed from each heat-treated sample (n = 10). Then, the cores were sheared perpendicular to the muscle fibres orientation using a Warner-Bratzler shear device (Chatillon, U.S.A.), in accordance with **Goodson et al. (2002)**.

Statistical analysis

The data processing for technological attributes of raw and heat-treated samples of meat was performed using a statistical program Statgraphics Plus Version 5.1 (AV Trading Umex, Dresden, Germany). For the

determination of significant difference among the tested groups, analysis of variance (ANOVA) with Scheffé's method was used.

RESULTS AND DISCUSSION

The effects of the feed supplements administration on selected technological properties of chicken meat are shown in Table 2 and Table 3. Regarding cooling losses of chicken meat, there was positive effect ($p \leq 0.05$) of feed additives, with the lowest losses being observed in bee pollen plus probiotic supplemented group (3.35%), followed by propolis plus probiotic supplemented group (3.58%). Also, there was found the positive effect for freezing losses of chicken meat, with, however, no statistical significance. The lowest value was observed in propolis plus probiotic supplemented group (2.78%), followed by bee pollen plus probiotic supplemented group (3.38%). The effect of the supplements was rather inappropriate for roasting losses owing to the higher values in experimental groups than that in control. Results indicated that supplementation of chicken diet with the feed additives was more effective in lowering of losses caused by cooling and freezing than those caused by roasting. In addition, the values of cooling and freezing losses were lower than those achieved in the study of **Haščík et al. (2015)** when the supplements were administered singly.

As far as colour measurement is concerned, more obvious results were achieved in thigh muscle. Lightness (*L) of thigh muscle was significantly ($p \leq 0.05$) improved by feed supplements. The improvement was shown by higher values in both bee pollen plus probiotic (54.32) and propolis plus probiotic supplemented group (54.44) when compared with control (51.64). In breast muscle, the significantly ($p \leq 0.05$) higher L* value was observed in bee pollen plus probiotic supplemented group (55.58) when compared with the other two groups.

Chicken breast muscle can be classified according to the

Table 2 Cooling loss, freezing loss and roasting loss of chicken meat (mean ±SD).

Parameter	Group			*S*
	C	E1	E2	
Cooling loss [%]	3.97 ±0.44^{a}	3.35 ±0.43^{b}	3.58 ±0.45^{ab}	**
Freezing loss [%]	3.53 ±1.00^{a}	3.38 ±0.68^{a}	2.78 ±0.97^{a}	NS
Roasting loss [%]	29.54 ±1.16^{a}	31.18 ±1.26^{b}	30.01 ±1.06^{a}	**

Legend: C – control group; E1 – experimental group with basal diet plus 400 mg bee pollen extract per 1 kg of feed mixtures and 3.3 g probiotic preparation added to drinking water**;** E2 – experimental group with basal diet plus 400 mg propolis extract per 1 kg of feed mixtures and 3.3 g probiotic preparation added to drinking water; mean – average, SD – standard deviation; a, b – means with different superscripts within row differ significantly; *S* – significance; **$p \leq 0.05$; NS = not significant.

Table 3 Instrumental colour values and shear force value of chicken breast and thigh muscle (mean ±SD).

Parameter		Group			*S*
		C	E1	E2	
Colour parameter					
CIE L*	breast	52.24 ±2.88^{a}	55.58 ±3.37^{b}	52.65 ±3.60^{ab}	**
	thigh	51.64 ±1.86^{a}	54.32 ±2.18^{b}	54.44 ±2.90^{b}	**
CIE a*	breast	0.07 ±0.06^{a}	0.13 ±0.43^{a}	0.49 ±0.78^{a}	NS
	thigh	1.94 ±0.64^{a}	4.17 ±1.58^{b}	2.30 ±1.39^{a}	**
CIE b*	breast	10.08 ±1.26^{a}	10.73 ±1.58^{a}	10.46 ±2.08^{a}	NS
	thigh	9.60 ±1.76^{a}	12.56 ±1.60^{b}	11.42 ±2.17^{ab}	**
Shear force value [kg.cm^{-2}]	breast	1.97 ±0.37^{a}	2.00 ±0.42^{a}	1.88 ±0.51^{a}	NS
	thigh	1.33 ±0.24^{a}	1.67 ±0.33^{b}	1.62 ±0.45^{ab}	**

Legend: C – control group; E1 – experimental group with basal diet plus 400 mg bee pollen extract per 1 kg of feed mixtures and 3.3 g probiotic preparation added to drinking water; E2 – experimental group with basal diet plus 400 mg propolis extract per 1 kg of feed mixtures and 3.3 g probiotic preparation added to drinking water; mean – average, *SD* – standard deviation; a, b – means with different superscripts within row differ significantly; *S* – significance; **$p \leq 0.05$; NS = not significant.

colour as: lighter than normal (L* >53), normal (48 < L* >53) and darker than normal (L* <48), as mentioned in the study of **Qiao et al. (2001)**. Since the L* value in bee pollen plus probiotic supplemented group (E1) exceeded the value of 53, the meat can be classified as lighter than normal while that in other groups (52.24 – group C, 52.65 – group E2) can be classified as normal.

Numerically higher redness (a*) of breast muscle, though not confirmed statistically ($p \geq 0.05$), was observed in group of chickens receiving the supplements (0.13 – group E1, 0.49 – group E2) in comparison with control (0.07). Redness (a*) of thigh muscle was significantly improved ($p \leq 0.05$) when bee pollen extract and probiotics were used (4.17 – group E1) in comparison with other groups (2.30 – group E2, 1.94 – C).

The values of yellowness (b*) of breast muscle were similar among the groups. However, the yellowness (b*) of thigh muscle increased by the dietary supplementation of bee pollen extract and probiotics (12.56 – group E1), as well as propolis extract and probiotics (11.42 – group E2) compared with control diet (9.60).

Jiang et al. (2014) have noticed that a* value (redness) is the most favoured by consumers and lower b* value (yellowness) indicates less pale meat. For this reason, we assume that low a* values found in our study are not quite convenient for consumers.

Results for the colour measurements are in agreement with **Lei and Kim (2013)** who investigated the effect of whole egg powder on meat quality in broiler chickens (Ross 308). In the study, L* values of breast muscle ranged from 55.1 to 57.8, a* values ranged from 14.0 to 14.9 and b* values ranged from 12.4 to 13.5. It is obvious that b* values observed in the study were much more high than those in the present study, that is why the meat has appeared as more red. However, there was no effect of added egg powder on colour parameters of chicken meat found.

Similar finding were reported by **Jiang et al. (2014)** using isoflavone as dietary supplement for Lingnan yellow male broilers. On the one hand, the supplementation resulted in a significant ($p \leq 0.05$) decrease in L* colour parameter (55.17 – 57.49), but on the other hand in a significant ($p \leq 0.05$) increase in a* colour parameter (12.55 – 14.00). Yellowness (b*) (17.59 – 20.92) was not affected by isoflavone supplementation.

Ros-Polski et al. (2015) reported significant influence ($p \leq 0.05$) of lightness (L*) (46.47 – 56.43) and redness (a*) (3.21 – 3.92), but not yellowness (b*) (12.63 – 12.80) adding sodium chloride (NaCl) to the chicken meat, which results are similar to this study.

Results of the present study, however, are not consistent with those obtained by **Dotas et al. (2014)**, who found much higher L* values (74.5 – 77.3 in breast muscle, 73.6 – 77.3 in thigh muscle) after partial replacement of soybean meal and corn with raw field peas, perhaps also because male broiler chickens (Ross 308) were used. Redness (a*) ranged from 4.3 – 6.4 in breast and 4.2 – 5.5 in thigh muscle, yellowness (b*) ranged from 17.4 – 23.3 in breast and 13.3 – 19.3 in thigh muscle.

Min et al. (2012) observed lower L* values in breast fillets of male broilers receiving distillers dried grains with solubles (DDGS) (54.94 – 58.6) compared with those fed a basal diet (59.02) while a* values were in rangeof 12.61 – 13.48 (11.90 in control). Rather different values were found in b* colour parameter (31.99 – 38.95 vs. 30.29 in control).

In another study, **Schilling et al. (2010)** also investigated DDGS as feed supplement in diet of broiler chickens and evaluated the effect on meat quality. They found no differences ($p \geq 0.05$) among breast meat from the different groups with respect to colour parameters. Yet, the results achieved in the study were similar to those in our study (except for b* values), the L* (52.9 – 53.8), a* (2.2 – 2.7) and b* values (2.4 – 3.2) for all groups were characteristic of normal broiler breast meat (L* < 55) at 24 h *post mortem*.

Also, **Cai et al. (2015)** observed similar values of colour parameters of breast muscle after supplementation of rare earth elements-enriched yeast in diet of broilers (Ross 308), however, with significant differences only in redness (b*). L* values ranged from 57.73 – 57.81, a* values ranged from 14.05 – 15.57, and b* values ranged from 15.34 – 17.17.

Akiba et al. (2001) evaluated effect of diet supplemented with *Phaffia rhodozyma*, yeast containing high levels of astaxanthin, on meat colour in broiler chickens. They found following values in breast muscle (*Pectoralis major*): L* values in range of 39.6 – 41.7, a* values in range of -0.4 – 2.4 and b* values in range of 8.2 – 8.8. The values in thigh muscle were as follows: 41.2 – 42.6 for lightness (L*), -1.2 – 3.8 for redness, and 15.8 – 16.0 for yellowness (b*). The effect was considered as very positive, owing to visible redness of meat from broilers receiving the supplement.

Miezeliene et al. (2011) reported that diet containing the addition of selenium in broilers diet had a significant effect on meat colour. Lightness of chicken breast significantly decreased ($p \leq 0.05$) (73.38 vs. 56.51), but redness (3.05 vs. 6.75) and yellowness (3.71 vs. 5.20) significantly increased ($p \leq 0.05$) with the addition of selenium in diet.

Our previous study **(Haščík et al., 2015)** showed that diet containing bee pollen, propolis and probiotics did not affect lightness and yellowness of chicken meat, but increased ($p \leq 0.05$) redness of breast muscle (0.59 – 1.33) and decreased ($p \leq 0.05$) redness of thigh muscle (1.33 – 1.84), which was not in accordance with this study, where all the colour parameters were increased.

Regarding shear force measurement (Table 3), none of supplements caused significant changes ($p \geq 0.05$) in tenderness of breast muscle, whereas both bee pollen plus probiotic and propolis plus probiotic supplementations (1.67 and 1.62 $kg.cm^{-2}$, respectively) increased ($p \leq 0.05$) the shear force in thigh muscle compared with control (1.33 $kg.cm^{-2}$). When comparing shear force values among the groups, bee pollen plus probiotic supplemented group showed higher values than the other two groups. Thus, the bee pollen extract in combination with probiotics has been considered as the least appropriate supplement.

These findings are consistent with the previous study **(Haščík et al., 2015)**, in which very similar shear force values were observed. In addition, the lowest values were found in both breast (1.89 $kg.cm^{-2}$) and thigh

(1.25 kg.cm^{-2}) muscle of broilers receiving propolis extract. In the present study, the best results were observed also in group receiving propolis extract (in combination with probiotics). It is, thus, likely that the propolis is the most effective in improving the tenderness of chicken meat among the supplements.

According to **Chen et al. (2007)**, tenderness is the most important factor in consumer perception of palatability and quality of meat products. Therefore, this attribute has drawn much attention from researchers.

Castellini et al. (2002) assessed effect of organic production on meat quality of male broiler chickens (56 days of age). In the organic group, there were higher shear force values of roasted samples found in both breast and thigh muscle (2.25 and 3.08 kg.cm^{-2}, respectively) compared with control (1.98 and 2.39 kg.cm^{-2}, respectively). When comparing with our study, the higher values observed in the study of **Castellini et al. (2002)** can be correlated to the higher age of chickens.

Since the most of researches have used various devices and cooked samples for the shear force measurement, it is difficult to directly compare the shear force values among the different studies.

In the study of **Min et al. (2012)**, significant difference was observed ($p \leq 0.05$) between broilers fed the distillers dried grains with solubles (DDGS) and control group with respect to shear force. With the addition of DDGS, shear force almost doubled (24.29 – 42.32 N), compared with that of control (12.79 N). Since the tender meat is more acceptable to consumers, dietary DDGS were evaluated as less suitable supplement.

Schilling et al. (2010) found relatively low shear force values (15.1 – 16.3 N) which indicate very tender meat that would be highly acceptable to consumers.

Similarly, **Chen et al. (2007)** reported shear force values of breast muscle for Arbor Acres broiler, Jingxing 100 crossbred chicken and Beijing fatty chicken at levels 17.36, 17.06 and 11.90 N, respectively.

CONCLUSION

In conclusion, the supplements evaluated in the study (bee pollen extract plus probiotics and propolis extract plus probiotics) reduced cooling ($p \leq 0.05$) and freezing ($p \geq 0.05$) losses. However, they slightly increased ($p \leq 0.05$) the losses during roasting. As regards colour measurement, the supplements elevated the values of L* colour parameter (lightness) in both breast and thigh muscle compared with group containing no supplements. The most noticeable effect of the supplements was, however, observed in redness (a*), because of presenting higher values. The b* colour parameter (yellowness) did not appear to be positively affected by the supplementation, as well as shear force values, which did not differ from each other except lower ($p \leq 0.05$) shear force value of thigh muscle in control. The present study demonstrated that bee pollen and propolis extract in combination with probiotics could be considered as suitable additives without negative indications in broiler chickens, because of apparent synergistic effect of mixture of the supplements.

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