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■ Keywords

Bone darkening, commercial processing plant, meat quality.

ABSTRACT

Black bone syndrome (BBS) affects poultry industry, and it is caused by the darkening of the tissue adjacent to the bone due to leak age of bone marrow contents during cooking. The objective of this experiment was to estimate BBS incidence in chicken thighs. A completely randomized experimental design, with two treatments (refrigerated or frozen) of 50 replicates each, was applied. The influence of BBS on meat quality was assessed according to bone lightness (*L), and meat appearance and sensorial characteristics. Lightness was measured using a colorimeter (Minolta® 410R) positioned on the proximal epiphyseal growth plate. Meat quality was evaluated after roasting by assigning scores for appearance (acceptable = no darkening, intermediate = little darkened, and unacceptable = severe darkening). Twelve refrigerated and 12 frozen thighs were used for sensorial analysis (adjacent muscle appearance, odor, tenderness, and flavor), assessed using a hedonic scale (1 = bad to 10 = very good) by trained panelists. Lightness was submitted to ANOVA and Tukey's test ($p < 0.05$), and the Wilcoxon test ($p < 0.05$) was used to analyze other characteristics. Confidence intervals were established for BBS based on *L values ($< 37.5 = \text{BBS}$ and $> 37.5 = \text{normal}$). The incidence of BBS was 35%, with a 16% increase thighs were frozen. Meat taste was not influenced by the treatments. Meat appearance, flavor, and tenderness were not affected by freezing or refrigeration, only by BBS degree. It was concluded that freezing increases the incidence of BBS and chicken thighs with bones presenting lower luminosity have worse meat quality.

INTRODUCTION

Brazilian poultry production presents outstanding results when compared to other meats produced in the country. For instance, in 2011, total poultry meat production achieved 11.4 million tons, while beef production was only 9 million tons, and pork production, as 3.6 million tons (Avisite 2011). The main reasons of this result are reduction in cost of poultry products, the general increase of consumers income, of the Brazilian population, and of public health concerns (Zilli *et al.*, 2005).

Consumers currently demand a wide range of poultry products, particular for convenient and value-added parts. This trend is explained by changes in the eating habits of the population and by consumers' concerns with convenience, nutritional quality, and food safety, as well as with affordable prices (Olivo, 2004). Deboned parts may show some meat defects, and may cause ejection by consumers, as well as poor sensorial characteristics, such as appearance and tenderness, which are highly valued by consumers (Beraquet, 1999).



Meat redness accompanied by the presence of blood is related to a meat defect called bone darkening or black bone syndrome, and it has been reported in cooked broiler meat parts. Black bone syndrome (BBS) is defined as a condition where the surface of the bone and adjacent muscle tissues become dark reddish brown or black after cooking (Smith & Northcutt, 2004). Measures to mitigate this problem have been sought since the early days of the meat processing industry, including the addition of D vitamin to broiler diets (Ellis & Woodroof, 1959), and different freezing regimens and cooking methods (Cunningham, 1974). This condition was previously reported by Lyon & Lyon (2002) and Saunders-Bladers & Korver (2006). However, recent observations of special chicken meat part on the shelves of supermarkets suggest that the problem is much more widespread than earlier reported (Smith & Northcutt, 2004). BBS is caused by a problem in the intramembranous ossification, and it impairs meat quality. It may also be related to poor broiler welfare during rearing (Whitehead, 2010).

In the supermarkets, darkened bones are frequently found, affecting the marketing of chicken meat. Recent reports mention that fast-food chains are using boneless chicken meat in order to reduce the problem (Lyon & Lyon, 2002). Therefore, due to the limited literature published on this subject and its impacts on the market, it is necessary to study how the effects of BBS can be reduced or eliminated.

This experiment aimed at evaluating the incidence of black bone syndrome in refrigerated and frozen broiler thighs.

MATERIAL AND METHODS

Sampling

One hundred pairs of chicken thighs were collected in a commercial processing plant located in Dourados,

MS, Brazil. The meat derived from a same flock of male Cobb® broilers, and the pair of thighs derived from each bird was individually packed to allow their identification. A completely randomized experimental design with two treatments of 50 replicates each was applied. Treatments consisted refrigerated (4 °C) or frozen (-10 °C) thighs.

Experimental procedure




Samples were submitted to the Laboratory of Meat Technology, School of Agrarian Sciences (FCA), Federal University of Grande Dourados (UFGD), to estimate the prevalence of BBS using qualitative meat characteristics (bone lightness, and meat appearance and sensorial analysis). Both thighs from each broiler carcass were used. The right thighs were deboned and submitted to lightness (L*) test, were the left thighs were used for meat quality analyses. The left thighs were roasted in an electric oven until internal temperature reached 90 °C. Raw bone lightness was determined using the Minolta colorimeter® 410R, positioned on the growth plate of the proximal epiphysis of the thigh.

After roasting, thighs were visually assessed to determine the darkening of the femur adjacent muscle tissues. Their appearance were scored as acceptable (region close to the bone did not present any darkening), intermediate (region close to the bone slightly darkened), and unacceptable (region close to the bone with severe darkening), as shown in Table 1.

The sensorial assessment of refrigerated meat and frozen thighs was performed by a panel of testers, using a 0-10 hedonic scale, where 0 = very bad and 10 = good appearance, tenderness and flavor.

Data were submitted to analysis of variance. Lightness was compared by the test of Tukey and the Wilcoxon test was used to compare the other parameters. All tests adopted the confidence interval of 95% ($p < 0.05$).

Table 1 – Scores used to assess black bone syndrome in broiler thighs.

BBS assessment			
Scale of acceptance	Acceptable	Intermediate	Unacceptable
Values of lightness (L*)	37.5 – 40.0	ns*	34.0 – 37.0
Visual examples			

ns = not significant



RESULTS AND DISCUSSION

Thighs affected by BBS were characterized as a function of lightness values, and those with values lower than 37.5 were considered as presenting BBS. Thighs with lightness values within the range of 37.5 – 40 were considered normal (Table 1). The incidence of thighs presenting black bone syndrome in both treatments (refrigerated and frozen) was 35%. However, there was a 16% increase in the incidence of BBS in frozen thighs compared with refrigerated thighs. Some authors (Saunders-Bladers & Korver, 2006; Lyon & Lyon, 2002; Lyon *et al.*, 1976; Spencer *et al.*, 1961) also observed higher incidence of darkening in frozen chicken leg bones. According to Mota (2012), it is possible to increase the proportion of normal bones using dietary vitamin supplementation.

Visually, frozen thighs presented an 18% increase in the incidence of an unacceptable black bone syndrome compared with refrigerated thighs (Figure 1). Similar results were obtained by Lyon & Lyon (2002) when evaluating the effect of temperature on chicken thigh meat color, and observed that low temperature storage darken sthigh meat adjacent to bone.

Relative to sensorial characteristics, meat taste was not influenced by treatments. Chiling or freezing did not affect meat appearance, odor, or tenderness, except when BBS was present (Table 2). When meat quality worsened, sensorial characteristics followed the same trend.

When meat lightness was evaluated, it was observed that the exposure to freezing increased BBS incidence in the evaluated samples. Whitehead (2009) supplemented broiler diets with 0 to 69 mg of 25-hydroxyvitamin D or with regular vitamin D₃ levels and measured the optical density reflected 10 to 15 mm of the proximal ends of tibias. The author verified that frozen browning was significantly lower ($p < 0.05$) in birds supplemented with 25-hydroxyvitamin D, indicating that its supplementation may influence the reduction of BBS. Previously, Ellis & Woodroof (1959) found that diet may affect chicken bone darkening; particularly low calcium or high vitamin D levels may promote more severe darkening.

The gross evaluation of the thighs after roasting in an electric oven showed that the freezing also negatively affected the meat. This result maybe explained by freezing and thawing. Freezing causes the formation of ice crystals, which make muscle fiber swell and cause their physical separation. When the meat is subsequently thawed, bone marrow contents leak to the adjacent tissues, which results in the dark appearance of the meat before and during cooking, as the red color turns brown or gray and, in severe cases, black (De Oliveira, 2000). The red color in meat is due to the hemoglobin present in the bone marrow, which is relatively porous in young birds. During cooking, hemoglobin is oxidized, and blackens the blood (Whitehead, 2010).

According Pereira (2003), depending on the proportion of ice crystals in the bone marrow, disruption of tissues is more or less severe. The cooking process can further contribute to the darkening of meat (Whitehead, 2010).

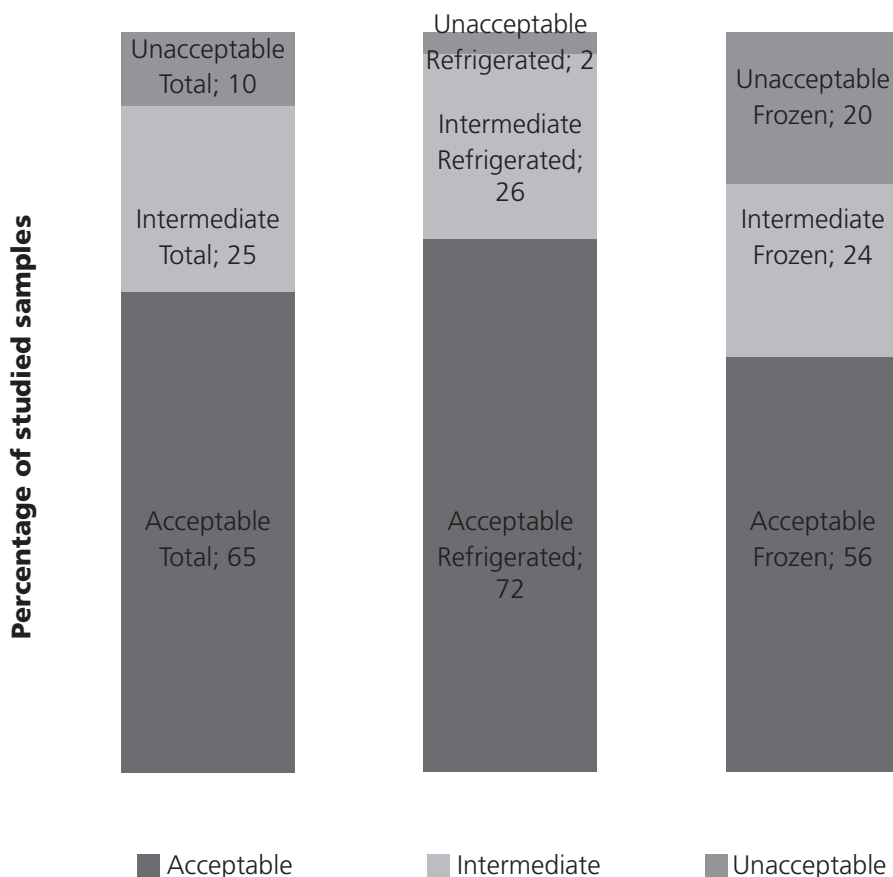


Figure 1 – Incidence of thighs presenting black bone syndrome after gross examination



However, Smith & Northcutt (2004) evaluated the lightness of thigh meat submitted to different cooking temperatures (after freezing) and did not observe any influence of cooking temperature on meat darkening. According to Saunders & Korver-Blades (2006), blood leakage and meat discoloration of whole thighs can be reduced when vitamin D₃ is supplemented in broiler diets, increasing consumers' acceptance.

Table 2 – Sensorial evaluation of broiler thighs meat for determining black bone syndrome

BBS incidence	Treatment	Appearance	Odor	Softness	Flavor
Acceptable	Refrigerated	6.4	8.5	8.5	8.0
	Frozen	6.5	6.9	7.4	8.0
	Mean	6.5a	7.5a	8.0a	8.0
Intermediate	Refrigerated	5.6	7.6	7.6	5.9
	Frozen	6.0	6.0	8.6	9.3
	Mean	5.8b	7.0a	7.9a	7.0
Unacceptable	Refrigerated	3.9	5.8	8.8	6.7
	Frozen	4.3	6.1	5.4	7.2
	Mean	4.1c	5.9b	6.1b	7.1

Means followed by different letters in the column differ by the test of Wilcoxon ($p > 0.05$).

The degree of bone darkening affected meat sensorial characteristics (appearance, odor and tenderness), reducing pane lists acceptance as darkening increased. Consistent results were reported by AMSA (1995), reinforcing that blood leakage from the marrow may reduce the acceptance chicken thigh meat presenting BBS. In the study of Oliveira (2000), bone darkening did not affect meat taste, odor, or texture, but it resulted in poor meat appearance. That author also reported that precooking the before freezing reduces the rate of darkening.

Chicken thighs stored in the freezer presented higher BBS incidence (gross and light examinations) compared with the chilled samples. Leakage of bone marrow negatively affected meat appearance, odor, and tenderness. Therefore, the rejection of chicken meat affected with BBS in the market may cause future problems for the poultry industry. Variations in meat quality can be related to processing and storage conditions (Olivo, 2006).

One method of meat cold storage is industrial, and it is the most widespread conservation technique used for meat and other perishable foods. Freezing preserves foods seasonal characteristics, ensures their long-distance transport, allowing their use for processing or consumption (Pardi *et al.*, 2001). It is one of the most valuable tools used in food technology because it enables the reduction of production costs, improves food quality, allows reducing losses and waste, and

preserves food flavor, color, texture, and their initial qualities (Baruffaldi & Oliveira, 1998).

ACKNOWLEDGEMENT

The authors wish to thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPQ for funding this study, and the company BR Foods for donating the meat samples.

CONCLUSION

The cold storage (refrigeration or freezing) of chicken thighs increases the incidence of the black bone syndrome, tending to reduce consumers' acceptance of the product, despite the lack of influence of BBS on meat flavor or odor. Further studies need to be carried out on how to improve chicken bone quality, considering that chickens thighs are commonly marketed chilled or frozen.

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