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Effect of Light Intensity and Handling During Rearing on Broiler Breast Meat Characteristics

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Abstract: This study was designed to evaluate the effects of light intensity and handling during rearing on broiler and meat quality factors. Male broilers were housed in light-tight rooms and subjected to Bright (BL) [15.0 Foot-Candles (FC)] or Dim (DL) (0.1 FC) intensity. To determine effects of handling on meat quality, birds were further divided into 3 handling groups either handling by Legs (L) or Wings (W), or No Handling (NoH). After processing and chilling at 51 d of age, breast filets were deboned at 2 h and 4 h PM and filet weights, filet dimensions (length, width, height and area), sarcomere length, cook-loss and tenderness were evaluated. Birds subjected to DL had greater live weights ($p<0.05$), post-chill weights and filet weights compared to birds reared in BL. The increase in filet weights observed for in DL was due to an increase in filet length and area. Light or handling treatments had no affect on DPM and other carcass defects. Cook-loss had no specific trend. Filets deboned at 2 h PM had higher shear values than those deboned at 4 h PM, regardless of light or handling. Within the 2 h PM deboning period, DL resulted in an increase in shear values, as well as sarcomere length, compared to BL treatments. This trend was not observed in the filets deboned at 4 h PM. In conclusion, dim light treatment resulted in longer, heavier filets but slightly tougher meat when filets were deboned at 2 h PM.

Key words: Light intensity, handling, meat quality, tenderness, filet dimensions

INTRODUCTION

One of the fastest growing areas of the poultry industry is the foodservice segment. To meet the needs of foodservice, breast meat often needs to be trimmed to tight specification for length, width, thickness and weight. These specifications are important to ensure uniform product portioning for consumer, proper bun coverage and to ensure that all product is cooked to a safe endpoint temperature. Over the years, genetic improvements in poultry have led to improved growth traits, maximized breast yields, decreased mortality and shortened grow-out period (Deaton and Reece, 1970; Halvorson and Jacobson, 1970; Charles *et al.*, 1992; Acar *et al.*, 1993). Because birds are heavier today due to genetic improvement, the filet size has increased proportionally.

Light intensity is one factor that is known to influence body weight (Shutze *et al.*, 1960; Beane *et al.*, 1962; Skoglund and Palmer, 1962; Deaton *et al.*, 1976; 1978; 1980; Cherry *et al.*, 1980; Charles *et al.*, 1992). Specifically, earlier studies have shown that birds raised under low-intensity light were heavier than birds raised under high intensity light (Shutze *et al.*, 1960; Beane *et al.*, 1962; Skoglund and Palmer, 1962; Deaton *et al.*, 1976; 1978, 1980; Cherry *et al.*, 1980; Charles *et al.*, 1992). When bird weight increases, filet dimensions would likely change and this could impact the degree of trimming that has to be done to achieve a uniform weight and size. However, there is relatively no information available to determine the impact of light intensity on overall filet dimensions.

In addition to uniform filet dimension, another aspect of consumer acceptability is meat that is free of visible defects. Bird handling has been shown to affect meat quality. Specifically, handling prior to processing has been related to increased incidence of meat quality defects and downgrading. Injuries caused by handling included bruising and dislocated and broken bones (Scott, 1994). In commercial processing plants, bruising is often caused by rough handling in catching, cooping, loading and hauling from farm to processing plant (Ringrose, 1953). Bruising caused by handling has a significant impact on meat yield due to downgrading (Hewel, 1986). Breast bruises are the most common, followed by leg and wing bruises (Hamdy *et al.*, 1961b). Therefore, it is important to understand how handling affects overall meat quality.

While studies show that there is a lot of variability in tenderness of filet deboned early PM, there is no information regarding the effect of light intensity on filet tenderness. Therefore, our study focused on determining the effect of light intensity and handling treatments on breast filet quality and characteristics. In addition, the study evaluated the effect of deboning time PM within the light treatments. By understanding how pre-slaughter (lighting and handling) and post-slaughter (deboning time) practices affect breast filet characteristics and quality, optimum conditions can be identified to improve meat quality.

MATERIALS AND METHODS

Bird management: Male Ross 344 x Ross 508 broilers (total n = 1080) were randomly placed in 12 light-tight environmentally controlled rooms (90 birds/room, 3.66 x 3.05 m) with litter-covered floors. Birds were provided corn-soy starter (1-16 d, 22.5% CP, 3,086 kcal ME/kg), grower (16-30 d, 20.8% CP, 3,119 kcal ME/kg), finisher (30-44 d, 19.0% CP, 3,155 kcal ME/kg) and withdrawal feeds (44-51 d, 16.7% CP and 3,197 kcal ME/kg). Water was available *ad libitum*.

Experimental treatments: Six rooms were provided a Bright Light Intensity (BL) of 15 Foot-Candles (FC) from 1-51 d of age. The other 6 were provided a Dim Light Intensity (DL) of 0.5 FC from 1-9 d and 0.1 FC from 9-51 d. Light was from incandescent bulbs and the intensity was monitored by digital illuminometer[1] and adjusted daily. A step-up lighting program consisting of several durations of light and dark was used in both treatments (Table 1). At 23 d, birds in each room were randomly divided into 3 equal groups and assigned to either No Handling (NoH), Leg Handling (L), or Wing Handling Treatments (W) and marked accordingly. At 37 and 44 d handling treatments were applied. Birds in the W treatment were captured by the wings and then held by the wings for 20s and weighed by suspending by the wings from a hanging scale. Similarly, birds in the L treatment were captured by the legs and then held by the legs for 20s and weighed by the legs from a hanging scale. Birds that were in the NoH treatment were not captured or weighed at 37 and 44 d. All birds were gently captured by the body and weighed in a cone on a top loading scale at 51 d.

Table 1: Step-up lighting program

Day	Hours Light (L) : Hours Dark (D)
1-9	23:1
9-16	12:12
16-23	14:10
23-30	17:7
30-37	20:4
37-51	23:1

Processing: For evaluation of processing parameters, the experimental design consisted of 2 replications (a total of 144 birds/replication), which is 24 birds/handling and light intensity treatment/replication (72 birds/light intensity treatment/replication). Birds were further divided into 2 deboning periods (n = 12 birds per replication x 2 replications) and deboned at 2 h or 4 h PM.

At 50 d, birds were weighed and wing tagged based on treatment. At 51 d, following a 10-h period of feed withdrawal, birds were hung on shackles and electrically stunned (50 V, 20 mA, 400 Hz). Birds were killed by a single cut to the throat severing the right carotid artery and jugular vein, followed by a 95s bleed-out. Subsequently, all birds were subscalded in 2.44 m long single pass s/s, steam injected scalder[2] at 56.6°C for 90s; defeathered in a 1.22 m long picker[3] for 42s; eviscerated[4] using automatic eviscerator and chilled in 2 C ice-slush of static tap water for 30 min.

Data collection: The chilled carcasses were deboned by removing the *Pectoralis* muscles (using the procedures of Hamm, 1981) at 2 h PM (post-chilling). Filets were trimmed of excess skin and wings were removed. Breast filet were visually observed for any sign of DPM. Thigh and wing were visually observed for deep thigh bruise and wing bruise, respectively. Whole breast were halved to obtain left and right filets and were used for determining of filet dimensions and meat quality characteristics. Filet dimension determinations included of weight, height, width, length and the area of the filet. Meat quality determinations included cook-loss, pH, tenderness and sarcomere length.

The left filets were cut parallel to the muscle fiber into 2 pieces (cranial and medial). Cranial sections were immediately frozen in liquid nitrogen and stored at -80°C until analyzed (<1 mo) for pH determination via the iodoacetate method (Sams and Janky, 1986). The medial section of the filet was stored at -20°C for <1 month for sarcomere length determination via the neon laser diffraction method of (Cross *et al.*, 1980) as modified (Sams and Janky, 1986).

After weighing, dimensions of right filets were determined using calipers[5], following tracing of the outline of each on plastic transparency sheets. Height, width and length were measured. Areas of filets were measured by summing the number of squares on graph paper that were covered by the tracing of each filet. Right filets were reweighed and stored on ice (<2°C) in drainable containers until the next day. They were then baked in foil-covered aluminum pans in an air convection oven[6] at 177°C to internal temperature 76°C. Cooked filets were cooled to room temperature and reweighed for cook loss determination. Cook loss was expressed as a percentage (Sams, 1992). All cooked filets were held overnight at 2°C and then subjected to shear analysis.

Shear value: Shear analysis was performed on duplicate 40 x 20 x 7 (L x W x H) mm samples cut from cranial and medial sections of each filet with the long axis of the sample parallel with the muscle fibers. Samples were weighed and placed in the Allo-Kramer shear cell attached to a (TA.XT2i) Texture Analyzer and sheared perpendicular to the direction of the muscle fiber. The (TA.XT2i) Texture Analyzer[7] was equipped with 10-blade Allo-Kramer shear compression cell and a 50 kg load cell; crosshead speed was set at 15 mm/sec. The shear values were calculated by averaging the two shear values for each bird and were expressed as kg of force/g of sample.

Statistical analysis: All data for each of the tests was analyzed by ANOVA using the General Linear Models procedure (SAS Institute, 1999). Because there were no differences based on handling, the data from all replicates of handling treatment were combined within lighting groups. Significance between means was determined by the use of Duncan's multiple range test (SAS Institute, 1999). Significance was defined at $p<0.05$.

RESULTS AND DISCUSSION

Light intensity effects on broiler weight: Broiler live weights were significantly greater in the DL treatment relative to the BL treatment (Table 2). Other research has also shown that birds reared in low intensity lighting were heavier than birds reared in high intensity light environments (Shutze *et al.*, 1960; Skoglund and Palmer, 1962; Beane *et al.*,1962; Deaton *et al.*, 1976; 1978; 1980; Cherry *et al.*, 1980; Charles *et al.*, 1992; Lien *et al.*, 2003). It has been suggested that rearing broilers under low intensity light results in improved growth because the broilers are less active; thereby wasting less energy in exercise (Deaton *et al.*, 1976; Proudfoot and Sefton, 1978; Newberry *et al.*, 1988). Since broiler live weights of DL greater than BL treatment were observed, it was in agreement and consistence with the previous studies that birds reared in low intensity light were heavier than those in high intensity.

Handling effects on broiler weight: While light intensity had an effect on broiler live weights, handling had no effect on broiler live weights. The incidence of DPM and other carcass defects did not vary ($p>0.05$) among the handling or lighting treatments (data not shown). Because some birds were handled by the legs and wings, it was thought that it might increase the incidence of DPM and deep thigh bruising. Studies examining the effect of pre-slaughter handling by legs or wings have previously indicated increases in incidence of DPM and thigh bruising (Ringrose, 1953; Hamdy *et al.*, 1961b; Taylor and Helbacka, 1968; Childs *et al.*, 1969; Hewel, 1986; Scott, 1994). However, our handling regime was not sufficient to induce the type of meat quality defects previously shown. Possibly the length of time during handling and intensity of handling treatment was not long enough to induce the bruise and the incidence of DPM as observed by other researchers.

Light intensity effects on filet weight and dimensions: Processed filet weights were higher for birds reared in DL compared to those reared in BL (Table 2). Increased filet weights based on dim lighting were expected, as the birds reared in dim lighting were heavier in general (Deaton *et al.*, 1976; Proudfoot and Sefton, 1978; Newberry *et al.*, 1988; Lien *et al.*, 2003). The yield of chicken breast meat increased gradually during the post-hatching stages and up to 85 days of age (Havenstein *et al.*, 2003) The increase in filet weights observed for the DL treatment was due to an observed increase in filet length (Table 2) and area (Table 2). The fibers start to grow rapidly about eight days after hatching and the diameter have increased by three hundred per cent within ten days (Kiessling, 1977). It continues to grow slowly up to seventy days. Muscle growth is based on parallel increase in both myofiber length and diameter in the early stage of growth. The muscle length, width and depth all increased until 15 weeks after hatching (Iwawoto *et al.*, 1993). As the muscle weight increased the myofiber diameter increased as well (Roy *et al.*, 2006). Therefore, the increase of filet length observed in the current study is consistent with the previous studies that have shown as the muscle growth increased, the myofiber length increased as well. Unlike filet length, other filet dimensions such as thickness and width were similar (Table 2) regardless of light treatment. The increased in the thickness and width might not be significant enough to show the differences, but it likely affected the area of filet and was related to the increased muscle growth.

Shear value: Shear values were analyzed to determine if light intensity would have any impact on tenderness of filets deboned early post-mortem (2 h) compared to those deboned at 4 h. It is known that post-mortem deboning time can influence the tenderness of meat. Studies have shown that the shear value of filets decreased gradually as deboning time increased from 2-24 h (Stewart *et al.*, 1984; Lyon *et al.*, 1985; Dawson *et al.*, 1987; Smith and Fletcher, 1992; Northcutt *et al.*, 2001; Liu *et al.*, 2004). Two hour deboning time is considered as early deboning times prior to rigor mortis

Table 2: Broiler live weight, filet weight and filet dimension based on light treatment

	Parameters						
	Broiler live	Filet					
Light treatments	weight (kg)	Weight (g)	Length (cm)	Area (cm^2)	Width (cm)	Height (cadial) (mm)	Height (cranial) (mm)
Dim	3.76[a]	286.31[a]	19.82[a]	139.53[a]	10.84[a]	34.70[a]	10.65[a]
Bright	3.61[b]	276.02[b]	19.33[b]	132.92[b]	10.68[a]	34.25[a]	9.84[a]

[a,b]Means (n = 48 per mean) within each row with no common superscript differ significantly ($p<0.05$).

Dim = Dim Light Treatment, Bright = Bright Light Treatment

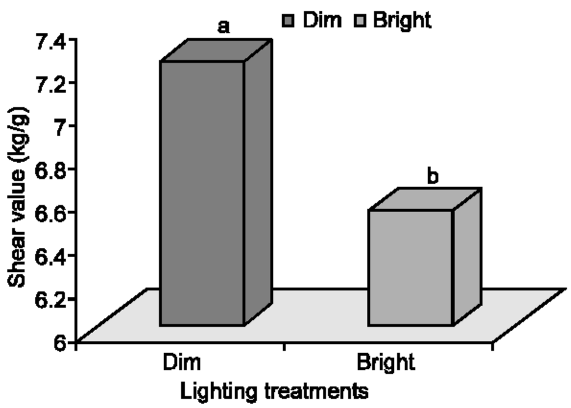

Fig. 1: Filet tenderness within 2 h PM deboning time. *Means within a time period differ significantly ($p<0.05$)
Dim = Dim Light Treatment,
Bright = Bright Light Treatment

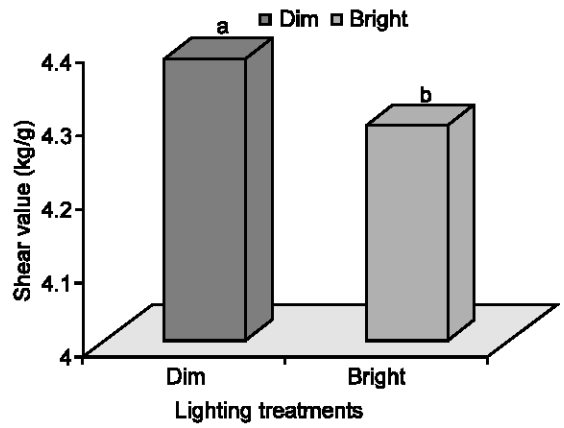

Fig. 2: Filet Tenderness within 4 h PM deboning time. *Means within a time period not significantly different ($p<0.05$)
Dim = Dim Light Treatment,
Bright = Bright Light Treatment

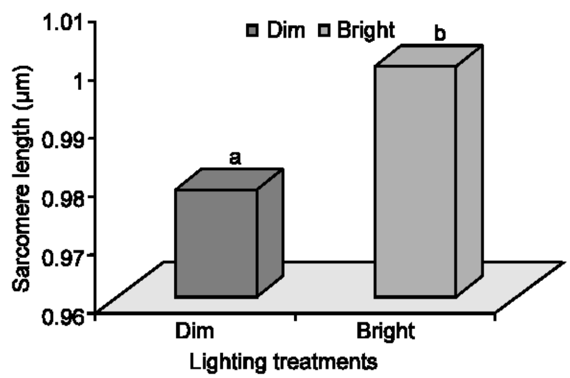

Fig. 3: Sarcomere length within 2 h PM deboning time. *Means within a time period differ significantly ($p<0.05$)
Dim = Dim Light Treatment
Bright = Bright Light Treatment

resolution (Stewart *et al.*, 1984; Lyon *et al.*, 1985; Dawson *et al.*, 1987). In the US poultry industry, it is not uncommon for breast filets to be deboned as early as 2 h PM. Filets deboned prior to rigor mortis resolution, which is between 3-6 h, may be tough (Lowe, 1948; Stewart *et al.*, 1984; Lyon *et al.*, 1985; Dawson *et al.*, 1987). On the other hand, filets harvested at 4 h PM are generally considered to have lower shear values and are most often considered tender. In the current study, differences in shear values were found in the filets deboned at 2 h post-mortem base on lighting treatment. Specifically, shear values were 7.22 kg/g for DL and 6.54 kg/g for BL (Fig. 1). Even though the shear values of filets from the DL treatment deboned at 2 h PM were higher than filets from BL, these shear values were still lower than the expected values of filets deboned at 2 h PM. In general, the shear values of filets from early deboning times prior to rigor mortis development are 8 kg/g or above (Lyon and Lyon, 1990; Sams *et al.*, 1992). In contrast, no differences were detected in the shear values of filets deboned at 4 h PM (Fig. 2). This result was expected because as the deboning time increase the shear value would be decreased, especially after 4 h of post mortem aging (Northcutt *et al.*, 2001; Liu *et al.*, 2004). These results suggest that low lighting intensity may effect the tenderness of filets deboned early post-mortem (2 h), however, light intensity would have no effect on tenderness of filets deboned at 4 h post-mortem.

The sarcomere length of filets from the DL treatment deboned 2 h PM was shorter than BL filets (Fig. 3). Sarcomere length is one of the factors related to poultry meat tenderness; the shorter the sarcomere length, the tougher the meat (Huxley and Hanson, 1954; Lawrie, 1991; McKee and Sams, 1998). Because shortened sarcomeres were observed, it is likely related to the lower shear values observed of BL filets deboned 2 h PM. Another factor assessed for meat quality is pH. The rate of pH decline after rigor mortis is important because it can impact the meat quality attributes such as color, Water Holding Capacity (WHC) and texture (Lehninger *et al.*, 1993; Pearson, 1994). The pH of filets was not significantly different regardless of lighting or handling treatments (Fig. 4).

Unlike any other parameters that were affected by lighting treatment, the trend in cook-loss data was not consistent (Table 3). Cook-loss data contained a light x handling interaction with the greatest percentage of cook-loss observed in the filets from the DL-W treatment, followed by the BL- NoH treatment and DL-L treatment ($p<0.05$). There are no information regarding the effect of lighting treatment on cook-loss. It was thought that these two parameters were not related to

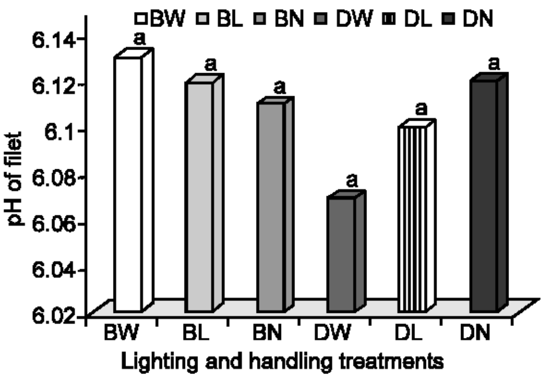

Fig. 4: pH of breast filet.
*Means within a time period not significantly different (p<0.05)
BW = Bright Light and Wing Handling Treatment
BL = Bright Light and Leg Handling Treatment
BN = Bright Light and No Handling Treatment
DW = Dim Light and Wing Handling Treatment
DL = Dim Light and Leg Handling Treatment
DN = Dim Light and No Handling Treatment

Table 3: Cook-Loss based on lighting and handling treatments

Lighting treatments	Handling treatments		
	Leg	Wing	No handling
Dim	28.75[a]	28.85[a]	26.86[a,b]
Bright	26.55[b]	26.08[b]	28.77[b]

[a,b]Means (n = 48 per mean) within each row with common superscript not differ significantly (p<0.05). Dim = Dim Light Treatment, Bright = Bright Light Treatment

each other as indicated by the lack of consistency of lighting treatment and cook-loss.

In summary, the DL treatment resulted in a 4% increase in body weight, greater bird and filet weight. However, DL resulted in slightly tougher meat when filets were deboned at 2 h PM, but this effect was not observed if filets were deboned at 4 h post-mortem. Handling treatment as applied in this study had no effect on meat quality attributes or filet dimensions and uniformity.

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[1]Model 93-1065F, Greenlee Textron, Inc., Rockford, IL-61109
[2]Cantrell Machine Co., Gainesville, GA 30503
[3]Model JM-32 C-M, Meyn USA, Inc., Gainesville, GA 30503
[4]Mark IV System ate, Pritchard, Atlanta, GA 30318
[5]MN .85 Mitutoyo Japan
[6]Model DEC5-32, Hobart Corp., Troy, OH 45374
[7]Model (TA.XT2i), Texture Technologies Corp., Scarsdale, NY/UK

Abbreviation key: TA = Texture Analyzer, DL = Dim Light, BL= Bright Light, FC = Foot Candles, PM = Post Mortem, NoH = No Handling, L = Handling by Legs, W = Handling by Wings, DPM = Deep Pectoral Myopathy, L = Light, D = Darkness, sec = seconds