PE1.51 Functional and biochemical properties of dark, firm, dry chicken breast meat 307.00

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***Abstract*— This study was performed to characterize dark, firm, dry (DFD) breast meat and compare its properties with normal breast meat. A further objective was to investigate the effect of liver glycogen at time of slaughter and muscle energy reserves at time of slaughter and 30 h postmortem on the incidence of DFD breast meat. Postmortem metabolism and quality characteristics of the *Pectoralis major* muscle were evaluated from cold stressed birds given 0 or 2 h of lairage. Samples were further categorized into normal (5.7≤pHu≤6.1; 46≤L*≤53) and DFD (pHu>6.1; L*<46) breast meat based on the ultimate pH (pHu) and color L* (lightness) values. Regardless of the lairage duration, DFD breast meat had significantly (P<0.05) higher pH (6.4 vs. 6.1), lower L* value (42 vs. 48), lower thaw loss (0.5% vs. 0.7%) and cook loss (10% vs. 13%), and higher water binding capacity (WBC; 49% vs. 39%) and processing cooking yield (PCY; 122% vs. 102%) compared to normal breast meat. Residual glycogen, free glucose and lactate concentrations were measured at both 5 min and 30 h postmortem and glycolytic potential (GP) was calculated based on total carbohydrate and lactate concentrations at time of sampling. There was a significant correlation between initial and ultimate GP and meat quality parameters, yet the correlation between the two GP values was low (0.55). GP values measured on 30h postmortem samples were higher than the GP values measured on samples collected 5 min after slaughter. Birds with DFD breast meat had significantly lower liver and muscle glycogen reserves and significantly lower breast muscle GP compared to birds with normal breast meat. Increasing lairage duration prior to slaughter resulted in an increase in the incidence (and possibly severity) of the DFD defect in breast meat of cold-stressed birds.**

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***Index Terms*— Breast meat, Broiler chicken, DFD meat, Glycolytic potential.**

I. INTRODUCTION

DARK, firm, dry (DFD) breast meat is a color defect in the meat industry, which has been shown to be influenced by seasonal changes and pre-slaughter poultry handling and transport conditions [7]. Characteristics such as higher pH and water holding capacity and lower lightness values have been associated with broiler DFD breast meat compared to pale, soft, exudative (PSE) meat [2,8,12,15].

Shortly after slaughter, anaerobic metabolism of glycogen into ATP predominates and glycogenolysis and glycolysis continues. The pH continues to drop due to lactate accumulation until glycogen stores are depleted or metabolic processes stop due to enzymatic arrest caused by low pH [3]. The glycolytic potential (GP) expresses the potential lactate formation in the muscles at exanguination and it is believed that GP at the moment of animal death is capable of predicting the final meat quality [4, 6].

Van Laack et al. [14] evaluated the effect of energy reserves at time of slaughter on the incidence of PSE broiler breast meat. However the relationship between DFD breast meat and muscle energy reserves at time of slaughter has not been extensively studied. Therefore, the aim of the current study was to investigate the effect of liver and breast muscle energy reserves at time of slaughter and muscle energy reserves at 30 h post slaughter on the incidence and properties of DFD breast meat compared to normal breast meat.

II. MATERIALS AND METHODS

Birds (n=360) were placed in a grid system (112cm x 71cm) within 2 drawers (15 birds/drawer), and placed on top of each other in a simulated transport system as part of a larger study to investigate transportation temperature on meat quality and animal welfare. Birds were taken off feed 7 h prior to start of the trial, which lead to 10 and 12 h of feed deprivation for the 0 and 2 h lairage periods, respectively. In each trial 30 birds were exposed to one of the assigned temperatures of -18, -15, -12, -8, -4, 20ºC for a duration of 3 h. From each group 10 birds (5 birds with 0 h and 5 birds with 2 h lairage) were selected from the first row of the simulated transport system for measuring postmortem muscle metabolites and

breast meat quality. Birds were hand slaughtered in a simulated commercial abattoir. Right after defeathering, core samples were taken from the right breast, frozen in liquid nitrogen and stored at -80ºC for muscle initial pH and glycolytic potential analysis. Liver samples were collected immediately following evisceration (~ 10 min postmortem), placed in liquid nitrogen and stored at -80ºC for liver glycogen analysis.

Chickens were deboned at 6-7 h postmortem. Breast meat was then placed on styrofoam trays and stored in a 4ºC cooler for further analysis, including. Drip loss (simulated retail display), color L*, a* and b* values (Minolta Chroma meter RC-400), and probe pH were measured at 30 h postmortem. Following analysis, breast meat pieces were vacuum packed individually and frozen at -30ºC for further analyses. Thaw loss (% weight lost during thawing over night at 4ºC), cook loss (% weight lost during cooking to internal temperature of 75ºC) and Warner Bratzler shear force (average shear force over 10 samples cut from each cooked breast) were measured on intact breast muscle. In addition, water binding capacity (WBC), processing cooking yield (PCY) and ultimate pH (using slurry method) were determined on each ground breast (*Pectoralis major*) fillet using a modification of the procedure proposed by Mallia et al. [8] and Van Laack et al. [14].

Total glucose (muscle and liver) and free glucose (muscle) concentrations were determined using the method modified from Passonneau and Lauderdale [11]. A Glucose Hexokinase assay kit (Sigma, GAHK-20) was used to measure the concentration of the generated NADPH using a spectrophotometer at 340 nm. Total carbohydrate content was expressed in µmol glucosyl units per gram weight of the sample. Lactate concentration was measured according to Hartschuh et al. [6] GP was calculated based on the equation proposed by Monin and Sellier [10]:

$$GP = 2 \times [\text{total glucose}] + \text{lactate}.$$

Data was analyzed using the ANOVA option of the general linear models (GLM) procedure of SAS (SAS Institute, Car. NC). Means were separated using Duncan's multiple range test option of the GLM procedure. Pearson's correlation coefficients (r), regression model (R^2), and probabilities were generated using the correlation procedures of SAS.

III. RESULTS AND DISCUSSION

Birds were grouped based on duration of lairage (rest given prior to slaughter) and meat quality defects into four groups of normal ($5.7 \leq pHu \leq 6.1$; $46 \leq L^* \leq 53$) or dark, firm, dry (DFD; $pHu > 6.1$; $L^* < 46$) breast meat with either 0 or 2h lairage. The normal and DFD groupings were adopted from Barbut et al. [2], and Bianchi et al. [5] with some modifications. As part of a larger study, exposure of birds to colder temperatures prior to slaughter increased the incidence of DFD breast meat. Therefore, as shown in Table 1, the average exposure temperature is significantly lower for birds showing the DFD defect. Breast meat with DFD defect had significantly ($P<0.0001$) higher ultimate pH (pHu; by 0.4 units) and was darker (42 vs. 48), redder (~1.5 unit redder) and less yellow (by 3 units) compared to normal meat (Table 1). In addition, a higher water holding capacity for both intact and ground meat was observed for DFD breast meat, as evidenced by the significantly ($P<0.01$) lower thaw and cook loss and higher water binding capacity (WBC) and processing cooking yield (PCY) compared to normal breast meat. These characteristics of DFD meat have been previously reported in other studies [1, 2, 8, 15]. No significant difference was observed for drip loss or shear values between DFD and normal breast meat in this study which agrees with Allen et al. [1] who did not report any difference in shear values between PSE and DFD samples.

Birds categorized for DFD breast meat had significantly lower initial muscle glycogen reserves compared to birds with normal breast meat regardless of the lairage duration (Table 2). However, no significant difference was observed in initial lactate or free glucose. On the other hand, concentration of free glucose and lactate at 30 h postmortem was significantly lower ($P<0.0001$) in breast meat of DFD chickens compared to the normal ones, whereas no difference in ultimate glycogen concentration was observed. Glycolytic potential (GP) was significantly lower ($P<0.0001$) for DFD breast meat at both 5 min and 30 h postmortem compared to the normal breast meat, regardless of lairage duration. Glycogen concentration was observed to be lower in the liver compared to the breast muscle. In addition, liver glycogen content at time of slaughter was significantly lower for DFD birds compared to the normal birds.

The 2 h lairage following the cold exposure and prior to slaughter increased the incidence of DFD breast meat by 14% to a total of 46% for 2 h lairage birds as compared to 32% for 0 h lairage birds. The high incidence of DFD breast meat in general is explained by the increased utilization of muscle (and liver) energy reserves in order for birds to maintain their shivering thermogenesis while exposed to the cold environmental conditions. In addition, the 2 h lairage exacerbated the situation for cold stressed birds, causing an increase in the incidence of DFD meat. Furthermore, the severity of DFD defect was slightly higher for the 2 h

lairage birds as indicated by the higher pHu and consequently lower cook loss, and higher WBC and PCY for this group (Table 1). A further drop in muscle glycogen reserves was expected for birds with 2 h lairage; however, this did not occur. Interestingly, the 2 h lairage resulted in a significantly (*P<0.0001*) higher liver glycogen content (23.1 vs. 18.5 μM/g) for birds with normal breast meat compared to the birds slaughtered shortly after treatment, while there was little change in liver glycogen for birds with DFD breast meat (16.2 vs 14.1 μM/g). Thus, normal birds given 2 h of lairage were able to recover or rebuild their liver glycogen reserve from other sources, such as body fat content, but for those that became DFD, there was greater need to increase the lower muscle energy stores.

The correlation between GP measured at 5 min and 30 h postmortem was 0.55 for this study (Table 3), while a higher correlation of 0.83 was reported between the 4 min and 30 h GP for the *longissimus dorsi* muscle of pigs [9]. Glucose and glucose-6-phosphate are intermediates produced during the transformation of glycogen to lactate. As expected, glycogen and free glucose concentrations were higher and lactate concentration was lower immediately after exanguination compared to sampling the day after slaughter. The content of glucose-6-phosphate was not measured separately in this study; however, Maribo et al. [9] reported no change in its content with sampling time. GP values measured at both 5 min and 30 h postmortem were significantly (P<0.0001) lower for DFD breast meat compared to the normal breast meat (Table 2). In addition, the 30 h GP values were higher overall compared to the 5 min GP values, which was unexpected. One explanation could be that the method for measuring total carbohydrate was not sensitive enough to account for all of the initial glycogen reserves, since glycogen is higher at time of slaughter and plays a more important role in the initial GP calculated compared to its role in the ultimate GP. Similar initial GP values were reported for breast meat of broilers exposed to minimal stress prior to slaughter (107 μM/g) [13].

High correlations of 0.70 and 0.72 were observed between ultimate pH and GP measured at 5 min and 30 h postmortem, respectively (Table 3), which is similar to previously reported data [14]. However, a lower correlation (r=0.61) was reported between GP and ultimate pH of LD muscle of pigs [9]. In addition, it was reported that GP could only predict 20% of the variation in chicken meat pHu when only normal breast meat was evaluated [13]. Furthermore, GP values reported in the current study could predict 40% of the variation in processing cook yield and 25% of the variation in color L* and b* values, cook loss and WBC of the breast meat. Initial muscle glycogen concentration was poorly correlated to meat quality parameters (Table 3). Lactate concentration at 30 h postmortem was highly correlated with GP at 30 h (99%), and was able to predict the ultimate quality of the breast meat to a similar extent as GP measured 30 h postmortem. This strong relationship between lactate concentration and breast pHu was not reported in studies of fast growing broiler chickens [13, 14], indicating that other parameters rather than GP might affect the ultimate pH of broiler chicken breast meat. The correlations between ultimate pH and all meat quality parameters were highly significant (P<0.0001) (Table 3), showing the importance of this factor on meat quality.

IV. CONCLUSION

DFD breast meat is a defect for the fresh meat industry; however, it has significantly higher ultimate pH, darker color and higher processing characteristics, which might be positive for further processed products. Breast meat of birds with DFD defect had significantly lower liver glycogen and muscle GP values compared to the normal breast meat. The 2 h lairage prior to slaughter of cold-stressed birds caused an increase in the incidence of DFD breast meat and a slight increase in the severity of the DFD defect, with no significant difference in muscle energy reserve. GP measured at both 5 min and 30 h postmortem correlated well with meat quality parameters, yet the correlation between the two measured values was quite low. Higher GP values were reported at 30 h compared to 5 min postmortem. Further assessment of biochemical processes involved in postmortem metabolism of DFD meat is necessary to explain some of the findings of the current study, particularly the difference in GP measured at different times postmortem and the increase in DFD defect with lairage for cold-stressed birds.

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Table 1- Meat quality characteristics for normal and DFD breast meat.

	0 h lairage		2 h lairage		*P*-value
	normal	DFD	normal	DFD	
n/group	47	22	38	32	
Exposure temp.	-3.3[a]	-14.1[b]	-2.5[a]	-12.2[b]	0.002
Ultimate pH	6.06[c]	6.38[b]	6.10[c]	6.47[a]	<.0001
Color (L*)	48.1[a]	42.6[b]	47.6[a]	42.3[b]	<.0001
Color (a*)	3.6[b]	5.0[a]	3.4[b]	4.7[a]	<.0001
Color (b*)	5.2[a]	2.1[b]	5.0[a]	1.7[b]	<.0001
Drip loss (%)	0.4[b]	0.5[a]	0.4[b]	0.4[ab]	<.0001
Thaw loss (%)	0.69[a]	0.49[bc]	0.61[ab]	0.4[c]	0.002
Cooking loss (%)	13.0[a]	10.7[b]	12.3[a]	9.1[c]	<.0001
Shear force (N)	12.8	11.9	12.8	12.8	0.107
WBC (%)	37.3[d]	46.1[b]	41.2[c]	51.2[a]	<.0001
PCY (%)	100.4[c]	116.7[b]	104.6[c]	126.4[a]	<.0001

*Means with the same letter in the same row do not differ (*P*<0.05)

Table 2- Muscle metabolites; free glucose (FG), lactate, glycogen and glycolytic potential (GP) at 5 min and 30 h postmortem (µM/g of sample).

	0 h lairage		2 h lairage		*P*-value
	normal	DFD	normal	DFD	
n/group	47	22	38	32	
Liver glycogen	18.5[b]	14.1[c]	23.1[a]	16.2[bc]	<.0001
5 min postmortem					
FG	3.8[a]	3.2[ab]	3.4[a]	2.5[b]	0.002
Lactate	39.8	30.7	37.4	31.7	0.09
Glycogen	34.0[a]	27.0[b]	35.5[a]	25.7[b]	0.0052
GP	108.4[a]	85.7[b]	107.8[a]	82.9[b]	<.0001
30 h postmortem					
FG	2.9[a]	1.0[c]	1.8[b]	1.2[bc]	0.0001
Lactate	118.5[a]	100.8[b]	118.2[a]	93.1[b]	<.0001
Glycogen	2.8	2.9	3.3	2.8	0.17
GP	129.1[a]	108.1[b]	127.8[a]	100.5[b]	<.0001

*Means with the same letter in the same row do not differ (*P*<0.05)

Table 3- Correlations between biochemical properties and meat quality traits.

	Gly5	GP5	Lac30	GP30	pHu	L*	WBC
Gly5	1						
GP5	0.79*	1					
Lac30	0.48*	0.54*	1				
GP30	0.50*	0.55*	0.99*	1			
pHu	-0.56*	-0.70*	-0.70*	-0.72*	1		
L*	0.34*	0.51*	0.51*	0.53*	-0.78*	1	
WBC	-0.38*	-0.43*	-0.48*	-0.49*	0.76*	-0.60*	1
PCY	-0.45*	-0.56*	-0.62*	-0.63*	0.91*	-0.74*	0.87*

* significant at P<0.001.

pHi=initial pH; Gly5=glycogen reserve at 5 min postmortem; GP5=glycolytic potential at 5 min postmortem; Lac30= lactate concentration at 30 h postmortem; GP30= glycolytic potential at 30h postmortem; pHu= ultimate.