

PROCESSING AND PRODUCTS

Breast Meat Quality and Composition in Unique Chicken Populations¹

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ABSTRACT The objective of this project was to examine the diversity of breast meat composition and quality traits among unique resource populations. Birds from 5 groups (inbred Leghorn, inbred Fayoumi, commercial broilers, F₅ broiler-inbred Leghorn cross, and F₅ broiler-inbred Fayoumi cross) were utilized. Contemporary stocks (broilers, inbreds, and crosses) were grown in a single house but in separate pens. Birds were harvested at 8 wk of age. Breast muscle weight, moisture, lipid and protein contents, color, pH, and Kramer shear force values were determined on birds from each group. Breasts from broilers contained lower percentages of protein ($P < 0.05$) and greater percentages of lipid ($P < 0.05$) compared with all

other groups. The 5 genetic stocks did not differ for Hunter L values or pH. The data indicate that the Leghorn inbred line breasts were a more pure and more intense red color than the crossbred contemporary ($P < 0.05$). Kramer shear force (kg/g sample) was higher ($P < 0.05$) in breasts from broilers than in breasts from the inbred lines. Our results demonstrate that the 5 genetic groups differed markedly in breast meat composition and quality characteristics. The described outbred by inbred advanced intercross lines will be useful in searches for genes affecting meat quality traits. Definition of the molecular factors that influence these traits will enhance our ability to make improvements in composition and quality of poultry meats.

(Key words: genetic line, meat quality, composition, pH, Kramer shear force)

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INTRODUCTION

Poultry meat appearance, water-holding capacity, texture, and composition all contribute to processing functionality and consumer acceptance of poultry products. Much information is available regarding perimortem and postmortem environmental factors that have a significant impact on these important quality attributes in poultry (Ali et al., 1999). In contrast, little is known about the influence of genetics on poultry meat quality.

Geneticists have made rapid genetic improvements through the use of intense selection for broiler growth rate, BW, and meat yield (Dransfield and Sosnicki, 1999). Deeb and Lamont (2002) documented dramatic growth and composition advantages in broilers compared with two inbred lines that have not been selected for growth traits.

Positive genetic correlations between breast weight and lightness and drip loss values (Le Bihan-Duval et al., 1999, 2001) suggest that improving breast weight through

selection has potential to result in production of lighter-colored breast meat with poorer water-holding capacity. Muscle protein metabolism can widely vary in birds with different rates and efficiency of gain (Schreurs et al., 1995). It is hypothesized that differences in growth rate among broilers and inbred lines will result in differences in meat appearance, texture, and composition. Xiong et al. (1993) documented muscle composition, pH, and protein extractability differences in 8 broiler crosses. Qiao et al. (2002a) concluded that genetic factors contribute to the variation in color of broiler breast meat. Differences in color and water-holding capacity have been attributed to broiler great-grandparent lines (Gonet et al., 2001). These reports illustrate that meat quality can be influenced by genetics of broilers. The extent to which poultry meat quality can be improved using selection strategies is not defined. The objective of the current project was to determine the diversity of meat quality traits among unique resource populations. Chickens from a contemporary broiler line, 2 inbred lines, and F₅ inbred line-broiler crosses were utilized to determine the contribution of genetics to breast muscle weight, composition, and quality.

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Abbreviation Key: IGCPRP = Iowa Growth and Composition Resource Population.

MATERIALS AND METHODS

The Iowa Growth and Composition Resource Population (IGCRP) was established by crossing 2 modern broiler sires, from a primary breeder's broiler male line, with 5 to 10 dams each from two highly inbred lines. The inbred lines were developed from over 50 generations of full-sib matings. One inbred line was originally composed from U.S. commercial Leghorn layers (Line Ghs6), and the other line (Line M15.2) was inbred from the Fayoumi breed, an imported breed native to Egypt. These lines are >99% inbred (Zhou and Lamont, 1999). In subsequent generations, IGCRP sires were always mated within each cross (broiler-Leghorn or broiler-Fayoumi cross) with 4 to 6 dams. Also during each generation, 4 broiler sires were mated with 3 to 5 unrelated broiler females, and 1 inbred male from each of the 2 inbred lines was mated with 3 to 5 full-sib inbred females of the same line. Birds of the F₅ generation from a single hatch were evaluated in this study.

Chicks of the 5 groups (F₅ broiler-inbred Leghorn cross, n = 10; F₅ broiler-inbred Fayoumi cross, n = 10; inbred Leghorn, n = 10; inbred Fayoumi, n = 10; and commercial broilers, n = 6) were grown to 8 wk of age. Contemporary stocks (broilers, inbreds, and crosses) were grown in a single house but separated by screen-wall dividers to prevent undue stress and competition as a result of the dramatic differences in body size of the different genetic stocks. Birds were raised in floor pens on wood shavings and had access ad libitum to feed and water. Birds were fed commercial corn-soybean-based diets meeting or exceeding all NRC requirements (NRC, 1994). From hatch to 4 wk, birds received starter feed with 20% protein and 3% fat.³ From 4 to 8 wk, birds were fed a grower ration⁴ (Whiton Feeds) with 18% protein and 4.1% fat.

Birds were killed by cervical dislocation at 8 wk of age. In order to eliminate potential differential effects of harvest procedures on different sized birds, some procedures such as electrical stunning and scalding were not utilized. McNeal et al. (2003) observed more severe early reaction with decapitation in the absence of stunning but reported that this method did not have a consistent effect on the occurrence of carcass defect scores. We did not observe broken bones or carcass redness in these birds. Breast muscles were removed from each carcass at 30 min postmortem, trimmed, weighed, and chilled on ice. The breast muscle from the right side of each carcass was used for pH, color, and proximate analysis.

Color and pH were measured at 24 h postmortem. Breast muscle ultimate pH was measured with a pH Star pH meter⁵ equipped with a glass electrode. Three mea-

surements were recorded and averaged for each breast. Color (Hunter L*, a*, and b* values) was measured on the medial surface of the breast muscle (in an area free from color defects, bruising, and hemorrhages) using the HunterLab Color Difference Meter⁶ (D65, 10° observer). Three measurements were taken on each breast. Saturation index $[(a^2 + b^2)^{1/2}]$ and hue angle $[\tan^{-1}(b/a)]$ were calculated for each sample (Little, 1975). Samples for proximate analysis were frozen until analysis at the Iowa State University Meat Chemistry Laboratory. Moisture content was determined with an oven drying method, and crude fat was determined by hexane extraction (AOAC, 1990). Protein was determined using a combustion method (AOAC, 1993).

The breast muscle from the left side of each carcass was designated for Kramer shear force evaluation. All samples were evaluated 3 d postmortem in the fresh, never-frozen state. Each cut was oven-broiled to 77°C in a preheated electric convection oven-broiler.⁷ Temperature of each cut was individually monitored using Omega precision fine-wire thermocouples⁸ attached to an Omega digital temperature monitor.⁹ Cook-loss percentage was determined by calculating loss of weight after cooking.

Cooked cuts were cooled to room temperature. A 2.5-cm² section was removed from the thickest portion of each cut and weighed. Kramer shear force was measured using an Instron Universal Testing Machine¹⁰ with a Kramer shear attachment. The Instron had a 10-kN load cell. Crosshead speed was 200 mm/min. Each square section was sheared across the muscle fibers. Shear force was reported as total force to shear per gram of sample.

Data were analyzed using two-way ANOVA including genetic group, sex, and their interaction. Differences between lines were calculated using the Tukey-Kramer test. Statistical analysis was carried out using JMP (SAS Institute, 2002). Significance was determined at $P < 0.05$.

RESULTS AND DISCUSSION

Use of the IGCRP offers a broad base to make meat quality and composition evaluations. Significant differences were found among the 5 different groups for most of the meat quality traits measured (Table 1). Significant sex effects illustrate heavier body and muscle weights for males than females. No crossover interactions were observed. Broilers were heavier than F₅ crosses and the inbred lines at 4 and 8 wk of age. The two inbred lines had lighter BW at 4 and 8 wk of age compared with the F₅ crosses (Table 2). As expected, the total breast muscle weight was highest for the broilers, intermediate for the F₅ crosses, and lowest for the two inbred lines (Table 2). Breast weight, as a percentage of BW was highest for broilers and lowest for the inbred lines, which is consistent with the observations in the F₂ generation (Deeb and Lamont, 2002). A departure from the results of the F₂ study is that breast weight as a percentage of BW was slightly, but significantly, greater in the F₅ generation broiler-Fayoumi cross than the F₅ broiler-Leghorn cross.

³Purina Mills Meat Builder, Purina Mills, St. Louis, MO.

⁴Whiton Feeds, Perry, IA.

⁵SFK Meat Systems, Denmark.

⁶Hunter Associates Laboratory, Reston, VA.

⁷Model 7091, Toastmaster, Inc., Macon, MO.

⁸Chromega/Alomega; Omega Engineering, Inc., Stamford, CT.

⁹Omega Engineering, Inc., Stamford, CT.

¹⁰Model 4502; Instron Corporation, Canton, MA.

TABLE 1. Effect of genetic group, sex, and their interaction on body weight, breast weight, composition, and quality characteristics

Item	Genetic group	Sex	Sex × genetic group
Trait			
Body weight 4 wk (g)	<0.0001	0.0001	0.014
Body weight 8 wk (g)	<0.0001	<0.0001	0.001
Total breast weight (g)	<0.0001	<0.0001	0.004
Breast (% body weight)	<0.0001	0.100	NS*
Meat composition			
Moisture (%)	NS	0.185	NS
Lipid (%)	<0.0001	0.015	0.002
Protein (%)	<0.0001	NS	0.135
Moisture/protein	0.005	NS	NS
Meat quality characteristics			
Hunter L*	NS	NS	NS
Hunter a*	0.011	NS	NS
Hunter b*	0.033	0.026	0.195
Ultimate pH	0.145	NS	NS
Cook loss (%)	<0.0001	NS	0.049
Kramer shear force (kg/g sample)	0.004	NS	0.191

*Not significant $P > 0.20$.

Lipid content of breasts was greater in females than males. The difference was more pronounced in broilers resulting in a significant sex-by-genetic-growth interaction. Lipid content was higher in breasts from broilers than breasts from crosses or inbred lines. In an earlier study on the F₂ generation, Deeb and Lamont (2002) demonstrated that broilers also had a greater percentage of abdominal fat than the inbred lines. This finding is expected as faster growing birds tend to have greater appetites (Gyles, 1988). No difference in lipid content was noted in the comparison of the broiler-Leghorn cross and its contemporary Leghorn inbred line. Interestingly, the Fayoumi inbred line produced breasts with a higher percentage of lipid than the broiler-Fayoumi cross (Table 2).

Breasts from broilers contained less protein on a percentage basis than all other groups (Table 2). No differences in protein content were noted in comparisons of the broiler-cross stock and their inbred-line contemporaries. There were no significant differences in moisture content associated with genetic line or cross (Table 2).

We hypothesized that differences in growth patterns would result in a change in ultimate pH. This hypothesis is based on possible differences in fiber type due to selection for lean growth (Dransfield and Sosnicki, 1999). An increase in muscle pH has been shown to improve water-holding capacity of meat from muscle by increasing the electrostatic repulsions between myofibrillar proteins

(Offer and Knight, 1988). The solubility of myofibrils from breast muscle is greatly diminished as pH is reduced from 6.0 to 5.75 (Xiong and Brekke, 1991). A small decline in pH in this range has the capacity to reduce water-holding capacity, gel strength, and emulsifying capacity of breast muscle (Daum-Thunberg et al., 1992). Le Bihan-Duval et al. (2001) reported a strong negative correlation between drip loss and ultimate pH. Definition of the genetic contribution to the variation in breast muscle pH will enable genetic improvement of these important processing characteristics. The results of this trial show that, despite the genetic distance and weight differences among different lines, ultimate pH did not differ among populations (Table 3).

Because consumers first evaluate meat products by visual appraisal, there is a great deal of interest in identifying factors that influence the color and lightness of chicken breast meat. Le-Bihan-Duval et al. (1999, 2001) suggested an important role of genetics in control of broiler breast color. Rapid pH decline (Froning, 1995) and low ultimate pH (Allen et al., 1997) have each been associated with light-colored chicken breast. Qiao et al. (2002b) demonstrated a strong negative correlation between broiler breast pH and lightness (L*) values and a positive correlation between pH and redness (a*) values. Pigment content can also affect product color (reviewed by Froning, 1995). A significant sex effect on Hunter b*

TABLE 2. Least squares means of body weight, breast weight, and breast composition

Genetic group	4 wk body weight (g)	8 wk body weight (g)	Breast weight (g)	Breast (% body weight)	Lipid (%)	Protein (%)	Moisture (%)
Broiler	879 ± 71 ^a	3,194 ± 265 ^a	327.9 ± 0.9 ^a	10.32 ± 0.4 ^a	1.08 ± 0.15 ^a	24.02 ± 0.39 ^c	73.42 ± 0.15
F5-Leghorn	508 ± 16 ^b	1,653 ± 78 ^b	135.4 ± 0.5 ^b	8.21 ± 0.2 ^c	0.47 ± 0.02 ^{bc}	25.34 ± 0.08 ^a	73.10 ± 0.09
F5-Fayoumi	526 ± 33 ^b	1,680 ± 114 ^b	148.1 ± 0.6 ^b	8.82 ± 0.3 ^b	0.20 ± 0.05 ^c	24.99 ± 0.07 ^{ab}	73.49 ± 0.07
Leghorn	173 ± 4 ^c	551 ± 12 ^c	35.2 ± 0.2 ^c	6.40 ± 0.1 ^d	0.48 ± 0.06 ^{bc}	25.00 ± 0.23 ^{ab}	73.13 ± 0.28
Fayoumi	186 ± 8 ^c	569 ± 38 ^c	36.5 ± 0.3 ^c	6.29 ± 0.2 ^d	0.65 ± 0.08 ^b	24.81 ± 0.10 ^b	72.97 ± 0.16

^{a-d}Means ± SEM within same column with different superscripts differ significantly ($P < 0.05$).

TABLE 3. Least squares means of breast meat Hunter L*, a*, and b* values

Genetic group	Hunter L*	Hunter a*	Hunter b*	pH
Broiler	43.34 ± 1.77	5.58 ± 0.88 ^a	13.53 ± 0.94 ^{ab}	5.82 ± 0.03
F5-Leghorn	43.05 ± 0.57	3.85 ± 0.25 ^b	13.12 ± 0.32 ^{bc}	5.78 ± 0.03
F5-Fayoumi	42.06 ± 1.29	6.13 ± 0.57 ^a	12.72 ± 0.41 ^c	5.83 ± 0.09
Leghorn	41.12 ± 0.41	6.27 ± 0.42 ^a	14.30 ± 0.18 ^a	5.88 ± 0.02
Fayoumi	40.31 ± 1.84	6.08 ± 1.04 ^{ab}	12.52 ± 0.63 ^{bc}	5.98 ± 0.06

^{a-c}Means ± SEM within the same column with different superscripts differ significantly ($P < 0.05$).

values was observed with breasts of males less yellow than those of females. Genetic background did significantly affect Hunter a* and b* values (Table 1). The Leghorn pure line had higher a* and b* values than the broiler-Leghorn cross (Table 3). These differences explain the lesser hue angle and greater saturation index observed for the Leghorn inbred line compared with the broiler-Leghorn cross. The data indicate that the Leghorn inbred line had a more pure and more intense red color than its crossbred contemporary. It is possible that these differences are a result of differences in muscle fiber type and pigment content in these lines. No differences were found between the genetic stocks for Hunter L* values (Table 1).

Texture has been described as the single most important quality attribute in determining consumers' ultimate satisfaction of a whole muscle poultry cut (Fletcher, 2002). Kramer shear force measures the textural integrity of cooked products. The mean Kramer shear force value for breasts from broilers was significantly greater than the mean Kramer shear force values for either of the inbred lines (Table 4). Although no difference was detected in a comparison between the two inbred lines, breasts from the broiler-Leghorn cross exhibited greater shear values than the broiler-Fayoumi cross. These results contrast the report of Shrimpton and Miller (1960) who reported that a more tender product was produced by faster-growing birds; this study, however, was based on within-line comparisons rather than between-line comparisons.

Examination of the Kramer shear force data requires consideration that muscle size may influence the results, which is particularly important when considering rigor development and chilling. Because the observed difference between F5-Leghorn and F5-Fayoumi cannot be attributed to variation in muscle weight (Table 2) other explanations for this observation need to be considered.

A difference in Kramer shear force may be due to several factors. A difference in the physiological maturity of

the birds at the time of harvest may result in a difference in collagen cross-linking. Collagen cross-linking increases with age and is often associated with increased toughness (Fletcher, 2002). Shrimpton and Miller (1960) identified a positive correlation between toughness and collagen content. Because all of the birds in the present trial were harvested at the same chronological age (8 wk), and during the rapid growth phase, it is unlikely that increased collagen content is the factor responsible for the observed difference in shear force.

Differences in the myofibrillar portion of muscle can also impact the textural properties of meat. This influence is due to the metabolic state of the muscle at the time of slaughter that dictates the response of the muscle tissue to the early postmortem period. If rigor develops after deboning, rigor shortening occurs and toughness increases (Dickens and Lyon, 1993). Higher shear force values in the broiler and F5-Leghorn groups could be explained by greater rigor shortening, which may be a result of breast removal before the onset of rigor (Cason et al., 2002). A difference in early postmortem muscle metabolism between genetic groups has the potential to affect the onset of rigor and muscle fiber shortening.

The most significant postrigor change in the myofibrillar fraction is fragmentation of the myofibrils caused by calpain-induced proteolysis of specific myofibrillar proteins (Huff-Lonergan et al., 1996). Proteolysis of myofibrillar proteins has often been associated with an improvement in tenderness of meat (Lonergan et al., 2001a,b). Although we cannot rule out any of these explanations for observed differences in texture, we hypothesize that the difference between F5-Leghorn and F5-Fayoumi could be due to the myofibrillar component of texture.

Observed differences in texture may be related to differences in muscle fiber size and metabolism. Fast-growing strains of birds have larger muscle fibers than slow-growing strains (Dransfield and Sosnicki, 1999). An increase

TABLE 4. Least squares means of breast meat cook loss and Kramer shear force value

Genetic group	Cook loss (%)	Kramer shear force (kg/g sample)
Broiler	11.47 ± 1.21 ^b	12.33 ± 1.61 ^a
F5-Leghorn	12.48 ± 0.70 ^b	10.96 ± 0.93 ^a
F5-Fayoumi	12.19 ± 0.53 ^b	8.27 ± 0.77 ^b
Leghorn	16.14 ± 0.45 ^a	7.22 ± 0.41 ^b
Fayoumi	16.26 ± 0.92 ^a	8.21 ± 0.55 ^b

^{a-c}Means ± SEM within the same column with different superscripts differ significantly ($P < 0.05$).

in fiber size may represent a change in muscle fiber type and thus a difference in postmortem muscle metabolism (Ono et al., 1993). In a comparison of different lines of chickens, Schreurs et al. (1995) demonstrated that calpastatin activity was highest in breasts from fast-growing lines when compared with birds with an average growth rate. Further, breasts from egg-type chickens had the lowest calpastatin activity and highest μ -calpain activity in the trial. Investigation of the role of the calpain enzymes and their muscle protein substrates in poultry muscle may help explain observed variation in tenderness.

The data presented here document the differences among three unrelated lines and their crosses in meat quality and composition. The described outbred by inbred advanced intercross lines will be useful in searches for genes affecting meat quality traits. Future studies will determine the biochemical character of muscles from these lines to determine the factors that contribute to differences in meat quality identified in the current study.

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