Postprint: Comparison of Muscle Quality Between High- and Low-Fat Broiler Chicken Lines

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Date: 2017-10-10T00:00:00+00:00

Abstract

This study aimed to conduct a comparative analysis of muscle quality differences between high- and low-fat line broilers. Using the 20th generation high- and low-fat line broilers developed by Northeast Agricultural University as experimental animals, conventional meat quality detection methods were employed to measure the physical traits, chemical traits, histological characteristics, and flavor compounds of muscle, and to compare these traits between the two lines. The results showed that: 1) Regarding physical traits, the cooking loss and drip loss of breast muscle in high-fat line broilers were significantly or extremely significantly higher than those in low-fat line broilers ($P<0.05$ or $P<0.01$), whereas the meat color lightness value (45 min) and yellowness value (45 min and 24 h), pH24 h, water loss rate, and shear force of breast muscle were significantly or extremely significantly lower than those in low-fat line broilers ($P<0.05$ or $P<0.01$); the pH24 h, drip loss, cooking loss, and shear force of thigh muscle in high-fat line broilers were extremely significantly higher than those in low-fat line broilers ($P<0.01$), whereas the meat color lightness value (45 min) and yellowness value (45 min and 24 h), pH45 min, and water loss rate of thigh muscle were significantly or extremely significantly lower than those in low-fat line broilers ($P<0.05$ or $P<0.01$). 2) Regarding chemical traits, the moisture and crude protein contents of breast and thigh muscles in high-fat line broilers were significantly or extremely significantly higher than those in low-fat line broilers ($P<0.05$ or $P<0.01$), while the crude fat content was extremely significantly lower than that in low-fat line broilers ($P<0.01$). 3) Regarding histological characteristics, the muscle fiber diameter of breast muscle in high-fat line broilers was significantly higher than that in low-fat line broilers ($P<0.05$), and the muscle fiber density of thigh muscle was extremely significantly higher than that in low-fat line broilers ($P<0.01$). 4) Regarding flavor compounds, the contents of sweet and umami amino acids, essential amino acids, and total amino acids in breast muscle of high-fat line broilers were significantly or extremely significantly higher than those in low-fat line broilers (P<0.05 or P<0.01); the contents of polyunsaturated fatty acids and essential fatty acids in breast and thigh muscles of high-fat line broilers were extremely significantly lower than those in low-fat line broilers (P<0.01). Overall, the physicochemical traits, histological characteristics, and flavor compound contents differed significantly between the muscles of high- and low-fat line broilers, indicating that long-term bidirectional selection for abdominal fat traits affects broiler muscle quality to a certain extent.

Full Text

Comparison of Meat Quality Between Fat and Lean Line Broilers

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Abstract: This study aimed to compare and analyze differences in muscle quality between fat and lean line broilers. Using the 20th generation of fat and lean line broilers developed by Northeast Agricultural University as experimental animals, conventional meat quality detection methods were employed to measure the physical properties, chemical properties, histological characteristics, and flavor compounds of muscle, and to compare these traits between the two lines. The results showed: 1) Regarding physical properties, the cooking loss and drip loss of pectoral muscle in fat line broilers were significantly or extremely significantly higher than those in lean line broilers (P<0.05 or P<0.01), while the meat color brightness value (45 min) and yellowness value (45 min and 24 h), pH24 h, moisture loss rate, and shear force of pectoral muscle were significantly or extremely significantly lower than those in lean line broilers (P<0.05 or P<0.01). For leg muscle, pH24 h, drip loss, cooking loss, and shear force of fat line broilers were extremely significantly higher than those in lean line broilers (P<0.01), while the meat color brightness value (45 min) and yellowness value (45 min and 24 h), pH45 min, and moisture loss rate were significantly or extremely significantly lower than those in lean line broilers (P<0.05 or P<0.01). 2) Regarding chemical properties, the moisture and crude protein contents of both pectoral and leg muscles in fat line broilers were significantly or extremely significantly higher than those in lean line broilers (P<0.05 or P<0.01), while the crude fat content was extremely significantly lower than that in lean line broilers (P<0.01). 3) Regarding histological characteristics, the muscle fiber diameter of pectoral muscle in fat line broilers was significantly higher than that in lean line broilers (P<0.05), and the muscle fiber density of leg muscle was extremely significantly higher than that in lean line broilers (P<0.01). 4) Regarding flavor compounds, the contents of sweet and umami amino acids, essential amino acids, and total amino acids in pectoral muscle of fat line broilers were significantly or extremely significantly higher than those in lean line broilers ($P<0.05$ or $P<0.01$), while the contents of polyunsaturated fatty acids and essential fatty acids in both pectoral and leg muscles of fat line broilers were extremely significantly lower than those in lean line broilers ($P<0.01$). In conclusion, significant differences exist in physicochemical properties, histological characteristics, and flavor substance contents between fat and lean line broilers, indicating that long-term divergent selection for abdominal fat traits affects broiler muscle quality to a certain extent.

Keywords: fat and lean line broilers; meat quality; histological characteristics; flavor substances

Introduction

In recent years, systematic selection for production performance has substantially increased growth rate and feed conversion efficiency in broilers. However, this selection targeting growth rate and feed conversion has brought many inevitable problems to commercial broiler production, most notably excessive fat deposition, particularly abdominal fat. Research has shown that excessive abdominal fat deposition negatively impacts feed conversion efficiency and carcass quality in broilers. Therefore, controlling excessive fat accumulation in chickens and breeding lean broiler lines has become an important research topic in modern broiler breeding.

Our research group established the only fast-growing white-feathered broiler abdominal fat divergent selection lines in China—fat and lean lines (hereinafter referred to as fat and lean lines)—using Arbor Acres (AA) grandparent stock as material and selecting for abdominal fat percentage and plasma very low-density lipoprotein content. These lines have been selected for 20 generations since 1996. Statistical analysis results show that the abdominal fat percentage differs extremely significantly between the fat and lean lines, with the fat line being 8.16 times that of the lean line. Additionally, these two lines show varying degrees of difference in blood biochemical indicators, reproductive traits, and intramuscular fat content, with intramuscular fat content differing significantly between the fat and lean lines and being negatively correlated with abdominal fat content. Studies have demonstrated that fat deposited within muscle is an important factor affecting meat quality and flavor, with higher intramuscular fat content resulting in better meat quality and flavor. Therefore, differences in intramuscular fat content will inevitably lead to differences in muscle quality.

Meat quality is a complex concept that is difficult to measure with a single indicator. Currently, meat quality is evaluated domestically and internationally from the following aspects: 1) Physical properties, which determine meat acceptability and mainly include meat color, pH, water-holding capacity, and tenderness. 2) Chemical properties, which determine nutritional value and include moisture, crude protein, and crude fat content. 3) Histological characteristics, which are important indicators determining meat tenderness and include muscle fiber diameter and density. 4) Flavor compounds, which determine meat flavor and include amino acid and fatty acid content. Therefore, this study comprehensively and systematically measured and compared the muscle quality of fat and lean line broilers from the above aspects to analyze the impact of abdominal fat accumulation on muscle quality.

Materials and Methods

1.1 Experimental Animals

This study used the 20th generation of fat and lean line broilers from Northeast Agricultural University as experimental animals, raised according to conventional broiler management practices. At 49 days of age, 70 broilers from each line were randomly selected (half male and half), fasted for 12 hours, and weighed alive. After slaughter, phenotypic traits were measured, and both sides of pectoral and leg muscles were separated for measurement of muscle physical properties. Simultaneously, 1 cm × 1 cm × 1 cm samples of pectoral and leg muscles were snap-frozen in liquid nitrogen and stored at -80°C for determination of muscle histological characteristics. The remaining pectoral and leg muscle samples were stored at -20°C for analysis of muscle chemical properties and flavor compounds.

1.2 Measurement Methods

1.2.1 Phenotypic Traits Live weight was measured before slaughter. After slaughter, carcass weight was first measured, then abdominal fat pad and gizzard peripheral fat were collected to obtain abdominal fat weight.

1.2.2 Muscle Physical Properties **Meat Color:** A portable colorimeter was used to measure the meat color of pectoral and leg muscles at 45 min post-slaughter and after storage at 4°C for 24 h. The colorimeter was standardized with a calibration plate, then the lens was placed vertically on the meat surface, tightly against it, and the capture button was pressed to automatically store color parameters. Measurements were repeated at different positions nine times per meat surface, and the average was taken. Meat color was expressed as lightness (L*), redness (a*), and yellowness (b*) values.

pH: A portable digital pH meter was used to measure pH of pectoral and leg muscles at 45 min post-slaughter and after storage at 4°C for 24 h, recorded as pH45 min and pH24 h, respectively. The electrode head was completely embedded in the meat sample during measurement, with three positions measured per sample and the average calculated.

Moisture Loss Rate: One cm-thick slices of pectoral and leg muscle were sampled using a 1.5 cm diameter circular sampler and weighed (m1). The sample was placed between two layers of gauze, padded with 18 layers of filter paper above and below, and pressed in a compression apparatus at 35 kg for 5 min. After pressure removal, the sample was peeled and weighed (m2). The calculation formula was:

Moisture loss rate (%) = [(m1 - m2) / m1] × 100

Drip Loss: Five cm × 3 cm × 1 cm strips of pectoral and leg muscle were sampled, trimmed of outer membrane and fat, and weighed (m3). The sample was threaded with fishline, hung with muscle fibers vertical, placed in a sealed container without touching the container, sealed, and stored at 4°C for 24 h. Surface juice was wiped with clean filter paper and the sample was weighed (m4). The calculation formula was:

Drip loss (%) = [(m3 - m4) / m3] × 100

Cooking Loss: The meat sample after drip loss measurement was placed in a plastic bag, air was removed, and the bag was sealed to make the meat surface tightly contact the plastic. The sealed bag was placed in a 75°C water bath for about 30 min until the internal temperature reached 70°C. After water bathing, the sample was placed at room temperature for 30 min, surface moisture was wiped with filter paper, and the sample was weighed (m5). The calculation formula was:

Cooking loss (%) = [(m3 - m5) / m3] × 100

Shear Force: The meat sample after cooking loss measurement was cut into 3 cm × 1 cm × 0.5 cm strips parallel to muscle fiber direction. Shear force was measured using a muscle tenderness meter, with three measurements per sample averaged and expressed in Newtons (N).

1.2.3 Muscle Chemical Properties Moisture content was determined by the oven drying method (GB/T 6435–2014). Crude fat content was determined by the Soxhlet extraction method (GB/T 6433–2006). Crude protein content was determined by the Kjeldahl method (GB/T 6432–1994). Two parallel samples were measured for each sample, with the average taken as the result.

1.2.4 Muscle Histological Characteristics The frozen muscle was trimmed into 1 cm × 1 cm × 0.5 cm pieces with a blade, embedded in embedding medium, pre-cooled in a cryostat (-21°C) for 30 min, sectioned at 10 m thickness, and stained with conventional hematoxylin-eosin (HE).

Muscle Fiber Diameter: Each slice was observed under an upright microscope (Nikon-Eclipse 80i, Japan), with five fields randomly photographed. Image-pro plus 6.0 software (Media Cybernetics, USA) was used to measure the diameter of 20 muscle fibers per field, totaling 100 fibers per slice, and the average was calculated.

Muscle Fiber Density: The observation and photography method was the same as above. Image-pro plus 6.0 software was used to measure the area of each field, then the number of muscle fibers in each field was counted. Muscle fiber density was obtained by dividing the number of fibers by the field area, and the average was calculated.

1.2.5 Muscle Flavor Compounds Amino Acid Content: High-performance liquid chromatography was used, commissioned to Heilongjiang Fisheries Research Institute for analysis with an amino acid analyzer. Seventeen amino acids were detected, including essential amino acids (threonine, valine, methionine, isoleucine, leucine, phenylalanine, lysine, arginine, and histidine) and sweet/umami amino acids (aspartic acid, threonine, serine, glutamic acid, glycine, alanine, and proline). Results were expressed as the percentage of individual amino acid content to muscle weight.

Fatty Acid Content: Fat was first extracted from muscle samples with chloroform and methanol, then fatty acid methyl ester samples were prepared with methanol-potassium hydroxide, and fatty acid composition was determined by gas chromatography with flame ionization detection. Unknown fatty acid content was determined by comparison with standard sample retention times. Results were expressed as the percentage of individual fatty acid content to total methylated fatty acids.

1.3 Data Processing and Analysis

Statistical software JMP 7.0 (SAS Institute, USA) was used for analysis. Based on the characteristics of the experimental population, the statistical model was constructed as follows:

$$Y = \mu + L + S + e$$

Where Y is the observed value of individual meat quality traits; is the population mean of meat quality traits; L is the fixed effect of line; S is the fixed effect of sex; and e is the random residual effect. Analysis results were expressed as least squares means ± standard error. P<0.05 was considered significant difference, and P<0.01 was considered extremely significant difference.

Results

2.1 Comparison of Phenotypic Traits Between Fat and Lean Line Broilers

As shown in Table 1 , the abdominal fat weight of fat line broilers was 90.63 g, which was extremely significantly higher than that of lean line broilers (P<0.01). There were no significant differences in live weight and carcass weight between the two lines (P>0.05).

Table 1. Comparison of phenotypic characters between fat and lean line broilers (n=70), g

Items	Fat line	Lean line
Body weight	1,593.82±25.09	1,581.99±24.24
Dressing weight	1,465.07±23.15	1,418.65±22.37
Abdominal fat weight	90.63±1.90A	11.29±1.83B

In the same row, values with different capital letter superscripts mean extremely significant difference (P<0.01), and with different small letter superscripts mean significant difference (P<0.05), while with the same or no letter superscripts mean no significant difference (P>0.05).

2.2 Comparison of Muscle Physical Properties Between Fat and Lean Line Broilers

As shown in Table 2 , for pectoral muscle, the cooking loss and drip loss of fat line broilers were significantly or extremely significantly higher than those of lean line broilers (P<0.05 or P<0.01), while the meat color brightness value (45 min) and yellowness value (45 min and 24 h), pH24 h, moisture loss rate, and shear force were significantly or extremely significantly lower than those of lean line broilers (P<0.05 or P<0.01). For leg muscle, pH24 h, drip loss, cooking loss, and shear force of fat line broilers were extremely significantly higher than those of lean line broilers (P<0.01), while the meat color brightness value (45 min) and yellowness value (45 min and 24 h), pH45 min, and moisture loss rate were significantly or extremely significantly lower than those of lean line broilers (P<0.05 or P<0.01).

Table 2. Comparison of muscle physical properties between fat and lean line broilers (n=70)

Items	Pectoral muscle	Leg muscle
	Fat line	Lean line
Brightness L* (45 min)	38.32±0.24b	39.08±0.23a
Brightness L* (24 h)	41.98±0.28	42.65±0.27
Redness a* (45 min)	3.79±0.14	3.58±0.13
Redness a* (24 h)	4.46±0.14	4.11±0.14
Yellowness b* (45 min)	4.63±0.11B	5.70±0.11A
Yellowness b* (24 h)	6.29±0.15B	7.51±0.14A
pH45 min	6.17±0.03	6.18±0.02
pH24 h	5.82±0.02B	5.92±0.02A
Drip loss (%)	2.83±0.09A	2.33±0.08B
Moisture loss rate (%)	14.12±0.64B	18.90±0.60A
Cooking loss (%)	19.37±0.47a	17.73±0.44b

Items	Pectoral muscle	Leg muscle
Shearing force (N)	21.25±1.00B	33.25±0.90A

In the same row, values of same muscle with different capital letter superscripts mean extremely significant difference (P<0.01), and with different small letter superscripts mean significant difference (P<0.05), while with the same or no letter superscripts mean no significant difference (P>0.05). The same as below.

2.3 Comparison of Muscle Chemical Properties Between Fat and Lean Line Broilers

As shown in Table 3 , the moisture and crude protein contents of both pectoral and leg muscles in fat line broilers were significantly or extremely significantly higher than those in lean line broilers (P<0.05 or P<0.01), while the crude fat content was extremely significantly lower than that in lean line broilers (P<0.01).

Table 3. Comparison of muscle chemical properties between fat and lean line broilers (n=70), %

Items	Pectoral muscle	Leg muscle
	Fat line	Lean line
Moisture	72.18±0.09A	71.77±0.08B
Ether extract	3.83±0.22B	6.13±0.20A
Crude protein	89.37±0.21A	86.26±0.19B

2.4 Comparison of Muscle Histological Characteristics Between Fat and Lean Line Broilers

As shown in Table 4 , the muscle fiber diameter of pectoral muscle in fat line broilers was significantly higher than that in lean line broilers (P<0.05), while muscle fiber density showed no significant difference (P>0.05). The muscle fiber density of leg muscle in fat line broilers was extremely significantly higher than that in lean line broilers (P<0.01), while muscle fiber diameter showed no significant difference (P>0.05). Muscle histological sections of fat and lean line broilers are shown in Figure 1 [Figure 1: see original paper].

Table 4. Comparison of muscle histology characteristics between fat and lean line broilers

Items	Pectoral muscle	Leg muscle
	Fat line (n=27)	Lean line (n=33)
Muscle fiber diameter (m)	49.85±0.96a	46.92±0.87b
Muscle fiber density (fibers/mm^2)	425.27±16.14	469.93±14.88

Items	Pectoral muscle	Leg muscle

Figure 1. Comparison of frozen slice in muscle tissue between fat and lean line broilers (20×)

A: lean cocks leg muscle; B: lean cocks pectoral muscle; C: lean hens leg muscle; D: lean hens pectoral muscle; E: fat cocks leg muscle; F: fat cocks pectoral muscle; G: fat hens leg muscle; H: fat hens pectoral muscle.

2.5 Comparison of Muscle Flavor Compounds Between Fat and Lean Line Broilers

As shown in Table 5 , for pectoral muscle, the contents of aspartic acid, threonine, serine, alanine, valine, isoleucine, leucine, tyrosine, phenylalanine, lysine, and arginine in fat line broilers were significantly or extremely significantly higher than those in lean line broilers ($P<0.05$ or $P<0.01$), while histidine content was extremely significantly lower than that in lean line broilers ($P<0.01$). The contents of sweet/umami amino acids, essential amino acids, and total amino acids in fat line broilers were significantly or extremely significantly higher than those in lean line broilers ($P<0.05$ or $P<0.01$). For leg muscle, the contents of threonine, serine, glycine, alanine, valine, isoleucine, leucine, lysine, and arginine in fat line broilers were significantly or extremely significantly higher than those in lean line broilers ($P<0.05$ or $P<0.01$), while methionine and histidine contents were significantly or extremely significantly lower than those in lean line broilers ($P<0.05$ or $P<0.01$). The contents of sweet/umami amino acids, essential amino acids, and total amino acids in fat line broilers showed a trend of being higher than those in lean line broilers, but the differences were not significant ($P>0.05$).

Table 5. Comparison of amino acid contents in muscle between fat and lean line broilers (n=10), %

Items	Pectoral muscle	Leg muscle
	Fat line	Lean line
Asp#	8.03±0.21A	7.07±0.21B
Thr*#	4.05±0.10A	3.53±0.10B
Ser#	3.61±0.09A	3.12±0.09B
Glu#	13.48±0.38	12.55±0.38
Gly#	3.48±0.09	3.31±0.09
Ala#	4.66±0.12a	4.18±0.12b
Cys	1.24±0.03	1.25±0.03
Val*	4.03±0.09A	3.63±0.09B
Met*	1.68±0.06	1.62±0.06
Ile*	4.24±0.10A	3.61±0.10B
Leu*	7.38±0.18A	6.39±0.19B

Items	Pectoral muscle	Leg muscle
Tyr	2.65±0.09A	1.99±0.09B
Phe*	4.82±0.16A	3.33±0.16B
Lys*	7.85±0.19A	6.82±0.19B
His*	1.38±0.14B	2.45±0.14A
Arg*	5.63±0.15A	4.95±0.15B
Pro#	2.64±0.07	2.68±0.07
EAA	41.06±1.00A	36.32±1.00B
SAA	39.96±1.04a	36.45±1.04b
TAA	80.88±2.03A	72.50±2.03B

- indicates essential amino acids, # indicates sweet/umami amino acids.*

As shown in Table 6 , a total of 20 fatty acids were detected in the muscles of fat and lean line broilers, including 9 saturated fatty acids and 11 unsaturated fatty acids. Fatty acids were mainly composed of palmitic acid, palmitoleic acid, stearic acid, oleic acid, and linoleic acid, with only linoleic acid and linolenic acid detected as essential fatty acids.

For pectoral muscle, the contents of myristoleic acid, palmitic acid, and palmitoleic acid in fat line broilers were extremely significantly higher than those in lean line broilers (P<0.01), while the contents of cis-10-heptadecanoic acid, linoleic acid, linolenic acid, cis-11-eicosadienoic acid, henicosanoic acid, and cis-11,14-eicosadienoic acid were significantly or extremely significantly lower than those in lean line broilers (P<0.05 or P<0.01). The content of monounsaturated fatty acids in fat line broilers was extremely significantly higher than that in lean line broilers (P<0.01), while the contents of polyunsaturated fatty acids and essential fatty acids were extremely significantly lower than those in lean line broilers (P<0.01).

For leg muscle, the contents of myristoleic acid, palmitic acid, palmitoleic acid, and oleic acid in fat line broilers were extremely significantly higher than those in lean line broilers (P<0.01), while the contents of heptadecanoic acid, cis-10-heptadecanoic acid, stearic acid, linoleic acid, linolenic acid, cis-11-eicosadienoic acid, henicosanoic acid, and cis-11,14-eicosadienoic acid were significantly or extremely significantly lower than those in lean line broilers (P<0.05 or P<0.01). The contents of saturated fatty acids and monounsaturated fatty acids in fat line broilers were extremely significantly higher than those in lean line broilers (P<0.01), while the contents of polyunsaturated fatty acids, unsaturated fatty acids, and essential fatty acids were extremely significantly lower than those in lean line broilers (P<0.01).

Table 6. Comparison of fatty acid contents in muscle between fat and lean line broilers, %

Items	Pectoral muscle	Leg muscle
	Fat line (n=23)	Lean line (n=23)
Myristic acid (C14:0)	0.60±0.02	0.61±0.02
Myristoleic acid (C14:1)	0.24±0.01A	0.15±0.01B
Pentadecanoic acid (C15:0)	0.16±0.01	0.14±0.01
Palmitic acid (C16:0)	26.64±0.33A	25.33±0.31B
Palmitoleic acid (C16:1)	6.15±0.28A	3.85±0.27B
Heptadecanoic acid (C17:0)	0.14±0.01	0.15±0.01
Cis-10-heptadecanoic acid (C17:1)	0.13±0.02B	0.21±0.02A
Stearic acid (C18:0)	7.34±0.27	7.19±0.26
Oleic acid (C18:1c)	36.60±0.63	35.09±0.62
Linolelaidic acid (C18:2c)	17.53±0.38B	23.80±0.37A
Arachidic acid (C20:0)	0.08±0.00	0.08±0.00
r-Linolenic acid (C18:3n6)	0.17±0.01B	0.25±0.01A
Cis-11-eicosadienoic acid (C20:1)	0.31±0.01b	0.33±0.01a
Henicosanoic acid (C21:0)	0.60±0.02b	0.68±0.02a
Cis-11,14-eicosadienoic acid (C20:2)	0.18±0.01B	0.26±0.01A
Behenic acid (C22:0)	0.07±0.01	0.05±0.01
Cis-8,11,14-eicosadienoic acid (C20:3n6)	0.48±0.05	0.40±0.05
Tricosanoic acid (C23:0)	1.43±0.20	1.58±0.20

Items	Pectoral muscle	Leg muscle
Cis-5,8,11,14,17-eicosadienoic acid (C20:5n3)	0.06±0.01	0.05±0.01
Cis-4,7,10,13,16,19-docosadienoic acid (C22:6n3)	0.12±0.02	0.10±0.02
SFA	37.45±0.67	35.85±0.66
MUFA	43.61±0.65A	39.65±0.64B
PUFA	18.68±0.30B	25.17±0.30A
UFA	62.55±0.67	64.15±0.66
EFA	17.71±0.30B	24.36±0.31A

SFA = saturated fatty acids, MUFA = monounsaturated fatty acids, PUFA = polyunsaturated fatty acids, UFA = unsaturated fatty acids, EFA = essential fatty acids.

Discussion

Meat quality directly affects consumer choice. Research shows that meat quality is influenced by a series of factors such as genetics, nutrition, age, weight, and other environmental conditions, with genetics considered one of the most important factors affecting meat quality. Berri et al. found that different abdominal fat contents led to significant differences in meat color, pH, and drip loss. Li et al. reported that different intramuscular fat contents in Beijing oil chickens caused significant differences in meat color and pH. The abdominal fat content and intramuscular fat content of fat and lean line broilers from Northeast Agricultural University both differ significantly, suggesting that muscle quality must differ between the two lines.

3.1 Comparison of Muscle Physical Properties Between Fat and Lean Line Broilers

Meat color is the external manifestation of physiological, biochemical, and microbiological changes in muscle, an important indicator for evaluating meat appearance, and also important for estimating poultry meat functional properties (such as water-holding capacity) and deep-processed chicken product quality. Meat color includes three values: lightness, redness, and yellowness. The lightness value is mainly affected by moisture exudation on the muscle surface; less water exudation results in weaker light reflection, lower lightness values, and a drier muscle surface. The redness value reflects the amount of myoglobin in muscle to a certain extent. The yellowness value reflects the change from yellow (ideal color) to blue in muscle; a smaller yellowness value indicates a more yellow meat color. The results show that the meat color lightness value at 45 min post-slaughter in fat line broilers was significantly lower than that in lean line broilers, while there was no significant difference in lightness value at 24 h post-slaughter, indicating inconsistent moisture exudation rates between the two lines. The meat color yellowness values at both 45 min and 24 h post-slaughter in fat line broilers were extremely significantly lower than those in lean line broilers, indicating that the meat color of fat line broilers is more yellow than that of lean line broilers.

Muscle pH is a direct indicator of muscle acidity and one of the important indicators reflecting meat quality. After slaughter, glycogen in muscle undergoes anaerobic glycolysis to produce lactic acid, and the accumulation of lactic acid and release of H+ from ATP hydrolysis lead to a decrease in post-slaughter muscle pH. Generally, the normal pH range for broiler muscle at 24 h post-slaughter is 5.8–6.3; values too high or too low are unfavorable for meat preservation and cooking. The results show that the pH range of lean line broiler muscle at 45 min and 24 h post-slaughter was 5.92–6.48, while that of fat line broilers was 5.82–6.63, indicating that the muscle pH of both lines was within the normal range. Poultry meat pH can also determine shelf life by affecting microbial reproduction in muscle; poultry meat with relatively lower pH has a longer shelf life. The results show that pH24 h of pectoral muscle in fat line broilers was extremely significantly lower than that in lean line broilers; pH45 min of leg muscle in fat line broilers was extremely significantly lower than that in lean line broilers, while pH24 h was extremely significantly higher than that in lean line broilers. Overall, the muscle pH of fat line broilers was relatively lower, suggesting that fat line broiler muscle may have a longer shelf life.

Muscle water-holding capacity is the ability of muscle tissue cells to retain moisture, which affects meat tenderness, color, and juiciness. The main indicators currently used to evaluate muscle water-holding capacity are moisture loss rate, drip loss, cooking loss, or cooked meat rate. Allen et al. believed that water-holding capacity could be comprehensively evaluated by measuring water-holding capacity, drip loss, and cooking loss, and that there is a certain correlation among the three, with water-holding capacity negatively correlated with drip loss and cooking loss; smaller drip loss and cooking loss indicate greater water-holding capacity. The results show that drip loss and cooking loss of both pectoral and leg muscles in fat line broilers were significantly higher than those in lean line broilers, indicating that the water-holding capacity of fat line broilers is lower than that of lean line broilers. However, some studies use moisture loss rate to evaluate water-holding capacity and have found a linear negative correlation between them. The results show that the moisture loss rate of both pectoral and leg muscles in fat line broilers was extremely significantly lower than that in lean line broilers, indicating that the water-holding capacity of fat line broilers is higher than that of lean line broilers. These two conclusions are completely opposite, showing that different evaluation criteria affect the judgment of muscle water-holding capacity. Therefore, it is difficult to judge the water-holding capacity of fat and lean line broiler muscle using a single indicator; which indicator is more representative and can better reflect muscle water-holding capacity requires further research.

Shear force is the dominant factor determining meat tenderness and one of the indicators of consumer satisfaction with meat texture. Abdullah et al. proved that shear force is significantly affected by breed, with smaller shear force indicating more tender meat and better meat quality. The results show that the shear force of pectoral muscle in fat line broilers was extremely significantly lower than that in lean line broilers, but the shear force of leg muscle in fat line broilers was extremely significantly higher than that in lean line broilers. This indicates that the pectoral muscle of fat line broilers is more tender than that of lean line broilers, while the leg muscle of lean line broilers is more tender than that of fat line broilers.

3.2 Comparison of Muscle Chemical Properties Between Fat and Lean Line Broilers

From the perspective of muscle chemical composition, meat quality mainly depends on moisture, crude protein, and crude fat content. Generally, higher dry matter content in muscle indicates higher nutrient content. However, some studies have shown that the moisture content in muscle is generally 70%–75%, and within this range, higher moisture content results in better muscle texture. The results show that the moisture contents of pectoral muscle in fat and lean line broilers were 72.18% and 71.77%, respectively, and those of leg muscle were 73.00% and 72.52%, respectively, all within the normal moisture content range. Meanwhile, the moisture contents of both pectoral and leg muscles in fat line broilers were significantly higher than those in lean line broilers, suggesting that the texture of fat line broiler muscle is better than that of lean line broilers.

In recent years, with increasing research on crude fat and crude protein in muscle, these contents have gradually been established as important indicators in meat quality studies. Since crude fat content is related to meat flavor and juiciness and determines meat texture, it has become one of the meat quality factors receiving particular attention. Chen et al. reported that crude fat content in muscle is inversely proportional to crude protein content. Li et al. studied the muscle quality of Bian chickens and found that crude protein content in pectoral muscle was higher than that in leg muscle, indicating higher nutritional value of pectoral muscle; crude fat content in leg muscle was extremely significantly higher than that in pectoral muscle, indicating poor fat deposition ability and poor meat flavor of pectoral muscle. The results show that the crude fat contents of both pectoral and leg muscles in lean line broilers were extremely significantly higher than those in fat line broilers, suggesting that lean line broiler muscle may have better meat quality characteristics, flavor, and texture. The crude protein contents of both pectoral and leg muscles in fat line broilers were significantly higher than those in lean line broilers, indicating that fat line broiler muscle has higher nutritional value.

3.3 Comparison of Muscle Histological Characteristics Between Fat and Lean Line Broilers

Meat quality is affected by muscle fiber type and diameter. Wu et al. comprehensively studied the meat quality of seven local chicken breeds in China and found that greater muscle fiber density and finer muscle fiber diameter resulted in more tender meat. The results show that the muscle fiber diameter of pectoral muscle in fat line broilers was significantly higher than that in lean line broilers, and the muscle fiber density of leg muscle in fat line broilers was extremely significantly higher than that in lean line broilers. This suggests that the pectoral muscle of lean line broilers is more tender than that of fat line broilers, while the leg muscle of fat line broilers is more tender than that of lean line broilers. However, these histological results are inconsistent with the shear force measurements for meat tenderness in this study. This may be because meat tenderness is affected by factors other than muscle fiber density and diameter; for example, as muscle fiber density changes, the filling substances between muscle fibers and muscle bundles (such as fat and connective tissue) also change, thereby affecting meat tenderness. Additionally, Zeng et al. believed that there is a positive correlation between sarcomere length in post-slaughter rigid muscle and meat tenderness, i.e., longer sarcomere length results in more tender meat. Liu et al. concluded that meat tenderness and aging are mainly determined by collagen content in muscle connective tissue, with less connective tissue resulting in more tender meat. Therefore, relying solely on muscle fiber density and diameter to measure meat tenderness is not entirely accurate.

3.4 Comparison of Muscle Flavor Compounds Between Fat and Lean Line Broilers

The content, type, and proportion of amino acids in muscle are the main indicators for evaluating protein quality and nutritional value in muscle and are related to meat quality and flavor. Generally, higher amino acid content indicates higher nutritional value. Muscle with higher essential amino acid content has higher nutritional value, and muscle with higher sweet/umami amino acid content has better flavor. Studies have shown that breed has a significant effect on various amino acid contents in muscle. Considering various amino acid contents, the contents of sweet/umami amino acids, essential amino acids, and total amino acids in pectoral muscle of fat line broilers were significantly or extremely significantly higher than those in lean line broilers, and these contents in leg muscle of fat line broilers also showed a trend of being higher than those in lean line broilers. Therefore, it can be inferred that the meat of fat line broilers has better nutritional value compared to lean line broilers.

Fatty acids are generally divided into saturated fatty acids and unsaturated fatty acids, with unsaturated fatty acids including polyunsaturated and monounsaturated fatty acids. The types and composition of fatty acids in muscle are decisive factors affecting muscle flavor and the physicochemical properties of intramuscular fat, and are also important indicators for evaluating muscle nutritional value. Fatty acids, especially polyunsaturated fatty acids, are important precursors for aroma reactions (oxidation of unsaturated fatty acids) in muscle and affect the formation of meat flavor. The results show that the contents of polyunsaturated fatty acids and essential fatty acids in both pectoral and leg muscles of lean line broilers were extremely significantly higher than those in fat line broilers. Therefore, it can be inferred that the meat of lean line broilers has better flavor compared to fat line broilers.

This study compared and analyzed various meat quality data of fat and lean line broilers. The results show that fat line broiler muscle is characterized by smaller meat color yellowness values, higher crude protein content, and higher contents of essential amino acids, sweet/umami amino acids, and total amino acids. In contrast, lean line broiler muscle is characterized by greater meat color lightness values, smaller drip loss and cooking loss, higher crude fat content, and higher contents of essential fatty acids and polyunsaturated fatty acids. Relatively speaking, fat line broiler muscle has higher nutritional value, while lean line broiler muscle has better meat flavor. Thus, long-term selection for abdominal fat traits has significantly affected the muscle quality of fat and lean line broilers, giving each line advantages in flavor and nutritional value.

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