TECHNOLOGICAL QUALITY OF BROILER BREAST MEAT IN RELATION TO MUSCLE HYPERTROPHY

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Background

In broiler, recent studies reported a great variability of the muscle *post mortem* metabolism with both the animal genetic background and the pre-slaughter stresses. Indeed, selection for rapid growth and/or muscle development can produce breast meat with slower pH decline, higher ultimate pH and consequently lower drip loss (Le Bihan-Duval et al., 1999; Berri et al., 2001) and therefore affect processing quality of meat. While some of pre-slaughter conditions which affect *post mortem* pH fall are well identified (Debut et al., 2003), the muscle characteristics responsible of the pH fall variations remains uncertain. In broiler, there is no evidence of changes in breast fibre typing with selection for growth (Rémignon et al., 1995). By contrast, fibre radial and longitudinal growth significantly increased with selection for breast yield (Guernec et al., 2003) but, as far as we know, the impact of such structural changes on further broiler breast meat quality has never been evaluated.

Objectives

The purpose of this study was to relate breast muscle development, including muscle fibre size, to *post mortem* metabolism and further breast meat quality. Phenotypic and genetic relationships between fibre and meat traits were estimated for a total of 600 commercial broilers. For all birds, we measured muscle fibre cross-sectional area, glycolytic potential, lactate content, *post mortem* pH fall and classical meat traits (colour, drip and thawing-cooking loss, Warner-Bratzler shear force). We also determined the proportion of connective tissue and the occurrence of giant fibres in relation to muscle fibre size or *post mortem* metabolism.

Materials and methods

Animals and muscle sampling

A total of 600 broilers (males and females), originating from a commercial grand-parental male line (Hubbard Europe, Chateaubourg, France), were reared under similar conditions in a conventional poultry house at the INRA Avian Research Centre (Nouzilly, France). Birds were reared in 2 successive batches of 300 birds. Feed and water were provided *ad libitum* throughout the growth period. After a 8-h feed withdrawal, six week-old broilers were weighed then slaughtered in the experimental processing plant of the Avian Research Centre. Broilers were electrically stunned in a water bath (60 mA; 125 Hz; 5 s) before bleeding by ventral neck cutting. After scalding (51°C; 3 min), plucking and manual gut removal, whole carcasses were air chilled in a cold room at 2°C for 24 h.

Fifteen minutes after slaughter, two samples of the right *Pectoralis major* (PM) were collected. One sample was rapidly frozen in isopentane cooled with liquid nitrogen and stored at -80°C until histology assays. The other was mixed in 0.55M perchloric acid (1 g / 10 mL) then stored at -20°C until metabolite measurements.

Pectoralis major muscle trait analyses

Lactate, free glucose, glucose from glycogen and glucose-6-phosphate were measured according to Dalrymphe and Hamm (1973). The glycolytic potential was calculated using the equation of Monin and Sellier (1985): glycolytic potential = 2 x [glycogen + glucose-6-phosphate + free glucose] + lactate. The mean cross

sectional area (CSA) of muscle fibres was determined as described by Rémignon et al. (1995) on 12 µm thick-cross sections stained with red azorubin. For 40 birds diverging for fibre CSA, the proportion of connective tissue was quantified by image analysis using the Visilog software (Noesis, France). For 54 animals diverging for fibre CSA and/or pH at 15 min *post mortem*, the occurrence of giant fibres was determined by using a micrometric ocular that comprises 25 intersection points. For each sample, we classified a total of 1000 intersection points in either 'normal fibre', 'giant fibre' or 'connective tissue' to assess the ratio giant fibres/normal fibres.

Meat trait measurements

Fifteen minutes after slaughter, pH of the right PM muscle (pH15) was recorded according to the 'iodoacetate reference method' described by Santé and Fernandez (2000). At this time, the muscle temperature was also checked. Twenty four hours *post mortem*, carcasses were dissected and measured for breast (*pectoralis major and minor*) weight and yield (calculated in relation to body weight). At this time, the PM muscle ultimate pH (pHu) and colour parameters (L*, a*, b*) were measured according to Berri et al. (2001). The upper half part of the PM muscle was hanged in plastic bag to determine drip loss during a 2 day-storage at 2°C (Debut et al., 2003). At 3 day post-mortem, the PM muscle was vacuum packaged, rapidly frozen in ethanol then stored at -20°C until thawing and cooking treatments. Thawing-cooking loss (One night at 4°C and 15 min at 85°C) was determined as: (muscle weight after cooking/muscle weight before freezing) x 100. The Warner-Bratzler maximal shear force (N/cm^2) was measured on cooked muscle samples (1 x 1 x 3 cm). Samples were sheared perpendicular to the longitudinal orientation of fibres using an Instron Universal Testing Machine with a triangular blade (height = 5.2 cm, width = 6.1 cm, thickness = 0.11 cm; speed = 80 mm/min).

Statistics

To assess the relationship between muscle fibre CSA and the other traits, phenotypic correlations were analysed with the CORR procedure of SAS (SAS Institute, 1989). Muscles were also classified in 5 classes of equal numbers according to their mean fibre CSA (RANK procedure of SAS) and a one-way analysis of variance was performed to test the effect of fibre CSA classes on other muscle traits (GLM procedure of SAS). Then, means were compared using a Newman-Keuls test for multiple mean comparisons. A multiple regression test was performed to assess the relative involvement of fibre CSA or muscle pH on the water retention and textural properties of breast meat. Finally, the genetic correlations between fibre CSA and other muscle traits were estimated by the REML (Restricted Maximum Likehood) methodology using the VCE software (Neumaier and Groeneveld, 1998) on a total of 600 birds born of 15 males and 64 females.

Results and discussion

Relationship between the fibre CSA and other muscle traits

The fibre cross sectional area (CSA) was highly phenotypically related to body weight (+0.51) and breast muscle weight (+0.65) and yield (+0.51). The increase in fibre CSA did not affect the proportion of connective tissue (about 21% of the muscle cross section surface) and did not induce fibre necrosis as it has been previously reported in turkey (Sosnicki et al., 1998). According to both the phenotypic and genetic correlations (table 1), as the fibre CSA increased the glycogen reserve of muscle before death (glycolytic potential) decreased. As a consequence, PM muscles with the largest fibres exhibited the highest ultimate pH. Besides, they contained the lowest lactate at 15 minutes *post mortem* and thus exhibited the highest pH15. As a consequence of their *post mortem* metabolism, PM muscles with the largest fibres exhibited the lowest L*, drip and thawing-cooking losses and were more tender after cooking. According to the multiple regression test (table 2), the drip loss and L* of meat appeared chiefly determined by the pHu and at a lower extent by the pH15 of muscle. By contrast, the properties of cooked meat (thawing-cooking loss and shear force) were also partly determined by the fibre CSA and therefore the muscle weight. The analysis of variance by class of fibre CSA confirmed that breast meat traits were greatly affected by muscle hypertrophy (table 3). Indeed, the drip and thawing-cooking losses as well as the maximal shear force of cooked meat were respectively 30% and 16% lower for breast from the highest fibre CSA class (average fibre CSA of 2447 μm^2) than for breast from the lowest fibre CSA class (average fibre CSA of 1257 μm^2).

Occurrence of giant fibres in relation to muscle fibre CSA and rate of pH fall

According to our observations, the occurrence of giant fibres in breast muscle was chiefly determined by the rate of pH fall (Table 4). Whatever the muscle weight and fibre diameter, the occurrence of giant fibres greatly increased when muscle pH15 was below 6.30. However, in muscles with pH15 above 6.30, the proportion of muscles in which giant fibre occurred was dependant of the fibre size. It was greater in muscles exhibiting large fibre CSA than in muscles exhibiting small fibre CSA. Therefore, the occurrence of giant fibres would be more sensitive to pH fall rate in muscles with large fibres than in muscle with small fibres.

Conclusions

According to the present study, the fibre diameter is closely phenotypically and genetically related to the overall and muscle growth of broilers, the increase in breast muscle weight resulting essentially from fibre hypertrophy. We reported that muscle hypertrophy did not alter overall breast muscle structure but induced a significant decrease in muscle glycogen reserve before death and lowered the rate of muscle pH fall *post mortem*. These changes resulted in breast meat with higher pH15 and pHu, and consequently a better water holding ability and a greater tenderness after cooking. In conclusion, this study did not evidence any genetic antagonism between growth rate or muscle development and breast meat quality and suggested that meat of current broiler genotypes selected for growth and breast yield are well adapted to further processing.

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Table 1: Phenotypic and genetic correlation between the fibre CSA and other PM muscle traits (n = 600).

	Correlation with fibre CSA	
	phenotypic	genetic
Glycolytic potential	-0.25	-0.52
Lactate (15 min *post mortem*)	-0.27	-0.41
pH (15 min *post mortem*)	0.38	0.40
pHu	0.22	0.61
L*	-0.27	-0.41
a*	0.08	-0.12
b*	0.002	-0.42
Drip loss	-0.24	-0.44
Thawing-cooking loss	-0.38	-0.63
Maximal shear force	-0.31	-0.64

Table 3: Growth and PM muscle traits in relation to fibre CSA (n = 600).

	Class 1 1257µm^2	Class 2 1582µm^2	Class 3 1812µm^2	Class 4 2048µm^2	Class 5 2447µm^2	*P*
Body weight (g)	1861^{d}	2025^{c}	2208^{b}	2248^{b}	2328^{a}	***
PM weight (g)	118.8^{e}	139.0^{d}	151.2^{c}	159.3^{b}	170.6^{a}	***
Breast yield (%)	16.5^{d}	17.6^{c}	17.7^{c}	18.4^{b}	18.8^{a}	***
Lactate (15 min; µM/g)	36.1^{a}	34.8^{a}	34.1^{a}	31.3^{b}	28.9^{b}	***
Glycolytic potential (µM/g)	111.6^{ab}	113.8^{a}	107.9^{bc}	105.0^{cd}	102.4^{d}	***
T° (15 min)	38.0	38.4	38.3	38.5	38.4	ns
pH (15 min)	6.39^{d}	6.42^{c}	6.44^{c}	6.48^{b}	6.53^{a}	***
pHu	5.62^{b}	5.61^{b}	5.65^{a}	5.66^{a}	5.68^{a}	***
L*	55.9^{a}	55.5^{a}	55.2^{a}	54.3^{b}	53.8^{b}	***
a*	-0.87	-0.89	-0.79	-0.79	-0.70	ns
b*	11.7	11.9	11.8	11.9	11.8	ns
Drip loss (%)	1.89^{a}	1.77^{b}	1.56^{b}	1.36^{c}	1.33^{c}	***
Thawing-cooking loss (%)	17.5^{a}	15.5^{b}	14.9^{b}	12.9^{c}	12.4^{c}	***
Maximal shear force (N/cm^2)	15.7^{a}	15.2^{b}	14.5^{b}	14^{c}	13.2^{d}	***

Means with different letter in the same row differ (P<0.05); ns = non significant; ***P<0.001

Tableau 2: Multiple regression test (n = 600).

Dependant variables	Partial R^2			Total R^2
	pHu	pH 15	AST	
Drip loss	0.168	0.089	0.001	0.293
	***	***	ns	
	pHu	pH 15	AST	
L*	0.374	0.070	0.002	0.446
	***	***	ns	
	AST	pHu	pH 15	
Thawing-cooking loss	0.145	0.081	0.062	0.289
	***	***	***	
	pHu	AST	pH15	
Maximal shear force	0.112	0.058	0.016	0.186
	***	***	***	

ns = non significatif ; ***P < 0.001

Table 4: occurrence of giant fibre (% GF) in relation to muscle fibre CSA and pH15 (n = 54).

Fibre CSA	pH15	% GF	N^{a}
1238 µm^2	pH < 6.30	3.59	80%
	6.30 < pH < 6.40	0.38	11%
	pH > 6.50	0	0%
2147 µm^2	pH < 6.30	3.92	83%
	6.30 < pH < 6.40	1.14	40%
	pH > 6.50	0.52	30%
CSA effect		ns	
pH15 effect		***	
CSA x pH15 effect		ns	

ns = non significant; ***P<0.001
[a]N = percentage of muscles in which giant fibre occurred