Reprod Nutr Dev (1996) 36, 523-530

Original article

Influence of increasing breast meat yield on muscle histology and meat quality in the chicken

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(Received 1 March 1996; accepted 26 July 1996)

Summary — The histological characteristics, ie, myofibre types and cross-sectional areas (CSA), of *pectoralis major* and *sartorius* muscles of 20 male chickens from two lines (ten birds from each line) divergently selected for breast meat yield were compared. Moreover, some quality parameters (ie, drip loss, ultimate pH value and meat colour) of the breast muscle were recorded. The animals from both lines displayed identical *pectoralis major* myofibre types and CSA. A slight difference in typology, but not in myofibre CSA, was observed in the *sartorius* muscle: animals with the highest breast meat yield tended to have a more pronounced glycolytic character. No significant difference was observed in the quality of breast meat (pH, colour and drip loss).

breast meat yield / muscle histology / meat quality / chicken

Résumé — Influence de l'augmentation du rendement en filets sur l'histologie musculaire et la qualité de la viande chez le poulet. *Vingt poulets mâles issus de deux lignées (dix oiseaux par lignées) sélectionnées de façon divergente sur le rendement en filet ont été comparés quant à leurs caractéristiques histologiques des muscles* pectoralis major *et* sartorius. *De plus, des paramètres de qualité de la viande du muscle pectoral ont été enregistrés. Les animaux des deux lignées présentent des fibres identiques en taille et typologie dans le muscle* pectoralis. *Une légère différence de typologie, mais pas de l'aire de section transversale, a été notée dans le muscle* sartorius. *Les animaux avec le rendement en filet le plus élevé ont tendance à avoir un caractère glycolytique plus marqué. En ce qui concerne la qualité de la viande du filet (le pH, la couleur et les pertes par exsudation), aucune différence significative n'apparaît entre les animaux des deux lignées.*

rendement en filet / histologie musculaire / qualité de la viande / poulet

INTRODUCTION

Selection for growth rate in broilers has been, and is still, very successful. It has led to increasing body weight at a given age so that animals can be slaughtered younger. Increasing the meat yields of the carcasses and more specifically in poultry, that of breast meat is of particular interest. However, while birds with increased growth rates

have generally heavier muscles, they also have more abdominal fat (Dunnington and Siegel, 1985). This characteristic is not required by poultry breeders, but is consequently of interest to improve the breast meat yields of the birds without increasing their fatness. Ricard et al (1994) reported that it is possible to select animals with a higher breast meat yield and less abdominal fat. Although this study offers interesting data for the grower or the geneticist, no details are given on the meat quality of these animals. It has long been demonstrated that many characteristics of the muscular tissue could be associated with meat quality (Ashmore, 1974; Dutson and Carter, 1985). For instance, the metabolic type of the muscle fibres is associated with the colour of meat (oxidative-red, glycolytic-white), its tenderness which is also partly a function of the diameter of the muscle fibres (Crouse et al, 1991), and its flavour and juiciness because oxidative fibres contain more lipids (Mottram and Edwards, 1983). The biochemical properties and the microstructure (Stephan et al, 1990) of these fibres also influence some of the parameters of the postmortem transformation of muscle such as pH decline, drip loss and meat colour (Henckel, 1992). The aim of this study was to compare some properties of muscle and meat from two broiler lines which were selected divergently for their breast meat and abdominal fat yields.

MATERIALS AND METHODS

Twenty animals (ten from each line) were randomly taken from a selected line (called Y33) or an unselected line (called Y11). The Y33 line was selected through eight generations for high breast meat yield and low abdominal fat. The animals were given access to food and water ad libitum throughout the rearing period. At 7 weeks of age, the animals from both lines were weighed and then stunned and decapitated. Prior to slaughtering, approximately 2 mL of blood was taken from their wing vein to obtain plasma for creatine kinase (CK) determination using the methods described by Mitchell and Maxwell (1994).

Histological measurements

Within 10 min postmortem, two muscles were excised and weighed. The *sartorius* m (SART, also called *extensor iliotibialis anterior* m according to George and Berger [1966]) is a thigh muscle which contains both slow (type I) and fast (types IIa and IIb) contracting fibres, while the *pectoralis major* (PM) m contains only fast contracting (type IIb) myofibres. In each muscle, the samples used for histochemical examinations were taken along a line parallel to the fibre axis. All samples were tied, usually at a slightly extended length, to wood rods to prevent shortening of the muscles during freezing in isopentane, cooled with liquid nitrogen and stored at −80 °C until histochemical analysis was performed. Serial cross sections, 12 μm thick, were obtained at −20 °C and processed by the myofibrillar ATPase technique after preincubation at pH 4.20, 4.35 and 10.4 (Guth and Samaha, 1969). Myofibres were classified as types I, IIa and IIb according to the terminology of Barnard et al (1982). Type I fibres were identified as being stable after acid preincubation and labile after alkaline preincubation, while type II fibres were labile after acid and stable after alkaline preincubation. To rule out the possibility of artifactual differences resulting from the histochemical procedure, muscle samples from both lines were put on the same slide during the preparation. Percentages and mean cross-sectional areas (CSA) of each fibre type were determined using a computerized image analysis system (Lefaucheur et al, 1992; for details see Buche, 1990). Percentages and mean CSA were determined on approximately 300 fibres in two random fields for each muscle. Because of its large myofibrillar heterogeneity, the SART muscle was divided into a fast portion (superficial) composed of type IIa and IIb fibres, and a mixed portion (deep) composed of type I, IIa and IIb fibres.

Meat parameters

Meat parameters were only measured on the PM muscle.

pH measurements

The measurements were taken at 15 min and 24 h postmortem and referred to as pH15 and pHu (ultimate pH), respectively. Two grammes of muscles were mixed in a solution of iodo-acetate buffer (5 mM) and the pH value of this solution was recorded with a portable pH-meter equipped with a combined electrode.

Drip loss measurements

Immediately after death, one complete PM muscle was weighed and placed in a polyethylene bag. The samples were kept at +4 °C during 24 h, then wiped and weighed. Drip loss was calculated and expressed as the percentage of the initial weight.

Colour measurements

The colour of the meat was evaluated by measuring L*, a* and b* parameters at 24 h postmortem with the Miniscan spectrocolourimeter (Hunterlab, Reston, VA, USA). Measurements were also performed after 48, 72 and 120 h of storage at +4 °C to estimate the stability of the colour.

Statistical analysis

The effect of the line on the various parameters was tested using a one-way analysis of variance (GLM procedure of the SAS system, SAS 1989). A Duncan test for multiple mean comparisons was used (SAS, 1989) to determine whether the variations of the meat colour during storage were significant.

RESULTS

Body and muscle weight

Table I shows that the body weights of the animals from both lines did not differ. In contrast, animals from the selected line (Y33) exhibited a heavier PM muscle weight (+15%) than animals from the Y11 line. Thus, the selected Y33 line had a better breast meat yield (+12%).

Myofibre typology

Fibre types are presented in table II. In the PM muscle, which is a completely fast-twitch muscle, no differences in fibres types (100% IIb) were found between animals from both lines. On the contrary, the muscle fibre typology in the SART muscle showed some significant differences. In its mixed part (which contains slow-twitch and fast-twitch, or I, IIa and IIb fibres), animals from the Y33 line showed more IIb fast glycolytic myofibres than those from the Y11 line (57 and 50%, respectively). No significant differences were

Table I. Comparisons of body weight (BW), *pectoralis major* (PM) weight and yield in the selected (Y33) and control (Y11) lines. Values are means ± SD ($n = 10$).

	Y33	*Y11*	F	*Line effect*
BW (g)	2 369 ± 88	2 324 ± 143	0.72	ns
PM (g)	129 ± 10	112 ± 12	12.29	*
Yield (% BW)	5.47 ± 0.39	4.83 ± 0.51	9.67	*

* $P < 0.05$; ns: not significant.

found in the percentages of type I and IIa myofibres despite the fact that animals from the Y11 line seemed to have more slow (I) and fast oxydoglycolytic (IIa) myofibres. Unlinke the results found in the mixed part, the fast region of the SART muscle of the animals from the Y33 line had a lower percentage of type IIb myofibres (79 and 85% for the Y33 and Y11 lines, respectively).

Myofibre areas

Results of the CSA are presented in table III. No significant differences were found in the size of the IIb fibres in the PM muscle. In the SART muscle, whatever the region or the myofibre type, the selection did not have any effect on the CSA of the fibres. Nevertheless, when the relative areas of the different

Table II. Comparisons of the percentages of myofibres in the *pectoralis major* (PM) and the *sartorius* (SART) muscles of the animals from both lines. Values are means ± SD ($n = 10$).

Muscle	*Y11*	*Y33*	F	*Line effect*
PM				
IIb	100	100	0	ns
SART, fast				
IIa	15.36 ± 3.6	21.31 ± 6.9	4.65	*
IIb	84.64 ± 3.6	78.69 ± 6.9	4.65	*
SART, mixed				
I	21.06 ± 5.5	18.44 ± 5.8	0.86	ns
IIa	28.65 ± 3.7	24.70 ± 6.9	2.02	ns
IIb	50.30 ± 4.6	56.86 ± 6.9	5.07	*

* $P < 0.05$; ns: not significant.

Table III. Comparisons of the cross-sectional areas (in μm^2) of the different myofibre types in the *pectoralis major* (PM) muscle and in the fast (SR) and mixed (SM) regions of the *sartorius* (SART) muscle of the animals of both lines. Values are means ± SD ($n = 10$).

Muscle	*Y33*	*Y11*	F	*Stat*
PM				
IIb	2 184 ± 526	2 234 ± 438	0.05	ns
SM				
I	1 362 ± 269	1 255 ± 291	0.58	ns
IIa	1 461 ± 292	1 340 ± 171	1.02	ns
IIb	1 402 ± 158	1 418 ± 257	0.02	ns
SR				
IIa	1 534 ± 255	1 437 ± 329	0.43	ns
IIb	1 715 ± 321	1 573 ± 358	0.69	ns

ns: not significant.

myofibre types were calculated in the SART muscle (fig 1), the results showed no differences in the deep part which contains both slow and fast myofibres. On the contrary, in the superficial part (entirely composed of fast contracting fibres) an increase in the relative area occupied by the IIa fibres (and an associate decrease for the IIb fibres) was observed in animals from the selected line.

Meat quality parameters

Results are presented in table IV and concern the PM muscle. No significant differences between the animals from both lines were found in the values of the plasma CK activity, pH15 and pHu, drip loss and L*a*b* values. As shown in figure 2, both lines showed similar postmortem variation in colour parameters. Only the b* value decreased significantly from day 1 to day 5 and this decrease was of similar magnitude in both lines. However, whatever the day, no significant differences were found between both lines for all these parameters.

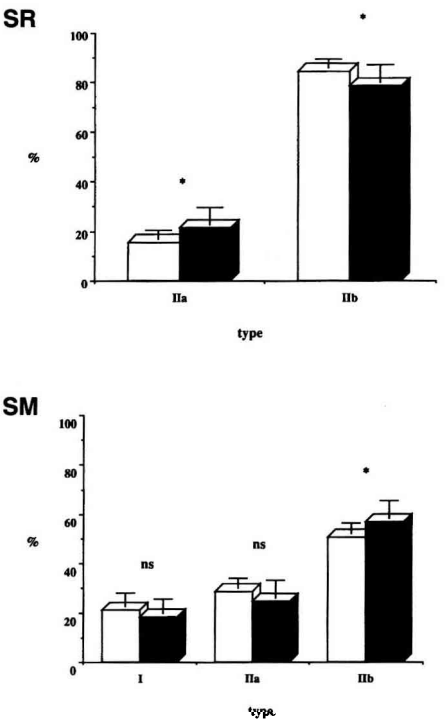

Fig 1. Comparisons of the relative areas of the different fibre types in the mixed (SM) and in the fast (SR) part of the *sartorius* muscle. Values are means ± SD ($n = 10$) and are computed from the cross-sectional areas and the percentage of each fibre type. ns: not significant, $p < 0.05$; □ Y11, ■ Y33.

DISCUSSION

Creatine kinase (CK) is an essential enzyme in skeletal muscle which is released in the plasma of birds in response to exercise, disease or stress (Mitchell et al, 1992). It has been suggested that elevated plasma CK levels indicate muscle damage because this enzyme is largely involved in the muscle energy metabolism but not to this extent in other tissues. In a few studies carried out on fast growing chickens (Mitchell and Sandercoock, 1994) or turkeys (Sosnicki et al, 1991; Cherel et al, 1995), it has been reported that this type of selection could lead to muscle structure alterations, which are visible by microscopical observations, and which are associated with a CK plasma activity elevation. In the present study, this was not the case either for the microscopical observations or for the CK activities. We may infer from this that the selection for increasing breast meat yield in the chicken does not improve PM muscle integrity.

It has been reported from studies carried out on chickens with different growth rates (Yamashita et al, 1976; Touraille et al, 1981a,b) that the age, rather than the size of the animal was the major factor affecting meat quality. This factor has an effect on taste parameters (particularly tenderness, flavour or juiciness) but not really on drip loss, pH or colour. Nevertheless, some authors have reported that the selection for

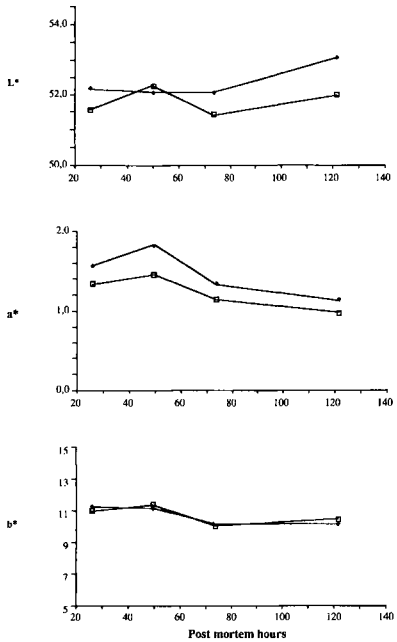

Fig 2. Postmortem variation of colour parameters in the *pectoralis major* muscle during a 5 day storage at +4 °C. Values are means ± SD (n = 10); —●— Y11, —■— Y33.

increasing muscularity could modify the colour of the meat during its storage at 4 °C for a few days, especially in turkeys (Kropf, 1993). In the present work, no particular differences between both lines were recorded concerning the pH values, the water-holding capacity or the colour during a 5 day keeping. It could be concluded therefore that selection for increasing breast meat yield in the chicken does not improve the technological parameters of the meat.

Many studies have been performed on animals with different growth rates, and they generally conclude that increasing growth rate induces dramatic changes in muscle weight and yield. The difference in muscle mass is generally explained by an increase in the CSA of the myofibre. This radial increase is generally associated with an increase in the total number of fibres (TNF) (Moss, 1968; Hooper, 1978). In the present study, no significant differences in the CSA of the different myofibres from the two muscles studied were observed. However, it can be noted that if the animals from both lines had the same breast myofibre sizes, their PM muscle masses were largely different. This difference could therefore be easily explained by a difference in the TNF or in the lengths of the fibers. Thus, the animal from the selected line could present PM muscles with more numerous myofibres. This difference, if it actually exists, in the

Table IV. Comparisons of plasma creatine kinase activity (CK), breast muscle pH, colour (L*a*b* system) and drip loss (as a percentage of weight) in the selected (Y33) and control (Y11) lines. Values are means ± SD (n = 10).

	Y33	*Y11*	F	*Line effect*
CK (IU)	801 ± 186	725 ± 154	0.98	ns
pH 15 min	6.37 ± 0.19	6.41 ± 0.22	0.16	ns
pHu	5.52 ± 0.14	5.57 ± 0.09	0.75	ns
Drip loss	1.83 ± 0.16	1.76 ± 0.14	1.17	ns
L*	51.26 ± 3.18	51.25 ± 2.01	0.01	ns
a*	1.68 ± 0.81	1.59 ± 0.95	0.05	ns
b*	12.16 ± 1.78	11.95 ± 1.01	0.1	ns

ns: not significant.

TNF of the muscle but not in the CSA of the muscle fibres, could considerably modify the result of the selection for increasing breast meat yield compared to that obtained with animals from fast or slow growing lines (Remignon et al, 1995 in the chicken; Fowler et al, 1980 in the quail).

In poultry, the quantitative changes observed in the muscle organization are generally not associated with modifications in the muscle fibre typology (Aberle and Stewart, 1983). In contrast, in mammals, Ashmore (1974) reported that an increase in muscularity is generally associated with an increase in fast glycolytic (IIb) muscle fibre percentages. In the present study, results from the PM muscle indicate that there is no fibre type modifications when breast meat yield is increased by genetic selection. On the contrary, in the SART muscle, slight differences in typology were observed. These changes were set towards a more glycolytic metabolism of the entire muscle in the selected Y33 line. This muscle exhibited a very different profile from its superficial to its deep region, but we do not know exactly what are the specific roles of these different parts. Nevertheless, the global typology and the location of this muscle in the thigh are in favour of a red oxydoglycolytic muscle involved in the general posture of the animal. The increase in the PM mass generated by selection could have changed the promptings applied to the different leg muscles, leading them towards a more glycolytic metabolism. This metabolic drift is much more able to respond to the larger requests due to the pectoral mass increase. However, we observed no modifications in the different muscle fibre sizes as was the case in birds subjected to regular exercise (Brackenbury and Holloway, 1991).

These differences in the global typology of the SART muscle result in a major difference when comparing the present results and those obtained with animals with different growth rates. In this latter case, it is generally reported that the major difference between slow and fast growing birds is the size but not the type of the different myofibres (Horak et al, 1989).

In conclusion, it should be noted that increasing PM muscle mass and yield does not influence the muscle organization and its associated meat technological parameters. Nevertheless, little differences have been found in the typology of one thigh muscle, and if this drift towards a more glycolytic character could be confirmed in other muscles, it could result in a whiter meat. Moreover, the myofibre typology drift could also reveal a major modification of the postural attitude of the selected birds, as could be suggested in the twisted leg syndrome often observed in modern fast growing broiler strains.

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