DIVERGENT SELECTION ON CONTRACTILE PROPERTIES OF LONGISSIMUS MUSCLE FIBERS IN THE PIG

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Background

The metabolic and contractile properties of muscle fibers are generally considered to influence the processing and sensory properties of pork meat *(Valin, 1988)*. Most studies are based either on comparisons between different types of muscles within animals, or on comparisons of the same muscle between animals reared in different conditions, or deal with the influence of a selection on growth performance on myofiber composition and meat quality traits *(Karlsson et al., 1993; Brocks et al., 1998)*. However, these factors may also influence meat quality through their effect on the repartition of lean and fat tissues in the carcass, thus preventing the identification of any relationships between muscle fiber type composition and meat quality.
A previous study undertaken at INRA during 6 generations on Large White pigs showed a large individual variation in metabolic and contractile properties of muscle fibers, as well as a high heritability, i.e. h^2=0.46 for the percentage and relative area of slow-twitch type I fibers *(Larzul et al., 1997)*. These results suggested that it should be possible to select animals on one of these traits in order to evaluate the specific influence of muscle fiber properties on meat quality and growth.

Objectives

The aim of the present study was to create, in a population of Large White pigs sharing similar genetic background and breeding conditions, two divergent lines for the relative area of type I fibers (RA-I) of *Longissimus lumborum* muscle (LL) at 70 kg body weight (BW), and to evaluate the influence of RA-I of LL on growth, carcass composition and meat quality traits at slaughter at 100 kg BW.

Methods

Animals. Two divergent lines for the RA-I of LL muscle were established in a population of Large White purebreds free of the halothane-sensitive (n) and RN$^-$ alleles. The selection criteria was measured *in vivo* on LL from a muscle biopsy taken at 70 $\pm$ 5 kg BW at the last rib level. Musle samples were quickly frozen in isopentane cooled by liquid nitrogen. Transverse sections were performed using a cryostat microtome and stained for actomyosin ATPase after preincubation at pH 4.35 to identify types I, IIA and IIB fibers *(Brooke and Kaiser, 1970)*. RA-I was determined from about 1500 myofibers using a computerized image analysis system *(Lefaucheur et al., 1992)*. From 154 males and 165 females tested at generation zero (G0), 5 boars and 30 females exhibiting the lowest RA-I (3.9 $\pm$ 0.8 and 3.5 $\pm$ 0.7%, respectively), and 5 boars and 30 females exhibiting the highest RA-I (12.5 $\pm$ 1.2 and 10.4 $\pm$ 1.9%, respectively), were mated to create the low (G1L) and high (G1H) lines, respectively.
Carcass, muscle, and meat quality traits. In vivo (IV) myofiber composition of LL at 70kg BW, as well as average daily gain (ADG) between 30 and 100 kg BW, were recorded on 316 G0, 225 G1L and 221 G1L pigs. All animals were slaughtered at 100 kg BW and, in each G1 line, females exhibiting either a very low value for RA-I at 70 kg BW in the G1L line (VL subgroup, n = 29) or a very high value in the G1H line (VH subgroup, n = 26) were chosen to carry out the following measurements. The day of slaughter, samples of LL were taken for measurement of pH 45 min after homogenization in 5 mM iodoacetate and *post mortem* (PM) myofiber typing. The day after slaughter, the right half carcass was cut and individual joints were weighted to estimate lean meat content *(Métayer et al., 1998)*. Ultimate pH (pH 24h) was measured on LL and *Biceps femoris* (BF) muscles using a glass pH meter probe, and colour of BF was measured using a Minolta chromameter and expressed as L (lightness), a (redness) and b (yellowness) values.
Statistical analyses. Genetic parameters (heritabilities and genetic and phenotypic correlations) and genetic trends for ADG and LL myofiber type composition traits were estimated using a REML procedure applied to an individual model *(Neumaier and Groeneveld, 1998)*. The comparison between "extreme" animals (VL vs VH subgroups) was carried out for carcass and meat quality traits using an analysis of variance *(GLM procedure, SAS, 1989)*.

Results and discussions

Heritability of RA-I (Table 1) was relatively high (0.29), but remained smaller than the 0.46 value previously reported by *Larzul et al. (1997)*, whereas heritabilities of ADG were similar in both studies (0.4). On the other hand, selection experiments for a high percentage of type I *(Nakamura et al., 1993)* or type II *(Suwa et al., 1996)* fibers carried out in rats during 4 or 7 generations report realized heritability values of 0.17 and 0.29, respectively. Phenotypic and genetic correlations confirm that types I and IIB percentages are closely and negatively related, whereas that of type IIA varies more independently. No significant phenotypic or genetic correlations between AGD and myofiber typing was observed. Table 2 reports that the difference between average genetic values of RA-I in G1L and G1H was 1.7%, i.e. 1.3 genetic standard deviation. These results show that the selection on RA-I of LL muscle was efficient to create a significant divergence as soon as the first generation. Correlated genetic responses were an increase in numerical percentage of type I fibers and a decrease in that of type IIB fibers, whereas proportion of type IIA fibers was less affected. Genetic values for ADG were not significantly affected, but show a tendency towards an increase in the H line and decrease in the L one. The large difference in RA-I observed between VL and VH pigs at 70 kg BW was dramatically reduced after slaughter at 100 kg BW, mostly due to a decrease in the RA-I of the VH group (Table 3). Since we also observed a decrease in the percentage of type I fibers in the same animals (data not shown), it can be suggested that some fibers switched from slow (I) to fast (II) type in that muscle, especially in pigs exhibiting a high RA-I at 70 kg BW. Nevertheless, this observation remains to be confirmed and elucidated. VH pigs exhibited significantly fatter carcasses than VL, as shown by their higher back fat weight, lower loin weight,

smaller loin / back fat ratio and lean meat content (Table 3). Thus, present results suggest that a higher RA-I is associated with fatter carcasses. This is in accordance with the lower percentage of type I fibers observed in some lean lines of pigs *(Brocks et al., 1998)*. In both muscles, rate and extent of pH fall and Lab values were similar between VL and VH animals.

Conclusions

Our results show that the divergent selection on RA-I of LL muscle of pigs at 70 kg BW was successful as soon as the first generation with an heritability of 0.29. Data obtained on the same animals, *in vivo* at 70 and *post mortem* at 100 kg BW, suggest a decrease in the RA-I of LL muscle, in particular in pigs exhibiting a very high RA-I at 70 kg BW. Comparison between extreme pigs showed that VL were fatter than VH pigs, without any difference for meat pH and colour. The present study brings new data which will help to settle additional selection experiments during more generations.

Literature

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Table 1. Heritabilities (on diagonal), genetic (± std error) (above diagonal) and phenotypic (below diagonal) correlations for ADG and LL muscle fiber traits at 70 kg BW (n=762)

	RA I	% I	% IIA	% IIB	ADG
RA I	0.29 ± 0.05	0.87 ± 0.05	-0.35 ± 0.13	-0.56 ± 0.10	0.17 ± 0.11
% I	0.78	0.28 ± 0.04	-0.29 ± 0.14	-0.74± 0.07	0.17 ± 0.11
% IIA	-0.30	-0.28	0.25 ± 0.06	-0.56 ± 0.10	-0.43 ± 0.14
% IIB	-0.50	-0.72	-0.46	0.27 ± 0.04	0.15 ± 0.11
ADG	0.12	0.13	-0.10	-0.05	0.41 ± 0.05

Table 2. Genetic trends for ADG (in g/j) and LL muscle fiber traits (n=762)

	Average genetic value			Std. deviation	
	G0	G1L	G1H	Genet.	Pheno.
RA I	-0.066	-0.869	0.828	1.33	2.40
% I	-0.074	-1.028	0.973	1.80	3.29
% IIA	0.105	0.378	-0.129	1.37	2.72
% IIB	-0.027	0.654	-0.837	1.95	3.67
ADG	2	-10	9	55	80

Tables 3, a and b. Least-square means of carcass and meat quality traits between extreme animals exhibiting either a very low (VL) or very high (VH) *in vivo* RA I of LL muscle at 70 kg BW.

3a. LL muscle fiber and carcass traits

	VL	VH	SE	*P*
n	29	26		
LL RA-I				
70 kg BW (IV)	4.35±0.37	13.31±0.49	1.34	***<0.001***
100 kg BW (PM)	3.66±0.40	6.05±0.53	1.44	***<0.001***
Cacass				
Dressing (%)	76.8±0.5	75.3±0.7	1.7	*0.062*
Weight (kg)				
Loin	12.10±0.17	10.88±0.23	0.60	***<0.001***
Back fat	3.24±0.17	3.91±0.23	0.59	***<0.021***
Ham	9.35±0.12	8.90±0.17	0.42	***<0.030***
Loin/back fat	3.93±0.24	2.92±0.32	0.82	***<0.012***
Lean meat content	60.52±1.05	55.13±1.41	3.60	***<0.003***

3b. Meat Quality traits

	VL	VH	SE	*P*
n	29	26		
LL muscle				
pH 45 min	6.40±0.06	6.41±0.08	0.21	*0.900*
pH 24 hrs	5.57±0.04	5.60±0.05	0.14	*0.667*
BF muscle				
pH 24 hrs	5.59±0.05	5.56±0.07	0.17	*0.678*
L*	47.7±1.2	49.0±1.6	4.1	*0.528*
a*	5.7±0.4	5.9±0.5	1.3	*0.694*
b*	8.0±0.3	8.3±0.4	1.2	*0.511*