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Original article

Comparative description of growth, fat deposition, carcass and meat quality characteristics of Basque and Large White pigs

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Abstract – Characteristics of growth, fat deposition, carcass and meat quality of pigs from the Basque Black Pied breed were described and compared with those of Large White pigs. Four pens, two per breed, of eleven pigs born during the same two week period, were simultaneously fattened and slaughtered, under the same conditions. The experiment was carried out over a fixed duration (124 days) and slaughter was carried out at a fixed average age (202 days). Basque pigs showed lower growth and feed efficiency and higher backfat depth (2.6 vs. 1.7 cm, $P < 0.001$) than Large White pigs. The difference was especially noticeable in the middle subcutaneous fat layer (0.5 cm, $P < 0.001$). The meat of Basque pigs was darker, redder, more marbled, and with higher pH values than in Large White pigs. Differences in fatty acid composition were observed between breeds but they were not statistically significant ($P > 0.05$) because of high variability observed between animals. The Basque breed exhibited an early and higher adipose development and a higher activity of enzymes responsible for lipid synthesis than the Large White. The diameter of intramuscular adipose cells was larger in Basque (40.2 vs. 33.0 μm, $P < 0.001$) than in Large White pigs. The results show the particular characteristics of the Basque breed as compared to pig lines highly selected for lean growth efficiency.

Basque pig / fattening performance / adipose tissue / meat quality

Résumé – Comparaison des performances de croissance, du développement des tissus adipeux, de la qualité de la carcasse et de la viande du porc Basque et Large White. Les performances de croissance, le développement des tissus adipeux et la qualité de la carcasse et de la viande de porcs de race Pie Noir du Pays Basque ont été étudiés et comparés à ceux de porcs de race Large White. Pour chaque race, deux lots de onze porcs, nés à la même période, ont été élevés dans les mêmes conditions de logement, d'alimentation, puis abattus au même âge. L'expérience a duré 124 jours et les animaux ont été sacrifiés à un âge moyen constant de 202 jours. Les porcs Basques ont eu une croissance et une efficacité alimentaire plus faibles que les porcs Large White, alors qu'ils ont eu une épaisseur de lard plus élevée (2,6 vs. 1,7 cm, $P < 0,001$). La différence était particulièrement apparente dans la couche moyenne de lard sous-cutané (0,5 cm, $P < 0,001$). La viande des porcs

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Basques a été plus foncée, plus rouge, plus marbrée, et avec des valeurs du pH plus élevées que celle des porcs Large White de référence. Des différences dans la composition en acides gras ont été observées entre les races, mais elles n'étaient pas statistiquement significatives ($P > 0,05$) en raison d'une grande variabilité entre animaux. Les caractéristiques des tissus adipeux ont été significativement différentes, montrant un développement précoce chez les porcs Basques avec des activités élevées des enzymes responsables de la synthèse des lipides. Le diamètre des cellules adipeuses intramusculaires était plus grand chez les porcs Basques (40,2 vs. 33,0 µm, $P < 0,001$). Les résultats ont mis en évidence les caractéristiques particulières de la race Basque par rapport aux lignées de porcs sélectionnées pour leur forte vitesse de croissance du tissu maigre.

porc Basque / performance d'engraissement / tissu adipeux / qualité de la viande

1. INTRODUCTION

The Basque Black Pied is one of those pig breeds that has lost its productive role during the last century. After a period of critical status, this breed has been recovered since 1981 and now several farmers maintain a small permanent population. The pig industry has focussed on increasing the efficiency of muscular tissue production. In Europe, selection has been successfully conducted to obtain leaner carcasses, higher growth rate, lower feed conversion and bigger litter size, based on a limited number of breeds. Two main consequences of this strategy of selection are the following: (1) pig genetic diversity has been eroded and (2) whole meat sensory characteristics and some reproductive and health traits have been undesirably affected [12]. Recently, conservation of genetic resources has become a high-priority goal to support future livestock improvement. Novel genetic variation is needed in order to respond to changes in the consumer's demand or to be integrated in sustainable agricultural systems [9]. This is why the interest in autochthonous breeds is increasing.

The Basque breed is an interesting breed from genetic, economic and biological points of view. In analyses of genetic diversity based on DNA, Laval et al. [9] indicated that this breed appeared to be the most "unique" in the set of the 12 breeds, belonging to seven European countries they analysed. This breed has an interesting aptitude for the production of dry-cured products and presents a much higher fat content in comparison with other breeds [8].

The aim of this work was to present the results of an experiment carried out to describe the main growth, fat deposition, and carcass and meat quality characteristics of animals of the Basque pig breed. A description was made by comparing the latter animals with a selected line of the Large White breed raised under the same intensive conditions and period, and slaughtered at the same age. This work provides information for future experiments aimed at obtaining a better understanding of the regulation of growth and body composition in pigs using the Basque breed.

2. MATERIALS AND METHODS

2.1. Animals and housing

Twenty-five Basque and 22 Large White piglets were initially sampled in order to ensure a minimum of twenty animals per breed during the fattening period. The Large White originated from a halothane-negative commercial line. An unexpected high mortality occurred in the Basque (28%) and only 18 of the 25 initial animals reached the end of the experimental period. No mortality was observed in the Large White breed. All piglets were males, surgically castrated at 1 week of age. They were born during the same two-week period (after heat synchronisation of sows) from 6 sows and 2 boars for the Basque and 9 sows and 5 boars for the Large White. Weaning took place between the third and fourth week after farrowing. The experiment was carried out on a farm located in the north of Navarra (Spain) and it took place from August until January. The pigs were housed in 4 pens, 2 per breed, randomly located on the farm. The pens had fully slatted floors and the buildings were environmentally controlled. The pigs were allocated to pens based on their weight and family relationships in order to have homogeneous pens. The objective was to have the minimum weight variability and the maximum number of families represented in each pen.

2.2. Experimental period, feeding and slaughtering

After a growing period of 54 days, the experimental period started at 78 days of age on average. The average weight of the pigs was 26.0 kg in Basque and 32.6 in Large White. All the animals were identically managed and fed a commercial diet containing barley (45%), corn (27%), soybean meal (24%), animal fat (1%) and vitamins and minerals (3%) ad libitum. The nutrient contents were 17.7% crude protein, 3.3% crude fat, 4.3% crude fibre, 0.9% lysine, 0.3% methionine and 3225 kcal per kg of digestible energy. Feed intake was measured in each of the 4 experimental pens every two days.

It should be remarked that the experiment was designed to measure different traits over a fixed duration. The pigs were slaughtered at 202 days on average, the same day and in the same slaughterhouse in order to minimise the effect of transport and slaughter on the results.

2.3. Measurement of growth and subcutaneous fat deposition

All pigs were individually weighed and scanned the day before they were slaughtered. An ultrasound A-mode scan (Renco Lean-Meater, Renco Corporation, USA) and an ultrasound B-mode scan (Sonovet 600, Medison Co. Ltd., Korea; 120 mm, 3.5 MHz) were used. Backfat depth was measured by the A-mode scan at the last rib and about 5 cm lateral to the midline at each segment of body length. A perpendicular ultrasound B-mode image was recorded at the same point but only on the right side. The area of the loin eye muscle and depth of the outer, middle, inner and total layer backfat were then estimated on a computer using specific image analyser software (Optimas V6.5; Media Cybernetics, USA).

2.4. Carcass and meat quality measurements

After slaughter, the carcasses were weighed (including the head and tail) and killing out percentage (carcass weight × 100 / live weight) was calculated. Two hours later, during chilling, muscle pH (Orion Research Potentiometer, Spain) and electrical conductivity (EC) (LF-Star, Matthäus, Germany) were measured in the *semimembranosus* muscle (pHi, ECi). At thirty hours post-mortem, pH and EC measures were repeated in the meat-processing plant (pHf, ECf). At this moment, the two hams (feet included) and the right boneless loin eye muscle were weighed and percent ratios with respect to carcass weight were calculated. The fifth and sixth left loin eye chops were removed from each animal to be stored in a freezer until the marbling score and fatty acid composition were determined later. Before freezing, a Minolta CM 2002 spectrophotometer (Minolta Co., Ltd., Japan) (D65/10°) was used to determine the CIE L* (lightness), a* (redness), and b* (yellowness) coordinates [1] in the sixth chop. Five measures were done in each chop on non-overlapped sites and the mean value, hue value [arctan (b*/a*)] and chroma value (saturation index) $[((a^*)^2 + (b^*)^2)^{1/2}]$ were calculated [1].

2.5. Adipocyte development and lipogenic activity

At the slaughterhouse, two samples, one of fat from the outer layer of subcutaneous fat and another of the *semimembranosus* muscle were taken out. The subcutaneous fat sample was placed in glass test tubes containing 10 mL of Tirode solution (0.15 mol NaCl; 6 mmol KCl; 2 mmol $CaCl_2$; 6 mmol glucose; 2 mmol $NaHCO_3$), pH 7.62, at 39 °C for later measurement of adipocyte size. After mincing, the adipocytes were separated using the collagenase digestion technique [13]. The diameter of approximately 200 adipocytes from each sample was measured using an image analyser (Imagenia 2000 V2.0, Biocom, France). The corresponding cell volumes were calculated from diameter measures. The s*emimembranosus* muscle sample was immediately frozen in liquid N_2 and stored at –80 °C until the analyses of the size of the intramuscular adipocytes and the activities of the enzymes acetyl-CoA-carboxylase (ACX, EC 6.4.1.2), malic (ME, EC 1.1.1.40) and glucose-6-phosphate-dehydrogenase (G6PDH, EC 1.1.1.49) were performed. Intramuscular adipocyte size was measured following a methodology similar to that used for subcutaneous tissue, using a sub-sample of 12 animals per breed. The lipogenic ACX enzyme activity was analysed by the $H^{14}CO_3^-$ fixation method and the activities of the G6PDH and ME enzymes were analysed by measuring NADPH formation at 37 °C by absorbance at 340 nm [11].

2.6. Marbling and fatty acid composition

The left fifth and sixth chops taken at the meat-processing plant from each animal were respectively used to analyse marbling score, by image analysis, and fatty acid composition, by gas chromatography. The quantity and distribution of marbling (visible intramuscular and intermuscular fat) was analysed from images of each chop taken with a photographic lens (Nikon, 28 mm). The images were stored digitally in a computer (Imagenia 2000 V2.0, Biocom, France). Later, they were processed, manually drawing the contour of the loin eye and automatically labelling the marbling flecks using the software algorithms. The loin eye area, the fat area, the marbling count and the marbling area (averaged area of marbling flecks) were recorded. The percent fat area and the densities of marbling count and area were computed against the loin eye area.

Fatty acid composition was obtained after extraction (with chloroform / methanol; 2:1) and methylation (with boron trifluoride / benzene / methanol; 25:20:55) of adipose tissue of the loin eye muscle. The methyl esters were analysed on a Hewlett-Packard chromatograph (HP-5890, Hewlett-Packard Co., USA) equipped with a flame ionisation detector and split injector (HP-7673, Hewlett-Packard Co., USA). Separations were performed using a capillary column (100 m × 0.25 mm × 0.25 μm) (HP-INNOWAX Crosslinked Polyethylene Glycol, Hewlett-Packard Co., USA). The conditions were the following: (a) carrier gas, helium at 1 mL per min; (b) oven temperature, 150 to 210 °C at 3 °C per min, 210 °C for 5 min, 210 to 250 °C at 4 °C per min, 25 min at 250 °C; (c) injector temperature, 225 °C; (d) detector temperature, 240 °C. Methyl ester standards for fatty acids (Sigma-Aldrich Química, S.A., Spain) were used to identify the peaks. The results are expressed as relative percentages.

2.7. Statistical analysis

All data were submitted to analysis of variance using breed as the main effect. Significance, residual standard deviation (R.S.D.) and least squares means of breed effect are reported in the Tables. The analyses were performed using SPSS software (v.11.5.1., SPSS Inc., USA).

3. RESULTS

3.1. Growth and subcutaneous fat deposition

Growth performance was lower in the Basque than in the Large White breed; the results are shown in Table I. During the fixed

Table I. Effect of breed on growth, loin eye area and subcutaneous fat deposition at slaughter (least squares means).

	Breed			
	Basque	Large White	R.S.D.	Significance[c]
Weight (kg)				
Initial	26.0	32.6	5.4	***
Slaughter	86.2	126.6	16.1	***
Average daily weight gain (g per day)	488	763	10	***
Loin eye area (cm^2)				
At the last rib level[a]	18.1	31.3	3.1	***
At the 5th rib level[b]	29.0	44.0	5.7	***
Overall backfat thickness (cm)				
Ultrasounds A-mode	2.42	1.57	0.31	***
Ultrasounds B-mode	2.60	1.74	0.42	***
Backfat layer thickness (cm)				
Outer layer	0.86	0.73	0.12	***
Middle layer	1.02	0.56	0.23	***
Inner layer	0.67	0.45	0.19	***

[a] "In vivo" ultrasounds B-mode;
[b] Analysis of image after slaughter;
[c] ***: $P < 0.001$.

fattening period of the experiment, the Large White pigs reached 126.6 kg of live weight whereas the Basque pigs weighed on average only 86.2 kg. Thus, the average daily weight gain was significantly lower in Basque pigs (488 vs. 763 g per d). The feed conversion ratio was 4.2 vs. 3.1 kg per kg and average daily feed intake was 2.3 and 2.0 kg per day in Basque and Large White pigs, respectively.

The lower performance of Basque pigs was in agreement with differences in the loin eye area and backfat thickness observed between the breeds. The loin eye area was significantly lower in the Basque breed at slaughter. As expected, the backfat thickness differences were opposite. Basque pigs showed a higher subcutaneous adiposity. The overall backfat thickness difference was close to 0.9 cm at slaughter (Tab. I). Differences in all the layers were observed, although of different magnitudes. The middle layer explained more than 50% of the overall backfat differences observed at slaughter between the breeds. The differences were small in the outer layer.

3.2. Carcass and meat quality

As expected, all carcass traits except for killing out percentage showed differences between breeds (Tab. II). The differences were especially important for loin eye and ham weight, although these were related to slaughter weight. They also depended on genotype because the loin eye plus ham weight with respect to carcass weight were also lower in Basque (27 vs. 32%).

Meat quality measurements are summarised in Table II. Lightness was lower and redness higher in Basque than in Large White. However, no significant difference

Table II. Effect of breed on carcass and meat quality traits (least squares means).

	Breed			
	Basque	Large White	R.S.D.	Significance[d]
Carcass weight (kg)[a]	65.0	95.7	12.6	***
Killing out percentage (%)	75.4	75.6	1.5	ns
Loin / carcass ratio (%)	4.78	6.28	0.44	***
Ham / carcass ratio (%)	22.54	25.41	0.76	***
Lightness, L*[b]	43.4	48.0	3.2	***
Redness, a*[b]	6.0	4.3	1.2	***
Yellowness, b*[b]	8.0	8.9	1.4	ns
Hue[b]	53.3	64.1	6.7	***
Chroma[b]	10.2	10.0	1.4	ns
pHi[c]	6.6	6.3	0.3	**
pHf[c]	6.0	5.7	0.2	***
ECi[c]	4.1	4.0	1.0	ns
ECf[c]	7.7	6.9	2.3	ns

[a] Including head and tail;
[b] According to AMSA [1]; Hue = arctan (b*/a*), angle in degrees; Chroma = $((a^*)^2 + (b^*)^2)^{1/2}$;
[c] pHi, pHf, ECi, ECf, pH and electrical conductivity (µSiemens) two and thirty hours post-mortem respectively;
[d] ns: not significant; **: $P < 0.01$; ***: $P < 0.001$.

was found for the b* value (Tab. II). The hue was lower in Basque than in Large White but the chroma was similar in both breeds. So, the loin eye muscle of Basque pigs can be characterised as less luminous, darker and redder than the same muscle of Large White pigs.

Despite the fact that all pigs were halothane-negative, differences in pH were found between the two breeds. Thus, lower initial and final pH values were found in Large White pigs (Tab. II). Electrical conductivity values showed a high variability between animals, especially for final EC, and no significant differences between breeds were estimated.

3.3. Adipocyte development and lipogenic activity

The size of adipose cells was significantly greater in Basque than in Large White. In Basque pigs, the diameter of adipocytes was 16% greater in subcutaneous fat and 22% in *semimembranosus* muscle (Tab. III). This result was consistent with higher subcutaneous fat content observed in Basque pigs. It was also in agreement with the lipid content estimated in *semimembranosus* muscle: 5.7% (s.e. 0.6) in Basque and 1.7% (s.e. 0.1) in Large White pigs (Soxhlet, ISO-1443-1973).

In reference to lipogenic enzyme activities, the results indicate that the Basque breed had a greater potential for fatty acid synthesis. The ACX activity was significantly higher in Basque than in Large White (Tab. III). In addition, the activities of the ME and the G6PDH enzymes were also significantly higher in the Basque. There was a high variability observed between animals, although the differences between the two breeds were large enough to be significant.

3.4. Marbling and fatty acid composition

No differences in the absolute values of fat area and number and size of fat flecks

Table III. Effect of breed on adipocyte development and lipogenic enzyme activities (least squares means).

	Breed		R.S.D.	Significance[b]
	Basque	Large White		
Subcutaneous adipose tissue				
Adipose cell diameter (µm)	92.6	79.7	10.1	***
Adipose cell volume (pL)	428	278	128	***
Semimembranosus muscle				
Adipose cell diameter (µm)[a]	40.2	33.0	3.6	***
Adipose cell volume (pL)[a]	35	19	10	***
ACX (nmol $HCO_3^-\cdot min^{-1}\cdot g^{-1}$ tissue)	0.4	0.3	0.1	*
ACX (nmol $HCO_3^-\cdot min^{-1}\cdot g^{-1}$ protein)	6.2	4.4	2.3	*
ME (µmol $NADPH_2\cdot min^{-1}\cdot g^{-1}$ tissue)	2.6	1.5	0.6	***
ME (µmol $NADPH_2\cdot min^{-1}\cdot g^{-1}$ protein)	44.2	24.7	9.8	***
G6PDH (µmol $NADPH_2\cdot min^{-1}\cdot g^{-1}$ tissue)	0.8	0.3	0.4	***
G6PDH (µmol $NADPH_2\cdot min^{-1}\cdot g^{-1}$ protein)	13.4	4.6	6.3	***

[a] Results corresponding to a sub-sample of 12 animals per breed;
[b] *: $P < 0.05$; ***: $P < 0.001$.

were found between breeds (Tab. IV). However, expressed on the basis of the loin eye area, the number (marbling count density) and the size (marbling area density) of fat flecks were significantly higher in the Basque than in the Large White pigs. The percentage of the fat area was also greater in Basque, 18.2% vs. 12.6%. These values represent inter and intramuscular fat area in the whole loin eye area of the fifth rib. They were in concordance with the chemical lipid content estimated in the equivalent area of the sixth rib: 15.0% (s.e. 0.9) in Basque and 7.9% (0.9) in Large White pigs (Soxhlet, ISO-1443-1973).

The profile of fatty acids is presented in Table IV. The most important fatty acids in terms of content were the acids oleic (C18:1), palmitic (C16:0), stearic (C18:0) and linoleic (C18:2). An unexpected high variability between animals was observed, and differences were only statistically significant ($P > 0.05$) for stearic fatty acid.

4. DISCUSSION

Growth characteristics were significantly different among breeds. The average daily weight gain was lower, and voluntary feed intake and feed conversion ratio was higher in Basque than in Large White pigs. The differences were similar to those reported by Labroue et al. [8] when comparing animals from both breeds though at different ages (at a fixed weight of 90 kg). They could be considered as a consequence of selection for growth efficiency of lean. Cameron and Curran [2] showed that the efficiency was improved by an increasing growth rate, although little change was produced in daily feed intake with selection for lean growth rate, but daily feed intake was reduced with selection on lean feed conversion.

A lower lean development and a noticeable high fat development were observed for Basque than for Large White pigs. The differences in subcutaneous fat tissue growth between breeds varied among fat layers. This

Table IV. Effect of breed on marbling and fatty acid composition of loin eye muscle (least squares means).

	Breed			
	Basque	Large White	R.S.D.	Significance[a]
Fat area (cm^2)	5.22	5.57	1.29	ns
Fat area (%)	18.2	12.6	2.8	***
Marbling count	27.53	28.68	8.69	ns
Marbling area (cm^2)	0.20	0.20	0.05	ns
Marbling count density (cm^{-2})	0.97	0.66	0.26	***
Marbling area density (%)	0.70	0.46	0.14	***
Fatty acid (%)				
C12:0	0.2	0.2	0.1	ns
C14:0	1.4	1.4	0.3	ns
C16:0	26.5	25.8	1.5	ns
C16:1 n-7	3.2	2.8	1.0	ns
C18:0	14.5	15.6	1.2	**
C18:1 n-9	39.3	36.3	7.4	ns
C18:2 n-6	8.7	11.2	5.5	ns
C18:3 n-3	0.3	0.3	0.1	ns
C20:0	0.8	0.8	0.2	ns
C20:1 n-9	0.9	1.0	1.9	ns
C20:3 n-6	0.1	0.1	0.1	ns
C20:4 n-6	2.6	2.7	2.1	ns
Total saturated	42.9	43.2	1.9	ns
Total monounsaturated	43.4	39.9	8.1	ns
Total polyunsaturated	13.8	17.0	7.9	ns
Unsaturated/saturated	1.3	1.3	0.1	ns

[a] ns: not significant; **: $P < 0.01$; ***: $P < 0.001$.

was in agreement with the results of the comparison between other genotypes and ages carried out by Eggert and Schinckel [5]. The difference in total subcutaneous fat deposition was basically related to the different development of the middle and inner layers. This result was in accordance with previous results [10] suggesting a greater metabolic activity of the middle layer. Leymaster and Mersmann [10] pointed out that selection against total backfat thickness seems to have emphasised the middle rather than the outer layer.

Backfat thickness was significant and positively correlated with adipose cell size as described in other populations [7]. Correlation coefficients were 0.64 and 0.76 in Basque and Large White pigs respectively. The greater adipocyte development observed in Basque pigs agreed with the results obtained in the comparison of other breeds. Comparing Pietrain and Meishan breeds, Hauser et al. [6] already described that the size of the adipocytes of subcutaneous and intramuscular tissues is higher in the obese breeds than in the leaner ones. The higher

ACX activity in the Basque breed indicates a greater potential for fatty acid synthesis than in the Large White breed. The ACX activity was low compared with its activity in other adipose tissues, but in accordance with the results obtained for intramuscular fat in other studies [11]. The production of NADPH was also higher in the Basque breed, inducing a higher content of lipids as observed in this breed. NADPH remains the limiting factor for the synthesis of the lipids in muscle. The ME activity was higher than that of the G6PDH indicating that NADPH production in the muscle was mainly by ME as previously observed by Mourot and Kouba [11]. In summary, the results on Basque pigs agree with the greater potential of lipid synthesis observed in obese breeds.

In most studies, fatty acid composition is affected by genotype with obese pigs having a lower linoleic acid content than lean pigs in both, subcutaneous [14] and intramuscular fat [3], and in contrast a higher concentration of monounsaturated fatty acids [3, 4, 8]. The average values found in the present study were in agreement with these results, although the estimated differences were not significant. The lack of significance should be related to the unexpected high variability observed between animals, but no satisfactory justification was found to explain this heterogeneity. Basque meat had lower lightness and higher redness values than Large White meat. The differences can be explained by the lack of selection for lean growth rate in Basque. Cameron et al. [4] found differences in lightness, redness and hue but not in yellowness when comparing meat from pig genotypes selected for lean growth rate. They suggested that selection of European pig populations has implied a reduction of darker muscle colour. The initial pH difference disagrees with the lower initial pH value found by Labroue et al. [8] for the Basque and other French autochthonous pig breeds when compared with the Large White. The final pH value suggests a tendency towards DFD ("Dark, Firm and Dry") meat in Basque pigs. Nevertheless, the final pH value in Large White pigs was also higher than the values estimated in other studies (e.g. [4]). Ante-mortem factors, irrespective of stress susceptibility of animals, might explain these values.

In summary, this work shows the particular characteristics of the Basque breed as compared to pig lines highly selected for lean growth efficiency. A difference was found for most of the traits. Basque pigs showed low lean growth efficiency and higher backfat depth. The meat of Basque pigs was darker, redder, more marbled, and with higher pH values than in Large White pigs. The Basque breed exhibited an early and higher adipose development with a larger diameter of adipose cells and a higher activity of enzymes responsible for lipid synthesis than the Large White. It is noteworthy that this work provides useful information to allow the design of future experiments aimed at answering a specific hypothesis on the underlying biological causes of differences observed between Basque and Large White breeds.

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