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Growth of body components and carcass composition of Iberian pigs of 10 to 150 kg body weight as affected by the level of feeding and dietary protein concentration[1]

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ABSTRACT: A total of 211 growing-finishing Iberian (IB) pigs from 4 separate and independent sets of trials were slaughtered at several stages of growth from 10 to 150 kg BW to determine growth and development of chemical and physical components of the cold eviscerated carcass (CC; without head, feet, and tail). Within each set of trials, a factorial arrangement of treatments, involving several concentrations of ideal protein in the diets as 1 factor and 2 or 3 levels of feed intake as the other, was used. The main objective of the present study was to provide information on the relative growth of physical and chemical components of the CC of IB pigs, which differed because of the dietary treatment imposed, involving a wide range of protein-to-energy ratios and feeding levels. Allometric relationships ($P <$ 0.001) were established between the weight of a chemical component in the CC and empty BW or CC weight. Irrespective of the adequacy of the dietary protein-to-energy ratio, the growth coefficient for CC weight relative to empty BW was >1 ($P < 0.001$), whereas those for protein, water, and ash relative to empty BW or CC weight were <1 ($P < 0.001$). In contrast, relative growth coefficients >1 ($P < 0.001$) were obtained for fat mass and total energy, reflecting the increase in fat relative content that occurs with increasing weight. Multiple-regression equations ($P < 0.001$) were developed using a stepwise procedure, which estimates the chemical (g/kg) or energy (MJ/kg) composition of CC as a function of empty BW, dietary protein-to-energy ratio, and feeding level, expressed as a multiple of the ME required for maintenance. It is concluded that even if the pattern of developmental growth for the IB pig may show some similarities (increased fat content or decreased proportional weight of some primal cuts with BW or age) with that observed for pigs of different genetic background, relevant differences were detected. They are related to a much smaller relative size of the IB pig lean tissues and cuts, their slower rates of growth, and the increased total body fat, with marked changes in its distribution among depots. Consequently, relationships obtained for lean or conventional genotypes are not applicable to the IB pig.

Key words: carcass composition, carcass measurements, developmental growth, Iberian pigs

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INTRODUCTION

Predictive equations describing tissue growth and chemical carcass composition are key tools for different purposes, including the evaluation of nutritional programs and carcass quality with major economic implications. Important differences in the pattern of relative growth of carcass components have been observed between pig genotypes (Tess et al., 1986; Gu et al., 1992; Quiniou and Noblet, 1995), precluding the application of relationships derived from lean and conventional genotypes to obese pigs. In a recent study (Nieto et al., 2012), we proposed a model to describe the response of the Iberian (**IB**) pig to protein and energy supply in terms of energy partition into protein and fat deposition and the energetic efficiency of the processes involved. In addition, we addressed the estimation of the relative growth of body components of IB pigs under differ-

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ent dietary treatments, involving a wide range of protein concentrations and levels of feeding. It was evident that the low genetic potential for lean-tissue deposition observed in the IB pig requires the use of specific equations. Comprehensive data describing compositional changes relative to tissue growth during development of IB pigs are still very limited (Mayoral et al., 1999). Consequently, accurate relationships between tissue growth and nutrient or energy supply are needed to define a specific feeding strategy to optimize carcass quality.

The present study provides additional information to our previous paper (Nieto et al., 2012), focusing primarily on the description of the relative growth of physical and chemical carcass components of IB pigs, which differed widely in the dietary treatment imposed. The aim was to gather complementary information that would allow accurate estimations of carcass chemical components and tissue growth and prediction of dissected tissue composition in the carcass of the IB pig, a subject of great interest for commercial evaluation and carcass grading. The main results concerning animal performance at each growth stage (Nieto et al., 2002; Barea et al., 2007; García-Valverde et al., 2008; Conde-Aguilera et al., 2011a), corresponding equations to estimate ADG and ad libitum feed intake, and 2 allometric equations to predict empty BW (**EBW**) from BW (Nieto et al., 2012) have been reported previously.

MATERIALS AND METHODS

The experimental protocol for each study was approved by the Bioethical Committee of the Spanish Council for Scientific Research (Madrid, Spain).

Animals, Feed, and Experimental Design

The carcass composition of a total of 211 growing-finishing IB pigs from 4 independent experiments was evaluated in this study. Ninety-nine of these pigs received an adequate dietary treatment (i.e., an optimal or suboptimal supply of AA relative to energy in their diet), leading to no differences in whole-body protein deposition when offered at the same feeding level. The pigs used in the experiments were described by Nieto et al. (2002), Barea et al. (2007), García-Valverde et al. (2008), and Conde-Aguilera et al. (2011a). The range of corresponding BW was 15 to 50, 50 to 100, 100 to 150, and 10 to 25 kg for those experiments, respectively. Data on carcass composition and traits at these BW ranges have been published elsewhere (Nieto et al., 2003; Barea et al., 2006; García-Valverde et al., 2008; Conde-Aguilera et al., 2011b). All pigs were purebred castrated boars of the Silvela strain supplied by a single breeding company (Sánchez Romero Carvajal Jabugo S.A., Seville, Spain).

A description of management protocol, experimental treatments, slaughter methods, and chemical analysis procedures has been reported by Nieto et al. (2012). Briefly, on arrival, the pigs were offered restrictively a commercial diet, formulated according to Whittemore et al. (2003) for conventional slow-growing pigs, which we assumed to have greater AA requirements than IB pigs, until they reached their target BW to begin the experiment. They were then housed individually in 2 or 5 m^2 pens, according to their body size, and randomly assigned to the experimental treatments. Within each experiment, several concentrations of dietary ideal protein, expressed as the ratio of apparent digestible protein to ME (**ApDP:ME**, g/MJ), and 2 or 3 levels of feed intake, expressed in terms of the ad libitum intake (i.e., times ad libitum), were used in a factorial arrangement of treatments (Table 1). The greatest level of feeding was fixed as 0.95 × ad libitum. A brief description of the procedure followed to estimate ad libitum intake was provided by Nieto et al. (2012). Within each experiment, the diets were prepared by diluting a high-protein diet, formulated to provide an optimum pattern of AA, with a protein-free mixture made to match the macronutrient content of the high-protein diet. Dietary CP (g/kg DM) and ME (MJ/kg DM) contents, respectively, were in the range of 101 to 223 and 14.6 to 15.5 (Nieto et al., 2002), 123 to 201 and 14.6 to 14.7 (Conde-Aguilera et al., 2011a), and 70 to 145 and 13.9 to 14.8 (Barea et al., 2007). In the study by García-Valverde et al. (2008), a single level of ideal protein was assayed (95 g/kg DM), and the experimental diet contained 14.8 MJ/kg DM of ME.

Experimental Procedure

During the experiments, the pigs were weighed weekly before feeding, and the daily feed allowance for the next week was adjusted for each pig accordingly. Water was freely available. Classical digestibility and balance trials were conducted toward the middle of the experimental period.

The comparative slaughter procedure was used to determine body composition, protein and fat accretion, and energy retention. When the experimental pigs reached their target BW for slaughter, they were starved for approximately 16 h, stunned electrically, and bled. The gut was emptied, and the blood, carcass, and noncarcass parts were weighed separately. The average BW and EBW at slaughter (obtained by adding all the body components collected) was determined. Four components were obtained for each pig: 1) carcass (including skin and hair), 2) head plus feet and tail, 3) viscera, and 4) blood. The viscera and blood were kept at -20°C for further analysis. The warm carcass weight was individually recorded and used to calculate dressing percentage for each pig. The head was removed

Table 1. The chemical composition of the cold carcass of Iberian pigs slaughtered at different BW

BW, kg	*n*	Slaughter wt, kg	Dietary treatment	Protein, g/kg	Fat, g/kg	Ash, g/kg	Water, g/kg	Energy, MJ/kg	Reference[1]
10 to 25	48	25.2 ± 0.1	ApDP:ME,[2] g/MJ						Conde-Aguilera et al. (2011b)
			10.87[3]	166	194	36.0	601	11.66	
			9.20[3]	162	202	37.6	594	11.89	
			7.86	154	237	34.3	568	13.09	
			5.96	145	268	34.1	542	14.11	
			SE	2	6	0.9	5	0.21	
			Feeding level[4]						
			0.70	161	219	36.9	578	12.54	
			0.95	152	232	34.1	575	12.84	
			SE	1	4	0.7	3	0.15	
15 to 50	71	49.9 ± 0.3	ApDP:ME, g/MJ						Nieto et al. (2003)
			12.19	124	382	26.6	458	18.12	
			10.83	136	364	32.5	464	17.70	
			9.63	132	377	30.4	458	18.14	
			8.24[3]	134	381	28.1	450	18.31	
			6.86[3]	133	395	25.7	439	18.89	
			5.16	127	407	27.1	433	19.21	
			SE	2	8	1.3	6	0.27	
			Feeding level						
			0.60	132	382	28.0	450	18.34	
			0.80	128	393	28.6	446	18.66	
			0.95	132	378	28.6	455	18.19	
			SE	2	6	0.9	5	0.21	
50 to 100	81	99.5 ± 0.2	ApDP:ME, g/MJ						Barea et al. (2006)
			8.05	104	516	30.2	345	22.97	
			6.53[3]	102	513	26.3	349	22.83	
			5.17[3]	103	524	27.8	337	23.29	
			3.68	98	538	26.2	329	23.73	
			SE	2	6	0.9	5	0.20	
			Feeding level						
			0.60	107	512	30.0	345	22.90	
			0.80	98	529	25.7	338	23.35	
			0.95	100	528	27.3	336	23.36	
			SE	2	5	0.8	4	0.18	
100 to 150	11	149.5 ± 1.3	ApDP:ME, g/MJ						García-Valverde et al. (2008)
			4.82[3]						
			Feeding level						
			0.70	105	569	23.1	302	25.13	
			0.95	98	576	21.8	303	25.21	
			SE	3	14	1.4	10	0.48	

[1]Taken from the experiments by Conde-Aguilera et al. (2011b), using a 4 (dietary protein content) × 2 [feeding level (FL)] factorial arrangement with 6 individually housed piglets per combination of treatments; Nieto et al. (2003), according to a 6 (dietary protein content) × 3 FL factorial arrangement with 4 individually housed piglets per combination of treatments; Barea et al. (2006), using a 4 (dietary protein content) × 3 FL factorial arrangement with 6 to 7 individually housed pigs per combination of treatments; and García-Valverde et al. (2008), with 5 to 6 pigs per FL.

[2]ApDP:ME = apparent digestible protein to ME ratio.

[3]Balanced or suboptimum protein-to-energy diet.

[4]Times voluntary intake.

by cutting at the occipito-atlas joint, and the feet were removed by cutting at the carpus-metacarpal and tarsus-metatarsal joints. The carcass was divided longitudinally. These components were chilled overnight, weighed, and sealed in plastic bags and kept at -20°C until analysis. The right half (the left half for the 15- to 50-kg pigs) of the cold eviscerated carcass (**CC**) and the rest of the body components were separately ground and homogenized. Finally, subsamples were taken for freeze-drying and subsequent analysis. Separate aliquots were analyzed for DM content, CP (total N × 6.25), ash, and GE as described by Nieto et al. (2012). Body fat was calculated assuming energy contents of 23.85 and 39.75 kJ/g for protein and fat, respectively (Wenk et al., 2001). The CC weight of the pigs in the experimental groups at the start of the trials was estimated from the average CC weight of an additional group of 6 pigs slaughtered at the start of each of the trials.

Midline back fat thickness measurements were made directly with a ruler at the first (**P_1**) and last (**P_2**) ribs and at the last lumbar vertebra (**P_3**). Carcass length (**Le**) was measured from the proximal end of the first rib to the pubic symphysis. The shoulder was separated from the loin and belly by a straight cut between the second and third ribs and a straight cut 2.5 cm ventral to the ventral edge of the scapula. The ham was removed from the loin by a straight cut between the second and third sacral vertebrae approximately perpendicular to the shank bones. Each cut retained its corresponding skin and subcutaneous fat. The loin was separated from the belly by a cut beginning just ventral to the ventral side of the scapula at the cranial end and followed the natural curvature of the vertebral column to the ventral edge of the psoas major at the caudal end of the loin. Each cut was weighed. After weighing, trimmed hams and shoulders were obtained by eliminating part of the external fat and skin using a knife to comply with the commercial requirements. Thereafter, trimmed shoulders and hams were physically dissected into skin, external adipose tissue (subcutaneous fat), intermuscular adipose tissue (intermuscular fat), muscle (including blood vessels, ligaments, tendons, and connective tissue), and bone. The weight of each dissected component was recorded.

Statistical Analyses

The SAS software (SAS Inst. Inc., Cary, NC) was used for all statistical analyses. Means of physical and chemical carcass components and their SE were calculated for each BW pig group. The individual pig was considered the experimental unit. All nonlinear regression equations were obtained by the PROC NLIN of SAS. A multiple regression was calculated with data obtained from pigs fed adequate protein-to-energy diets to predict CC daily gain from BW and level of feeding expressed as a multiple of the energy requirements for maintenance (**ME_m**). Regression analysis was also used to estimate the ad libitum intake expressed as ME intake (MJ/d) and a function of BW. For pigs that consumed their full 0.95 × ad libitum allowance, their ad libitum intake was calculated as grams of feed consumed/0.95. Multiple-regression equations were calculated using a stepwise forward procedure to estimate the chemical composition of CC (g/kg) as a function of EBW, dietary protein-to-energy ratio, and feeding level expressed as a multiple of ME_m. Partial F tests were made to ascertain the statistical significance of the regression terms, removing those with $P > 0.05$. Also, multiple-regression equations were calculated using a stepwise approach to estimate the chemical component mass (kg) or total energy (MJ) in CC as a function of EBW and linear carcass measurements.

Cold carcass weight was estimated as an allometric function of EBW. The mathematical model of Huxley (1932) was also used to describe allometric or differential growth of carcass tissues or chemical components in the experimental animals. This nonlinear regression analysis was applied to each body constituent as EBW or CC increased. Several equations were fitted to the data to analyze the relationship between the weight of a physical or chemical carcass component (kg) and EBW (kg) or CC weight (kg). The r^2 and the residual SD (**RSD**) were used as measures of goodness of fit.

RESULTS

Overall mean values for the chemical composition (g/kg) of CC of the pigs slaughtered at various BW after consuming diets that differed in protein-to-energy ratio given at different feeding levels are presented in Table 1. On average, protein content in CC ranged from 157 to 102 g/kg and fat from 226 to 573 g/kg as BW increased from 25 to 150 kg. Water content changed concomitantly with CC protein, ranging from 657 g/kg at 25 kg BW to 303 g/kg at 150 kg BW. Ash content changed from 35.5 g/kg at 25 kg BW to 21.8 g/kg at 150 kg BW. The energy value of the CC of the IB pig increased from 12.69 MJ/kg at 25 kg BW to 25.17 MJ/kg at 150 kg BW.

Multiple-regression equations were constructed to predict the chemical (g/kg) and energy (MJ/kg) composition of the CC of pigs growing from 10 to 150 kg BW as a function of EBW, ApDP:ME (g/MJ), and feeding level expressed as a multiple of ME_m [ME intake:ME_m; $ME_m = 413\ \text{kJ}\cdot\text{kg}^{-1}\ \text{BW}^{0.75}\cdot\text{d}^{-1}$]. Best fits were obtained by these equations ($P < 0.001$):

$$\text{Protein} = 189 \pm 5 - 1.33 \pm 0.08 \times \text{EBW} + 0.0055 \pm 0.0005 \times \text{EBW}^2 + 0.93 \pm 0.32 \times \text{ApDP:ME} - 4.15 \pm 0.95 \times \text{ME intake:ME}_m\ (n = 211;\ r^2 = 0.875;\ \text{RSD} = 8.54), \quad [1]$$

$$\text{Fat} = 99 \pm 17 + 7.10 \pm 0.28 \times \text{EBW} - 0.0278 \pm 0.0018 \times \text{EBW}^2 - 4.2 \pm 1.1 \times \text{ApDP:ME} + 8.1 \pm 3.4 \times \text{ME intake:ME}_m\ (n = 211;\ r^2 = 0.941;\ \text{RSD} = 30.2), \quad [2]$$

$$\text{Water} = 659 \pm 12 - 5.85 \pm 0.21 \times \text{EBW} + 0.023 \pm 0.001 \times \text{EBW}^2 + 3.61 \pm 0.90 \times \text{ApDP:ME}\ (n = 211;\ r^2 = 0.941;\ \text{RSD} = 24.0), \quad [3]$$

$$\text{Ash} = 0.109 \pm 0.055 \times \text{EBW} + 0.0007 \pm 0.0004 \times \text{EBW}^2 + 2.11 \pm 0.17 \times \text{ApDP:ME} + 2.85 \pm 0.60 \times \text{ME intake:ME}_m\ (n = 211;\ r^2 = 0.954;\ \text{RSD} = 6.48), \quad [4]$$

$$\text{Energy} = 9.07 \pm 0.52 + 0.256 \pm 0.010 \times \text{EBW} - 0.001003 \pm 0.000063 \times \text{EBW}^2 - 0.152 \pm 0.041 \times \text{ApDP:ME} \ (n = 211;\ r^2 = 0.939;\ \text{RSD} = 1.09), \quad [5]$$

The CC (without the head, feet, and tail) of the growing IB pigs accounted for 66.2% of EBW in the pigs slaughtered at 25 kg BW and increased to 74.1%, 78.3%, and 79.1% of EBW in pigs of 50, 100, and 150 kg BW (Table 2). Differences with respect to percentage values observed for pigs receiving adequate protein-to-energy diets were negligible. In pigs fed adequate protein-to-energy diets, CC gain (g/d) at each stage of production can be predicted as a function of the average BW and level of feeding, expressed as a multiple of ME_m, by the following regression equation ($P < 0.001$):

$$\text{CC gain} = -222 \pm 19 + 2.54 \pm 0.12 \times \text{BW} + 151 \pm 6 \times \text{ME intake:ME}_m \ (n = 99;\ r^2 = 0.947;\ \text{RSD} = 37.1), \ [6]$$

The growth pattern of the main primal cuts of the CC of pigs growing from 10 to 150 kg BW is presented in Table 2. As proportions of CC weight, leaner cuts tended to decline with increasing slaughter weight or CC weight. Table 3 and Fig. 1 show allometric relationships, which predict the total mass of a chemical component (kg) in the CC of the growing pigs as a function of EBW or CC weight. Relative to EBW, the growth coefficient of CC was >1, indicating that it was greater than that of EBW. The allometric coefficients for protein, water, and ash masses were <1, indicating the increased accretion rates during the earlier stages of growth. In contrast, fat accretion, and, consequently, energy accretion (known to increase concomitantly with EBW) relative growth coefficients were >1, reflecting the increase in relative fat content when increasing the BW (and age). Noticeably, Eq. [3.1] and [3.7] (Table 3), describing the growth of CC relative to EBW in pigs under all treatments ($n = 211$) and subjected to the adequate dietary regimes ($n = 99$), respectively, did not differ. Values of r^2 and RSD indicated that CC weight can be accurately explained by EBW. They also showed that total energy content in CC, and also water, fat, and protein weight, can be also accurately estimated by either EBW or CC weight. The CC weight (kg) of the pigs can also be related to the CC protein mass (kg) and total lipid mass in CC (kg) by the following equations ($P < 0.001$), respectively, for pigs under all treatments or adequate dietary regimens:

$$\text{CC weight} = 4.50 \pm 0.30 \times \text{CC protein}^{0.848 \pm 0.027} + 1.87 \pm 0.14 \times \text{CC lipid}^{0.893 \pm 0.016} \ (n = 211;\ r^2 = 0.998;\ \text{RSD} = 1.37), \ [7]$$

$$\text{CC weight} = 4.58 \pm 0.42 \times \text{CC protein}^{0.831 \pm 0.041} + 1.90 \pm 0.19 \times \text{CC lipid}^{0.892 \pm 0.022} \ (n = 99;\ r^2 = 0.998;\ \text{RSD} = 1.59), \quad [8]$$

Several multiple regression equations were constructed to relate the chemical component mass in the CC (kg) of the growing pigs with EBW and back fat thickness measurements, made at the first rib, last rib, or last lumbar vertebra, or carcass length. Best fit equations obtained for the regression equations are shown in Table 4.

The relative growth coefficients of CC main primal cuts of pigs growing from 10 to 150 kg BW are presented in Table 5. As fat tissues grew at a greater rate than CC did, their relative growth coefficients were >1. The total weight of hams and shoulders increased with slaughter and CC weight, but their yield percentages remained nearly constant at slaughter weights ≥100 kg (Table 2). The proportion of dissectible fat in shoulder and ham increased dramatically at all stages of growth, causing an important reduction in lean-tissue relative content at BW >50 kg (Table 6). Also, bone and skin relative proportions declined.

DISCUSSION

The Iberian pig production is mainly focused on the production of dry-cured meat products, particularly loins, hams, and shoulders, whose high quality is linked, among other factors, to a great intramuscular fat content (García et al., 1996). An enhanced deposition of fat in muscular tissues requires slaughter at heavy weights, even when this practice implies increased fat accumulation in the carcass during the finishing period of growth.

The growth of body components and total whole-body chemical composition of the IB pig do not adjust to growth models published for lean and conventional genotypes (Tess et al., 1986; Wagner et al., 1999; Fisher et al., 2003; Wiseman et al., 2007), implying substantial differences in nutrient requirements. Differences among genotypes in developmental changes in body composition must be accounted for by an efficient conversion of feed resources, optimizing the expression of genetic potential, and for a better understanding of genotypic divergence in nutritional requirements (Tess et al., 1986; Gu et al., 1992). Previously (Nieto et al., 2012), we analyzed earlier work on the response of the IB pig to changes in energy and protein supply (Nieto et al., 2002; Barea et al., 2007; García-Valverde et al., 2008; Aguinaga et al., 2011; Conde-Aguilera et al., 2011a). The main objective of these studies was to derive the optimum protein (Lys) to energy ratio in the diet to allow for the expression of maximum protein deposition rates. From the analysis, we derived specific relationships for this slow-growing, obese breed to estimate the

Table 2. Mean weights and yield of primal cuts in half of the cold carcass of Iberian pigs slaughtered at different BW[1]

	10 to 25 kg BW		15 to 50 kg BW		50 to 100 kg BW		100 to 150 kg BW	
Item	Weight, kg	Yield,[2] %	Weight, kg	Yield, %	Weight, kg	Yield, %	Weight, kg	Yield, %
All dietary treatments (n = 211)								
n	48		71		81		11	
Total BW	25.2 ± 0.1	—	49.9 ± 0.3	—	99.5 ± 0.2	—	149.5 ± 1.3	—
Empty BW[3]	23.4 ± 0.1	92.9	48.3 ± 0.3	96.8	97.0 ± 0.2	97.5	144.4 ± 1.0	96.6
Warm carcass[4]	18.7 ± 0.1	79.9	40.6 ± 0.3	84.0	84.8 ± 0.3	87.4	126.7 ± 1.1	87.7
Cold carcass[5]	15.5 ± 0.1	66.2	35.8 ± 0.2	74.1	75.9 ± 0.2	78.3	114.2 ± 1.0	79.1
Sirloin	0.057 ± 0.002	0.750	0.111 ± 0.002	0.628	0.174 ± 0.003	0.470	0.266 ± 0.009	0.480
Butt lean	0.325 ± 0.010	4.29	0.859 ± 0.017	4.84	1.447 ± 0.018	3.90	1.746 ± 0.068	3.14
Loin	0.351 ± 0.010	4.63	0.821 ± 0.012	4.62	1.224 ± 0.022	3.30	1.550 ± 0.072	2.79
Ribs	0.556 ± 0.007	7.37	0.934 ± 0.013	5.28	1.652 ± 0.020	4.46	2.384 ± 0.090	4.29
Spine	0.497 ± 0.016	6.56	0.886 ± 0.023	5.00	1.287 ± 0.029	3.47	1.72 ± 0.14	3.09
Back fat	0.272 ± 0.006	3.60	1.019 ± 0.024	5.72	3.47 ± 0.06	9.34	5.43 ± 0.21	9.76
Shoulder	1.90 ± 0.02	25.1	4.51 ± 0.04	25.5	8.18 ± 0.07	22.0	13.1 ± 0.3	23.6
Trimmed shoulder	1.47 ± 0.01	19.5	3.02 ± 0.02	17.0	5.06 ± 0.05	13.6	8.49 ± 0.19	15.3
Ham	2.52 ± 0.02	33.3	5.31 ± 0.05	29.9	10.11 ± 0.05	27.3	14.9 ± 0.2	26.7
Trimmed ham	2.17 ± 0.02	28.7	4.21 ± 0.04	23.7	7.23 ± 0.05	19.5	11.5 ± 0.2	20.7
Kidney fat	0.089 ± 0.004	1.18	0.564 ± 0.015	3.16	1.87 ± 0.04	5.03	2.98 ± 0.10	5.37
Belly	0.937 ± 0.012	12.4	2.90 ± 0.03	16.3	7.19 ± 0.07	19.4	11.1 ± 0.2	19.9
Carcass length, cm	50.6 ± 0.3	—	58.7 ± 0.2	—	74.8 ± 0.2	—	78.6 ± 0.9	—
Midline back fat thickness, cm								
First rib	2.20 ± 0.10	—	3.87 ± 0.08	—	6.53 ± 0.09	—	8.8 ± 0.4	—
Last rib	1.33 ± 0.06	—	2.43 ± 0.05	—	5.12 ± 0.08	—	6.8 ± 0.4	—
Last lumbar	1.28 ± 0.05	—	2.18 ± 0.05	—	5.45 ± 0.10	—	5.8 ± 0.3	—
Adequate protein-to-energy diets (n = 99)								
n	24		24		40		11	
Total BW	25.2 ± 0.1	—	50.8 ± 0.5	—	99.5 ± 0.4	—	149.5 ± 1.3	—
Empty BW	23.4 ± 0.1	92.6	49.3 ± 0.5	97.0	96.9 ± 0.3	97.4	144.5 ± 1.0	96.7
Warm carcass	18.6 ± 0.1	79.5	41.6 ± 0.5	84.4	84.7 ± 0.4	87.4	126.7 ± 1.1	87.7
Cold carcass	15.4 ± 0.1	65.8	36.5 ± 0.4	74.0	75.8 ± 0.3	78.2	114.2 ± 1.0	79.0
Sirloin	0.061 ± 0.002	0.814	0.114 ± 0.004	0.632	0.176 ± 0.004	0.480	0.266 ± 0.009	0.480
Butt lean	0.317 ± 0.013	4.22	0.874 ± 0.025	4.88	1.436 ± 0.026	3.87	1.746 ± 0.068	3.14
Loin	0.356 ± 0.012	4.76	0.842 ± 0.019	4.68	1.211 ± 0.038	3.27	1.550 ± 0.072	2.79
Ribs	0.557 ± 0.009	7.42	0.897 ± 0.020	5.01	1.686 ± 0.027	4.54	2.384 ± 0.090	4.29
Spine	0.501 ± 0.026	6.66	0.918 ± 0.042	5.11	1.325 ± 0.040	3.57	1.72 ± 0.14	3.09
Back fat	0.257 ± 0.009	3.43	1.051 ± 0.040	5.84	3.43 ± 0.09	9.24	5.43 ± 0.21	9.76
Shoulder	1.86 ± 0.02	24.9	4.53 ± 0.06	25.3	8.21 ± 0.08	22.1	13.1 ± 0.3	23.6
Trimmed shoulder	1.48 ± 0.01	19.7	3.09 ± 0.04	17.2	5.11 ± 0.07	13.8	8.49 ± 0.19	15.3
Ham	2.53 ± 0.02	33.8	5.39 ± 0.09	29.9	10.16 ± 0.07	27.4	14.9 ± 0.2	26.7
Trimmed ham	2.20 ± 0.02	29.3	4.26 ± 0.09	23.7	7.27 ± 0.07	19.6	11.5 ± 0.2	20.7
Kidney fat	0.077 ± 0.005	1.03	0.556 ± 0.024	3.08	1.876 ± 0.048	5.04	2.98 ± 0.10	5.37
Belly	0.928 ± 0.016	12.4	2.93 ± 0.05	16.3	7.15 ± 0.08	19.3	11.1 ± 0.2	19.9
Carcass length, cm	50.3 ± 0.4	—	58.5 ± 0.3	—	74.9 ± 0.3	—	78.6 ± 0.9	—
Midline back fat thickness, cm								
First rib	2.08 ± 0.15	—	4.06 ± 0.14	—	6.49 ± 0.13	—	8.8 ± 0.4	—
Last rib	1.30 ± 0.10	—	2.46 ± 0.07	—	5.14 ± 0.11	—	6.8 ± 0.4	—
Last lumbar	1.29 ± 0.08	—	2.14 ± 0.09	—	5.60 ± 0.16	—	5.8 ± 0.3	—

[1]Taken from the experiments by Conde-Aguilera et al. (2011b), Nieto et al. (2003), Barea et al. (2006), and García-Valverde et al. (2008) in pigs growing from 10 to 25, 15 to 50, 50 to 100, and 100 to 150 kg BW, respectively.

[2]Primal cut yield calculated as percentage of the dissected cold half carcass weight.

[3]Calculated as the sum of warm carcass, total viscera and organs, and blood.

[4]Including head, feet, and tail.

[5]Without head, feet, and tail.

Table 3. Allometric relationships ($Y = aX^b$) between the weight of a chemical component in cold carcass (Y, kg) and empty BW (X, kg) or cold carcass weight (X, kg)

Item	Mean	a	SE of a	b	SE of b	r^2	RSD[1]	Equation No.
X = empty BW, kg								
All dietary treatments (n = 211; P < 0.001)								
Cold carcass[2,3]	50.7 ± 2.0	0.4776	0.0101	1.1085	0.0032	0.998	0.0271	[3.1]
Protein	5.700 ± 0.175	0.1931	0.0126	0.8116	0.0099	0.970	0.0847	[3.2]
Fat	24.08 ± 1.23	0.0191	0.0042	1.6725	0.0149	0.984	0.1273	[3.3]
Water	19.13 ± 0.52	0.8984	0.0416	0.7357	0.0071	0.981	0.0609	[3.4]
Ash	1.407 ± 0.050	0.0293	0.0045	0.9226	0.0179	0.927	0.1523	[3.5]
Energy, MJ	1,093 ± 53	1.7436	0.1995	1.5138	0.0102	0.991	0.0872	[3.6]
Adequate protein-to-energy diets (n = 99; P < 0.001)								
Cold carcass[2,3]	55.4 ± 3.1	0.4762	0.0150	1.1078	0.0040	0.999	0.0256	[3.7]
Protein	6.177 ± 0.280	0.2085	0.0184	0.7967	0.0125	0.976	0.0795	[3.8]
Fat	27.03 ± 1.98	0.0147	0.0068	1.7243	0.0215	0.985	0.1367	[3.9]
Water	20.38 ± 0.83	0.9480	0.0610	0.7238	0.0091	0.984	0.0579	[3.10]
Ash	1.481 ± 0.075	0.0332	0.0069	0.8876	0.0235	0.934	0.1492	[3.11]
Energy, MJ	1,222 ± 85	1.5025	0.1612	1.5423	0.0147	0.991	0.0936	[3.12]
X = cold carcass weight, kg								
All dietary treatments (n = 211; P < 0.001)								
Protein	5.700 ± 0.175	0.3315	0.0184	0.7324	0.0086	0.972	0.0815	[3.13]
Fat	24.08 ± 1.23	0.0576	0.0063	1.5112	0.0114	0.988	0.1075	[3.14]
Water	19.13 ± 0.52	1.4667	0.0563	0.6638	0.0061	0.983	0.0575	[3.15]
Ash	1.407 ± 0.050	0.0545	0.0065	0.8307	0.0163	0.925	0.1544	[3.16]
Energy, MJ	1,093 ± 53	4.7589	0.1771	1.3671	0.0072	0.994	0.0676	[3.17]
Adequate protein-to-energy diets (n = 99; P < 0.001)								
Protein	6.177 ± 0.280	0.3558	0.0275	0.7190	0.0111	0.976	0.0785	[3.18]
Fat	27.03 ± 1.98	0.0460	0.0098	1.5592	0.0162	0.989	0.1143	[3.19]
Water	20.38 ± 0.83	1.5409	0.0856	0.6531	0.0081	0.985	0.0569	[3.20]
Ash	1.481 ± 0.075	0.0603	0.0095	0.8008	0.0212	0.934	0.1490	[3.21]
Energy, MJ	1,222 ± 85	4.1949	0.1399	1.3939	0.0103	0.995	0.0726	[3.22]

[1]RSD = residual SD.

[2]Without head, feet, and tail.

[3]Growth coefficient and constant relative to empty body weight.

relative growth of body components, define changes in nutrient and energy requirements, and allow accurate estimations of whole-body protein and lipid deposition in response to nutrient and energy supply. In the present paper, an analysis was made to determine the effect of feed intake and protein supply on carcass composition and carcass traits of IB pigs growing from 10 to 150 kg BW. The aim was to gather complementary information that would allow accurate estimations of chemical components and tissue growth and prediction of dissected tissue composition in the carcass of the IB pig, which is of great interest for commercial evaluation and for specific recommendations of practical diet formulation.

As shown by Eq. [1] to [4], carcass chemical composition was sensitive to changes in dietary supply of protein and energy, with the level of feeding being the most important determinant of protein and fat content, which is in agreement with de Lange et al. (2003). In our study, from the examination of compositional changes, it is evident that a substantial decrease in the relative proportion of protein and water in CC occurs on increas-

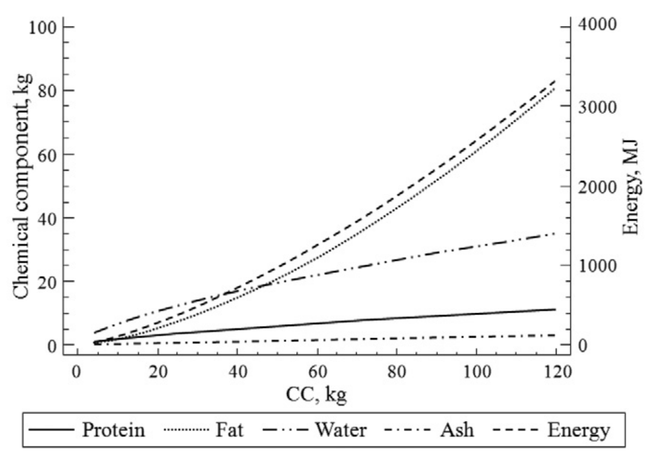

Figure 1. Allometric relationships between cold carcass weight (CC; without head, feet, and tail) and total mass of cold carcass chemical components or total energy in Iberian pigs growing from 10 to 150 kg, fed diets with adequate protein-to-energy ratio at several feeding levels (n = 99).

Table 4. Multiple regression equations relating the chemical component mass in cold carcass (kg) to empty BW (EBW, kg) and back fat thickness (mm) or carcass length (cm) of Iberian pigs slaughtered at different BW[1,2]

Item	Equation	r^2	RSD[3]
All dietary treatments (n = 211)			
Protein	$1.01 \pm 0.08 + 0.083 \pm 0.002 \times \text{EBW} - 0.240 \pm 0.043 \times P_3$	0.958	0.517
Protein	$0.99 \pm 0.08 + 0.078 \pm 0.003 \times \text{EBW} + 0.147 \pm 0.065 \times P_2 - 0.286 \pm 0.047 \times P_3$	0.959	0.512
Protein	$0.074 \pm 0.003 \times \text{EBW} + 0.145 \pm 0.065 \times P_2 - 0.317 \pm 0.047 \times P_3 + 0.022 \pm 0.002 \times \text{Le}$	0.993	0.512
Fat	$-9.95 \pm 0.30 + 0.466 \pm 0.012 \times \text{EBW} + 0.91 \pm 0.23 \times P_2$	0.988	2.01
Fat	$0.572 \pm 0.006 \times \text{EBW} - 0.217 \pm 0.007 \times \text{Le}$	0.995	2.02
Fat	$24.5 \pm 7.0 + 0.548 \pm 0.013 \times \text{EBW} - 1.04 \pm 0.22 \times \text{Le} + 0.007 \pm 0.002 \times \text{Le}^2$	0.988	1.95
Fat	$0.511 \pm 0.013 \times \text{EBW} + 1.27 \pm 0.25 \times M - 0.230 \pm 0.008 \times \text{Le}$	0.996	1.91
Water	$5.04 \pm 0.21 + 0.232 \pm 0.009 \times \text{EBW} - 0.37 \pm 0.16 \times P_2$	0.965	1.42
Water	$0.198 \pm 0.007 \times \text{EBW} - 0.34 \pm 0.11 \times P_3 + 0.112 \pm 0.044 \times \text{Le}$	0.996	1.35
Water	$-23.0 \pm 4.7 + 0.186 \pm 0.009 \times \text{EBW} + 0.85 \pm 0.15 \times \text{Le} - 0.006 \pm 0.001 \times \text{Le}^2$	0.970	1.32
Ash	$0.017 \pm 0.002 \times \text{EBW} + 0.069 \pm 0.034 \times M$	0.970	0.275
Ash	$-1.39 \pm 0.25 + 0.010 \pm 0.002 \times \text{EBW} + 0.034 \pm 0.006 \times \text{Le}$	0.883	0.251
GE, MJ	$-371 \pm 11 + 20.2 \pm 0.4 \times \text{EBW} + 35.6 \pm 8.5 \times P_2$	0.991	73.6
GE, MJ	$-378 \pm 12 + 20.5 \pm 0.5 \times \text{EBW} + 28.5 \pm 9.7 \times M$	0.991	75.2
Adequate protein-to-energy diets (n = 99)			
Protein	$1.08 \pm 0.12 + 0.082 \pm 0.003 \times \text{EBW} - 0.228 \pm 0.054 \times P_3$	0.963	0.549
Protein	$1.18 \pm 0.13 + 0.087 \pm 0.005 \times \text{EBW} - 0.308 \pm 0.092 \times M$	0.961	0.565
Protein	$2.65 \pm 0.76 + 0.081 \pm 0.005 \times \text{EBW} - 0.036 \pm 0.016 \times \text{Le}$	0.959	0.581
Fat	$-6.15 \pm 0.92 + 0.486 \pm 0.017 \times \text{EBW} - 2.07 \pm 0.58 \times M + 0.307 \pm 0.058 \times M^2$	0.991	1.99
Fat	$0.525 \pm 0.016 \times \text{EBW} + 1.03 \pm 0.31 \times P_2 - 0.226 \pm 0.010 \times \text{Le}$	0.996	2.10
Fat	$24.9 \pm 10.3 + 0.510 \pm 0.020 \times \text{EBW} + 0.96 \pm 0.31 \times P_2 - 1.05 \pm 0.33 \times \text{Le} + 0.007 \pm 0.003 \times \text{Le}^2$	0.990	2.05
Fat	$26.8 \pm 10.5 + 0.538 \pm 0.017 \times \text{EBW} + 0.61 \pm 0.24 \times P_3 - 1.09 \pm 0.33 \times \text{Le} + 0.007 \pm 0.003 \times \text{Le}^2$	0.990	2.07
Fat	$29.7 \pm 10.5 + 0.507 \pm 0.021 \times \text{EBW} + 1.14 \pm 0.37 \times M - 1.20 \pm 0.33 \times \text{Le} + 0.008 \pm 0.003 \times \text{Le}^2$	0.990	2.05
Water	$3.64 \pm 0.53 + 0.216 \pm 0.011 \times \text{EBW} + 0.95 \pm 0.39 \times P_2 - 0.134 \pm 0.038 \times {P_2}^2$	0.971	1.43
Water	$2.41 \pm 0.62 + 0.223 \pm 0.012 \times \text{EBW} + 1.51 \pm 0.39 \times M - 0.205 \pm 0.039 \times M^2$	0.975	1.34
Water	$-22.0 \pm 7.0 + 0.189 \pm 0.012 \times \text{EBW} + 0.83 \pm 0.22 \times \text{Le} - 0.006 \pm 0.002 \times \text{Le}^2$	0.973	1.39
Ash	$0.017 \pm 0.001 \times \text{EBW} + 0.061 \pm 0.027 \times P_3$	0.974	0.275
Ash	$0.015 \pm 0.002 \times \text{EBW} + 0.151 \pm 0.044 \times M - 0.011 \pm 0.004 \times M^2$	0.976	0.264
Ash	$-1.13 \pm 0.33 + 0.011 \pm 0.002 \times \text{EBW} + 0.028 \pm 0.007 \times \text{Le}$	0.892	0.253
GE, MJ	$-384 \pm 18 + 20.86 \pm 0.62 \times \text{EBW} + 26 \pm 12 \times P_2$	0.991	82.6
GE, MJ	$-286 \pm 29 + 21.25 \pm 0.58 \times \text{EBW} - 48 \pm 21 \times P_2 + 8.48 \pm 2.05 \times {P_2}^2$	0.992	76.6
GE, MJ	$-283 \pm 33 + 22.80 \pm 0.49 \times \text{EBW} - 87 \pm 27 \times P_3 + 9.77 \pm 2.85 \times {P_3}^2$	0.992	80.2
GE, MJ	$-224 \pm 35 + 21.41 \pm 0.64 \times \text{EBW} - 85 \pm 22 \times M + 11.65 \pm 2.19 \times M^2$	0.993	74.5

[1]Midline back fat measurements made at the first rib (P_1), the last rib (P_2), and the last lumbar vertebrae (P_3); M, means of P_1, P_2, and P_3 values.

[2]Carcass length (Le) measured from the proximal end of the first rib to the pubic symphysis.

[3]RSD = residual SD.

ing BW or CC weight, paralleling an enhanced fat deposition. The allometric growth coefficients for protein, ash, and water were lower than unity, whereas that of fat (and, consequently, energy) was >1, reflecting the dramatic increase in fat content that takes place with increased weight or age. Concomitantly, a decrease in the proportion of weight of primal cuts as the animal grows can be observed, even if they increase their mass as a result of the diluting effect caused by the marked deposition of fat tissues. This enhanced fat deposition is easily detected by the great increase in back fat thickness.

This pattern of developmental growth is commonly observed for other pig breeds (Carr et al., 1978; Tess et al., 1986; Gu et al., 1992; Wagner et al., 1999; de Lange et al., 2003; Wiseman et al., 2007). The most relevant differences with respect to lean and conventional pig breeds are focused on the comparatively smaller relative size of lean tissues in the IB pigs, their rates of growth, and the increased total body fat with marked changes in its distribution among depots. To predict tissue composition, pigs of different genetic background serially slaughtered at regular intervals between 15 and 110 kg BW and determined for chemical components were analyzed by Quiniou and Noblet (1995). The lipid content of EBW differed widely among genetic groups, whereas the protein content was more constant. Consequently, the water content was lower in the obese pigs than in the conventional or lean pigs. In line with our observations on the specificity of the response of the IB pig to ingested nutrients, common relationships were observed for the lean and conventional pigs, which

Table 5. Allometric relationships ($Y = aX^b$) between the weight of primal cuts in the cold carcass (Y, kg) of Iberian pigs and cold carcass weight (X, kg)[1]

Item	Mean	a	SE of a	b	SE of b	r^2	RSD[2]	Equation No.
All dietary treatments ($n = 211$; $P < 0.001$)								
Sirloin	0.131 ± 0.004	0.068	0.017	0.764	0.017	0.904	0.183	[5.1]
Butt lean	1.010 ± 0.034	0.109	0.029	0.909	0.017	0.934	0.175	[5.2]
Loin	0.907 ± 0.027	0.223	0.066	0.835	0.017	0.923	0.176	[5.3]
Ribs	1.199 ± 0.037	1.107[3]	0.214	0.712	0.011	0.949	0.120	[5.4]
Spine	0.995 ± 0.029	2.011	0.635	0.638	0.020	0.828	0.212	[5.5]
Back fat	2.02 ± 0.11	0.00015	0.00006	1.567	0.015	0.981	0.158	[5.6]
Shoulder	5.77 ± 0.21	0.547	0.072	0.920	0.007	0.987	0.077	[5.7]
Ham	7.02 ± 0.25	0.923	0.062	0.891	0.004	0.996	0.041	[5.8]
Kidney fat	1.083 ± 0.061	0.0000031	0.0000008	1.863	0.023	0.968	0.247	[5.9]
Belly	4.53 ± 0.21	0.0094	0.0016	1.268	0.008	0.992	0.082	[5.10]
Adequate protein-to-energy diets ($n = 99$; $P < 0.001$)								
Sirloin	0.143 ± 0.006	0.057	0.020	0.781	0.019	0.943	0.163	[5.11]
Butt lean	1.061 ± 0.051	0.093	0.037	0.921	0.021	0.946	0.184	[5.12]
Loin	0.952 ± 0.042	0.189	0.092	0.849	0.022	0.934	0.189	[5.13]
Ribs	1.29 ± 0.62	0.88[3]	0.24	0.733	0.014	0.964	0.119	[5.14]
Spine	1.068 ± 0.046	1.719	0.844	0.654	0.026	0.855	0.222	[5.15]
Back fat	2.28 ± 0.18	1.690	0.00008	1.553	0.018	0.986	0.158	[5.16]
Shoulder	6.29 ± 0.34	0.481	0.082	0.932	0.008	0.992	0.071	[5.17]
Ham	7.63 ± 0.39	0.877	0.088	0.896	0.005	0.996	0.045	[5.18]
Kidney fat	1.229 ± 0.098	0.0000023	0.0000007	1.883	0.029	0.975	0.252	[5.19]
Belly	5.01 ± 0.33	0.0102	0.0026	1.259	0.009	0.994	0.080	[5.20]

[1]Mean weight of primal cut in cold half carcass

[2]RSD = residual SD.

[3]$P > 0.05$.

were not applicable to the obese (Meishan) pigs. From Eq. [7] and [8], it can be assumed that the deposition of 1 kg of protein and fat in the carcass is associated with 4.6 and 1.9 kg of carcass gain, respectively. For EBW gain, these coefficients were 5.4 and 1.7 (Nieto et al., 2012).

A substantial divergence is observed in respect to the coefficients in similar growth models constructed for lean or conventional pigs. For instance, Quiniou and Noblet (1995), in nonobese pigs, obtained coefficients of 5.1 and 0.6 for body protein and body fat deposition, respectively. These coefficients were, respectively, 4.4 and 1.0 in Meishan pigs. On the basis of data published by Siebrits (1984) on obese pigs, Quiniou and Noblet (1995) reported that EBW gain in these animals was associated with coefficients of 3.5 and 1.3 for body protein accretion and fat deposition, respectively.

Empty body weight and back fat thickness have been used by several authors to predict the chemical composition of BW or body components (Shields et al., 1983; Rook et al., 1987; Dourmad et al., 1997). Shields et al. (1983) reported that from the range of carcass measurements examined (percentage lean cuts, dressing percentage, back fat thickness, carcass length, or LM area), equations based on back fat thickness had greatest r^2 and lowest RSD values for predicting the percentage of chemical components in the chilled carcass. In the present study, the multiple-regression equations constructed on the basis of EBW and back fat thickness or carcass length had similar accuracy when used as predictors of the chemical component mass in the carcass of the IB pigs. However, when used as a single independent variable, carcass length was a poorer predictor for both protein and fat carcass content than EBW and showed similar accuracy to back fat thickness to predict carcass protein content (data not shown).

Comprehensive data describing compositional changes during development of IB pigs are still very limited. Mayoral et al. (1999) studied the age-related changes in carcass traits of free-range IB pigs. Under the traditional management system, the pigs remained outdoors for the entire productive cycle. As a consequence, their growth rate was strongly determined by the seasonal availability of food. The pattern of nutrient supply, involving periods of great shortage or imbalance, makes these results not directly comparable to the present work. The pigs attained their slaughter weight (mean value, 152.75 kg) at 482 d of age. Growth rates of primal cuts, ham, and shoulder were far lower than those observed in the present study. These differences are not surprising as it is recognized that feeding regimen is an important factor that may influence developmental growth, resulting in substantial variations in relative growth coefficients (Davies et al., 1980; Gu et al., 1992). In the present study, we have focused on differ-

Table 6. Mean weights and yield of tissue components in shoulders and hams of Iberian pigs slaughtered at different BW[1]

	10 to 25 kg BW		15 to 50 kg BW		50 to 100 kg BW		100 to 150 kg BW	
Item	Weight, kg	Yield, %	Weight, kg	Yield, %	Weight, kg	Yield, %	Weight, kg	Yield, %
All dietary treatments (*n* = 211)								
n	48		71		81		11	
Shoulder	1.90 ± 0.02		4.51 ± 0.04		8.18 ± 0.07		13.1 ± 0.3	
Trimmed shoulder	1.47 ± 0.01	77.4	3.02 ± 0.02	67.0	5.06 ± 0.05	61.9	8.49 ± 0.19	64.8
Skin	0.102 ± 0.001	6.94	0.250 ± 0.005	8.28	0.292 ± 0.005	5.77	0.399 ± 0.016	4.70
Subcutaneous fat	0.262 ± 0.007	17.8	0.642 ± 0.020	21.3	1.91 ± 0.03	37.7	3.42 ± 0.11	40.3
Intermuscular fat	0.081 ± 0.002	5.44	—	—	—	—	0.698 ± 0.062	8.22
Muscle[2]	0.711 ± 0.011	48.4	1.62 ± 0.02	53.6	2.10 ± 0.03	41.5	3.03 ± 0.09	35.7
Bone	0.242 ± 0.002	16.5	0.463 ± 0.004	15.3	0.722 ± 0.006	14.3	0.826 ± 0.020	9.73
Ham	2.52 ± 0.02		5.31 ± 0.05		10.11 ± 0.05		14.9 ± 0.2	
Trimmed ham	2.17 ± 0.02	86.1	4.21 ± 0.04	79.3	7.23 ± 0.05	71.5	11.5 ± 0.2	77.2
Skin	0.119 ± 0.002	5.48	0.283 ± 0.005	6.72	0.324 ± 0.005	4.48	0.453 ± 0.015	3.94
Subcutaneous fat	0.291 ± 0.008	13.4	0.778 ± 0.024	18.5	2.16 ± 0.03	29.9	4.41 ± 0.15	38.3
Intermuscular fat	0.113 ± 0.002	5.21	0.110 ± 0.006	2.61	0.436 ± 0.009	6.03	0.830 ± 0.027	7.22
Muscle[2]	1.173 ± 0.025	54.1	2.40 ± 0.03	57.0	3.34 ± 0.05	46.2	4.55 ± 0.10	39.6
Bone	0.332 ± 0.003	15.3	0.625 ± 0.005	14.8	0.940 ± 0.008	13.0	1.08 ± 0.02	9.39
Adequate protein-to-energy diets (*n* = 99)								
n	24		24		40		11	
Shoulder	1.86 ± 0.02		4.53 ± 0.06		8.21 ± 0.08		13.1 ± 0.3	
Trimmed shoulder	1.48 ± 0.01	79.6	3.09 ± 0.04	68.2	5.11 ± 0.07	62.2	8.49 ± 0.19	64.8
Skin	0.105 ± 0.002	7.09	0.243 ± 0.008	7.86	0.296 ± 0.007	5.79	0.399 ± 0.016	4.70
Subcutaneous fat	0.234 ± 0.007	15.8	0.674 ± 0.037	21.8	1.92 ± 0.04	37.6	3.42 ± 0.11	40.3
Intermuscular fat	0.077 ± 0.003	5.20	—	—	—	—	0.698 ± 0.062	8.22
Muscle[2]	0.741 ± 0.006	50.1	1.63 ± 0.03	52.8	2.12 ± 0.05	41.5	3.03 ± 0.09	35.7
Bone	0.244 ± 0.003	16.5	0.464 ± 0.006	15.0	0.731 ± 0.009	14.3	0.826 ± 0.020	9.73
Ham	2.53 ± 0.02		5.39 ± 0.09		10.16 ± 0.07		14.9 ± 0.2	
Trimmed ham	2.20 ± 0.02	87.0	4.26 ± 0.09	79.0	7.27 ± 0.07	71.6	11.5 ± 0.2	77.2
Skin	0.126 ± 0.003	5.73	0.278 ± 0.008	6.53	0.328 ± 0.006	4.51	0.453 ± 0.015	3.94
Subcutaneous fat	0.272 ± 0.009	12.4	0.815 ± 0.039	19.1	2.15 ± 0.04	29.6	4.41 ± 0.15	38.3
Intermuscular fat	0.103 ± 0.002	4.68	0.129 ± 0.011	3.03	0.434 ± 0.012	5.97	0.830 ± 0.027	7.22
Muscle[2]	1.236 ± 0.016	56.2	2.45 ± 0.05	57.5	3.38 ± 0.06	46.5	4.55 ± 0.10	39.6
Bone	0.333 ± 0.004	15.1	0.624 ± 0.008	14.6	0.955 ± 0.012	13.1	1.08 ± 0.02	9.39

[1]Taken from the experiments by Conde-Aguilera et al. (2011b), Nieto et al. (2003), Barea et al. (2006), and García-Valverde et al. (2008).

[2]Including blood vessels, ligaments, tendons, and connective tissue.

ences in relative growth coefficients because of adequacy in dietary protein-to-energy ratio. Pigs fed with optimal or suboptimal protein-to-energy diets showed slightly greater growth coefficients for fat and energy but similar growth coefficients for lean CC components. Tuitoek et al. (1997) determined the effect of feeding diets that varied in protein content on body composition of growing-finishing Yorkshire gilts between 20 and 100 kg BW. Fat content in the carcass was greatest in gilts on the lowest dietary protein treatment. However, none of the carcass cuts was affected by the dietary protein level, which is in line with our own observations. In the present study, although the total weight of hams and shoulders increased with slaughter and CC weight, their yield percentages remained nearly constant at slaughter weights >100 kg. Their growth coefficients <1 relative to CC weight indicate that they are early growth traits, as shown by others (Gu et al., 1992; Fisher et al., 2003).

In conclusion, specific relationships have been constructed that accurately predict the growth of the carcass and the relative growth of chemical components and tissues in the carcass of the IB pig. These relationships are not applicable to pigs of a different genetic background, as they do not adjust to growth models published for lean and conventional genotypes, implying substantial differences in nutrient requirements.

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