Computed tomography evaluation of gilt growth performance and carcass quality under feeding restrictions and compensatory growth effects on the sensory quality of pork

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Abstract

Restricted feed can affect the body composition of pigs. Body composition can be studied non-destructively in live pigs using computed tomography (CT). The objective was to investigate the effect of different feeding restriction strategies on the productive and carcass quality parameters of gilts during growth via CT images and the effects of such strategies on meat quality, sensory properties and consumer preferences. Moreover, we sought to determine whether CT is a suitable tool for this purpose in this type of study. Thus, 36 Pietrain x (Large White x Landrace) gilts were assigned to the following three feeding strategies: 1) *ad libitum* feeding (AL) during all fattening periods (AL-AL); 2) AL feeding between 30 and 70 kg target body weight (TBW) followed by restriction (84% of AL) until 120 kg TBW (AL-RV); and 3) restriction feeding (78% of AL) between 30 and 70 kg TBW followed by AL until 120 kg TBW (RV-AL). When the pigs reached 30, 70, 100 and 120 kg, they were CT scanned to obtain the carcass composition parameters. At 120 kg TBW, the pigs were slaughtered, and the carcass and meat quality was determined. The loins were collected for trained panel evaluation and consumer tests. The panellists evaluated the odour, flavour and texture attributes of cooked loins. A total of 120 consumers scored the overall acceptability, tenderness, odour and flavour. The results showed a decrease of 76% and 80% in the average daily gain and average daily feed intake during the restriction period compared with the *ad libitum* in the growth phase, respectively, and a decrease of 89% and 87% in these parameters during the fattening phase, respectively. A restriction reduces the body fat content during the period of the restriction. Differences in the carcass and cut composition and meat quality were not observed at the end of the experiment among the treatments. Regarding sensory quality, meat from the animals in the AL-AL treatment was tougher than that from animals in the RV-AL and AL-RV treatments. Nevertheless, these differences were not detected by consumers, who did not provide significantly different scores for acceptability. Thus, when preparing feeding strategies, these results should be considered to optimize costs and increase benefits. Furthermore, computed tomography represents a non-destructive technology suitable for determining carcass composition before slaughter.

Keywords: feeding restriction, performance, pig, consumer, trained panel

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Introduction

Feed restrictions have been investigated to optimize the cost of production by maximizing the gross margin while still achieving an adequate pork quality (Heyer and Lebret, 2007). The effect of feeding strategies on pig performance and carcass and meat quality depends on the feed intake, dietary composition and feeding strategies (Daza et al., 2003; Heyer and Lebret, 2007; Li and Patience, 2017). Feed restriction during growth periods decreases the average daily gain (ADG) and fat thickness and increases the carcass and cut lean meat content (Bee et al., 2007; Heyer and Lebret, 2007). The importance of these effects depends on the degree and type of restriction, whether animals are slaughtered at the same age or weight (Bee et al., 2007) and whether compensatory growth occurs due to a re-alimentation period of sufficient duration (Lebret et al., 2007).

Feeding strategies may also affect meat quality; however, this effect is not clear since contradictory results have been obtained for tenderness (Bee et al., 2007; Heyer and Lebret, 2007; Kristensen et al., 2004). Other meat quality parameters have been investigated, such as juiciness, cooking loss and colour, and significant differences were not observed for different feeding restriction strategies or diet compositions (Kristensen et al., 2002; Lebret et al., 2001). However, other studies have reported that pigs under restriction feeding produce meat that is less juicy (Ellis et al., 1996) and has higher cooking losses (Bee et al., 2007).

Computed tomography (CT) technology is a non-destructive technology based on X-rays that can be used to scan live pigs at different moments of their life cycle, allowing for the quantification and mathematical description of the growth of pigs and their body components (Carabús et al., 2015; Lambe et al., 2013). CT produces a series of images that allow for visualization of the inner part of the body in two dimensions, although each image has a thickness and represents a three-dimensional image. Images are shown in grey scale, and for each individual image, software can be used to determine the thickness, area and angle (Carabús et al., 2015; Carabús et al., 2017). Furthermore, by joining several images, volume can be determined, either of the whole image or certain tissues differentiated by the HU values (Lambe et al., 2013). An analysis of all the images can be used to study the volume associated with each HU value and obtain prediction equations to estimate the composition characteristics of several tissues or whole bodies (Font-i-Furnols et al., 2015; Zomeño et al., 2016). Thus, CT can be used to determine body tissue composition at one moment of growth or at several moments during growth while avoiding (serial) slaughter during the application of different feeding strategies or investigating the effects of the sex or genotype of pigs (Carabús et al., 2014; Font-i-Furnols et al., 2015; Lambe et al., 2013).

The effect of different feeding strategies, *i.e.*, combinations of *ad libitum* and restriction feeding periods on the body composition, have only been previously studied using serial slaughters or ultrasound measures. Therefore, the aim of the present study was to investigate the effects of different feeding strategies on the productive parameters and on the body composition and carcass quality parameters of gilts during growth via CT images. The effects of such strategies on meat quality, sensory properties and consumer preference were then determined. Moreover, we also evaluated whether CT was a suitable tool for this purpose in this type of study.

Materials and Methods

Animals and Diets

Thirty-six Pietrain x (Large White x Landrace) gilts were distributed into 4 groups and assigned to the following 3 feeding strategies: 1) *ad libitum* feeding (AL) during the entire growth (AL-AL) period; 2) AL feeding between 30 and 70 kg target body weight (TBW) followed by restriction (84% of AL) until 120 kg TBW (AL-RV); and 3) restriction feeding (78% of AL) between 30 and 70 kg

TBW followed by AL until 120 kg TBW (RV-AL). The composition and nutritional values of the diets are presented in Table 1.

Pigs were reared in individual pens and were weighed every two weeks. Feed restriction was calculated every two weeks based on the body weight and average daily feed intake (ADFI) of *ad libitum* pigs. Additionally, at the end of each period, the fat depth and muscle thickness were measured with a Piglog 105 ultrasound device (Frontmatec A/S, Smørum, DK) at the last rib and at 4–6 cm from the midline.

One pig that received the RV-AL treatment died at the beginning of the experiment, and another pig that received the same treatment died after the last TC scan at 120 kg.

CT Scanning and Image Analysis

Pigs were CT scanned when they reached 30, 70, 100 and 120 kg. When pigs reached each target weight, they were fasted for eight hours and then transported to the CT facility. Intramuscular sedation with azaperone (0.1 mg/kg body weight) and ketamine (0.2 mg/kg body weight) along with intravenous sedation with propofol (0.22 mg/kg body weight) for the 100 and 120 kg pigs were applied to anaesthetize them before scanning with a General Electric HiSpeed Zx/I CT scanner (GE Healthcare, Madrid, Spain). The acquisition conditions were as follows: 140 kW; 145 mA; 512×512 matrix; axial; 7 mm thickness (30 kg TBW) and 10 mm thickness (70,100 and 120 kg TBW); 350 to 460 mm field of view; and the STD+ reconstruction algorithm. After scanning, pigs were returned to the experimental farm to continue the study.

Computed tomography images were analysed using the software *VisualPork* (Bardera et al., 2012; Boada et al., 2009). Based on previous studies (Carabús et al., 2014, 2015), three images (tomograms) were selected for analysis at the following anatomical location: between the 11th and 12th ribs, between the 3rd and 4th lumbar vertebrae, and at the ham level in the joint between the femur and the pubis bones. In each image measurements of the loin area and perimeter in loin cuts, the total area and perimeter in the ham, and the subcutaneous fat area and perimeter were made (Figure 1). The distribution of the volume associated with each Hounsfield value was also determined and used to determine the lean meat content of the carcass and pieces as well as the weight of the pieces according to the equations developed by Font-i-Furnols et al. (2015). Additionally, the ash, moisture, protein and fat contents of the carcass were calculated according to the equations developed by Zomeño et al. (2016). The 'Generalitat de Catalunya' ethical committee approved the protocol (DAMM Order Number: 8277).

Slaughter, Quality Measurements and Sampling

After the last CT scan of the 120 kg TBW pigs, the animals were sent back to the farm for 13 ± 4 d. During this period, pigs were fed the same diet and amount as before the CT scan. Then, after approximately 20 h fasting, pigs were transported on 4 different days to an experimental abattoir located in IRTA (Monells) for slaughter after CO_2 stunning. The live weight and warm carcass weight were recorded, and the yield was calculated. The back fat thickness and muscle depth were measured at 6 cm from the midline at the intercostal space between the 3rd and 4th last ribs via a Fat-O-Meat'er (FOM) (Frontmatec A/S, Smørum, DK). These two measures were used to determine the carcass lean meat percentage (LMP) using the official Spanish equation for FOM (LMP=

64.53 −0.876*fat_thickness +0.181*muscle_depth; Commission Implementing Decision 2012/384/EU).

At 45 min after slaughter, the pH values of the *longissimus thoracis* (LT) muscle at the last rib level and the *semimembranosus* muscle of the ham were measured with a Crison tool with a Xerolyt electrode (Crison, Barcelona, Spain). The minimum fat thickness (plus skin) (F-ZP) was measured perpendicular to the skin surface of the carcass over the *gluteus medius* (GM) muscle, and the muscle depth was measured between the medular canal and the cranial end of the *gluteus medius* muscle (M-ZP). Additionally, the backfat thickness was measured in the midline at the level of the last rib.

Subsequently, the carcasses were placed in a chilling room at 2°C, and 24 h *post mortem*, the cold left half carcass was weighed and the ultimate pH was measured in the LT and SM muscles. The electrical conductivity was measured using a Pork Quality Meter (PQM-Kombi, Aichach, Germany) in the same muscles. Furthermore, the loin muscle (from the 3rd–4th last rib in the caudal direction) was sampled for further analysis. Samples were vacuum packed and stored at −20ºC until use, except for the samples evaluated for marbling, colour and drip losses because these analyses were performed immediately.

Marbling was determined by a trained technician using the National Pork Producers Council (NPPC, 1999) standards, which range from 1 (devoid of marbling) to 10 (abundantly marbled). At the same position, colour was determined after 15 min of blooming with a Minolta CR 400 colorimeter (Konica Minolta Business Solutions Spain S.A., Madrid, Spain), to obtain the luminosity (L*), redness (a*) and yellowness (b*) variables (CIE, 1976), and the Japanese Scale of Colour from 1 (pale) to 6 (dark colour) was determined (Nakai et al., 1975). From the same loin, two samples 2.7 cm in diameter were used to determine drip losses by means of the Rasmussen and Andersson (1996) method. Intramuscular fat was measured by a near infrared FoodScan system (Foss Analytical, Hillerød, Denmark) at wavelengths between 850 nm and 1050 nm.

The loin was cooked in an oven (FAGOR Innovation Class A; Fagor Electrodomésticos, S. Coop., Mondragón, Spain) at 200ºC until reaching an internal temperature of 71ºC. Cooking losses were determined by the weight difference. The same cut, after it had cooled, was used for texture analysis. The Warner-Bratzler test was performed using the Texturometer TA.XT2 (Stable Micro Systems Ltd., Godalming, United Kingdom).

Trained Panel Test

The trained panel test was performed in a sensory room at IRTA-Monells according to the ISO standard 8589:2007. The evaluation was carried out by eight trained panellists. Four training sessions were performed to establish the final attributes to be evaluated and to fix the measurement scale. The final attributes, which were obtained by consensus in these sessions, were odour (pork, pig and abnormal), flavour (pork, pig, abnormal, acid, sweet and metallic) and texture attributes (hardness, juiciness after first chewing, juiciness during chewing, tenderness, fibrosity and chewiness) (Table 2). The attributes were evaluated via a numerical intensity scale ranging from 0 (low/weak) to 10 (high/strong). A total of 10 sessions, with 3 samples per session (one of each dietary treatment), were carried out.

Sample preparation was the following: meat slices (1.5 cm thick) were cooked in a pre-heated oven (at 200ºC) until reaching an internal temperature of 72°C. After cooking, the slices were cut into 4 pieces each, wrapped in aluminium foil marked with a 3-digit code, and kept warm until they were distributed to the panellists monadically and following a designed order to avoid the first sample and carry-over effect.

Consumer Study

A total of 120 consumers were randomly selected in Barcelona in an attempt to simulate the Spanish national distribution for age and gender (Table 3). Ten sessions were carried out over 2 d, with 12 consumers per session. The sample preparation was the same as that used in the trained panel sensory evaluation. Each consumer evaluated three pieces of meat from each feeding treatment under blinded conditions. Samples were served monadically to the consumers and in a different order to avoid the first sample and carry-over effect. Consumers were asked to eat unsalted crackers toast and drink water between evaluating the different samples and also before evaluating the first one. For each sample, the consumers were asked to score the overall acceptability, tenderness, odour and flavour according to a 9-point scale (from 1 ‘dislike extremely’ to 9 ‘like extremely’). To obtain a more specific response from consumers, the intermediate point corresponding to 5 ‘neither like nor dislike’ was not included. In addition, demographic information and habits of consumption for each participant were also recorded.

Statistical Analysis

All statistical analyses were performed using SAS software (version 9.3, SAS Institute, Inc., Cary, NC, USA), and individual animals were considered the experimental unit. ANOVA was performed using the MIXED procedure. For productive parameters, the model included treatment as a fixed effect. Additionally, the body weight at the beginning of each feeding phase was included as a covariate. For the carcass quality variables, the same model was applied, but carcass weight was included as a covariate; for the meat quality variables, the slaughter day was included as a blocking effect. Regarding the CT variables, the model considered repeated measures and included the feeding strategy, target body weight and their interactions as fixed effects. In this analysis, a weighted least squared approach was applied to address the heteroscedasticity of variance due to the differences of weight, *i.e.,* at each TBW, the dependent variables were weighed by the inverse of the standard deviation of the residuals. The level of significance was established at a *P* value lower than 0.5.

For the trained sensory data, the model was applied to the previously standardized data to correct for differences in the use of the scale between panellists, the feeding treatment and panellists within each session were included as fixed effects and the session was included as a blocking effect. Standardization (mean and standard deviation) was performed for the samples. The model for the consumer study data included the feeding treatment as a fixed effect and the consumer as a random effect. In all analyses, Tukey's test was used to determine significant ($P<0.05$) differences between feeding treatments.

Results and Discussion

Productive Parameters by Feeding Strategies

Since the experiment was designed at fixed weights, no differences in body weight at the beginning or at the end of the experiment were obtained (Table 4). Furthermore, the productive parameters between the 30 and 70 kg period were not significantly different between AL-AL and AL-RV pigs. This result was expected since during this period the feeding strategy was the same for both treatments (*ad libitum*).

Not surprisingly, when pigs were restricted, they required more days to achieve the TBW. Although this effect was common for restriction during the growing phase RV-AL (30–70 kg) and the finishing phase AL-RV (70–120 kg), the impact was greater during the growing phase RV-AL (15 d *vs.* 8 d, which represents 133% *vs.* 117%), probably because the restriction was higher (78% *vs.* 84% of *ad libitum*). Overall, restricted pigs (RV-AL and AL-RV) needed 10 additional days to achieve the same body weight as AL-AL pigs, although the total feed intake was similar for all pigs. This finding implies that since pigs were slaughtered at the same final weight, the age of restricted pigs at slaughter was higher than that of those fed *ad libitum* throughout the growing period.

Thus, in RV-AL pigs, even though the re-alimentation period after the feed restriction reduced the finishing period by 4 days compared with that in AL-AL pigs, this reduction was not enough to compensate for the higher number of days RV-AL pigs needed during the growing phase.

When pigs were restricted to 78% *ad libitum* in the growing phase (RV-AL), their growth rate was 24% lower ($P<0.05$) than non-restricted pigs (AL-AL), and during the finishing phase it was 17% higher, which indicates that these pigs appeared to exhibit compensatory growth as a consequence of nutrient deficiency during growth.

Applying a higher restriction (65% *ad libitum*) than in the present work, a decrease of the growth rate in the restriction period (30–70 kg) and a significant increase of the growth rate in the re-alimentation period (70–110 kg) of 13% were reported by Heyer and Lebret (2007). Similarly, Lebret et al. (2007) observed a significant decrease (30%) in growth rate in restricted pigs followed by a non-significant increase (7%) during the re-alimentation period when a restriction of 70% *ad libitum* was applied between 30 and 80 kg. Madsen and Bee (2015) found a decrease in growth of 16% in pigs restricted to 89% in energy from 27 to 60 kg compared with that of non-restricted pigs and an increase of growth in the re-feeding period (from 60 to 102 kg) of 16%. Considering the total growth of pigs, the ADG and ADFI in AL-RV pigs were 94% and 93%, respectively, and in the RV-AL pigs they were 93% and 91% of those of AL-AL pigs, respectively. For ADG, this difference tended to be different between treatments (P=0.06).

In studies in which the growing and finishing period were established at the same age instead of weight, a decrease in growth rate during restriction was also reported, followed by an increase during the finishing period, indicating a compensatory growth effect (Daza et al., 2003; Kristensen et al., 2002; Therkildsen et al., 2004). Nevertheless, in the present study, the average daily weight gain during the whole period was not significantly different between treatments.

However, during finishing, the results were similar since the ADFI of RV-AL pigs was 108% greater than that of AL-AL pigs in both studies, indicating a compensatory feed intake. However, the total feed consumption during finishing was not significantly different between treatments, probably because the study was designed considering fixed weights.

The feed conversion ratio was not significantly different in any phase, in agreement with the study of Bee et al. (2007). However, in other works, significant differences were found in the feed conversion ratio or in feed efficiency between AL-AL and RV-AL during the re-feeding period or both when the study was carried out at a fixed weight and at a fixed age (Heyer & Lebret, 2006; Lebret et al., 2007; Therkildsen et al., 2004).

The fat thickness of restricted pigs during the growth phase (RV-AL) measured at the farm with ultrasound was 1.5 mm less (84% reduction) than that of AL-AL pigs (P<0.05). Heyer and Lebret (2007) and Lebret et al. (2007) also reported a decrease in fat depth during the restriction phase of 1.8 mm and 2.4 mm, respectively. The higher reduction in fat thickness in these studies than in the present one may be due to the higher restriction applied (65% and 70% *vs.* 78%, respectively). In addition, loin thickness was not affected by the feeding treatment from the initial live weight to the final live weight (Table 4) in agreement with Lebret et al. (2007).

Carcass Composition by Feeding Strategy During Growth

Morphometric measures of live pigs from CT images. The loin area and perimeter between the 3rd and 4th *lumbar vertebrae* were similar for all dietary treatments during growth except at 70 kg TBW (Figure 2). At this weight, the loin area was significantly larger in RV-AL pigs than that in AL-AL pigs but not in AL-RV pigs, probably because AL-RV pigs initially tended to have a larger (P<0.10) loin area than AL-AL pigs. The loin perimeter at 70 kg was significantly higher in RV-AL and AL-RV pigs than that in AL-AL pigs. Note that between the 11th and 12th ribs, no differences in loin area or perimeter were found at any weight (Figure 3). This finding might indicate that the differences of the effect of the restriction depend on the anatomical region and could explain the difficulty of understanding the capacity of pigs to compensate for lean tissue losses.

In similar studies, when fixed weights were applied, no differences in muscle depth or in muscle area were found after the restriction period before the re-feeding period (Bee et al., 2007; Heyer & Lebret, 2007; Lebret et al., 2007). However, when the study was performed at fixed ages, important reductions in muscle area were obtained in restricted pigs compared with that in those fed *ad libitum* (Bee et al., 2007; Kristensen et al., 2002; Therkildsen et al., 2004), which was also associated with a reduction in weight.

The RV-AL pigs in the present study presented lower increases in subcutaneous fat area and fat thickness during the restriction period (growing phase) compared with that in the other treatments, although they showed greater increases in these traits with respect to the other treatments during the *ad libitum* period (finishing phase); thus, these traits were not significantly different among the treatments at the end of the finishing phase, in agreement with the results of Madsen and Bee (2015) and Heyer and Lebret (2007). Surprisingly, no differences in fat thickness were obtained although a tendency ($P<0.10$) can be seen at 11th-12th rib level. These reductions/recoverings in the fat area and fat thickness in RV-AL pigs were observed in the loin and ham regions and indicate that fat deposition was greater than lean deposition after the restriction of feeding (Heyer and Lebret, 2007). These findings also indicate that compensatory growth is in the form of fat tissue growth and little or no muscle growth.

Animals from the AL-RV feeding strategy had a significantly lower subcutaneous fat area than animals from the AL-AL feeding strategy at TBW 100 and 120 kg in the loin images, which was expected because the daily feed intake decreased significantly.

In the ham images, the subcutaneous fat area and thickness were not significantly different between animals from any treatment at 120 kg (Figure 4), although there were differences at 70 kg ($P<0.05$) and 100 kg ($P<0.10$). According to these results, all of these strategies are suitable for producing the same type of ham; thus, the easiest and least costly strategy for a farm should be utilized. Furthermore, modifications of these strategies (e.g., changing the restriction applied or the time and length of application) should be studied to obtain economical improvements in the production of ham by the pork industry.

Carcass and cut composition measured in live pigs from CT images. Regarding carcass composition (Table 5), the lean content was significantly lower in AL-AL pigs than that in RV-AL restricted pigs at 70 kg, in agreement with Heyer and Lebret (2007) and Lebret et al. (2007). In fact, the lean content decreased by 2.6% on average in AL-AL pigs and by only 0.64% in RV-AL pigs after the restriction period. However, although at 70 kg AL-RV pigs received the same feeding treatment as AL-AL pigs, no significant differences were found between AL-RV and RV-AL. The lack of differences was probably because although at the beginning of the experiment AL-AL pigs and AL-RV pigs had no significant differences in lean meat percentage, it was on average 0.94% higher in AL-AL pigs. In the re-alimentation period (after 70 kg), RV-AL pigs had an important decrease in lean meat percentage (3.71% until 100 kg and 5.86% throughout the period), which was associated with an increase in fat. When the restriction was applied in the finishing period (AL-RV pigs), the decrease in lean meat content was lower (0.91% until 100 kg and 2.47% throughout the period) suggesting that the effect was less important in this phase.

The evaluation of the same animal non-destructively at different weights by means of CT allowed the observation of the evolution of the lean meat content during growth without the need for serial slaughtering. Heyer and Lebret (2007), Lebret (2007) and Madsen and Bee (2015), also did not find significant differences in the lean meat content at the slaughter weight. In animals slaughtered at the same age, Therkildsen et al (2004) did not find differences between treatments, while Kristensen et al. (2002) found a higher lean meat content in animals restricted in the finishing phase than that of those fed *ad libitum* during growth or of those with an initial restriction feeding followed by a re-feeding period.

Only the fat composition (in kg) presented a significant interaction between the feeding effect and TBW. In this case, significant differences were not observed between feeding treatments at 30 and 120 kg, although at 70 and 100 kg, the fat weight was higher in AL-AL pigs than that in in restricted pigs (RV-AL at 70 kg and AL-RV at 100 kg). When the proportion is considered, a significant interaction can be found ($P<0.10$ for ash content and $P<0.05$ for fat, moisture and protein content). Differences between feeding treatments were obtained at 70 and 100 kg. Fat proportion followed the same pattern as the fat weight, and the protein content should logically follow the opposite pattern, *i.e.,* when fat is higher, protein is lower. The feeding restriction treatments did not significantly influence the carcass composition (ash, moisture and protein) at the final weight, but CT technology allowed us to see the influence of these feeding treatments on the carcass composition during growth. Heyer and Lebret (2007) using serial slaughters reported that feed restriction reduced adipose tissue and slightly increased lean deposition at the muscle level from 30 to 70 kg TBW.

The cut composition results are presented in Table 6. The interaction between the TBW and feeding treatment was only significant for the fat parameters. The feeding treatments had an effect at 70 and 100 kg, although no effect was observed at the beginning or the end of the experiment. At 70 kg, the fat content of the animals that received the RV-AL treatment was significantly lower in all cuts than that in those that received the AL-RV and AL-AL treatments. At 100 kg, the animals fed AL-RV had significantly lower fat than those fed AL-AL, and the fat content of the animals fed RV-AL was in between that of the two other treatments. The lack of differences in the weight of the primal cuts by feeding treatment is probably because the study was performed at fixed weights. In fact, studying the proportion of cuts at a fixed weight, Bee et al. (2007) did not find differences at the end of the growing phase between animals fed *ad libitum* and those restricted, while at fixed ages, higher proportions of loin and ham and lower proportions of belly were observed in restricted animals at the end of the growing phase. Thus, moving the slaughter time or changing the pattern of restriction would result in a final product with different characteristics and composition, which could be adapted to the demands of the market.

The use of CT to study the evolution of the carcass composition during the growth of the animals avoids the slaughter of animals; data from the same animal can be collected, showing the changes and differences between treatments during the growing period. This is an original contribution of this study that has been made possible due to the use of this non-destructive technology.

Final carcass quality measurements obtained directly from carcasses after slaughter. All of the carcass quality characteristics measured after slaughter showed non-significant differences among feeding treatments, thus indicating a lack of effect of the restriction applied during the growing or finishing phases on the final carcass quality (Table 7). However, the present results do not rule out the possibility that the RV-AL strategy results in carcasses with more fat than that in the other treatments. Likely, an effect on carcass grade could be found if the restriction period or the degree of restriction were greater. In fact, Madsen and Bee (2015) reported a high lean meat content and low fat content in carcasses from pigs subjected to restricted feeding in the growing and finishing periods compared with those subjected to AL-AL and RV-AL feeding. However, Cho et al. (2006) did not find differences in the carcass grade or back fat depth when a restriction (90% of consumed feed for the last two weeks and restriction during all growing-finishing periods) was applied.

Thus, under the conditions of the present experiment, a restriction at different times of the pig growth cycle does not affect the final carcass quality. The ADFI and ADG during total growth were higher and the number of feeding days were lower for the AL-AL feeding strategy, and this information must be considered when formulating diets and determining the feeding strategy to obtain the maximum economic benefit without affecting the quality of the final product.

The lean meat content estimated with CT at 120 kg in live pigs (Table 5) was slightly higher than that estimated with FOM directly in the carcass (Table 7), but in both cases, no significant differences were found between feeding strategies. This difference might be due to the error of prediction of lean meat content associated with each of the technologies, which is approximately 1.04% (and R^2= 0.95) for CT (Font-i-Furnols et al., 2015) and 1.86% (and R^2= 0.80) for FOM (Gispert and Font i Furnols, 2012). Furthermore, the correlation between lean meat content measured in live pigs with CT and in carcasses with FOM was 0.76, lower than the 0.87 reported by Lucas et al. (2017).

Images from CT in live pigs allowed us to see some differences in fat thickness at 120 kg measured between the 3rd and 4th lumbar vertebrae and between the 11th and 12th ribs (*i.e.*, the 3rd and 4th last ribs) (Figures 2 and 3). However, significant differences were not found in measures carried out directly with FOM in the carcasses after slaughter between the 3rd and 4th last ribs and at 6 cm of the midline (Table 7). This difference might be because the measurement was not taken exactly at the same place. Furthermore, animals were slaughtered 13 ± 4 d after the last scan, and this difference in time could also affect the fat content of the final product. In fact, the correlation between the fat thickness measured in the CT images and that of those measured with FOM was 0.68, while in a previous work, when these fat thicknesses were measured in exactly the same place and at the same time, the correlation was 0.92 (Lucas et al., 2017).

In the ham region, although fat measurements were taken at different places (and times) in live animals with CT (Figure 4) and in carcasses with a ruler

(Table 7), no significant differences between treatments were found. Correlations between both fat thickness measurements was 0.68. These findings support the use of CT as a non-destructive method, which can be used to predict the carcass quality of pigs before slaughter. Moreover, this method presents advantages in accuracy and a lack of time restrictions on the evaluation of the growth performance and body composition of pigs.

Meat and Sensory Quality by Feeding Strategy

No significant differences (P<0.05) were observed in any of the meat quality measurements among the three feeding treatments (Table 7). Previous studies have shown a decrease in intramuscular fat under restriction (Affentranger et al., 1996; Heyer and Lebret, 2007), which is inconsistent with the present results. However, other studies (Kristensen et al., 2004; Kristensen et al., 2002) are consistent with the present study and did not find a significant effect of feeding treatment (AL-AL compared with several combinations of restriction) based on the colour parameters (L*, a* and b*), intramuscular fat content or ultimate pH. Nevertheless, the same authors found an effect on shear force, which was higher in pigs fed AL-RV than that in pigs fed RV-AL (the growing phase from 29 to 90 d and finishing phase from 91 to 165 d, and restricted 60% of *ad libitum*).

Table 8 shows the sensory scores given by trained panellists base on the feeding strategy. The results show that significant differences occurred for pork meat odour, which was slightly higher in AL-AL pigs than in AL-RV pigs, and for pig odour, which was slightly higher in the RV-AL pigs than in AL-RV pigs. Regarding flavour, meat from pigs fed AL-RV presented higher (P=0.002) acid scores than meat from pigs from the other feeding treatments. Nevertheless, in all cases, the scores were similar, and such differences might not be relevant.

When the in-mouth texture attributes were considered, significant differences were found in hardness, which was 0.4 and 0.6 points higher in animals fed AL-AL than AL-RV and RV-AL, respectively. Additionally, tenderness tended ($P<0.10$) to be higher in animals fed AL-RV than AL-AL and RV-AL. These results might not seem to be consistent, but tenderness can be affected by other characteristics, such as juiciness and fibrosity. While no significant differences were found in juiciness, fibrosity was significantly higher in animals fed AL-AL than AL-RV. No significant differences were found in the other evaluated attributes.

Previous reports have shown that feeding strategies can modify the proteolysis and tenderness *post mortem* (Kristensen et al., 2002). Nevertheless, the effect is not clear because some studies have shown that meat from animals subjected to constraints is slightly tougher than that from animals fed *ad libitum* (Bee et al., 2007; Ellis et al., 1996), while others have reported that meat from the *longissimus thoracis* of gilts restricted to 69% in the growing period (from 28 d to 80 d of life) and then fed *ad libitum* until slaughter at day 140 showed higher tenderness scores than meat from gilts fed *ad libitum* during all growing and finishing periods (Kristensen et al., 2004). This effect was not detected in meat from gilts in the *biceps femoris* muscle. Furthermore, the results were different when meat from castrated pigs was considered. Moreover, other studies show that pork from pigs subjected to intake restriction is not different in tenderness than that from pigs fed *ad libitum* (Chaosap et al., 2011; Heyer and Lebret, 2007). Heyer and Lebret (2007) did not find significant differences in tenderness; however, they reported differences in juiciness (meat from animals fed *ad libitum* presented slightly higher juiciness scores than those from animals restricted to 65% during the growing period from 30 to 70 kg), which is consistent with those found by Ellis et al. (1996) and inconsistent with the results presented here.

Considering these results, the differences between studies may be due to the duration and quantity of the restriction, the sex of the animals used in the experiment, and the muscle studied, and these differences likely explain the contradictory results of the feeding restriction strategies on tenderness. In our experiment, the restriction period was divided by different TBWs and not the growing days of the pig. Additional details about different feeding periods must be evaluated to confirm the effect of feeding treatment on meat tenderness.

All significant differences in the sensory characterization of meat from the different feeding strategies were numerically very low, which may explain why the consumer scores were not significantly different in the overall acceptability, tenderness, odour and flavour among the three different feeding strategies (Table 8), which was also suggested by Heyer and Lebret (2007). Intramuscular fat and/or marbling is considered to have an influence on some sensory qualities (Fernandez et al., 1999; Font-i-Furnols et al., 2012). In the present project, no differences in intramuscular and marbling were detected (Table 7), which may have had an influence on the lack of sensory differences between meats from different feeding strategies.

In conclusion, the results presented in this paper show clear differences in the growth rate and fat composition of the pigs among different feeding strategies during growth, although these effects are not found in the final product probably due to compensatory effects. The carcass and meat quality of the final product are not highly affected by the feeding strategy, although from the sensorial point of view, meat from animals with some restriction during growth may produce slightly less tough meat than those from animals fed *ad libitum* during all the growing periods; however, this difference does not appear to have consequences in the consumers' acceptability of the meat. Thus, combining restrictions at different periods of growth probably would not represent a good strategy to reduce costs because at the end the pigs ate the same amount of feed and more days are needed to reach the targeted slaughter weight. Such information may be valuable for the porcine industry for identifying the most economical feeding strategy because an important effect on the final quality of the meat and its acceptability by consumers was not observed. Moreover, CT represents a very suitable approach for determining carcass composition during growth before slaughter.

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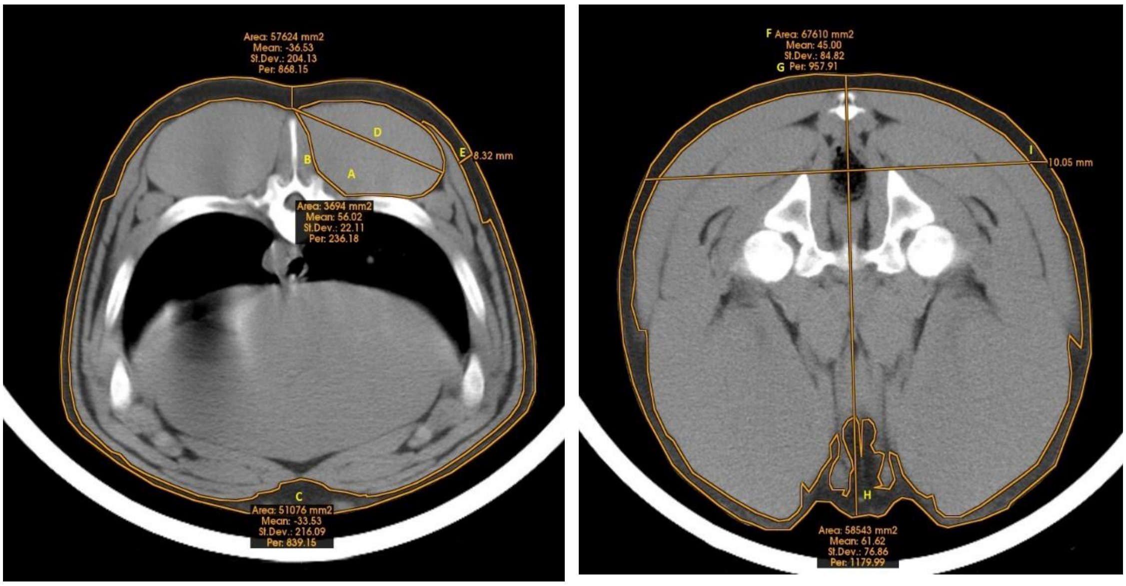

(a) (b)

Figure 1. Anatomical measures obtained from the tomograms obtained at the 11^{th}-12^{th} rib and 3^{rd}-4^{th} lumbar vertebrae levels (a) (A: loin eye area; B: loin eye perimeter; C: subcutaneous fat area; D: maximum width of the longissimus area; E: lateral fat thickness at the edge of D perpendicular to the skin) and at the ham in the joint of the femur and pelvis bones (b) (F: area of the whole ham; G: perimeter of the whole ham image; H: subcutaneous fat area; I: lateral fat thickness at the upper part of the bones level).

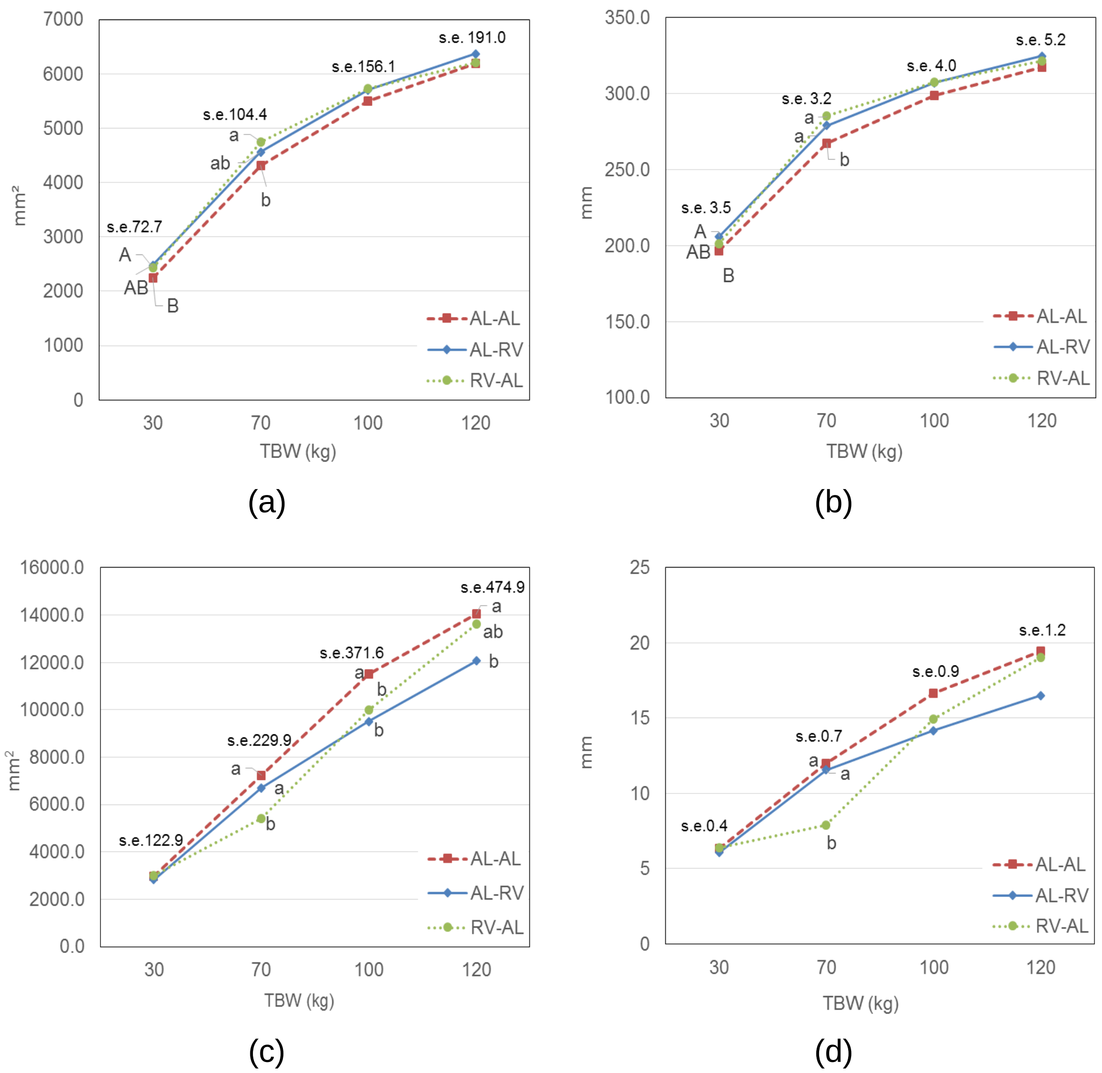

Figure 2. Measures obtained from computed tomography images between the 3rd and 4th lumbar vertebrae: (a) loin area, (b) loin perimeter, (c) subcutaneous fat area, and (d) subcutaneous fat thickness.

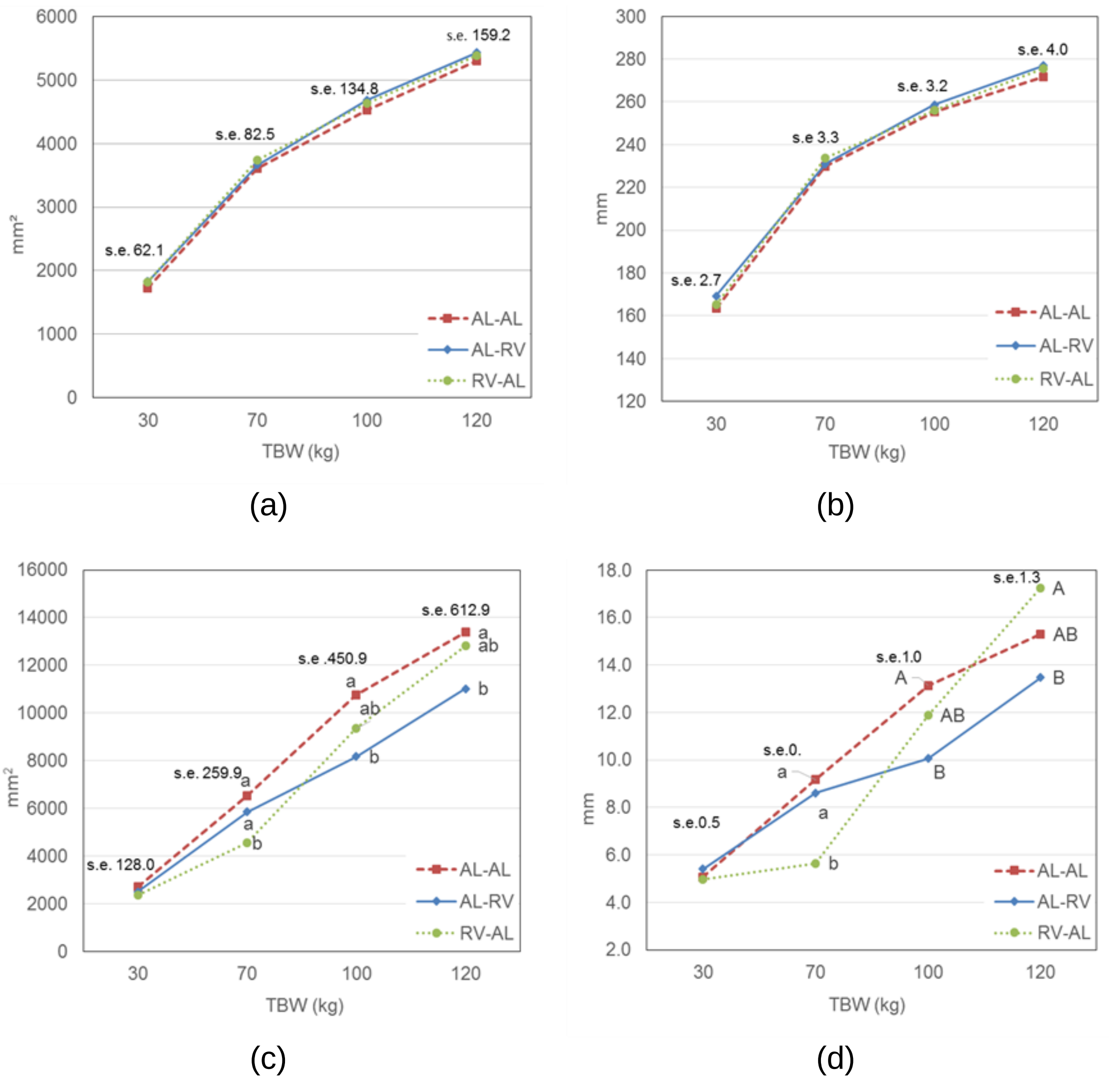

Figure 3. Measures obtained from computed tomography images between the 11th and 12th ribs: (a) loin area, (b) loin perimeter, (c) subcutaneous fat area, and (d) subcutaneous fat thickness by feeding treatment (n=12 each): AL-AL: Feeding ad libitum (AL) during all period of growth; AL-RV: Feeding AL until 70 kg and then volume limited to 84% until slaughter; RV-AL: Feeding volume limited to 78% of AL in growth period and then AL until slaughter.

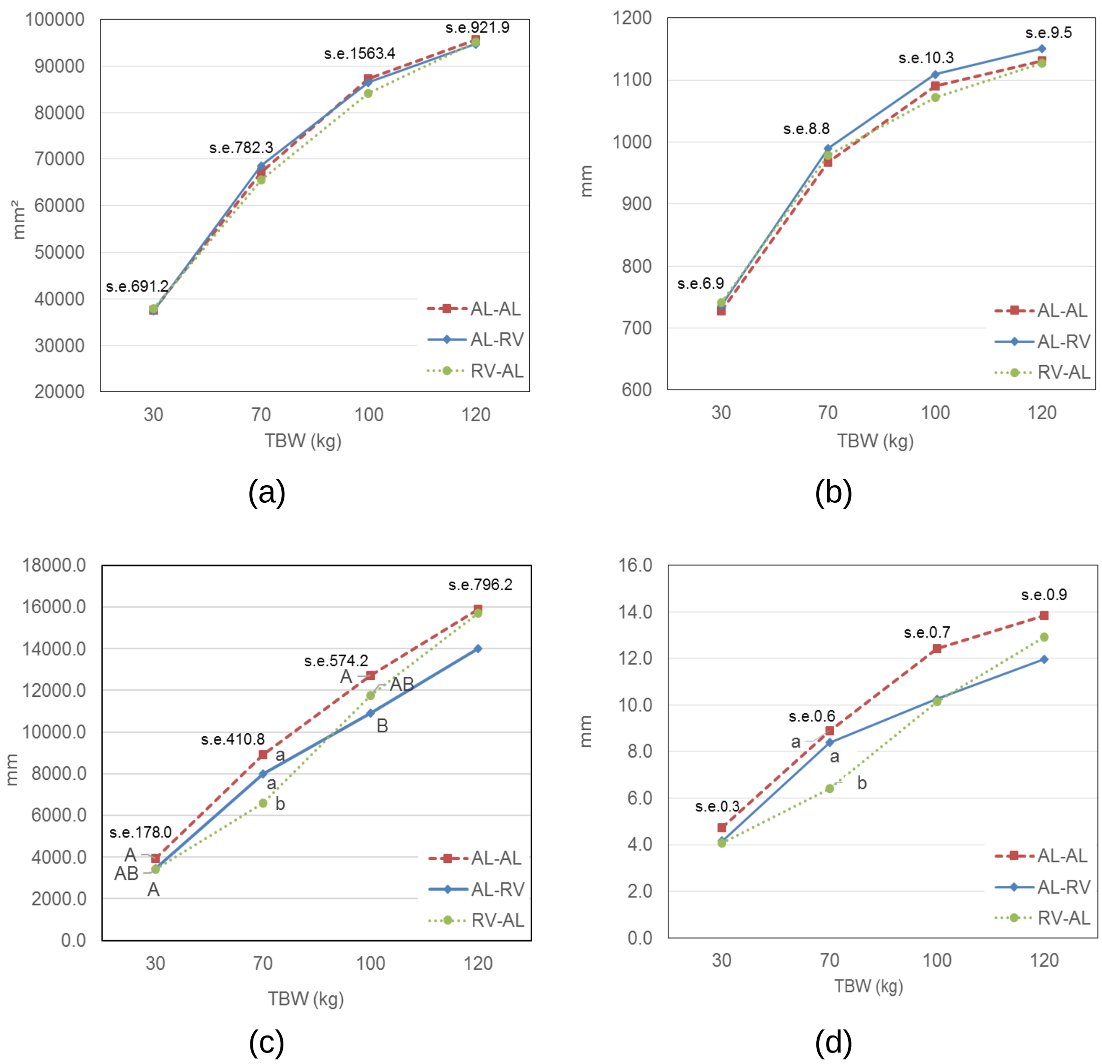

Figure 4. Measures obtained from computed tomography images in the ham: (a) total area, (b) perimeter, (c) subcutaneous fat area, and (d) subcutaneous fat thickness by feeding treatment (n=12 each): AL-AL: Feeding ad libitum (AL) during all period of growth; AL-RV: Feeding AL until 70 kg and then volume limited to 84% until slaughter; RV-AL: Feeding volume limited to 78% of AL in growth period and then AL until slaughter.

Table 1. *Composition of the experimental diets for different feeding strategies*

Ingredient, %	Growing diet	Finishing diet
Composition from tables		
Wheat	30.00	25.64
Maize	25.00	25.00
Barley	12.32	13.95
Triticale	1.50	11.11
Soybean meal	13.38	7.17
Rapeseed meal	6.00	6.00
Wheat middling's	---	---
Biscuit meal	4.56	3.20
Rice bran	1.50	1.60
Peas	---	1.50
Molasses	1.00	1.00
Fat 3/5 Grefacsa	1.24	0.76
L-Lysine HCl	0.68	0.60
DL-Methionine	0.09	0.08
L-Threonine	0.16	0.13
L-Tryptophan	0.19	0.03
Dicalcium phosphate	0.66	---
Limestone	0.68	1.22
Salt	0.34	0.30
Vitamin and mineral premix[1]	0.20	0.20
Chemical composition		
Gross energy, Mcal/kg	3.904	3.923
Net energy, Mcal/kg	2.264	2.275
Ether extract, g/kg	50.4	35.7
Crude fibre, g/kg	26.7	28.7
Crude protein, g/kg	175.4	148.1
Total lysine, g/kg	9.80	7.70
Total threonine, g/kg	6.40	5.80
Total methionine, g/kg	3.50	2.80
Total Met+Cys, g/kg	6.20	5.10

[1] Provided per kg feed: vitamin A (E 672), 5500 UI; vitamin D3 (E 671), 1100 UI; vitamin E (alfa tocopherol), 7 mg; vitamin B1, 0.5 mg; vitamin B2, 1.4 mg; vitamin B6, 1 mg; vitamin B12, 8 µg; vitamin K3, 0.5 mg; calcium panthotenate, 5.6 mg; nicotinic acid, 8 mg; choline, 120 mg; Fe (E 1) (from FeSO4·7H2O), 80 mg; I (E 2) (from Ca(IO3)2), 0.5 mg; Co (E 3) (from 2CoCO3·3Co(OH)2·H2O), 0.4 mg; Cu (E 4) (from CuSO4·5H2O), 5 mg; Cu (E 4) (from the amino acid quelate), 5 mg; Mn (E 5) (from MnO), 40 mg; Zn (E 6) (from ZnO), 100 mg; and Se (E 8) (from Na2SeO3), 0.25 mg.

Table 2. *Codes and description of the sensory attributes evaluated by the trained panellists.*

Attribute[1]	Definition
ODOUR	
Pork meat	Intensity of boiled pork with normal smell
Pig	Intensity of living pig smell
Abnormal	Intensity of off-odour
FLAVOUR	
Pork meat	Intensity of boiled pork with normal flavour during chewing
Pig	Intensity of living pig flavour
Abnormal	Intensity of off-flavour during chewing / residual
Acid	Ref: Citric acid
Sweet	Ref: Sugar
Metallic	Ref: Blood
TEXTURE	
Hardness	Force required to compress meat between molars and first bite
Juiciness at first bite	Amount of water released from first bite
Juiciness during chewing (5 bites)	Amount of water released during chewing (after 5 bites)
Tenderness	Ease at which meat is divided into small particles when chewing.
Fibrosity	Amount of fibres during chewing (ref. asparagus)
Chewiness	Amount of required bites before swallowing the meat

[1]Scored from 0: low/weak to 10: high/strong

Table 3. *Socio-demographic characteristics of the participants in the consumer study.*

	Women	Men	Total
Participants			
Total (n)	68	52	120
Total%	56.7	43.3	100.0
Age group (%)			
<26 years-old	8.8	11.5	10.0
26-40 years-old	19.1	30.8	24.2
41-60 years-old	38.2	30.8	35.0
>61 years-old	33.8	26.9	30.8
Education level (%)			
Primary	13.2	17.3	15.0
Secondary	51.5	50.0	50.8
University	35.3	32.7	34.2
Do you decide on/perform the purchasing of meat at home? (%)			
Yes	92.7	63.5	80.0
No	0.0	21.2	9.2
only decide	4.4	13.5	8.3
only purchase	2.9	1.9	2.5
Where do you buy meat? (multiple choice answer)			
Traditional butcher	43.9	35.5	40.4
Supermarket/Hypermarket Butchery	28.0	34.2	30.6
Packed meat in Super/Hypermarket	25.2	28.9	26.8
Others	2.8	1.3	2.2

Table 4. *Productive parameters by feeding strategy during the growing and finishing periods*[+]

	Feeding strategy[1]				
	AL-AL	AL-RV	RV-AL	RMSE	P-value
n	12	12	11		
Growing 30-70 kg					
Days	46.3[b]	46.3[b]	61.6[a]	6.6	<.0001
BW initial, kg	33.13	33.88	32.67	2.23	0.432
ADG, g/d	867[a]	879[a]	657[b]	80	<.0001
ADFI, g/d	2109[a]	2128[a]	1677[b]	118	<.0001
FCR, kg/kg	2.45	2.43	2.59	0.25	0.245
Feed consumption, kg	97.9	96.8	104.0	12.41	0.339
Fat thickness[2], mm	9.1[a]	8.3[ab]	7.6[b]	1.0	0.003
Muscle depth[2], mm	47.1	47.9	49.6	2.5	0.073
Finishing 70-120 kg					
Days	49.4[b]	57.8[a]	45.2[b]	6.6	0.0003
ADG, g/d	955[b]	852[c]	1116[a]	97	<.0001
ADFI, g/d	2799[a]	2436[b]	3016[a]	232	<.0001
FCR, kg/kg	2.94	2.90	2.71	0.28	0.137
Feed consumption, kg	137.9	139.4	136.0	15.00	0.860
Fat thickness[2], mm	12.9	11.5	12.8	1.5	0.059
Muscle depth[2], mm	60.5	58.7	60.4	4.1	0.478
Total 30-120 kg					
Days	95.7[b]	104.1[ab]	106.8[a]	9.4	0.020
BW final, kg	120.13	121.83	123.41	3.48	0.093
ADG, g/d	912	856	852	65.9	0.063
ADFI, g/d	2463[a]	2287[b]	2244[b]	123	0.0003
FCR, kg/kg	2.71	2.69	2.64	0.21	0.731
Feed consumption, kg	235.7	236.2	240.0	20.69	0.867

ADG: Average daily gain; ADFI: Average daily feed intake; FCR: Feed conversion

+Different letters within a row indicate significant (P <0.05) differences between feeding strategies (ratio).

[1]AL-AL: Feeding ad libitum (AL) during all period of growth; AL-RV: Feeding AL and then volume limited to 84% until slaughter; RV-AL: Feeding volume limited to 78% of AL and then AL until slaughter.

[2]Fat thickness and muscle depth measured on the P2 point in live pigs with an ultrasonic device.

Table 5. *Carcass body composition predicted from computed tomography images from the whole live pig by target body weight (TBW) and feeding* treatment (FT[1]) (n=12 for AL-AL and AL-RV and n=11 for RV-AL).

TBW (kg)	30			70			100			120				*P*-value[3]	
FT	AL-AL	AL-RV	RV-AL	AL-AL	AL-RV	RV-AL	AL-AL	AL-RV	RV-AL	AL-AL	AL-RV	RV-AL	RMSE	FT	TBWxFT
Lean %	64.14	65.08	64.96	61.45^{b}	62.37^{ab}	64.32^{a}	59.15^{b}	61.46^{a}	60.61^{ab}	58.42	59.90	58.46	1.44	0.1223	<.0001
Composition (kg)[2]															
Ash	0.78	0.81	0.73	1.86	1.97	1.84	2.66	2.62	2.54	3.14	3.10	3.02	0.55	0.3361	0.9492
Fat	3.41	3.27	3.00	10.00^{a}	9.71^{a}	8.36^{b}	18.62^{a}	15.34^{b}	16.12^{ab}	25.50	22.23	24.40	1.46	0.0093	0.0091
Moist[5]	17.20	17.46	17.05	34.92	35.59	34.49	49.75	46.71	46.34	58.27	55.00	54.23	2.14	0.2811	0.7648
Protein	4.59	4.66	4.35	10.61	10.92	10.64	15.45	14.59	14.30	18.29	17.20	16.92	1.23	0.2128	0.7608
Composition (%)[2]															
Ash	2.93	2.96	2.91	3.06	3.13	3.13	2.96	3.11	3.02	2.79	2.92	2.77	0.38	0.1386	0.0709
Fat	11.25^{a}	11.04^{ab}	10.63^{b}	15.81^{a}	15.36^{a}	13.81^{b}	21.56^{a}	18.61^{b}	19.57^{b}	24.95	22.26	23.98	1.32	0.0077	0.0007
Moisture[5]	66.25	66.31	67.01	61.09^{b}	61.22^{ab}	62.40^{a}	55.98^{b}	58.28^{a}	57.86^{a}	53.38	55.64	54.58	1.27	0.0106	0.0383
Protein	18.09	18.15	18.06	18.10^{b}	18.28^{ab}	18.47^{a}	17.60^{b}	18.15^{a}	17.84^{ab}	16.97	17.45	16.93	0.63	0.0649	<.0001

[1]AL-AL: Feeding ad libitum (AL) during all period of growth; AL-RV: Feeding AL and then volume limited to 84% until slaughter; RV-AL: Feeding volume limited to 78% of AL and then AL until slaughter.
[2] Predicted using the equations obtained by Zomeño et al. (2016) from live pig images to estimate composition of minced carcasses.
[3]*P*-value for the TBW was significant (P<0.001) for all variables.

Table 6. *Cuts composition predicted from computed tomography images from the whole live pig by target body weight (TBW) and feeding treatment (FT[1])* (n=12 for AL-AL and AL-RV and n=11 for RV-AL).

TBW (kg)	30			70			100			120				*P*-value[5]	
FT	AL-AL	AL-RV	RV-AL	AL-AL	AL-RV	RV-AL	AL-AL	AL-RV	RV-AL	AL-AL	AL-RV	RV-AL	RMSE	FT	TBWxFT
Main cuts (kg)[2]															
Lean5[3]	6.06	6.24	5.90	13.47	13.93	13.52	20.03	18.85	18.39	23.53	22.13	21.42	1.50	0.273	0.762
Fat4[3]	1.37	1.29	1.23	4.30[a]	4.09[a]	3.34[b]	7.62[a]	6.16[b]	6.61[ab]	9.71	8.46	9.21	0.92	0.007	0.001
Bone4[3]	0.97	0.97	0.91	1.79	1.81	1.73	2.40	2.31	2.26	2.79	2.65	2.60	0.49	0.198	0.959
Ham[2]															
Weight	3.28	3.30	3.18	7.41	7.47	7.03	11.15	10.15	10.21	13.29	12.34	12.45	0.94	0.035	0.237
Lean	2.47	2.55	2.40	5.40	5.56	5.34	7.80	7.36	7.24	9.05	8.58	8.41	0.87	0.255	0.792
Fat	0.44	0.42	0.40	1.30[a]	1.24[a]	1.03[b]	2.28[a]	1.86[b]	2.00[ab]	2.90	2.54	2.76	0.50	0.007	0.001
Bone	0.32	0.32	0.30	0.58	0.59	0.56	0.77	0.75	0.73	0.90	0.85	0.84	0.28	0.198	0.959
Loin[2]															
Weight	1.81	1.83	1.74	4.79	4.83	4.51	7.48	6.76	6.81	9.03	8.34	8.42	0.80	0.035	0.237
Lean	1.24	1.28	1.19	3.04	3.15	3.05	4.52	4.27	4.17	5.28	5.00	4.85	0.70	0.294	0.800
Fat	0.26	0.24	0.23	1.13[a]	1.08[a]	0.86[b]	2.13[a]	1.70[b]	1.84[ab]	2.77	2.40	2.62	0.50	0.007	0.001
Bone	0.32	0.32	0.29	0.60	0.61	0.58	0.81	0.78	0.76	0.95	0.90	0.88	0.29	0.198	0.959
Shoulder[2]															
Weight	1.86	1.87	1.80	4.24	4.27	4.02	6.12	5.68	5.71	7.09	6.75	6.80	0.92	0.045	0.267
Lean	1.31	1.34	1.27	2.80	2.90	2.81	4.09	3.87	3.78	4.77	4.51	4.37	0.66	0.281	0.776
Fat	0.35	0.33	0.32	1.01[a]	0.97[a]	0.81[b]	1.57[a]	1.36[b]	1.44[ab]	1.82	1.71	1.81	0.33	0.008	<.0001
Bone	0.21	0.21	0.20	0.40	0.41	0.39	0.54	0.52	0.51	0.63	0.60	0.59	0.23	0.198	0.960
Belly[2]															
Weight	1.19	1.20	1.15	2.90	2.92	2.74	4.59	4.12	4.15	5.60	5.12	5.18	0.64	0.032	0.223
Lean	0.77	0.79	0.75	1.68	1.74	1.69	2.59	2.40	2.33	3.11	2.86	2.76	0.58	0.221	0.683

Fat	0.30	0.28	0.27	0.97[a]	0.93[a]	0.76[b]	1.75[a]	1.42[b]	1.53[ab]	2.25	1.96	2.14	0.44	0.007	0.001
Bone	0.12	0.12	0.11	0.21	0.21	0.20	0.28	0.27	0.26	0.32	0.31	0.30	0.16	0.200	0.966
Tenderloin[2]															
Weight	0.20	0.20	0.19	0.45	0.46	0.45	0.67	0.63	0.61	0.79	0.74	0.72	0.28	0.270	0.756

[1]AL-AL: Feeding ad libitum (AL) during all period of growth; AL-RV: Feeding AL and then volume limited to 84% until slaughter; RV-AL: Feeding volume limited to 78% of AL and then AL until slaughter.

[2]Prediction using the equations obtained for live pig images from Pietrain x (Landrace x Large White) by Font-i-Furnols et al. (2014) to estimate the carcass composition from dissection.

[3]Lean5: lean content of the ham, shoulder, loin, belly and tenderloin from dissection; Fat4 and Bone4: predicted fat and bone content of the ham, shoulder, loin and belly obtained by dissection.

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Table 7. *Carcass and meat quality measurements by feeding strategy*[1]

	AL-AL	AL-RV	RV-AL	RMSE	P-value
n	12	12	10		
Live weight (kg)	126.82	127.66	130.62	5.68	0.283
Warm carcass weight (kg)	104.46	105.40	107.02	4.85	0.474
Yield (%)	82.37	82.59	81.90	1.18	0.394
Cold left carcass weight (kg)	53.02	53.68	54.44	2.55	0.439
Fat thickness[2] (mm)	22.13	20.91	23.28	3.50	0.305
Muscle depth[2] (mm)	66.12	63.29	63.17	4.63	0.247
Lean meat[2] (%)	57.10	57.66	55.55	3.46	0.370
F-ZP[3] (mm)	18.21	16.02	20.07	4.69	0.168
M-ZP[4] (mm)	78.80	80.86	80.09	5.68	0.685
Last rib fat thickness (mm)	28.94	25.87	26.63	4.87	0.298
Moisture (%)	73.64	73.79	74.06	0.53	0.296
Intramuscular fat%	2.06	1.90	1.79	0.41	0.432
pH 45 SM	6.63	6.61	6.62	0.18	0.962
pH 45 LT	6.67	6.53	6.56	0.22	0.378
pHu SM	5.58	5.58	5.57	0.07	0.930
pHu LT	5.62	5.62	5.62	0.09	0.977
ECuSM (mS)	4.19	5.55	4.19	1.96	0.173
EC LT(mS)	3.86	4.38	3.58	1.16	0.415
Marbling NPPC[5]	1.59	1.47	1.43	0.59	0.838
Drip loss (%)	2.36	3.34	2.55	1.97	0.461
Cooking loss (%)	34.53	33.75	34.43	2.42	0.708
EJC6	2.92	2.55	2.54	0.51	0.230
*L**	48.65	49.37	49.18	1.79	0.660
*a**	8.60	7.77	8.32	1.15	0.247
*b**	1.61	1.24	1.38	0.55	0.315
Shear force (N)	5.42	5.37	5.01	0.73	0.454

[1]AL-AL: Feeding *ad libitum* (AL) during all period of growth; AL-RV: Feeding AL until 70 kg and then volume limited to 84% until slaughter; RV-AL: Feeding volume limited to 78% of AL in growth period and then AL until slaughter.

[2]Fat and muscle thickness measured with Fat-O-Meat'er between the 3rd and 4th last rib at 6 cm from the midline and lean meat % obtained from these two measures.

[3]F-ZP: minimum fat thickness over the muscle *gluteus medius.*

[4]M-ZP: muscle thickness between the medullar canal and the cranial edge of the muscle *gluteus medius.*

[5] Marbling scale from 1 (very low) to 10 (very high)

[6] Colour scale from 1 (pale) to 6 (dark colour).

SM: *Semimembranosus* muscle; LT: *Longissimus thoracis* muscle; pH 45: pH measured at 45 min *post mortem*; pHu: Ultimate pH; ECu: Ultimate electrical conductivity.

Table 8. *Sensory characteristics (trained panel and consumer acceptability) of the meat from pigs fed different restriction strategies*[1].

	AL-AL	AL-RV	RV-AL	RMSE	P-value
TRAINED PANEL[2]					
Odour attributes					
Pork meat	4.1^{a}	3.8^{b}	4.0^{ab}	0.8	0.042
Pig	1.3^{ab}	1.1^{b}	1.5^{a}	0.8	0.005
Abnormal	0.9	0.9	0.9	0.4	0.524
Flavour attributes					
Pork meat	4.0	3.8	3.9	0.8	0.260
Pig	1.0	1.0	1.2	0.7	0.196
Abnormal	0.8	0.8	0.8	0.4	0.513
Acid	1.7^{b}	2.2^{a}	1.9^{b}	0.9	0.002
Sweet	1.8	1.7	1.9	0.7	0.222
Metallic	1.5^{B}	1.7^{A}	1.7^{AB}	0.7	0.065
Texture attributes					
Hardness	4.8^{a}	4.4^{b}	4.2^{b}	1.0	0.001
Initial juiciness	1.9	1.8	1.9	0.7	0.952
Final juiciness	3.5	3.5	3.6	0.9	0.713
Tenderness	4.0^{B}	4.3^{A}	4.0^{B}	0.9	0.038
Fibrosity	3.5^{a}	3.2^{b}	3.4^{ab}	0.6	0.030
Chewiness	5.0	4.8	4.8	1.0	0.228
CONSUMER TEST[3]					
Overall acceptability	5.9	6.0	6.3	1.5	0.182
Tenderness	5.5	5.5	5.9	1.9	0.211
Odour	6.1	6.2	6.3	1.5	0.514
Flavour	6.1	6.2	6.3	1.6	0.681

[1] AL-AL: Feeding ad libitum (AL) during all period of growth; AL-RV: Feeding AL and then volume limited to 84% until slaughter; RV-AL: Feeding volume limited to 78% of AL and then AL until slaughter. Different superscripts indicated significant differences between treatments (a,b, P<0.05: A,B: P<0.10).

[2] Scores from 1 (low/weak) to 10 (high/strong).

[3] Scores from 1 (I dislike it extremely) to 9 (I like it extremely).