PAPER

EFFECT OF PIG SLAUGHTER WEIGHT ON CHEMICAL AND SENSORY CHARACTERISTICS OF TERUEL DRY-CURED HAM

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ABSTRACT

A preliminary study was carried out with 36 barrows to investigate the effect of slaughter weight (SW; 120, 130 and 140 kg) on chemical, instrumental and sensory characteristics of Teruel dry-cured ham. The intramuscular fat content tended to increase and salt, potassium nitrate and sodium nitrite contents decreased as SW increased. The panelists detected wider subcutaneous fat and lower cured colour, saltiness, hardness and fibrousness in hams from heavier pigs but no difference was observed on overall quality assessment. In conclusion, pig SW affected some chemical and sensory traits of dry-cured ham, which contributes to increase the heterogeneity.

- Keywords: slaughter weight; chemical characteristics; sensory quality; dry-cured ham; heavy pigs -

INTRODUCTION

Spain is the world leader in dry-cured ham and shoulder production reaching annually 40 million pieces (MAGRAMA, 2013). The Protected Designation of Origin (PDO) "Teruel ham" was the first Spanish PDO to control and guarantee the ham production. It establishes several requirements to try to ensure uniformity and quality in the end product (BOA, 2009). Some of them are related to the pig management (crossbreed Duroc x (Landrace x Large White) and slaughter weight (SW) between 120 and 140 kg), others are checked at the abattoir (carcass weight >84 kg, fat thickness over the *Gluteus medius* muscle >16 mm and fresh ham weight >11.5 kg) and others are concerning to the dry-curing process (length >18 months, weight loss of ham = 35-40% and cured ham weight >7 kg).

In spite of fulfil it, a great heterogeneity among pieces of Teruel ham is observed even when they come from the same cellar. One of the main problems manifested by the Teruel ham industry is the wide range of piece weights due to the different pig SW which carry out differences in the quality. To our knowledge, the information about the effect of the pig management on quality of this kind of ham is quite limited because most of experiments have been focused on fresh pork extrapolating the results to the cured product (LATORRE et al., 2009a and 2009b).

Therefore, the aim of this study was to investigate the effect of pig SW (120, 130 and 140 kg) on some instrumental, chemical and sensory characteristics in Teruel dry-cured ham.

MATERIAL AND METHODS

Slaughter of experimental pigs

A total of 36 Duroc x (Landrace x Large White) barrows were used in a preliminary study. There were three experimental treatments in base on preplanned SW of pigs: 120, 130 and 140 kg (118.9 ± 3.21 kg, 128.7 ± 3.53 kg and 139.2 ± 3.62 kg as average; and 189, 203 and 217 ± 3 days of age, respectively), which fulfilled the *Consortium* rules of the PDO Teruel ham. Animals belonged to the same farm and the previous feeding and management was exactly the same for all of them. At the abbatoir (Jamones y Embutidos Altomijares, S.L., Formiche Alto, Teruel, Spain), pigs were slaughtered and carcasses were processed according to standard commercial procedures (the whole hams were taken from the carcass, with no cut between hind shank and leg, because were intended for dry-curing process). After fitting market demands (round shape), hams were trimmed, removing part of external fat, and individually weighed.

Dry-curing process and sampling of hams

The left ham from each carcass was subjected to the drying process according to the *Consortium* rules of Teruel ham (BOA, 2009). Briefly, the femoral artery of the pieces was manually pressed in order to purge the blood residues and reduce the risk of spoilage later on. At 3 days *postmortem*, the salting period started. For it, hams were coated with a mixture (0.3 g $NaNO_2$, 0.4 g KNO_3 and 10 g NaCl per kg of raw ham) and kept at 2°-4°C and 80-90% relative humidity for a variable time depending on the green ham weight (1 day/kg of ham). The next step was washing hams with cold water to remove the excess salt before starting the post-salting period. For it, pieces were stored at 3°-6°C and 80-90% relative humidity for 60, 70 and 80 days for pigs slaughtered at 120, 130 and 140 kg, respectively. During the last stage (ripening period), hams were dried increasing the temperature (from 10° to 30°C) and decreasing the relative humidity (from 85 to 70%). The process was finished when total weight loss of pieces reached 35-40% of initial weight. The individual weight of hams was recorded throughout the process to calculate the weight loss by phase.

When dry-cured period ended, a total of 12 processed hams were randomly selected (4 hams per each SW). The limited number of replicates was due to the preliminary nature of the study. From each ham, a sample of 600±55 g and 20 mm thick was taken transversally, as is described in Fig. 1, and was intended for the chemical analyses. Other sample of 1,100±60 g from the central part ("maza") was taken (Fig. 2) and was intended for the analysis of instrumental colour and sensory evaluation. All samples were moved to the laboratory and were vacuum packaged and stored at 4°±2°C in darkness during one week until the analyses.

Fig. 1 - Cross-section of a dry-cured ham intended for chemical analyses.

Fig. 2 - Sample of a dry-cured ham intended for colour measures and sensory analysis.

Chemical analyses and instrumental measure of colour

The chemical analyses were carried out in the *Semimembranosus* (SM) muscle of each sample because it is the reference muscle in the PDO Teruel ham (BOA, 2009). Moisture content was determined by drying at 103°± 2°C to a constant weight (BOE, 1979) and Folch method (FOLCH *et al.*, 1957) was employed for determining intramuscular fat (IMF) content. To estimate the salt content, chlorides were extracted with water–ethanol (60:40 v/v) and quantified by the Carpentier-Volhard method (AOAC, 1984). To determine the nitrites content, sodium nitrite was measured by absorption spectrophotometry at 520 nm using an equipment HITACHI model U-1100 (USA). Also, the nitrates content was obtained measuring the potassium nitrate using the same spectrophotometer at 410 nm.

From "maza" samples, colour was measured on *Biceps femoris* (BF) and SM muscles and also on subcutaneous fat by a chromameter (CM 2002, Minolta Camera, Osaka, Japan), previously calibrated against a white tile according to manufacturer recommendations, using objective measurements (CIE, 1976). The average of three random readings was used to measure lightness (L*, a greater value is indicative of a lighter colour), redness (a*, a greater value is indicative of redder colour), and yellowness (b*, a greater value is indicative of a more yellow colour). Additionally, chroma (C*) and hue angle (H*) were calculated as $C^* = \sqrt{(a^{*2} + b^{*2})}$ and as $H° = \tan^{-1}(b^*/a^*) \cdot 57.29$, respectively. Chroma is related to the quantity of pigments and high values represent a more vivid colour denoting lack of greyness, and H° is the attribute of a colour perception denoted by blue, green, yellow, red, purple, etc. related with the state of pigments (WYSZCECKI and STILES, 1982).

Evaluation of sensory characteristics

Ham samples were assessed by a trained panel of 10 members (ISO 8586-1, 1993). To acquaint panelists with product attributes and intensities, six 1 h training sessions took place over a 4-week period prior to sample testing. The sensory analysis was performed in individual cabins under controlled environmental conditions and a red light to obscure meat colour (ISO 8589, 1988). The panel sessions were held at mid-morning, about 3 h after breakfast. Slices (1.5 mm) of the "maza" were obtained with a slicing machine about 1 h before tasting, in order to allow slices to reach room temperature (22°C). They were served on plates to panelists, which were told to taste narrow slice sections including both BF and SM muscles.

A profile of 18 sensory attributes of dry-cured ham was assessed. Attributes were grouped in appearance, odour, texture, flavour and acceptability. For evaluating overall quality, panel members were asked to give a semihedonic quality score, based on their expertise in integrating ham sensory attributes into a conclusive quality value. Attributes were rated on a 9-point structured scale (1 = very low to 10 = very high). About 50 ml of water at room temperature and 20 g of unsalted bread were provided between successive hams. A total of four sessions were carried out at 22°C in a sensory panel room equipped with white fluorescent lighting (Philips TLD 86, 5600°K, 800 lux). The sample order was randomized within assessors and sessions.

Statistical analyses

All data were analysed as a completely randomized design using the General Linear Model procedure of SAS (1990). Briefly, the Normal distribution for all variables was checked. The statistical model included the SW (120, 130, and 140 kg) as main effect. Additionally, when significant differences were detected, linear effects were evaluated. For the sensory data, a previous GLM procedure of SPSS (2005) was performed including the session and SW for each panelist as fixed effect. Afterwards, another GLM was performed with the mean per attribute and per SW obtained from the previously corrected data file. Duncan's test was used to compare means where the variance analysis indicated a significant effect. The experimental unit was the animal (n=12 for ham weight losses and n=4 for chemical, instrumental and sensory traits). A value of $P<0.05$ was used to assess the significance, whereas a P-value between 0.05 and 0.10 was classified as a trend.

RESULTS AND DISCUSION

Weight loss of hams during dry-curing process

As it was expected, the ham weight, either fresh or dry-cured, increased linearly as pig SW increased (P<0.001) (Table 1). The rate of increase in fresh weight was 1.28 kg and in dry weight 1.15 kg per each 10 kg SW of pigs. The difference between both (approx. 10%) would indicate that heavier hams had lower weight loss through the drying process than lighter hams. In fact, when this variable (total loss) was calculated, a linear reduction by 2.6 percentage units for every 10-kg increase above 120 kg was observed (P<0.001). The processing length was shorter in lighter than in heavier hams (72, 76, and 80 weeks for 120, 130 and 140 kg SW, respectively) to fulfil the requirement about total loss (35-40%) established by the *Consortium*. In summary, pig SW affects fresh ham weight which, in turn, influences process technology such as the salting, post-salting and ripening length and carries out differences in final weight losses of product.

The main differences among treatments in the ham weight loss happened at the beginning of the process. In fact, during salting and post-salting periods, linear and significant reductions in ham weight loss were observed (1.1 and 1.5 percentage units per each 10 kg of pig SW, respectively; P<0.001). The weight loss during the first stages is due to water that dissolves the salt and intensively drips out of ham. In the later periods of processing, the weight loss is because of evaporation from the surface and an equilibration inside the ham (TOLDRÁ, 2002). In the current trial, a decrease in ham weight loss during the ripening period was found as pig SW increased, although it was only numerical (18.9, 18.5 and 18.3% for 120, 130, and 140 kg SW, respectively). CANDECK-POTOKAR and SKRLEP (2012) reported that one of the factors with highest influence on processing losses, especially in that phase, was the fat thickness which serves as a barrier for water evaporation. Although cover fat depth was not measured instrumentally, the visual evaluation of panelists confirmed that it was wider in heavy than in light pigs. The ripening is the longest period and therefore a higher ham weight loss was found during that stage (18.5% as average) whereas it was lower for salting and post-salting phases (7 and 12% as average, respectively). A high variability of data was observed during the ripening period and it might explain, at least in part, the lack of significant influence of the ham weight in that phase. The values of ham weight loss through the processing were similar to those obtained by PEINADO et al. (2005) in hams from Pietrain-sired pigs slaughtered with 122 kg.

Chemical analyses and instrumental colour

The chemical analyses of dry-cured ham showed values (/100 g wet matter) of moisture from 47.0 to 50.0 g and of IMF from 12.5 to 13.5 g (Table 2). Those results are close to those found by GOU *et al.* (2008) in hams with regular pH values. Although it was not significant, the moisture content seems to be lower in heavier hams, probably due to the longer processing length and/or the higher fat content of the piece. Also, TIBAU et al. (2002) detected less moisture in the carcasses from older and heavier pigs, suggesting that the activity of hydrolytic enzymes was reduced in cured hams. The IMF content, detected in the trial, tended to increase linearly (by 0.438 g/100 g per each 10 kg; P<0.10) as pig SW increased. The positive correlation between IMF of pork and SW of pigs has been widely demonstrated in the literature (WEATHERUP *et al.*, 1998; LATORRE *et al.*, 2009b). The different pig age determines a high variability in the composition characteristics of

Table 1. The effect of pig slaughter weight on weight loss of hams during the dry-curing process.

	Slaughter weight, kg			SEM [a]	R^2	Slope	P [b]
	120	130	140				
Ham weight, kg							
Fresh	11.9z	13.5y	14.5x	0.29	0.45	+0.128	***
Dry-cured	7.1z	8.4y	9.4x	0.22	0.54	+0.115	***
Weight loss during dry-curing process, %							
Salting	8.2x	6.7y	6.2y	0.32	0.33	-0.11	***
Post-salting	13.3x	12.4xy	10.3y	0.49	0.37	-0.15	***
Ripening	18.9	18.5	18.3	0.61			NS
Total	40.4x	37.6y	34.8z	0.94	0.34	-0.26	***
Dry-curing process length, weeks	72	76	80				

[a] SEM: standard error of the mean (n=12).
[b] P: level of statistical significance. NS: P>0.10; ***P<0.001. x,y,z Within a row, means without a common superscript letter differ (P<0.05).

Table 2. The effect of pig slaughter weight on some traits related to chemical composition of dry-cured hams [a].

	Slaughter weight, kg			SEM [b]	R^2	Slope	P [c]
	120	130	140				
Moisture, g/100 g	49.97	47.32	47.12	1.202			NS
Intramuscular fat, g/100 g wet matter	12.54	13.20	13.42	0.511	0.21	+0.044	†
Sodium chloride, g/100 g wet matter	5.74	5.30	4.71	0.284	0.31	-0.0511	†
Potassium nitrate, mg/kg wet matter	2.23x	1.23y	1.01z	10.172	0.29	-0.061	**
Sodium nitrite, mg/kg wet matter	153.6x	98.5y	67.8z	0.17	0.28	-4.262	**

[a] Measured on *Semimembranosus* muscle.
[b] SEM: standard error of the mean (n=4).
[c] P: level of statistical significance. NS: P>0.10; †P<0.10; **P<0.01. x,y,z Within a row, means without a common superscript letter differ (P<0.05).

muscle because older pigs had more time for fat retention. In turn, different chemical composition carries out differences in other variables as is described as follows.

The sodium chloride content tended to be reduced in almost 1 percentage point (P<0.10) as SW of pigs increased from 120 to 140 kg which indicates a less amount of salt absorbed by heavier hams. The values detected for it ranged from 4.7 to 5.7 g/100 g wet matter which are normal for this kind of product and similar to those found by GARCÍA-REY *et al.* (2004) and GARCÍA-GIL *et al.* (2012) although these authors concluded that it also depends on other factors such as pH, skin trimming or pressing. It is necessary to ensure a minimum salt content in hams to maintain microbiological stability and to avoid excessive softness (VIRGILI *et al.*, 1995; RUÍZ-RAMÍREZ *et al.*, 2006). On the other hand, an excessive salt content causes undesirable saltiness and contributes to increased risk of high blood pressure (MORGAN *et al.*, 2001). In the present study, the trend to a lower salt content as pig SW increased is positive under a healthy point of view because nowadays low salt levels are recommended in human diet (ARMENTEROS *et al.*, 2012).

The potassium nitrate and sodium nitrite contents decreased (P<0.01) as pig SW increased. The addition of nitrificant salts to dry-cured ham reinforces the preservative effect of salt by inhibiting the growth of *Clostridium botulinum.* Nitrite, which is the active form, also contributes to the development of dry-cured ham flavour and to the formation of the characteristic reddish colour in the final product. However, a compromise between microbiological and toxicological safety must be achieved (TOLDRÁ *et al.*, 2009). Low levels of nitrite in the end product are recommended to minimize the possibility of nitrosamines generation. The reduction in NaCl, $NaNO_2$ and KNO_3 contents might be related to the size or weight of hams. It can be possible that the diffusion of these chemical compounds in the aqueous phase of muscle in heavier pieces will be less intensive and thus heavier hams exhibit lower contents than those lighter.

No effect of treatment was observed on colour of dry-cured ham measured at BF and SM muscles or at subcutaneous fat (P>0.10) (data not shown). The values of L*, a* and b* were similar to those reported by CILLA *et al.* (2006) obtained in hams with the same curing length from pigs of the same crossbred and SW. However, the influence of pig SW has been more deeply evaluated on colour of fresh meat than on that of dry-cured products being the results always subject of debate. As SW increased, some authors (GARCÍA-MACÍAS *et al.*, 1996; LATORRE *et al.*, 2004) found a redder colour and with high myoglobin content in *Longissimus dorsi* muscle whereas other authors (UNRUH *et al.*, 1996; WEATHERUP *et al.*, 1998) observed that colour was independent of SW. In the case of dry-cured products, such as ham, other factors can have more influence on colour than pig SW, i.e. the use of salt nitrite during the processing. In spite of the effect found on sodium nitrite content in the present trial, a lack of influence was observed on colour traits measured by a Minolta chromameter at BF and SM muscles, and also at subcutaneous fat. However, the panelists detected lower cured colour in hams from heavier pigs which might be related, in part, to the low nitrite content detected.

Sensory characteristics

The cured colour of ham decreased in BF (P<0.01) and in SM (P<0.05) muscles as pig SW increased (Table 3). Besides the nitrite content, other factors can affect the colour of cured ham, such as the dry-curing length. In fact, CILLA *et al.* (2005) found, in hams of 8.5-9.5 kg, that the cured colour of BF muscle increased as the processing length increased from 12 to 26 months. Probably, in the present trial, the difference in the length of processing (from 72 to 80 weeks) was not enough to cause a detectable effect.

In addition, panelists observed higher subcutaneous fat whereas SW increased (P<0.001), in agreement with results of several authors who

Table 3. The effect of pig slaughter weight on some sensory characteristics of dry-cured ham [a].

	Slaughter weight, kg			SEM [b]	P [c]
	120	130	140		
Appearance attributes					
Cured colour at *Biceps femoris* muscle	5.89x	5.72x	5.06y	0.173	**
Cured colour at *Semimembranosus* muscle	7.19x	6.86xy	6.61y	0.158	*
Colour homogeneity	5.64	6.00	5.50	0.223	NS
Intramuscular fat at *Biceps femoris* muscle	7.06	7.23	7.33	0.220	NS
Intramuscular fat at *Semimembranosus* muscle	5.92	6.06	6.31	0.221	NS
Subcutaneous fat	5.31x	6.41y	6.44y	0.185	***
Visual defects	1.64	2.00	1.72	0.172	NS
Odour attributes					
Aroma	6.11	5.94	6.25	0.181	NS
Odour defects	1.64	1.56	1.34	0.189	NS
Texture attributes					
Hardness	5.50x	5.00xy	4.58y	0.256	*
Crumbliness	5.56	5.58	5.75	0.268	NS
Pastiness	2.78	3.11	3.58	0.276	NS
Fibrousness	3.51x	3.00xy	2.33y	0.291	*
Flavour attributes					
Flavour	6.08	5.89	5.75	0.182	NS
Saltiness	5.64x	5.44xy	4.94y	0.179	*
Rancid flavour	1.31	0.92	0.94	0.152	NS
Flavour defects	1.33	1.68	1.33	0.205	NS
Acceptability					
Overall quality assessment	6.28	6.22	6.17	0.191	NS

[a] Measured by a numerical scale (1-10).
[b] SEM: standard error of the mean (n=4).
[c] P: level of statistical significance. NS: P>0.10; *P<0.05; **P<0.01; ***P<0.001. x,y Within a row, means without a common superscript letter differ (P<0.05).

measured it instrumentally (WEATHERUP *et al.*, 1998; LATORRE *et al.*, 2009b). The increased adiposity could limit their marketability. In spite of those findings in covering fat and the trend to a higher IMF content detected analytically, the sensory study showed only a numerical effect (P>0.10) on IMF observed by panelists. LATORRE *et al.* (2004) reported that fat thickness at level of *Gluteus medius* muscle, which is covering the ham, increased by 2.3 mm for each 10 kg increase in SW above 116 kg but these authors neither find any influence on IMF. It would confirm the study of HUFF-LONERGAN *et al.* (2002) who reported a positive linear but moderate correlation (r=0.45) between backfat depth of carcass and IMF of meat.

The visual defects ranged from 1.64 to 2.00 points and were not affected by treatment (P>0.10). Also, there were no differences in odour attributes (P>0.10). However, the texture resulted harder and more fibrous in hams from lighter pigs than in those from heavier pigs (P<0.05). RUÍZ-CARRASCAL *et al.* (2002) found that hardness and fibrousness had an inverse relationship with IMF content whereas a significant correlation was detected between IMF or marbling and juiciness. In addition, a lower fibrousness has been also related to lower water losses, due to the different processing length, and also as a consequence of a low salt content and a high proteolitic index (SÁNCHEZ-MOLINERO and ARNAU, 2010). In this sense, a lower salty flavour was detected as pig SW increased (P<0.05) which is in accordance with the differences (trend) found analytically in sodium chloride content. Although high salt content is trying to be avoided in foods for human, this organoleptic attribute is appreciated in products such as dry-cured ham by consumers (CILLA *et al.*, 2005).

Finally, no effect of pig SW was observed on overall quality assessment (P>0.10). It can be explained because the increase of SW would improve some attributes demanded by consumers but also others undesirable. In addition, the lack of a clear effect of pig SW on IMF, whose relation with sensory quality has been well demonstrated, might have also conditioned the final score of panelists.

CONCLUSIONS

The increase of slaughter weight of pigs from 120 to 140 kg (currently accepted by PDO Teruel ham) provided heavier hams that carried out several chemical and sensory differences in the quality of the final product. If certain homogeneity is desirable, the range of slaughter weight of pigs should be shortened. In addition, future research works in processing technology also would help to reduce some differences, especially in chemical composition.

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