ELSEVIER

Meat Science 61 (2002) 347–354

MEAT SCIENCE

www.elsevier.com/locate/meatsci

Influence of sensory characteristics on the acceptability of dry-cured ham

J. Ruiz[a,*], C. García[a], E. Muriel[a], A.I. Andrés[b], J. Ventanas[a]

[a]*Tecnología y Bioquímica de los Alimentos, Facultad de Veterinaria, Universidad de Extremadura, Av. Universidad s/n, 10071, Cáceres, Spain*
[b]*Tecnología de los Alimentos, Escuela de Ingenierías Agrarias, UEX, Ctra. de Cáceres s/n, 06071 Badajoz, Spain*

Received 24 July 2001; received in revised form 28 August 2001; accepted 1 October 2001

Abstract

The influence of different sensory attributes on the acceptability of dry-cured Iberian ham was studied. Partial least squares regression analysis showed that juiciness and several flavour traits were the major attributes positively influencing acceptability of dry-cured Iberian ham, whereas yellowness of the fat, dryness and fibrousness showed a negative influence. Using stepwise multivariate regression, juiciness and flavour intensity were the two traits that better explained the acceptability of dry-cured ham, the linear model obtained showing a regression coefficient of 0.526. The regression coefficient of acceptability with juiciness and flavour intensity was higher using a piecewise linear regression model ($R^2 = 0.759$) showing, therefore, a discontinuous relationship between these variables. However, results on product acceptability have been obtained using trained panellists and it might be possible that the use of a consumer panel would change these conclusions.

Keywords: Iberian ham; Sensory evaluation; Acceptability; PLS; Stepwise regression

1. Introduction

Dry-cured Iberian ham is the most valuable meat product of Spain, with a first-rate consumer acceptance. This high consumer acceptability is mainly sustained on its unique and very appreciated sensory features, which are the consequence of both the characteristics of the raw material and the prolonged traditional processing method that requires between 1 and 2 years ripening. Hams from pure Iberian pigs finished extensively with acorns and cured for about 24 months processing, reach the highest prices in the market. The effect of different factors concerning the raw material and the processing on dry-cured Iberian ham characteristics have been previously considered in several studies (Andrés, Cava, Mayoral, Tejeda, Morcuende, & Ruiz, 2001; Andrés, Ruiz, Mayoral, Tejeda, & Cava, 2000; Ruiz, Cava, Antequera, Martín, Ventanas, & López-Bote, 1998). Moreover, a number of studies have been devoted to elucidate the relationship between several chemical parameters and different sensory traits in Iberian ham (Ruiz, Ventanas, Cava, Andrés, & García, 1999, 2000), and other types of dry-cured hams (Buscailhon et al., 1994; Careri, Mangia, Barbieri, Bolzoni, Virgili, & Parolari, 1993; Flores, Grimm, Toldrá, & Spanier, 1997; Hinrichsen & Pedersen, 1995).

However, little research has been dedicated to determine the relationship between the sensory characteristics of dry-cured ham with its acceptability. Furthermore, it is not unusual in scientific and non-scientific literature to assume the relationship between sensory traits and overall quality found in studies about other meat products, or to confer positive or negative implications to objective sensory traits. Both assumptions may lead to mistakes when evaluating which sensory features really matter in dry-cured ham.

Multivariate statistics are powerful and useful tools for evaluating sensory data. Multivariate analysis can be used for exploratory investigations (to reveal general patterns in data), correlative (to establish links between parameters or to predict specific values of parameters), and classification (to reveal or predict specific groupings among samples) purposes.

The objective of this work was to study the influence of different sensory characteristics on the overall quality of dry-cured Iberian ham and to establish which of

* Corresponding author. Tel.: +34-27-257169; fax: +34-27-257110.
E-mail address: jruiz@unex.es (J. Ruiz).

0309-1740/02/$ - see front matter
PII: S0309-1740(01)00204-2

these sensory traits show a greater effect on the overall quality. This would be useful for ham producers, since it would allow controlling those features directly related to the acceptability of the ham.

2. Materials and methods

2.1. Experimental design

Ten hams obtained from 10 Iberian pigs (140–145 kg live weight) finished on the traditional extensive production system, in which acorns and pasture are the basic food source, were processed into cured hams according to the traditional method during the first stages of processing (Ruiz, Ventanas, Cava, Timón, & García, 1998). In the last stage (the ripening of the hams in a cellar) one group (five hams) was processed in a method shorter than the traditional one, being ripened for 9 months (420 days of total processing time) while the other group (five hams) was ripened for 15 months, according to the traditional prolonged method, the total time of the curing process being 600 days. Hams were bone-in 6.0 ± 0.4 kg weight. Six different slice locations were evaluated. Slices were taken in a parallel direction to the ham bones and to most of the muscle fibers from the muscles included in the samples. Three slice locations corresponded to three depths from the surface of the front (cranial) part of the ham to the ham bones meanwhile the other three corresponded to three depths from the surface of the back (caudal) part to the ham bones. Anatomical references were used in order to obtain slices containing exactly the same muscles.

2.2. Sensory analyses

Ham slices were assessed by a trained panel of 14 members, using a descriptive analysis method (Ruiz, Ventanas et al., 1998). Panellists were trained and had participated in sensory evaluation of dry-cured ham for 2 years. Individual flavour and aroma recognition thresholds were used to select the subjects. Selected subjects underwent further training in dry-cured ham sensory characteristics during two years, using hams with different characteristics (i.e. feeding, breed, etc.). Subjects had a total of 120 h of training in preparation for descriptive analysis. Consistency of panellists was validated using the Rasch model (García, Ventanas, Antequera, Ruiz, Cava, & Alvarez, 1996).

Two samples corresponding to two different slice locations from two hams were evaluated in each session, a total of 30 sessions being carried out (three per week). Sample order was randomized. The panel was held at 11:00, 3 h after breakfast. For each sample three extremely thin slices (0.5 mm) of about 8 g each were given to the panellists. Slices were obtained using a knife and were served immediately on glass plates, both the slices and the plates being at room temperature (20–23 °C). At least one of the slices contained 1cm of subcutaneous fat. A glass of about 100 ml of water at 12 °C was provided for each assessor between the two samples. All sessions were done in a six-booth sensory panel room at 22 °C equipped with white fluorescent lighting. Twenty traits about sensory characteristic of Iberian ham, grouped in appearance of the fat (yellowness, pinkness and oiliness), appearance of the lean (redness, brightness and marbling), texture of the fat (firmness), texture of the lean (dryness, fibrousness, juiciness and hardness), aroma (aroma intensity and "acorn ham" aroma) and flavour (saltiness, sweetness, bitterness, flavour intensity, after taste, cured flavour and rancid flavour), were assessed by the panellists using an unstructured 10-cm scale, ranging from less (0 cm) to more (10 cm), following the sensory descriptive test developed previously by García et al. (1996). The sensory traits, their definitions and extremes are explained in Table 1 (Ruiz, Ventanas et al., 1998).

Acceptability of each ham was evaluated by the panellists once the session has finished using an unstructured 10-cm scale ranging from completely unacceptable (0 cm) to like extremely (10 cm).

2.3. Statistical analyses

Partial least squares regression analysis (PLS) was used to show the relationship between overall quality of the ham and sensory traits evaluated. PLS is a bilinear modelling method where information in the original X-data is projected onto a small number of underlying variables (PLS components), and a linear relationship between such components and the Y-data is calculated. In the present study the PLS1 method, where only one variable (dry-cured ham acceptability) is predicted by several X-variables (sensory traits), was carried out using the Unscrambler software (CAMO, ASA, Oslo, Norway).

The general purpose of multiple regression is also to learn more about the relationship between several independent or predictor variables (sensory traits in this study) and a dependent or criterion variable (overall quality of the ham). The method for selecting the independent variables was the Forward Stepwise Regression (Statistica, StatSoft, Tulsa, OK, USA), in which the independent variables are individually added or deleted from the model at each step of the regression until the "best" regression model is obtained. The F to enter for carrying out the forward stepwise method was set to 3 and the F to remove was set to 1.

In order to study further the relationship between the selected independent variables and the dependent one (acceptability), non-linear regression models were tested (logistic, exponential and piecewise regression) using

Statistica (StatSoft, Tulsa, OK, USA). Further explanation of piecewise linear regression is included in Section 3.

3. Results and discussion

In the present study, samples from hams ripened under either a short or a long processing, and from different slice locations, each one including different muscles, were sensory analysed. These different samples somewhat reproduce the actual heterogeneity in dry-cured Iberian ham features the consumer can find in the market or in the restaurants, and allow enough variability to study the influence of different sensory traits on the acceptability. The effect of processing time and slice location on sensory characteristics has been previously examined (Ruiz, Ventanas et al., 1998). In earlier papers and using information from the same hams, we also examined the relationship between sensory attributes and different chemical variables, such as volatile compounds (Ruiz, Ventanas et al., 1999), amino acids and peptides (Ruiz, García, Díaz, Cava, Tejeda, & Ventanas, 1999), and fat, moisture and fatty acid composition (Ruiz et al., 2000). In the present one, the relationship between acceptability and sensory traits was studied using a PLS1 model, in which a combination of X-variables predicts a dependent Y-variable.

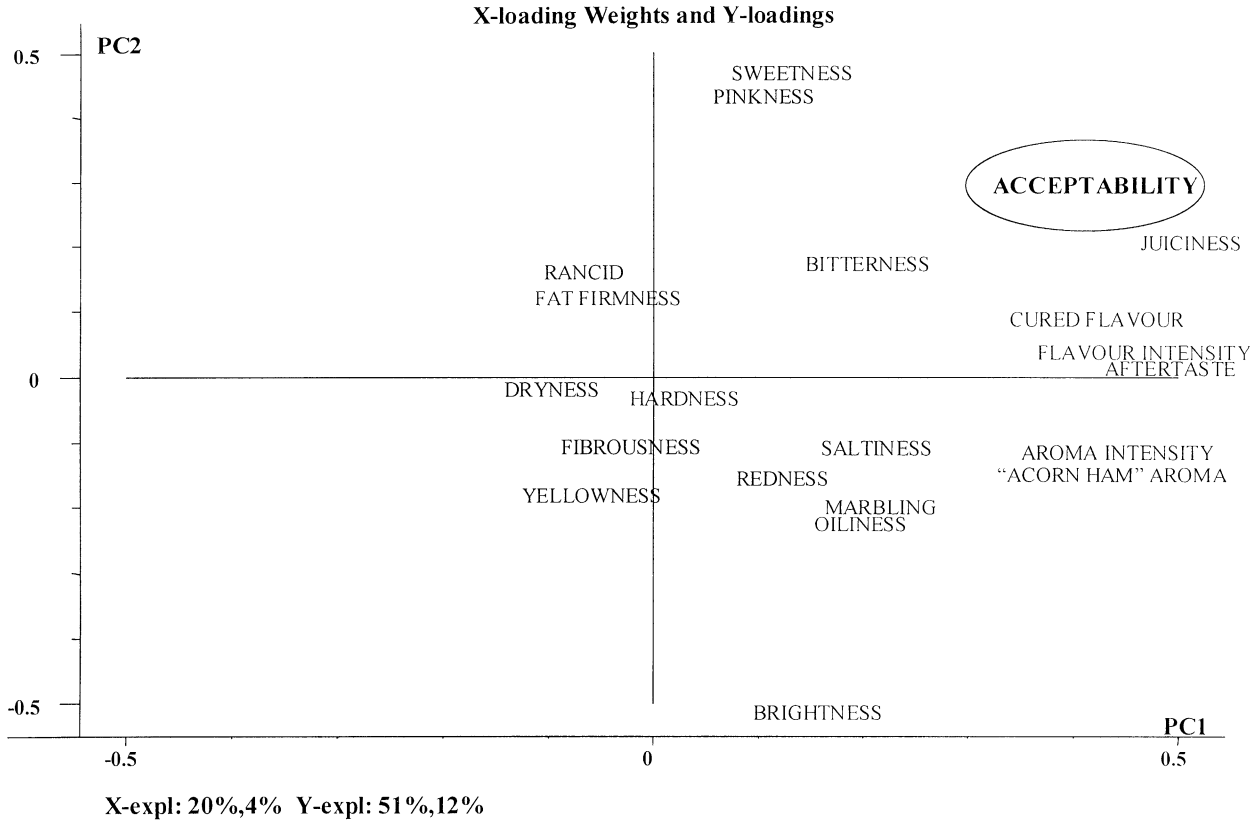
Including preference variables in a descriptive profiling study in which trained panellists are utilised is not an entirely correct procedure (Risvik, 1994). However, in spite of the general agreement among sensory scientists that affective data should be obtained from subjects selected to represent the population of consumers, the practice of having small trained or experienced panels make affective judgements in addition to rating intensity of attributes is fairly common (Love, 1994). In fact, asking affective questions to trained panellists has long been, and still is, a useful approach to study such kind of relationship in meat and meat products (Nute, Jones, Dransfield, & Whelehan, 1987; Safari, Fogarty, Ferrier, Hopkins, & Gilmour, 2001). In the present study, since the number of panellists was rather high (14 members), and the affective question was asked separately at the end of the session, information about the relationship between descriptive traits and preference might be useful.

Fig. 1 is a plot of the loadings for the first two partial least squares components. The first component was able to predict 51% of the variation in the acceptability of the ham whereas the second only explained 12%. Therefore, a fairly good prediction for acceptability using descriptive sensory traits was achieved.

Table 1
Sensory atributes, definitions and extremes[a]

Sensory trait	Definition
Appearance	
Yellowness	Level of yellow colour of the fat (white to intense yellow)
Pinkness	Level of pink areas in the fat (complete white to numerous pink areas)
Oiliness	Level of liquid fat on the surface (complete solid to very oily)
Redness	Intensity of red colour in the lean (pale pink to dark red)
Brightness	Intensity of bright on the lean surface (dull to very bright)
Marbling	Level of visible intramuscular fat (very lean to intense marbled)
Texture	
Fat firmness	Effort required to bite through subcutaneous fat with front teeth (very soft to very firm)
Hardness	Effort required to bite thorough lean and to convert the sample to a swallowable state (very tender to very firm)
Dryness	Amount of juices present in the mouth in the first chews (very dry to very wet)
Fibrousness	Extent to which fibres/strands are perceived on chewing (not to very fibrous)
Juiciness	Impression of lubricated food during chewing (not to very juicy)
Aroma	
Aroma intensity	Level of overall odour before eat the sample (odourless to very intense odour)
"Acorn ham" aroma	Intensity of a special odour, which is characteristic in hams from pigs extensively fed on acorns (very low to very high)
Flavour	
Saltiness	Level of salt taste (not to very salty)
Sweetness	Level of sweet taste (not to very sweet)
Bitterness	Level of bitter taste (not to very bitter)
Flavour intensity	Level of overall flavour (flavourless to very intense flavour)
After-taste	Intensity and time extension of the flavour after swallow the sample (very low to very high)
Cured	Intensity of the typical flavour from cured meat products (very low to very high)
Rancid	Intensity of the rancid flavour (very low to very high)

[a] Each attribute scored in an unstructured line of 10 cm.



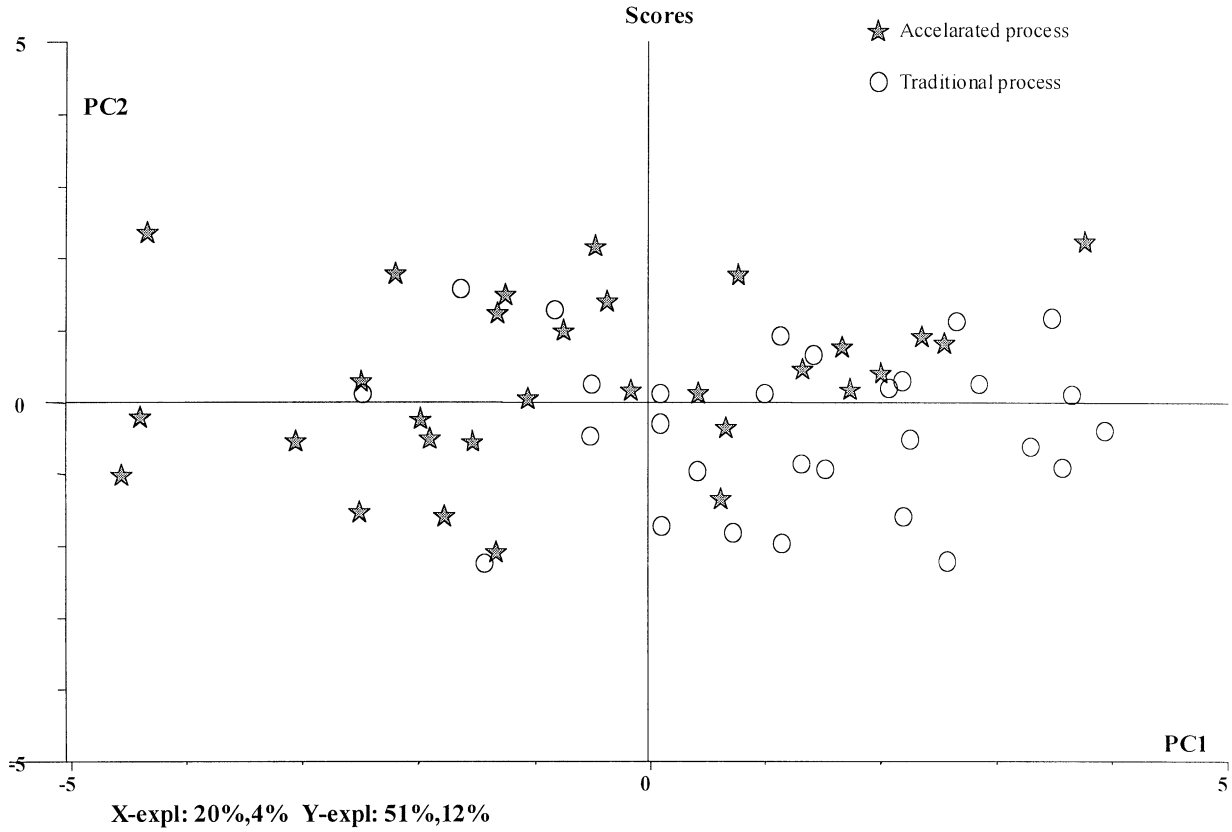


Fig. 1. Loading and score plots of factors 1 and 2 obtained from partial least squares regression analysis (PLS1) of acceptability (dependent variable) and sensory traits (independent variable).

Juiciness and several flavour traits, such as cured flavour and flavour intensity had the highest positive loadings on component 1, in which acceptability also showed the highest loadings. Therefore, it seems that both the juicy sensation perceived during chewing and the flavour are the main features determining the acceptability of dry-cured Iberian ham. This was confirmed carrying out a stepwise multiple regression analysis, in which the independent variables that explain a higher proportion of the variance of the independent one are selected (Table 2). Both juiciness and flavour intensity were the only two variables that fulfilled the conditions for entering in the model (F to enter = 3, F to remove = 1). The linear regression equation obtained showed a regression coefficient (R^2) of 0.526.

Juiciness also has an important role on overall quality of cooked fresh meat (Chambers & Bowers, 1993). Juiciness is related to the degree of lubrication of the food during the chewing and the subsequent swallowing. However, the relationship between the subjective sensation and any objective measurement has not been clearly understood (Winger & Hagyard, 1994). At any rate, the juiciness of meat products is considered to arise from the moisture released by the product during chewing and the moisture from saliva (Winger & Hagyard, 1994). Intramuscular fat stimulates the saliva secretion and contributes itself to the juiciness by coating on the tongue, teeth and other parts of the mouth (Dikeman, 1987). Due to the dehydration that takes place during the processing of dry-cured products, the direct contribution of intramuscular fat itself plays a very important role in the juiciness of this type of products (Ruiz, Ventanas et al., 1998). Therefore, considering together such results and those observed in the present study, intramuscular fat content seems to have a very important role in overall quality of dry-cured Iberian ham, the higher the fat content, the higher the acceptability. Among the factors influencing intramuscular fat content, the swine breed and the rearing are the main ones. Iberian pig is a non-selected pig breed with a high tendency to accumulate fat (Lopez-Bote, 1998). The traditional extensive system in which the pigs are reared involves high slaughter weights and a high energetic diet during the finishing period, when the pigs are almost fully developed (Mayoral et al., 1999). This leads to very fat animals, with almost 60% fat in their carcasses and between 5 and 10% intramuscular fat (Mayoral et al., 1999). It seems, therefore, that both breeding and rearing systems, significantly contribute to the definition of the quality of dry-cured Iberian ham. Thus, modern trends focussed on increasing production of Iberian pig meat, involving crossbreeding with other pig breeds or accelerated rearing systems that reduce the amount of fat, could negatively influence the acceptability of dry-cured Iberian ham.

However, along with sensory characteristics, healthy aspects may affect consumer choice behaviour. In this sense, a possible detrimental effect of high fat content on consumer preference should be considered, because the descriptive panel used might not be able to interpret consumer demand for low-fat products. Nevertheless, high fat content of meat products from Iberian pigs is proverbial and well-known by consumers.

For cooked meat, flavour appears to be not as essential in the definition of product quality as far as no off-flavour can be detected (Pearson, 1994). Conversely, the present results showed that this attribute is likely to play an important role in affecting Iberian ham acceptability. This result confirms traditional and empirical knowledge about dry-cured Iberian ham production, since the procedure to control the ripening and quality of the hams in the industry involves the evaluation of the aroma by an expert. Previous works dealing with this matter pointed out the importance of intense aromas on the quality of ham (Buscailhon et al., 1994; Parolari, 1994).

The flavour of a food is a combination of its taste and smell, which are produced by non-volatile and volatile compounds, respectively. Raw meat is generally characterized as being salty, metallic and bloody tasting with a sweet aroma (Reineccius, 1994). During the subsequent processing numerous precursors react to form the characteristic taste and aroma of dry-cured ham (Ruiz, García et al., 1999; Ruiz, Ventanas et al., 1999). A positive effect of the ripening time on the concentration of some volatile compounds with positive influence on cured flavour of dry-cured Iberian ham has been previously observed, those hams processed under an accelerated method showing a weaker flavour (Ruiz, Ventanas et al., 1999). Not only the processing but the rearing of the pigs has a marked influence on the flavour of Iberian ham, those hams from pigs fed extensively on acorns and pasture showing a stronger flavour (García et al., 1996). Therefore, keeping the traditional rearing system, in which the pigs are free-reared and fed on acorns, and the prolonged processing of the hams, rather than accelerated ones, also appear as essential ways to produce more acceptable Iberian hams.

Neither a quadratic nor an exponential model improved the regression between acceptability and juiciness and flavour intensity (data not shown). Nevertheless, using piecewise linear regression a considerably higher regression coefficient was obtained ($R = 0.759$; Table 3). In piecewise linear regression two separate linear regression equations are estimated; one for the y values that are less than or equal to the breakpoint and one for the y values that are greater than the breakpoint. Given that the regression coefficient obtained using piecewise regression was higher than in the linear regression model, it seems that there is a discontinuity in the relationship between the dependent and the

independent variables. In the present case, the breakpoint was 5.81, and thereafter, coefficient for juiciness remained high whereas that for flavour intensity was much lower. This could mean that flavour intensity is very important in dry-cured Iberian ham acceptability, those hams with a lack of flavour showing a poorer acceptability. However, once the intensity of the flavour is high enough, such relationship is not as strong. On the other hand, juiciness positively influences dry-cured Iberian ham acceptability throughout the studied range, the greater the juiciness, the higher the acceptability of dry-cured Iberian ham.

Most studies dealing with sensory evaluation of cooked fresh meat show that tenderness is the major factor affecting acceptability of fresh meat (Pearson, 1994). However, the present study shows that, contrary to cooked fresh meat, hardness does not influence dry-cured ham acceptability (Fig. 1). Similarly, Buscailhon et al. (1994) mentioned the difficulty in anticipating the effect of dry-cured ham texture on consumer acceptability.

Yellowness of the fat, fibrousness, dryness, fat firmness and rancid flavour showed a negative relationship with acceptability in the PLS regression analysis (Fig. 1). However, it seems that this negative influence was not very important, since the absolute values of the loadings were small.

Yellowness of the fat and rancid flavour are caused by lipid oxidation. During ripening of dry-cured Iberian ham lipid oxidative phenomena develop, leading to formation of several flavour compounds, some of them showing rancid notes, specially those from oxidation of linoleic (C18:2 *n*-6) and arachidonic (C20:4 *n*-6) acids (Ruiz, Ventanas et al., 1999). As a consequence of these oxidative reactions, coloured polymers are formed, the fat exhibiting yellow to orange colours (Barton-Gade, 1984). Yellowness of the fat is considered a defect in fresh meat (Barton-Gade, 1984) and some meat products (Arvanitoyannis, Bloukas, Pappa, & Psomiadou, 2000). Rancidity is a major problem in the meat industry, specially in processed meat products that should be stored either refrigerated or frozen (Skibsted, Mikkelsen, & Bertelsen, 1998). Therefore, it seems that, following the same trend as in many other meat products, excessive lipid oxidation leads to decreased acceptability in dry-cured Iberian ham.

Presence of antioxidant substances like α-tocopherol reduces lipid oxidation during ham processing (Isabel et al., 1999). Free-range Iberian pigs fed on acorns and pasture shows higher amounts of compounds with antioxidative properties in their muscles than those fed on concentrates, most likely because of the high amount of tocopherol in the pasture (Rey, Lopez-Bote, & Arias, 1997). Moreover, those pigs fed on acorns show high amounts of oleic acid (C18:1 *n*-9) in muscle lipids, whereas those fed on concentrates usually show higher amounts of linoleic acid (C18:2 *n*-6; Andrés et al., 2001). The latter is more prone to autooxidation and compounds derived from its oxidation show rancid notes. These two features lead to lower amounts of compounds from lipid oxidation and reduced rancid notes in hams from pigs fed on acorns and pasture (Rey et al., 1997). These results strengthen the importance of feeding the pigs on acorns and pasture in order to obtain dry-cured Iberian ham with higher acceptability.

The negative influence of some textural traits like fibrousness or dryness on overall acceptability has been previously described in cooked meat (Chambers & Bowers, 1993). Fibrousness is caused both by the presence of insoluble collagen and by the aggregation of myofibrilar proteins due to the dehydration occurred during the ripening process (Córdoba, Antequera, Ventanas, López-Bote, García, & Asensio, 1994). Dryness is mainly determined by the amount of moisture retained in the ham after the processing (Chizzolini et al., 1996). Therefore, these two traits strongly depend on the degree of dehydration achieved during the processing, which is controlled by the temperature and relative

Table 2
Estimation of the relationship between dry-cured Iberian ham acceptability and the sensory traits by the multiple regression stepwise method

	Intercept	Coef. juiciness	Coef. flavour intensity	R^2	*F* to enter	*P*
Step 1	1.479	0.668		0.446	46.75	0.0000
Step 2	0.679	0.558	0.359	0.526	9.54	0.0031

Table 3
Estimation of the relationship between dry-cured Iberian ham acceptability and juiciness and flavour intensity by the piecewise linear regression method

$Intercept_1$	Coef. juiciness	Coef. flavour intensity	$Intercept_2$	Coef. juiciness	Coef. flavour intensity	Breakpoint	R^2
1.890	0.337	0.305	3.646	0.324	0.130	5.812	0.759

humidity conditions underwent by the hams during the ripening process, and the characteristics of the raw material, specially the water holding capacity and the amount of fat. Since the incidence of exudative meats in Iberian pigs is practically inexistent (García Cachán, 1992), fat content is the main factor in the raw material influencing the degree of dehydration during dry-cured Iberian ham processing. As cited previously, Iberian ham processing is considerably long. If the process is shortened, flavour might be impaired (Ruiz, Ventanas et al., 1999). Therefore, again intramuscular fat content seems to be important in acceptability, since it regulates the degree and rate of dehydration, high levels of fat allowing long processing times that produce intense flavour, with a degree of dehydration low enough to avoid negative consequences on texture, and hence, on overall acceptability.

Finally, when observing the score values of each sample in the PLS components (Fig. 1), long processing hams tended to locate closer to the traits positively related to acceptability. This was most likely due to differences in flavour traits, since textural traits like juiciness or dryness did not show statistical differences between processing times, as it has been discussed in a previous study (Ruiz, Ventanas et al., 1998).

4. Conclusions

Juiciness and flavour intensity seem to be the most important features in determining dry-cured Iberian ham acceptability, the juicier and the more intense the flavour of the ham, the better the ham quality. Consequently, both the raw material and processing, influence dry-cured Iberian ham acceptability, since juiciness is mainly based on intramuscular fat content, which depends on raw material composition, and flavour is developed during the processing from a number of precursors present in the raw material. Therefore, these results highlight the importance of maintaining the traditional free-range rearing system of Iberian pigs and the prolonged processing. Further research involving a larger number of hams and a consumer panel assessment is needed to better understand the relationship between sensory profile and dry-cured ham acceptability.

References

Andrés, A. I., Cava, R., Mayoral, A. I., Tejeda, J. F., Morcuende, D., & Ruiz, J. (2001). Oxidative stability and fatty acid composition of pig muscles as affected by rearing system, crossbreeding and metabolic type of muscle fibre. *Meat Science*, *59*, 39–47.

Andrés, A. I., Ruiz, J., Mayoral, A. I., Tejeda, J. F., & Cava, R. (2000). Infuence of rearing conditions and crossbreeding on muscle colour in Iberian pigs. *Food Science and Technology International*, *6*, 315–321.

Arvanitoyannis, I. S., Bloukas, J. G., Pappa, I., & Psomiadou, E. (2000). Multivariate data analysis of Cavournas—a Greek cooked meat product. *Meat Science*, *54*, 71–75.

Barton-Gade, P. A. (1984). Some experiences on measuring the quality of pork fat. In J. D. Wood (Ed.), *Fat quality in lean pigs* (pp. 47–52). Langford: AFRC Meat Research Institute.

Buscailhon, S., Berdagué, J. L., Bousset, J., Cornet, M., Gandemer, G., Touraille, C., & Monin, G. (1994). Relations between compositional traits and sensory qualities of French dry-cured ham. *Meat Science*, *37*, 229–243.

Careri, M., Mangia, A., Barbieri, G., Bolzoni, L., Virgili, R., & Parolari, G. (1993). Sensory property relationship to chemical data of Italian type dry-cured ham. *Journal of Food Science*, *58*, 968–972.

Chambers, E., & Bowers, J. R. (1993). Consumer perception of sensory qualities in muscle foods. *Food Technology*, *47*, 116–120.

Chizzolini, R., Novelli, E., Campanini, G., Dazzi, G., Madarena, G., Zanardi, E., Pachioli, M. T., & Rossi, A. (1996). Lean colour of green and matured Parma hams: comparative evaluation of sensory and objective data. *Meat Science*, *44*, 159–172.

Córdoba, J. J., Antequera, T., Ventanas, J., López-Bote, C., García, C., & Asensio, M. A. (1994). Hydrolysis and loss of extractability of proteins during ripening of Iberian ham. *Meat Science*, *37*, 217–227.

Dikeman, M. E. (1987). Fat reduction in animals and the effects on palatability and consumer acceptance of meat products. *Proceedings of the Reciprocal Meat Conference*, *40*, 93–105.

Flores, M., Grimm, C. C., Toldrá, F. A., & Spanier, A. M. (1997). Correlations of sensory and volatile compounds of Spanish 'Serrano' dry-cured ham as a function of two processing times. *Journal of Agricultural and Food Chemistry*, *45*, 2178–2186.

García, C., Ventanas, J., Antequera, T., Ruiz, J., Cava, R., & Alvarez, P. (1996). Measuring sensorial quality of Iberian ham by Rasch model. *Journal of Food Quality*, *19*, 397–412.

García Cachán, M. D. (1992). Carcass and meat quality of pigs from Castilla-León. PhD thesis. University of León.

Hinrichsen, L. L., & Pedersen, S. B. (1995). Relationship among flavor, volatile compounds, chemical changes, and microflora in Italian-type dry-cured ham during processing. *Journal of Agricultural and Food Chemistry*, *43*, 2932–2940.

Isabel, B., Timón, M. L., Cava, R., García, C., Ruiz, J., Carmona, J. M., & López-Bote, C. J. (1999). Dietary alpha-tocopheryl acetate supplementation modify dry-cured ham volatile profile and acceptability. *Irish Journal of Agricultural and Food Research*, *38*, 137–142.

Lopez-Bote, C. J. (1998). Sustained utilization of the Iberian pig breed. *Meat Science*, *49*(suppl), S17–S27.

Love, J. (1994). Product acceptability evaluation. In A. M. Pearson, & T. R. Dutson (Eds.), *Quality attributes and their measurement in meat, poultry and fish products* (pp. 337–358). London: Blackie Academic & Professional.

Mayoral, A. I., Dorado, M., Guillén, M. T., Robina, A., Vivo, J. M., Vázquez, C., & Ruiz, J. (1999). Development of meat and carcass quality characteristics in Iberian pigs reared outdoors. *Meat Science*, *52*, 315–324.

Nute, G. R., Jones, R. C. D., Dransfield, E., & Whelehan, O. P. (1987). Sensory characteristics of ham and their relationships with composition, visco-elasticity and strength. *International Journal of Food Science and Technology*, *22*, 461–476.

Parolari, G. (1994). Taste quality of Italian raw ham in a free-choice profile study. *Food Quality and Preference*, *5*, 120–133.

Pearson, A. M. (1994). Introduction to quality attributes and their measurement in meat, poultry and fish products. In A. M. Pearson, & T. R. Dutson (Eds.), *Quality attributes and their measurement in meat, poultry and fish products* (pp. 1–17). London: Blackie Academic & Professional.

Reineccius, G. (1994). Flavor and aroma chemistry. In A. M. Pearson, & T. R. Dutson (Eds.), *Quality attributes and their measurement in meat, poultry and fish products* (pp. 184–201). London: Blackie Academic & Professional.

Rey, A. I., Lopez-Bote, C. J., & Arias, R. S. (1997). Effect of extensive feeding on alpha-tocopherol concentration and oxidative stability of muscle microsomes from Iberian pigs. *Animal Science*, *65*, 515–520.

Risvik, E. (1994). Sensory properties and preferences. *Meat Science*, *36*, 67–77.

Ruiz, J., Cava, R., Antequera, T., Martín, L., Ventanas, J., & López-Bote, C. J. (1998). Prediction of the feeding background of Iberian pigs using the fatty acid profile of subcutaneous, muscle and hepatic fat. *Meat Science*, *49*, 155–163.

Ruiz, J., García, C., Díaz, M. C., Cava, R., Tejeda, J. F., & Ventanas, J. (1999). Dry cured Iberian ham non-volatile components as affected by the length of the curing process. *Food Research International*, *32*, 643–651.

Ruiz, J., Ventanas, J., Cava, R., Andrés, A. I., & García, C. (1999). Volatile compounds of dry-cured Iberian ham as affected by the length of the curing process. *Meat Science*, *52*, 19–27.

Ruiz, J., Ventanas, J., Cava, R., Andrés, A. I., & García, C. (2000). Textural traits in dry-cured ham as affected by fat content and composition. *Food Research International*, *33*, 91–95.

Ruiz, J., Ventanas, J., Cava, R., Timón, M. L., & García, C. (1998). Sensory characteristics of Iberian ham: influence of processing time and slice location. *Food Research International*, *31*, 53–58.

Safari, E., Fogarty, N. M., Ferrier, G. R., Hopkins, L. D., & Gilmour, A. (2001). Diverse lamb genotypes. 3. Eating quality and the relationship between it objective measurement and sensory assessment. *Meat Science*, *57*, 153–159.

Skibsted, L. H., Mikkelsen, A., & Bertelsen, G. (1998). Lipid-derived off-flavours in meat. In F. Shahidi (Ed.), *Flavor of meat, meat products and seafood* (pp. 217–256). London: Blackie Academic & Professional.

Winger, R. J., & Hagyard, C. J. (1994). Juiciness- its importance and some contributing factors. In A. M. Pearson, & T. R. Dutson (Eds.), *Quality attributes and their measurement in meat, poultry and fish products* (pp. 94–124). London: Blackie Academic & Professional.