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Sensory characteristics of Iberian ham: influence of processing time and slice location

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Sensory characteristics of ten hams from Iberian pigs ripened for 420 and 600 days were assessed. Six slice locations were evaluated, corresponding to three depths from the caudal and the cranial part of each ham. Processing time had the most effect on aroma and flavour traits, hams ripened in the long method showing higher values in flavour strength ($p \leq 0.0001$), cured flavour ($p \leq 0.001$) and after taste ($p \leq 0.0001$); it also affected two appearance characteristics but did not show any texture difference. On the other hand, slice location caused changes in the appearance and the texture but had a low influence of the flavour. © 1998 Canadian Institute of Food Science and Technology. Published by Elsevier Science Ltd. All rights reserved

Keywords: Iberian ham, sensory evaluation, processing time, slice location.

INTRODUCTION

Cured Iberian ham is the most valuable meat product of Spain, with a first-rate consumer acceptance. It is produced from uncooked hams of Iberian hogs, following a prolonged traditional method that requires between 1 and 2 years ripening. Hams from pure Iberian pigs finished extensively with acorns and cured during about 24 months processing, reach the highest prices in the market. The effect of breeding and feeding on the Iberian ham characteristics have been previously studied in several papers (Antequera *et al*., 1992, 1996; López *et al*., 1992; García *et al*., 1996; Cava *et al*., 1997; Ruiz *et al*., 1998). Regarding ripening time, the meat industry has tried to use shorter processes in order to minimise costs, even though hams with a shorter ripening time have a lower price in the market.

Several researchers have identified chemical changes occurring in different muscles during the ripening of Iberian ham, e.g., protein and amino acids evolution (Córdoba *et al*., 1994*a*,*b*), lipolysis and lipid oxidation (Antequera *et al*., 1992, 1993), Maillard reactions (Ventanas *et al*., 1992) and volatile compounds formation (García *et al*., 1991; López *et al*., 1992). The changes during processing and the differences between muscles reported in these papers affect compounds related to sensory characteristics, but there is no scientific study directly focused on these characteristics.

In contrast to other types of ham in which several studies have shown differences in sensory characteristics between hams from short and long matured ripening (Careri *et al*., 1993; Buscailhon *et al*., 1994), very little research has been devoted in the past to determine sensory characteristics along processing in Iberian hams. The results obtained in other kind of hams are not always useful in the case of dry-cured Iberian ham, since in the latter the ripening time is much longer and some of the sensory attributes are different. Some of these specific traits have been selected in a previous paper (García *et al*., 1996), from those employed usually by ham manufacturers and consumers.

The objectives of this work were (1) to determine the differences in the sensory characteristics of dry-cured Iberian hams reaching the longest and the shortest processing time allowed by the Spanish Specific Designation of Origin (SDO) "Dehesa de Extremadura" (Diario Oficial de Extremadura, 1990) for this type of hams, in order to check if they could be the basis of the differences in market prices and (2) to study the influence of the anatomical location on these sensory characteristics.

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MATERIALS AND METHODS

Experimental design

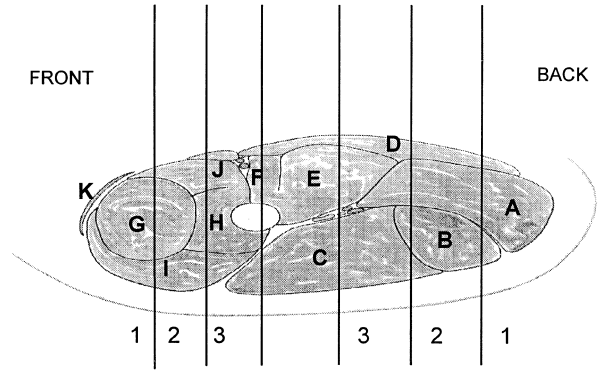
A 2×6 factorial design with two processing times and six slice locations was conducted to evaluate the influence of ripening length and variations within the ham on sensory characteristics of dry-cured Iberian ham. Ten hams obtained from ten Iberian pigs (140–145 kg live weight), which were finished 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 (Córdoba *et al.*, 1994*b*). Relative humidity and temperature from each processing stage are shown on Table 1. In the last stage (the ripening of the hams in a cellar) one group was processed in a method shorter than the traditional one, being left to ripen for 9 months (420 days of total processing time) (**420d**). The other group was ripened for 15 months, according to the traditional prolonged method, the total time of the curing process being 600 days (**600d**). Hams were bone-in 6.0 ± 0.4 kg weight. These times of processing correspond to the minimum and the maximum required for Iberian hams of this weight by the Specific Designation of Origin (SDO) "Dehesa de Extremadura" (Diario Oficial de Extremadura, 1990). Six different slice locations were evaluated; they are represented in Fig. 1. 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 (**F-1**, **F-2**, **F-3**) meanwhile the other three corresponded to three depths from the surface of the back (caudal) part to the ham bones (**B-1**, **B-2** and **B-3**). Anatomical references were used in order the slices contain exactly the same muscles.

Sensory analyses

In order to evaluate the influence of the last phase of ham ripening (the cellar stage) extension and the slice location on the ham sensory characteristics, ten hams were assessed by a trained panel of 14 members, using a descriptive analysis method (García *et al.*, 1996) for twenty different attributes.

Panelists 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., pig feeding, pig breed...). Subjects had a total of 120 h of training in preparation for QDA.

Two samples corresponding to two different slice locations from two hams were evaluated in each session, a total of thirty sessions being carried out (3 per week). Sample order was randomized. The panel was held at 11



MUSCLES

A.- *M. semimembranosus*
B.- *M.semitendinosus*
C.- *M. biceps femoris*
D.- *M. gracilis*
E.- *M.adductor*
F.- *M. pectineus*
G.- *M. rectus femoris*
H.- *M. vastus intermedius*
I.- *M. vastus lateralis*
J.- *M. vastus medialis*
K.- *M. sartorius*

Fig. 1. Ham slice locations and muscle involved in each location.

Table 1. Stages in the processing of Iberian hams, together with the relative humidity, temperature and duration of each one

Stage of processing	Characteristics
Salting	The hams were thoroughly rubbed with salt containing 1% potassium nitrate, and placed in piles with alternate beds of ham and salt for 10 days at 1–4°C and 90–95% relative humidity (RH)
Postsalting	The hams were brushed to free them of the salt left on the surface. Then they were hung and left for 90 days in a chamber. The first 60 days at 4°C and 90% RH, and then the temperature was increased and the RH decreased to 15°C and 80% RH respectively
Drying	During the summertime, the hams were kept at environmental conditions for 60 days, where the temperatures varied between 18 and 30°C and the RH between 50 and 80%
Ripening	The hams were divided into two groups and kept in the same cellar; one group was left to ripen for 9 months (420 days of total processing time) and the other for 15 months (600 days of total processing time). The conditions in the cellar were highly constant: temperatures varied between 15 and 20°C and RH between 60 and 70%

a.m., 3 h after breakfast. Three extremely thin slices (0.5 mm) of about 8 g for each sample were given to the panelists. 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 slice containing 1 cm of subcutaneous fat was given to each panelist. 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 6 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 14 panelists using an unstructured 10 cm line, 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 2.

Statistical analyses

The effect of duration of processing (**420** and **600** days) and the location of the slice (**F-1**, **F-2**, **F-3**, **B-1**, **B-2** and **B-3**) were analysed by two-way analysis of variance together with interaction (duration × location), using the GLM procedure (SAS, 1988). If the location effect or the interaction was significant, the Tukey's test was used at the 5% level to make pairwise comparisons between sample means. Data were presented as the mean of each group and standard error of the mean (SEM) together with the p values of the main effect and interaction. Data of interaction are presented as a figure only when the interaction showed $p \leq 0.05$ values.

RESULTS AND DISCUSSION

Tables 3 and 4 show the scores from the two different processing times and the six slice location in appearance and texture traits. Only three traits (fat yellowness, lean redness and hardness) showed interaction between the two variables studied (processing time and slice location) (Fig. 2). Means from each slice location in 420 and

Table 2. Sensory atributes, definitions and extremes

Sensory traits	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)
Bright	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 which is present in the mouth in the first chews (very dry to very wet)
Fibrousness	Extent to which fibers/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)

Each attribute scored in an unstructured line of 10 cm.

Table 3. Mean values for the appearance traits evaluated of samples from dry-cured Iberian ham of two processing times (420d and 600d) and six slice locations (F-1, F-2, F-3, B-1, B-2 and B-3) together with the *p* values of both factors and of interaction

Sensory traits	Processing time		Slice location						SEM	*p* values		
	420 $n=30$	600 $n=30$	F1 $n=10$	F2 $n=10$	F3 $n=10$	B1 $n=10$	B2 $n=10$	B3 $n=10$		Processing time	Slice location	Interaction
Yellowness	2.99	3.02	3.11^{a}	3.18^{a}	3.20^{b}	2.30^{b}	3.10^{c}	3.12^{a}	0.07	0.8357	0.0020	0.0470
Pinkness	3.27	2.38	3.13^{ab}	2.96^{abc}	3.40^{a}	2.51^{bc}	2.59^{bc}	2.25^{c}	0.08	0.0001	0.0001	0.1131
Oiliness	5.92	5.76	5.34^{b}	5.71^{ab}	6.08^{a}	6.24^{a}	5.78^{ab}	5.91^{ba}	0.07	0.2901	0.0050	0.4954
Redness	5.25	5.48	4.82^{c}	6.20^{a}	5.79^{ab}	4.27^{d}	5.39^{b}	5.80^{ab}	0.06	0.0294	0.0001	0.0035
Bright	5.23	5.37	4.63^{c}	5.12^{c}	5.89^{a}	5.78^{ab}	5.18^{bc}	5.26^{abc}	0.07	0.2907	0.0001	0.4071
Marbling	4.34	4.57	3.05^{c}	3.45^{c}	4.33^{b}	5.98^{a}	5.55^{a}	4.47^{b}	0.08	0.0775	0.0001	0.4593

Means within a row in slice locations followed different letters differ ($p \leq 0.05$).Values represent scores from an unstructured scale ranging from less (0) to more (10).

Table 4. Mean values for the texture traits evaluated of samples from dry-cured Iberian ham of two processing times (420d and 600d) and six slice locations (F-1, F-2, F-3, B-1, B-2 and B-3) together with the *p* values of both factors and of interaction

Sensory traits	Processing time		Slice location						SEM	*p* values		
	420 $n=30$	600 $n=30$	F1 $n=10$	F2 $n=10$	F3 $n=10$	B1 $n=10$	B2 $n=10$	B3 $n=10$		Processing time	Slice location	Interaction
Firmness	3.36	3.45	3.79^{a}	3.25^{ab}	3.37^{ab}	2.98^{b}	3.52^{ab}	3.52^{ab}	0.07	0.5003	0.0193	0.9051
Hardness	3.95	4.06	4.14	4.03	4.15	3.88	3.92	3.91	0.06	0.4110	0.7241	0.0284
Dryness	3.56	3.66	4.17^{a}	3.67^{ab}	3.53^{b}	3.22^{b}	3.41^{b}	3.65^{ab}	0.07	0.4311	0.0010	0.2446
Fibrousness	3.78	3.96	3.98	3.66	3.75	3.75	3.80	4.31	0.07	0.2176	0.0955	0.5881
Juiciness	5.55	5.79	5.33^{b}	5.69^{ab}	5.78^{b}	6.17^{a}	5.72^{ab}	5.38^{b}	0.06	0.0572	0.0011	0.9468

Means within a row in slice locations followed different letters differ ($p \leq 0.05$).Values represent scores from an unstructured scale ranging from less (0) to more (10).

600 days processing hams of this three traits are represented in Fig. 2.

Processing time did not affect the fat oiliness, but the pinkness of the fat was different ($p \leq 0.0001$). Yet, all traits related with the fat appearance were affected by the location of the slice. Fat pinkness is described as a particular characteristic of Iberian hams. However, neither any scientific investigation about this colour of the fat, nor any relationship with physical or chemical parameters has been found in the literature. Further research about the relationship between the pink colour of the fat with unsaponifiable matter compounds is currently being carried out. The oiliness was affected ($p \leq 0.05$) by slice location as well. Most factors affecting oiliness were controlled in this experiment (e.g., temperature during the sensory evaluation, pigs feeding, slaughter weight, pigs sex...). So, the variations in oiliness were most likely attributable to differences in fatty acid composition between anatomical location of fat, as reported in other pig breeds by Malmfors *et al.* (1978).

The redness of the lean was the only trait of lean appearance that showed changes produced by processing time (Table 3). Variations in the red colour of lean agree with what is generally admitted in Iberian ham industry and with the increase in pigment concentration during the whole process we have observed in a previous experiment (García *et al.*, 1992). This variation was not equal in every slice location, as it reflected interaction between both main effects (Fig. 2), the superficial back slices of the ham showing lower redness values in the longer processing time. This is most likely due to these slices are less protected against ambient exposure than deeper ones, and this fact could affect the stability of the nitrosilmyoglobin (Parolari, 1996).

All traits concerning lean appearance were highly affected by slice location ($p \leq 0.0001$). Muscles within the ham possess a different muscle fibre type population, this fact affecting myoglobin and intramuscular fat content (Beecher *et al.*, 1965). Both pigment and fat differences among muscles have been corroborated in Iberian ham in previous studies (García *et al.*, 1992; Antequera *et al.*, 1994), and satisfactorily explain the sensory results shown in the present paper.

No texture trait reflected any effect of the processing time (Table 4), and only the hardness of the lean presented a significant interaction between duration and slice location (Fig. 2). That means that variations in lean hardness were different among slice locations over the two processing times, but when observing the figure there were no trends apparent. An increase in firmness

and dryness during the curing process has been reported by Buscailhon *et al.* (1994) in French cured ham, but by comparing hams of 179 and 273 days of processing. In the study reported in the present paper, the processing time was much longer, and in the final stage the moisture losses that could cause an increase in dryness or hardness, were low enough to go undetected (about 40% in 420 days hams and nearly 38% in 600 day ones).

Slice location affected the fat firmness ($p \leq 0.05$), the lean dryness ($p \leq 0.001$) and the juiciness ($p \leq 0.05$) (Table 4). These results point out that differences in muscle composition and the different extent of dehydration depending on the distance from the muscle to the ham surface, cause differences in texture traits. These findings have been previously reported by Matassino *et al.* (1987) in Parma ham.

Most aroma and flavour traits were affected by the shortening of the processing time (Table 5). There was an increase in saltiness ($p \leq 0.05$) and a decrease in sweetness ($p \leq 0.0001$) from 420 to 600 days. The sodium chloride, amino acids, peptides and nucleotides are mainly responsible for the taste of meat and meat products (MacLeod, 1986), and, in cured ham, specially the glutamic acid and salt concentrations (Careri *et al.*, 1993). So, proteolysis, further amino acid biochemical reactions, i.e. Maillard reactions (Ventanas *et al.*, 1992) and dehydration are the alleged causes of the changes in these flavour traits.

The two aroma traits (aroma intensity and 'acorn ham' aroma) and three flavour traits (flavour intensity, after-taste and cured flavour) exhibited higher values in hams with the longer processing time (Table 5). An increase in flavour intensity along the ripening has also been reported in other ham types (Careri *et al.*, 1993; Buscailhon *et al.*, 1994). In fact, a weaker flavour of Iberian hams ripened throughout a shorter processing is a

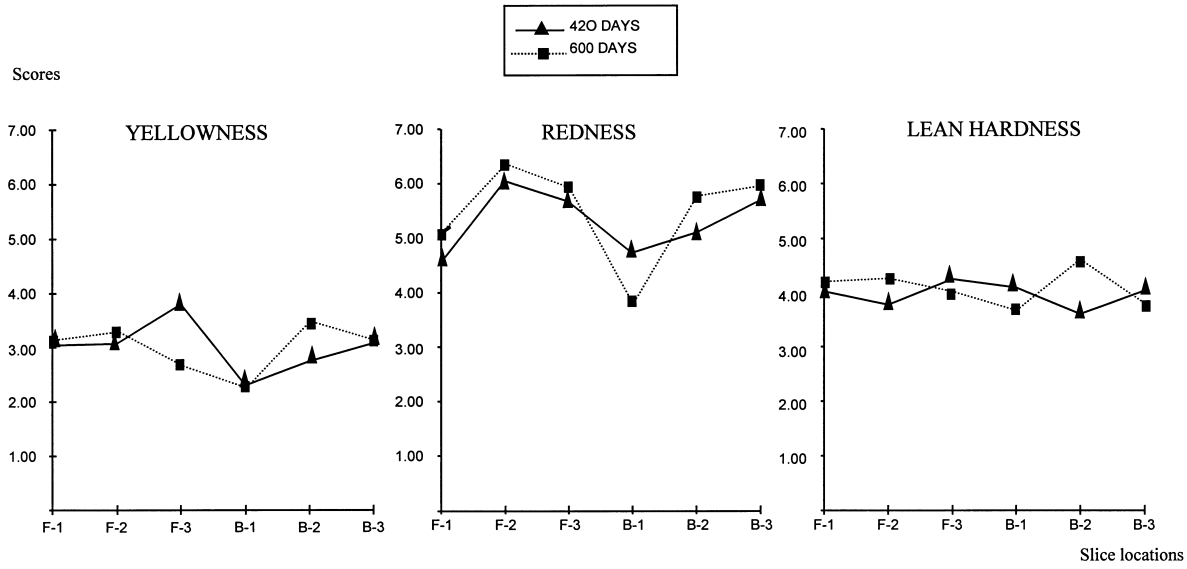


Fig. 2. Sensory score means of traits that showed interaction (duration × location) of each slice location in hams from 420 and 600 days of processing. Each value is the mean of 5 samples. Values represent scores from an unstructured scale ranging from less (0) to more (10).

Table 5. Mean values for the aroma and the flavour traits evaluated of samples from dry-cured Iberian ham of two processing times (420d and 600d) and six slice locations (F-1, F-2, F-3, B-1, B-2 and B-3) together with the *p* values of both factors and of interaction

	Processing time		Slice location							*p* values		
Sensory traits	420 $n=30$	600 $n=30$	F1 $n=10$	F2 $n=10$	F3 $n=10$	B1 $n=10$	B2 $n=10$	B3 $n=10$	SEM	Processing time	Slice location	Interaction
Aroma intensity	5.32	5.74	4.89[b]	5.70[a]	5.79[a]	5.65[a]	5.59[a]	5.63[a]	0.07	0.0026	0.0014	0.1609
Acorn ham aroma	5.35	5.78	5.11	5.62	5.66	5.84	5.68	5.51	0.07	0.0031	0.0627	0.5174
Saltiness	3.80	4.17	4.11	4.08	3.91	3.85	4.11	3.87	0.08	0.0179	0.8333	0.6706
Sweetness	2.90	2.37	2.82	2.48	2.55	2.93	2.41	2.57	0.07	0.0001	0.1977	0.6035
Bitterness	1.35	1.41	1.43	1.34	1.35	1.34	1.39	1.44	0.06	0.5785	0.9928	0.3699
Flavour intensity	5.05	5.61	5.07	5.35	5.60	5.27	5.52	5.19	0.06	0.0001	0.1395	0.8604
After taste	4.94	5.52	4.95	5.31	5.37	5.12	5.42	5.23	0.07	0.0001	0.3668	0.9649
Cured	4.92	5.43	5.31	5.41	5.35	5.11	5.14	4.72	0.08	0.0009	0.1340	0.5735
Rancid	2.49	2.21	2.68	2.31	2.56	2.25	2.07	2.16	0.08	0.0600	0.1292	0.7459

Means within a row in slice locations followed different letters differ ($p \leq 0.05$).Values represent scores from an unstructured scale ranging from less (0) to more (10).

common problem, well known by ham manufacturers and consumers. This problem is known as 'lack of cellar' in the trade (Ventanas and Córdoba, 1992) and is one of the main reasons argued by the Iberian ham Specific Designation of Origin (SDO) to reject hams ripened during a time shorter tim 420 days. In the present paper, the occurrence of this flavour taint in Iberian ham has been detected with a trained panel for the first time. It is noticeable that there were differences in flavour traits scores between hams reaching processing times that comply with the conditions established by the SDO. These observations are in agreement with the increase of some volatile compounds during ripening reported in Iberian ham (Antequera *et al*., 1992; Ventanas *et al*., 1992) and other types of hams (Careri *et al*., 1993; Buscailhon *et al*., 1994; Bolzoni *et al*., 1996). On the other hand, only aroma intensity exhibited differences ($p \leq 0.05$) among slice locations of the flavour traits evaluated.

CONCLUSIONS

Iberian ham flavour was enhanced by increasing the processing time from 420 to 600 days; however, texture and appearance showed little difference between the two processing times. This could be one of the reasons that explains the lower price in the trade of hams ripened in a shorter process than the traditional one. On the other hand, slice location affected mainly the texture and the appearance, with small differences in aroma and flavour.

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