Food Chemistry 67 (1999) 423–427

Food Chemistry

www.elsevier.com/locate/foodchem

Analytical, Nutritional and Clinical Methods Section

Sensory and analytical properties of Spanish dry-cured ham of normal and defective texture

J.A. García-Garrido [a,*], R. Quiles-Zafra [a], J. Tapiador [a], M.D. Luque de Castro [b]

[a] R & D Department, Navidul S.A., E-45500 Torrijos, Toledo, Spain
[b] Department of Analytical Chemistry, Faculty of Sciences, University of Córdoba, E14004 Córdoba, Spain

Received 22 June 1998; accepted 5 May 1999

Abstract

The influences of sensory features, such as pastiness, colour, crusting and the presence of white spots (mainly due to tyrosine deposits, but also to phenylalanine), as well as that of analytical parameters, such as pH and moisture, fat, protein, salt and non-protein nitrogen contents, on the quality of Spanish dry-cured ham, were evaluated. For this purpose, 600 hams from 20 batches, produced over a 10-month period, were evaluated for the previous factors. Regression analysis of the data thus obtained revealed relationships such as those of texture defects to colour and to analytical parameters (moisture, salt and protein contents) in muscle of the end product, to be the keys to a defective texture in ham. Consequently, these parameters are essential with a view to assessing the quality of the raw material.

1. Introduction

The quality of dry-cured ham is defined in terms of such parameters as colour, texture, aroma and flavour (Rovira, Ordóñez & Jaine, 1996). As shown by the abundant literature on the quality and defects of cured ham, achieving optimal levels of the previous properties entails the curing over long periods of suitable raw materials under carefully controlled conditions such as temperature, moisture and the amount of added salt (Arnau, Guerrero, Hortós & García Regueiro, 1996).

A defective texture significantly detracts from the quality of ham as the end product is too soft and greasy to the touch, and exhibits extraneous aroma and flavour (Parolari, Virgili & Schivazappa, 1994). Among other products requiring curing for a long period, these anomalies have been detected in Parma ham, defective pieces of which were found to contain increased peptide and free aminoacid concentrations (Parolari, Rivaldi, Leonelli, Bellati & Bovis, 1988). Several studies have suggested that uncontrolled proteolytic activity results in considerably impaired protein mechanical properties (Virgili, Parolari, Schivazappa, Soresi Bordini & Borri, 1995). Because increased residual levels of cathepsin B are known to be closely related to anomalous proteolysis indices and textures, this enzyme system has been deemed responsible for proteolysis in ham (Parolari, Virgili et al., 1994; Virgili, 1995). The defect has also been related to porcine genetics (Parolari, Rivaldi, Leonelli, Bellati & Bovis, 1988) and to excessively low salt concentrations during curing (Martín, Córdoba, Antequera, Timón & Ventanas, 1998; Toldrá & Etherington, 1988; Virgili et al., 1995).

The aim of this work was to relate the presence of a sensorial evaluated defective texture in Spanish dry-cured ham to the major compositional parameters of the end product.

2. Material and methods

2.1. Raw material and curing

Refrigerated hams weighing 10–12 kg were obtained from various suppliers and processed 3–5 days after slaughtering. The hams were subjected to the typical Spanish dry-curing procedure, as implemented by the manufacturer. Once the process was finished, suitable samples were chosen for sensory and chemical analysis, as described in the following section.

* Corresponding author.

0308-8146/99/$ - see front matter
PII: S0308-8146(99)00144-2

2.2. Sampling

Twenty batches (300 hams each) of products being prepared for marketing were randomly selected over a 10-month period. From each batch, 30 hams were randomly chosen for evaluation by three Navidul technicians, with recognized experience, after boning and cross-sectioning at hip level. From each batch assessed, two slices were taken (one from the highest-rated and the other at the lowest-rated hams). The slices, 5–10 cm thick, and both from *semimembranous* and *biceps femoris* muscles, were vacuum-packaged and refrigerated prior to analysis.

2.3. Sensory evaluation

Ham samples were sensorially assessed by a group of experts (Navidul technicians specialized in the detection of anomalous sensory properties) in accordance with the Spanish UNE standard (1996). The parameters evaluated were as follows:

a. Pastiness, which designates a textural defect involving a lack of elasticity in the product. This makes it difficult for the ham to regain its shape upon deformation and results in an oily touch in the defective zone. In any case, this is no sign of undercuring or excessive moisture.
b. Anomalous (non-uniform) cut colour. The zone, exposed after a slice is cut, exhibits a central portion that lacks the typical red colour of the cured product (Arnau, 1998).
c. Crusting, which involves the undesirable hardening of some muscles on the outer portion of the ham piece and also, occasionally, slight cracking that is only apparent on cutting.
d. White spots of variable size formed by tyrosine and, to a lesser extent, phenylalanine deposits on the inside of the ham (Arnau et al., 1996).

Each ham piece was assessed individually for these defects by each expert technician. From the individual scores thus obtained, an arithmetic mean was computed that was used to rate the pieces as poor (1–2), normal (2–3) or excellent (3–4).

2.4. Analytical methods

2.4.1. pH measurement

To 5 g of homogenized sample, 5 ml of bidistilled water was added, the resulting suspension being allowed to stand for 15 min before its pH was measured by using a Crison GLP 21 pH-meter.

2.4.2. Compositional analysis

The moisture, fat, protein and salt contents were determined as per the official methods of analysis of the Spanish Ministry of Health (1994).

2.4.3. Proteolysis index

Non-protein nitrogen was determined by using a slightly modified version of the method of Córdoba (1990). Briefly, 5 g of sample was homogenized with 6 vols of cold $HClO_4$. After 1 h at 4°C, the extract was filtered through Whatman no. 6 paper and the filtrate was adjusted to pH 6.00 with 30% (w/v) KOH and made to 100 ml. Finally, a volume of 20 ml of the diluted extract was analysed for nitrogen by the Kjeldahl method, using a digester and a Büchi semi-automatic distiller.

2.5. Statistical analysis

Experimental data were statistically processed by using the SPSS 8.0 for Windows package.

3. Results and discussion

3.1. Sensory evaluation

3.1.1. Pastiness

Hams were classified into two groups according to this sensory property. Group 1 comprised those hams that were given a score of 3–4 (i.e. absence of this defect) and Group 2 those that were given a lower score because they were defective to a greater or lesser extent in this respect. The proportion of highly or markedly defective textures was 11.7%, and that of slightly defective textures — which often go unnoticed by the average consumer — 10.6%. These results are consistent with those of Virgili et al. (1995) for Parma ham in spite of the radical technological differences between both processes (namely, selection criteria for the raw material, ingredients, salting procedure, stoving temperature and relative humidity).

3.1.2. Colour, crusting and white spot formation

Table 1 gives the proportions in which a defective colour, crusting and the formation of white spots (tyrosine deposits) were detected in the two ham groups established in terms of pastiness. Table 2 shows the statistics for these data. As can be seen, the presence of a pasty texture and a defective colour were strongly correlated (Spearman's correlation coefficient $+0.738$, $p<0.0001$). In this respect, myoglobin was reported to inhibit endogenous proteolytic activity in vitro (Rosell, Flores & Toldrá, 1996); because the colour of cured ham is closely related to the initial amount of myoglobin in the muscle (Fox & Ackerman, 1968), the presence of a defective colour or texture may to some extent be related to the myoglobin level in the muscle.

If textural defects are taken to be the dependent variable, then the sensory evaluation of the colour of cured ham accounts for over 60% of the variance ($\eta^2=0.614$). On the other hand, the correlation between textural defects and crusting is low; however, as can be seen

Table 1
Incidence (%) of an anomalous colour, crusting and white spot formation in hams of normal and defective texture rated with scores from 1 to 4 in each factor

		Anomalous colour				Crusting				White spot formation			
Group	n	1	2	3	4	1	2	3	4	1	2	3	4
1	290	0	0	4.8	95.2	0	33.3	66.7	0	0	0	9.5	90.5
2	280	17.4	39.1	26.1	17.4	4.3	21.7	39.1	34.8	4.3	8.7	43.5	43.5

Table 2
Correlation of textural defects with an anomalous colour, crusting and white spot formation

Defect	Spearman's r	Significance	η	η^2
Anomalous colour	+0.7385	0.0001	0.7838	0.6143
Crusting	−0.271	0.0707	0.4850	0.2352
White spots	+0.5012	0.0005	0.5013	0.2513

from Table 1, such defects are more markedly correlated to crusting in hams of normal texture. Spearman's correlation coefficient for the presence of white spots on the ham was $+0.501 (p < 0.001)$; formation of white spots due to tyrosine deposits was more marked in hams of defective texture, where an increased proteolytic activity led to increased levels of free amino acids such as tyrosine and, to a lesser extent, phenylalanine, which eventually precipitated under the prevailing environmental conditions (Arnau et al., 1996).

3.2. Compositional analysis

Samples of both defective and normal texture were subjected to chemical and physico-chemical analyses (pH, fat, moisture, protein, salt and non-protein nitrogen) in both *semimembranosus* and *biceps femoris* muscle. The results and their precisions (expressed as coefficients of variation), summarized in Table 3, are consistent with those previously reported by other authors for Spanish dry-cured ham (Arnau, 1987).

The analysis of variance, of the parameters studied, revealed significant differences between the two sample groups (normal and defective texture), at $p < 0.0001$. The univariate analysis also revealed significant differences ($p < 0.0001$) between both types of texture as regards moisture content ($\%H_{sm}$) and protein content ($\%PROT_{sm}$) in *semimembranosus* muscle, and NPN contents relative to total nitrogen ($\%NNP_{sm}$ and $\%NPN_{bf}$) and salt contents ($\%NaCl_{sm}$ and $\%NaCl_{bf}$) in both *semimembranosus* muscle and *biceps femoris* muscle.

As can be seen from Table 3, hams with a defective texture exhibited high moisture/protein ratios in both types of muscle as a result of both increased moisture—which, as noted earlier, decreases crusting—and decreased protein contents relative to ham with a normal texture.

On the other hand, the average salt content was lower in hams with a defective texture ($p < 0.001$), even though

Table 3
Analytical results for hams of normal and defective texture[a,b]

		Hams of normal texture				Hams of defective texture			
Variable	%CV[c]	Mean (n=21)	%CV[d]	Minimum	Maximum	Mean (n=23)	%CV[e]	Minimum	Maximum
pH_{sm}	0.56	5.78	2.77	5.38	5.94	5.83	2.92	5.55	6.3
pH_{bf}	0.56	5.7	3.86	5.11	5.96	5.82	3.26	5.5	6.27
$\%H_{sm}$	0.33	44.48	5.87	40.6	52.33	49.68	5.25	41.11	53.86
$\%H_{bf}$	0.33	57.64	2.82	54.8	60.64	58.07	4.03	52.32	61.89
$\%PROT_{sm}$	1.23	43.3	4.85	37.2	46.6	36.7	6.52	29.7	41.3
$\%PROT_{bf}$	1.23	30.6	10.4	26.5	38.6	29.1	5.98	26.6	36.01
$\%SALT_{sm}$	0.71	7.91	10.24	6.29	9.05	6.35	10.87	4.78	7.56
$\%SALT_{bf}$	0.71	8.92	8.74	7.71	10.3	7.09	11.4	5.48	8.14
NNP_{sm}	2.79	1.34	6.71	1.12	1.55	1.76	7.39	1.51	2.1
NPN_{bf}	2.79	1.38	5.80	1.2	1.59	1.78	6.18	1.4	2.08
$(H/P)_{sm}$		1.03	11.7	0.89	1.41	1.38	8.70	1.13	1.66
$(H/P)_{bf}$		1.9	8.95	1.52	2.15	2	6.5	1.63	2.31

[a] Results expressed as percentages relative to wet matter except for NPN (% of total N).
[b] %H = % moisture %PROT = %protein %SALT = %NaCl sm = *membranous* muscle bf = *biceps femoris* muscle.
[c] Coefficient of variation obtained for 22 control samples analysed throughout the ham testing period.
[d] Coefficient of variation for the analytical results for the samples of normal texture.
[e] Coefficient of variation for the analytical results for the samples of defective texture.

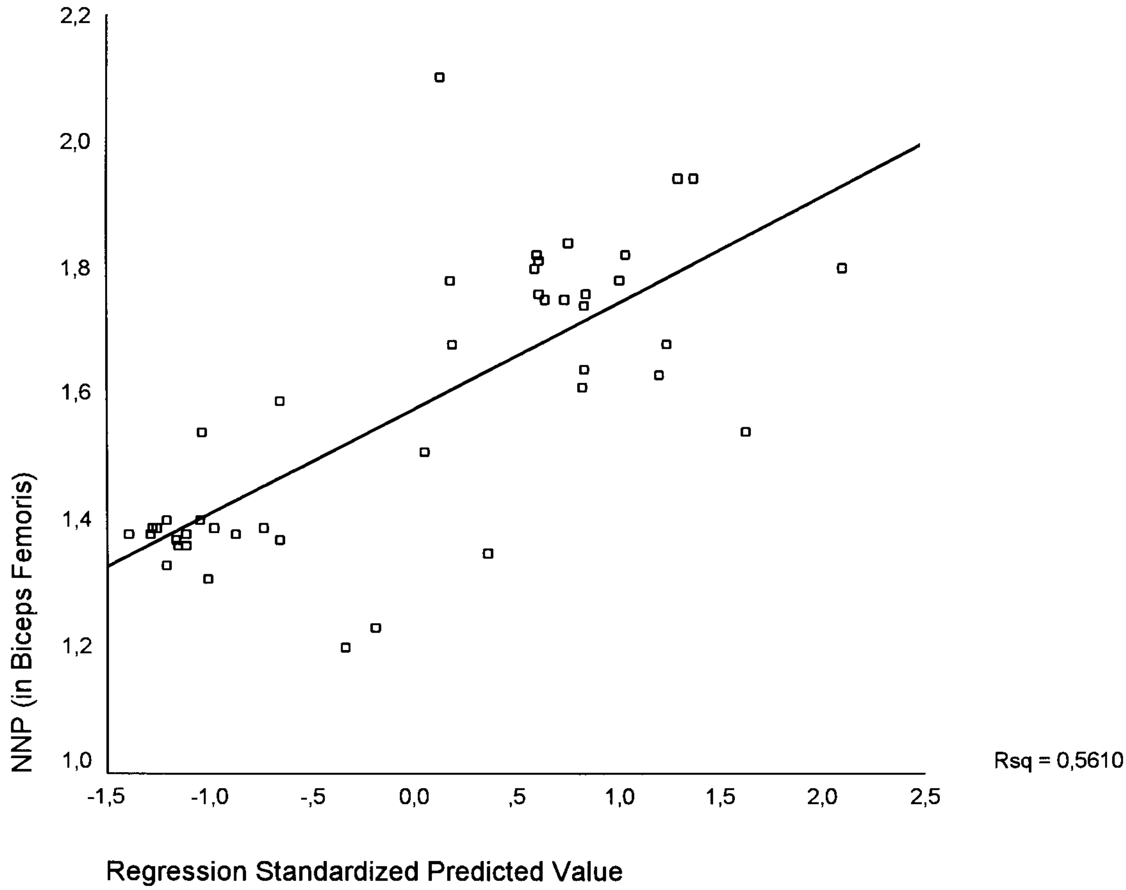

Fig. 1. Multiple linear regression of NPN values.

diffusion of salt to the most moist zones in the ham throughout the manufacturing process can mask more marked differences in NaCl levels—particularly in the *biceps femoris* zone, where the textural defect usually appears. Thus, while some authors (Parolari, Virgili et al., 1994; Sárraga, Gil, Arnau, Monfort & Cussó, 1989; Virgili et al., 1995) claim that proteolytic activity in ham is governed by NaCl, we found hams of both normal and defective texture to contain salt levels of 6.2–8.1% by wet weight in both types of muscle (Table 3).

NPN levels were 30% higher in pieces of defective texture than in normal hams; these levels are only slightly higher than those obtained by Parolari, Rivaldi et al. (1988) in Parma ham. A defective texture in ham is obviously related to strong proteolysis relative to ham with a normal texture. The analysis of the correlation matrix reveals a high correlation between the defect pastiness and non-protein nitrogen in *biceps femoris* muscle ($r = 0.876$), which is usually more markedly affected by textural defects than is *semimembranous* muscle. The multiple regression analysis of the NPN content in *biceps femoris* against compositional parameters was carried out by using the stepwise variable selection method with F-to-enter = 0.05 and F-to-remove = 0.1. The graph thus obtained is shown in Fig. 1.

4. Conclusions

Based on the results obtained in this work, ham texture is significantly related to colour as are texture defects to compositional parameters such as moisture, protein and NaCl) contents. On the other hand, texture defects are closely related to the NNP index, a measure of the extent of proteolysis in the muscle. This latter result is consistent with those of Virgili et al. (1995) for Parma Ham, and should therefore be considered in control analysis of the raw material. In this respect, the moisture and protein contents in the end product are two keys to the statistical confirmation of textural defects in ham. As such, they should also be included in raw material characterizations.

Finally, the NaCl content in the sample does not appear to be unequivocally related to textural defects; this may be the result of other variables such as temperature and moisture playing more prominent roles at the different stages of ham curing.

References

Arnau, J., Guerrero, L., Hortós, M., & García Regueiro, J. A. (1996). The composition of white film and white crystals found in dry-cured hams. *Journal of the Science of Food and Agriculture, 70*, 449–452.

Arnau, J. (1998) El jamón curado: Tecnología y análisis de consumo, (pp. 71–86). *44th international congress of meat science and technology*, Eurocarne, Madrid

Córdoba J. J. (1990). *Transformaciones de los componentes nitrogenados durante la maduración del jamón de cerdo ibérico*. PhD thesis, University of Extremadura.

Fox, J. B., & Ackerman, S. A. (1968). Formation of nitric oxide myoglobin: mechanisms of the reaction with various reductants. *J. Food Sci., 33*, 364.

Martín, L., Córdoba, J. J., Antequera, T., Timón, M. L. & Ventanas, J. (1998) Effects of salt and temperature on proteolysis during ripening of Iberian ham. *Meat Science*, *49*, 145.

Parolari, G., Rivaldi, P., Leonelli, C., Bellati, M., & Bovis, N. (1988). Taste quality of Italian raw ham in a free-choice profile study. *Industria Conservé, 65*, 45–51.

Parolari, G., Virgili, R., & Schivazappa, C. (1994). Relationship between cathepsin B activity and compositional parameters in dry-cured hams of normal and defective texture. *Meat Science, 38*, 117–122.

Rosell, C. M., Flores, M., & Toldrá, F. (1996). Myoglobin as an endogenous inhibitor of proteolytic muscle enzymes. *Journal of Agricultural and Food Chemistry, 44*, 3453.

Rovira, J., Ordóñez, M., & Jaime, I. (1996). Clasificación de perniles frescos para la elaboración de jamón serrano. *Eurocarne, 45*, 39–44.

Sárraga, C., Gil, M., Arnau, J., Monfort, J. M., & Cussó, R. (1989). Effect of curing salt and phosphate on the activity of porcine muscle proteases. *Meat Science, 25*, 71.

Spanish Ministry of Health (1994). *Métodos oficiales de análisis*. Tomo IV. Madrid: Ministerio de Agricultura, Pesca y Alimentación.

Toldrá, F., & Etherington, D. J. (1988). Examination of cathepsin B, D, H and L activities in dry-cured hams. *Meat Science, 23*, 1–7.

UNE. (1996). Análisis sensorial. Tomo 1: Alimentación. Guía general para la selección, entrenamiento y control de jueces. Parte 2: Expertos. Norma Española UNE 87024-2:1996. Ed. AENOR N.A. 71.970.

Virgili, R., Parolari, G., Schivazappa, C., Soresi Bordini, C., & Borri, M. (1995). Sensory and texture quality of dry-cured ham as affected by endogenous cathepsin B activity and muscle composition. *Journal of Food Science, 60*, 1183–1186.