RELATIONSHIP BETWEEN SENSORY CHARACTERISTICS OF DRY-CURED HAM AND ELECTRICAL IMPEDANCE SPECTROSCOPY (EIS) MEASUREMENTS

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Background:
Sensory properties of dry cured ham are strongly affected by raw material characteristics and technological processing. The presence of PSE (Pale, Soft and Exudative meat) and DFD (Dark, Firm and Dry meat) hams could affect their sensory properties in an important way (Arnau, 1991; Guerrero *et al.* 1999). This is specially important for DFD meat which normally leads to defective texture characteristics such as pastiness and adhesiveness which are important handicaps for the commercialisation of the sliced product. NaCl content and texture of dry-cured ham can be affected by the presence of PSE muscles in the ham (Arnau *et al.* 1995; Ordoñez, 2001). The classification of green hams in different quality groups could be very useful in order to reduce the incidence of flavour and texture defects in the final product by optimising the processing conditions for each group. Different instruments have been developed based on measurements of the electrical conductivity as predictor of early post-mortem changes and intramuscular fat (Schmitten *et al.* 1987; Madsen *et al.* 1999; Forrest *et al.* 2000) showing different results and effectiveness. However, very little information is available about the impact of all these measurements on the final characteristics of a dry-cured meat product.

Objective:
The aim of this study is to asses the ability of a new prototype based on Electrical Impedance Spectroscopy (EIS) described by Oliver *et al.* (2001) as predictor of the dry-cured ham saltiness and texture characteristics.

Methods:
The study was conducted on 89 hams selected from commercial carcasses including PSE ($pH_{45}<6.0$), DFD ($pH_{24}>6.0$) and normal hams. All the pH measurements were taken in the *Semimembranosus* muscle (SM). At 24 hours post-mortem the ham weight, ham conformation (maximum height from the rind to the higher point of the SM muscle measured with a calliper) and fat thickness in the rump (subcutaneous fat measured with a ruler) were recorded. At 36 hours post-mortem four electrical parameters were obtained in two different regions of each ham: *Semimembranosus* muscle (SM) and *Biceps femoris* region (BF). These parameters were: R_0 or the electrical impedance modulus (Ω) at low frequencies; Rinf or the electrical impedance modulus (Ω) at high frequencies; α or the shape adjustment parameter; and Fc or the characteristic frequency (kHz) that corresponds to the frequency at which the imaginary part of the electrical impedance is largest in absolute value. A fifth parameter was introduced (Ratio) as the relation between Rinf and R_0. This parameter is proportional to the ratio of extracellular water to total water content in the ham (Lozano *et al.* 1995). The electrical data were obtained using the EIS equipment described by Oliver *et al.* (2001) scanning from 8 kHz to 1 MHz.
All the green hams were salted at 36 hours post-mortem with a mixture of NaCl, KNO_3 and $NaNO_2$ (99%, 0.5% and 0.5% respectively). After 6 days of resting fully covered with this mixture at 0-4°C and Relative Humidity (R.H.) higher than 85% they were covered with another mixture of NaCl, dextrose and sodium ascorbate (95%, 3% and 1% respectively) in the same conditions until a total salting time of 1.3 days per kg of green ham weight was reached. Afterwards they were washed in cold water and hung at 2-6°C and R.H. of 70-90% during 35 days. The ageing process consisted in three different steps: 10-14°C and R.H. of 60-80% for 70 days; 18-22°C and R.H. of 60-75% for 70 days; 26-30°C and R.H. of 60-70% for 21 days. At the end of the drying period the hams were individually weighted, deboned and sliced. The chemical and sensory analysis were performed on slices perpendicular to the centre of the femur.
Moisture as weight loss at 103±2°C (Presidencia del Gobierno, 1979) and sodium chloride by the Charpentier-Volhard method (ISO, 1970) were determined separately for SM and BF muscles in each dry-cured ham. The sensory analysis was carried out separately for both muscles as well (SM and BF) using an expert panel of six members. In each session each assessor evaluated the same four randomly selected hams (both muscles), blocking the order of presentation and the first-order carry-over effects (MacFie et al. 1989). The descriptors evaluated (hardness, pastiness, crumbliness, adhesiveness, fibrousness and saltiness) were quantified using a non-structured scale ranging from 0 (absence) to 10 (intense). The definition of each texture attribute as well as the references used to illustrate the maximum intensity of each of them were described by Guerrero *et al.* (1999). The data were analysed using the MEANS, GLM, PRINCOMP and DISCRIM procedures from the SAS statistical package (SAS, 1987).

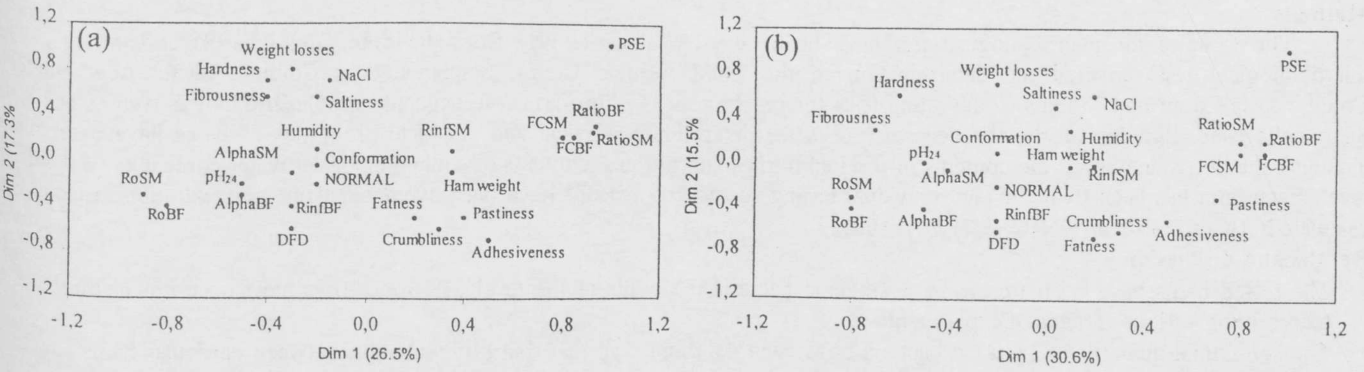
Results and discussion:
Table 1 shows the main traits of the different hams used for this study. The ham weight and its conformation may have an important effect on the texture of the final product. Ham conformation could impede salt diffusion to the inner muscles and increase texture defects such as pastiness (Guerrero *et al.* 1996). According to this, ham conformation should affect BF muscle more than SM muscle. However, in the present study both, external (SM) and internal (BF) muscles, showed a noticeable pastiness value that suggests that others factors such as ham fatness (Gou *et al.* 1995) and proteolytic potential (Parolari *et al.* 1994) should be taken into account to justify these figures. The pH values show the wide range of the sample studied, including both PSE and DFD hams. In general the variation in all the parameters studied was important enough how to determine the correlation between these variables and the electrical data recorded.

Table 1: Descriptive statistics of meat quality characteristics and sensory properties (mean values over assessors).

Characteristics	Mean	S.D.	Max.	Min.
Ham weight (kg)	11.10	0.81	13.51	8.93
Conformation (cm)	14.96	1.00	17.10	12.10
Fat thickness rump (cm)	1.20	0.64	5.30	0.20
pH_{45}	6.09	0.32	6.90	5.45
pH_{24}	5.75	0.37	6.84	5.38
Ham weight loss	30.08	3.32	40.91	22.95
BF muscle				
Adhesiveness	3.63	1.48	7.97	1.00
Hardness	3.84	0.69	5.25	2.17
Crumbliness	4.27	0.84	6.50	2.88
Pastiness	1.72	1.53	8.13	0.25
Fibrousness	1.76	0.57	3.50	0.50
Saltiness	3.10	0.57	4.38	1.50
NaCl (%) (dry matter)	9.49	1.66	14.38	5.32
Humidity (%)	70.22	1.44	73.12	63.52
SM muscle				
Adhesiveness	2.47	1.49	7.63	0.55
Hardness	3.71	0.73	5.88	2.33
Crumbliness	5.34	0.75	7.50	3.88
Pastiness	1.87	1.65	8.47	0.25
Fibrouness	2.00	0.88	4.88	0.60
Saltiness	2.60	0.48	3.63	1.25
NaCl (%) (dry matter)	13.21	1.56	16.71	9.02
Humidity (%)	62.81	1.18	65.47	60.45

Figure 1 shows the relationship between the different parameters for each muscle. It is important to notice the differences found between the two muscles. In this sense, and for the BF muscle, texture defects (pastiness and adhesiveness) were correlated with the fatness of the ham and closer to DFD hams. Arnau *et al.* (1998) and Guerrero *et al.* (1999) observed also that the use of DFD meat was not advisable for dry-cured ham because important problems in texture were found. PSE hams tend to have higher weight losses, hardness and saltiness. For BF muscle there was no clear relationship between electrical and sensory parameters. The ability of the electrical parameters in the SM muscle to detect texture defects seems to be higher than in the BF muscle. In fact, and using a discriminant analysis, the electrical measurements obtained were able to correctly classify 69.2% of the hams with high pastiness values compared with the 56.0% obtained for the BF muscle. These differences could be explained by a different origin of pastiness in both muscles. For the BF muscle pastiness and adhesiveness seems to be produced by their high pH_{24}. The hams with the highest pastiness and adhesiveness values in the BF muscle had a mean pH_{24} value of 5.96. This value was significantly higher ($p<0.05$) than that of the hams with low pastiness scores. There was no significant difference in pH_{24} for SM muscle between hams with high and low pastiness values, the mean value for the pH_{24} being 5.62 for the pastiest hams. In this case the origin of pastiness seems to be different and related to a higher proteolytic activity. For this reason PSE hams, which are also better predicted by the electrical parameters studied than DFD hams (Oliver *et al.* 2001), are better correlated with the electrical parameters and texture properties. This last result tends to indicate that those hams having higher extracellular water (Lozano *et al.* 1995) are also the PSE hams and those with higher pastiness and proteolysis in agreement with Ordoñez (2001). Saltiness cannot be well predicted in any case using the electrical data in the samples studied.

Figure 1. Principal Component Analysis for BF (a) and SM (b) muscles.



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