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# Effect of $pH_{24}$, NaCl content and proteolysis index on the relationship between water content and texture parameters in *biceps femoris* and *semimembranosus* muscles in dry-cured ham

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**Abstract**

The aim of the present study was to determine the effect of pH level and NaCl content on the relationship between water content and texture parameters in *semimembranosus* and *biceps femoris* muscles in dry-cured ham. The experiment was undertaken using 18 hams, selected in a commercial slaughterhouse. Half of the hams had a pH < 5.7 and the rest a pH > 6.2, measured in the *semimembranosus* muscle at 24-h post mortem ($pH_{SM24}$). The hams were treated with 20, 50 or 80 g of NaCl per kg of ham. At the end of the aging process nine samples from *semimembranosus* and *biceps femoris* muscles were dried to different levels of water content covering the range from 22.4% to 58.5%. At the end of the drying period, a Texture Profile Analysis was used to determine textural parameters. Samples from *biceps femoris* muscle and samples from hams with low $pH_{SM24}$ showed a higher proteolysis index (100 × non-protein nitrogen/total nitrogen) than samples from *semimembranosus* muscle and samples from hams with high $pH_{SM24}$, respectively. The proteolysis index decreased when the added NaCl amount increased. The proteolysis index was the parameter that best explained the modifications in the relationship between water content and the texture parameters (hardness, cohesiveness and springiness) of dry-cured ham muscles and it would be considered in order to predict the texture in dry-cured ham at different drying levels. Dry-cured hams with a lower proteolysis index were more prone to present harder texture at low water contents, which is typical of hams with crustiness problems.


*Keywords:* Hardness; Water content; pH; NaCl content; Proteolysis index; Dry-cured ham

## 1. Introduction

Texture is an important quality criterion for the certification of the Traditional Spanish dry-cured ham "Jamón Serrano" as a Guaranteed Traditional Speciality (Fundación Jamón Serrano, 1998). The most important texture problems described in dry-cured ham are crust formation (Arnau, 1998; Flores, 2001; García-Garrido, Quiles-Zafra, Tapiador, & Luque de Castro, 1999), excessive softness (Parolari, Virgili, & Schivazappa, 1994; Virgili, Parolari, Schivazappa, Bordini, & Borri, 1995) and pastiness (Arnau, 1991; Arnau, Guerrero, & Sárraga, 1998; García-Garrido, Quiles-Zafra, Tapiador, & Luque de Castro, 2000; García-Rey, García-Garrido, Quiles-Zafra, Tapiador, & Luque de Castro, 2004).

The crust development in dry-cured ham has been related to a dramatic increase of hardness during drying because the water content at the surface of the product reaches a critical value (Serra, Ruiz-Ramírez, Arnau, & Gou, 2005). This critical value has been reported to be different in dry-cured loin (Ruiz-Ramírez, Serra, Gou, & Arnau, 2005b), suggesting that intrinsic characteristics

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of the muscle and/or of the process could also affect the crust development.

Ruiz-Ramírez, Arnau, Serra, and Gou (2005a) found slight effects of the fresh ham pH (measured on m. *semimembranosus* at 24 h post mortem, $pH_{SM24}$) and of the amount of added NaCl on the relationship between texture parameters and water content. This study was carried out with samples from *semimembranosus* and *biceps femoris* muscles, cured at $2 \pm 2$ °C for 45 days with NaCl amounts that ranged from 20 to 80 g of NaCl per kg of muscle, and subsequently dried at $3 \pm 2$ °C. Under these conditions, a low proteolytic index was found. However, during the traditional drying process of the ham, NaCl contents are lower (especially in the *biceps femoris* muscle at the initial stages) and the temperatures are higher than the reported values in Ruiz-Ramírez et al. (2005a) study. Consequently, a higher proteolytic activity is expected (Sárraga, Gil, Arnau, Monfort, & Cussó, 1989; Toldrá, Rico, & Flores, 1993), which has been related to higher pastiness and excessive softness (Arnau, 1991; García-Garrido et al., 2000; Parolari et al., 1994; Toldrá & Flores, 2000; Virgili et al., 1995) and which could also affect the relationship between water content and texture parameters (Ruiz-Ramírez et al., 2005a).

The proteolytic activity in meat products depends, among other factors, not only on NaCl content and temperature, but also on pH (Arnau et al., 1994; Arnau et al., 1992; Arnau, Guerrero et al., 1998; Schivazappa et al., 2002), which affects the proteolytic activity during the process and the final texture of the dry-cured ham (Arnau, Guerrero et al., 1998).

Several published studies show the effect of NaCl, temperature and pH on the final texture of dry-cured hams, however none of them studied the effect of these parameters on the relationship between water content and texture. The knowledge of this relationship is important in order to better determine the target weight loss to obtain the desired texture.

The aim of this study was to determine the effect of pH level, NaCl content and proteolysis index on the relationship between water content and texture parameters in two muscles from dry-cured ham.

## 2. Materials and methods

A complete 2-way factorial design was applied to obtain different pH levels and NaCl contents in dry-cured ham muscles at the end of the process. The factors were the pH measured on M. *semimembranosus* (SM) at 24-h post mortem ($pH_{SM24}$) and the amount of NaCl added during the salting process. With this design samples with different proteolysis index were obtained. At the end of the ageing process samples from SM and *bicep femoris* (BF) muscles were dried to different levels of water content in order to determine the relationship between water content and texture parameters.

### 2.1. Ham selection

Two groups of 9 green hams each with an average weight of $11 \pm 2$ kg were selected by $pH_{SM}$, measured with a combined electrode (Ingold 406, Ingold, Urdof, Switzerland) attached to a portable pH-meter (Crison 507, Crison Instruments S.A, Barcelona, Spain). The $pH_{SM24}$ was lower than 5.7 for the low $pH_{SM24}$ group and higher than 6.2 for the high $pH_{SM24}$ group.

### 2.2. Dry-cured ham process

The hams were manually rubbed with the following mixture (g/kg of raw ham): 0.5 of $KNO_3$, 0.3 of $NaNO_2$ and, depending on the salting treatment, 20, 50 or 80 of NaCl. Three hams from each $pH_{SM24}$ group were assigned to each salting treatment. After covering the lean part of the pieces with the salt, hams were individually vacuum packed in polyamide and polyethylene bags (SACOLIVA® permeability: 2.6 g $H_2O/m^2$/day at 23 °C/85%RH) and were placed horizontally in trays at $2 \pm 2$ °C for 33 days (salting period). Every five days hams were rubbed with the non-absorbed salt and packed again.

After salting, hams were washed with cold water and hung in a drying room at $2 \pm 2$ °C and $78 \pm 2$% RH, and at a constant air velocity of 0.09 m/s. A week later the RH was decreased to 70–75%, and kept constant for 2 months (resting period). Afterwards, during the ageing period, the relative humidity was gradually decreased and the temperature gradually increased (Table 1). Ham weight losses were monitored.

### 2.3. Sampling

The SM and *biceps femoris* (BF) muscles were excised from the dry-cured hams (Fig. 1). Thereafter, nine samples from each muscle (18 hams × 2 muscles × 9 samples = 324 samples) were shaped into a parallelepiped ($40 \times 20 \times 20$ mm). The rest of the muscle was ground and vacuum packed in metallic bags (SACOLIVA® permeability: <1 mg $H_2O/m^2$/day, to 23 °C/85% HR), and stored at $2 \pm 2$ °C for further physicochemical analysis.

Table 1
Parameters of process stages

| Stage | Time (days) | Temperature (°C) | Relative humidity (%) |
|---|---|---|---|
| Salting period | 33 | $2 \pm 2$ | – |
| Resting period | 61 | $2 \pm 2$ | $78.0 \pm 2.0$ |
| Ageing period 1 | 13 | $10 \pm 2$ | $67.5 \pm 2.5$ |
| Ageing period 2 | 110 | $15 \pm 2$ | $57.5 \pm 2.5$ |
| Ageing period 3 | 72 | $28 \pm 2$ | $65.0 \pm 5.0$ |