SPANISH DRY-CURED HAM AGING PROCESS: COLOUR CHARACTERISTICS

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BACKGROUND

Dry-cured ham is a nonhomogeneous product that has undergone a salting and dehydration processes, both of which influence the dynamics of water, salt, nitrate and nitrite migration (Arnau *et al.* 1995). The dry-curing process has three principal stages: salting postsalting and dry-maturation or aging (Fernández-López *et al.* 1994). During dry-maturation stage water activity (Aw) decreases, which is the main factor enabling for the preservation of the product in question. It is an essential stage which often plays a critical role in developing the essential characteristics (texture, colour, flavor) expected of the product. Although the dry-maturation stage is very complex (various chemical, ultrastructural and physical change takes place) no definitive study has been made of it. It is the longest stage in the dry curing process and may be traditional or accelerated. Some Spanish dry-cured hams are exposed to temperatures of 22-34°C and 65% relative humidity during the last month of processing, a step known as "estufado", to enhance the sensorial properties for which these products are appreciated.

OBJECTIVES

The general aim of the research described in this paper was to study the colour (CIELAB co-ordinates) and chemical (moisture and salt content, residual nitrite level, water activity and pH) characteristics of different muscles (*Semimembranosus*, *Semitendinosus* and *Bicep femoris*) in dry-cured hams at the end of the aging process.

METHODS

Materials: Twelve hams were studied during the 10 mo of dry curing to which they were submitted. The green hams from an E.U. authorized slaughter house were obtained from 6 mo old pigs, each weighing about 10 kg. The hams were selected according to their pH (5.6-5.8) which was measured in the *Semimembranosus* muscles after tumbling to eliminate the residual blood in the green hams. After selection of the hams the surface of each ham was immediately nitrified with a commercial dry salt mixture. The hams were then piled in stainless steel tubs in a cold storage room (2 ± 1°C) for one day, after which they were completely covered with salt (the traditional method) and left for 11 days piled in the cold storage room (2.5 ± 1°C and RH: 90 ± 5%). At the end of the salting stage the excess salt was brushed off and the hams were washed with cool water (< 10°C). The salted hams were then hanging in another cold storage room (2.5 ± 1°C and RH: 85 ± 5%) for 3 weeks (postsalting stage). The dry-maturation stage lasted 9 mo, the first 8 mo in a controlled cellar (16 ± 6°C and RH: 75 ± 5%) and the last month at ambient temperature (28 ± 6°C and RH: 65 ± 10%).

Sample preparation: For this study, three 2 cm thick slices (center section) were taken from each ham (Fernández-López et al.

Analysis: The moisture content was determined according to the ISO method (1975a). Results were expressed as water (g)/g dry tissue. Chloride concentration was determined according to the ISO method (1970) and the results were expressed as NaCl (g)/g dry tissue. Residual nitrite level was determined according to the ISO method (1975b) with the results expressed as parts per million (ppm). pH determinations were taken using a Crison 507 pHmeter and a Crison CAT. nº 52-32 electrode (Crison Instruments, S.A., Alella, Barcelona, Spain). All these analysis were performed in triplicate. Colour co-ordinates [Lightness (L*), Redness (a*) and Yellowness (b*)] and psycophysical magnitudes [Chroma (C*) and Hue (h*)] were determined using a Minolta CM1000 spectrophotometer, with D65 as the light source and 10° as the standard observer (Cassens *et al.* 1995). The Colour of each sample was determined by averaging 9 separate measurements. Análisis of variance and Tukey test were used to determine significant differences ($P<0.05$) in each parameter. A multiple regression analysis was made of the physical attributes to the physicochemical attributes. All statistical analysis were made using BMDP Statistical Software.

RESULTS AND DISCUSSION

Table 1 reflects the means of each chemical and colour attributes in the dry-cured hams at the end of the aging process. For moisture, significant differences ($P<0.05$) were found between all muscles (SM, ST and BF) (Table 1). A moisture gradient can be observed with SM showing the lowest values, and BF muscle the highest. This could be due to muscle position within the ham. Since SM is the outer muscle and is subjest to surface dehydration, while ST and BF are covered by skin, conective tissue and fat. For chloride concentration significant differences ($P< 0.05$) between all the muscles (SM, ST and BF) (Table 1) were found, with BF showing the highest values. This increase in salt concentration in BF could be closely connected to the higher moisture content since more salt could be dissolved. During the dry-curing process the salt diffuses from the surface to the inner muscles (ST and BF), this inversion of the salt content arising from the natural tendency of the NaCl/moisture to equilibrate between different ham muscles (Arnau *et al.* 1995). The lower values for the salt content found in SM muscle could be due to migration towards the more humid muscles. No statistical differences in the residual nitrite level were found between muscles ($P>0.05$), as the levels were very low and showed a high dispersion, in all three. No statistical differences in pH ($P>0.05$) were found between muscles (Table 1) although the values of this parameter increased throughout the dry-curing process due to aminoacids and other basic compounds liberation during all the dry-maturation stage. For lightness (L*), significant differences ($P<0.05$) between all muscles were found (Table 1). SM muscle showed the lowest values and BF the highest. Lightness is related to the thin aqueous layer on the muscle`s surface. These results suggest that lightness in these muscles depends on the water content (moisture) and water movement (dehydration) towards the surface. In these types of meat product salt plays and important role in L* (decrease) (Pérez-Alvarez *et al.* 1997a). SM muscle is the only muscle to come into direct contact with salt and this regulates the salt difussion towards the others muscles as well as the water movements from ST and BF muscles to outside. Lineal regression analysis for this colour co-ordinate demonstrated it was only related with moisture content and water activity ($r = 0.823$; $P<0.01$). For redness (a*) only SM muscles showed significant differences ($P<0.05$) from the other muscles. SM muscle showed the lowest redness and BF the highest (Table 1). The relation reported between a* and myoglobin concentration (Johansson *et al.* 1991) may be one of the reasons for the differences seen in the

redness between these muscles. Another important factor which should be taken into account is the salt content, because this additive can increase this co-ordinate (Fernández-López, 1998). This phenomenon could be responsible for the fact that BF muscles showed the highest a* values (these muscles has the highest salt concentration). However, besides the myoglobin concentration and salt content is important to mention the nitrosomyoglobin which developes during the dry-curing process. This compound has also been associated with the characteristic colour of dry-cured meat products. Identical results to those for redness were found for yellowness, with ST again showing the highest values and BF the lowest (Table 1). The lower values for yellowness recorded for SM muscles could be due to salt concentration or dehydration, both arising from treatment during the salting stage. The ham at this stage is totally covered by salt, and SM muscles are in direct contact with it, which could produce Mb oxidation. It must also be taken into account that in this muscle it is possible for the salt content to reach 15% at this stage (Sayas-Barberá, 1997). For chroma (C*) significant differences ($P<0.05$) between all the muscles were found (Table 1). As in the case of the L*, a* and b*, SM muscles showed the lowest value and BF muscles the highest. As in the case of the b*, these differences between muscles could be due to the effect of salt on Mb during the process (oxidation and denaturation). For hue (H*) only SM muscles showed significant differences ($P<0.05$) with the other muscles, but no differences were found between the other two muscles (Table 1). According to the Spanish colour nomenclature the hue for SM, ST and BF are included in the red hue (Instituto nacional de racionalización, 1981). For a*/b* ratio only the SM muscles showed significant differences ($P<0.05$) with ST and BF muscles, with no differences between these two muscles. The behaviour of the SM, ST and BF muscles for this factor was different to that observed for the colour co-ordinates, since SM showed the highest value and ST the lowest. Warren *et al.* (1996) reported that higher values of this ratio indicate more redness whit these changes being mainly due to the loss of the b* coordinate.

CONCLUSIONS

SM muscles showed the lowest values for all the chemical and color parameters except the a*/b* ratio while BF muscles had the highest values except for the same a*/b* ratio. Differences were found in the moisture content, salt concentration, water activity, lightness, chroma, and the a*/b* ratio between the three muscles analysed. BF and ST muscles showed no differences for redness, yellowness and hue. Lightness was highly correlated with moisture and water activity values.

PERTINENT LITERATURE

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Table1.- Mean value of chemical and colour parameters in *Semimembranosus* (SM), *Semitendinosus* (ST) and *Biceps femoris* (BF) muscles in dry-cured ham.

Muscle	L*	a*	b*	C*	H*	a*/b*	pH	Moisture	Nitrite	Chloride
SM	25.98^{a}	8.85^{a}	5.49^{a}	10.41^{a}	31.81^{a}	1.61^{a}	5.92^{a}	0.423^{a}	5.93^{a}	4.89^{a}
ST	32.59^{b}	12.58^{b}	8.82^{b}	15.36^{b}	35.03^{b}	1.42^{b}	6.03^{a}	0.853^{b}	6.94^{a}	7.11^{b}
BF	34.80^{c}	15.55^{b}	10.50^{b}	18.77^{c}	34.02^{b}	1.48^{b}	6.12^{a}	1.03^{c}	12.36^{a}	8.01^{c}

[a-c] For each variable, means within the same column with different superscripts differ significantly ($P<0.05$).