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Physical and chemical changes in different zones of normal and PSE dry cured ham during processing

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The changes of moisture, pH, NaCl, nitrate and nitrite in different zones of the ham during the process were evaluated in 15 normal and 15 PSE hams. No difference in pH was found between PSE and normal hams. When all the sampling times were analysed together, the PSE hams were found to contain more moisture and NaCl than normal hams in certain muscles. In most zones, pH increased during the process. The external zones showed a higher salt concentration at the beginning, but this trend reversed during aging owing to salt penetration from the drier external zones to the more humid inner zones. The total NaCl in the lean tissue of the hams increased after salting and remained constant after the resting phase. Nitrate diminished quickly during the resting period, especially in the external zones, whereas nitrite increased after the salting period and did not exceed 10 ppm at the end of the process.

Dry cured ham is a nonhomogeneous product that undergoes a salting and dehydration process that determines the dynamics of the migration of the water, NaCl, nitrate and nitrite.

INTRODUCTION

The main hurdles for microbiological stability of dry cured ham are pH, temperature and water activity (Leistner, 1985). Tarr (1941) offered the first proof that nitrite was the agent responsible for the cured flavour and also that it had an antimicrobial function.

A pH below 6·0 at 24 h *post mortem* is one of the requirements for optimal curing of hams. The pH does not further diminish during the process, and remains around 6·0 in Spanish ham (Flores *et al.*, 1985; Carrascosa *et al.*, 1988), Parma ham (Raczynski *et al.*, 1978; Bellatti *et al.*, 1983) and country style ham (Melo *et al.*, 1974). Therefore, it is not an important parameter in the monitoring of microbial growth during the aging process.

A decrease in water activity is the main factor responsible for the preservation of the product. This is achieved essentially by the penetration of salt and removal of water from the meat. Several studies have been carried out on NaCl distribution during the process (Fröystein *et al.*, 1989; Palmia *et al.*, 1992) and on changes in physical and chemical characteristics during the process (Baldini *et al.*, 1977; Flores *et al.*, 1985), but none of them have included anatomical dissection.

Potassium nitrate is used for meat curing, but must be reduced to nitrite in order to give the meat the characteristic colour of cured meat products. Huerta (1986) studied the evolution of nitrate and nitrite at three levels in the central part of the ham during the process.

Meat of a pale, soft and exudative nature (PSE) is a serious problem in the meat industry. The weight losses of Parma hams classified as PSE were 4% higher than in normal hams and no difference was found in NaCl concentration (Maggi & Oddi, 1988). Increased weight loss and a small increase in salt absorption were observed in cured PSE country style hams (Kemp *et al.*, 1974). There are very few studies on the effect of PSE on the physicochemical characteristics of dry cured ham, using Spanish technology (Arnau, 1991).

The aim of the present study is to analyse the changes of moisture, pH, NaCl, nitrate and nitrite in different zones of normal and PSE hams during the dry curing procedure.

MATERIAL AND METHODS

Ham selection

Fifteen normal and 15 PSE gilt hams weighing between 9 and 10 kg were selected according to their electrical conductivity and pH.

Measurements of electrical conductivity were taken with a Quality meter (Tecpro) at 24 h *post mortem*. The pH was measured at 45 min (pH_{45}) and 24 h *post mortem* (pH_{24}), using a portable pH meter (Crison). Both pH and conductivity were measured in the *Semimembranosus* muscle. Hams with a $pH_{45} < 6·0$ and

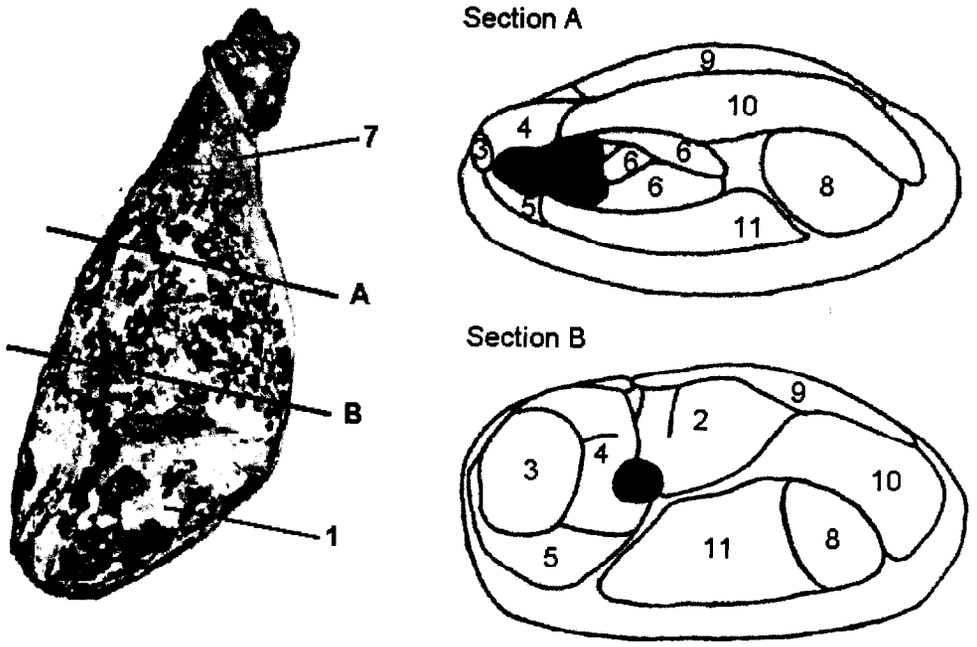

Fig. 1. Muscle sample location with two cross-sections of a dry cured ham (for key see text).

conductivity > 10 μs were considered as PSE, and hams with a $pH_{45} > 6{\cdot}0$ and conductivity <6 μs were regarded as normal. Hams with a $pH_{24} > 6{\cdot}2$ were rejected.

Processing

The hams were refrigerated for 2 days at 1–3°C and then nitrified with a dry salt mixture of 9·6 g of NaCl and 0·4 g of KNO_3 per kg of ham. After 24 h they were covered with salt for a period of 1 day per kg of ham. Afterwards the hams were washed in cold water and hung at 3–5°C in an atmosphere with a relative humidity between 70 and 80% for 30 days, increasing the temperature 1·5°C weekly until the sixth month. Afterwards they remained at 12–14°C for 27 days.

Sampling

Three normal and 3 PSE hams were sampled at each of the following periods: 24 h *post mortem*, postsalting (18 days), resting (50 days) and aging (122 and 207 days). When the bones, skin and fat had been removed the lean tissue was divided up into 11 sampling zones (Fig. 1): 1, butt; 2, *M. Adductor*; 3, *M. Rectus femoris*; 4, *M. Vastus medialis* and *Vastus intermedius*; 5, M. *Vastus lateralis*; 6, *Gastrocnemius*; 7, shank (muscular zone around tibia and fibula); 8, *M. Semitendinosus*; 9, *M. Gracilis*; 10, *M. Semimembranosus*; 11, *M. Biceps femoris*.

Physicochemical analysis

Weight losses of hams due to processing were evaluated relative to their initial fresh weight. The following analyses were carried out on each sampling zone. The pH was determined with 10 g of ham in 90 g of distilled water. Moisture was measured by weight loss at 103 ± 2°C (Presidencia del Gobierno, 1979). Sodium chloride content was analysed using the Charpentier–Volhard method. Nitrate was reduced with a Cd column and measured by colorimetric reaction (AOAC 7041). Nitrite was determined by the colorimetric method by reaction with Griess reagent (Presidencia del Gobierno, 1979). The NaCl and the KNO_3 amounts (g) in the lean tissue were calculated as the sum of the amounts in the 11 zones studied, which were in turn calculated by multiplying the NaCl or the KNO_3 contents by the muscle weight.

Statistical analysis

Least-square analyses of variance were used (SAS, 1985). The fixed effects of meat quality (PSE and normal), sampling time and sampling zone, their interactions and the random effect of ham were included in the analyses. Nonsignificant interactions were dropped from the model. The analysis for total NaCl in the lean tissue included meat quality and sampling time of the process as fixed effects and initial weight of the raw ham as a covariate. Differences were tested using the least significant difference test.

RESULTS AND DISCUSSION

Moisture and weight losses

Moisture diminished in the salting process owing to the osmotic effect produced by the salt that covered the entire surface of the ham, and during the resting and aging stages by dehydration (Table 1). The amount of weight loss during the salting, resting and aging periods in PSE hams was not significantly different from that

Table 1. Mean moisture content (%) in different zones of dry cured ham during processing and PSE effect on moisture content in each zone

Zone	PSE–normal	Sampling time (days)					msd[1]
		0	18	50	122	207	
Butt	–0·3	$72{\cdot}9a^{f}$	$67{\cdot}4b^{de}$	$65{\cdot}4c^{de}$	$58{\cdot}0d^{cd}$	$49{\cdot}9e^{cd}$	1·40
M. Adductor	–0·1	$73{\cdot}6a^{def}$	$68{\cdot}6b^{cd}$	$66{\cdot}6b^{cde}$	$59{\cdot}5c^{c}$	$48{\cdot}6d^{de}$	2·19
M. Rectus femoris	2·5*	$75{\cdot}1a^{ab}$	$70{\cdot}2b^{bc}$	$67{\cdot}2c^{cd}$	$63{\cdot}6d^{ab}$	$54{\cdot}8e^{ab}$	2·27
M. Vastus medialis and *intermedius*	2·1*	$75{\cdot}5a^{a}$	$70{\cdot}8b^{b}$	$67{\cdot}7c^{bc}$	$62{\cdot}7d^{b}$	$53{\cdot}6e^{bc}$	2·43
M. Vastus lateralis	1·6*	$74{\cdot}3a^{bcd}$	$71{\cdot}7b^{ab}$	$69{\cdot}3c^{ab}$	$65{\cdot}5d^{ab}$	$59{\cdot}3e^{a}$	1·94
M. Gastrocnemius	0·7	$74{\cdot}1a^{cd}$	$72{\cdot}7a^{a}$	$69{\cdot}9b^{a}$	$65{\cdot}3c^{ab}$	$59{\cdot}0d^{a}$	1·54
Shank	2·0*	$74{\cdot}7a^{abc}$	$68{\cdot}6b^{cd}$	$65{\cdot}8c^{cde}$	$63{\cdot}7d^{ab}$	$56{\cdot}2e^{ab}$	1·37
M. Semitendinosus	1·9*	$73{\cdot}2a^{ef}$	$71{\cdot}5b^{ab}$	$67{\cdot}5c^{bc}$	$63{\cdot}7d^{ab}$	$56{\cdot}9e^{ab}$	1·67
M. Gracilis	2·1*	$73{\cdot}1a^{f}$	$61{\cdot}6b^{f}$	$57{\cdot}4c^{f}$	$37{\cdot}1d^{e}$	$28{\cdot}5e^{f}$	2·21
M. Semimembranosus	0·5	$74{\cdot}6a^{abc}$	$66{\cdot}8b^{e}$	$64{\cdot}7b^{e}$	$56{\cdot}3c^{d}$	$44{\cdot}8d^{e}$	2·74
M. Biceps femoris	1·2*	$74{\cdot}1a^{cde}$	$71{\cdot}6b^{ab}$	$69{\cdot}8c^{a}$	$65{\cdot}9d^{a}$	$59{\cdot}2e^{a}$	1·37
msd[2]		0·95	1·72	2·05	3·03	4·91	

Means within a row with different letters are significantly different ($P<0{\cdot}05$).
Means within a column with different superscripts are significantly different ($P<0{\cdot}05$).
*Difference between PSE and normal quality is significant ($P<0{\cdot}05$).
[1]msd = Minimum significant difference between sampling times ($P<0{\cdot}05$).
[2]msd = Minimum significant difference between sampling zones ($P<0{\cdot}05$).

of normal hams ($P>0{\cdot}05$). These results do not concur with those found in other studies, which used different technologies (Maggi *et al.*, 1988; Kemp *et al.*, 1974). The mean moisture levels over all the sampling times of *Rectus femoris, Vastus medialis* and *intermedius, V. lateralis*, shank, *Semitendinosus, Gracilis* and *Biceps femoris* were significantly higher in PSE hams than in normal hams ($P<0{\cdot}05$), perhaps due to the lower fat content of PSE hams (Gispert *et al.*, in press). Moisture content diminished more quickly in the Butt and external muscles of the cushion that are not covered by skin and fat (*Gracilis, Adductor* and *Semimembranosus*). The differences between muscles in the cushion (zones 2, 8, 9, 10 and 11) were greater than in the knuckle (3, 4 and 5) due to the presence of intermuscular fat between the *B. femoris* and the *Semimembranosus* muscles and the greater thickness of the cushion and the fat and connective tissue covering the knuckle.

As the hams were aged without any application of fat on the surface, the differences in water content between the external and internal muscles were greater than in other studies carried out on Parma ham, where fat is applied during aging (Baldini *et al.*, 1977).

pH

PSE and normal hams differed only in pH_{45}, but not during the process ($P>0{\cdot}05$). The zones with a higher pH at the beginning of the process were the shank, *Gracilis, Gastrocnemius, R. femoris* and *V. medialis* and *intermedius*. The pH value diminished during the salting period in *Gracilis* muscle, perhaps because of the loss of phosphate (Arnau *et al.*, 1993), or some other basic compounds, and the salt uptake (Migaud & Frentz, 1978; Córdoba, 1990). Afterwards, pH in this muscle increased during the resting period due to the crystals of Na_2PO_4H, which came mainly from the *Semimembranosus* muscle (Arnau *et al.*, 1993). In the other zones, pH increased or remained practically unchanged during resting and the initial aging period (122 days). This evolution has been attributed to proteolysis and the formation of basic compounds (Melo *et al.*, 1974; Bartholomew & Blumer, 1977). After 122 days the pH did not change significantly ($P>0{\cdot}05$) (Table 2), which is in accordance with the results of Flores *et al.* (1985) and Baldini *et al.* (1977).

NaCl

The lower water holding capacity of PSE meat compared to that of normal meat could facilitate the dissolution of NaCl on the surface of the meat, which is the principal factor regulating the penetration of NaCl into the ham (Söheim & Gumpen, 1986). Mean NaCl contents over all the sampling times were higher in PSE hams than in normal hams only in the *Semimembranosus* and *Semitendinosus* muscles ($P<0{\cdot}05$). This may be due to the PSE detection system used in this study accounting only for *Semimembranosus* muscle. The *Semitendinosus* muscle could be affected by salt uptake of the *Semimembranosus* muscle, since they are anatomically adjacent (Tables 3 and 4). The shank is the most isolated zone and salt penetration takes place mainly through the skin and fat, which absorb salt during the salting period and deliver it to the muscle (Table 4). This could explain the increase in salt concentration on dry matter (d.m.) in the shank during the resting period.

The NaCl concentration (d.m.) in the *Semimembranosus* muscle diminishes during aging owing to migration towards the more humid muscles (Table 4). The increase in salt concentration (d.m.) in zones 5, 6, 8 and 11 is due to the higher moisture which dissolves more NaCl. The *Gracilis* muscle presented the highest

Table 2. Mean pH in different zones of dry cured ham during processing

Zone	Sampling time (days)					msd[1]
	0	18	50	122	207	
Butt	5·7c^{dc}	5·8c^{cd}	6·0b^{de}	6·3a^{cde}	6·4a^{bcd}	0·13
M. Adductor	5·9c^{bc}	5·8c^{cd}	6·3b^{bc}	6·5a^{b}	6·5a^{ab}	0·20
M. Rectus femoris	6·1ab^{ab}	6·0b^{abc}	6·2ab^{cd}	6·3a^{cde}	6·3a^{cd}	0·23
M. Vastus medialis and *intermedius*	6·3ab^{a}	6·2b^{ab}	6·4a^{ab}	6·4a^{bc}	6·4a^{abcd}	0·20
M. Vastus lateralis	5·8c^{bcd}	5·8c^{cd}	6·0b^{de}	6·3a^{de}	6·3ab^{cd}	0·17
M. Gastrocnemius	6·0c^{abc}	5·9c^{bc}	6·2b^{cd}	6·4a^{bcd}	6·3ab^{cd}	0·17
Shank	6·2b^{ab}	6·2b^{a}	6·4a^{ab}	6·5a^{b}	6·4a^{abc}	0·16
M. Semitendinosus	5·9b^{bc}	5·9b^{cd}	6·0b^{e}	6·2a^{ef}	6·2a^{cd}	0·19
M. Gracilis	6·1b^{ab}	5·8c^{cd}	6·6a^{a}	6·7a^{a}	6·6a^{a}	0·19
M. Semimembranosus	5·5b^{d}	5·7b^{d}	6·1a^{cde}	6·3a^{de}	6·2a^{d}	0·22
M. Biceps femoris	5·7b^{cd}	5·8b^{cd}	6·0a^{de}	6·1a^{f}	6·2a^{d}	0·20
msd[2]	0·36	0·24	0·20	0·15	0·20	

Means within a row with different letters are significantly different ($P < 0·05$).
Means within a column with different superscripts are significantly different ($P < 0·05$).
[1]msd = Minimum significant difference between sampling times ($P < 0·05$).
[2]msd = Minimum significant difference between sampling zones ($P < 0·05$).

salt concentration during the salting period and the lowest at the end of the process. These results indicate that, salt concentration in dry cured ham changes during the process due to the penetration of salt from the external dry zones towards the more humid zones (Table 4). These results do not agree with those of Flores *et al.* (1985), who found no changes in NaCl after the second month in rapid and slow processes, using another sampling method. Baldini *et al.* (1977) obtained smaller differences between the zones of Parma ham due to the application of fat to the surface during aging and also to the presence of skin covering a large part of the ham. The inversion of NaCl concentration could be explained by the natural tendency of the NaCl/moisture ratio to equilibrate between different zones of the ham (Table 5) during the process, but the distance between different zones or the presence of fat, bones and conjunctive tissue barriers could reduce the rate at which this process takes place.

The salt content increased in the muscular part from 169 g per ham after the salting period to 230 g per ham at the end of the resting period. During aging, NaCl may be absorbed by internal bones (the femur, tibia and fibula), which may account for the nonsignificant diminution of NaCl (Table 3). These results indicate that much of the salt absorbed by the muscles after the salting period may come from the nonmuscular zones (the skin, aitch and fat).

Table 3. Mean sodium chloride content (%) in different zones of dry cured ham and the mean estimated amount of NaCl in the lean tissue of ham during processing and the PSE effect

Zone	PSE–normal	Sampling time (days)				msd[1]
		18	50	122	207	
Butt	–0·4	4·9c^{bc}	6·4b^{ab}	7·1ab^{a}	8·0a^{ab}	1·16
M. Adductor	0·1	4·3c^{cd}	4·6bc^{cde}	5·1ab^{cd}	5·7a^{d}	0·66
M. Rectus femoris	–0·1	3·2c^{de}	5·1b^{cd}	5·7b^{bc}	6·9a^{bcd}	0·85
M. Vastus medialis and *intermedius*	–0·1	2·8d^{ef}	4·1c^{def}	5·1b^{cd}	6·3a^{cd}	0·70
M. Vastus lateralis	–0·1	2·0d^{efg}	3·8c^{ef}	5·7b^{bc}	7·4a^{abc}	1·05
M. Gastrocnemius	0·4	1·0d^{g}	2·6c^{g}	4·0b^{de}	5·9a^{cd}	0·83
Shank	–0·4	2·6c^{ef}	4·3b^{def}	4·6b^{cd}	5·7a^{d}	0·83
M. Semitendinosis	1·0*	1·1c^{g}	3·6b^{fg}	4·2b^{de}	6·0a^{cd}	1·01
M. Gracilis	–0·6	10·9a^{a}	5·6b^{bc}	2·9c^{e}	3·1c^{e}	0·68
M. Semimembranosus	1·2*	5·8ab^{b}	6·9a^{a}	6·9a^{ab}	5·6b^{d}	1·27
M. Biceps femoris	0·3	1·8c^{fg}	4·4b^{def}	5·9b^{abc}	8·6a^{a}	1·60
msd[2]		1·24	1·07	1·38	1·57	
Estimated NaCl (g) in lean tissue	–2	169b	230a	228a	208ab	54·1

Means within a row with different letters are significantly different ($P < 0·05$).
Means within a column with different superscripts are significantly different ($P < 0·05$).
*Difference between PSE and normal quality is significant ($P < 0·05$).
[1]msd = Minimum significant difference between sampling times ($P < 0·05$).
[2]msd = Minimum significant difference between sampling zones ($P < 0·05$).

Table 4. Mean sodium chloride content (% on dry matter) in different zones of dry cured ham during processing and PSE effect

Zone	PSE–normal	Sampling time (days)				msd[1]
		18	50	122	207	
Butt	–0·8	15·0b^{b}	18·4a^{a}	16·9ab^{a}	16·0ab^{bc}	2·39
M. Adductor	0·6	13·8a^{bc}	13·9a^{bc}	12·7ab^{bcd}	11·2b^{de}	1·63
M. Rectus femoris	0·8	10·6b^{cd}	15·5a^{b}	15·7a^{abc}	15·3a^{bc}	1·68
M. Vastus medialis and *intermedius*	0·2	9·7b^{cde}	12·6a^{cd}	13·6a^{abcd}	13·6a^{cde}	1·49
M. Vastus lateralis	0·2	7·0c^{def}	12·3b^{cd}	16·3a^{ab}	18·0a^{ab}	2·56
M. Gastrocnemius	1·1	3·7d^{f}	8·7c^{e}	11·5b^{d}	14·4a^{bcd}	1·85
Shank	–0·6	8·3b^{de}	12·6a^{cd}	12·5a^{bcd}	13·0a^{cde}	1·89
M. Semitendinosus	3·3*	3·6c^{f}	11·0b^{de}	11·7ab^{cd}	14·0a^{cd}	2·53
M. Gracilis	–0·8	28·2a^{a}	13·1b^{bcd}	4·7c^{e}	4·4c^{f}	1·76
M. Semimembranosus	3·2*	17·6ab^{b}	19·5a^{a}	15·9b^{ab}	10·1c^{e}	3·22
M. Biceps femoris	1·1	6·4c^{ef}	14·8b^{bc}	17·4ab^{a}	21·0a^{a}	4·55
msd[2]		4·18	2·76	4·0	3·80	

Means within a row with different letters are significantly different ($P<0·05$).
Means within a column with different superscripts are significantly different ($P<0·05$).
*Difference between PSE and normal quality is significant ($P<0·05$).
[1]msd = Minimum significant difference between sampling times ($P<0·05$).
[2]msd = Minimum significant difference between sampling zones ($P<0·05$).

Table 5. Mean NaCl/moisture relation in different zones of dry cured ham during processing and PSE effect

Zone	PSE–normal	Sampling time (days)				msd[1]
		18	50	122	207	
Butt	–0·7	7·2d^{bc}	9·7c^{a}	12·3b^{a}	16·0a^{a}	2·32
M. Adductor	0·1	6·3c^{c}	7·0c^{bc}	8·6b^{bc}	11·8a^{bc}	1·42
M. Rectus femoris	–0·6	4·5c^{d}	7·6b^{b}	9·1b^{b}	12·7a^{bc}	1·81
M. Vastus medialis and *intermedius*	–0·3	4·0d^{de}	6·0c^{bc}	8·2b^{bc}	11·9a^{bc}	1·49
M. Vastus lateralis	0·3	2·8d^{def}	5·5c^{cd}	8·7b^{bc}	12·5a^{bc}	1·91
M. Gastrocnemius	0·6	1·4d^{f}	3·7c^{d}	6·3b^{c}	10·0a^{c}	1·51
Shank	–0·8	3·8c^{de}	6·6b^{bc}	7·3b^{bc}	10·2a^{c}	1·51
M. Semitendinosus	1·5*	1·5c^{f}	5·3b^{cd}	6·7b^{bc}	10·6a^{c}	1·76
M. Gracilis	–1·6*	17·7a^{a}	9·7b^{a}	8·0c^{bc}	11·1b^{c}	1·68
M. Semimembranosus	2·0*	8·7b^{b}	10·7ab^{a}	12·3a^{a}	12·6a^{bc}	2·58
M. Biceps femoris	0·3	2·5c^{ef}	6·4b^{bc}	9·1b^{b}	14·6a^{ab}	2·74
msd[2]		1·78	1·89	2·44	3·07	

Means within a row with different letters are significantly different ($P<0·05$).
Means within a column with different superscripts are significantly different ($P<0·05$).
*Difference between PSE and normal quality is significant ($P<0·05$).
[1]msd = Minimum significant difference between sampling times ($P<0·05$).
[2]msd = Minimum significant difference between sampling zones ($P<0·05$).

Nitrate and nitrite

No significant differences were found between PSE and normal hams ($P>0·05$). After the salting period, concentrations higher than 200 ppm were recorded in all the muscles, showing that nitrate diffuses very quickly. This may be due to the slight interaction between nitrate and proteins, which facilitates a faster diffusion rate than chloride or nitrite (Fox, 1980). The *Gracilis* and butt present the highest nitrate values, which diminish quickly during the resting period (Table 6) by migration of nitrate into the ham and transformation into nitrite caused by the nitrate reductase activity of *Micrococcaceae*, which increases during this phase to 10^5 to 10^7 cfu/g (Hugas *et al.*, 1987; Carrascosa *et al.*, 1988; Silla *et al.*, 1989). At the end of the process, the *Gracilis* muscle presented the lowest level of nitrate, and the level in the *Semimembranosus* was lower than that in the *B. femoris*, butt, shank and *V. lateralis*, which are more humid. This low nitrate level could be the result of the tendency to equilibrate the nitrate/moisture ratio between different zones of the ham. The estimated values of nitrate in lean tissue diminished quickly during the resting period and more slowly during aging.

The nitrite increased during the postsalting period, especially in the external zones, but practically disappeared at the end of the aging period (Table 7). These findings agree with the results of Huerta (1986).

Dry cured ham is a nonhomogeneous product that has undergone a salting and dehydration process that influences the dynamics of water, NaCl, nitrate and nitrite migration.

Table 6. Mean potassium nitrate contents (ppm on dry matter) in different zones of dry cured ham and mean estimated amounts of KNO_3 (g) in ham lean tissue during processing

Zone	Sampling time (days)				msd[1]
	18	50	122	207	
Butt	862a[a]	487b[a]	397b[a]	293b[a]	202·4
M. Adductor	556a[bc]	105b[c]	159b[bc]	186b[bc]	113·2
M. Rectus femoris	580a[abc]	339b[ab]	285b[ab]	248b[ab]	155·8
M. Vastus medialis and *intermedius*	505a[cd]	201b[bc]	290b[ab]	243b[ab]	116·7
M. Vastus lateralis	468a[cd]	415ab[a]	319b[ab]	289b[a]	147·5
M. Gastrocnemius	349a[cd]	206b[bc]	275ab[abc]	263ab[ab]	128·6
Shank	475a[cd]	445ab[a]	338bc[a]	306c[a]	120·9
M. Semitendinosus	248b[d]	369a[ab]	247b[abc]	240b[ab]	76·8
M. Gracillis	812a[ab]	64b[c]	118b[c]	115b[c]	83·5
M. Semimembranosus	437a[cd]	325b[ab]	247c[abc]	194c[b]	77·3
M. Biceps femoris	386ab[cd]	412a[a]	347ab[a]	315b[a]	74·4
msd[2]	283·8	197·7	165·7	77·1	
Estimated KNO_3 (g) in lean tissue	0·77a	0·54b	0·43c	0·37c	

Means within a row with different letters are significantly different ($P < 0·05$).
Means within a column with different superscripts are significantly different ($P < 0·05$).
[1]msd = Minimum significant difference between sampling times ($P < 0·05$).
[2]msd = Minimum significant difference between sampling zones ($P < 0·05$).

Table 7. Mean sodium nitrite content (ppm on dry matter) in difference zones of dry cured ham during processing

Zone	Sampling time (days)			msd[1]
	50	122	207	
Butt	249a[a]	54b	8b	96·2
M. Adductor	238a[a]	53b	11b	44·8
M. Rectus femoris	153a[abc]	52b	6b	86·7
M. Vastus medialis and *intermedius*	135a[abcd]	9b	6b	40·0
M. Vastus lateralis	51a[cd]	22ab	< 5b	35·5
M. Gastrocnemius	76a[bcd]	< 5b	< 5b	40·5
Shank	43a[cd]	10b	< 5b	27·9
M. Semitendinosus	21[d]	11	8	14·7
M. Gracilis	188a[ab]	9b	< 5b	54·4
M. Semimembranosus	77a[bcd]	8b	< 5b	27·3
M. Biceps femoris	16a[d]	< 5b	< 5b	7·3
msd[2]	119·2	54·2	14·2	

Means within a row with different letters are significantly different ($P < 0·05$).
Means within a column with different superscripts are significantly different ($P < 0·05$).
[1]msd = Minimum significant difference between sampling times ($P < 0·05$).
[2]msd = Minimum significant difference between sampling zones ($P < 0·05$).

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