ELSEVIER

Food Chemistry 64 (1999) 13–19

Food Chemistry

Reducing salt content of dry-cured ham: effect on lipid composition and sensory attributes

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Received 12 December 1997; received in revised form 19 February 1998; accepted 1 April 1998

Abstract

The salt content of dry-cured ham must be reduced to adapt the product to the taste of the consumer and to human health recommendations. This study dealt with the effect of lowering salt content on the lipid composition and sensory attributes of 18-month-old Corsican dry-cured hams. Six were salted according to a long time salting method and six according to a short time method (STS). The latter was lower in both total and free chlorides (4.7% v 7.3% and 1.5% v 2.0%, respectively) and in dry matter (23.8% v 25.2%). The composition of the intramuscular lipids was similar for both salting methods except that the proportion of polyunsaturated fatty acids of the phospholipids was higher in STS hams (42.3% v 34.0%). The salting method had no significant effect on the appearance of the hams (marbling, colour). However, the STS hams were less salty and their aroma notes related to fat such as rancid, fatty and buttery were more pronounced.

1. Introduction

In southern countries, dry-cured ham is of great economical interest because the two hams of a pig carcass represent about two-thirds of its value (Russo et al., 1991). The technology of its processing varies from one country to another but it always includes salting and ripening periods which contribute to the stability of the product and to the typical flavour of the dry-cured ham.

Salting is one of the key steps in dry-cured ham processing for several reasons (Goutefongea, 1988). Salt is a bacteriostatic agent which inhibits germ growth, thus reducing the risk related to pathogenic germs. It reduces water activity, which prevents the meat from putrefying. It gives meat its salty taste which is related to the free chloride content. It finally contributes to giving the ham its dark colour (Durand and Vendeuvre, 1980).

In some southern Mediterranean countries, such as Corsica where the technology of salting remains traditional, hams are buried in salt for a long period (3–4 days/kg of ham). If the technology is efficient for a long term preservation of dry-cured ham, the meat is left with a strong salty taste and it contains up to 11% salt after 18 months of processing (Coutron, 1996). In comparison, Iberian or Italian hams contain only 5 to 9% salt (Parolari et al., 1984; Bellati et al., 1985; Astiasaran et al., 1988; Melgar et al., 1990). Consequently, the salt content of Corsican hams must be reduced to suit the consumer's taste and to follow human health recommendations. The simplest way to achieve this is to shorten the salting period as it was done in Spain for Iberian dry-cured hams. Before introducing this change, we have to check for any negative consequences it might have on the sensory attributes of the hams. Indeed, salt affects numerous chemical reactions such as proteolysis and oxidation which are involved in the development of the typical flavour of dry-cured hams. For example, reducing salt, which is a pro-oxidant agent (Pearson et al., 1977) could affect the aroma of ham because oxidation is one of the main sources of volatiles in dry-cured hams (Berdagué et al., 1991; Barbieri et al., 1992; Lopez et al., 1992).

The aim of this study is to evaluate the effect a reduction in the salt content of the meat would have on the chemical composition and on the sensory attributes of Corsican dry-cured ham. We compared the chemical

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0308-8146/98/$19.00
PII: S0308-8146(98)00111-3

composition and the sensory attributes of *Biceps femoris* from 18-month-old hams salted according to two methods : a long time salting (LTS)(4–5 days/kg of ham) and a short time salting (STS)(1–1.5 days/kg of ham). The following parameters were measured : dry matter, salt, total lipid, neutral lipid, phospholipid, free fatty acid, monoacylglycerol and diacylglycerol contents, UV absorbance of lipids, TBA test and sensory attributes of hams.

2. Materials and methods

2.1. Green hams

Six Corsican pigs (3 males, 3 females) were used. They were reared according to the traditional Corsican extensive rearing system (Secondi et al., 1992). They were 20 months old and weighed 110 kg when they were slaughtered. The carcasses were kept at 4°C for 24 h. The 12 hams (6 right, 6 left) were cut and identified. They weighed 9.5 kg on average. The *B. femoris* of green hams had a pH of 5.5, a high water holding capacity and a water activity of 0.97. The meat colour was red (3–4 on the Japanese scale). The muscle contained 30% dry matter, 5.5% lipids including 5% neutral lipids and 0.44% phospholipids. The amounts of monoacyl- and diacylglycerols and free fatty acids were 0.8, 0.9 and 5.4%, respectively. The fatty acid compositions of triacylglycerols, free fatty acids and phospholipids are reported in Table 1.

2.2. Dry-cured ham processing

The six left hams were salted according to the traditional method used in Corsica (long time salting method (LTS) and the six right ones according to the method currently used in Spain for Iberian hams (short time salting method (STS). In the former method, the hams are thoroughly rubbed with dry salt and buried in a pile of salt at 4°C for 30 to 45 days (4 days per kg of ham). Then they are washed for 24 h to remove the excess salt. In the latter method, only the section of the hams is rubbed with salt and then covered with salt at 4°C for 10 days (1 day per kg of ham). The hams are then brushed to remove the excess of salt before being kept at 4–5°C for three weeks. After salting, both LTS and STS hams were hung for nine months in a drying room at 8–10°C and 75–90% relative humidity. They were kept under environmental conditions in a cellar (temperature range of 14–18°C and relative humidity of 75%) until the end of the ripening (18 months). At the end of the process, *B. femoris* were dissected and frozen at −80°C until being analysed.

2.3. Chemical analyses

The pH was measured directly in the muscle with a Knick pH-meter equipped with an Ingold dagger electrode.

Water activity was measured with a Lutz apparatus from 75 g of *biceps femoris*. The dry matter was

Table 1
Fatty acid composition of lipid fractions from *biceps femoris* of green hams (% of methyl esters)

	Acylglycerols[a] ($n=6$)		Phospholipids ($n=6$)		Free fatty acids ($n=6$)	
14:0	1.2	(0.1)	0.3	(0.1)	0.6	(0.2)
16:0	22.8	(0.7)	23.0	(2.3)	19.0	(3.0)
18:0	11.0	(0.4)	9.6	(0.9)	6.4	(0.9)
Saturated	35.1	(0.9)	32.9	(2.2)	25.9	(3.8)
16:1	3.4	(0.6)	0.9	(0.2)	2.6	(0.3)
18:1	50.8	(1.4)	17.0	(0.9)	27.5	(2.5)
20:1	1.0	(0.1)	0.4	(0.1)	0.5	(0.3)
Monounsaturated	55.2	(1.4)	18.3	(1.0)	30.9	(3.0)
18:2	7.8	(0.7)	29.4	(2.6)	27.0	(3.9)
20:2	0.4	(0.05)	0.9	(0.2)	0.8	(0.4)
20:3	0.1	(0.01)	1.4	(0.2)	0.9	(0.2)
20:4	0.8	(0.2)	12.5	(3.0)	9.4	(1.0)
22:4	—		1.1	(0.1)	0.6	(0.1)
N-6	9.1	(0.6)	45.3	(1.6)	38.8	(3.5)
18:3	0.6	(0.1)	0.6	(0.2)	1.0	(0.2)
20:5	—		0.7	(0.2)	0.9	(0.2)
22:5	—		1.5	(0.3)	1.8	(0.2)
22:6	—		0.6	(0.1)	0.7	(0.1)
N-3	0.6	(0.1)	3.5	(0.6)	4.3	(0.4)
Polyunsaturated	9.7	(0.7)	48.8	(2.0)	43.1	(3.6)

[a] Acylglycerols = sum of tri-, di- and monoacylglycerols. Values in parentheses are standard deviation.

determined by weighing a muscle sample before and after it was dried in an oven at 103°C for 24 h.

The total and free chloride contents of ham were measured with a chlorometer equipped with a silver electrode. Total chlorides were quantified from 10 g of ham homogenised in distilled water and placed in a boiling water bath for 1 h. Free chlorides were quantified from 10 g of ham homogenised in distilled water and kept at room temperature for 3 h. Both homogenates were filtered after addition of 2 ml of 15% ferrocyanide solution and 2 ml of 30% zinc acetate solution. Results were expressed in g of Na Cl/100 g of muscle.

2.4. Lipid analyses

2.4.1. Lipid extraction

Muscles were carefully trimmed to remove adipose tissues and were minced in a blender. Lipids were extracted from 10 g of muscle with chloroform/methanol (2:1) according to the method of Folch et al. (1957). The extracts were dried under vacuum on a rotary evaporator. The total lipid content was weighed and expressed in g $100\,g^{-1}$ of muscle. The phospholipid content was calculated ($P\times25$) after phosphorus was determined in the total lipid extract by the method of Bartlett (1959). The neutral lipid content was estimated by the difference between total lipid and phospholipid contents. Phospholipids and neutral lipids were expressed in g $100\,g^{-1}$ of muscle.

2.4.2. Lipid extract fractionation

For further lipid characterisation, the total lipid extracts were fractionated into neutral lipids and phospholipids on silica cartridges (Sep-Pack, Waters) following the procedure described by Juaneda and Rocquelin (1985).

2.4.3. Free fatty acid quantification

Free fatty acids were purified from the neutral lipids using an anionic exchange resin (Amberlyst A26) as described by Gandemer et al. (1991). Fifty mg to 100 mg neutral lipids were dissolved in 15 ml of a mixture of acetone/methanol 2:1 (v/v). After addition of 100–200 mg of the resin and heptadecanoic acid (internal standard), the mixture was shaken during 30 min. Non-resin bound lipids were removed by washing the resin with acetone/methanol 2:1 (v/v). Resin was then transferred into a dry tube for methylation.

2.4.4. Acylglycerol quantification

The triacyl-, diacyl- and monoacylglycerols were quantified according to a method adapted from that of Myher and Kuksis (1984). Five mg to 10 mg neutral lipids were introduced in a conic vial. The solvent was evaporated under N_2 and the lipids were silylated using 250 ml of a mixture of BSTFA:TMCS (80/20) (composed of pyridine, trimethylchlorosilane (TMCS) and bis-trimethyl-silyl-trifluoro-acetamide (BSTFA)) (Pierce Chem., Co., Rockford, USA). The vial was immediately closed with a Teflon cap. The reaction was achieved in 30 min at room temperature. The mixture was evaporated under N_2 and the derivatives were dissolved in 2 ml of hexane. The silylated components (TMS) were then analysed by gas liquid chromatography. The chromatograph was a Delsi DI 700 equipped with a flame ionisation detector and an 'on-column' injector (SGE). One μl of the sample was injected in a capillary column (DB5, SGE, 7 m length, 0.32 mm internal diameter, 0.1 μm film thickness) containing a non-polar stationary phase (5% phenylmethyl–95% siloxane). The oven temperature was maintained at 120°C for 5 min, increased from 120°C to 230°C at $20°C\,min^{-1}$ and from 230°C to 330°C at $15°C\,min^{-1}$ and then held at 335°C for 5 min. The detector temperature was maintained at 350°C. The carrier gas was hydrogen and its flow was maintained at $2\,ml\,min^{-1}$. The derivatives were eluted according to their molecular weight in less than 25 min. The response coefficients of the compounds were determined according to an internal standard, the tricaprin, for which the coefficient was set at 1. Data were collected with a system including an 'acquisition box', software and a computer (Apex, Stang, France). Results were expressed as mg $100\,g^{-1}$ of *biceps femoris*.

2.4.5. Fatty acid composition

The fatty acid composition of triacylglycerols, free fatty acids and phospholipids was determined by gas liquid chromatography. Methyl esters were prepared according to the method of Morrison and Smith (1964). The gas chromatograph was equipped with a split and an on-column injectors and a flame ionisation detector (Hewlett-Packard 5890). The methyl esters were separated using a capillary column (DB 225, J and W, 30 m long, 0.32 mm internal diameter, 0.25 μm film thickness) containing a polar stationary phase (cyanopropylphenyl-methylpolysiloxane). The flow rate of carrier gas (H2) was set at $2\,ml\,min^{-1}$. Triacylglycerol methyl esters were injected using the split injector, the split flow rate was set at $30\,ml\,min^{-1}$. The oven temperature was held at 150°C for 3 min, increased to 190°C at $10°C\,min^{-1}$, held at 190°C for 10 min, and from 190°C to 210°C at $20°C\,min^{-1}$, and then maintained at 210°C for 10 min. The injector and detector temperatures were held at 250°C. Free fatty acid and phospholipid methyl esters were injected using the on-column injector. The oven temperature was held at 50°C for 3 min, increased from 50 to 180°C at $10°C\,min^{-1}$, held at 180°C for 10 min, increased from 180 to 210°C at $20°C\,min^{-1}$ and then maintained at 210°C for 10 min. The detector temperature was set at 250°C. Data were collected with a system including an 'acquisition box', software and a computer (Apex, Stang, France). The individual fatty acid methyl

esters were identified by mass spectrometry using a bench mass spectrometer (HP MSD 5971A). The results were expressed as per cent of the total fatty acid methyl esters present.

2.4.6. Oxidation measurement

Lipid oxidation was estimated according to the method of Klein (1970). About 250 μg of total lipid extracts were dried under N_2. and then dissolved in 2 ml of cyclohexane. Spectra were recorded on a Varian, Cary 13. The ratio between the absorbances at 232 and 215 nm was defined as the conjugated diene value and the ratio between the absorbances at 275 and 215 nm was defined as the carbonyl value. TBA reactive substances were quantified according to the procedure of Salih et al. (1987) modified by Ahn et al. (1993). A 5-g sample was combined with 16 ml of perchloric acid (3.86%). The mixture was homogenised and filtered on Whatman filter. A 2 ml aliquot of the filtrate was mixed with 2 ml of 0.02 M TBA solution and then kept in the dark at room temperature for 17 h. The absorbance was read at 532 nm against a blank that contained all the reagents. The results were expressed as μg of TEP g^{-1} of muscle.

2.4.7. Sensory analysis

The panel was composed of 12 subjects (7 females and 5 males) experienced in the sensory analysis of meat products. They had been trained to taste dry-cured ham in several previous experiments and were trained during three sessions for the present experiment. For salty and acid tastes, they had to rank 4 solutions with an increasing concentration of salt or acetic acid according to the intensity of taste. For aiding to describe the aroma, they smelt different references put on snippets: fresh fat of pork, rancid fat of pork, dry-cured ham, hazelnut powder, vanillin, isoamyl acetate (banana), acetic acid (vinegar), isovaleric acid (blue cheese), 2–3 butanedione (butter) and 1-octen-3-ol (mushroom). The definition and significance of texture attributes were previously determined by Mioche and Touraille (1990), Civille and Szczesniak (1973) and Skinner (1988). Our panellists listed descriptive attributes after smelling and tasting samples of STS and LTS dry-cured hams. Eighteen descriptors were selected for establishing the profile according to the standard NF-ISO-11035 (1995) (see Table 3).

Slices (3 mm thick) were cut in *biceps femoris* of dry-cured hams using a CELME electric slicer. In each session, a panellist monadically tasted 8 samples (4 animals×2 salting methods). Samples were randomly given to each subject. Three sessions were performed so that each panellist tasted the same ham twice. Eventually we obtained 24 marks per attribute and per ham. The panellists scored the 18 attributes on non-structured scales of 10 cm ranging from less to more. The scale covered marks ranging from 1 to 20.

2.4.8. Statistical analysis

The data were compared using a Student T test. The relations between the sensory attributes were studied by principal component analysis performed on the data of all the dry-cured hams.

3. Results

3.1. Physico-chemical parameters

The technological yield was similar for the two types of hams. It was 63.2% for the LST hams and 62.0% for the STS hams. The pH of the meat at the end of the process was also similar (6.1). In contrast, the LTS hams exhibited a higher water activity than the STS hams (0.90 v 0.87).

The salting method significantly affected the dry matter and the total and free chloride contents of the hams. The STS hams contained less dry matter (23.8% vs 25.2%), less total chlorides (7.6% vs 11.5%) and 25% less free chlorides which shows that the STS method restricted salt uptake by hams. But the salting method had no significant effect on most of the lipid parameters. In both STS and LTS hams, the total lipid, neutral lipid and phospholipid contents were not significantly different (3.9 and 5.0%, 3.8 and 4.8% and 0.18 and 0.17%, respectively). The degree of lipid oxidation in hams was close whatever the test considered A232/A215 or A275/A215 ratio or TBA test. The degree of lipolysis was similar in both types of hams except that the monoacylglycerol content was higher in STS hams than in LTS ones (3.7 vs 2.4% of neutral lipids).

The fatty acid compositions of acylglycerols were similar in the two types of hams. Saturated, monounsaturated and polyunsaturated fatty acids accounted for 34.4, 54.4 and 11.5, respectively. The salting method significantly affected the proportion of polyunsaturated fatty acids (PUFA) of phospholipids. Thus the PUFA proportion in phospholipids decreased less sharply in STS than in LTS hams (Table 2). The loss reached 48% of the 20:4 content of green ham phospholipids in LTS hams and was restricted to 7% in STS hams. The same trend was observed for the PUFA proportion in free fatty acids but the difference was not significant (30.9 vs 33.7%).

3.2. Sensory attributes of hams

Among the 18 sensory attributes of hams considered, only five were affected by the salting method (Table 3). The odour and the texture of the meat were not significantly affected. The meat was brighter and less salty in STS hams. Many aroma attributes were similar in both hams: dry-cured ham, fruity, hazelnut, blue cheese, foot and mushroom. The aroma notes related to intramuscular lipids such as rancid, fatty and buttery aroma depended

Table 2
Effect of salting on fatty acid composition of phospholipids from *biceps femoris* of dry cured hams (% of methyl esters)

	Long time salting ($n=6$)		Short time salting ($n=6$)		p value
14:0	0.9	(0.1)	0.7	(0.1)	ns
16:0	22.9	(1.7)	21.2	(2.5)	ns
18:0	13.5	(0.7)	12.3	(1.2)	ns
Saturated	37.2	(1.7)	34.2	(3.7)	ns
16:1	1.9[a]	(0.5)	1.3[b]	(0.3)	**
18:1	25.9	(7.6)	21.5	(3.8)	ns
20:1	0.9	(0.3)	0.7	(0.2)	ns
Monounsaturated	28.7	(8.0)	23.4	(4.1)	ns
18:2	22.3	(6.1)	23.4	(5.1)	ns
20:2	1.1	(0.5)	1.0	(0.1)	ns
20:3	1.0	(0.4)	1.1	(0.2)	ns
20:4	6.5[b]	(2.3)	11.6[a]	(4.0)	**
22:4	1.0[b]	(0.2)	1.5[a]	(0.5)	**
N-6	31.9	(8.4)	38.7	(6.2)	ns
18:3	0.6	(0.1)	0.5	(0.2)	ns
20:5	0.2[b]	(0.1)	0.6[a]	(0.3)	**
22:5	0.8[b]	(0.2)	1.7[a]	(0.8)	*
22:6	0.4[b]	(0.2)	0.8[a]	(0.4)	*
N-3	2.1[b]	(0.2)	3.5[a]	(1.2)	**
Polyunsaturated	34.0[b]	(8.4)	42.3[a]	(7.0)	**

[a,b] On the same row, means with different superscripts differ significantly. Significance levels: ns = not significant; *$p < 0.05$; **$< p < 0.01$. Values in parentheses are standard deviation.

Table 3
Effect of salting on the sensory attributes of dry cured hams (mean score from sensory analysis)

	Long time salting ($n=6$)		Short time salting ($n=6$)		p value
Odour					
Fruity (cheese)	10.1	(1.0)	9.6	(0.7)	ns
Aspect					
Redness	11.4	(3.3)	11.9	(3.1)	ns
Marbling	10.8	(3.4)	11.1	(3.0)	ns
Brightness	9.3[b]	(1.7)	10.8[a]	(1.5)	*
Taste					
Salty	12.6[a]	(1.0)	10.8[b]	(1.1)	*
Sour	9.4	(0.9)	8.2	(1.0)	ns
Aroma					
Rancid	8.6[b]	(0.5)	9.2[a]	(0.7)	x
Dry ham	10.0	(0.7)	10.3	(0.8)	ns
Mushroom	6.6	(0.5)	6.9	(0.8)	ns
Fruity	9.3	(0.6)	8.7	(0.6)	ns
Fatty	7.8[b]	(1.0)	8.6[a]	(0.9)	*
Buttery	6.2[b]	(0.4)	6.7[a]	(0.5)	*
Hazelnut	5.8	(0.3)	5.5	(0.3)	ns
Blue cheese	7.0	(1.0)	6.9	(0.7)	ns
Foot	5.9	(1.0)	5.9	(0.8)	ns
Texture					
Fibrousness	11.2	(1.0)	11.0	(1.4)	ns
Mellowness	10.2	(2.2)	11.0	(1.4)	ns
Dryness	8.5	(1.9)	7.5	(1.7)	ns

[a,b] On the same row, means with different superscripts differ significantly. Significance levels: ns = not significant; x = $p < 0.1$; *$p < 0.05$; **$< p < 0.01$. Values in parentheses are standard deviation.

on the salting method. They were more pronounced in the meat of STS hams than in that of LTS hams.

A principal component analysis was carried out on the 18 sensory attributes. The percentage of the variance explained by the plan 1–2 was 60.7% of the total variance (Fig. 1). Axis 1 was determined by the texture attributes. Fibrousness was opposite to mellowness which was related to fat aroma and, to a lesser extent, to marbling. This result suggests that the texture of Corsican dry-cured ham largely depends on its lipid content. Aroma notes such as dry-cured ham, fruity, sour and salty were opposite to fat and butter aroma which means that aroma related to meat are opposite to those arising from fat. Axis 2 was determined by hazelnut aroma and, at the opposite by some negative aroma such as rancid, foot and blue cheese. Note that fatty and rancid aroma were located close to marbling note, which indicates that these notes were strongly related to the lipid content of hams.

4. Discussion

4.1. Salting and meat taste

STS caused a significant decrease in the salt content of hams, which is close to what is usually reported for Italian Parma hams (Palmia et al., 1992). When STS was used, the amount of salt which penetrated the meat was reduced, decreasing both total and free chloride amounts. This explains why the STS hams were judged less salty because the salty taste depends on the free salt amount in the meat (Durand and Vendeuvre, 1980).

4.2. Salting and lipid oxidation

We observed a decrease in the amount of polyunsaturated fatty acids in phospholipids while the fatty acid composition of triacylglycerols remained unchanged. These results are consistent with previous ones which indicated that phospholipids are the main substrates of lipid oxidation in meat and meat products because they contain a large amount of long chain polyunsaturated fatty acids (Wilson et al., 1976; Gandemer, 1990). After 18 months of processing, the amount of PUFA in phospholipids were lower in LTS hams than in STS hams. This result is explained by the fact that salt is a pro-oxidant agent in meat and meat products (Cheftel and Cheftel, 1976; Pearson et al.,

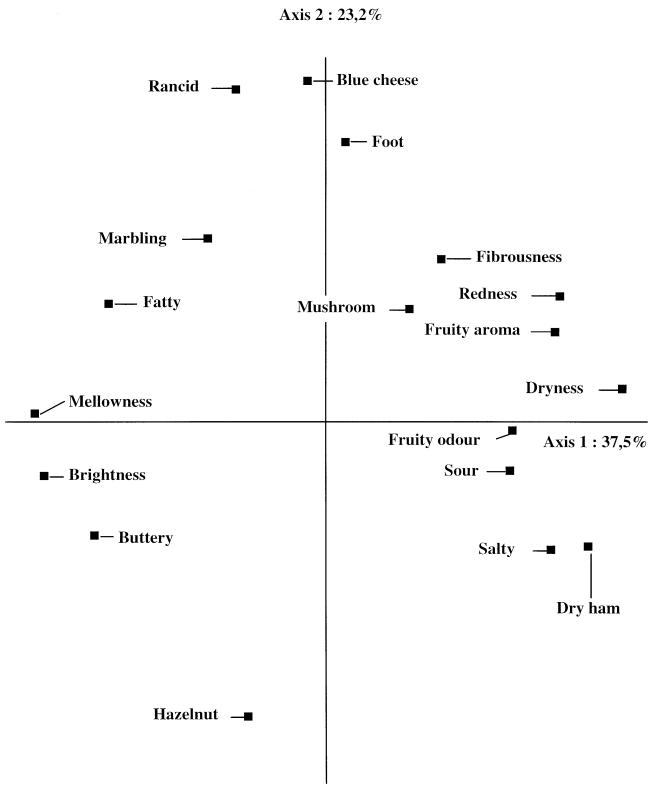

Fig. 1. Principal component analysis of the sensory attributes: plot of the first and second principal components.

1977). We can conclude that reducing salt in dry-cured ham contributes to reducing lipid oxidation.

4.3. Salting and meat aroma

The salting method did not influence the red colour and the marbling score of the ham slice. These results are in agreement with previous ones which indicated that these parameters vary from one pig to another according to rearing conditions, genotype, age and feed (Monin, 1983). The salting method did not affect texture but aroma largely depended on it. However, reducing salt in dry-cured ham did not affect the aroma notes related to the typical aroma of ham such as dry-cured ham, fruity, hazelnut and blue cheese (Garcia et al., 1991; Barbieri et al., 1992; Careri et al., 1993). In contrast, it largely affected the aroma notes related to lipids. This result was unexpected because the STS hams, which were less oxidised, were those exhibiting the higher rancid aroma and also, fat and butter aroma. Consequently this is not explained by the level of lipid oxidation. We can postulate that the STS hams had more intense aroma from lipids because they were less salty. The panellists perceived the aroma related to intramuscular fat in STS hams because these aroma compounds would be not masked by a too strong salty taste as it is probably the case in LTS hams.

5. Conclusion

Our study indicates that substituting a short time salting process for the traditional long one contributes to reducing the salt content and salty taste of the ham, which suits the consumer better. Although it reduces the oxidation of lipids, the short salting process promotes the negative flavour related to them (rancid, fatty, buttery) at the expense of more favourable aroma such as dry-cured ham and fruity. Consequently reducing salt in Corsican dry-cured hams can cause difficulties because they are rich in lipids and are processed for at least 18 months. The introduction of the short salting method in Corsican technology raises the question of defining the optimum content of intramuscular lipids and the optimum length of processing for the production of a high quality Corsican ham.

Acknowledgements

This work was carried out with the financial support of the EC AIR project 'Establishing scientific bases for control and improvement of sensory quality of dry-cured hams in southern European countries' (no. AIR2-93-1757).

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