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Physicochemical Changes During Processing of Chinese Xuanwei Ham

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ABSTRACT

Fifty porcine hind legs were processed into dry-cured ham using the traditional Xuanwei process. Sensory and physicochemical changes during processing were studied. The sensory traits (color, texture, odor, taste) of the ham improved during the 4 mth fermentation stage. The moisture content and water activity of muscles decreased and the salt content increased during fermentation. Moisture and water activity of muscles affected the development of a surface crust that is not wanted. Total volatile basic nitrogen, $NaNO_2$ in all muscles and the acid value in the subcutaneous fat increased during processing. The peroxide value increased with time during prefermentation and decreased during fermentation. Use of 90 mg $NaNO_2$ per kilogram of meat improved the color of the final product without posing any food safety issues. During the salting, the pH of the meat decreased with time, but the pH increased rapidly during fermentation. The percentage of saturated free fatty acids increased during fermentation while the percentage of unsaturated free fatty acids decreased. This suggested that the unsaturated free fatty acids were the main fatty acids that underwent peroxidation during the ham fermentation.

Keywords: Chinese dry-cured ham, Xuanwei ham, meat fermentation, physicochemical property, sensory evaluation

INTRODUCTION

Xuanwei ham is similar to Iberian dry-cured ham and is a dry-cured ham of China that has been produced for at least the last 300 y in Xuanwei, a city in Yunnan Province, southwest P.R. China. Nearly 21,000 tonnes of the ham is produced each year. The traditional production process starts with the hind legs of a local breed of pig. Cut and trimmed legs (that is, 'green ham') that have been pressed by hand to remove blood are held under cool conditions for 24 h for ripening. The legs are then salted by hand. This is followed by a 'drying' stage that lasts 40 d. A 120 d fermentation stage then follows. Figure 1 illustrates the main stages of production of Xuanwei ham (Huang *et al*., 2009). The total process takes nearly 190 d. Xuanwei ham is mostly sold within China, but a substantial amount is exported. Unlike many of the European dry-cured

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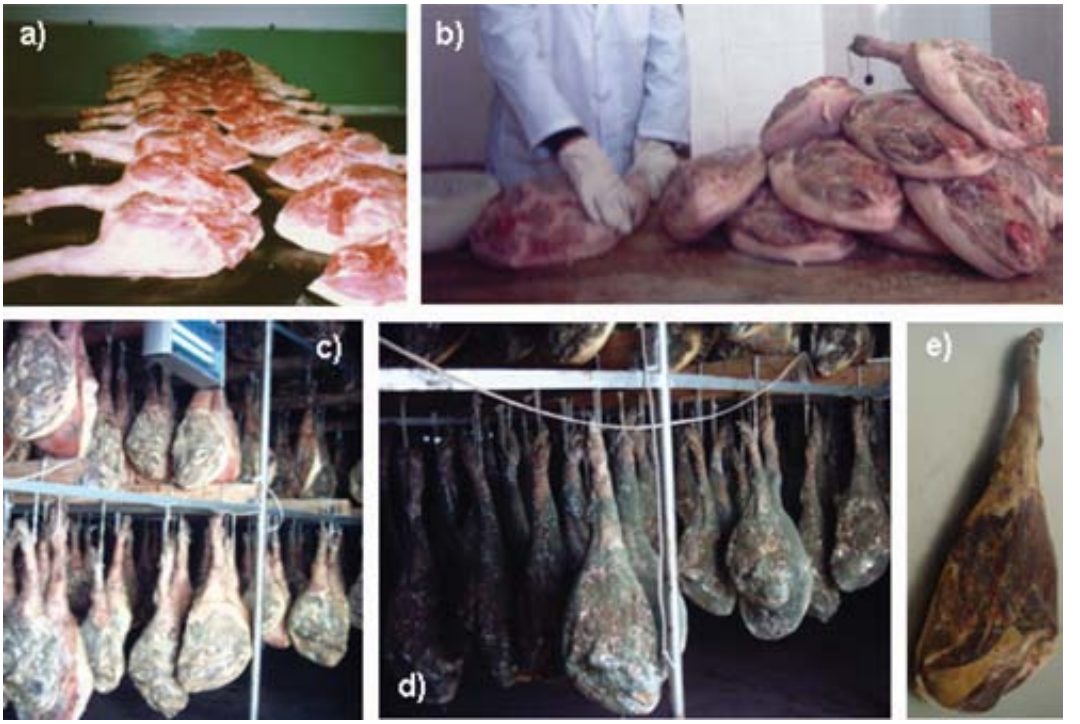

Figure 1 Stages of production of Xuanwei dry-cured ham: a) green ham; b) salting; c) drying; d) fermentation; e) typical presentation of the final product (Huang *et al*., 2009).

hams, the microbiology, biochemistry and development of the physicochemical characteristics during production of Xuanwei ham have been barely investigated.

The composition of Xuanwei ham based on w/w of lean meat has been reported (Jiang *et al.,* 1990) as: protein (30.4%); fat (10.9%); amino acids (10.3%); moisture (42.2%); and salt (8.8%). Xuanwei ham is particularly rich in vitamin E (45 mg/100 g). The chemical and volatile compounds found in Xuanwei ham have been extensively studied (Qiao and Ma, 2004). The biceps femoris muscle of the ham has moisture content of 47.3% (w/w), salt content of 9–12% (w/w) and water activity of 0.83 to 0.85 (Qiao and Ma, 2004). The thiobarbituric acid and total volatile basic nitrogen (TVB-N) values in the biceps femoris muscle have been reported to be 0.50–0.70 mg/kg and 46.5–55.5 mg/kg, respectively (Qiao and Ma, 2004). The biceps femoris muscle has a free amino acids content of 9 g/100g dry matter. Nearly 90 compounds have been found in the volatile fraction of the ham. These include 15 different hydrocarbons, 9 alcohols, 22 aldehydes, 6 ketones, 3 acids and 7 esters. The taste and flavor of the ham have been ascribed to the presence of volatile compounds and free amino acids such as glutamic acid, proline and alanine.

The first quality standard for Xuanwei ham was issued in 2001 by the Chinese authorities (Chinese National Standard, 2001). This standard requires Xuanwei ham to have the following attributes: no more than 48% moisture in the meat; no more than 12.5% NaCl in the meat; no more than 4 mg $NaNO_2$ per kg of meat; a nitrogen trimethylamine level of no more than 1.3 g/100 g; and a peroxide value in the fat of no more than 32 meq/kg. Xuanwei ham contains more salt than other types of dry-cured hams (Careri *et al.,* 1993; Andres *et al.,* 2004). However, because of the

adverse health effects of a high intake of salt, Xuanwei ham is being increasingly produced with reduced salt content (Lu and Yang, 1988).

Although many aspects of the composition of Xuanwei ham are known (Jiang *et al.,* 1990; Lu and Yang, 1988), few studies have discussed the changes in composition and the various physicochemical properties during production of the ham. The present work reports on the physicochemical and sensory changes that occur in the ham during its production.

MATERIALS AND METHODS

Source and processing of ham

Fifty hind legs, or green hams (11 ± 0.7 kg each), were harvested from a single crossbreed (Yorkshire × Duroc × local Wujin) of locally slaughtered and skinned pigs that had been raised in the Kunming Gao-Shang-Gao pig farm, Kunming, China. Trimmed green ham was processed according to the traditional Xuanwei process. The process consisted of the stages shown in Figure 2. Variations of temperature and relative humidity (RH) in the ham room during 189 d of processing are shown in Figure 3 (Huang *et al.,* 2009).

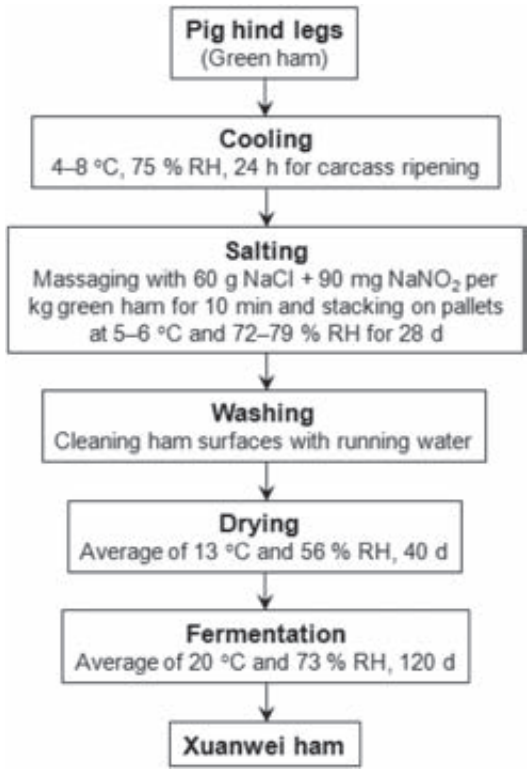

Figure 2 Flowsheet for the production of Xuanwei dry-cured ham showing temperature, relative humidity (RH) and days for various stages.

Ham sampling

Biceps femoris (BF) and semimembranosus (SM) muscles were sampled from five randomly selected hams at each of the following stages of processing: green ham (day 1), the middle and end of salting (days 14 and 28), the middle and end of drying (days 48 and 68 of processing) and fermentation (days 98, 128, 158 and 188 of processing). The samples were used for sensory evaluations and measurements of physicochemical properties.

Physicochemical analyses and sensory properties

The samples were used to determine the moisture content, levels of sodium chloride and sodium nitrite, water activity, pH, TVB-N values and the free fatty acids (FFAs) contents. Samples of subcutaneous fat under the BF muscle of the ham were used for the determination of the acid value and the peroxide value. All analyses followed the Chinese Standard for Food Hygiene Analysis (Chinese National Standard, 2004). Sodium chloride was determined by potentiometric titration with silver nitrate in an autotitrator and expressed as a percentage by weight (w/w) of ham. The nitrite concentration was measured spectrophotometrically at 546 nm (model-722, Shanghai Precision & Scientific Instrument Co., Ltd., P.R. China) according to Andrade *et al.* (2003). The moisture content was

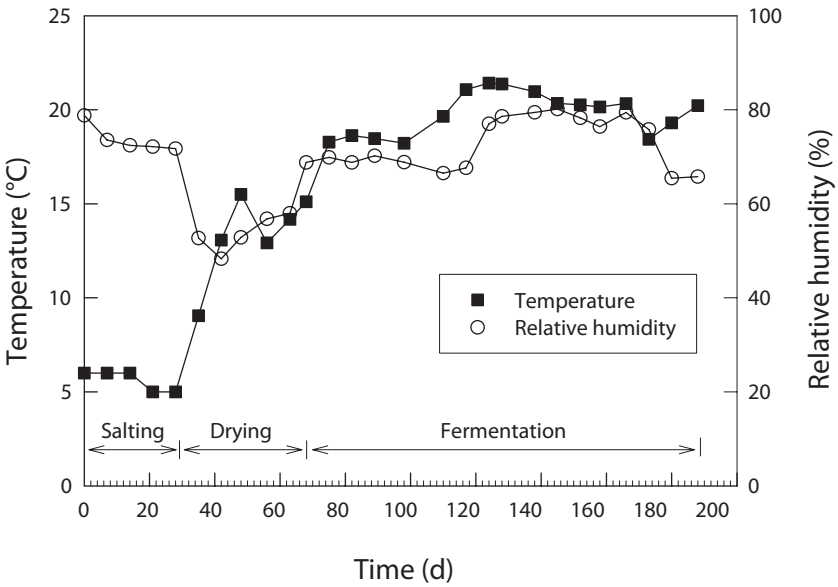

Figure 3 Temperature and relative humidity in the ham room during processing (Huang *et al.*, 2009). (The vertical bars show the standard deviation for values).

evaluated by drying a 3 g sample of blender-homogenized ham to constant weight in an oven at 103 ± 2 °C. The pH was determined by homogenizing a 10 g sample in 90 g of distilled water in a blender and measuring the pH (HANNA–HI9025, Hanna Instrument, Italy) of the supernatant. Water activity was measured at 25 °C using a water activity apparatus (SJN5021, Jiang Ning Machine Factory, P.R. China). The acid value was determined by titrimetry with KOH. All analyses were carried out in triplicate.

The free fatty acid composition of the BF and SM muscles was analyzed by high pressure gas chromatography-spectrometry (HPGC) on extracts of ham samples collected during the various stages of fermentation. Methyl esters of the FFAs were prepared according to the Chinese National Standard (1998) and Gandemer *et al.* (1991), by mixing 0.5 g samples (dry matter) with 5 mL of methanolic hydrogen chloride and 1 h incubation at 70 °C. Methyl esters were quantified using HPGC (Hewlett-Packard HP-5890-II, Palo Alto, CA, USA) equipped with a split injector and flame ionization detector. The column temperature varied as follows: 2 min at 195 °C, raised to 215 °C at a rate of 5 °C/min and held at 215 °C for 6 min. The temperature of the injector was 240 °C and the temperature of the detector was 250 °C. The flow rate of the carrier gas (N_2) was 30 mL/min. FFAs were identified by comparing their retention times with that of the internal standards (Sigma, St. Louis, MO, USA). The results were expressed as a percentage of the total free fatty acid methyl esters.

A composite rating scale was used for judging sensory properties. Five hams of *BF* muscles were selected for the tests at each stage of the fermentation. Samples (200 g each) were taken from the biceps femoris muscle of each ham for evaluation by 12 experienced panelists. Samples were cut into 2 mm thick slices and steamed in a cooker for 20 min and cooled to room temperature. Subsequently, four slices (about 10 g total) of each sample were served immediately on a white porcelain plate to each panelist. A glass of about 100 mL of distilled water was provided

to each assessor to clean the mouth between tastings. The four attributes of thirteen sensory traits consisting of appearance (pink, rose-red, reddish), odor (intense, rancid, cured), taste (salty, cured, rancid, undesirable) and texture (firm, dry, soft) were assessed and given scores ranging from the most disliked to the most liked.

Statistical analyses

Results from the chemical and sensory analyses were statistically analyzed using the one-way ANOVA procedure of SPSS version 10.0 (SPSS Inc., Chicago, IL, USA) to determine the *F*-values and whether any two data were significantly different at the more than 95% ($P < 0.05$) confidence level.

RESULTS AND DISCUSSION

Influence of temperature and relative humidity on quality traits

In the salting phase, the temperature was maintained at approximately 5–6 °C (Figure 3) to control microbial growth and prevent ham spoilage due to endoenzyme activity. During salting, the relative humidity in the ham room was kept between 75% and 85% to improve the penetration rate of the curing agents into the ham. The salted hams were hung for drying in a room at a temperature of 10–15 °C and 50–60% relative humidity. The curing ingredients had already penetrated to some depth and this controlled any microbial action and endoenzyme activity. Nevertheless, a relatively low temperature of 10–15 °C (Figure 3) was necessary to prevent spoilage because the ham was still relatively moist. A temperature of less than 10 °C would have slowed the diffusion of curing agents into the ham. The drying temperature of Xuanwei ham is significantly higher than for some of the European dry-cured hams but the length of the drying stage is lower. For example, dry-cured hams such as Italian Parma ham and Spanish Serrano ham are typically hung in cold rooms at 5 °C for 2 mth after salting (Hinrichsen and Pedersen, 1995; Flores and Grimm, 1997).

Texture is an important quality attribute of dry-cured hams. Development of a suitable texture requires control of the relative humidity during processing as low relative humidity causes rapid evaporation of water from the surfaces of the ham and this produces an undesired crusted surface (Serra *et al.,* 2005). The crust can block the transport of moisture from the interior of the ham to the surface and, as a consequence, the interior remains too moist. On the other hand, if the relative humidity is too high, it prevents moisture loss from the ham and this induces microbial growth and spoilage. It is essential to control the rate of evaporation from the ham to maintain a balance between evaporation from the surface and the transport of moisture from the interior tissue to the surface. The relative humidity used during drying of Xuanwei ham is lower than the 65% relative humidity that is used during loft-fermentation of Jinhua ham (Lin *et al.,* 1992), another dry-cured ham of China, and Iberian ham (Andres *et al.,* 2004).

During fermentation, the curing salts diffuse to achieve a uniform concentration throughout the ham and the water content of the ham decreases. As the moisture content decreases, the temperature in the ham room is gradually increased from 15 to 25 °C (Figure 3) and the relative humidity is raised to 70% to ripen the ham. A relatively high temperature and relative humidity facilitate lipolysis and proteolysis of the ham. This is necessary for the development of the desired flavor and taste (Toldra, 1998). However, excessively rapid proteolysis results in a bitter taste because of less than favorable fermentation (Parolari *et al.,* 1994; Sforza *et al.,* 2001).

Sensory qualities of the ham during fermentation

The results of the sensory evaluations of

ham color, texture, odor and taste at various times during fermentation are shown in Table 1. All of the quality attributes of the ham improved as the fermentation progressed. The greatest improvements ($P < 0.5$) in the scores for various quality attributes were seen after 3 mth of fermentation (Table 1). The results suggested that a 3 mth fermentation may be sufficient to achieve the required quality but the quality is measurably improved by prolonging the fermentation to 4 mth.

Changes in moisture content and water activity during processing

In green ham, the moisture content and water activity are uniformly high (Table 2). Moisture content and water activity declined with time during processing, but this occurred slightly faster in the semimembranosus muscles than in the biceps femoris tissue. As a consequence of this difference in moisture contents, the texture of the biceps femoris muscle was always softer than the texture of the semimembranosus muscle by sensory analysis ($P < 0.05$).

By the end of 3 mth of fermentation, the water activity in all tissue had been reduced to well below 0.9, or lower than the minimum value that can support bacterial activity (Jay, 2001). However, prolonging the fermentation to 4 mth reduced the moisture content and water activity further. A reduced moisture content reduces

Table 1 Sensory evaluation of ham (mainly *BF* muscle) during fermentation.

Time (mth)	Color (20 points)	Texture (15 points)	Odor (30 points)	Taste (35 points)	Total (100 points)
1	15.0±0.36^{b}	11.7±0.41^{b}	22.5±0.44^{b}	25.6±0.16^{b}	74.8±1.07^{b}
2	15.8±0.40^{b}	12.8±0.38^{a}	23.6±0.77^{ba}	26.8±0.88^{ba}	79.0±1.74^{ab}
3	17.2±0.38^{a}	13.0±0.25^{a}	24.2±0.66^{a}	28.2±0.75^{a}	82.5±1.61^{a}
4	17.5±0.34^{a}	12.6±0.38^{a}	25.4±0.64^{a}	29.0±0.84^{a}	84.5±1.85^{a}

Values with different superscripts within a column are significantly different ($P < 0.05$).

Four attributes with 13 sensory traits, consisting of appearance (pink, rose-red, reddish), odor (intense, rancid, cured), taste (salty, cured, rancid, undesirable) and texture (firm, dry, soft), were assessed and given scores ranging from the most disliked to the most liked.

Table 2 Changes in moisture content and water activity of muscle during ham processing.

Stage length	Moisture content (% w/w)		Water activity (a_w)	
	Semimembranosus	Biceps femoris	Semimembranosus	Biceps femoris
Green ham	73.78±0.40^{a}	73.78±0.40^{a}	0.979±0.012^{a}	0.979±0.012^{a}
Salting				
14 d	68.59±0.46^{b}	70.50±0.50^{ab}	0.940±0.014^{b}	0.960±0.013^{ab}
28 d	65.11±0.57^{bc}	68.64±0.46^{b}	0.910±0.029^{c}	0.954±0.034^{b}
Drying				
20 d	62.70±0.13^{dc}	64.78±0.34^{cd}	0.896±0.020^{c}	0.930±0.027^{bc}
40 d	60.93±0.22^{de}	62.64±0.36^{de}	0.887±0.018^{cd}	0.919±0.017^{cd}
Fermentation				
1mth	57.95±0.84^{fe}	61.80±0.57^{de}	0.880±0.017^{cd}	0.900±0.015^{cd}
2 mth	55.13±0.37^{gf}	61.00±0.29^{de}	0.873±0.015^{de}	0.893±0.014^{de}
3 mth	53.56±0.52^{hg}	58.76±1.35^{ef}	0.865±0.007^{de}	0.880±0.009^{de}
4 mth	47.64±0.39^{i}	55.35±1.49^{f}	0.852±0.019^{e}	0.872±0.017^{e}

Note: Values with different superscripts within a column are significantly different ($P < 0.05$) for processing time.

spoilage and improves the keeping quality of the ham.

Changes in peroxide value and acid value in subcutaneous fat during processing

The peroxide value increased rapidly from around 2 meq/kg to nearly 12 meq/kg during the salting and drying phases (Figure 4). Subsequently, during fermentation, the peroxide value declined slowly to a final value of about 9 meq/kg. Similar observations have been reported during the production of Iberian ham (Antequera *et al.,* 1992). Peroxidation of fats during salting and drying causes a rapid rise in the peroxide value. The subsequent decline in the peroxide value has been associated with the conversion of peroxidation intermediates to compounds such as alcohols, aldehydes and ketones (Antequera *et al.,* 1992; Toldra, 1998). A further explanation for the decline is the claimed interaction of peroxides with the proteolysis products of fermentation (Girard, 1992). The final peroxide value was substantially less than 32 meq/kg (the upper limit stipulated by the Chinese National Standard (2001) for dry-cured ham).

The increase in the acid value with the duration of processing followed a sigmoidal curve (Figure 4). There was barely any increase in acidity during salting and drying, but acidity increased exponentially during the early fermentation phase to ultimately attain an asymptotic value of around 16 mg/g. The rise in acidity was caused by the liberation of free fatty acids as a consequence of the lipolysis of fat due to endogenous lipases and oxidation.

The final acid value was significantly lower than the 34–46 mg/g reported for Jinhua ham (Lin *et al.,* 1992), but substantially higher than 4 mg/g of Chinese salted meat which was stipulated by the Chinese Standard (Chinese National Standard, 2001). The quality of Xuanwei ham and Chinese ham is excellent with an acid value above 4 mg/kg. This is accepted by the Chinese National Standard for Xuanwei ham and Chinese ham without standardizing their acid values, because Xuanwei ham and Chinese ham are processed hams with a fermentation period longer than 3 mth to increase the acid value.

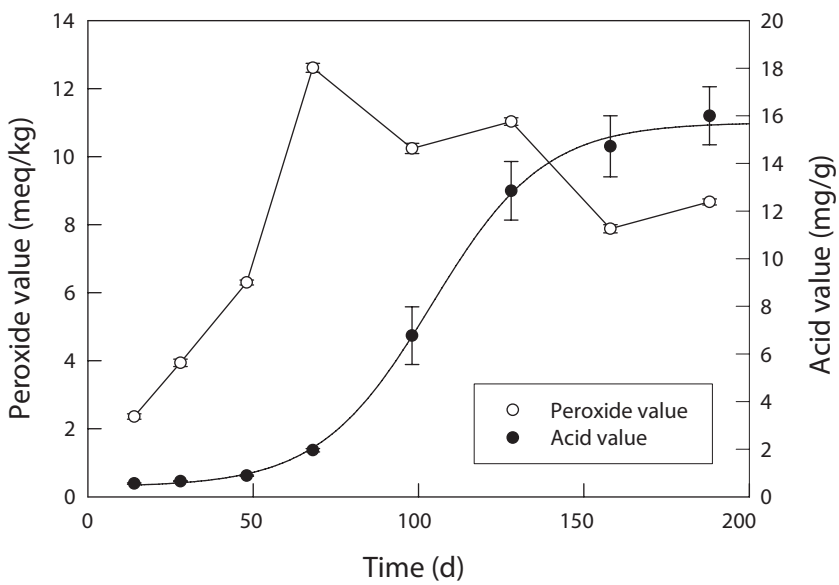

Figure 4 Changes in peroxide and acidity values of fat during ham processing. (The vertical bars show the standard deviation for values).

Changes in TVB-N and $NaNO_2$ contents during ham processing

TVB-N is a measure of proteolysis of the meat. Changes in TVB-N values and $NaNO_2$ contents of the ham during processing are shown in Figure 5. TVB-N increased during processing in both biceps femoris and semimembranosus muscles. The rate of increase was relatively slow in the salting and drying stages (that is, the first 70 d in Figure 5) compared to the rate of increase during fermentation. Clearly, most of the proteolysis occurred during fermentation. The TVB-N in the semimembranous muscle was always greater than in the biceps femoris muscle, due to differences in proteolysis. Changes in the TVB-N value can be correlated to flavor development. A cured-meat flavor develops once the TVB-N value approaches about 25 mg/100g, but an unpleasant odor is produced if the TVB-N value exceeds 100 mg/100g (Zhu and Zhang, 2004). The final value of TVB-N was around 40 mg/100 g. Others studies have reported a value of around 70 mg/100 g for Xuanwei ham and Jinhua ham (Lu and Yang, 1988; Lin *et al.*, 1992).

Nitrite plays an important role in the development of the pink-red color and flavor in cured meats (Girard, 1992). However, if the concentration of residual nitrite in meat products is too high, this presents a food safety problem; therefore, the residual nitrite must remain below a safe value. In the present study, $NaNO_2$ increased gradually in the biceps femoris muscle from 0.4 mg/kg to 2.38 mg/kg. In the semimembranosus muscle, the $NaNO_2$ level decreased rapidly from 3.8 mg/kg during early salting to 0.93 mg/kg on day 70 of processing; it then increased slowly to a final value of 2.6 mg/kg by the end of fermentation. These changes were due to the diffusion of curing ingredients in the ham tissue and due to the decreasing moisture content of the ham. At less than 3 mg/kg, the residual nitrite in the final ham was substantially less than the upper limit of 20 mg/kg stipulated in the Chinese National Standard (2001). Therefore, curing Xuanwei ham with 90 mg $NaNO_2$ per kg meat does not pose any food safety problems.

Changes in muscle pH and salt content during ham processing

Figure 6 shows the changes in the pH and NaCl content during the ham production process. Except for a small initial decline from

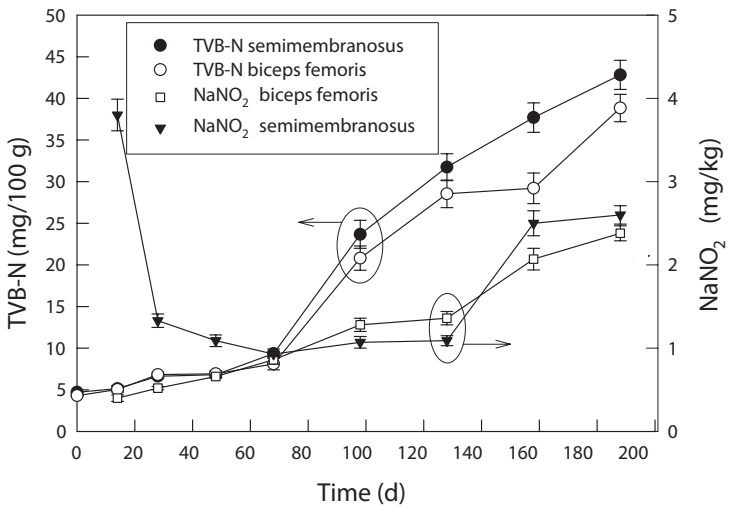

Figure 5 Changes in total volatile basic nitrogen (TVB-N) and $NaNO_2$ content of muscles during ham processing. (The vertical bars show the standard deviation for values).

the green ham stage (pH = 5.9), the pH generally rose with processing time to a final pH of around 6.3. The formation of small peptides, free amino acids and ammonia through proteolyis contributed to the increase in pH. Proteolysis is caused by endogenous meat enzymes and the action of microorganisms (Girard, 1992). The semimembranosus muscle usually had a slightly higher pH than the biceps femoris muscle.

The NaCl content of both semimembranosus and biceps femoris muscles increased with time, to finally attain a value of 8.7%. This increase was due to moisture loss by evaporation. The salt content of the final ham was significantly less than the upper limit of 12.5% stipulated by the Chinese National Standard (2001).

Changes in free fatty acids contents in the ham during fermentation

Lipolysis is chiefly responsible for the flavor of ham. Table 3 shows the changes in the contents of free fatty acids (C_{12}–C_{20}) in the biceps femoris and semimembranosus muscles during ham fermentation. The results suggested that oleic (C18:1), linoleic (C18:2), palmitic (C16:0) and stearic (C18:0) acids were the main free fatty acids released from the fat during fermentation. Lipolysis of fat is caused mainly by the endogenous enzymes. This concurs with reporting on Spanish Serrano ham (Motilva *et al.,* 1993). The relative proportion of the saturated free fatty acids (SFAs) such as palmitic and stearic acids increased during fermentation, whereas the percentage of unsaturated free fatty acids (UFAs) such as oleic, linoleic and linolenic (C18:3) acids decreased as the fermentation progressed. This suggested that the unsaturated fatty acids were preferentially oxidized during the fermentation. Yang *et al*. (2005) reported similar results for Xuanwei ham fermentation.

The FFA profiles for the biceps femoris and semimembranosus muscles were not significantly different. In all samples, the percentage of SFAs decreased in the early part of the fermentation and increased after about 60 d. The percentage of monounsaturated fatty acids (MUFAs) decreased gradually because of degradation during fermentation. The percentage of polyunsaturated fatty acids (PUFAs) increased in the early part of the fermentation and decreased after about 60 d. The rapid decrease in PUFAs after 60 d of fermentation was likely caused by the

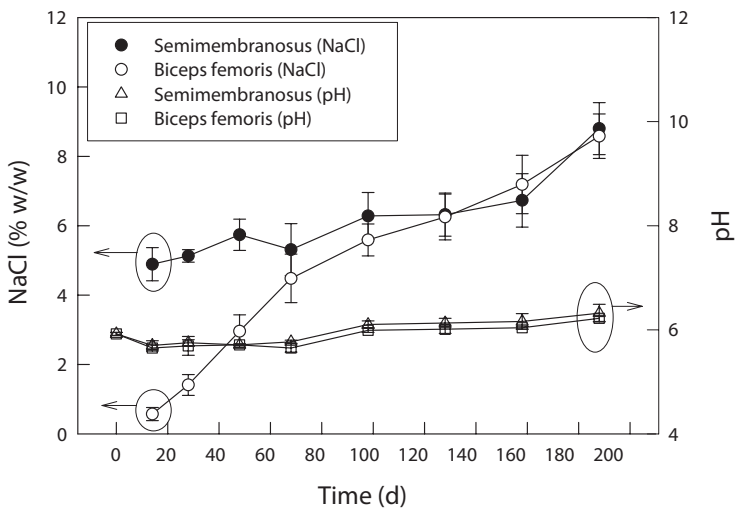

Figure 6 Changes in pH and NaCl content of muscles during ham processing (Huang *et al*., 2009). (The vertical bars show the standard deviation for values).

degradation of the PUFAs into smaller molecules such as alcohols, ketones and aldehydes. These results were in agreement with She and Tong. (2005), who found that there was a preferential degradation of unsaturated fatty acids during processing of Jinhua ham.

CONCLUSIONS

The combination of temperature and relative humidity profiles used in the present work was satisfactory for producing Xuanwei ham with acceptable quality traits of color, texture, odor and taste. Obtaining the desired product required a 188 d process that included a 120 d fermentation phase. A shorter period of fermentation did not produce a satisfactory product. The final product met the requirements of the Chinese Standard (Chinese National Standard, 2001) for Xuanwei ham in terms of the salt content, the peroxide value and the residual nitrite level, but the acid value has not been stipulated by the Standard (Chinese National Standard, 2001), possibly because the Standard stipulates an unrealistically low value.

In view of the low levels of residual nitrite in the final product, curing with 90 mg

Table 3 Changes in free fatty acids (FFAs; g FFA/100 g total FFAs) in muscles during ham fermentation.

FFA	Fermentation time (d)				
	0	30	60	90	120
BF-C12:0	0.43±0.02^{a}	0.53±0.05^{a}	0.22±0.02^{b}	0.12±0.02^{b}	0.17±0.03^{b}
SM-C12:0	0.22±0.04^{b}	0.53±0.09^{a}	0.15±0.03^{b}	0.17±0.03^{b}	0.29±0.08^{b}
BF-C14:0	1.27±0.06^{a}	1.97±0.12^{a}	0.79±0.03^{b}	1.12±0.09^{a}	0.90±0.06^{b}
SM-C14:0	1.17±0.08^{b}	2.84±0.18^{a}	0.78±0.08^{b}	1.12±0.08 ^{b}	0.95±0.09^{b}
BF-C16:0	21.52±0.49^{ab}	22.74±1.10^{a}	20.83±0.55^{ab}	19.78±1.01^{b}	22.30±0.54^{a}
SM-C16:0	21.59±0.40^{b}	25.07±0.82^{a}	21.08±0.95^{b}	21.09±0.80 ^{b}	23.06±1.24^{a}
BF-C16:1	3.01±0.15^{a}	2.10±0.06^{a}	2.11±0.16^{a}	3.28±0.18^{a}	2.77±0.27^{a}
SM-C16:1	2.40±0.19^{a}	2.80±0.16^{a}	2.00±0.14^{a}	3.38±0.16^{a}	3.16±0.29^{a}
BF-C18:0	15.57±0.59^{b}	8.64±0.26^{c}	14.39±0.61^{b}	14.51±0.53^{b}	28.19±1.10^{a}
SM-C18:0	14.58±0.25^{b}	3.73±0.36^{c}	14.48±0.58^{b}	11.83±0.48^{b}	29.71±1.29^{a}
BF-C18:1	49.60±1.9^{a}	44.53±1.53^{a}	30.90±1.13^{bc}	35.11±1.32^{b}	27.89±0.91^{bc}
SM-C18:1	52.88±1.47^{a}	40.64±1.83^{b}	29.80±1.26^{c}	36.74±1.28^{cb}	25.12±1.21^{c}
BF-C18:2	7.68±0.84^{c}	21.70±0.44^{a}	29.47±1.64^{a}	22.71±0.84^{a}	16.46±1.10^{b}
SM-C18:2	6.30±0.80^{e}	22.36±0.64^{bc}	30.25±1.63^{a}	23.33±1.12^{b}	15.40±0.78^{d}
BF-C18:3	0.74±0.06^{ab}	0.68±0.05^{b}	0.97±0.09^{ab}	1.54±0.07^{a}	1.03±0.03^{ab}
SM-C18:3	0.63±0.08^{c}	1.04±0.15^{ab}	1.03±0.19^{ab}	1.38±0.21^{a}	1.78±0.17^{a}
BF-C20:0	0.20±0.01^{b}	0.48±0.09^{a}	0.43±0.08^{ab}	0.70±0.07^{a}	0.36±0.07^{b}
SM-C20:0	0.22±0.01^{c}	0.31±0.06^{bc}	0.42±0.08^{b}	0.48±0.07^{b}	0.68±0.09^{a}
BF-∑SFA	38.99±0.72	34.36±0.63	36.55±1.37	36.22±1.45	51.91±2.21
SM-∑SFA	37.78±0.77	32.48±0.57	36.92±1.87	34.16±1.59	54.64±2.94
BF-∑MUFA	52.61±1.30	46.63±1.63	33.01±1.73	38.39±1.12	30.67±1.48
SM-∑MUFA	55.28±1.96	43.45±1.91	31.80±2.03	40.11±1.35	28.28±1.20
BF-∑PUFA	8.41±0.14	22.38±0.79	30.34±1.93	24.25±1.42	17.49±2.04
SM-∑PUFA	6.93±0.58	23.40±1.48	31.28±1.08	24.71±1.43	17.18±1.24

* Values with different superscripts within a row are significantly different ($P < 0.05$) for processing time. *BF* = biceps femoris; *SM* = semimembranosus; SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids.

sodium nitrite per kg of green ham, did not pose any food safety problems. A controlled combination of the production conditions as demonstrated in the presents study is expected to consistently provide Xuanwei ham of an acceptable overall quality.

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