PROCESSING PARAMETERS INVOLVED IN THE DEVELOPMENT OF TEXTURE AND TYROSINE PRECIPITATES IN DRY-CURED HAM: MODELISATION OF TEXTURE DEVELOPMENT

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Abstract. - The aim of this study was to quantify the effects of different processing parameters on texture development and the incidence of white film and tyrosine crystals in dry-cured ham. Hams were dry-salted for 0.65, 0.8 or 1.0 days/kg. After drying for 45 days at 5 ºC, they were dried at 10, 15 or 20 ºC until reaching 33% weight loss and, thereafter, dried at 25 ºC until reaching 36 or 40% weight loss. The salting time, drying temperature and target weight loss significantly affected the texture and incidence of white film and tyrosine crystals. A beneficial effect of drying at 20 ºC on texture was found, which was especially important for low target weight loss (33%). Besides, hams dried at 20 ºC and those with 40% weight loss showed higher incidence of tyrosine crystals. Contour plots and predictive models for texture can be used to define optimal processing parameters.

Key words – Dry-cured ham, texture, tyrosine precipitates, salting, drying, temperature, predictive modelling.

1. Introduction

The texture of dry-cured ham is one of the most important quality criteria for consumer acceptability and is of interest for the industry (Cilla, *et al.*, 2005; Schivazappa, C. & Virgili, R. 2020). The main texture defects are excessive softness (Parolari, Virgili & Schivazappa, 1994) and pastiness which are mainly related to raw material characteristics such as pH, genetics and fat content (García-Rey *et al.*, 2004; García-Rey, Quiles-Zafra & Luque de Castro, 2006; Carcò *et al.*, 2019; Candek-Potokar, M. & Skrlep, M. 2012) and processing conditions such as temperature, time and salt content (Ruiz-Ramírez *et al.*, 2005; Coll-Brasas *et al.*, 2021). A proteolysis activity contributes to texture development by breaking down the muscle structure (Monin *et al.*, 1997). However, when proteolysis is excessive the structure is severely damaged and unpleasant textures appear (Contreras *et al.*, 2020). Proteolysis index (PI = 100 x non-protein nitrogen / total nitrogen) is even used as quality criteria in PDO Parma ham, considering that values on *Biceps femoris* muscle should be below 31% (Consorzio del Prosciutto di Parma, 1992). Tapiador-Farelo & García-Garrido (2003) found an incidence of 12% pastiness defect in hams with a standard salt content (salted 1 day/kg of green ham). This defect increases when salt content is reduced (Tomažin *et al.*, 2020) producing severe problems during slicing because of high adhesiveness (Gou *et al.*, 2008; Pérez-Santaescolástica *et al.*, 2018) and reducing consumer acceptability (Morales *et al.*, 2008). For this reason, studies for the development of new strategies and corrective actions to reduce this defect has been carried out (Coll-Brasas *et al.*, 2019; Fulladosa *et al.*, 2021; Pérez-Santaescolástica *et al.*, 2018).

A high proteolysis index also favours tyrosine precipitates in dry-cured ham as tyrosine crystals or white film (Arnau *et al.*, 1996). These crystals are normally present in dry-cured hams aged for a period longer than 12 months, but they can also be found in hams aged for only 5 months (Arnau *et al.*, 1996). White film on a cut surface appears several days after

slicing (Butz *et al.*, 1974) or in some cases within a few hours (Arnau, 1991). The main component of the white film and crystals is tyrosine (Arnau *et al.*, 1996; Comi *et al.*, 1981; Silla, Innerarity & Flores, 1985) followed by phenylalanine (Arnau *et al.*, 1996), which both are the result of proteolysis.

In order to reduce textural problems and the development of tyrosine precipitates in dry-cured ham, it is necessary to more deeply study aspects related to quality of raw material and processing conditions such as saltiness, drying level, temperature and their combined effects. The development of mathematical models could help to make the effect of different factors on texture and tyrosine crystals and white film formation more clear, allowing modification/adaptation of the processes of elaboration according to the most influencing parameters.

The aim of this work was to study the effect of the raw material pH (pH_{SM24h}) and processing conditions (salting time, drying temperature and target weight loss) on texture development, white film intensity and incidence of tyrosine crystals in dry-cured ham. Texture predictive models aimed at optimising the process of elaboration of dry-cured ham were also developed.

2. Material and methods

2.1 Raw material selection and process of elaboration

One hundred and sixty nine raw hams were obtained from two commercial slaughterhouses, supplied from animals which were lean crosses of Large White and Landrace (L, n= 151) and fattier crosses with 50% Duroc breed (F, n= 18) in order to obtain a batch of hams with a wide range of fat contents. All animals were slaughtered during winter season. The pH determination was performed with a Crison Basic pH meter (Crison Instruments S.A., Barcelona, Spain) in the *Semimembranosus* muscle at 24 h *post mortem*

(pH_{SM24h}). All hams were weighed (11.9 kg ± 1.1 kg) and salted according to the traditional system with some modifications in order to obtain four salting groups (SG). In brief, hams were manually rubbed with the following mixture (g/kg of raw ham): 0.15 KNO_3, 0.15 $NaNO_2$, 1.0 dextrose, 0.5 sodium ascorbate and 10 NaCl. Thereafter, the hams were pile salted at 3 ± 1 ºC and 85 ± 5% RH. F hams were salted for 0.65 days/kg (F0.65) to obtain a reduced salting group. In contrast, L hams were salted for 0.65 days/kg (L0.65), 0.8 days/kg (L0.8) and 1 day/kg (L1.0) for a reduced, standard and high salting group respectively. After salting, the hams were washed with cold water and dried at 3 ± 2 ºC and 80 ± 5% RH for 45 days (post-salting period). Thereafter, all of the hams from the L and F breeds continued the drying process at different Drying Temperatures (DT; 10 ºC, 15 ºC or 20 ºC) (Table 1) and at 55-60% RH, until a weight loss of 33% was reached. The processing time to reach 33% weight loss ($t_{33\%}$) was recorded. Thereafter, hams were assigned to different Target Weight Losses: 33% (TWL33), the minimum weight loss accepted for Traditional Speciality Guaranteed of Jamón Serrano; 36% (TWL36), as a standard weight loss; and 40% (TWL40) to highlight the effect of drying on soft texture. After reaching 33% weight loss, hams were dried at 25 ºC.

2.2 Sampling procedure

When hams reached the target weight loss, the aitch bone and femur were removed and they were transversally cut at the coxofemoral joint level. The cushion part was trimmed and five slices were obtained: three 2.0 cm thick slices and two 1.5 cm thick slices. *Biceps femoris* (BF) muscles from the first three slices were sampled and used for instrumental texture analysis right after sampling. After texture analysis, BF samples were individually minced, vacuum packed and stored at 4 ± 2 °C until the chemical analyses (moisture content and NaCl content) were performed (within under three weeks). From each minced BF sample, a subsample of 30 g was frozen and stored at -19 ± 1.5 °C until PI analysis

(non-protein nitrogen and total nitrogen content) was performed. The 4th and 5th slices were vacuum packed and stored at 4 ± 2 °C for 4 weeks. Thereafter, tyrosine crystals and white film evaluation were performed. All samples were packed in plastic bags of polyamide/polyethylene (oxygen permeability of 50 $cm^3/m^2/24h$ at 23 ºC and water permeability of 2.6 $g/m^2/24h$ at 23 ºC and 85% RH, Sacoliva® S.L., Spain).

2.3 Instrumental texture analysis

According to a previous study (Coll-Brasas *et al.*, 2019), a minimum of five parallelepipeds were cut from each BF muscle with the same dimensions (2 cm x 2 cm x 1.5 cm). The pieces were wrapped in polyvinyl chloride (P.V.C.) film (oxygen permeability of 20,000 $cm^3/m^2/24h$ and water vapour transmission of 200 $g/m^2/24h$, Macopal S.L., Spain) to reduce drying and kept at 4 ± 2 °C for 24 hours for temperature stabilisation in a temperature control cabinet (Model EC-360, Radiber S.A., Barcelona, Spain). A Stress Relaxation test (SR) was performed by using a Universal Texture Analyser TA.TX2 (Stable Micro Systems Ltd., Surrey, England) provided with a 30 kg load cell and a 60 mm diameter compression plate. Samples were compressed to 25% of their original height, perpendicular to the muscle fibre bundle direction, at a crosshead speed of 1 mm/s and at a temperature of 4 ± 2 °C.

The force decay or relaxation versus time $Y_{(t)}$ was recorded obtaining a deformation curve and it was calculated as follows:

$$Y_{(t)} = \frac{F_0 - F_{(t)}}{F_0}$$

Where F_0 (N) is the initial force and $F_{(t)}$ is the force recorded after t seconds of relaxation. The force decay at 2 s (Y_2) and 90 s (Y_{90}) were calculated (Morales *et al.*, 2007). For each parameter, the average of the five samples was used for the statistical analyses.

2.4 Chemical analysis

The following chemical analysis was performed. Moisture content was determined by drying at 103 ± 2 °C until a constant weight was reached AOAC (1990). NaCl content on a dry-matter basis (DM%) was determined according to ISO 1841-2 (1996) by using a potentiometric titrator 785 DMP Titrino (Metrohm AG, Herisau, Switzerland). Non-Protein Nitrogen content (NPN) was determined by precipitation of proteins with trichloroacetic acid (Gáspár, 1984) followed by determination of the total nitrogen (TN) in the extract with the Kjeldahl method ISO 937 (1978). The Proteolysis Index (PI) was calculated as a percentage of the ratio between NPN and TN. All the analyses were done in duplicate.

2.5 Evaluation of tyrosine precipitates

Evaluation of the incidence of tyrosine crystals was carried out by counting the number of crystals on the cut surface of the whole ham slice. The evaluation of the intensity of the white film was performed on the surface of the ham slices by using a 0-10 intensity scale, where 0 means no presence of white film and 10 means that the whole slice is covered with white film. Samples were assigned to different groups according to their intensity range: from 0 to 1.25; from 1.25 to 2.5; from 2.5 to 3.75; from 3.75 to 5.0; from 5.0 to 6.25; from 6.25 to 7.5; from 7.5 to 8.75 and from 8.75 to 10) considering mean intensity of 0.625; 1.75; 3.1; 4.4; 5.6; 6.8; 7.8 and 9.1 for each group respectively. Evaluation was carried out by a three-member expert panel trained following ASTM (ASTM, 1981). The average score of the 3 experts for each sample was used for the statistical analysis.

2.6 Statistical analysis

Processing time, physicochemical characteristics (moisture content, NaCl content, PI) and texture (F_0, Y_2, Y_{90}) for BF muscle and tyrosine precipitates (incidence of tyrosine crystals

incidence, white film intensity) in the whole slice were analysed using the GLM procedure of the SAS package (SAS Institute, 2019). The following linear model was fitted:

$$Y_{ijkl} = \mu + b*(pH_{SM24h})_{ijkl} + SG_i + DT_j + TWL_k + (SG*DT)_{ij} + (SG*TWL)_{ik} + (DT*TWL)_{jk} + e_{ijkl}$$

Where Y_{ijkl} is the observed value (dependent variable); μ and b are constants of the model; $(pH_{SM24h})_{ijkl}$ is the pH on *Semimembranosus* muscle 24h *post mortem* (covariate); SG_i is the salting group (i = 1,…,4); DT_j is the drying temperature until 33% weight loss is reached (j: 1,2,3); TWL_k is the target weight loss group (k: 1,2,3) and e_{ijkl} is the random residual.

Counter plots for Y_{90} were plotted on DT and TWL parameters for each salting group using JMP (SAS Institute, 2019). A model for predicting Y_{90} was developed by using these continuous variables that had a significant effect in the previous GLM analysis (SAS Institute, 2019).

3. Results and discussion

LS-means of main factors in the linear model and regression coefficient of PH_{SM24h} used as a covariable are shown in Table 2. Table 3 shows the LS-means of parameters with significant interaction DT*TWL ($p < 0.05$). Interactions SG*DT and SG*TWL were removed from the model since no significant effect on texture or the incidence of precipitates was found.

3.1 Texture of BF muscle

Values of pH_{SM24h} ranged between 5.40 and 6.05 for all the salting treatments. No significant linear effect of pH_{SM24h} on texture was neither detected ($p>0.05$), although several authors have previously proved the influence of meat pH on the texture of the final product (Guerrero, Gou & Arnau, 1999; Morales *et al.*, 2007). The pH_{SM24h} of raw material had a positive relationship with processing time and a negative relationship with NaCl

content (Table 2). Previous studies have also found that hams with lower pH dry faster (Guerrero *et al.*, 1999). Hams with low pH are reported to be more prone to develop soft textures (Ruiz-Ramírez *et al.*, 2005). However, this fact was not observed in our results probably because hams with lower pH were processed for less time and had higher NaCl content, which hinders the development of soft textures.

Significant differences in texture between salting groups, drying temperature groups and target weight loss groups were found. A decrease of salting time in L hams resulted in a significant decrease of F_0 and an increase of Y_2 and Y_{90} ($p<0.05$), as previously described by several authors (Morales *et al.*, 2007; Ruiz-Ramírez *et al.*, 2005). F hams needed more time to reach a weight loss of 33% and had lower salt content and moisture content than L hams with the same salting time, as expected due to their higher fat content.

As expected, the processing time decreased when increasing drying temperature. Hams dried at 20 ºC dried slightly faster and showed lower moisture content and Y_{90} values, but higher PI in BF muscle than hams dried at 15 or 10 ºC. Similarly, the increase in target weight loss reduced the moisture content, Y_2 and Y_{90} and increased F_0, as previously described in the literature (Morales *et al.*, 2007; Ruiz-Ramírez *et al.*, 2005). Hams subjected to this for more time at 25 ºC (TWL40) showed higher PI (Arnau *et al.*, 1997).

There was a significant interaction between Drying Temperature (DT) and Target Weight Loss (TWL) for Y_2 and Y_{90} (Table 3). The beneficial effect of drying at 20 ºC until reaching 33% weight loss (lower Y_2 and Y_{90} values), in comparison to drying at 10 ºC or 15 ºC, was less important if hams were subjected to an additional drying at 25 ºC (until reaching a final weight loss of 36% or 40%). The additional drying at 25 ºC also reduced Y_2 and Y_{90} values, especially in hams that have been dried at 10 ºC or 15 ºC. In fact, according to the literature, mild thermal treatment (30 ºC) of short duration (10 days) can improve texture in BF muscle of dry-cured hams processed at temperatures below 18 ºC (Gou *et al.*, 2008). An

increase in temperature can produce changes such as unfolding and protein-protein association of the myofibrillar components of the muscle, changing textural properties (Tornberg, 2005).

The higher Y_2 and Y_{90} values have been related to an increase in proteolytic activity (Morales *et al.*, 2007). However, we found significant differences between salting groups for texture, but not for PI. In the same way, the drying temperature group and target weight loss group with higher Y_2 and Y_{90} values showed a lower PI index. It seems that factors other than proteolysis activity (e.g., final moisture and salt contents) might have a significant influence on BF texture or that PI index does not account for all the proteolytic activity related to texture development. The proteolysis indexes found in this study (e.g. in F0.65, L0.8, DT20, TWL36 and TWL40) were higher than the maximum values proposed by the PDO Parma ham (Consorzio del Prosciutto di Parma, 1992).

The total amount of salt in the ham is not expected to change during drying, so the differences found in NaCl (DM%) in BF muscle between the different target weight losses are explained by the differences in moisture content between BF muscle and the rest of the ham (Arnau *et al.*, 1995). NaCl/moisture tends to reach an equilibrium in the whole ham; therefore, salt diffuses from the dryer surface to the humid inner parts (such as BF muscle). However, drying conditions and the characteristics of the raw material can influence equalization to a different extend.

The values of PI in BF muscle increased between TWL33 and TWL40. During drying, NPN/moisture increased more in the external parts due to moisture reduction than in BF muscle. This difference is a driving force that moves water soluble NPN from the outer part of ham to the inner part in a similar way as it occurs with NaCl and could partially explain the differences in proteolysis ratio (Gratacós-Cubarsí *et al.*, 2013).

3.2 Tyrosine precipitates

The crystallisation of tyrosine generated by proteolysis is facilitated by structural damage to the bulk of ham to form tyrosine crystals (e.g. if it is frozen before salting or at the end of process) or on the irregularities of cut surface to form white film (Arnau, Gou & Guerrero, 1994). In this study, the parameters that increased PI also increased the incidence of tyrosine crystals. In this sense, when salting time increased from L0.8 to L1.0 tyrosine crystals incidence decreased (Table 2). Hams dried at 20 ºC and those with TWL of 40% showed higher PI and higher incidence of tyrosine crystals than DT10 or DT15 hams, and TWL33 hams respectively ($P<0.05$). However, F0.65 hams, which had similar PI to L0.65 hams, showed the lowest incidence of tyrosine crystals, but the highest white film intensity. These differences could be due, among other factors, to differences in structural damages that affect the nucleation step and the higher fat content of F0.65. Fat content could slow down tyrosine diffusion inside the ham which would be detrimental to nucleation and crystal growth.

The pH_{SM24h} showed a negative relationship with the incidence of tyrosine crystals incidence and white film intensity, but not with PI. This could be due to the fact that PI was measured in the BF muscle only at the end of the process, whereas the incidence of tyrosine crystals and white film intensity were measured on the whole slice.

White film intensity is also expected to be related to PI, however their formation is affected by tyrosine crystal formation (Arnau, 1991; Butz *et al.*, 1974). Tyrosine that has precipitated previously on the tyrosine crystals will not precipitate as white film on the cut surface when the product is sliced (Arnau *et al.*, 1996). In this sense, TWL40 hams, which showed the highest incidence of tyrosine crystals, showed lower white film intensity than TWL36 hams ($P<0.05$). In fact, the decrease of white film intensity when hams were dried from 36% weight loss to 40% weight loss was more important in those hams previously dried at 20 ºC than in those dried at 10 ºC or 15 ºC (Table 3). This could be due to the

highest incidence of white crystals and perhaps to the reduction of free tyrosine content in the long ageing process (Sforza *et al.*, 2006). White film intensity at 33% weight loss increased significantly ($P<0.05$) when DT increased from 10 ºC to 15 ºC, but the increase was not significant ($P>0.05$) when DT increased from 15 ºC to 20 ºC (Table 3), probably because of the increase in the incidence of tyrosine crystals.

3.3 Texture at different processing conditions

Because the final texture is dependent on a combination of multiple factors, definition of the optimal processing conditions needs to be evaluated in globally. Contour plots in Figure 1 represent, for each salting group, variation of Y_{90} according to target weight loss and drying temperature since they are the factors that significantly influenced texture development in this study. Previous studies considered dry-cured ham samples with Y_{90} values above 0.734 as defective or soft (Morales, *et al.*, 2007). In contrast, hams with Y_{90} values below 0.682 were defined as hams with hard texture (Morales, *et al.*, 2007). Taking this into account, in this study, dry-cured ham samples with $Y_{90}>0.690$ were considered as hams with soft textures.

Contour plots in Figure 1 draw optimal processing conditions at intervals to achieve optimal texture. In F0.65 hams, optimal texture was achieved at mild temperatures (20 ºC) and weight losses higher than 36%. Optimal textures could be also achieved at low temperatures if target weight loss was higher. In contrast, higher temperatures and weight losses were needed in L0.65 hams to improve the texture. The differences found between L and F hams on the achievement of the optimal textures can be due to both fat and salt contents. Reduction of salt content in lean hams produced hams more prone to develop defective textures. When salt content was not reduced (L0.8 and L1.0) any processing temperature was suitable to achieve an optimal texture if hams were dried to a minimum weight loss of 36%. In the case of L0.80 hams, higher weight losses were needed to achieve

an optimal texture, in comparison to L1.0 hams where the higher salt content reduced the incidence of soft textures. The contour plots help to visually understand the effect of processing parameters on texture development.

The Y_{90} behaviour of F hams is different to L hams. Therefore, a model to predict Y_{90} was only developed for L hams, which included Salting Time (ST, days/kg), Drying Temperature (DT, ºC) and Weight Loss (WL, %), their quadratic terms and their double interactions as predictor variables. Non-significant terms were excluded from the model.

The fitted model was:

$$Y_{90} = 1.3636404 - 0.089638 \cdot ST - 0.003091 \cdot DT - 0.016857 \cdot WL + 0.0017824 \cdot (WL - 35.833)^2 + 0.0006686 \cdot (DT - 14.9007) \cdot (WL - 35.833)$$

The predictive error and R^2 of the final model were 0.030 and 0.72, respectively. Figure 2 shows the relationship between the predicted and the analysed texture parameter (Y_{90}). The linear model provides a fairly accurate prediction of Y_{90} in the whole range of Y_{90} values. Therefore, using this predictive model, processing conditions can be set up to reach the desired texture in the final product. Figure 3 shows an example of predicted Y_{90} at different weight losses and drying temperatures for a specific salting time (0.8 days/kg). Results agree with the interaction DT*WL effect on Y_{90} (Table 3).

There are other relevant parameters that can influence texture development which can be determined at industrial level using non-invasive technologies. Fat content of raw hams (De Prados *et al.*, 2015), NaCl content during processing (Fulladosa *et al.*, 2015; Schivazappa *et al.*, 2017) and internal characteristics of the product such as intramuscular fat (Muñoz *et al.*, 2015) might help to optimize texture development. More complex models including the mentioned parameters should be developed before the implementation of a

texture optimisation system to improve the texture of dry-cured ham production in the industry.

4. Conclusions

Development of texture and tyrosine precipitates formation is a complex issue that depends on multiple factors such as drying temperature, the achieved weight loss, pH_{SM24h} and NaCl content and needs to be undertaken in a global way. In this sense, texture predictive models based on the information obtained using non-invasive technologies during the process and processing conditions could be useful to optimise processes of elaboration and achieve optimal textures.

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FIGURES

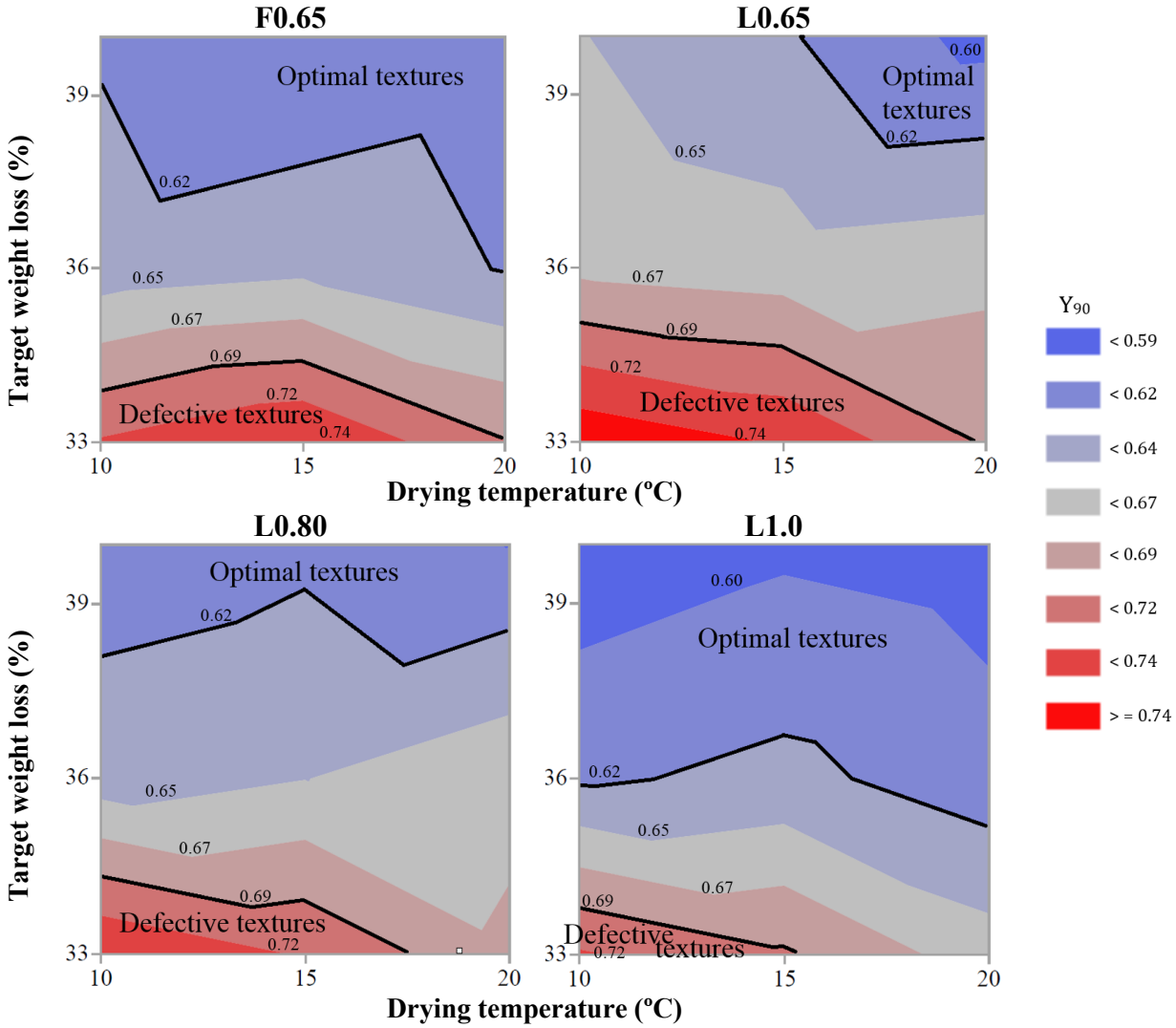

Figure 1: Estimation of instrumental texture (Y_{90}) using contour plots for each Salting group. Hams with Y_{90}>0.690 were considered as soft textures, whereas hams with Y_{90}<0.620 optimal textures.

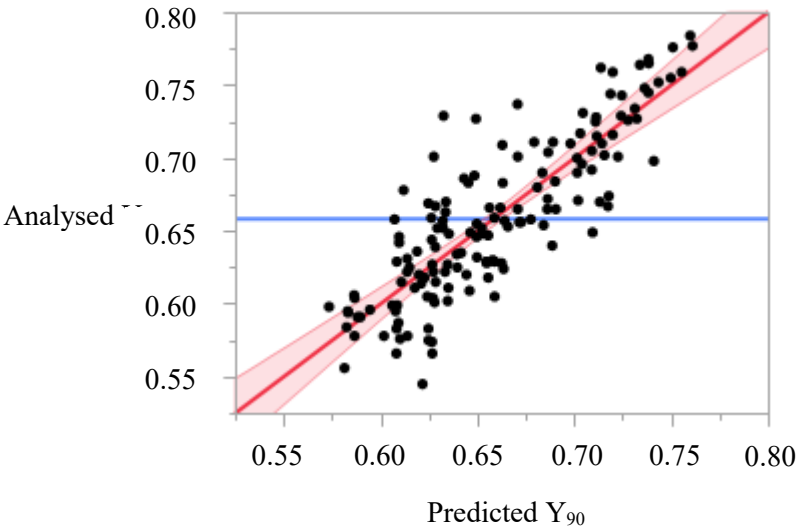

Figure 2: Relationship between predicted and analysed Y_{90} values on L hams.

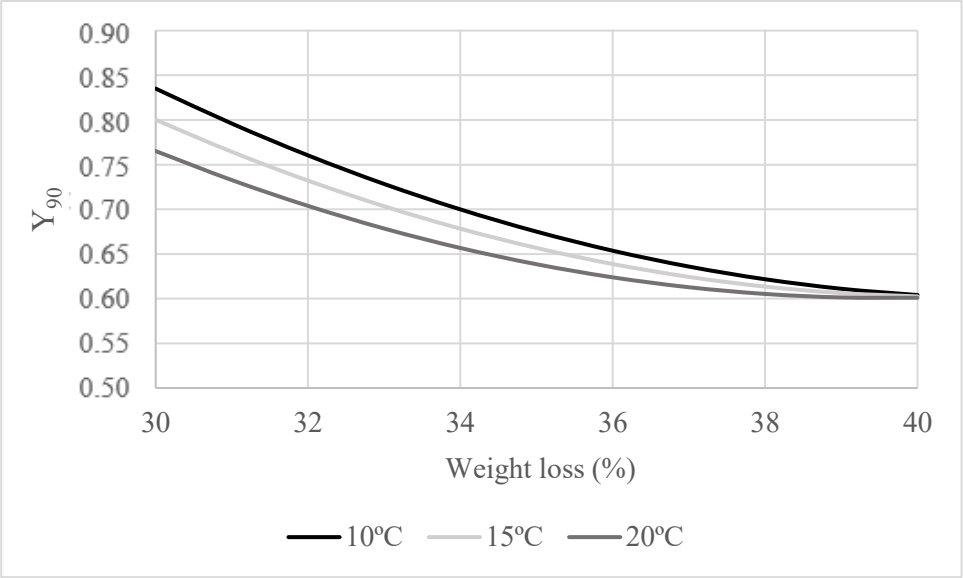

Figure 3: Predicted Y_{90} at different weight losses and temperatures on L hams for salting time of 0.80 days/kg of ham. (RMSE=0.030; $R^2 = 0.72$).

TABLES

Table 1: Distribution of the hams (n = 169) according to the salting group (SG; L/F: lean/fatty hams, 0.65/0.8/1.0: salting days/kg of ham), target weight loss (TWL; 33%, 36% or 40%) and drying temperature (DT; 10 ºC, 15 ºC or 20 ºC).

Salting group	Target Weight loss	Drying temperature		
		10 ºC	15 ºC	20 ºC
F 0.65	33%	3	2	3
	36%	2	2	1
	40%	1	2	2
L 1.0	33%	6	6	6
	36%	8	7	6
	40%	3	4	4
L 0.8	33%	7	6	7
	36%	7	6	5
	40%	4	3	4
L 0.65	33%	6	6	6
	36%	6	6	6
	40%	5	6	5

Table 2: Regression coefficients (and standard errors) for pH_{SM24h} in the linear model. LS-means of instrumental texture (F_0, Y_2 and Y_{90}) and chemical parameters on *Biceps femoris* muscle, tyrosine precipitates (tyrosine crystals incidence and white film intensity) in the whole slice, and overall processing time for all the processing conditions.

		Processing time	Chemical parameters				Texture parameters			Tyrosine precipitates	
		Total Processing time (days)	Moisture (%)	NaCl (DM%)	NPN/Moisture (%)	PI (%)	F_0 (N)	Y_2	Y_{90}	Tyrosine crystals	White film
pH_{SM24h}											
Regression Coefficient (Standard error; se)		233* (50.8)	-1.07 (0.99)	-1.62* (0.75)	-0.04 (0.21)	-2.91 (1.93)	1.971 (3.981)	-0.0275 (0.0189)	-0.0221 (0.0196)	-13.22* (6.42)	-2.60* (0.98)
LS-means	*Salting Group*										
	F0.65	564^{a}	58.6^{b}	9.8^{d}	2.7^{a}	31.9^{ab}	21.18^{bc}	0.370^{ab}	0.657^{abc}	3.2^{c}	7.4^{a}
	L0.65	384^{b}	59.9^{a}	13.9^{c}	2.4^{b}	30.9^{ab}	17.26^{c}	0.372^{a}	0.671^{a}	21.2^{a}	5.9^{b}
	L0.8	424^{b}	59.1^{ab}	15.1^{b}	2.6^{ab}	32.0^{a}	20.99^{b}	0.357^{b}	0.655^{b}	20.8^{a}	5.5^{bc}
	L1.0	393^{b}	59.1^{ab}	17.3^{a}	2.4^{b}	30.2^{b}	26.87^{a}	0.338^{c}	0.634^{c}	14.7^{b}	5.1^{c}
	Drying Temperature Group										
	DT10	459	59.6^{a}	14.1	2.4^{b}	29.6^{b}	22.16	0.363	0.665^{a}	9.5^{b}	5.8
	DT15	436	59.3^{ab}	14.1	2.5^{b}	30.9^{b}	20.59	0.363	0.659^{a}	13.7^{b}	6.2
	DT20	429	58.6^{b}	13.9	2.7^{a}	33.1^{a}	21.97	0.352	0.639^{b}	21.7^{a}	5.9
	Target Weight loss Group										
	TWL33	405^{a}	61.1^{a}	13.3^{c}	2.2^{c}	29.8^{b}	12.45^{c}	0.403^{a}	0.712^{a}	12.0^{b}	5.8^{b}
	TWL36	441^{ab}	59.7^{b}	14.0^{b}	2.5^{b}	31.2^{ab}	21.08^{b}	0.349^{b}	0.641^{b}	13.1^{b}	6.7^{a}
	TWL40	478^{a}	56.7^{c}	14.8^{a}	2.9^{a}	32.7^{a}	31.19^{a}	0.326^{c}	0.608^{c}	19.8^{a}	5.4^{b}
RMSE		78.8	1.53	1.17	0.33	2.99	6.168	0.0293	0.0304	9.84	1.45

$^{a-d}$ means within columns with different letters are significantly different ($p<0.05$). RMSE: root mean square error of the linear model.

*Regression coefficient significantly different to 0 ($p<0.05$).

Table 3: LS-means of texture analyses (Y_2 and Y_{90}) in *Biceps femoris* muscle and white film intensity in the whole slice according to the interaction Drying temperature x Target Weight loss.

Drying temperature	Target Weight loss	Y_2	Y_{90}	White film intensity
10 ºC	33%	0.421^{a}	0.738^{a}	4.43^{b}
	36%	0.338^{cd}	0.637^{c}	7.01^{a}
	40%	0.330^{cd}	0.619^{cd}	5.90^{ab}
15 ºC	33%	0.411^{a}	0.720^{a}	6.27^{a}
	36%	0.349^{bcd}	0.644^{c}	6.60^{a}
	40%	0.328^{cd}	0.612^{cd}	5.77^{ab}
20 ºC	33%	0.378^{b}	0.679^{b}	6.75^{a}
	36%	0.358^{bc}	0.643^{c}	6.59^{a}
	40%	0.319^{d}	0.595^{d}	4.46^{b}
RMSE		0.0293	0.0304	1.450

$^{a-d}$ means within columns with different letters are significantly different ($p<0.05$). RMSE: root mean square error of the linear model.