

EFFECT OF LEAN AND FAT CONTENT ON SALT UPTAKE IN ITALIAN-TYPE DRY-CURED HAM

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Abstract – The present study investigates the variation in salt uptake during salting for hams with the same weight but different lean and fat content. The results showed that lean hams absorbed more salt than fat hams. As a rule, when the salting method is based on the addition of a salt excess covering ham for a limited time, the length of the salting phase is traditionally related to the weight of fresh ham. According to the achievements of the present work, the response of fresh hams to salting process is affected by the lean and fat content too. As a consequence, to reduce salt variability in final product, raw hams should undergo different salting times according to weight, fat and lean content. The use of the *in-line* Fat-Analyzer™ device, for measuring fat and lean content in raw hams before salting, was a tool to reduce salt variability in dry-cured hams.

Key Words – Fresh ham, *In-line* classification Salting phase, NaCl content

I. INTRODUCTION

High intakes of dietary salt (sodium) have been related to hypertension, cardiovascular disease, certain cancers and other health problems [1, 2]. Average daily salt consumption in the western world (10-12 grams) largely exceeds recommendations from WHO/FAO of 5 grams per day [3]. Processed meats contribute to increase sodium intake and, because of this, reducing sodium should become a major issue for meat processors. According to recent surveys, salt reduction is an on-going process within dry-cured ham industry, that is managed by means of the salting procedures [4]. The salting process should ensure a NaCl intake sufficient for process safety, with a low variability among hams. The salting process can be either performed by covering the ham with a salt excess or by adding a limited salt amount calculated according to ham weight. In the first case salt intake is managed by means of the process length, while, in the second

case, added salt is calculated as an established percentage of ham weight.

Differences due to raw matter are regarded as one of the main sources of variability for salt intake; the study faces this issue for the first type of salting process (hams covered with salt). In particular, the aim is to evaluate differences in salt uptake due to variations in lean and fat content occurring in hams falling in the same weight range.

II. MATERIALS AND METHODS

The study was undertaken purchasing 72 fresh hams in a local slaughterhouse in three times in July, November and February respectively. A preliminary selection was made collecting U, R and O marked legs according to EUROP grid classification [5]. Selected fresh hams had an average weight of 13.5 ± 0.3 kg, and a pH_{24h} in *Semimembranosus* muscle within the range 5.50 – 5.90, to prevent drawbacks in salting process due to poor meat quality.

Prior to salting, the hams were trimmed to achieve a standardized lean exposed surface for salt diffusion (nearly 20 cm distance between the *Femoris* bone head and the trimming line was kept). For each ham, subcutaneous fat thickness under *Caput Femoris* bone was manually measured. Next, ham scanning was performed using the Fat-Analyzer™ system (Lenz Instruments, S.L., Barcelona, Spain) to predict the lean and the fat content [6]. The system measures the dielectric permittivity of each ham, which is correlated with fat content. Scanned hams were refrigerated at 3 °C to avoid possible temperature induced errors.

Equations 1 and 2 were applied for the prediction of fat (F) and lean (L) weight of each ham [7]:

$$F = \gamma_F \cdot W + \alpha_F \cdot S + \beta_F \quad (1)$$

$$L = \gamma_L \cdot W + \alpha_L \cdot S + \beta_L \quad (2)$$

where W = weight of fresh ham (kg), S = signal given by Fat Analyzer™.

In Eq. 1 $\gamma_F = 0.57$, $\alpha_F = -3.03$, $\beta_F = -0.62$

In Eq. 2 $\gamma_L = 0.37$, $\alpha_L = 2.52$, $\beta_L = 0.43$

The salting phase was carried out in two steps. During each step, ham rind was manually rubbed with wet salt (1.5% of ham weight), while the lean exposed surface of ham was fully covered with dry salt (4.5% of ham weight). Hams were stored at 1-3 °C and 80-90% relative humidity (first salting). After 8 days, hams were brushed to remove the salt remained on the surface and salted again (second salting) with wet salt in the rind (1.5 % of ham weight) and dry salt in the exposed lean surface of ham (2.5% of ham weight). Hams rested in the same environmental conditions reported for the first salting, up to a maximum of 19 days.

At each established times (at day 5, 6, 8, 9, 11, 12, 14, 15 and 19), 6-8 hams were withdrawn from the salting cellar, brushed to remove salt, weighted and dissected to divide the lean, including inter and intramuscular fat, from the subcutaneous fat with rind and from the bone. The weight of each part was recorded and the percentage on whole ham weight was calculated. Lean with inter and intramuscular fat was minced separately. Moisture was determined according to AOAC [8] 960.39 official method. NaCl content was calculated from chloride content determination, after extraction with warm water (40 °C) and potentiometric titration of the aqueous extract with Titrand 809 Metrohm Ltd (Herisau, Switzerland).

Statistical analysis

All the statistical analyses were carried out with SPSS statistical package (ver. 13.5). Green hams classification was run with K-Means Cluster Analysis; Box-plot charts were used to show the distributions of estimated lean and fat percentages in fresh hams. Curve Estimation procedure with plot models was used to calculate equations and display curves for salt intake over salting.

III. RESULTS AND DISCUSSION

Fresh ham measurements

Sample selection was aimed at collecting fresh hams within a narrow range of weight and pH, but with a large variation in lean, fat content and fat thickness. Data of fresh hams displayed in Table 1 confirm the expected variability in fat and lean

content (values estimated by means of Equations 1 and 2).

Table 1. Mean, standard deviations (S.D.), and % coefficient of variation (C.V.) of measurements on fresh hams (n = 72).

Item	Mean	S.D.	C.V.
pH _{24h}	5.67	0.07	1.23
Fat thickness (cm)	2.96	0.92	31.1
Ham weight (kg)	13.5	0.31	2.30
Lean weight* (kg)	9.01	0.53	5.88
Fat weight* (kg)	2.71	0.55	20.3

* Estimated values by means of Fat Analyzer TM

Fresh hams were analyzed by means of K-Means Cluster Analysis, to classify fresh hams in two homogeneous groups (clusters) according to measured variables. No information on initial cluster centers was provided and the final cluster centers (average variable values of hams classified in different clusters) were calculated. Thirty-nine and thirty-three hams were classified in Cluster 1 (CL1) and Cluster 2 (CL2) respectively. Even if CL1 and CL2 were chosen to maximize the differences among hams in different clusters, the analysis of variance between CL1 and CL2 was reported to display the contribution of each variable to separate the groups (Table 2).

Table 2. One-way analysis of variance (ANOVA) on variables of fresh ham in CL1 and CL2.

Item	CL1	CL2	P-values
pH _{24h}	5.67	5.67	0.926
Fat thickness (cm)	3.63	2.15	0.000
Ham weight (kg)	13.5	13.4	0.486
Lean weight* (kg)	8.61	9.47	0.000
Fat weight* (kg)	3.20	2.13	0.000

*Estimated values by means of Fat Analyzer TM

According to variable values reported in Table 2, hams grouped in CL1 and CL2 can be regarded as “fat” and “lean” respectively. Distributions of lean and fat percentages calculated on the whole ham weight are displayed in Figure 1: hams in the range 20-27% fat and 60-67% lean belong to CL1, while hams within 12-20% fat and 67-74% lean are in CL2. As displayed in Figure 1, fat and lean percentage distributions in different clusters do not overlap.

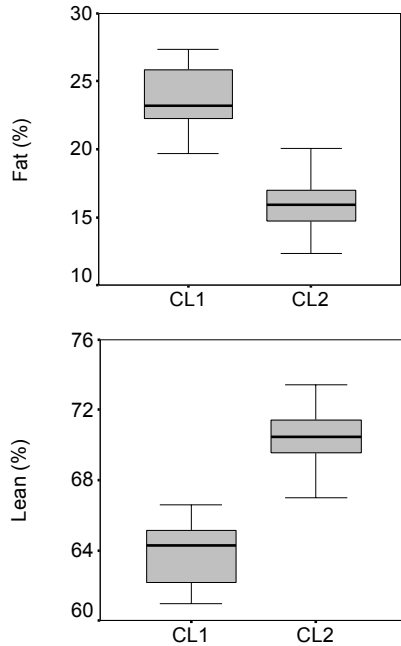


Figure 1. Box-plots of Fat(%) and Lean (%) in clusters.

Analysis of hams during salting process

At established deadlines during salting, 3-4 hams/cluster were dissected (destructive procedure), and the NaCl and moisture content of the lean part (including intra- and intermuscular fat) were measured. Models of salt uptake were separately calculated for hams belonging to CL1 and CL2. NaCl content was expressed as a percentage on dry matter basis in order to compare salt content of hams with increasing weight loss over salting time. The curve displayed in Fig. 2a shows the increase in salt uptake during the salting process for hams grouped in CL1 (fat hams).

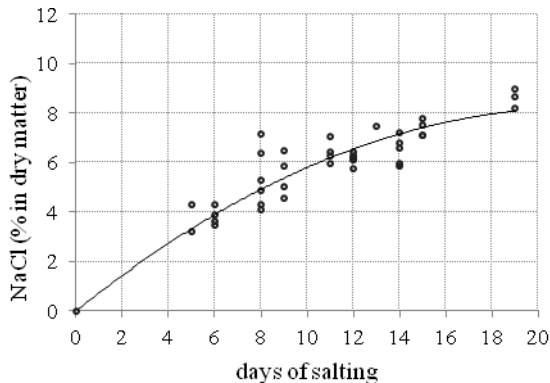


Figure 2a. Salt uptake model for hams of Cluster 1

The model shown in Figure 2a is based on Eq. 3:

$$NaCl(DM) = 0.73x - 0.02x^2 \quad (3)$$

x = salting days, $R^2 = 0.98$

According to 2nd Fick's law, the rate of salt increase over time is negatively affected by the decrease in salt concentration gradient along the direction of salt diffusion (assumed from surface to the centre of ham). Moreover, according to the applied salting process (ham surface fully covered with salt), the layer on surface can be regarded as a continuous source of salt.

The next model is the curve (Figure 2b) plotted to display CL2 samples (lean hams).

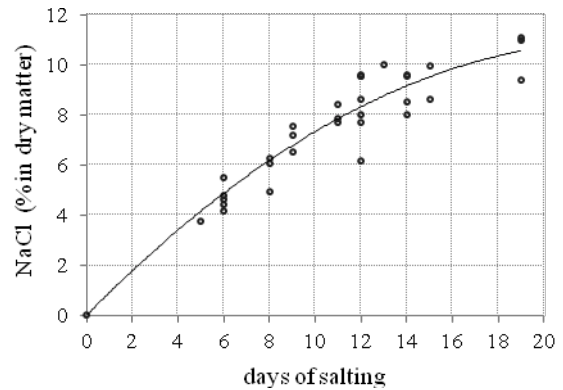


Figure 2b. Salt uptake model for hams of Cluster 2

The model shown in Figure 2b is based on Eq. 4:

$$NaCl(DM) = 0.94x - 0.02x^2 \quad (4)$$

x = salting days, $R^2 = 0.98$

According to Eq. 3 and 4, CL2 lean hams have a higher salt intake, at defined salting conditions, than CL1 fat hams.

Due to ham selection procedures (narrow range of weight and pH) and equal salting conditions, the variations in salt intake between hams of CL1 and CL2 are to be mainly ascribed to differences in diffusion data and coefficients occurring in lean and fat hams [9].

The antagonist role played by ham fat (outer and inner layers) toward NaCl diffusivity is a key factor to account for salt differences displayed by Figure 2a and 2b.

Fresh ham classification (Table 2 and Figure 1) based on lean and fat content as predicted by Eq. 1 and 2, was even supported by the dissection weights given by salted hams. Measures of whole salted ham, lean (desalted weight including intra- and intermuscular fat) and subcutaneous fat weight were used for the classification procedure as made for fresh hams (Table 2): 38 hams out of 39 were reassigned to CL1 and 32 out of 33 to CL2 (data not reported).

Salt content quantified in hams dissected during the salting process, was nearly 30% lower in fat hams than in lean hams (on average 165 vs. 219 grams in CL1 and CL2 respectively). The difference is significant ($P < 0.05$) either if expressed in percent on wet muscle (1.96 vs. 2.38) or on dry muscle (5.95 vs. 7.70). Salt differences found in the lean part of ham at the end of the salting process can be regarded as the main source of variability for salt amount in the final outcome. Contribution to final NaCl content of salt located in fat at the end of the salting step is fairly constant regardless of the thickness of fat layer [4]; furthermore, high processing weight losses increase salt concentration in very shrunk dry-cured hams.

IV. CONCLUSION

A significant increase in salt intake was demonstrated for lean hams during the salting process if compared with their fat counterparts. This means that the length of the salting period should be adapted according to lean and fat content of hams under salting to avoid an excess or a lack of salt in dry-cured ham. As a consequence, the *in-line*, non-invasive estimate of lean and fat content of fresh hams, allows the length of the salting process to fit ham features, preserving safety and nutritional quality and improving the homogeneity of production; in this respect, it could be a useful tool in the strategy of salt reduction.

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