PE3.03 **Computed Tomography: Usefulness and Applications in Dry-cured Ham** 211.00

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***Abstract*—Implementation of new technologies to control dry-cured ham processes and prevent sensory defects is of major interest for dry-cured ham producers. Computed tomography (CT) is a non invasive imaging technique that allows visualization of structures of different density. Because of the high density of salt ions, salt intake and distribution during dry-cured ham elaboration process can be easily followed. Moreover, predictive models allow the determination of salt and water content throughout the process. In this study, potential of CT to study the process of salting, freezing/thawing processes and some important defects such as crustiness and hollow extent were evaluated.**

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***Index Terms*— computed tomography, dry-cured hams, optimization, sensory defects, crustiness.**

## I. INTRODUCTION

Computed tomography (CT) is a non invasive technology initially only applied in medicine [1] which has been extended to other fields. In meat science, CT has been found to be useful for the estimation of animal body composition [2], to study fat distribution in salmon [3] or to optimize dry-curing processes [4, 5, 6].

X-rays emitted by the CT equipment lose part of their energy when they interact with body tissues. The degree of attenuation depends on the tissue density [7]. CT attenuation measurements of a sample are collected to generate an image in grey levels called a tomogram in which brighter tones represent higher x-ray attenuations. These images are useful to study body composition or food processes such as curing/salting because different biological structures and salt may be distinguished. For example, salted parts of meat appear brighter (high attenuation of X-rays) in the tomogram than non-salted parts because of the higher density of salt ions (Figure 1).

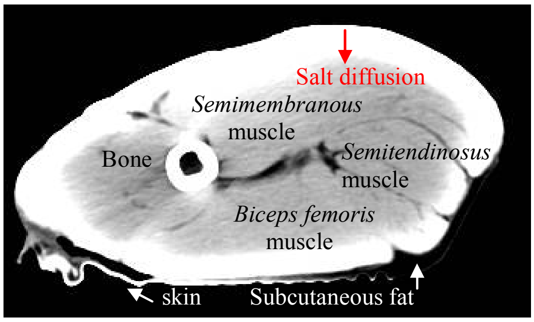


**Figure 1.** Tomogram of a dry-cured ham slice at the end of the salting process taken by computed tomography.

Several predictive models to quantify salt and water content in dry-cured ham have been recently developed [8, 9, 10]. Thus, tomograms may be converted to images where salt and water content can be visualized (Figure 2). These images of salt and water distribution can be generated using a Matlab script written in house [11].

Implementation of new technologies to control dry-cured ham processes and prevent defects is of major interest for dry-cured ham producers. The aim of this study was to show the utility of CT to study salting, freezing/thawing processes and sensory defects such as crust on the ham surface and hollow extent.

## II. OPTIMIZATION OF SALTING PROCESSES

Elaboration process of dry-cured ham may be studied, controlled and optimized using CT. Images of salt distribution show that diffusion of salt during the elaboration process mainly happens through the lean surface of the ham since subcutaneous fat acts as a barrier (Figure 2A). During the process, salt diffuses to the centre of the ham and water content decreases (Figure 2B). Internal area of *Biceps femoris* is the last area reached by the salt and therefore has low microbiological stability. During drying, salt becomes homogenously distributed, increasing up to values around 4% NaCl in the internal parts (Figure 2C).

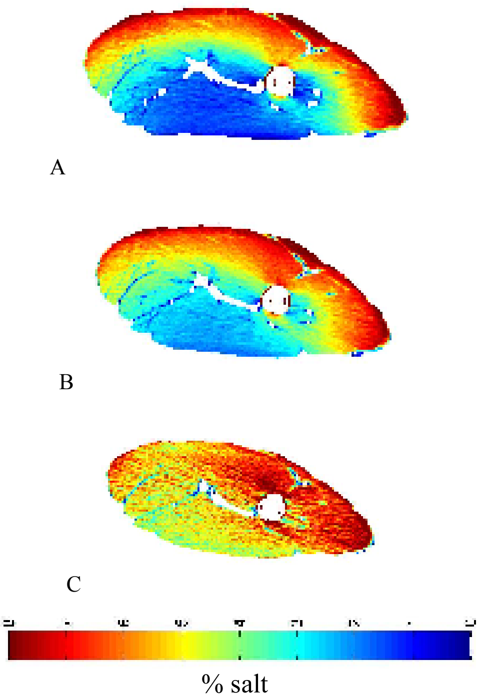


**Figure 2.** Distribution of salt during dry-cured ham elaboration process. A) after salting, b) at the end of resting, c) after 3 months drying.

CT has already been used to study the effect of several factors on salting processes. García-Gil et al [12] studied the effect of partially skinning the ham according to V shape, the effect of green hams pressing and the effect of salting temperature on overall salt content. Santos-Garcés et al [11] also studied the effect of freezing/thawing processes before salting on salt and water diffusion during dry-cured ham production.

Nutritional improvement (such as reduction of salt content) is an issue of major interest for food standard agencies in many European countries as it is a primary target for their preventive health management strategies. In this sense, CT could be especially useful to optimize elaboration processes to produce low salt content products.

At the end of the resting period, salt should be evenly distributed in the ham to reduce the incidence of pasty textures and guarantee microbiological safety. Determination of its duration is important, especially when salt content is reduced because longer resting periods are needed. Characterization of threshold values ($a_w$, salt and water content), in the most critical zones at different intervals of the process, could help to improve safety and quality of the product.

## III. STUDY OF DRY-CURED HAM FREEZING/THAWING PROCESSES AND ITS EFFECT ON SALTING

Freezing and thawing of hams has become a common process in the dry-cured ham industry. Because density of water in solid phase is lower than in liquid phase, freezing/thawing processes can be easily followed using CT. Figure 3 show tomograms obtained during freezing/ thawing of a green ham. Fresh hams (a) show higher attenuation values than hams after 21 h in freezing (b) or hams completely frozen (c). During thawing process the inverse phenomenon can be observed (d-e).

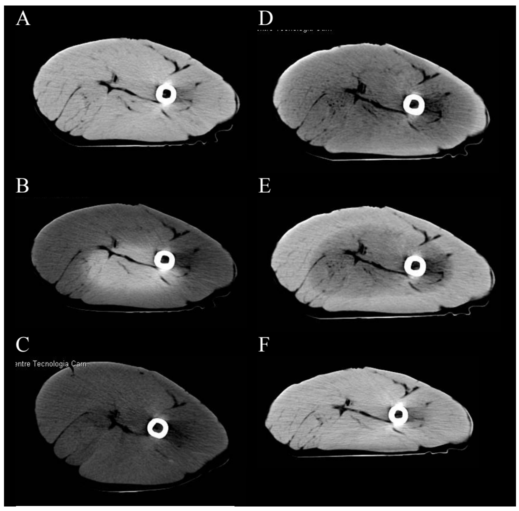


**Figure 3.** Tomograms obtained during the freezing and thawing process of a green ham. a) fresh, b) 21 h freezing, c) 87 h freezing, d) 24 h thawing, e) 78 h thawing, f) 196 h thawing.

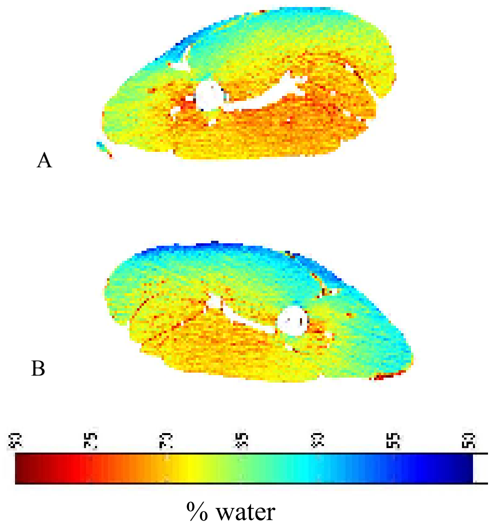


**Figure 4.** Comparison of water distribution of a dry-cured ham slice at the end of the resting period. A) Fresh, B) Frozen/thawed ham.

Study of different freezing/thawing conditions using CT would give additional information to enable a thorough study of the consequences of this process.

Moreover, knowledge of the effect of freezing/thawing processes on the salting procedures can help to control final salt content in dry-cured ham. In previous studies, it has been observed that salt diffusion is influenced by freezing processes [13, 14, 15]. CT images of salt and water distribution in frozen or thawed hams through the process would also be useful to characterize duration of the salting and resting period during elaboration. As shown in Figure 4, water distribution of a fresh ham and a frozen/thawed ham at the end of the resting period is significantly different.

## IV. EVALUATION OF DRY-CURED HAM DEFECTS

### CRUSTINESS EVALUATION

Development of a crust on dry-cured ham surface is related to hams with low intramuscular fat and a great amount of intermuscular fat. In this sense, CT may be useful to identify green hams with these characteristics and therefore to select the most appropriate genetic line to avoid this defect.

In meat industry, evaluation of crust level is normally done by pressing the ham surface with the fingers [16]. In the finished and sliced product the assessment of crustiness can be done by using visual scales. In order to develop such scale, CT can help to select those samples having different intensity of this technological defect.

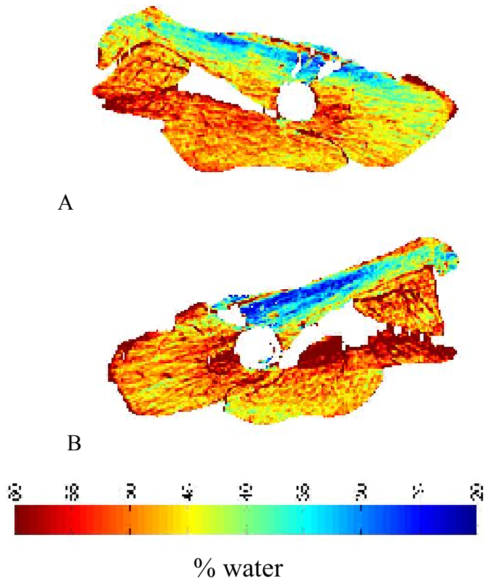


**Figure 5.** Images of water distribution representing two different levels of crustiness on the ham surface. A) No crust, B) Moderate crust.

CT can also be used to instrumentally evaluate different levels of crust on dry-cured ham. In order to evaluate quantitatively the degree of crustiness, colour images of water distribution can be used. Water distribution images of a ham without crust and a ham with moderate crust on the surface are shown in Figure 5. Hams without crust on the surface show a homogeneous drying of the slice, even if *Semimembranosus* and *adductor* muscles are drier (Figure 5A). In hams having a moderate crust, *adductor* muscle, in which crust is typically developed, water content values are low (around 20-30 % water) whereas water content in *Biceps femoris* and *Semitendinosus* muscles is above 50 % (Figure 5B).

### HOLLOW EXTENT EVALUATION

Hollow extent in dry-cured ham is mainly due to a rapid retraction of the ham during drying which may induce formation of cavities around the coxofemoral joint. In these cavities, there are appropriate conditions for microbial development. CT can be used to detect and determine the degree of damage by measuring the extent of the cavities when using different elaboration conditions. It may help to optimize industrial processes to avoid this problem.

## V. CONCLUSION

Computed tomography has been demonstrated to be a useful tool to optimise dry-cured ham elaboration process as well to detect and evaluate typical defects of dry-cured ham.

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