Development of a mathematical model for the drying process of Spanish cured ham

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Introduction

In the food industry, salting and drying are mass transfer processes leading to time-varying water and salt content profiles. It is important to quantify and assess the time course of these two variables to better understand their effects on the biochemical evolution and textural properties that develop during the production of dry-cured ham.

Figure 1. Ham drying process at CARTESA Facilities in Teruel, Spain.

The final quality of dry-cured ham depends on the evolution of proteolysis during manufacture in response to changes in various factors such as temperature, water content and salt content.

Materials and methods

3D ham geometry and meshing

Building an accurate 3D representation of a ham was a complex task. A 3D camera with a LIDAR sensor was used to take the first image, on which the geometry of the ham was built using a CAD software. This geometry was then measured using Comsol® Multiphysics software.

Heat transfer and mass transfer modelling

Heat transfer and predicting ham temperature change in response to air temperature variation during the pre-drying or drying/ripening stages was modelled by Fourier's law. The different mass transfer processes occurring during the dry-cured ham production process was modelled classically using Fick's equation. Finally, we solved the equations using Comsol® Multiphysics software.

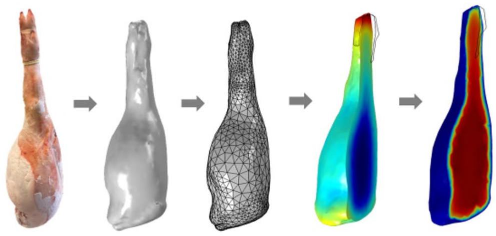

Figure 2. 3D ham geometry, meshing and models of ham

Objectives

Building a 3D multiphysics model based on finite elements to estimate the water activity and salt and water content distributions during the drying process of Spanish cured ham.

Results

As a result, the time-space distribution of salt content and water content can be visualized anywhere in the 3D ham geometry.

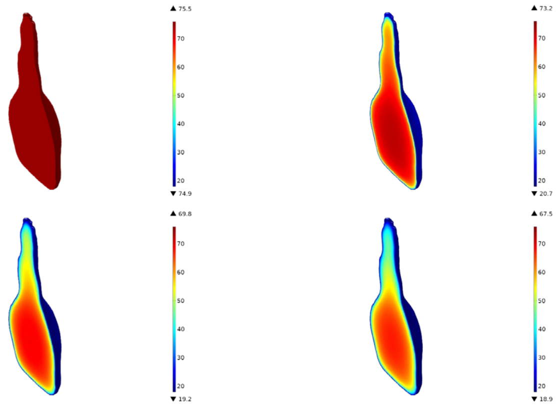

Figure 3. Water content of the ham at 0, 35, 50 and 70 days after the start of the curing process.

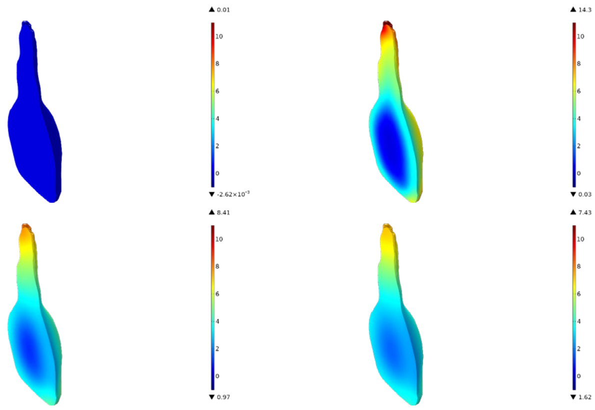

Figure 4. Salt content of ham at 0, 35, 50 and 70 days after the start of the curing process

As shown in the images, we can now predict the salt and water content of the ham at any point in its 3D geometry and at any time during the drying process.

With this data, we are now working on simulating the proteolysis of the ham.

Conclusions

This study describes a finite element model that simulates water and salt transfers in a real ham. The "numerical ham" model presented here can predict the time course of salt content, water content, aw and total weight loss during the different stages of dry-cured ham production.

This "numerical ham" model constitutes a valuable numerical tool to help industrial operators build scenarios to produce dry-cured hams.

However, in order to be fully predictive and more accurate in predicting water and salt contents, the current version of this "numerical ham" model will have to be improved by considering the decrease in ham volume due to drying.

This tool will form part of the digital twin of the whole value chain of the Spanish cured ham production process.

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