COMBINED HYPERSPECTRAL IMAGING AND PREDICTIVE MICROBIOLOGY FOR NON-INVASIVE EVALUATION OF FOOD SAFETY

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I. INTRODUCTION

Hyperspectral imaging (HSI) technology can provide non-invasively spatial physicochemical information of food products and has been previously used to evaluate the composition and quality defects of food products [1]. On the other hand, predictive microbiology models are mathematical tools able to simulate microbial behaviour in foods, i.e., growth, survival, or inactivation of pathogens using key extrinsic factors (process temperature) and intrinsic factors (pH and a_w) [2]. The aim of this work was to explore the potential of a non-invasive and rapid approach for food safety evaluation consisting of the use of non-invasive HSI results as input information of microbiology models to predict the growth probability of *Staphylococcus aureus* in two different types of dry-cured ham.

II. MATERIALS AND METHODS

Four hundred 10 mm-thick samples with a diameter of 3 cm were obtained from commercial dry-cured hams to construct the a_w predictive model using HSI. Besides, 3 dry-cured ham slices from two different dry-cured ham types were prepared to predict microbiological growth. Ham type 1 had a reduced salt content, whereas Ham type 2 followed a standard salting process. Analytical a_w was determined using AquaLab Series 3 (Lab-Ferrer, Spain). Images from all the samples and slices were acquired using a hyperspectral imaging system (Resonon Inc., Bozeman, MT, USA) in a wavelength range of 400-1000 nm with 300 wavebands at 2 nm intervals in the spectral domain. Models were developed using Partial Least Squares regression (PLSR) using PLS Toolbox, version 8.1.1 (Eigenvector Research, Inc., Wenatchee, WA, USA) (calibration set, n=272). The best combination of pre-treatments was selected based on the lowest error of prediction and the lowest number of latent variables (LV). The goodness of fit of the models was assessed using the coefficient of determination (R^2) and the root mean square error of Prediction (RMSEP) (validation set, n=128). Chemical images were calculated from the slice's images using the a_w predictive models developed. The a_w values at percentile 50 (a_wP50), 75 (a_wP75) and 90 (a_wP90) were determined from the cumulative distributions of a_w after removing fat streaks of the slice. The growth/no growth boundary model for *Staphylococcus aureus* on vacuum-packaged ready-to-eat meats at room temperature (21 ºC) developed by Borneman et al (2009) was applied. The input values were the a_wP50, a_wP75 and a_wP90 values obtained with HSI and a pH of 5.8 (assumed as the reasonably foreseeable worse-case scenario)

III. RESULTS AND DISCUSSION

The model developed can predict a_w in dry-cured ham slices with a low error (RMSEP= 0.0130) and a high linearity (R^2=0.93) (Figure 1). Although this error is higher than analytical error, it is considered useful for the new methodology. The chemical images obtained from the acquired HSI images after applying the mentioned predictive model for the two studied dry-cured ham types showed qualitative differences on the a_w values and on their distribution.

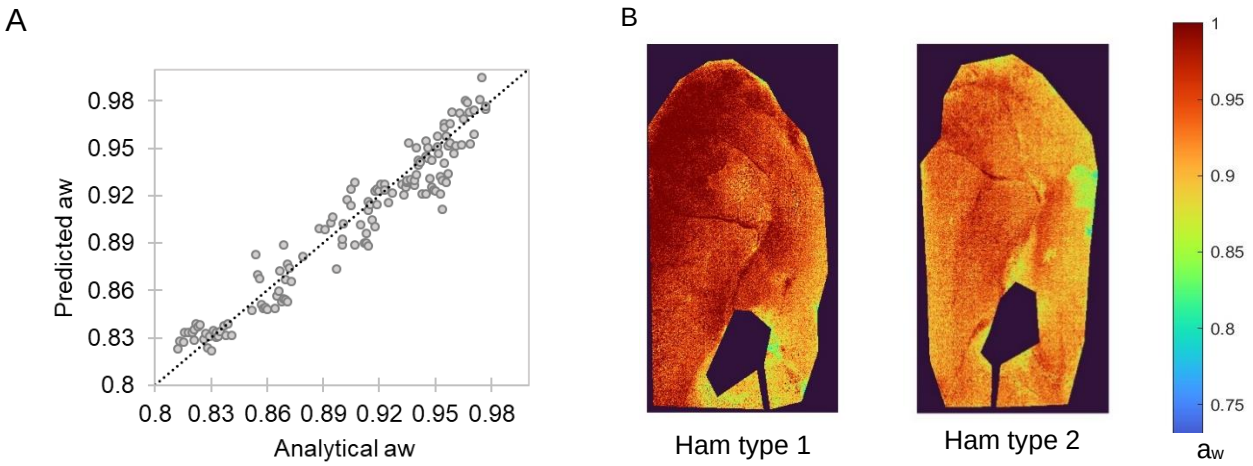

Figure 1. Predicted vs analytical a_w of validation set (A) and the chemical images for the two ham types obtained using the a_w predictive model (B).

Table 1 shows the outputs of the simulations about the growth probability of *S. aureus* using the 50th, 75th and 90th percentiles of the predicted a_w as input values. Results show that the assessed dry-cured ham supported the growth of the pathogen to a variable probability depending on the ham type and the used a_w percentile. The pixel-to-pixel information on a_w obtained using HSI provides relevant information for the safety evaluation of the product since pathogenic bacteria respond to the local rather than to the average physicochemical characteristics of the product. However, the use of this information instead of analytical mean values (corresponding to a_wP50) increases growth probability. Removal of intramuscular fat streaks from these images before determining a_w percentiles might also have an effect and should be defined before implementation of the new methodology.

Table 1. Probability of *Staphylococcus aureus* growth at room temperature (21ºC).

Ham type	n	pH	awP50	Growth probability	awP75	Growth probability	awP90	Growth probability
Ham type 1	3	5.8	0.947	77%	0.971	87%	0.985	91%
Ham type 2	3	5.8	0.921	62%	0.943	75%	0.965	85%

IV. CONCLUSION

The new methodology might be useful to evaluate food safety non-invasively. However, a validation of the methodology is needed to define the optimal percentiles to be used and the effect of other parameters such as intramuscular fat streaks in the analysis to ensure its reliability.

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