NON-DESTRUCTIVE ANALYSIS OF HAZELNUT OXIDATION IN DIFFERENT ENVIRONMENT PLASTIC PACKAGING USING NIR-HSI

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Introduction

Hazelnuts have a historic relevance in the economy and diet of the Mediterranean region, providing healthy fats, proteins, vitamins, and minerals. Assessing their quality and shelf life is crucial due to their susceptibility to oxidative rancidity, which degrades both nutritional and sensory properties [1].

Traditional methods for detecting lipid oxidation are destructive (both for packaging and hazelnuts) and impractical for continuous monitoring, as they require sample preparation and laboratory analyses, such as the Rancimat method. However, employing near-infrared (NIR) hyperspectral imaging (HSI) can potentially provide a non-destructive analysis method to monitor hazelnut oxidation in plastic packaging. This technique offers a rapid, eco-friendly, and cost-effective solution, enhancing quality assurance in hazelnuts from producer to distributor [2,3].

Aim of study

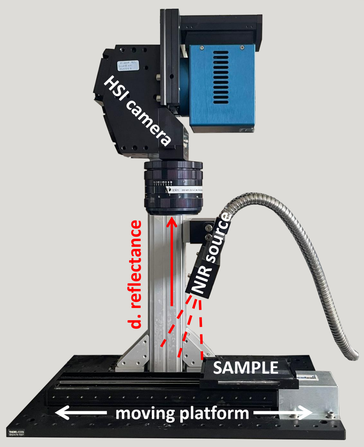
The aim of this study is to evaluate the effectiveness of near-infrared hyperspectral imaging (NIR-HSI) as a non-destructive analysis method for monitoring the oxidation process in hazelnuts stored in plastic bags. By examining hazelnuts under different environmental conditions (air, nitrogen, vacuum) and storage conditions (ambient light and temperature, constant dark and temperature), this research seeks to develop a reliable technique for the early detection of oxidative changes, ultimately enhancing quality assurance of hazelnuts.

» Proving that NIR-HSI is an effective tool for the early detection and monitoring of bagged hazelnut oxidation.

Materials and Methods

The NIR-HSI images were acquired using a line mapping system (320 sensors) working in the wavelength range of 938–1630 nm with a spectral resolution of 4.85 nm, recording a total of 142 wavelength channels (λ) for each spectrum (Headwall Photonics, Inc. Massachusetts. USA, kindly donated by FOSS Analytics A/S, Denmark, and lent by J.M. Amigo, UPV/EHU).

The region of interest (ROI) of the images had 5 x 7 cm (300 x 300 µm resolution). The measurements were performed in diffuse reflectance mode. The camera was calibrated using white and dark references and transformed into log(1/R) absorbance units [4].



Every sample (hazelnut bag) contained 12 hazelnuts of the Ribeta variety, randomly sampled, shelled and bagged at day 0. They were packaged with 3 different atmospheres: air, nitrogen and vacuum; and were stored both in light, with changing temperature, and dark, with constant temperature, conditions. Three replicate bags of each condition were measured (3 x 2 x 3 = 18 bags).

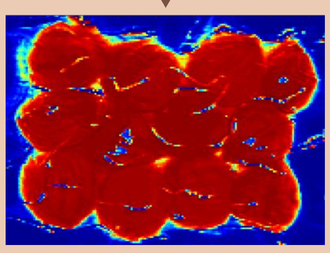
The background pixels in each image were identified and excluded from the data prior to modelling. Moreover, the mean spectrum of each sample was also calculated and used for the oxidation process characterisation.

Hypertools v4 was used for the image processing and PLS_Toolbox v9.2 on MATLAB R2022b for the data curation and statistical analysis.

Data acquisition and curation

↓ HSI-NIR & Log (1/R)

↓ Crop, SNV & PCA



↓ Tresholding on PC1

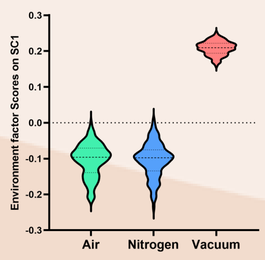
Object recognition? - - - →

Results

ANOVA-simultaneous component analysis (ASCA): the ideal tool for decomposing the variance in the considered experimental factors

ASCA model on the whole matrix
(18 bags*19 days x 120 λ)

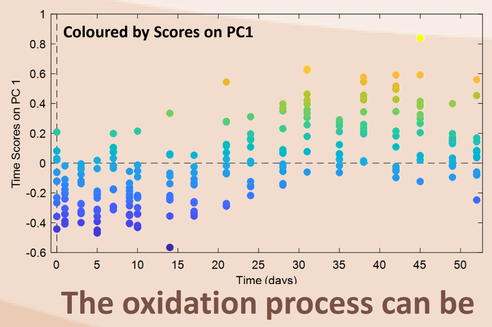
Factor	PCs	Effect (%)	*p*-value
Time	18	20.50	0.001*
Environment	2	14.66	0.001*
Light	1	8.55	0.001*
Time x Envir.	20	8.73	0.001*
Time x Light	18	5.54	0.001*
Envir. x Light	2	2.28	0.001*
Residuals		39.75	



Even if the bags used were made of the same polymer and similar thickness, this result suggests that the observed variability corresponding to this factor is not related to oxidation in different environments, but to spectroscopic differences.

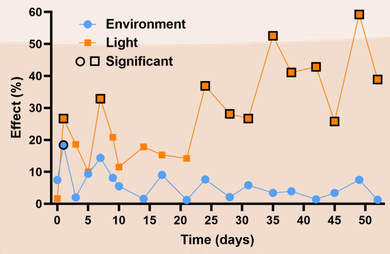
ASCA model without vacuum bags
(12 bags*19 days x 120 λ)

Factor	PCs	Effect (%)	*p*-value
Time	18	34.37	0.001*
Environment	2	0.93	0.017*
Light	1	12.04	0.001*
Time x Envir.	20	2.51	0.996
Time x Light	18	8.09	0.001*
Envir. x Light	2	1.39	0.003*
Residuals		40.67	



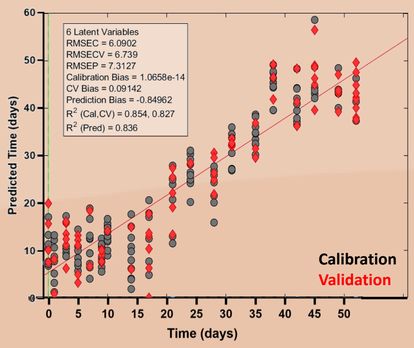
The oxidation process can be monitored using HSI-NIR

One ASCA per day (12 bags x 120 λ)

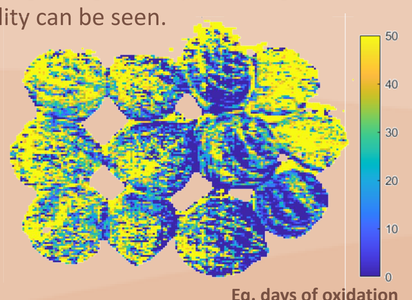


The environment did not have a considerable effect on the oxidation process, the light and temperature did, though. Even more notable at advanced stages of the process.

Preliminary PLS regression to predict the stage of oxidation



This regression can be used to predict individual pixels of an image: e.g. Image of day 42, a high variability can be seen.



Conclusions

» The combination of HSI-NIR and ASCA proved to be a good method for studying the factors affecting the oxidation process of bagged hazelnuts.

» The results about the effect of different environments are not conclusive. The air and nitrogen bags were not air-tight for so long time, and the differences with the bags under vacuum are not sample-related.

» Exposition to light and changing temperature was seen to be a relevant factor in the oxidation process as shown in literature.

» A regression model built using a representative oxidation process can be potentially used for the assessment of individual pixels or hazelnuts in an image, providing an individualised monitoring.

» HSI-NIR can be a good basis for a green analytical methodology to monitor hazelnut oxidation process and shelf-life, increasing product quality.

References

[1] López *et al*., Influence of Drying Conditions on the Hazelnut Quality. I. Lipid Oxidation. Drying Technology. 15(3–4) (1997) 965–977. DOI: https://doi.org/10.1080/07373939708917271

[2] Pannico *et al*., Non-destructive detection of flawed hazelnut kernels and lipid oxidation assessment using NIR spectroscopy. J. Food Engineering. 160 (2015) 42-48. DOI: https://doi.org/10.1016/j.jfoodeng.2015.03.015

[3] Moscetti *et al*., Hazelnut Quality Sorting Using High Dynamic Range Short-Wave Infrared Hyperspectral Imaging. Food and Bioprocess Technology, 8 (2015) 1593-1604.

[4] Ozaki et al,. Near-Infrared Spectroscopy. (2021). DOI: https://doi.org/10.1007/978-981-15-8648-4

Acknowledgements

We thank Jose Manuel Amigo, for lending us the hyperspectral camera, providing the fantastic Hypertools toolbox and the assistance.

Grant URV Martí i Franqués – Banco Santander (2021PMF-BS-12).
Grant URV-IRTA Martí i Franqués (2020PMF-PIPF-6).
Grant URV-IRTA Martí i Franqués (2023PMF-PIPF-49).

Chemometrics and Sensorics for Analytical Solutions (CHEMOSENS, ref.2021 SGR 00705, Departament de Recerca i Universitats, Generalitat de Catalunya).

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