Impact of storage conditions and time on iron distribution and state in a 3D-printed hybrid food

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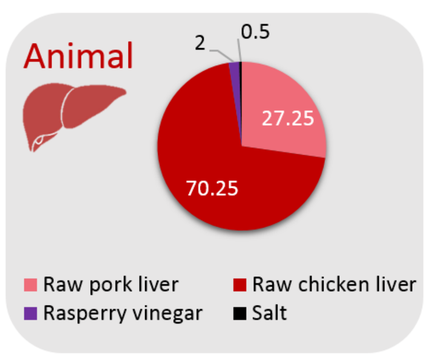
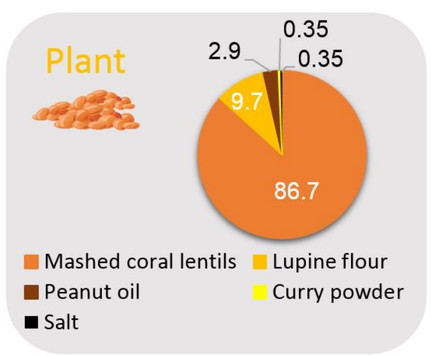
BACKGROUND

Iron deficiency is the leading cause of **anemia**, which affects about 25% of the world's population [1]. Several approaches are being explored to address these deficiencies, including the development of **new iron-rich foods** in which iron would be provided naturally through the nutritional richness of the ingredients involved.

However, iron absorption is related to complex mechanisms and depends on the form of iron, **heme iron (HI) or non-heme iron (NHI)**, and on the other components of the food. Moreover, the chemical and textural properties of the food may be affected by storage conditions and time [2,3]. In this context, this study investigated the time-course chemical changes at the microscopic scale in a **hybrid food composed of liver and lentils**, comprising several forms of iron.

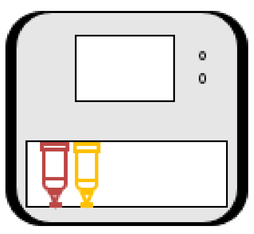
MATERIALS AND METHODS



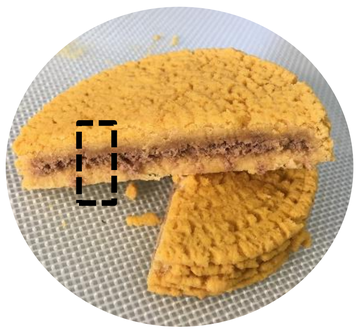


Pre-heating
50 °C / 15 min

Commercial
3D food printer



20% animal mixture
80% plant mixture

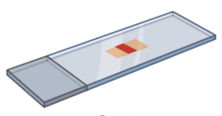


1- 180 °C / 5 min; 70% steam

2- 2 modified atmosphere packaging (MAP):
- Oxygen-rich (O_2-MAP)
- Nitrogen-rich (N_2-MAP)

3- Timepoints for analysis:

Cryofixation in liquid N_2 cooled isopentane



Cuts
6 and 10 µm

- **X-ray fluorescence (XRF)**
- **µ-X-ray Absorption Near Edge Structure (XANES)**
- FT-IR spectroscopy
- Histological stained

Liquid N_2 grinding

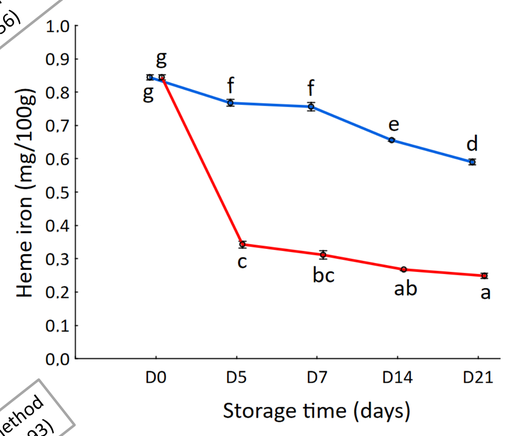
Powder

- **Iron contents**
- **XANES**
- Lipid oxidation

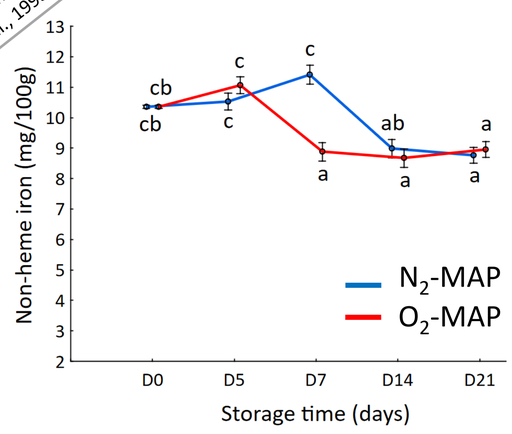
RESULTS

Iron contents

Hornsey's method (1956)



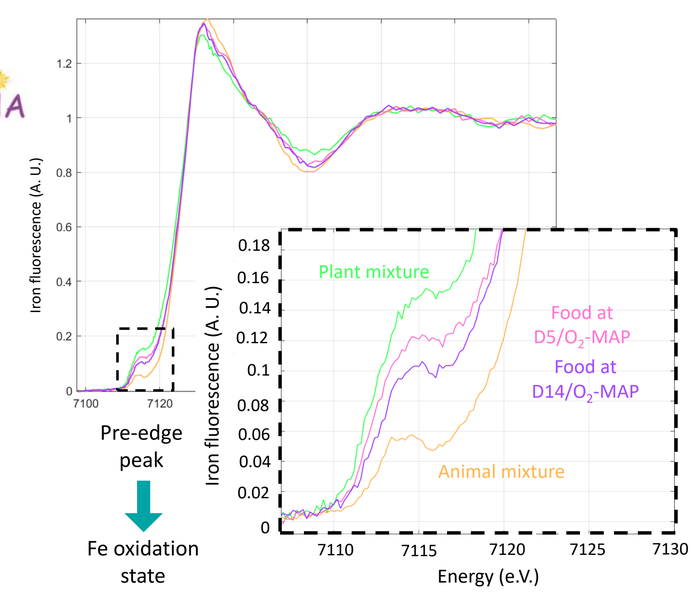
Ferrozine method (Ahn et al., 1993)



Drop in HI content under **O_2-MAP between days 0 and 5** due to oxidation

Fe K-edge normalized XANES spectra

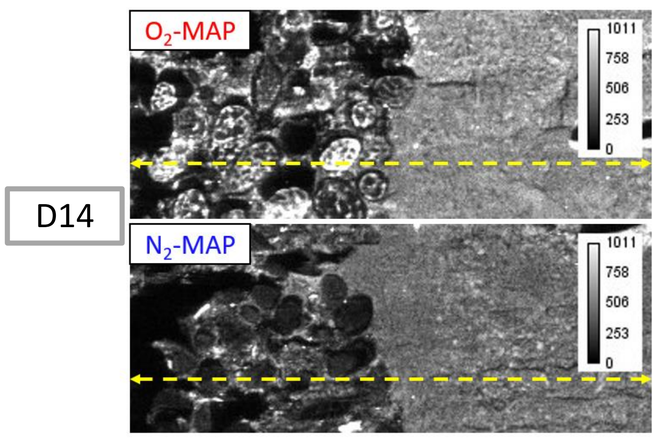
SOLEIL SYNCHROTRON
LUCIA

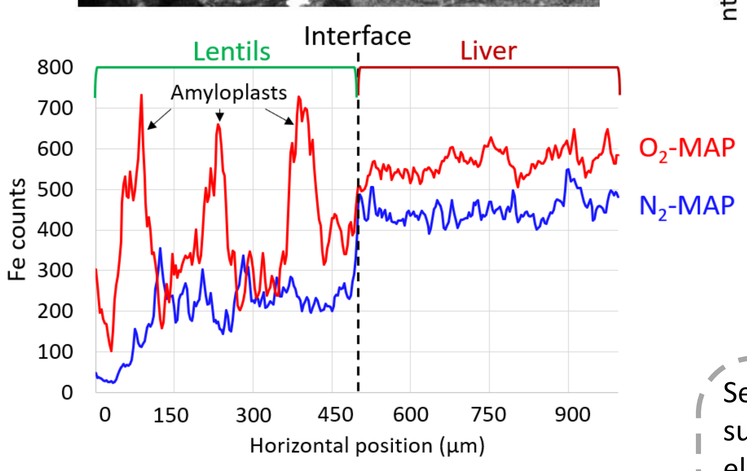


Chemical forms of iron varies depending on the **mixtures source** (specific spectral signature) and on the **storage time**

Prospects: Identification of iron oxidation states

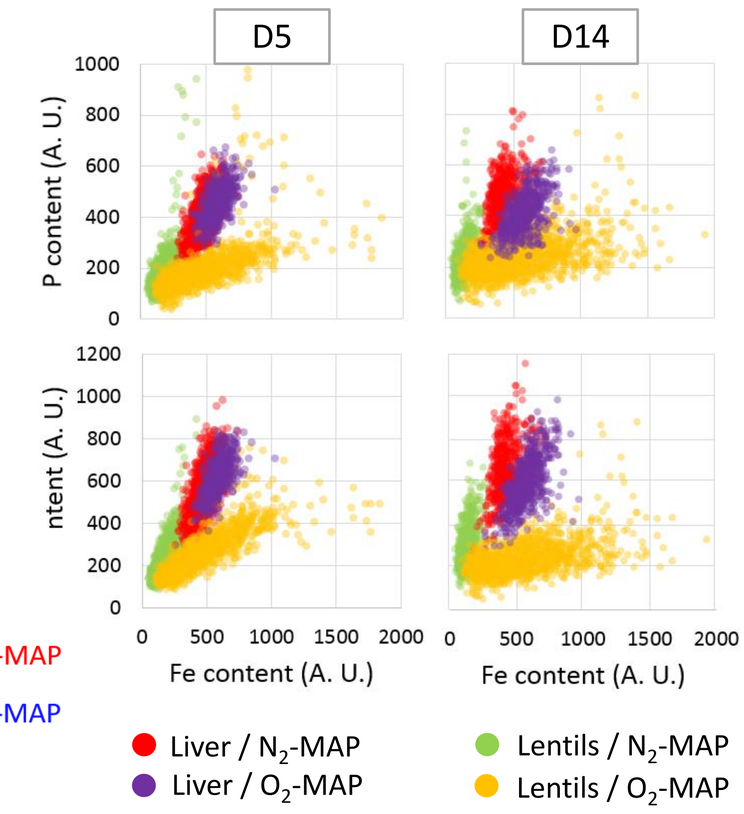
XRF maps and corresponding iron profiles





- Overall **higher concentration** of iron in the foods that were stored **under O_2-MAP**
- More heterogeneous distribution of iron in plant part which was mainly accumulated in the amyloplasts [4]

Plot correlation between iron and other elements obtained from XRF maps



Several Fe populations depending on the samples suggesting different bondings between iron and other elements:
- Binding of iron to sulfur proteins?
- Colocalization of iron and phosphate in ferritin core?

Changes in the **atomic environment** of iron depending on the storage conditions

CONCLUSIONS

This study highlighted the **effect of time in storage and MAP composition** on oxidation mechanisms in animal/plant hybrid food containing different iron forms.

Most of the changes were observed from **day 5 for foods stored under O_2-MAP**, which resulted in a **change in the distribution and forms of iron** in animal and plant parts as indicated by the **decrease in HI** and the modification of the **atomic environment** of iron.

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