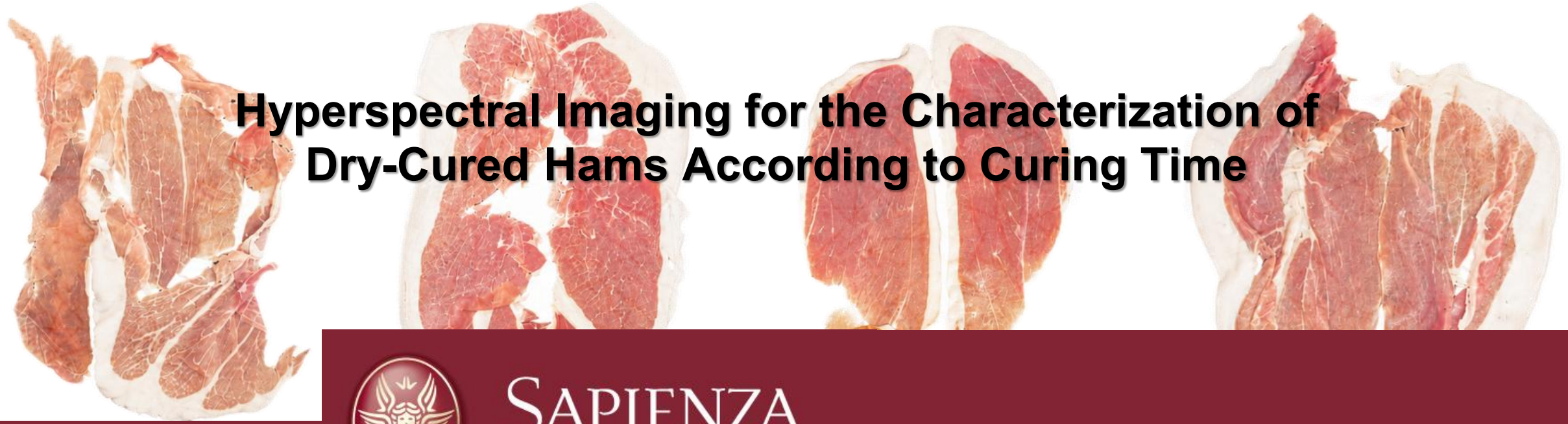


Hyperspectral Imaging for the Characterization of Dry-Cured Hams According to Curing Time

SAPIENZA
UNIVERSITÀ DI ROMA

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SIENA 2026

Background & Context

- **Economic & Quality Significance:** Dry-cured ham (e.g., Prosciutto di Parma) is a high-value protected product (PDO/PGI) requiring strict quality assurance.
- **Curing Time Impact:** Maturation period (12 vs. 24 months) profoundly influences flavor, texture, protein hydrolysis, and lipid oxidation.
- **Drawbacks of Traditional Testing:** Standard analytical tools (Kjeldahl, gravimetric drying, combustion) are destructive, costly, slow, and sample-limited.
- **Non-Destructive Solution:** Hyperspectral Imaging (HSI) provides spatial-spectral mapping for rapid, non-destructive quality evaluation.



HAMTRACE project

How do we prove authenticity in a global food system vulnerable to fraud?

HAMTRACE is a European project aiming to strengthen the authenticity, traceability and transparency of dry-cured ham supply chains by combining analytical chemistry, AI and digital technologies.

Advancing European Dry Cured Ham Value Chains with Data-Driven Authentication and Global Traceability Standards (HAMTRACE)

HAMTRACE | EU MSCA Project (2025–2029)
Smart traceability for fraud-free food

Aim of the study

Tissue Discrimination

Evaluate SWIR hyperspectral imaging (1000–2500 nm) to clearly separate **adipose** (*fat*) and **muscle** (*lean*) tissues across ham slices based on compositional contrast.

Curing Time Evaluation

Investigate **spectral evolution** in adipose and lean tissues individually when comparing 12-month and 24-month cured Prosciutto di Parma samples.

Chemometric Exploration

Apply Principal Component Analysis (PCA) with optimized preprocessing pipelines to reveal **key spectral bands** driving tissue and age differentiation.

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Materials

Parma ham - 12 months



Parma ham - 24 months



Ham Samples: Two independent Prosciutto di Parma hams representing 12-month and 24-month curing stages.

Experimental Setup

- **HSI Device:** Specim SisuCHEMA XL workstation equipped with an Imspector N25E spectrograph.
- **Spectral Range:** SWIR (1000–2500 nm), 256 contiguous spectral channels.
- **Data Dimensions:** 335×284×256 pixels (12 months) and 459×320×256 pixels (24 months).
- **Software:** Eigenvector PLS Toolbox 9.5 within MATLAB R2024b environment.



Optimized Preprocessing Workflows

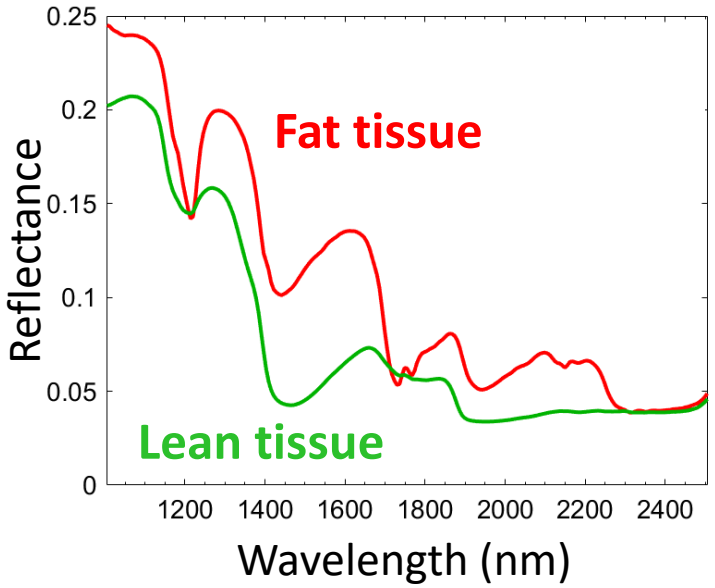
Target Analysis	Spectral Range	Applied Preprocessing Chain	Objective
Adipose vs. Lean	1000 – 2500 nm	SNV (scale offset = 1.0) + Detrend + 2nd Deriv (w=17pt) + Mean Center	Remove scatter/baseline shifts & highlight chemical contrast between fat and muscle
Adipose (12m vs 24m)	1000 – 1600 nm	Gap Segment 1st Derivative (gap=5, segment=5) + Mean Center	Focus on dominant lipid C–H overtones and minimize moisture variation noise
Lean (12m vs 24m)	1000 – 2500 nm	1st Derivative (order=2, window=15pt, weighted tails) + Mean Center	Capture subtle protein-water matrix changes and progressive dehydration signatures

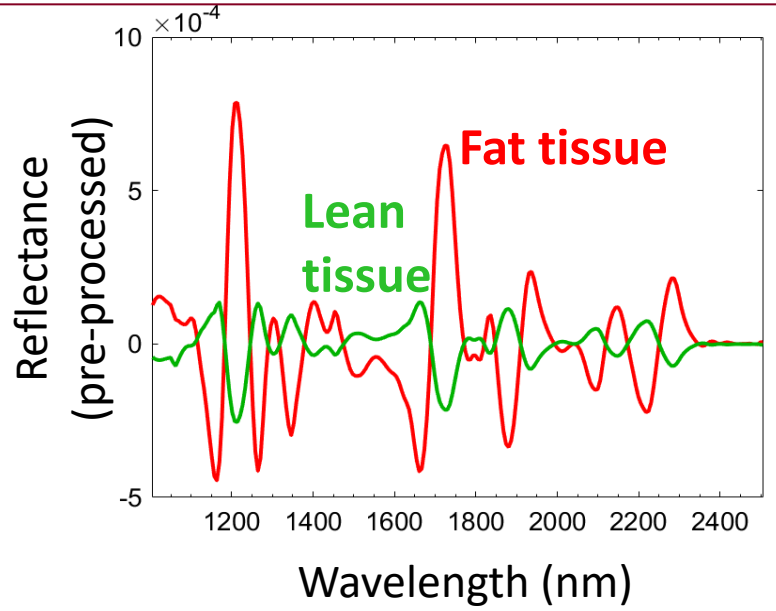
> *Tailoring specific derivative and normalization pipelines to each tissue component substantially reduced physical scattering artifacts caused by slice surface variations.*

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Key SWIR Spectral Fingerprints

Adipose vs. Lean





Adipose (Lipid) Signature

1200 nm: C–H 2nd overtone absorptions of fatty acid chains.

1700 – 1760 nm: C–H 1st overtone region associated with lipid structures.

2200 – 2350 nm: Combination bands of C–H stretching and deformation in triacylglycerols.

Lean (Protein-Water) Signature

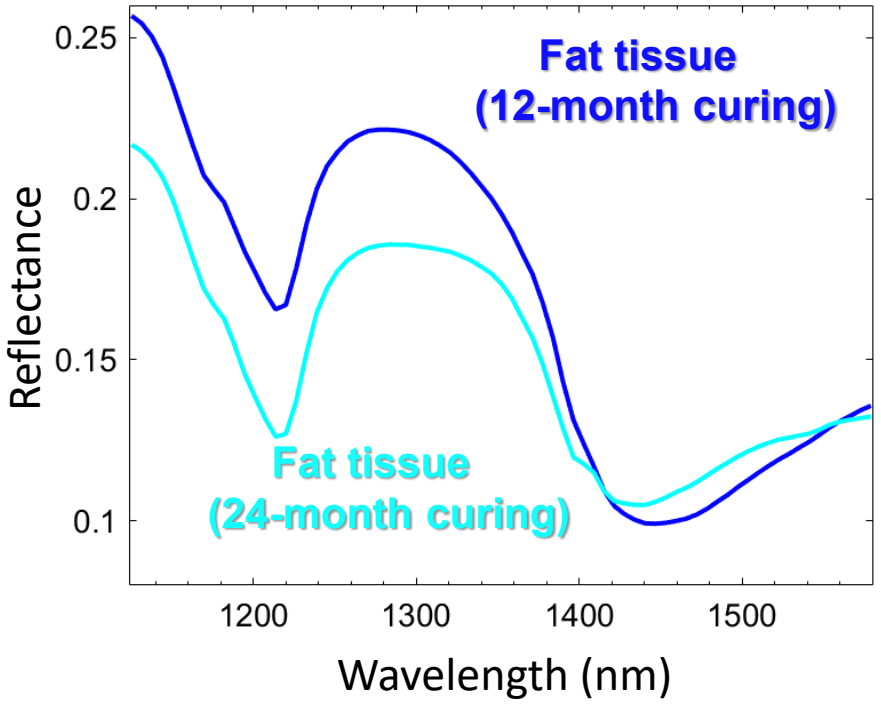
1450 nm & 1900–1950 nm: Strong O–H stretching overtones & water absorption bands.

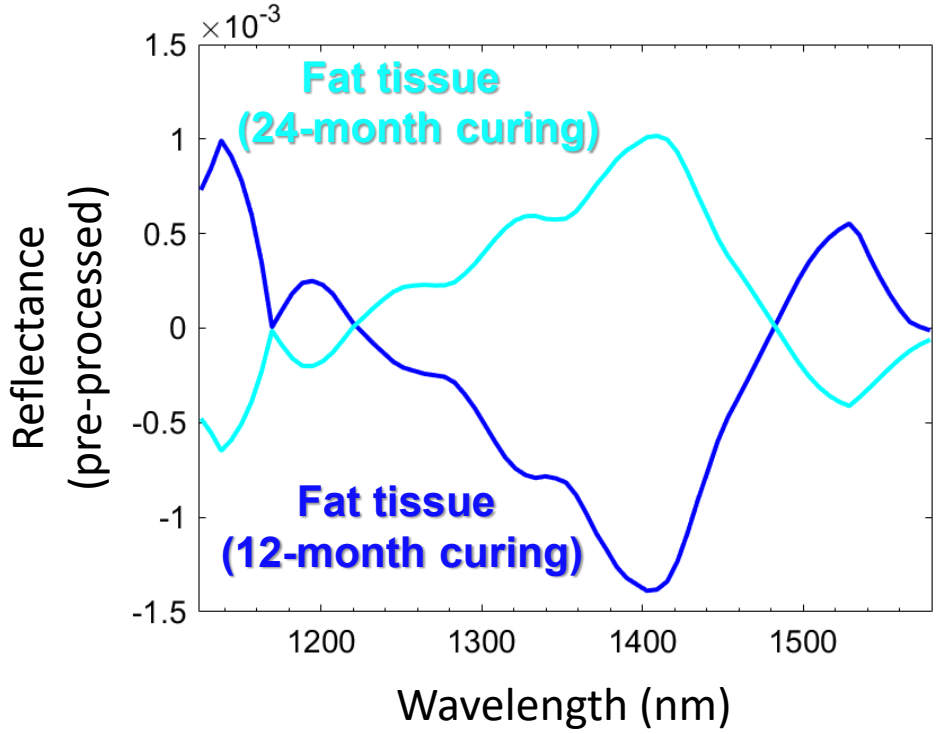
2000 – 2200 nm: N–H, C–H, and C=O combination bands from muscle proteins.

Curing Modifications: Dehydration shifts water peaks and exposes hydrolysed peptide bands.

Key SWIR Spectral Fingerprints

Adipose (12m vs 24m)





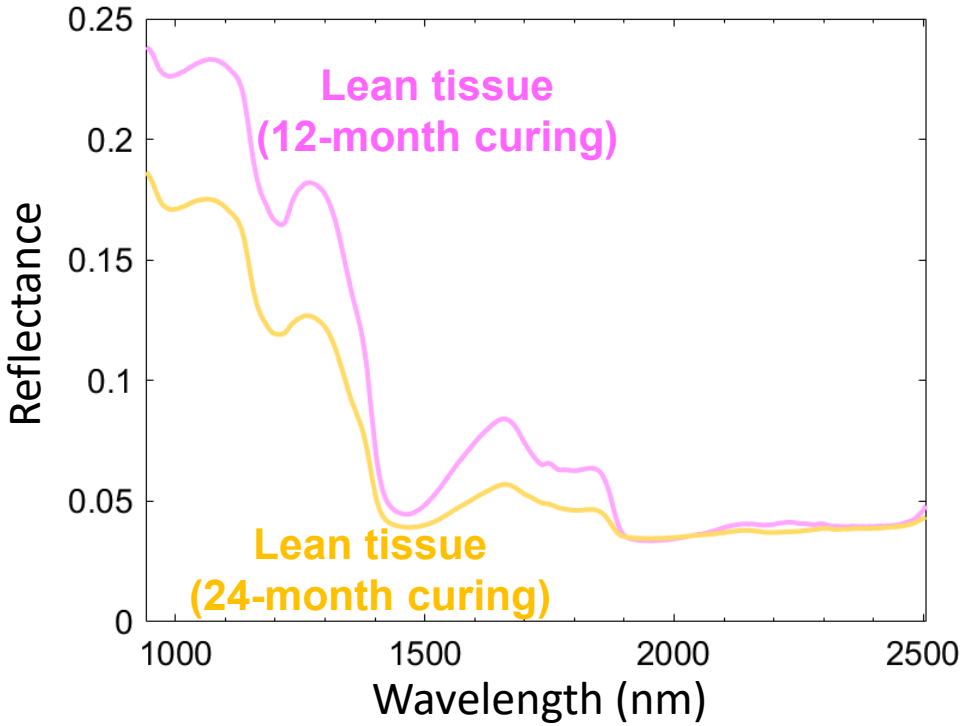
Focus on the 1000–1600 nm spectral range

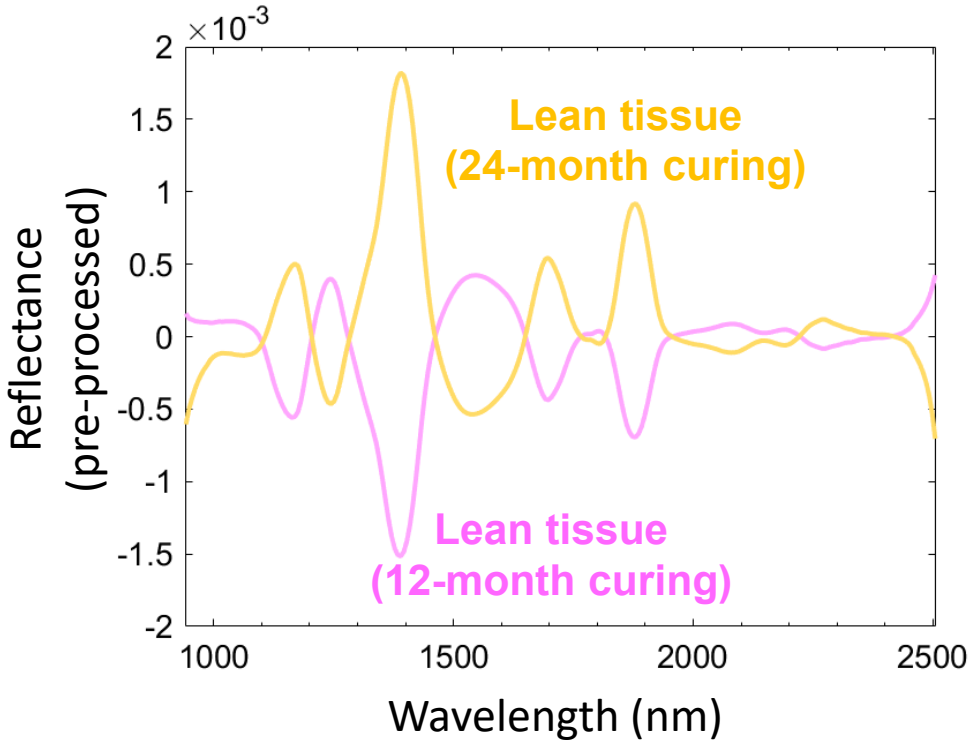
Spectral differences may reflect changes during the curing process

Chemical Drivers: Loadings show high contributions at 1150–1250 nm (C–H lipid overtones) and 1400–1500 nm (residual water & lipid structure)

Key SWIR Spectral Fingerprints

Lean (12m vs 24m)





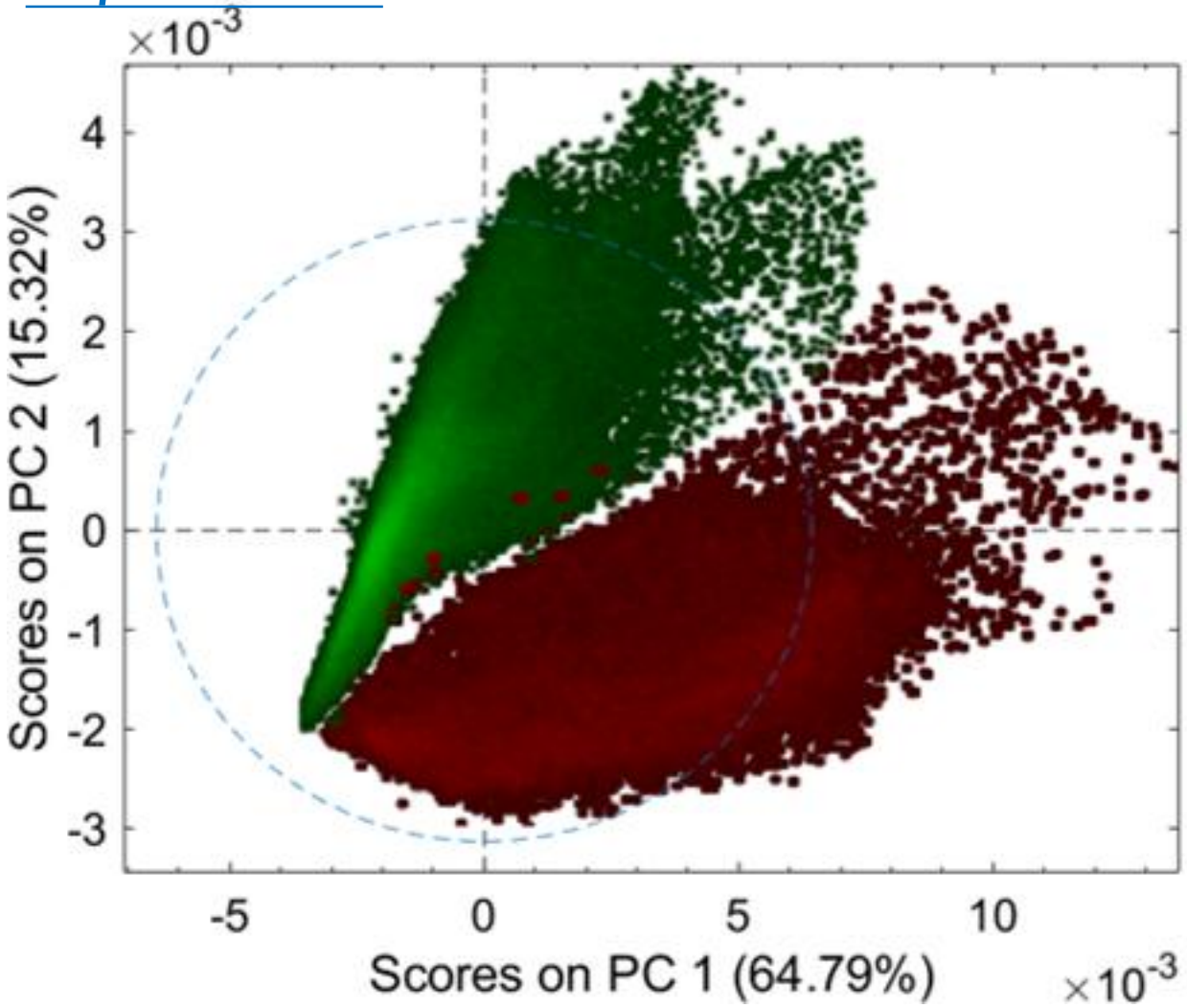
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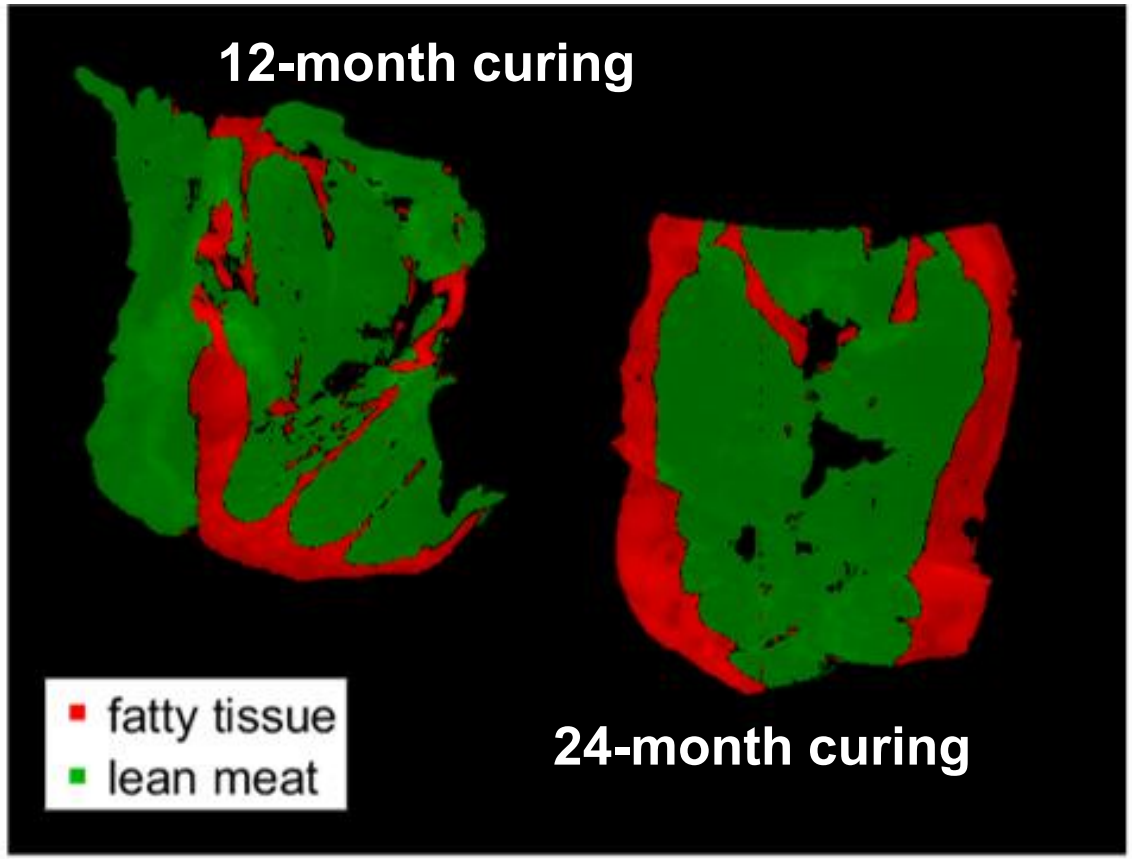
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Principal Component Analysis

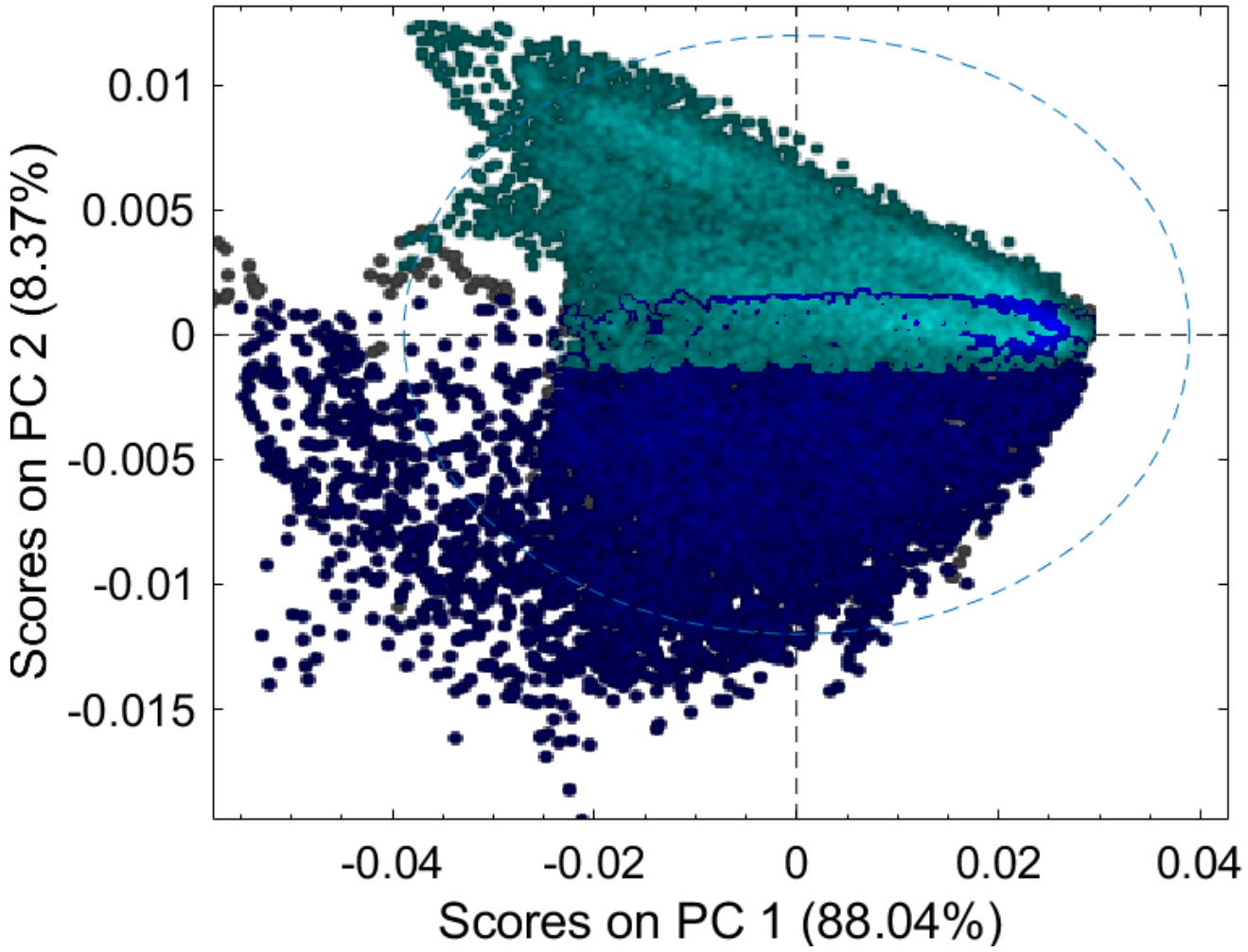
Adipose vs. Lean

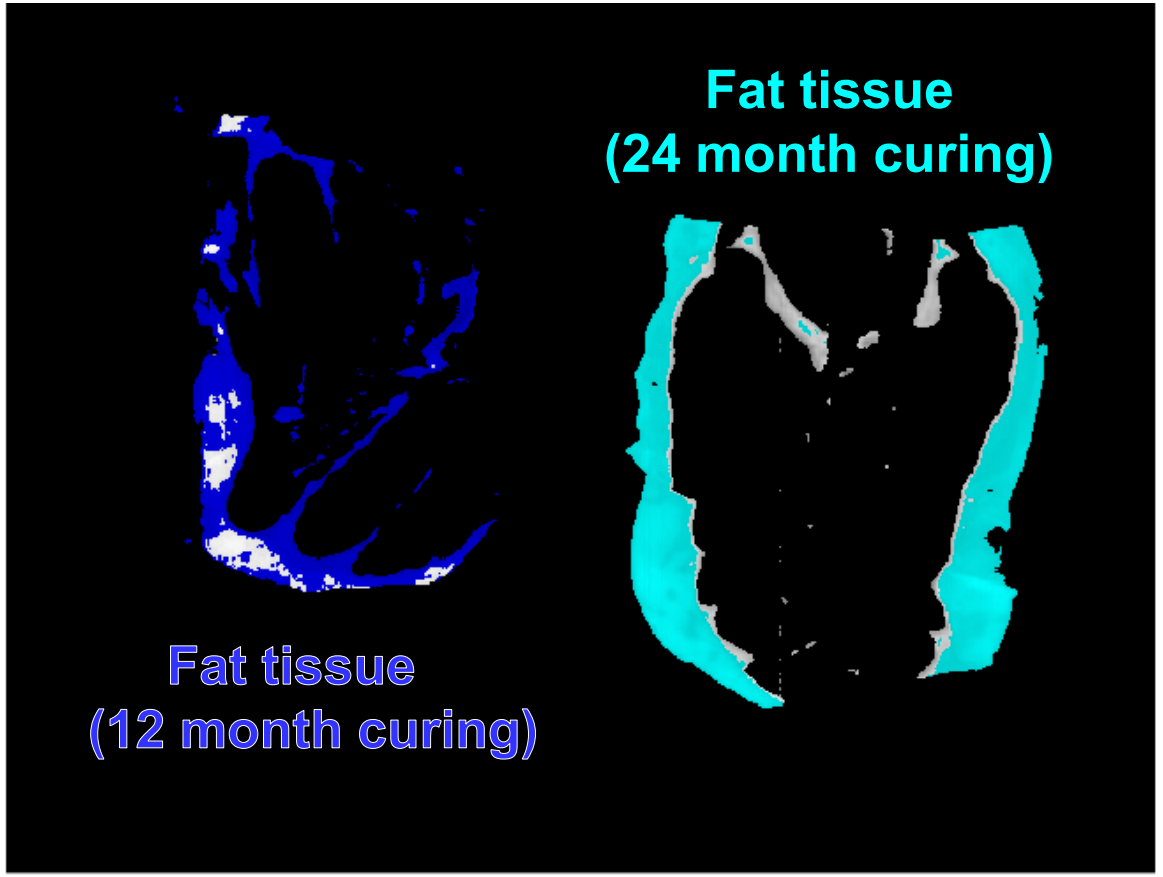




Principal Component Analysis

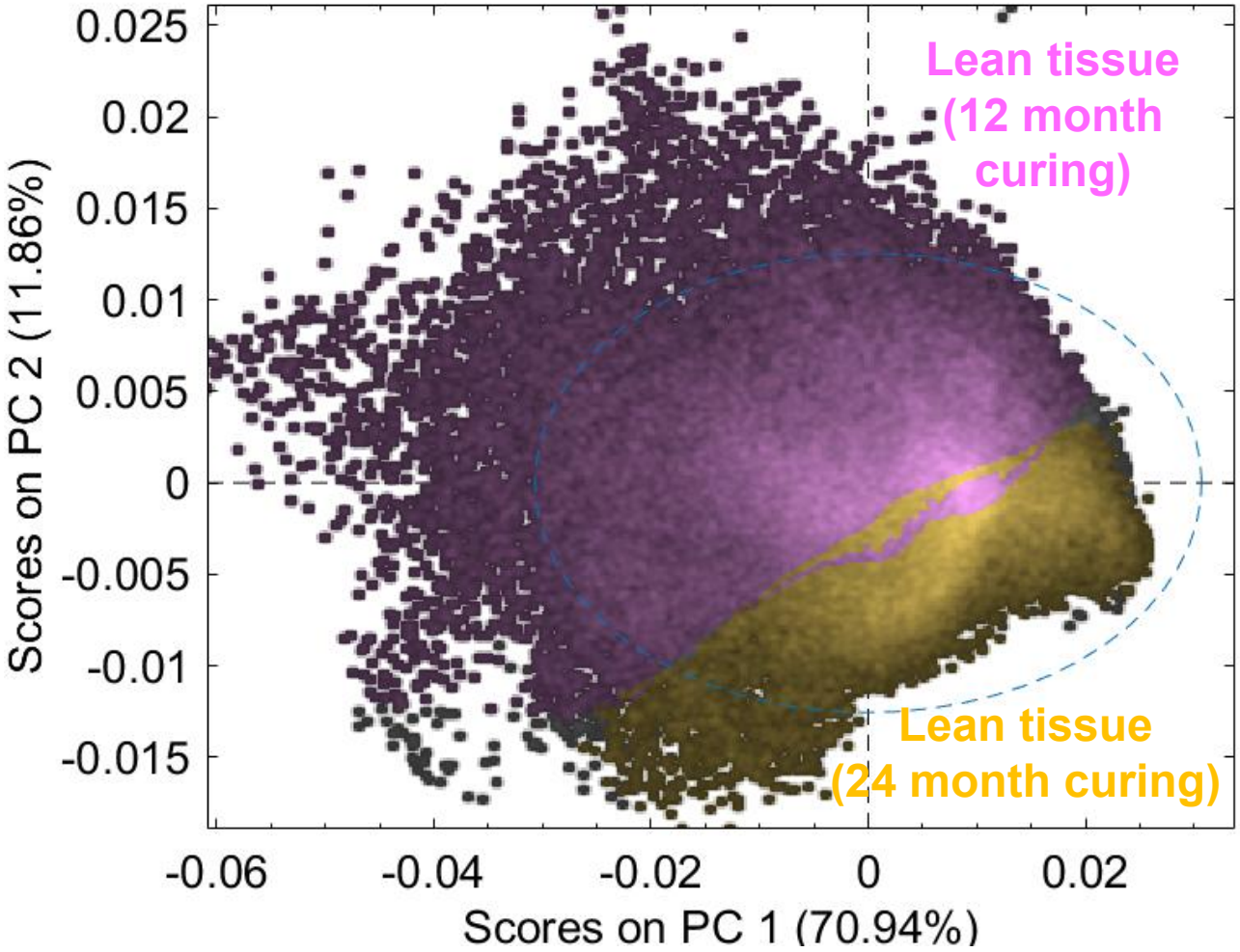
Adipose (12m vs 24m)

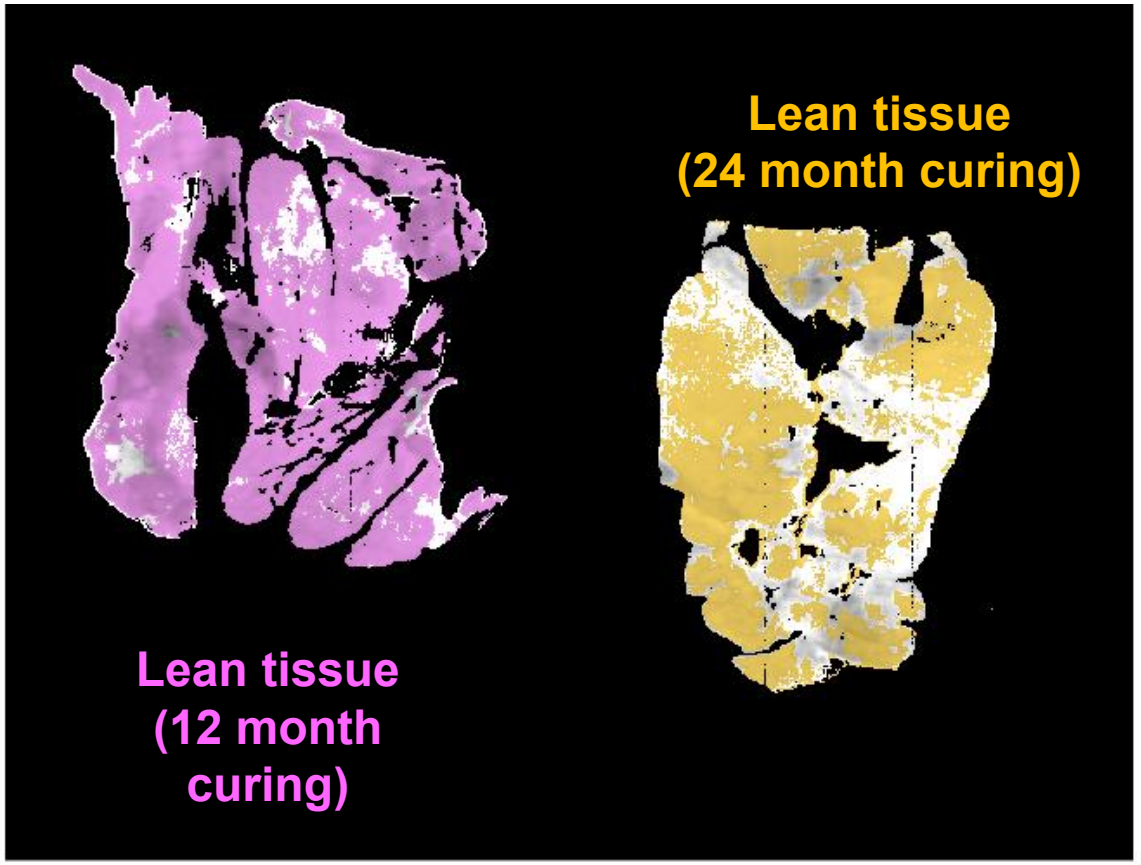




Principal Component Analysis

Lean (12m vs 24m)





Discussion: Physical & Matrix Effects

Slice Thickness & Surface

Variations in **manual slicing thickness** and **micro-roughness** alter light path lengths and induce scattering dispersion in score plots.

Muscle Fiber Orientation

Anisotropic orientation of muscle fibers affects local light penetration, reflection angles, and polarization phenomena.

Matrix Dishomogeneity

Local moisture gradients, intramuscular fat specks, and **salt diffusion** fronts create natural pixel-level variance.

Conclusions & Future Work

- **Proof of Concept:** SWIR HSI reliably discriminates adipose/lean tissues and shows clear spectral trends linked to 12 vs 24-month curing.
  - **Tissue discrimination:** PCA captured spectral differences between adipose and lean tissues.
  - **Curing effect:** Spectral differences between 12- and 24-month samples suggested changes in the physicochemical characteristics of both tissues.
  - **Preliminary results:** Trends were observed, but the limited dataset does not allow definitive classification.



- **Dataset Expansion:** Future research will analyze larger sample sizes across diverse origin protocols (e.g., Italian vs. Spanish hams).
- **Supervised Models:** Development of PLS-DA and machine learning classifiers for automated authenticity and age verification.

Thank you for your attention!



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Food Hub

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