Truth in the Code : DNA Intelligence for Food Authenticity

Combating Fraud and Ensuring Origin

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THEROS

The Invisible Threat: Food Fraud

A Global Challenge

- **Economic Impact**: food fraud affects 1% of the global food industry at a cost of about $10-$15 billion a year (recent expert estimates put the cost as high as $40 billion annually.
- **Health Risks**: Undeclared allergens, harmful contaminants, and species substitution.
- **Trust Deficit**: Consumers increasingly demand transparency; one scandal can destroy brand reputation.

"Traditional paper trails are no longer enough to guarantee authenticity."

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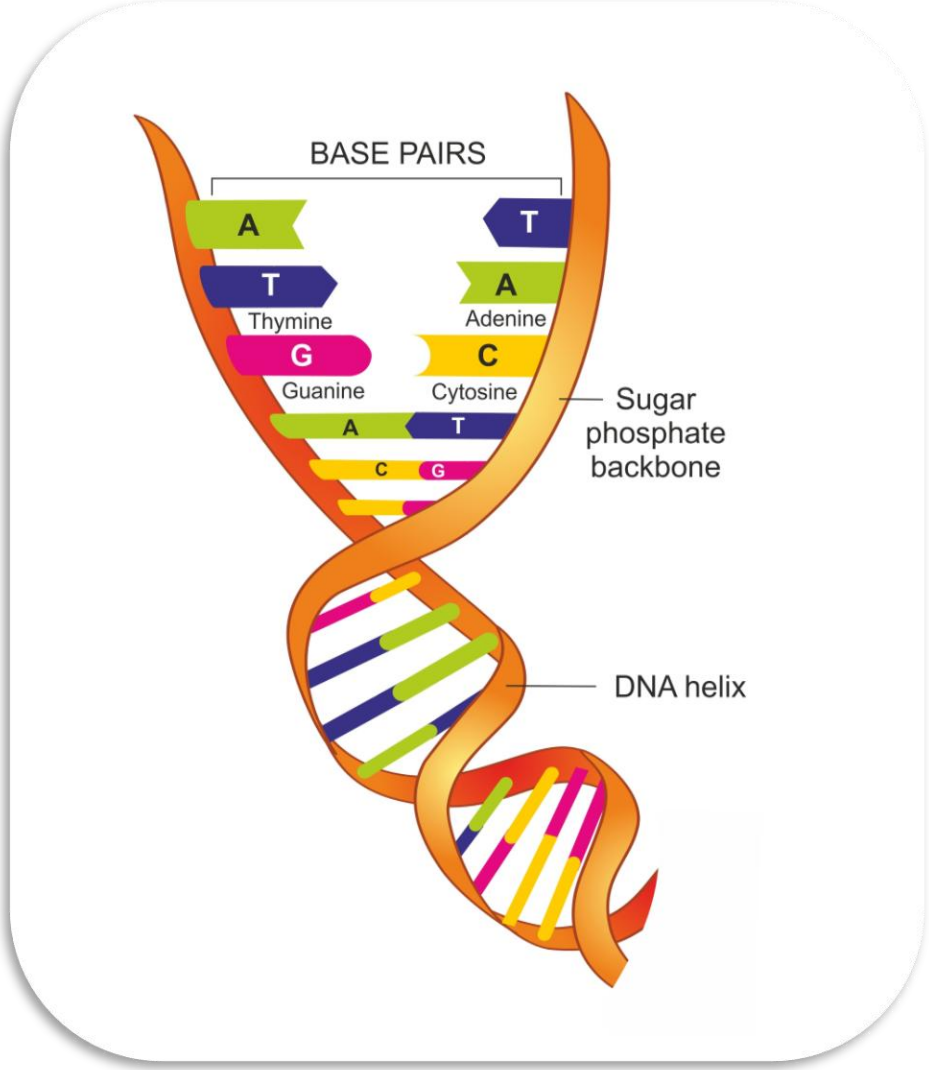
What is DNA Intelligence?

Nature's Code

Every biological organism carries a **unique genetic signature**. DNA Intelligence leverages this code to verify it's identity with absolute certainty.

Unlike packaging or labels, which can be faked, DNA is intrinsic to the product itself. **It provides a forensic-level "truth" that connects the physical product directly to its biological origin.**



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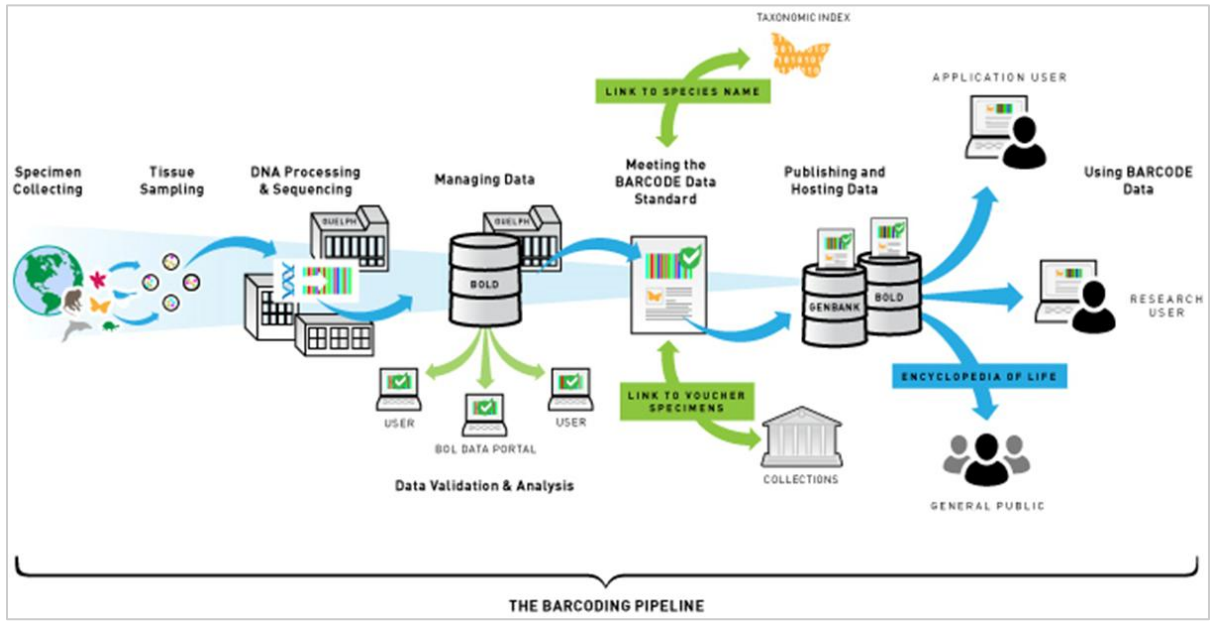
Technology: DNA Barcoding



The Genetic Fingerprint

Just as a retail barcode identifies a product, a "DNA Barcode" identifies a species using a short, standardized gene region.

- **Animals (*COI* Gene):** Used to identify meat and fish species (e.g., distinguishing Cod from Haddock).
- **Plants (*rbcL/matK*):** Used for herbs, spices, and grains.
- **Fungi (*ITS*):** Critical for identifying mushrooms and yeasts.

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THEROS Case Study: Galician Mussels

The Challenge

A significant form of commercial adulteration is the fraudulent labeling of non-Galician mussels as originating from the region, which often have a higher market value due to their **Protected Designation of Origin (PDO)**

Geographical Origin Substitution: Mussels cultivated elsewhere (even within the EU) might be mislabeled as originating from the Galician rías to fetch a premium price associated with the PDO status.

Species Mislabeling: The Mytilus complex includes several species (*M. galloprovincialis*, *M. edulis*, *M. trossulus*) that can hybridize and are morphologically similar. Lower quality or non-native species may be substituted.

Processing Challenges: Once the mussels are processed (e.g., canned, marinated, or de-shelled), morphological identification becomes impossible, facilitating mislabeling further down the supply chain.

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THEROS Case Study: Galician Mussels

The DNA Solution

DNA analysis offers a robust solution because genetic material can be used to determine both the species and, in some cases, the geographical origin of the mussel.

Key DNA-based approaches

DNA Barcoding: This method uses a specific, standardized gene region to identify the species in fresh and canned products.

Bacterial Metagenome Analysis: This method identifies the bacterial composition of the mussels, influenced by its specific environment, that can act as a natural biomarker for its geographical origin and serve as a tool for traceability.

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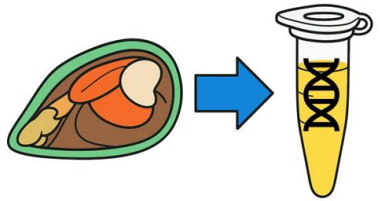
From Sample to Truth:
The DNA based authenticity kit Workflow



1. Sampling

Collection from Port, Purification & Canning facilities.

2. Extraction

Isolating DNA using Lab (CTAB) or Field (DirectLyse) protocols.

3. Amplification

PCR targeting COI, 16S, or PAPM genes.

4. Analysis

HRM, Sequencing & Metagenomics for identification.

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DNA Extraction Protocols

Protocol Comparison

Two extraction options were rigorously tested to ensure versatility in both lab and field conditions.

- **CTAB Protocol:**
  - Optimized for: Fresh, frozen, and canned mussels.
  - Condition: Standard Laboratory settings.
- **NucleoType DirectLyse Reagent:**
  - Optimized for: Fresh and frozen mussels.
  - Condition: **On-site extraction** (Quick & Easy).

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Target Gene Selection

Three gene regions selected based on research for robust species identification.

COI Gene

Cytochrome Oxidase Subunit I

Mitochondrial DNA (~650bp). The standard "barcode" for unique species identification across animals.

16S Gene

Mitochondrial 16S rRNA

Encodes ribosomal RNA. Used alongside COI for confirming phylogenetic relationships.

PAPM Gene

Polyphenolic Adhesive Protein

Nuclear gene with non-repetitive regions. Excellent for **HRM analysis** to distinguish hybrids.

Portability & Speed

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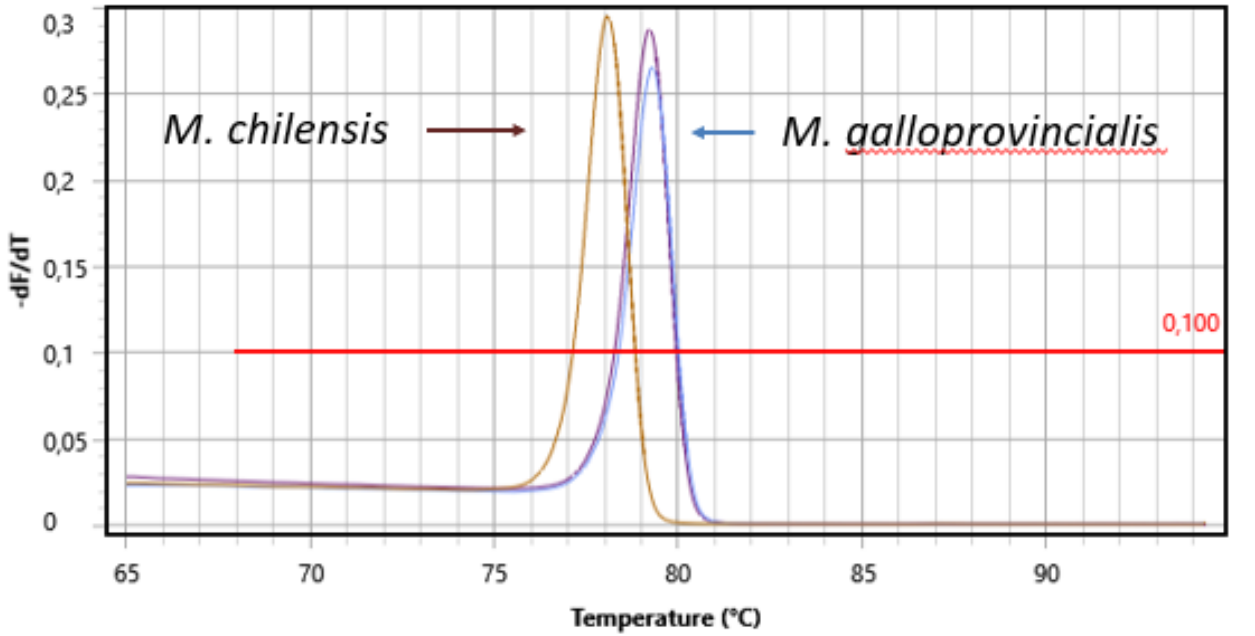
Results: COI, 16S & PAPM

Species Differentiation

Successful distinction between *M. galloprovincialis* and *M. chilensis*.

- **COI & 16S Gene:** Differentiation based primarily on sequence analysis (Sequencing).
- **PAPM Gene:** Distinguishes species via a SNP (G/T) resulting in different melting peaks (~100bp product).
- **Limitation:** These biomarkers cannot distinguish *M. galloprovincialis* from different geographic regions (e.g., Spain vs Greece).



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The Geographic Challenge

Same Species, Different Origin

Genetically, a mussel (*M. galloprovincialis*) from Spain is nearly identical to one from Greece.

The Problem: Fraudsters can mislabel cheaper mussels as premium Galician (PDO) mussels.

The Solution: ML approach & Analysis of the microbiome (bacteria) living inside the mussel, which varies by location.

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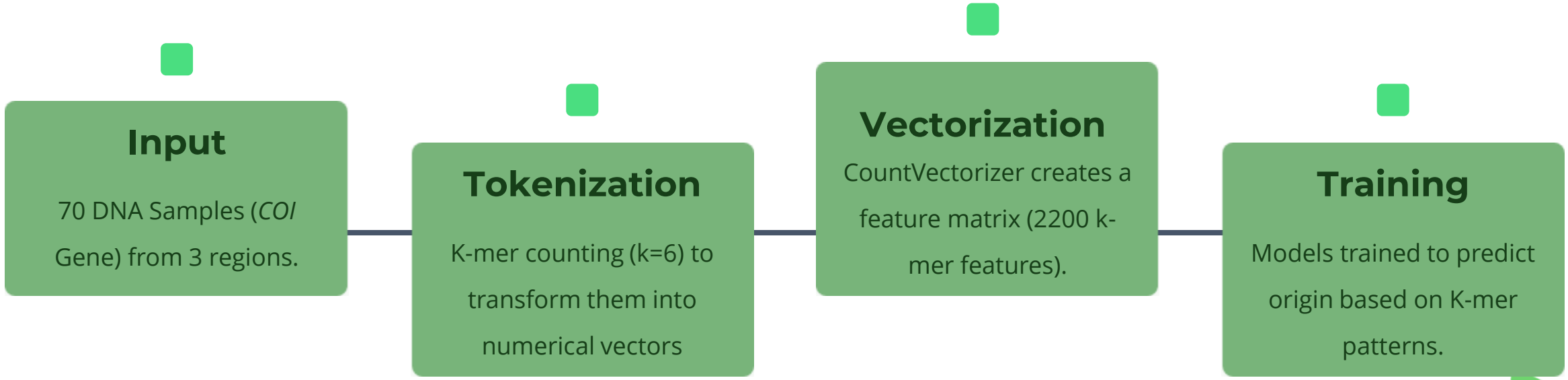
ML Pipeline: DNA Classification

Transforming Biology into Data

We processed DNA sequences using machine learning algorithms for the automated transformation and classification of DNA profiles.



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Results: DNA Classification Models

Multinomial Naive Bayes (MNB)

94.4%

ACCURACY

Robust performance on probabilistic features.

Multiclass Logistic Regression

100%

ACCURACY

Perfect separation on the test dataset.

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Results: Decision Making Models

Predicting Region based on Product Type + Melting Temperature (*COI*).

DECISION TREE CLASSIFIER ACC.

99%

ARTIFICIAL NEURAL NETWORK (ANN) ACC.

99%

Conclusion: Simple physical parameters combined with melt curves are highly predictive of origin.

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Metagenomics Strategy

Microbiome Fingerprinting

We performed deep sequencing on pooled samples from three key regions to identify unique bacterial signatures.

Spain (Galicia)

Target for PDO verification.

Greece

Possible origin for substitution.

Chile

Different species (*M. chilensis*) and common origin of substitution.

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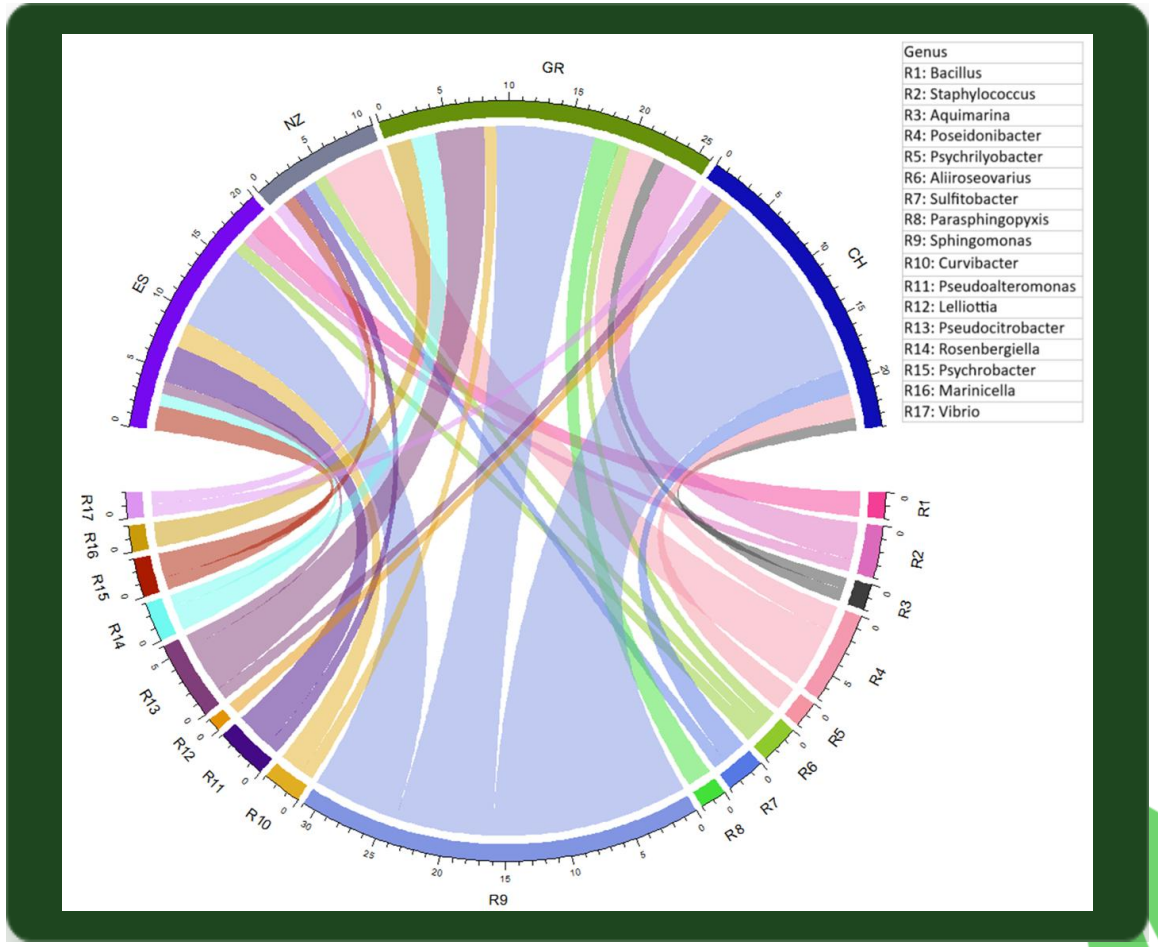
Microbiome Diversity Results

Species Identification Count

Number of unique bacterial species identified per region:

GREECE	**193 Species**
SPAIN	**58 Species**
CHILE	**47 Species**



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Primary Biomarker: Pseudoalteromonas

The "Spanish Signature"

We identified one bacterial species as a key candidate.

Pseudoalteromonas

- **Spain:** Detected at Ct 20-25 (High Abundance).
- **Greece/Chile:** Detected at Ct >30 (Trace/Absent).

- Associated with marine eukaryotes. Demonstrates clear differential abundance, robust candidate marker.

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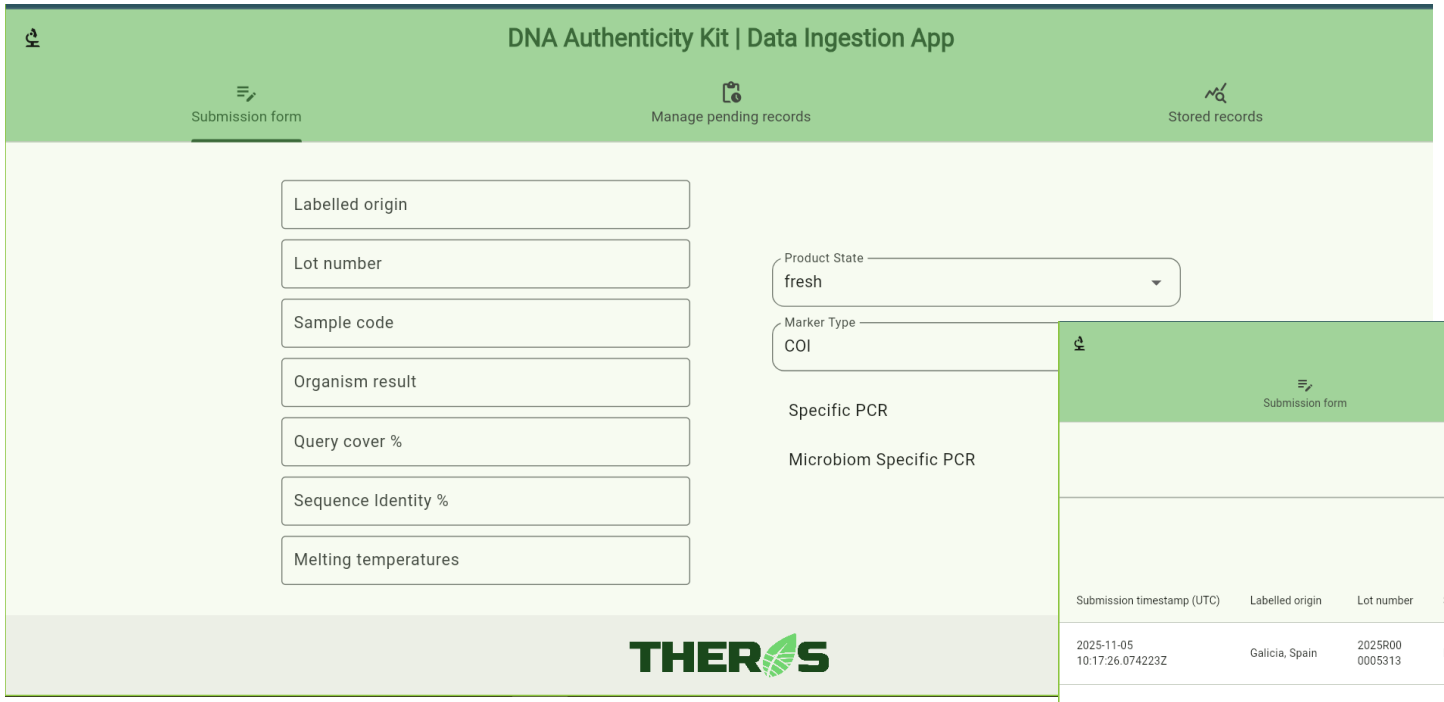
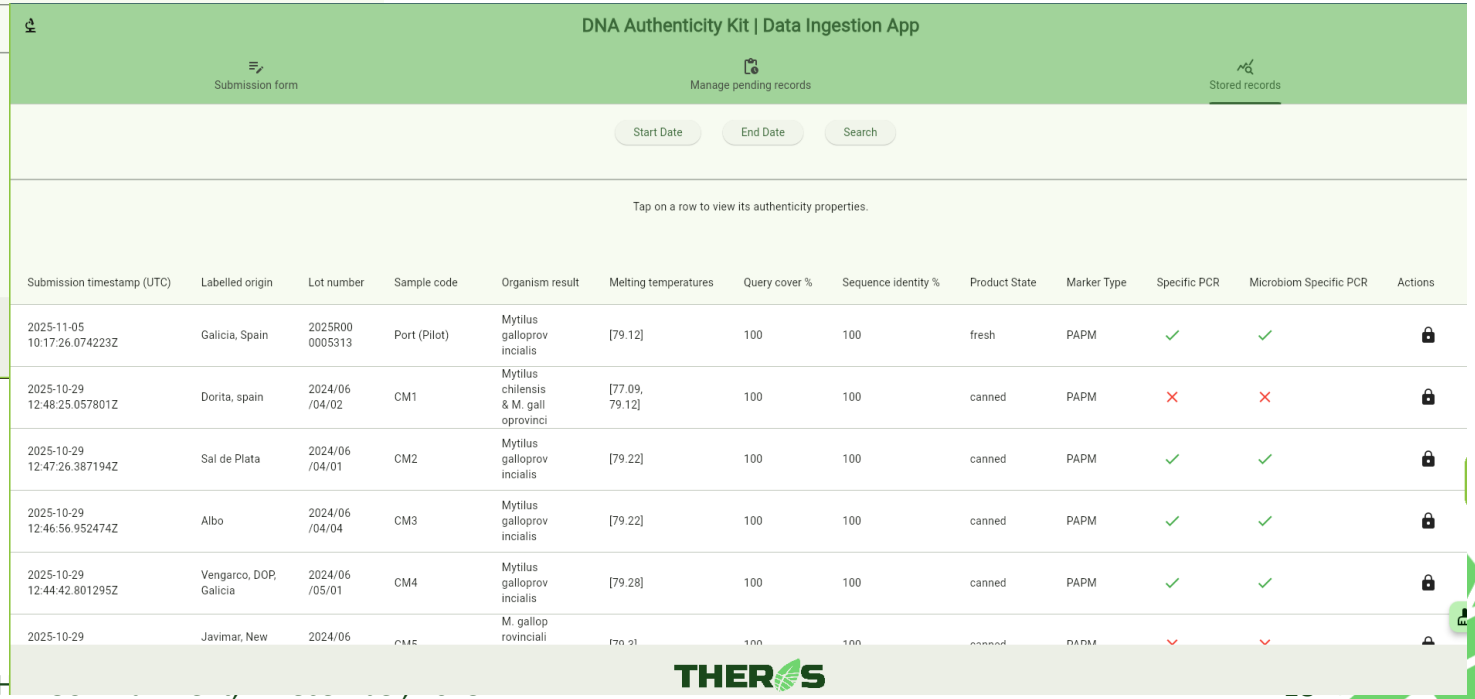
DNA authenticity kit | Data Ingestion App

All results/data are inserted and stored





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Spanish Pilot Deployment

Port

Sample Point 1

Raw material intake.

Purification

Sample Point 2

Processing facility.

Canning

Sample Point 3

Final product verification.

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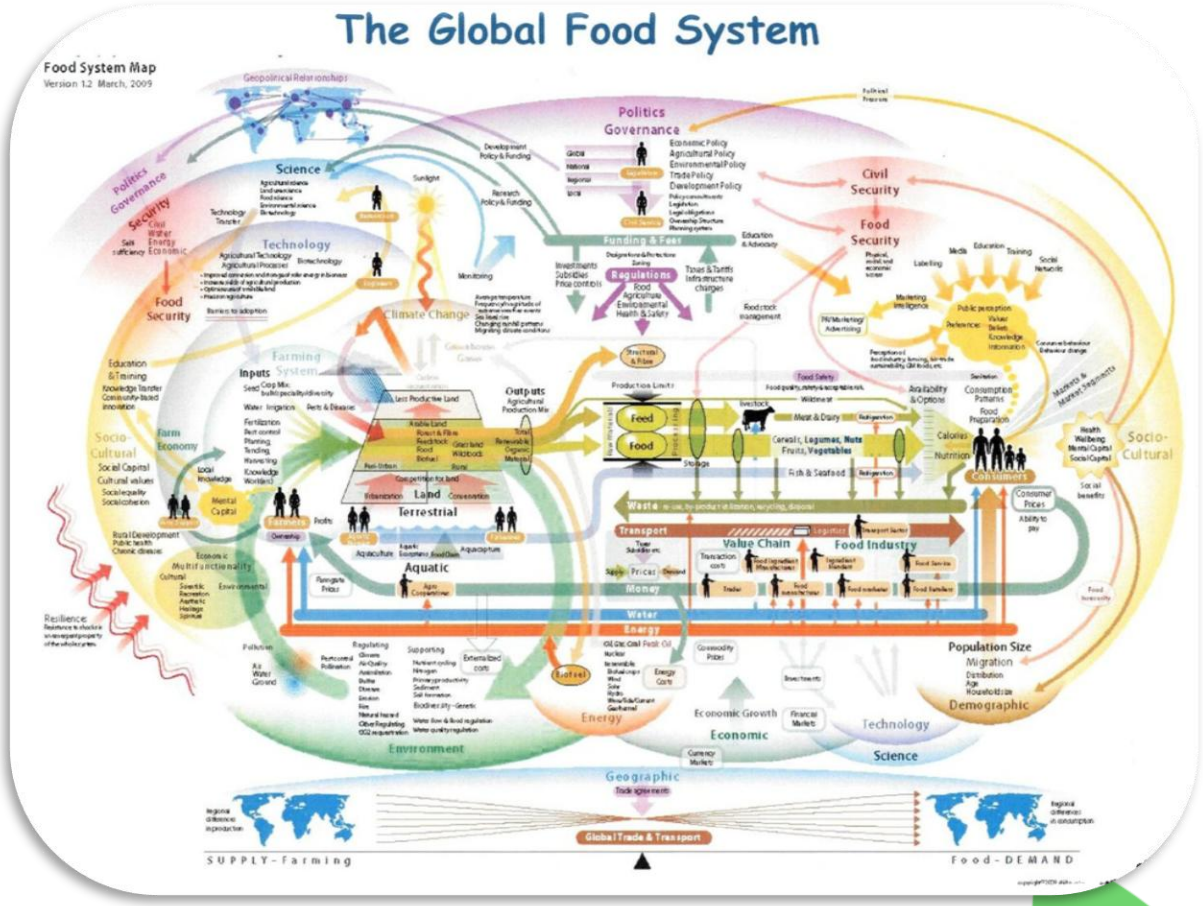
Spanish Pilot Deployment

Impact: Traceability & Transparency

Empowering the Chain

DNA tools move us from "claims" to "proof". This transparency builds a resilient supply chain.

- **For Regulators:** Scientific evidence for enforcement and compliance checks.
- **For Industry:** Protection from supplier fraud and "fair competition" for honest producers.
- **For Consumers:** Confidence that "Local", "Organic", or "Premium" labels are authentic.



EU Green Deal Alignment

Farm to Fork Strategy

The EU's ambitious plan aims for a fair, healthy, and environmentally-friendly food system.

- **Traceability:** Mandatory verification for high-risk products (Honey, Seafood, Olive Oil).
- **Sustainability:** Verifying "Organic" claims and preventing biodiversity loss.
- **Safety:** Rapid detection of pathogens aligns with public health mandates.

DNA Intelligence is a key enabler of these goals

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Key Takeaways

- The challenge of food fraud is too big and too costly to ignore.
- **DNA Intelligence** offers science-based proof of a product's true species and its origin.
- Our work demonstrates that advanced techniques like **DNA Barcoding**, **Metagenomics**, and **Machine Learning** can be combined into practical solutions to protect products like the premium Galician Mussels.
- Technologies are becoming **faster**, **portable**, and more **accessible**.

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Thank you for your attention!

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