Exploring Non-Invasive Instruments to Assess the Microbiological Quality and Authenticity of Meat and Meat Products

Organized by: Microbial Modelling and Risk Analysis PDG

Moderator: Panagiotis Skandamis, Researcher, Agricultural University of Athens, Greece

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Webinar Housekeeping

• It is important to note that all opinions and statements are those of the individual making the presentation and not necessarily the opinion or view of IAFP.

• All attendees are muted. Questions should be submitted to the presenters during the presentation via the Questions section at the right of the screen. Questions will be answered at the end of the presentations.

• This webinar is being recorded and will be available for access by IAFP members at www.foodprotection.org within one week.
Dr. Panagiotis N. Skandamis is Professor of Food Microbiology and Food Quality Control and Food Hygiene in the Agricultural University of Athens and member of the BIOHAZ panel of European Food Safety Authority (EFSA). He has worked as a post-doctoral fellow in the Department of Animal Science of Colorado State University in USA. In 2004, he joined the Department of Food Science & Technology of AUA. Dr. Skandamis has (co-) authored 187 original research papers in journals of SCI, 30 book chapters, another two, currently under preparation, edited 1 book and has a total number of 7042 citations (h-index 37).

His research is funded by 5th-7th EU Framework Programs, HORIZON 2020, competitive Grants from Greek Research and Technology Funding Agency, as well as direct contracts with the Greek Food Industry in the following areas: (i) active antimicrobial and intelligent packaging of foods; (ii) food spoilage and safety; (iii) biofilm formation and removal by chemical and natural disinfectants, (iv) predictive microbiology of foods and quantitative microbial risk assessment, (v) application of antimicrobial interventions; (vi) detection, isolation and subtyping of foodborne pathogens from foods and food processing environments.

He has been Associate Editor in Food Research International (2012-2017). Currently he is serving as scientific co-editor in Journal of Food Protection and member of the Editorial Board in Applied and Environmental Microbiology, International Journal of Food Microbiology and Frontiers in Microbiology.

Dr. Skandamis is member of the scientific committee of International Conference in Predictive Microbiology in Foods (ICPMF) since 2008, member of the organizing committee of European symposium of International Association of Food Protection (IAFP) since 2015, and current co-President of the FoodMicro 2020. He is also Chair of the Professional Development Group of “Microbial Modelling and Risk Assessment” of IAFP.

Predictive Modeling software development: Dr. Skandamis is the developer of GroPIN (www.aua.gr/psomas), a Predictive Modelling Software tool, which constitutes a database of >400 kinetic and probabilistic models for pathogens and spoilage organisms in response to a variety of intrinsic and extrinsic foods parameters (e.g., T, pH, aw, preservatives, atmosphere, etc.).
George Nychas is Professor in Food Microbiology in the Dept of Food Science & Human Nutrition of Agricultural University of Athens (Greece). The last 25 years coordinated 6 European Projects and participated in more than 35 EU projects (budget >15 M €).

Through these projects, the team of Prof. G-J., Nychas has acquired extensive experience on; (a) on modelling the behaviour of microbial populations throughout the food chain to assist reliable estimation of microbial food safety risk (b) Implementation of Process analytical technology (PAT) in Food Industry introducing sensors (non destructive non- invasive) (c) the assessment of food safety and spoilage through microbiological analysis in tandem with metabolomics and data mining.

So far he has published 284 papers (Scopus) with ca. 14700 citations and h=71 and he is (i) Chairman of food safety group of European Technological platform food for life (ii) member of the pool of scientific advisors on risk assessment for DG SANCO, while he served as co-chair (2008-2010) in the Professional Development Group of “Microbial Modeling and Risk Analysis” of International Association for Food Protection, member of the Biohazard panel and the Advisory Forum of EFSA, external expertise to the European Parliament, President of the Greek Food Authority.

Recently (Nov 2018) he was listed among the top 1% of highly cited researchers in the field of Agriculture Science (Web of Knowledge – Clarivate)
Exploring Non-Invasive Instruments to Assess the Microbiological Quality, Fraud and Authenticity of Meat and Meat Products

George-John NYCHAS
Laboratory of Microbiology and Biotelogy of Foods, Department of Food Science and Human Nutrition
Agricultural University of Athens, Athens, Greece
WEBINAR’s STRUCTURE

- **Definitions;** Quality vs Safety vs Fraud vs Food Crime
- **Current approaches;** Assessing Meat Quality, Safety & Adulteration
- **Future approaches;** Assessing Meat Quality, Safety & Adulteration
- **Tools;** (a) Non-destructive methods for assessing meat quality, safety and Fraud (b) Implementation of ML in meat quality safety, authenticity (c) IoT serving meat sector
- **Use Cases;** Meat microbiological quality, beef vs horsemeat, beef vs pork & poultry vs pork
WEBINAR’s STRUCTURE

▪ **Definitions:** Quality vs Safety vs Fraud vs Food Crime
  - Current approaches: Assessing Meat Quality, Safety & Adulteration
  - Future approaches: Assessing Meat Quality, Safety & Adulteration

▪ **Tools:**
  - (a) Non-destructive methods for assessing meat quality, safety and Fraud
  - (b) Implementation of ML in meat quality safety, authenticity
  - (c) IoT serving meat sector

▪ **Use Cases:**
QUALITY vs SAFETY

Food safety is dealing with all those hazards, whether chronic or acute, that may make food injurious to the health of consumers, and is not negotiable.

Quality includes all other attributes that influence a product's value e.g. spoilage, flavour, texture, contamination and adulteration.
[QUALITY vs SAFETY] vs FRAUD

Fraud in the context of food, means that the description of the origin of food, its composition and how it has been obtained and/or prepared, shall be truthful, i.e.

(i) nothing of lesser economic value must be added, or

(ii) removed if it is of higher economic value.

(iii) the information about origin, composition, etc

Meat fraud:
Examples;
Pork does not belong in a kebab (beef or lamb) or a beef sausage.
Food crime can be defined as “serious fraud and related criminality within food supply chains that impacts the safety or the authenticity of food, drink or animal feed. It can be seriously harmful to consumers, food businesses and the wider food industry.”

Examples of food crime include the use of stolen food in the supply chain, unlawful slaughter, diversion of unsafe food, adulteration, substitution or misrepresentation of food, and document fraud.
WEBINAR’s STRUCTURE

- Definitions; Quality vs Safety vs Fraud vs Food Crime
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- Use Cases;
Current Food Safety Management System

The (whole) production process is based on the analysis of THE END / FINISHED product.

Nychas et al., 2016, Curr. Opin. Food Sci. 12: 13–20
Current Tools

- **Sensory analysis** *(expensive, time-consuming)*

- **Conventional microbiology** *(Results in 2-3 DAYS)*

- **Molecular tools** *(results in 18-30 HOURS)*

- **Single (bio-chemical metabolite) compound** *[not feasible]*

- **Modelling (Predictive)**; Few public free and private software are available [Initial population should be known (measurements take 18 to 72 h)]

Food Industry, Food Authorities and consumers need results in minutes, if not in seconds!!!
WEBINAR’s STRUCTURE

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Future Approaches....

![Diagram of Process Analytical Technologies](image-url)

(What is) Process Analytical Technology (PAT)

Basis for the concept of “Quality by Design”: holistic systematic approach in which predefined specifications, processes and critical parameters are taken into account in quality control.
Future Tools

Process Analytical Technologies (PAT)  
[Implementation of QbD]

- Sensors; In – On – At line analytical instruments to measure parameters (including Next Generation Sequencing)

- Data Science; Data Analytics, Data mining, Machine Learning

- Information Communication Technology
**PAT’s Tools; (a) Sensors**

*In – On – At line non-invasive analytical technologies (desktop, handheld, miniaturized) based on spectroscopy and/or image analysis to measure quality & safety parameters*
**PAT’s Tools; (a) Sensors**

In – On – At line non-invasive analytical technologies (desktop, handheld, miniaturized) based on spectroscopy and/or image analysis to measure quality & safety parameters.
List of representative rapid methods e.g. Imaging and Spectroscopy applied in meat which their measurement can be ‘translated’ into quality parameters

<table>
<thead>
<tr>
<th>Type of Sensor</th>
<th>Food Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imaging</td>
<td>Beef fillets, Meat, Pork, beef, Chicken fillets, Packaged beef, Beef and horsemeat (minced)</td>
<td>Spoilage, adulteration (horse), meat colour, pseudomonads, microbial counts</td>
</tr>
<tr>
<td>Spectroscopy</td>
<td>Animal origin foods: beef, pork, lamb, pork, poultry</td>
<td>Spoilage Detection of adulteration, Quality control analysis, Assessment of microbial contamination</td>
</tr>
</tbody>
</table>

Ropodi et al. Trends in Food Sci. & Techn. 50,11-25
**PAT’s Tools; (b) Data Science ...concluded**

Data Science; Data mining, Data analysis, Machine Learning

A massive amount of data is generated by various analytical instruments and this is a challenging issue for food safety.

<table>
<thead>
<tr>
<th>products</th>
<th>purpose</th>
<th>data analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef fillets, Meat, Pork, beef, Prawn, Beef, horsemeat, Minced mutton, Pork, Minced beef, Minced beef</td>
<td>Spoilage, Monitoring meat colour, Adulteration, Detection of adulteration, Detection of beef and horse meet, Quality control analysis, Assessment of microbial contamination, authentication, adulteration detection (pork proportion in minced mutton), Freshness (TVB-N content), Identification of frozen-then-thawed minced beef labelled as fresh</td>
<td>Principal Component Analysis (PCA), Principal Component Regression (PCR) Hierarchical Component Analysis (HCA) Partially Linear Model (PLM) Partially Least Squares Regression (PLS) PLS - discriminant analysis (PLS-DA) Linear Discriminant Analysis (LDA) Support Vector Machine (SVM) Least Squares-SVM, Artificial Neural Networks (ANN) k-Nearest Neighbors Algorithm (kNNA) Random Forest Regression (RFR)</td>
</tr>
</tbody>
</table>


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**Wavenumbers (cm⁻¹):**


**Acetophenone,** **Methyl ethyl ketone (MEK)**, **Methyl hexanone,** **Phenylpropionaldehyde,** **2-Methyl-2-pentanone,** **Acetone,** **1-Decanol,** **2,5-Octadien-3-one,** **Octanedione or 2,5-Decenal**

**Prawn - Meat**

*Pork* - *Meat* - *Pork* - *Meat*
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- Use Cases; Meat microbiological quality, beef vs horsemeat, beef vs pork & poultry vs pork
USE CASE 1; Assessing microbial quality of minced pork

Article

Estimation of Minced Pork Microbiological Spoilage through Fourier Transform Infrared and Visible Spectroscopy and Multispectral Vision Technology

Lemonia-Christina Fengou, Evgenia Spyrelli, Alexandra Lianou, Panagiotis Tsakanikas, Efstathios Z. Panagou and George-John E. Nychas

Laboratory of Microbiology and Biotechnology of Foods, Department of Food Science and Human Nutrition, Agricultural University of Athens, Iera Odos 75, 11855 Athens, Greece

* Correspondence: gjn@aua.gr
The use of metabolomics analytical platform in tandem with machine learning allows to assess the freshness of meat samples.

- **Combining analytical instruments (metabolomics) & machine learning**

  - Pork, beef, poultry
  - Metabolomics fingerprinting
    - Microbiological analysis
  - Metabolomics data
  - Regression model (Machine learning)
  - Bacterial count

- The use of metabolomics analytical platform in tandem with machine learning allows to assess the freshness of meat samples.
Combining analytical instruments (metabolomics) & machine learning

- Microbiological spoilage experiments

Minced pork

Packaged in *modified atmospheres* (80% O$_2$-20% CO$_2$) and stored at:
- *Isothermal* conditions (4, 8, 12°C)
- *Dynamic temperature* conditions (periodic temperature changes between 4 and 12°C)

4 batches 431 samples
Minced pork; FTIR (A) & VIS (B) measurements; Comparison between observed and predicted total viable counts (TVC) by PLSR model

Training (solid symbols, 170 samples); validation (open symbols, 58 samples) datasets (solid line: the ideal y = x line; dashed lines: the ±1 log; The root mean squared error (RMSE, log CFU/g) for the prediction of the test (external validation) dataset for the FTIR and VIS models was 0.915 and 1.034, respectively, while the corresponding values of the coefficient of determination (R2) were 0.834 and 0.788.
USE CASE 2; Beef vs Pork

Multispectral image analysis approach to detect adulteration of beef and pork in raw meats

A.I. Ropodi a,1, D.E. Pavlidis a,1, F. Mohareb b, E.Z. Panagou a, G.-J.E. Nychas a,∗

a Agricultural University of Athens, School of Food, Biotechnology & Development, Dept Food Science & Human Nutrition, Lab of Microbiology & Biotechnology of Foods, Iera Odos 75, Athens 11855 Greece
b The Bioinformatics Group, Biomedical Engineering Centre, Cranfield University, College Road, Bedford, MK43 0AL, UK
The original data set consists of 319 minced meat samples. Specifically:

- **100% Pork**: 21 batches x 5 replicates = 105 samples
- **100% Beef**: 22 batches x (4) 5 replicates = 109 samples
- **70,50 & 30% beef vs pork**: 21 batches x 5 replicates = 105 samples

Packaging: MAP (80% O₂, 20% CO₂).
- Samples were provided from a local meat processing plant.
Materials & Methods-Multi Spectral Imaging (VideometerLab) In Action
Materials & Methods – Multi Spectral Imaging (VideometerLab)

- Wavelengths ranging from 405-970nm (visible & NIR region).
LDA and PLS-DA (12 PLS components) for both validation set and external validation batch with 3 classes (pork—adulterated—beef).

<table>
<thead>
<tr>
<th></th>
<th>LDA</th>
<th>PLS-DA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Validation set</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>classified as</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pork</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>adulterated</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>beef</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Recall</td>
<td>83.3%</td>
<td>83.3%</td>
</tr>
<tr>
<td>Precision</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>is pork</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>is adulterated</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>is beef</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Recall</td>
<td>80%</td>
<td>100%</td>
</tr>
<tr>
<td>Precision</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>LDA</th>
<th>PLS-DA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EXTERNAL Validation BATCH</strong></td>
<td></td>
<td></td>
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<tr>
<td>classified as</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pork</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>adulterated</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>beef</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Recall</td>
<td>80%</td>
<td>100%</td>
</tr>
<tr>
<td>Precision</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>is pork</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>is adulterated</td>
<td>35</td>
<td>45</td>
</tr>
<tr>
<td>is beef</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Recall</td>
<td>77.8%</td>
<td>100%</td>
</tr>
<tr>
<td>Precision</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>is pork</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>is adulterated</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>is beef</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Recall</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Precision</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Multispectral imaging (MSI): A promising method for the detection of minced beef adulteration with horsemeat

Athina I. Ropodi, Efstatios Z. Panagou, George-John E. Nychas*

Laboratory of Microbiology and Biotechnology of Foods, Department of Food Science and Human Nutrition, Faculty of Foods, Biotechnology and Development, Agricultural University of Athens (AUA), Ieraodas 75, Athens, 11855, Greece

Multispectral Imaging (MSI); a Promising Method for the Detection of Minced Beef Adulteration with Horsemeat (Food Control 2017)
Background knowledge & Previous work

• DNA-based methods are very accurate however, they are expensive, time-consuming and require highly-trained personnel.

• Limited number of studies have been published concerning rapid methods and meat adulteration, mostly featuring vibrational spectroscopy instruments (IR, Raman)

• Concerns/ Limitations of published studies:
  – The samples come from one meat batch and is not representative of variability found in real life.
  – The number of tested samples is usually small.
  – Validation without external (independent) data
Experiment Design

Beef & Horse fillets were purchased & minced (3 different batches)

100% beef
90% beef - 10% horsemeat
80% beef - 20% horsemeat
60% beef - 40% horsemeat
40% beef - 60% horsemeat
20% beef - 80% horsemeat
100% horsemeat

The mixed samples were stored at 4°C for 6, 24 & 48h

240 MS images were captured using VideometerLab.

Image segmentation & Data analysis*

Meat was mixed in order to achieve various % w/w levels of adulteration

*http://www.metaboanalyst.ca
Results con/ed

PCA 3D

- common autolight/calibration
Effect of Storage on adulteration assessment

Principal Components Analysis

- PCA – 2D
- PCA – 3D

Scores Plot

Legend
- Group 0
- Group 100
- Group 20
- Group 40
- Group 60
- Group 80

Pure at 0h
Effect of Storage on adulteration assessment

Partial Least Square Discriminant Analysis

- PLS-DA – 2D
- PLS-DA – 3D
Concerns ...

.. Since the discrimination among various levels of adulteration is more complex depending on whether the horse samples are freshly minced or not.... a more sophisticated algorithm was used for model development such as FOREST TREE
Results from Random Forest

- Only one sample was categorized in a non-adjacent category.
- Only 3.8% of samples were categorized in a ≥20% category.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Predicted as 0</th>
<th>Predicted as 60</th>
<th>Predicted as 80</th>
<th>Predicted as 90</th>
<th>Predicted as 100</th>
<th>Class error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is 0 (0 B/100H)</td>
<td>32</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Is 60</td>
<td>0</td>
<td>30</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0.0625</td>
</tr>
<tr>
<td>Is 80</td>
<td>0</td>
<td>3</td>
<td>26</td>
<td>2</td>
<td>0</td>
<td>0.161</td>
</tr>
<tr>
<td>Is 90</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>28</td>
<td>3</td>
<td>0.0968</td>
</tr>
<tr>
<td>Is 100</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>27</td>
<td>0.156</td>
</tr>
</tbody>
</table>
Rapid detection of minced pork and chicken adulteration in fresh, stored and cooked ground meat

Lemonia-Christina Fengou *, Panagiotis Tsakanikas, George-John E. Nychas **

Laboratory of Microbiology and Biotechnology of Foods, Department of Food Science and Human Nutrition, School of Food and Nutritional Sciences, Agricultural University of Athens, Iera Odos 75, 11855, Athens, Greece
Experimental design

**Purchase of meat (pork, chicken)**

- b1
- b2
- b3
- b4
- b5
- b6
- b7
- b8
- b9
- b10
- b11
- b12

**Sample preparation**

1. **Adulteration level:**
   - 0%, 10%, 25%, 40%, 50%, 60%, 75%, 90%, 100%
   - Samples per adulteration level: 5
   - Number of samples: 180
2. **Adulteration level:**
   - 0%, 25%, 50%, 75%, 100%
   - Samples per adulteration level: 6
   - Number of samples: 120
3. **Adulteration level:**
   - 0%, 25%, 50%, 75%, 100%
   - Samples per adulteration level: 3
   - Number of samples: 60

**Image acquisition**

- Freshly ground samples (0h).
- Samples stored at 4 °C (24h & 48h).
- Cooked samples.

Fengou et al., 2021 (Food Control)
Confusion matrix for SVM classification for the **External Validation (n=90)** of the fresh samples using MSI data considering **3 classes**; 0% pork-100% chicken (0%) - adulterated (A) - 100% pork-0% chicken (100%).

<table>
<thead>
<tr>
<th>True class</th>
<th>0%</th>
<th>A</th>
<th>100%</th>
<th>Recall (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>100.00</td>
</tr>
<tr>
<td>A</td>
<td>0</td>
<td>62</td>
<td>0</td>
<td>100.00</td>
</tr>
<tr>
<td>100%</td>
<td>0</td>
<td>3</td>
<td>11</td>
<td>78.57</td>
</tr>
</tbody>
</table>

| Precision (%) | 100.00 | 95.38 | 100.00 | **Accuracy (%) 96.67** |

Fengou et al., 2021 (Food Control)
Support Vector Machine (SVM) classification of fresh, stored at 4° C, and cooked minced pork, poultry or mixed [0% pork - 100% chicken and vice versa] samples, using Multi Spectral Imaging data. Nine (9) or three (3) steps of Adulteration were considered while External Validation evaluated with either 90 or 45 no of samples

<table>
<thead>
<tr>
<th>type of meat</th>
<th>No of samples</th>
<th>condition of meat samples</th>
<th>adulteration steps/Replicates/validation samples</th>
<th>Accuracy (%) External Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>pork vs poultry, Adulteration from 0 to 100% (steps either 9 or 3) &amp; 3,5 or 6 replicates</td>
<td>360</td>
<td>Fresh</td>
<td>9 /6/ 90</td>
<td>84,44</td>
</tr>
<tr>
<td></td>
<td>360</td>
<td>Fresh</td>
<td>3 /6/ 90</td>
<td>96,67</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>stored for 24H</td>
<td>9 /5/ 45</td>
<td>73,33</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>stored for 48H</td>
<td>9 /3/ 45</td>
<td>66,67</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>stored for 24H</td>
<td>3 /5/ 45</td>
<td>97,78</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>stored for 48H</td>
<td>3 /3/ 45</td>
<td>95,56</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>cooked</td>
<td>9 /5/ 45</td>
<td>84,44</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>cooked</td>
<td>3 /5/ 45</td>
<td>95,56</td>
</tr>
</tbody>
</table>
### Summarizing ...

<table>
<thead>
<tr>
<th>Type of sensor</th>
<th>Food type</th>
<th>Purpose</th>
<th>Number of samples</th>
<th>Data analysis</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTIR, MSI</td>
<td>minced beef</td>
<td>Detection of frozen-then-thawed minced beef labelled as fresh.</td>
<td>105</td>
<td>PLSDA, SVM</td>
<td>Ropodi et al., 2018</td>
</tr>
<tr>
<td>MSI</td>
<td>beef vs. horsemeat</td>
<td>Minced beef adulteration with horsemeat, as well as model performance during storage in refrigerated conditions.</td>
<td>110 (350 images)</td>
<td>PLSDA, RF, SVM</td>
<td>Ropodi et al., 2017</td>
</tr>
<tr>
<td>MSI</td>
<td>beef vs. pork</td>
<td>Minced beef fraudulently substituted with pork and vice versa.</td>
<td>220</td>
<td>PLSDA, LDA</td>
<td>Ropodi et al., 2015</td>
</tr>
<tr>
<td>Type of sensor</td>
<td>Food type</td>
<td>Purpose</td>
<td>Number of samples</td>
<td>Data analysis</td>
<td>Reference</td>
</tr>
<tr>
<td>----------------</td>
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<tr>
<td>MSI</td>
<td>pork vs. chicken</td>
<td>Detection of meat adulteration in fresh, stored, and cooked meat.</td>
<td>360 samples/images (fresh) 180 images (stored) 180 images (cooked)</td>
<td>SVM</td>
<td>Fengou et al., 2021 (Food Control)</td>
</tr>
<tr>
<td>MSI, Vis, Fluo</td>
<td>pork vs. chicken &amp; beef vs. offal</td>
<td>Detecting minced meat substitution of: (i) beef with bovine offal and (ii) pork with chicken (and vice versa) both in fresh and frozen-thawed samples.</td>
<td>120 samples pork vs. chicken 120 samples beef vs. offal</td>
<td>PLS transformed spectral data, SVM</td>
<td>Fengou et al., 2021 (foods)</td>
</tr>
</tbody>
</table>
Future Tools

Process Analytical Technologies (PAT)  
[Implementation of QbD]  

• Sensors; In – On – At line analytical instruments to measure parameters (including Next Generation Sequencing)

• Data Science; Data Analytics, Data mining, Machine Learning

• Information Communication Technology
PAT’s Tools; (c) ICT

Information/data management and continuous optimization

**Exposé:** Let your customer know the quality and story details of the product they are holding.

1. **Your Food’s Journey**
   - COLLECTED: 23/05/2021
   - AT YOUR HAND (Municipality Of Kropia): 26/05/2021

2. **Processing Plant**
   - 24/05/2021

3. **The Farms**
   - PAT’S Tools; (c) ICT

4. **Exposing the Journey**
   - Product specific details removed
MeatTrack
DEMOCRATIZING TRACEABILITY AND QUALITY

PAT’s Tools; (c) ICT

Expose: Let your customer know the quality and story details of the product they are holding.

Agritrack’s CEM
Customer Engagement Module

1. Expose your food's journey before it reached your hands.
   - Your Food’s Journey
   - Collected: 23/05/2021
   - Processed:
   - 24/05/2021
   - At Your Hand (Municipality Of Krapina)
   - 26/5/2021

2. 24/05/2021
   - At Your Hand (Municipality Of Krapina)

3. Processing Plant
   - The meat you hold was collected on 23/05/2021 from our Prime farms located at: PALAIOSKIA, PRAKTOI

4. Processing Plant
   - We pasteurized and bottled the milk you held on 24/05/2021 at our processing facility at the Entrance of our Plant.

Note: Product specific details removed.
Summary - Conclusions – Future Plans

• FTIR, MSI, VIS are indeed a promising methods for assessing microbial quality of meat and meat products as well as for the detection of fraud / adulteration of meat.

• Storage of minced meat has a significant effect on the images captured by the MSI instrument and consequently on the final developed model.

• More experiments involving different batches should be added, so that the developed model takes into account the variability found among different batches.

• Further, independent validation of the model(s) developed should be performed.
Meat adulteration/fraud


SPOILAGE; Beef, Pork, Poultry,


- Papadopoulou, et al. (2011) Contribution of Fourier transform infrared (FTIR) spectroscopy data on the quantitative determination of **minced pork** meat spoilage Food Research International 44, 3264-3271


- Papadopoulou, etal. (2013) Potential of a portable electronic nose in rapid and quantitative detection of the microbial spoilage of **beef fillets**. Food Research Int. 50,241

- Dissing et al. (2013). Using multispectral imaging for spoilage detection of **pork meat**. Food and Bioprocess Technology 6, 2268-2279

DATA SCIENCE


DiTECT: Digital Technologies as an enabler for a continuous transformation of food safety system. Funded by HORIZON 2020 www.ditect.eu

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Exploring Non-Invasive Instruments to Assess the Microbiological Quality and Authenticity of Meat and Meat Products

THANKS FOR YOUR ATTENTION

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Join us for these upcoming webinars:

December 1  Process Validation to Meet FSMA Regulations Part 3: Validation Report

December 8  Why Quantification? The Road to Revolutionizing Food Safety

January 26, 2022  Practical Guidance for Validation Studies: From Start to Finish

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