International Association for Food Protection

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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International Association for Food Protection WEBINAR

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.

Today’s Moderator

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

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.).

Today's Presenters

George Nychas
Professor, Agricultural University of Athens, Greece

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 284papers (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**
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- 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.

[QUALITY vs SAFETY vs FRAUD] vs FOOD CRIME

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

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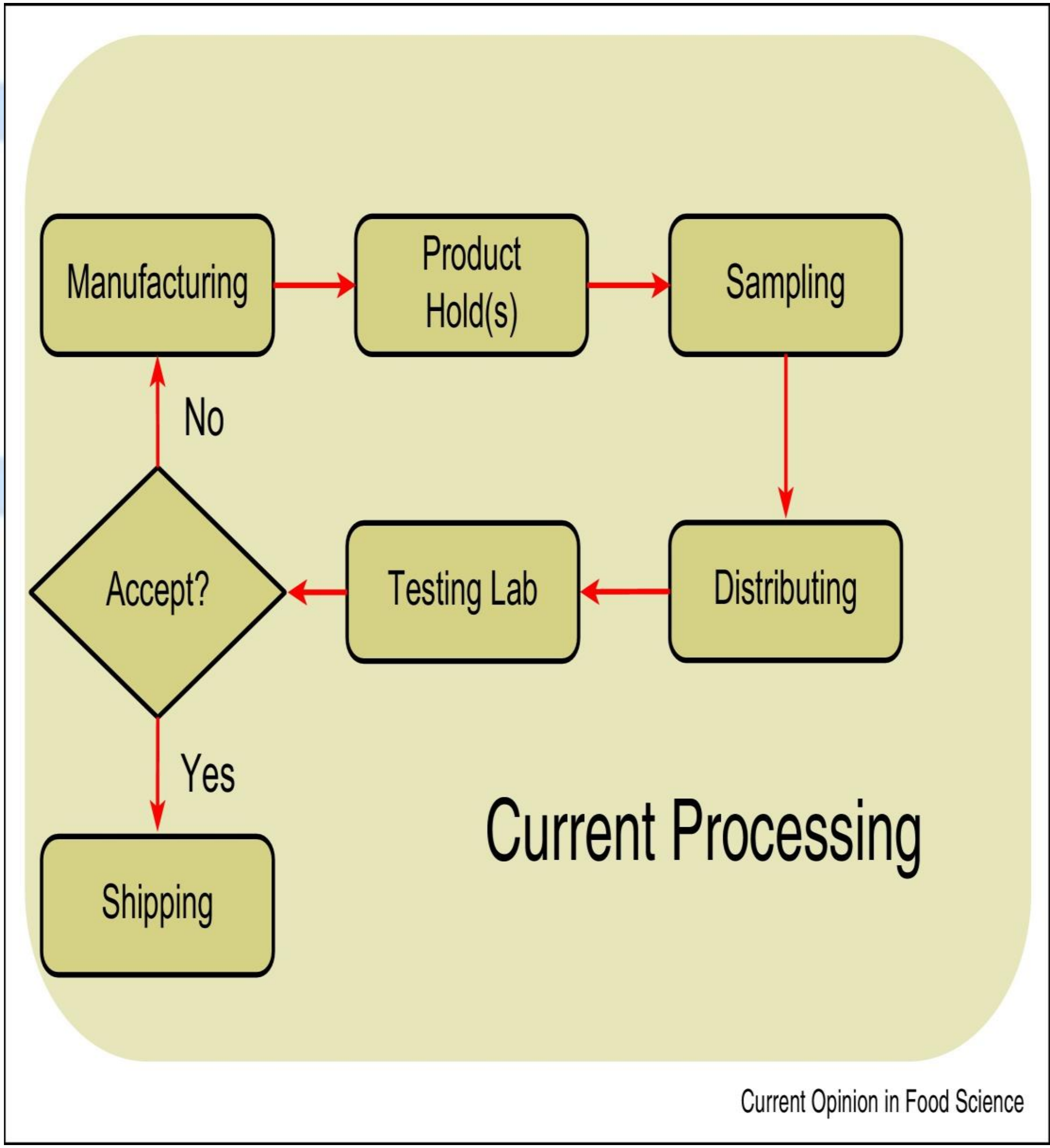
- Use Cases;

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!!!

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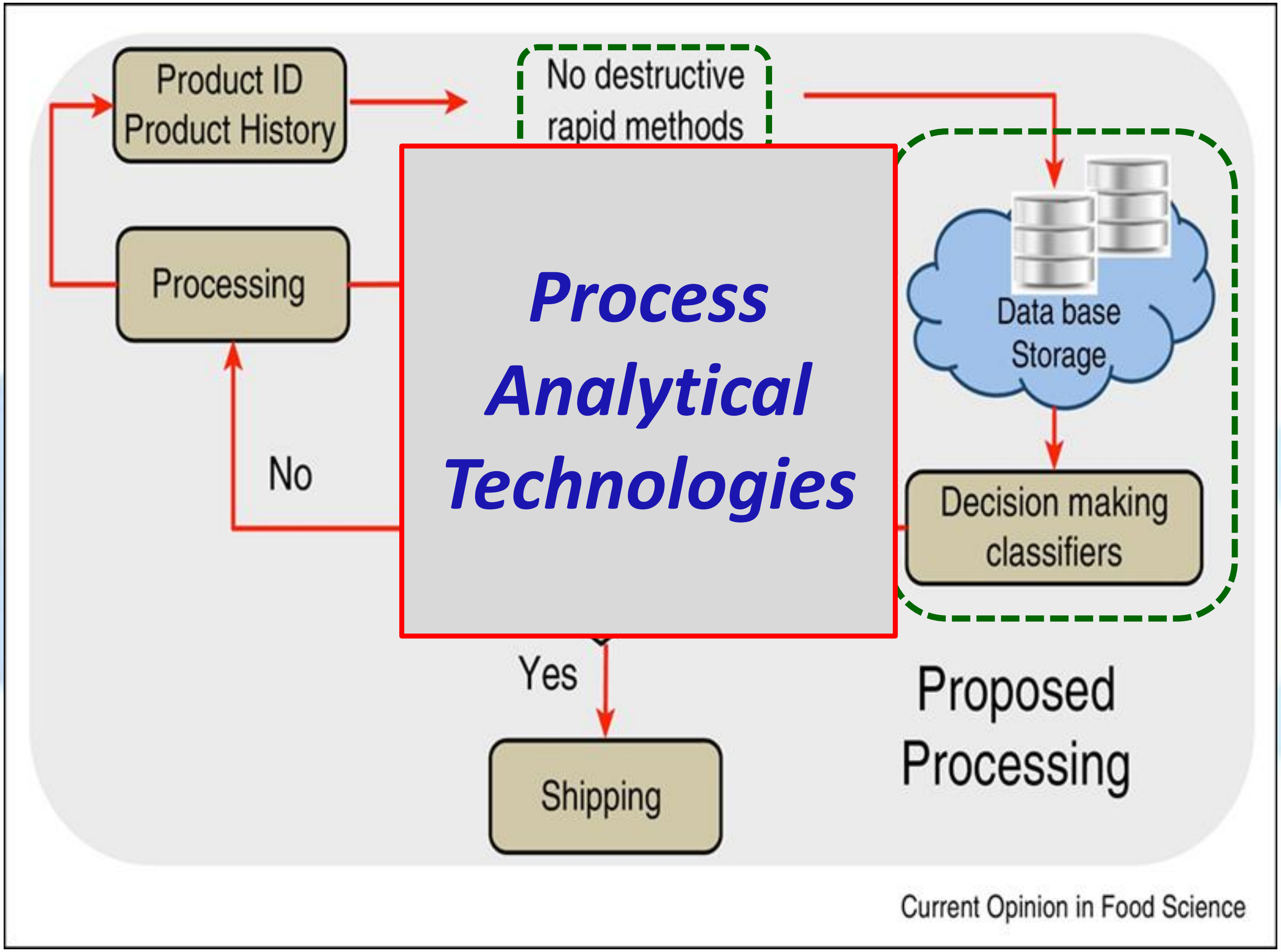
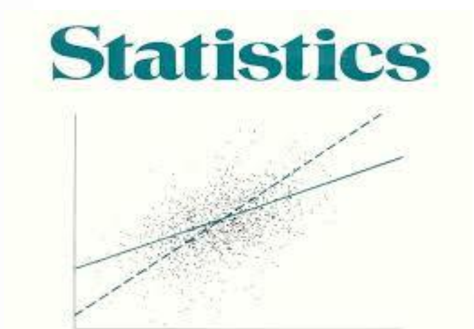
Future Approaches ….



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

(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



PAT

Future Tools

Process Analytical Technologies (PAT) [Implementation of QbD]

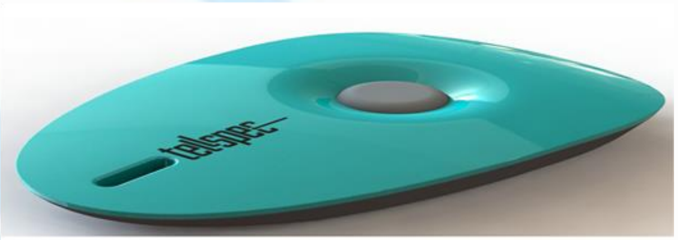
- Sensors; In – On – At line analytical instruments to measure parameters (including Next Generation Sequencing)
- Data Science; Data Analytics, Data mining, Machine Learning
- Information Communication Technology

PAT's Tools; (a) Sensors

In – On –At line n*on-invasive analytical technologies (desktop, handheld, miniaturized) based on spectroscopy and/or image analysis *to measure quality & safety parameters

PAT's Tools; (a) Sensors *con/ed*

In – On –At line n*on-invasive analytical technologies (desktop, handheld, miniaturized) based on spectroscopy and/or image analysis *to measure quality & safety parameters

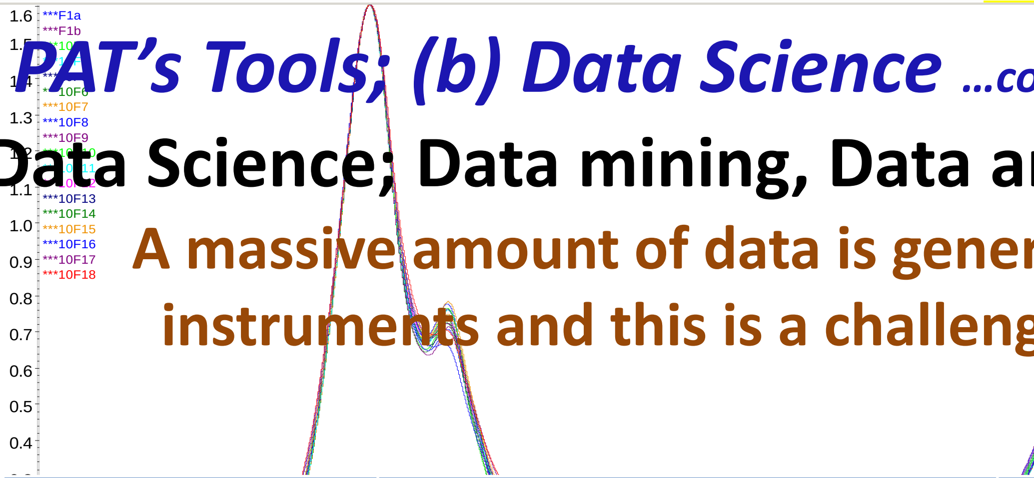


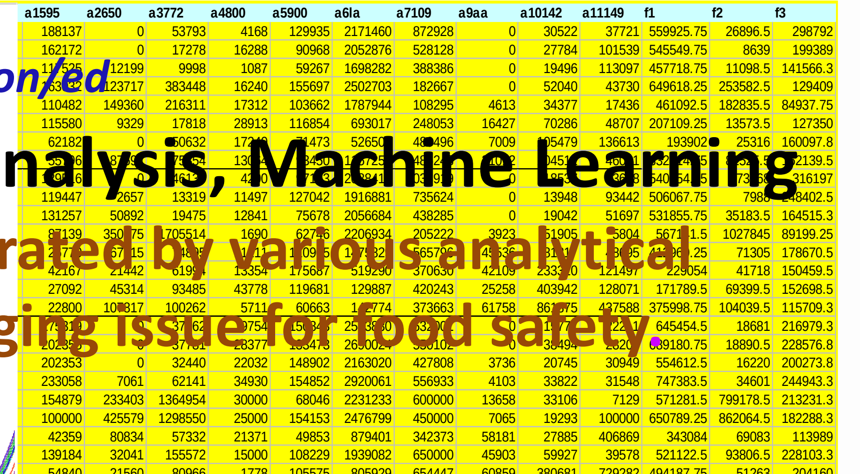
PAT's Tools; (a) Sensors .. con/ed

List of representative rapid methods e.g. Imaging and Spectroscopy applied in meat which their measurement can be 'translated' into quality parameters

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

Ropodi et al. Trends in Food Sci. & Techn. 50,11-25



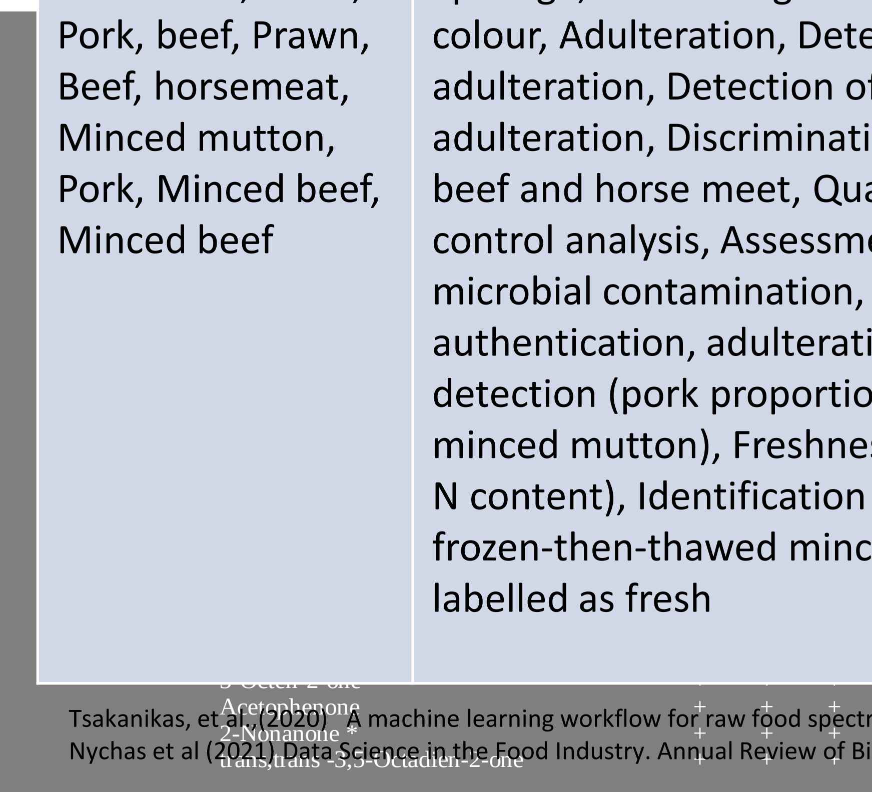


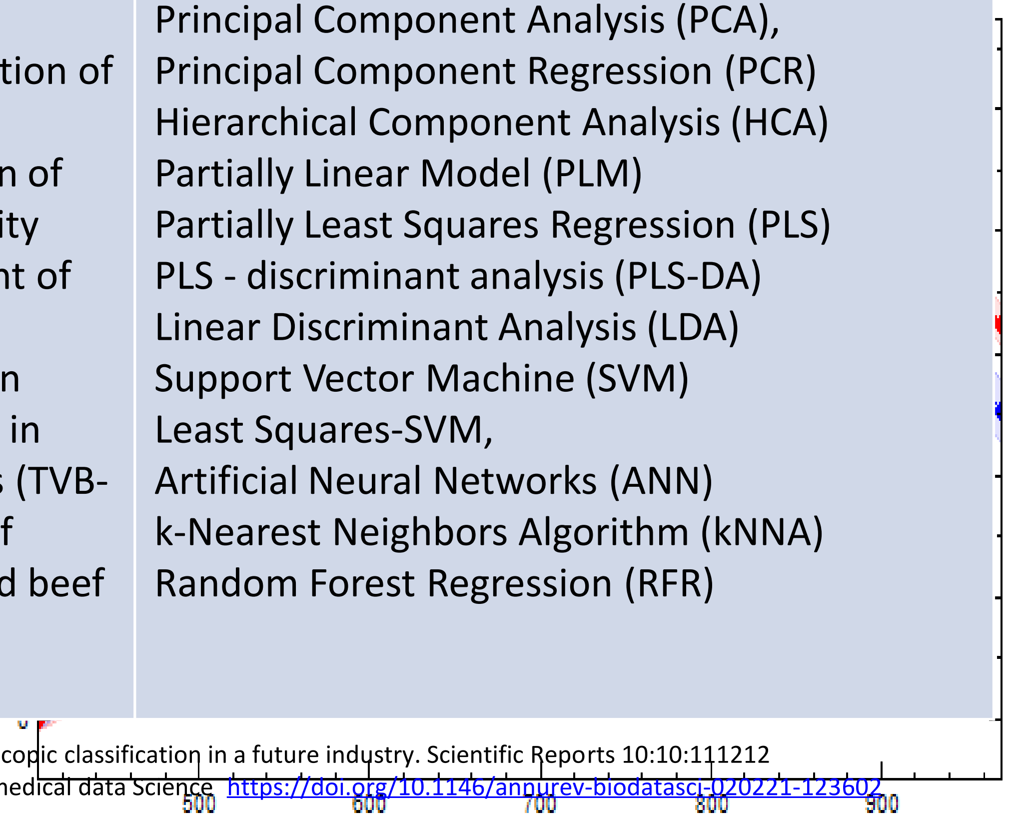
PAT's Tools; (b) Data Science ...cont/ed

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

products	purpose	data analysis
Beef fillets, Meat, Pork, beef, Prawn, Beef, horsemeat, Minced mutton, Pork, Minced beef, Minced beef	Spoilage, Monitoring meat colour, Adulteration, Detection of adulteration, Detection of adulteration, Discrimination 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	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)





Tsakanikas, et al., (2020) A machine learning workflow for raw food spectroscopic classification in a future industry. Scientific Reports 10:10:111212
Nychas et al (2021) Data Science in the Food Industry. Annual Review of Biomedical data Science https://doi.org/10.1146/annurev-biodatasci-020221-123602

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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

foods

MDPI

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

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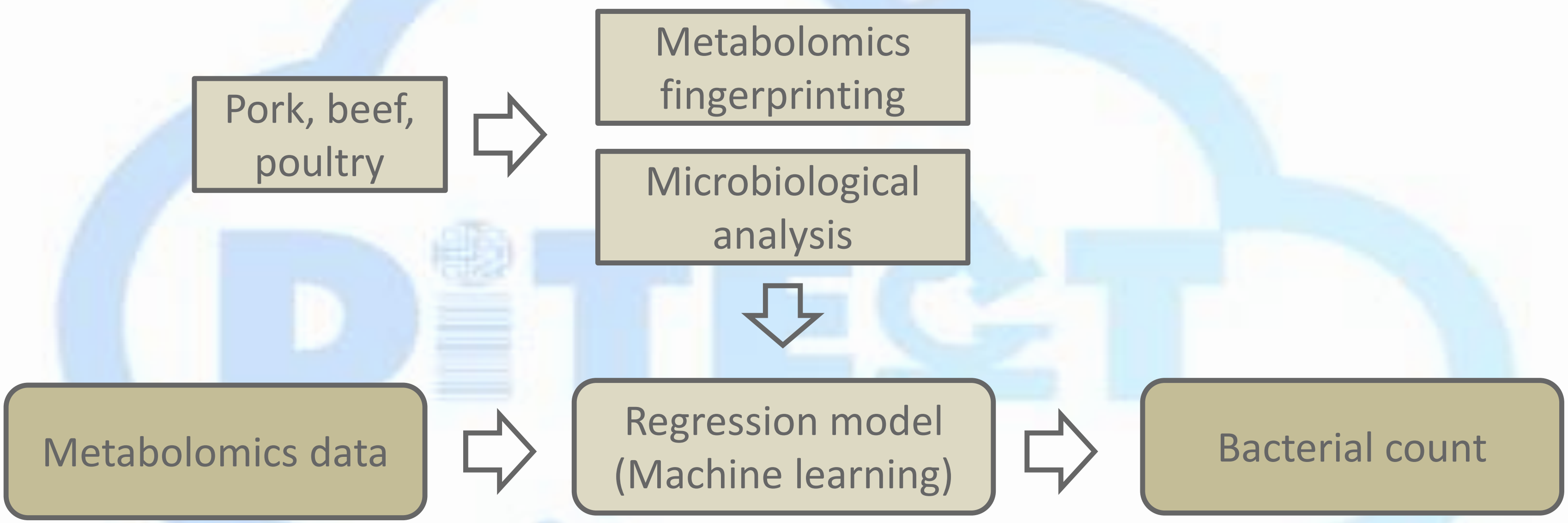
Combining analytical instruments (metabolomics) & machine learning



- 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:

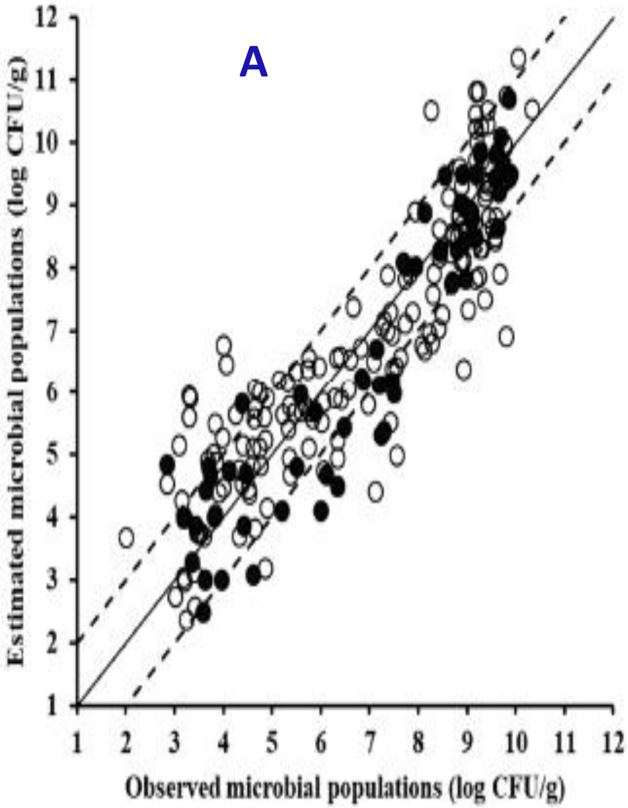
- ***Isothermal*** conditions (4, 8, 12°C)
- ***Dynamic temperature*** conditions (periodic temperature changes between 4 and 12°C)

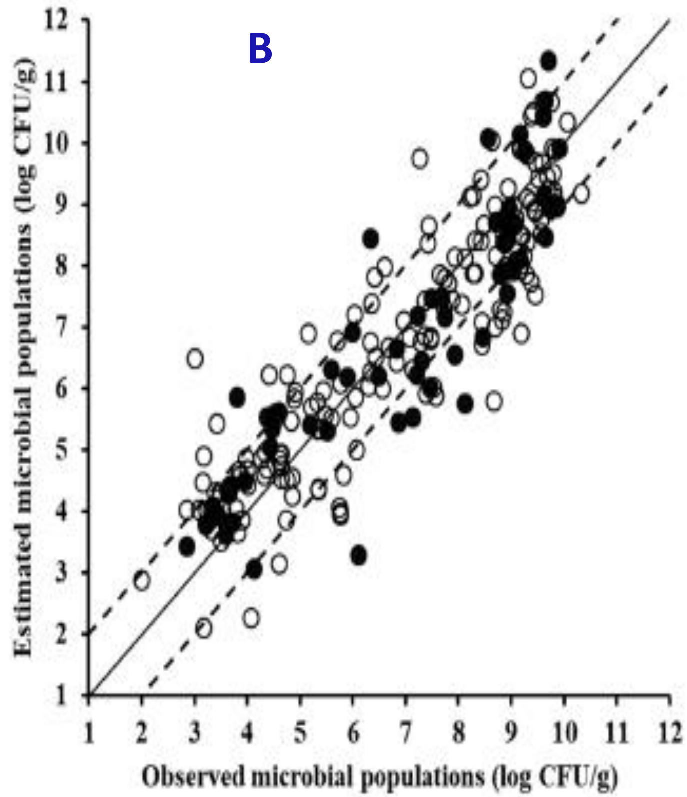
4 batches
431 samples

Microbiological analysis

VideometerLab/ FTIR

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

Food Research International 67 (2015) 12–18

Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

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,*]

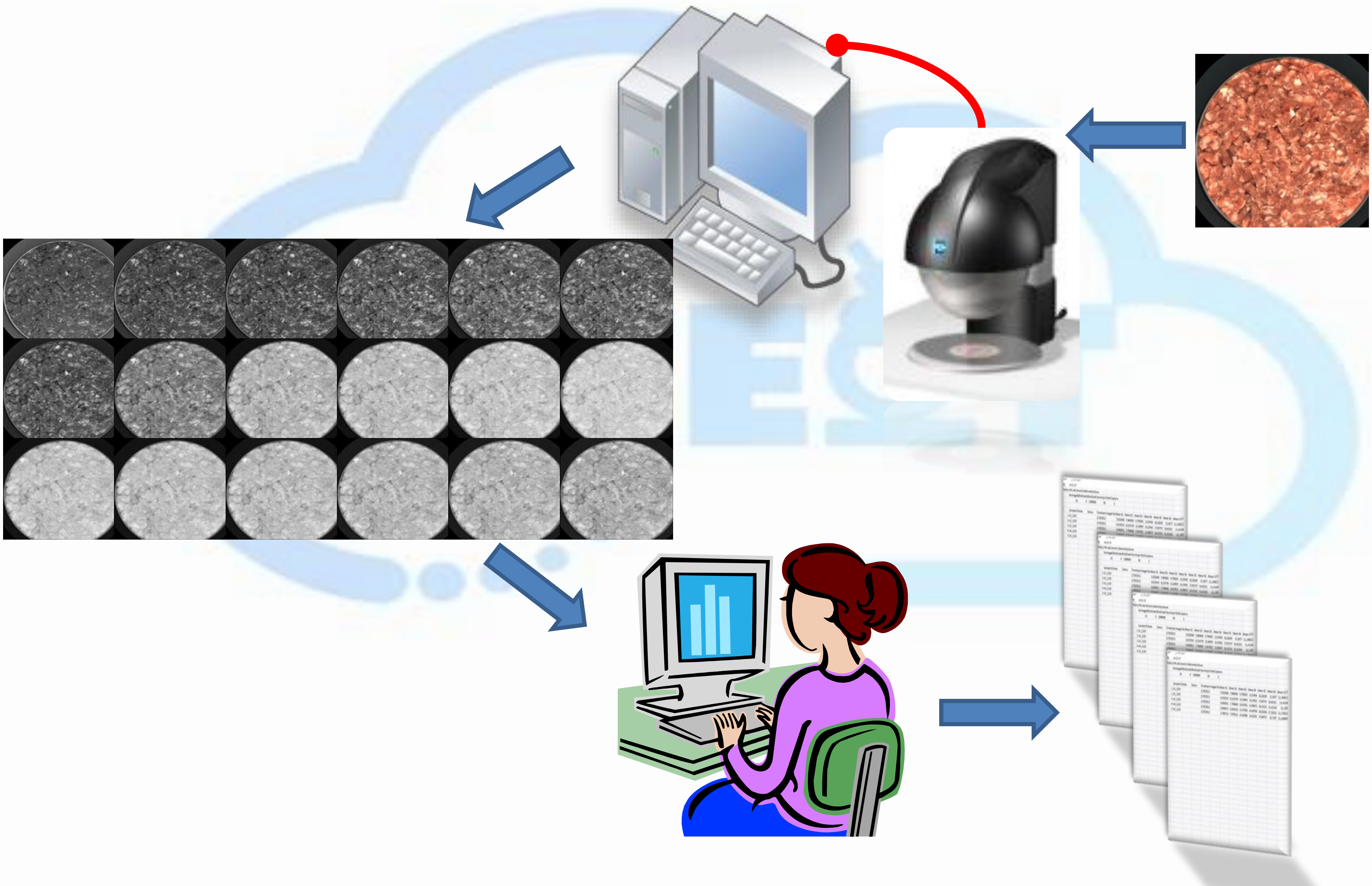
[a] Agricultural University of Athens, School of Food, Biotechnology & Development, Dept Food Science & Human Nutrition, Lab of Microbiology & Biotechnology of Foods, Iera Odos 75, Athens 11855 Greece

[b] The Bioinformatics Group, Biomedical Engineering Centre, Cranfield University, College Road, Bedford, MK43 0AL, UK

Materials & Methods - Sample data

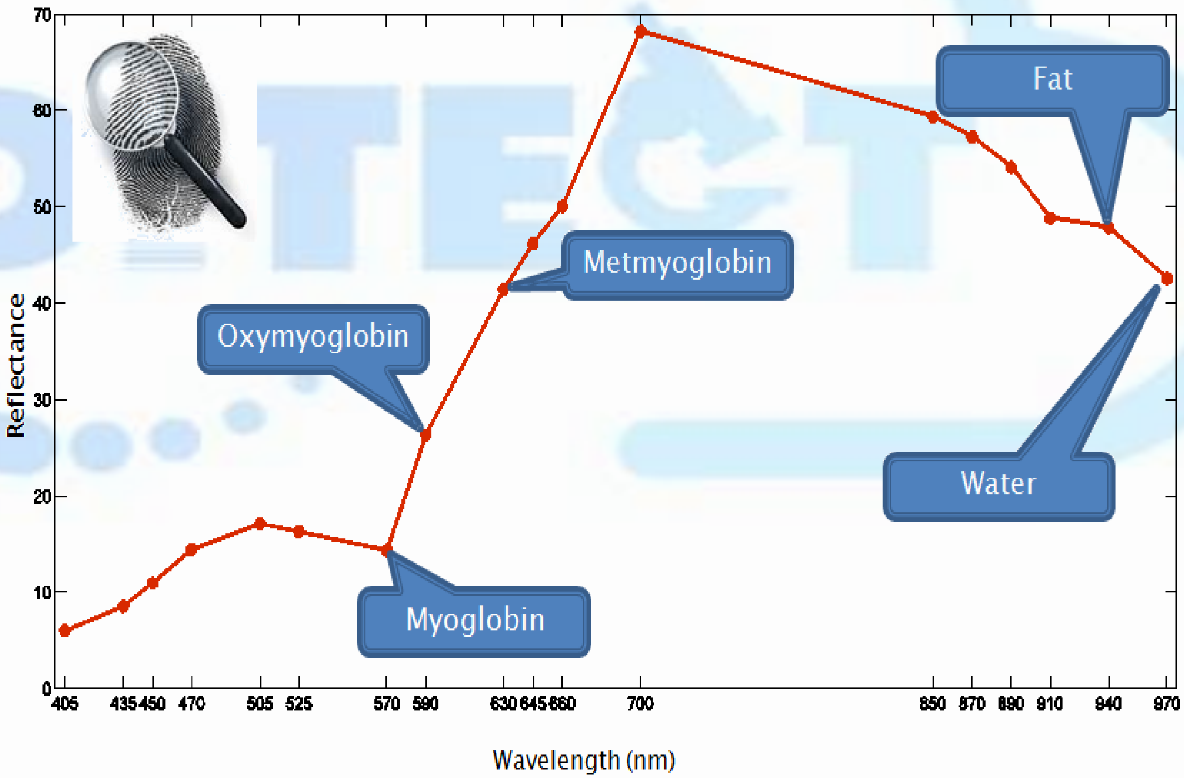
- The original data set consists of 319 minced meat samples. Specifically:
  - 100% Pork; 21 batches x 5 replicates = 105 samples
  - 100% Beef; 22 batches x (4) 5 replicates = 109 samples
  - 70,50 & 30 % beef vs pork; 21 batches x 5 replicates = 105 samples
- Packaging: MAP (80% O_2, 20% CO_2).
- Samples 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).



Wavelengths (nm)
405
435
450
470
505
525
570
590
630
645
660
700
850
870
890
910
940
970

LDA and PLS-DA (12 PLS components) for both validation set and external validation batch with 3 classes (pork—adulterated—beef).

Validation set

LDA					PLS-DA				
	classified as					classified as			
	pork	adulterated	beef	Recall		pork	adulterated	beef	Recall
is pork	5	1	0	83.3%	is pork	5	1	0	83.3%
is adulterated	0	54	0	100.%	is adulterated	0	54	0	100%
is beef	0	0	6	100.%	is beef	0	0	6	100%
Precision	100%	98.2%	100%		Precision	100.%	98.2%	100%	

EXTERNAL Validation BATCH

LDA					PLS-DA				
	classified as					classified as			
	pork	adulterated	beef	Recall		pork	adulterated	beef	Recall
is pork	4	0	1	80%	is pork	5	0	0	100%
is adulterated	0	35	10	77.8%	is adulterated	0	45	0	100%
is beef	0	0	5	100%	is beef	0	0	5	100%
Precision	100%	100%	31.5%		Precision	100%	100%	100%	

USE CASE 3; Beef vs Horsemeat

Food Control 73 (2017) 57–65

Contents lists available at ScienceDirect

Food Control

journal homepage: www.elsevier.com/locate/foodcont

ELSEVIER

Multispectral imaging (MSI): A promising method for the detection of minced beef adulteration with horsemeat

Athina I. Ropodi, Efstathios 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), IeraOdos 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

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

The mixed samples were stored at 4^0C for 6, 24 & 48h

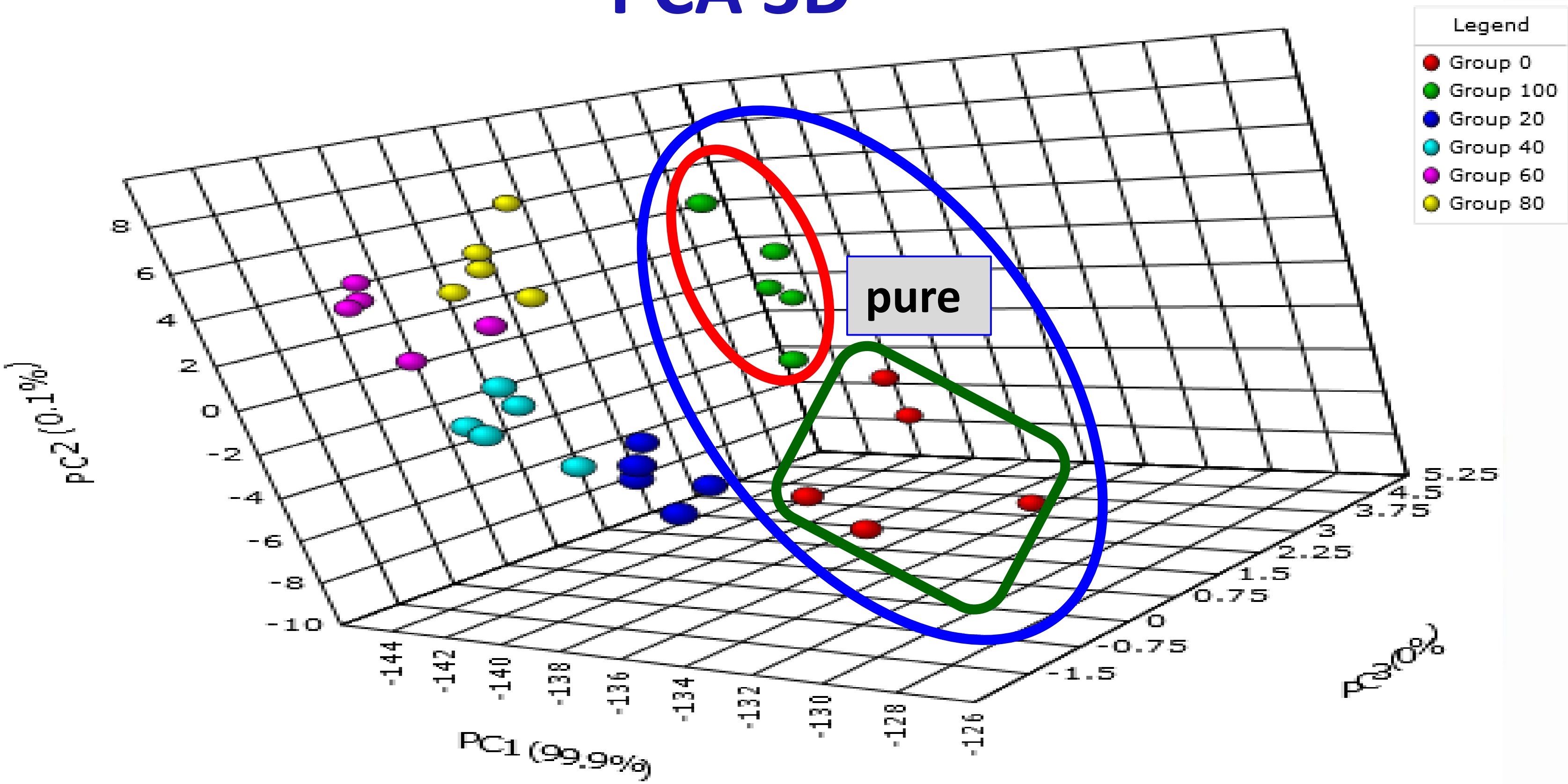
240 MS images were captured using VideometerLab.

Image segmentation & Data analysis*

*http://www.metaboanalyst.ca

Results con/ed

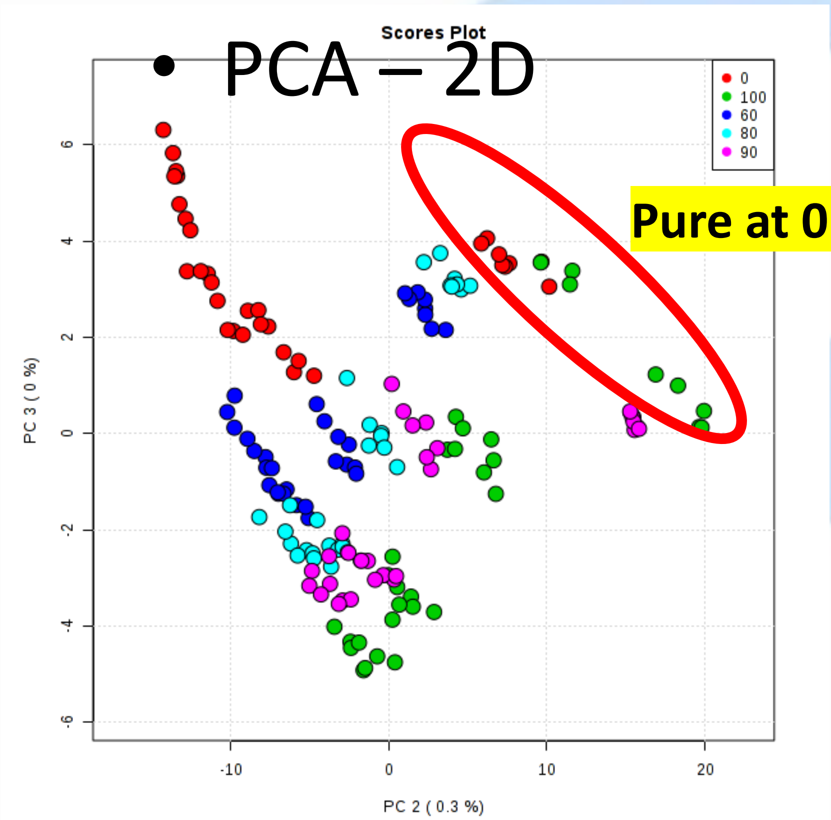
PCA 3D



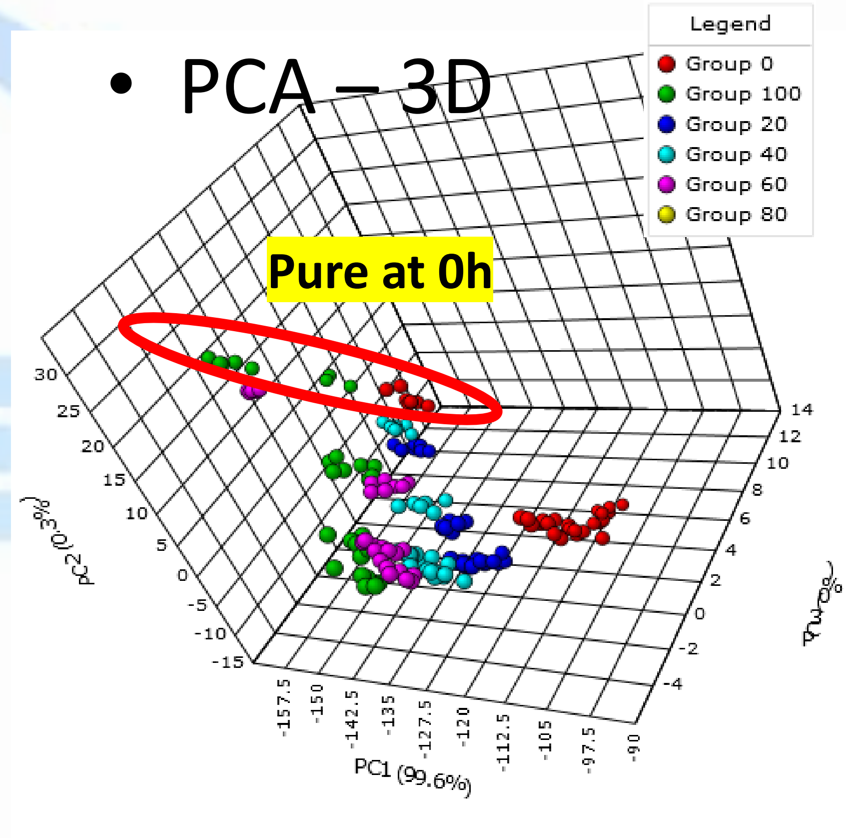
- common autolight/calibration

Effect of Storage on adulteration assessment

Principal Components Analysis



• PCA – 2D

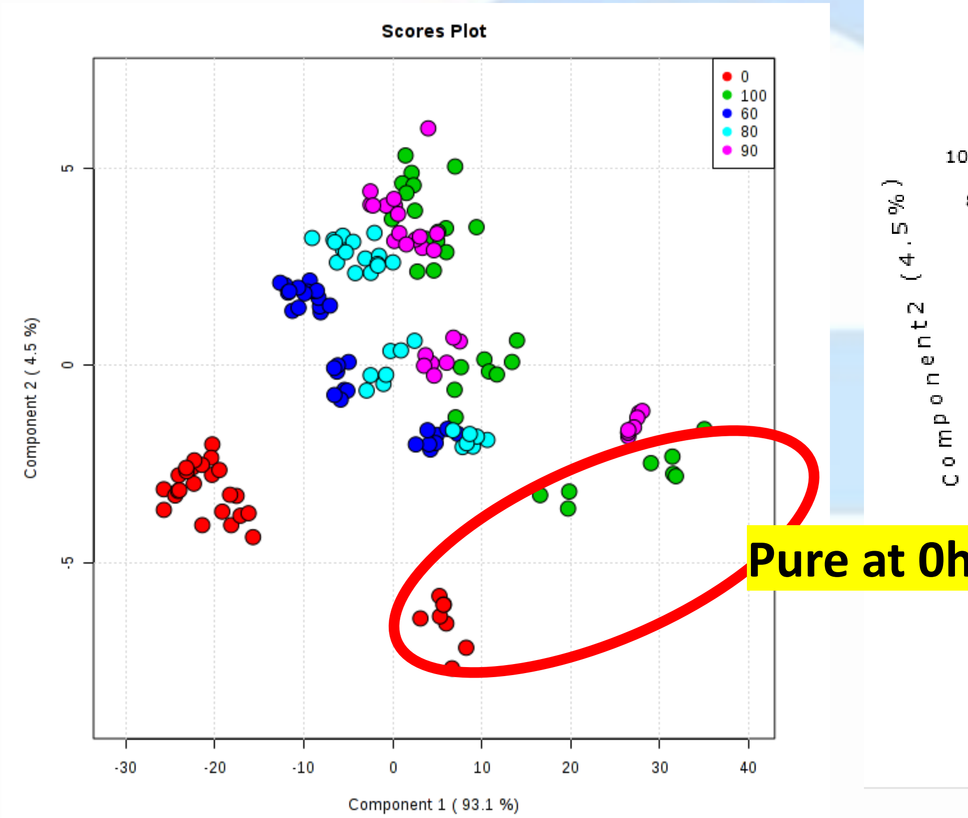


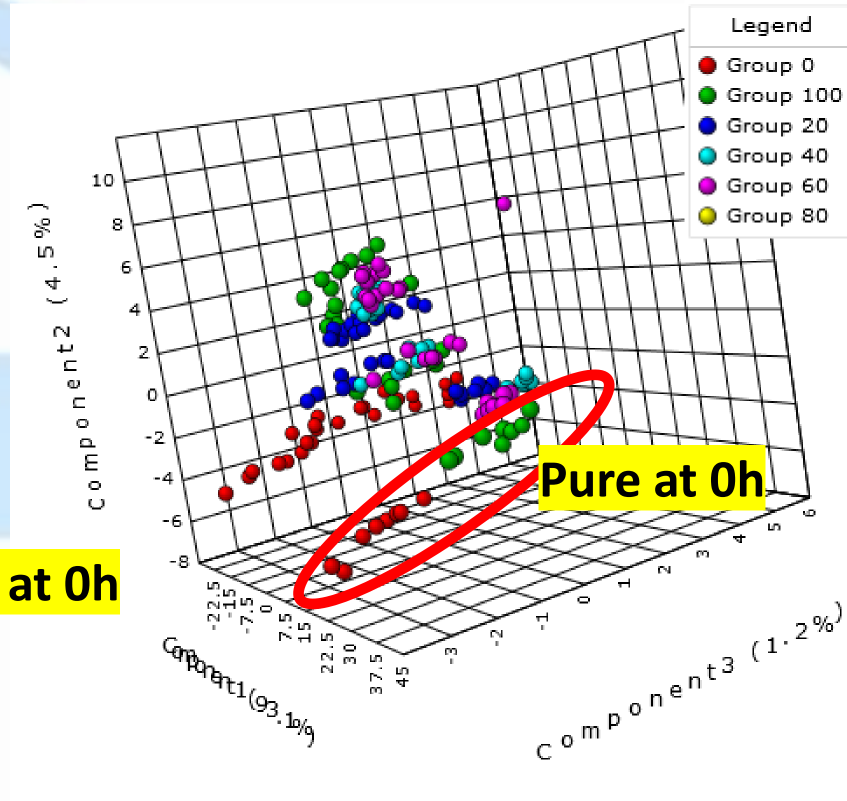
• PCA – 3D

- PCA – 2D
- PCA – 3D

Effect of Storage on adulteration assessment

Partial Least Square Discriminant Analysis



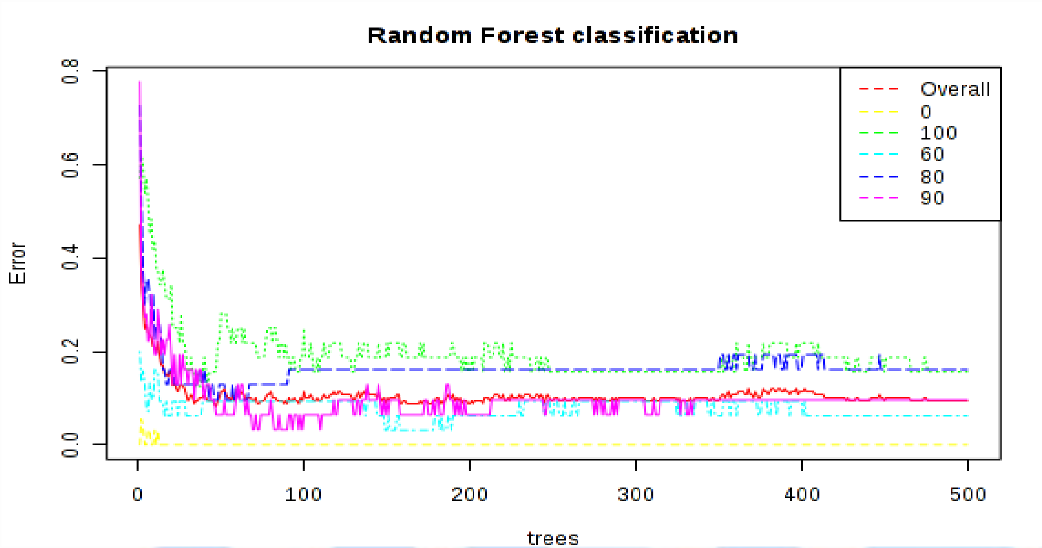


- PLSDA – 2D
- PLSDA – 3D

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.

Sample	Predicted as 0	Predicted as 60	Predicted as 80	Predicted as 90	Predicted as 100	Class error
Is 0 (0 B/100H)	32	0	0	0	0	0.0
Is 60	0	30	***2***	0	0	0.0625
Is 80	0	***3***	26	2	0	0.161
Is 90	0	0	0	28	3	0.0968
Is 100	0	0	***1***	4	27	0.156

USE CASE 4; pork vs poultry

Food Control 125 (2021) 108002

Contents lists available at ScienceDirect

Food Control

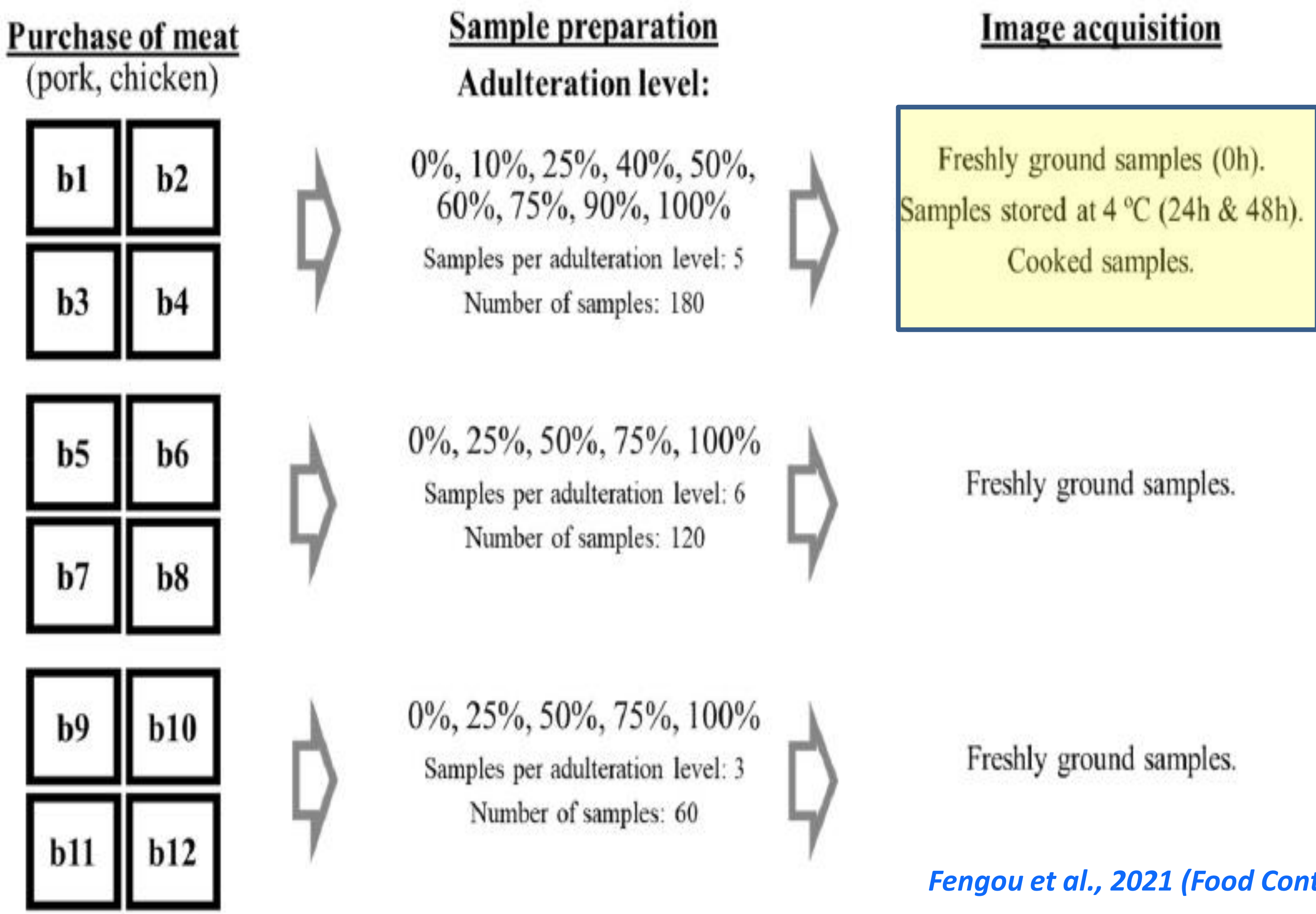
journal homepage: www.elsevier.com/locate/foodcont

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



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%).

	Predicted class			
True class	0%	A	100%	Recall (%)
0%	14	0	0	100.00
A	0	62	0	100.00
100%	0	3	11	78.57
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 4º 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

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

Summarizing …

Type of sensor	Food type	Purpose	Number of samples	Data analysis	Reference
FTIR, MSI	minced beef	Detection of frozen-then-thawed minced beef labelled as fresh.	105	PLSDA, SVM	Ropodi et al., 2018
MSI	beef vs. horsemeat	Minced beef adulteration with horsemeat, as well as model performance during storage in refrigerated conditions.	110 (350 images)	PLSDA, RF, SVM	Ropodi et al., 2017
MSI	beef vs. pork	Minced beef fraudulently substituted with pork and vice versa.	220	PLSDA, LDA	Ropodi et al., 2015

Summarizing …

Type of sensor	Food type	Purpose	Number of samples	Data analysis	Reference
MSI	pork vs. chicken	Detection of meat adulteration in fresh, stored, and cooked meat.	360 samples/images (fresh) 180 images (stored) 180 Images(cooked)	SVM	Fengou et al., 2021 (Food Control)
MSI, Vis, Fluo	pork vs. chicken & beef vs. offal	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.	120 samples pork vs. chicken 120 samples beef vs. offal	PLS transformed spectral data, SVM	Fengou et al., 2021 (foods)

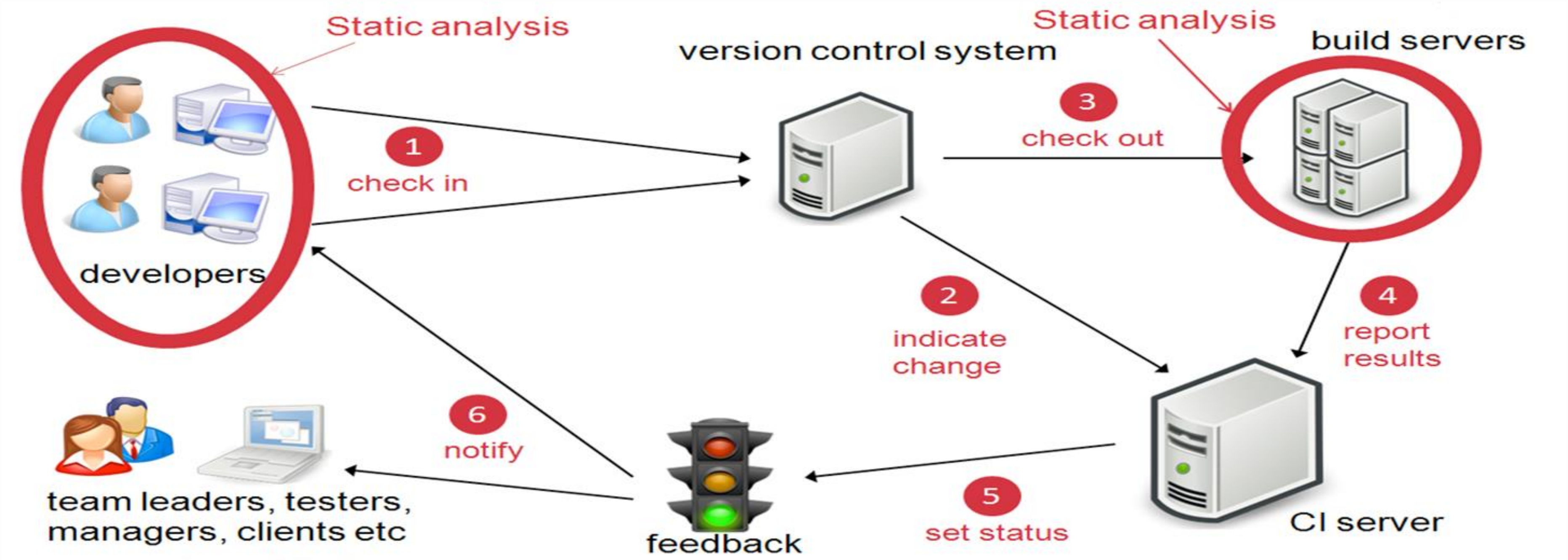
Future Tools

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



Tsakanikas, et al.,(2020) A machine learning workflow for raw food spectroscopic classification in a future industry. Scientific Reports 10:10:111212
Nychas et al (2021) Data Science in the Food Industry. Annual Review of Biomedical data Science https://doi.org/10.1146/annurev-biodatasci-020221-123602

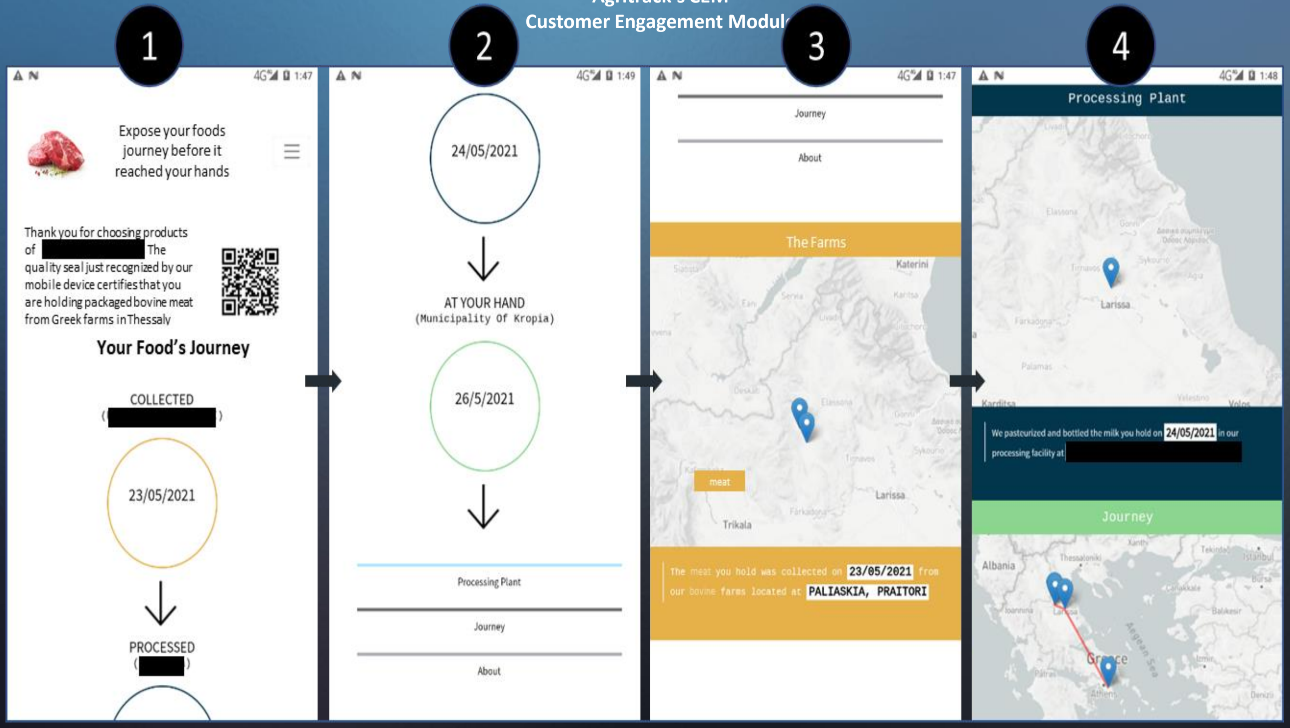
PAT's Tools; (c) ICT

MeatTrack
DEMOCRATIZING TRACEABILITY AND QUALITY

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

Ledger Based Certificate

Agritrack's CEM
Customer Engagement Module



Note:
Product specific details removed

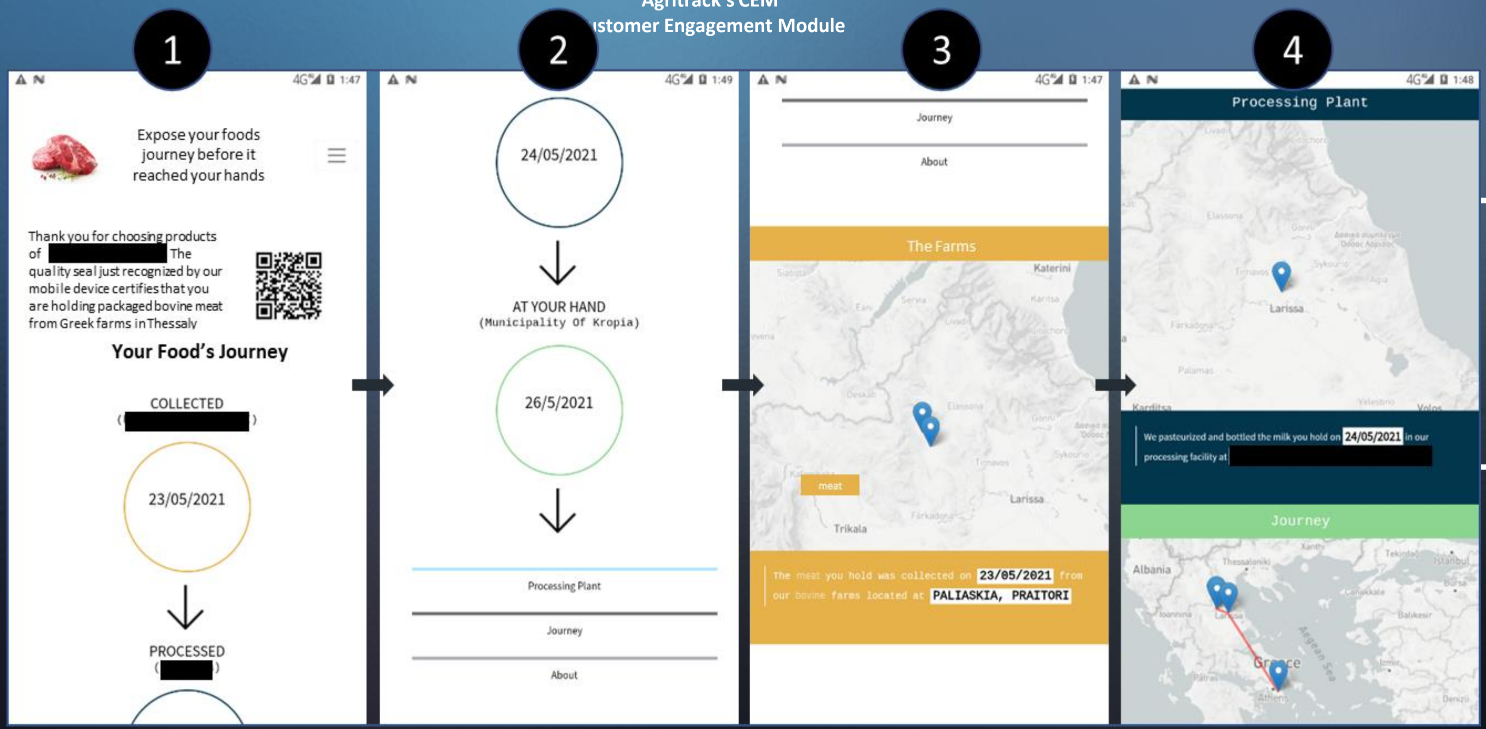
PAT's Tools; (c) ICT

QUALITY FROM FARM TO FORK

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

Ledger Based Certificate

Agritrack's CEM
ustomer Engagement Module



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

1. **Ropodi, A. I., Pavlidis, D. E., Mohareb, F., Panagou, E. Z., & Nychas, G. J. (2015). Multispectral image analysis approach to detect adulteration of beef and pork in raw meats. *Food Research International*, *67*, 12-18.**
2. **Ropodi, A. I., Panagou, E. Z., & Nychas, G. J. E. (2017). Multispectral imaging (MSI): A promising method for the detection of minced beef adulteration with horsemeat. *Food Control*, *73*, 57-63.**
3. **Ropodi, A. I., Panagou, E. Z., & Nychas, G. J. E. (2018). Rapid detection of frozen-then-thawed minced beef using multispectral imaging and Fourier transform infrared spectroscopy. *Meat science*, *135*, 142-147.**
4. **Fengou, L. C., Tsakanikas, P., & Nychas, G. J. E. (2021). Rapid detection of minced pork and chicken adulteration in fresh, stored and cooked ground meat. *Food Control*, *125*, 108002.**
5. **Fengou, L. C., Lianou, A., Tsakanikas, P., Mohareb, F., & Nychas, G. J. E. (2021). Detection of Meat Adulteration Using Spectroscopy-Based Sensors. *Foods*, *10*(4), 861.**

SPOILAGE; Beef, Pork, Poultry,

- Ammor, et al. (2009)– "Rapid Monitoring of the Spoilage of Minced Beef Stored Under Conventionally and Active Packaging Conditions Using Fourier Transform Infrared Spectroscopy in Tandem with Chemometrics" Meat Science 81, 507-515
- Argyri, et al (2010) Rapid qualitative and quantitative detection of beef fillets spoilage based on Fourier transform infrared spectroscopy data and artificial neural networks 20/7 Sensors and Actuators B 145, 146-154
- Panagou et al. (2011). A comparison of artificial neural networks and partial least squares modelling for the rapid detection of the microbial spoilage of beef fillets based on Fourier transform infrared spectral fingerprints. Food Micro 28, 782-790
- 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
- Argyri, et al.(2013) A Comparison of Raman and FT-IR Spectroscopy For The Prediction of Meat Spoilage. Food Control 29, 461-470
- 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
- Fengou, et al. (2019) Estimation of Minced Pork Microbiological Spoilage through Fourier Transform Infrared and Visible Spectroscopy and Multispectral Vision Technology, Foods (MDPI) 8,238 doi:10.3390/foods8070238

DATA SCIENCE

- Ropodi, A, E.Z. Panagou and G.-J. E. Nychas (2016) Data mining derived from Food analyses using non-invasive/non-destructive analytical techniques; Determination of Food authenticity, quality & safety in tandem with Computer Science Disciplines, Trends in Food Science & Technology 50,11-25

- Mohareb, F., Iriondoa, M., Doulgeraki, A.I, Van Hoekc, A., Aarts, H., Cauchia, M, and Nychas, G-J (2015) Identification of meat spoilage gene biomarkers in *Ps. putida* using gene profiling, Food Control 57, 152-160

- Fengou, L-C., Mporas, I., Syrelli, E., Lianou, A., Nychas, G-J (2020) Estimation of the Microbiological Quality of Meat Using Rapid and Non-Invasive Spectroscopic Sensors IEEE Access - DOI 10.1109/ACCESS.2020.3000690

- Nychas, G., Sims, E., Tsakanikas, P., Mohareb, F. (2021) Data Science in Food Industry. Annual Rev. in Biomedical Data Science (Nature Series) In press

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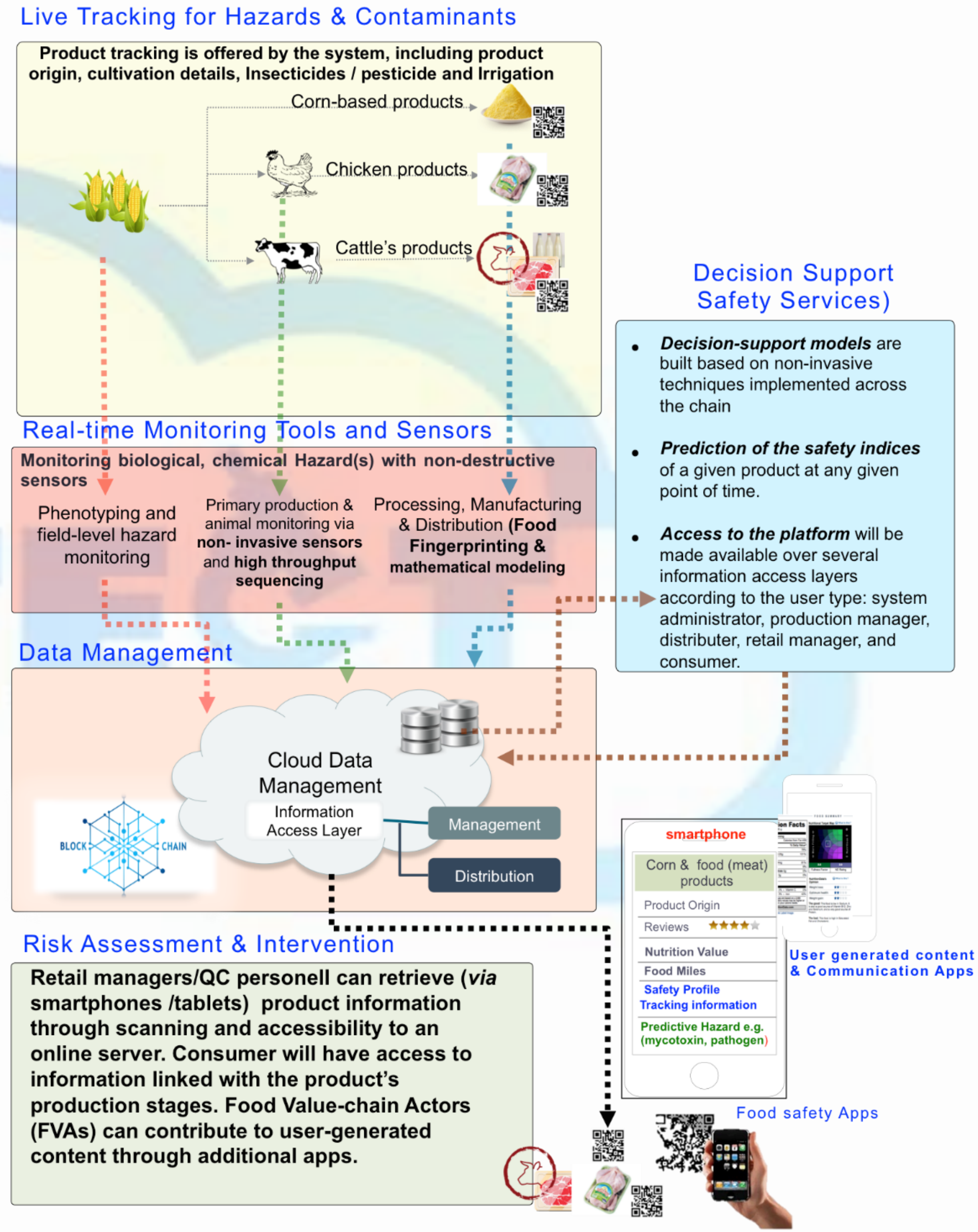


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AGRITRACK

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

THANKS FOR YOUR ATTENTION

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