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Bio-digitalization strategies of the Mediterranean Food Supply Chain to enhance Food Integrity and Shelf-life through Predictive and Cloud-based Tools

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MEDIFIT Overview

MEDIFIT is a consortium partnership of 12 entities consisting of 7 enterprises (retailers, SMEs, big industry), 3 academic organizations, 2 authorities.

The overall objective of MEDIFIT is to enable traceability and authenticity control of traditional Mediterranean foods using latest analytical and software technologies.

The focus is on high added value Mediterranean products, honey and cheese, which hold nutritional value and are important for biodiversity conservation.

MEDIFIT develops and demonstrates a flexible, modular and standards-based software framework that provides end-users the necessary communication interfaces and web-based software solutions facilitating the implementation of innovative non-targeted analytical methods for assessing food traceability and integrity.

BIOFRESHCLOUD Overview

BIOFRESHCLOUD is a consortium partnership of 6 entities consisting of 2 enterprises (retailers, SMEs), 4 academic organizations.

BioFreshCloud develops an integrated, innovative, and eco-friendly approach to assess optimal shelf-life and minimize food losses of strawberries and tomatoes produced in the Mediterranean region, by combining food bio-preservation technologies, food modelling, and Food Cloud tools.

Bio-preservation strategies are developed based on a circular and bioeconomy approach, by up-cycling crop residues of both produces to sustainable and biological solutions applicable to these same products and enhance their shelf-life.

Predictive models are a cornerstone in the project aimed at estimating food quality and safety for strawberry and tomato and integrated into the optimization of bio-preservation strategies by considering their effect.

The final BIOFRESHCLOUD goal is to incorporate this bio-digital and multidisciplinary approach into a cloud-based platform to enable end-users to manage shelf-life dynamically along the food supply.

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SYMPOSIA: New advances in food safety and quality of honey

The sensory analysis applied to the authentication of honeys

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Sensory analysis is the examination of a product through the evaluation of the attributes perceptible by the sense organs, such as colour, odour, taste, aroma, and texture. It allows to establish the sensory profile of diverse foods and can be useful in knowing how they are perceived by the consumer. Nowadays, the sensory analysis constitutes an essential basis for the determination of food quality. It is an indispensable and complementary part of the traditional laboratory physico-chemical analysis.

In particular, sensory evaluation becomes important in verifying the authenticity of honeys, since it can reveal the presence of botanical components not picked up by other analytical systems (physicochemical and melissopalynological). Unfortunately, it does not exist an international legislation that combines these three types of needed analyses to authenticate the honey (pollinic, physico-chemical and sensory analysis).

Recently, the European Commission concluded that the chemical and biological characteristics of genuine honeys should be generated and stored in a publicly available database. This process would require obtaining samples by authorized personnel from carefully selected honey producers. Also, the private sector mentioned that the authenticity of a sample will have to be defined beforehand. In this sense, the sensory profiles of the unifloral honeys from different botanical and geographical origin should be studied and introduced in this publicly available database.

Key role of melissopalinology on honey authentication and quality control

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Melissopalynology is a branch of palynology (study of pollen and spores) based on the analysis of pollen grains (melliferous and non-melliferous) and honeydew elements present in honey. Pollen analysis is carried out by subjecting honey sediment to microscopic analysis. Under the microscope, pollen grains and honeydew elements are identified and counted. The number of pollen grains in honey is based on the floral source honey comes from. However, it is also influenced by different factors such as the morphology and physiology of the flower, aspecs related to the behavior of bees while foraging, and the degree of contamination of the bee colony.

Melissopalynological analysis allows honey quality control by providing some important information about both honey botanical and geographical origin, adulteration and frauds, honey extraction methods, etc.

The identification and counting of pollen grains under the microscope require time (30minutes-1hour/sample) depending on the complexity of the pollen spectrum. Another matter is the classification of honey as unifloral or multifloral, as all flowers do not provide honeybees with the same amount of pollen, the production of pollen depends on the plant itself. In some cases, according to this production, pollen types are classified as under-represented pollen or as over-represented pollen.

Furthermore, an agreed international standard is needed when it comes to define unifloral honey types based on the required percentage of pollen counting. There is no well recognized consensus so, finally laboratories clasify honeys according not only to pollen analysis but also sensory and physico-chemical analysis.

Volatile and semivolatile compounds in honey and influence of chemical extraction and gastrointestinal digestion of honey on its antioxidant, antimicrobial and anti-inflammatory activities

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To characterize honeys from different botanical origins produced in Castilla y León (Spain) according to their melisopalynological analysis, study of volatile and semi-volatile compounds, phenolic compounds and their biological properties. To study the effect of different extractions, chemical and physiological (in vitro digestion) on these phenolic compounds and biological properties.

Volatile and semivolatile honey compounds were analyzed after solvent extraction with ethyl acetate and final GC-MS determination. 231 volatile and semi-volatile substances were identified in the 30 studied samples and some compounds were proposed as markers for some of the botanical origins of the samples (heather, chestut, bird's-foot trefoil, honeydew and “forest” honeys).

The effect of chemical extraction and in vitro digestion of different kinds of honey on biological activities (antioxidant, antimicrobial and anti-inflammatory) was investigated. The antioxidant activity was evaluated against three radicals (ABTS•+, ROO•, •OH), and the antimicrobial activity was studied against five bacteria (Staphylococcus aureus, Listeria monocytogenes, Escherichia coli, Streptococcus mutans and Pseudomona aeruginosa) and one yeast (Candida albicans). The results show that in comparison with raw honeys, the methanolic extracts exhibited lower values for antioxidant activity and higher anti-inflammatory and antimicrobial activities against L. monocytogenes. The digested honeys showed higher antioxidant activity than the pre-digested honeys, as well as higher antimicrobial activity against S. aureus and L. monocytogenes, which underlines the possible antioxidant and antimicrobial effects of honey in the human body after the digestion process.

With the set of the 30 aromatic fingerprints an aromatic profile consisting of 231 volatile and semi-volatile substances was elaborated and some compounds were proposed as markers for botanical origins. Heather honeys showed the highest values of antioxidant, anti-inflammatory and antimicrobial activity. Methanolic extracts showed a lower antioxidant and antimicrobial activity (except L. monocytogenes) but higher anti-inflammatory activity than crude honeys. The soluble fraction after in vitro digestion showed a higher antioxidant and antimicrobial activites against S. aureus and L. monocytogenes but lower anti-inflammatory activity.

Gas chromatography proved to be a suitable technique for the determination of the profile in volatile and semi-volatile compounds, obtaining an aromatic fingerprint for each honey and obtaining markers for some botanical

origins. Methanolic extracts obtained from honey due to their anti-inflammatory activity can be useful in the fields of cosmetics and pharmacy.

The challenge of making a healthy and tasty honey powder with a clean label

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To set up reliable procedures to make powdered honey with the maximum possible quantity of honey and the minimum possible quantity of carriers of natural origin, avoiding further addition of anti-caking agents. Thus, the resulting honey powders can be labelled as “Clean Label” and “Real Food”

Three ling-heather (Calluna vulgaris (L.) Hull) honeys were dried. Three drying techniques (spray-drying, vacuum drying and freeze-drying), and three natural carriers (Arabic gum, whey protein isolate and potato maltodextrin) were researched (URL: https://doi.org/10.1016/j.lwt.2021.112063). Spray drying was carried out in open-cycle system, with 120±1 ◦C air inlet temperature, and 67.5±2.5 ◦C air outlet temperature, maintaining the air flow rate at 50 mm. Vacuum drying was carried out at 60 ◦C and 100 mbar for 24 h. Freeze-drying was carried out by previously freezing the samples at -30 ◦C for 5 h, and thereafter at -80 ◦C for 24 h. Finally, samples were subjected to freeze drying at 0.112 mbar for 3 days. After drying and cooling (in the case of spray drying and vacuum drying), powdered honeys were grounded and stored away from humidity in glass jars at 4 oC without the need to add anti-caking agents. The highest quantity of honey in the dried product that could be pulverized was 50% using spray drying, 60% using vacuum drying, and 75% using freeze-drying. The highest recoveries were obtained by vacuum drying and freeze-drying. Maltodextrin provided honey powders with the lowest moisture and hygroscopicity, and the highest solubility. Both vacuum dried and freeze-dried honeys exhibited the best visual, olfactory, gustatory and gustatory–olfactory perceptions.

Honey can be efficiently dried by vacuum drying and freeze-drying, only using maltodextrin as carrier. Vacuum dried and freeze-dried honey powders contain a high quantity of honey, showing excellent sensory characteristics.

Powdered honey obtained by vacuum drying and freeze-drying using maltodextrin as carrier, can be preserved at a low temperature with no anti-caking agents, so that it can be labelled as “Clean Label” and “Real Food”, satisfying the most demanding customers and markets.

SYMPOSIA: Biofreshcloud tools for enhancing shelf-life of vegetables products

Novel predictive models and biopreservation innovations aimed at prolonging the freshness and safety of fresh produce

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The BiofreshCloud project brought together food stakeholders from different countries to develop tools and sustainable strategies aimed at extending the shelf-life of fresh produce. In addition to compiling a series of predictive models available in the scientific literature to describe microbiological and physicochemical changes in these crops, various assays have been conducted to gather data for the development of novel models. The project also evaluated innovative and sustainable food packaging systems.

The effects of the storage temperature and water activity (a_w) of a simulated strawberry medium on the probability of *Botrytis cinerea* germination have been assessed, considering that this fungus is the main responsible for the pre- and post-harvest losses of strawberries. The germination data was further modelled by using a reparametrized asymmetric model to estimate germination parameters, while secondary cardinal models were used to describe the effects of a_w on the germination parameters. Regarding biopreservation innovations, the effects of a Raspberry-lignocellulosic nanofibers (Raspberry-LNFB) coating on the physicochemical characteristics of strawberries over their storage have been assessed by using both traditional methods and image analysis.

B. cinerea germination was highly affected by a_w as shown by the developed models. At 20°, which is the optimum *B. cinerea* germination temperature, increasing a_w from 0.92 to 0.99, decreases germination times and increases germination rates. Temperatures ranging from 15 to 25 °C do not affect the germination probability at high a_w values (≥ 0.98). With respect to coating application for strawberry preservation, lower size loss (%) and weight loss (%) of coated fruit were observed compared to control and uncoated from the 10^{th} day of storage. Additionally, lower colour changes were observed in coated fruit compared to the control. However, fungal damage increases significantly from the 9th storage day and did not differ between coated and uncoated fruit.

The models developed and compiled within the BiofreshCloud project are useful tools to define process parameters that assure an extended shelf-life of strawberries. The results of coating application can be useful for the optimization of coating formulations that aim to extend the shelf-life of strawberries by reducing fungal germination and damages, without causing significant changes to their physicochemical parameters. These results/models will be available in open access tools.

Development and application of non-target methods in the shelf-life assessment of tomato and strawberry

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The FAO reports that globally, approximately 33 % of produced food for consumption is either wasted or lost. The fruit and vegetable industry is considered the biggest contributor to global food losses and wastes, and reducing them and extending shelf life are current challenges.

This study aimed to assess the dynamic shelf life of tomatoes and strawberries across the production-distribution chain, employing quality and microbiological models within realistic storage conditions.

Innovative methodologies, including image analysis and Vis-NIR technology, were utilized to evaluate fruit quality under different time, temperature, and relative humidity scenarios during food chain stages such as harvesting, warehouse storage, packaging, distribution, and retail. Employing a stochastic approach, the study estimated shelf life by utilizing collected data as inputs for predictive models capturing changes in quality attributes (e.g., weight loss, appearance) and microbial populations (e.g., spoilage and foodborne pathogens) throughout storage. Shelf life models, based on appearance scores ranging from 1 to 5, were developed for tomatoes and strawberries. Physicochemical and predictive microbiology models were validated and refined with experimental data before being implemented in the MicroHibro software.

The holistic integration of non-target methods, quality, and microbiological models in evaluating the shelf life of tomatoes and strawberries signifies a comprehensive approach, notably contributing to waste reduction in postharvest stages.

The capacity to predict the dynamic shelf life of these fruits based on storage conditions and initial quality facilitates the development of more efficient strategies for reducing food waste and increase food safety. This method can be a valuable tool for the food industry to minimize food losses and ensure optimal fruit quality for consumers.

Hyperspectral Imaging and Pattern Recognition for Detecting Adulteration in Goat Cheese Samples

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Economically motivated adulterations (EMA) in food products, including addition, dilution, substitution, simulation, and mislabelling, are concerning due to their potential economic gains. Goat milk and its products, for instance, have usually higher prices due to their seasonal availability, being prone to adulteration. In fact, dairy products are commonly targeted, with European Commission reports highlighting dairy as one of the most adulterated food types. This research aimed to map and estimate adulterant concentrations in cheese samples, evaluate the performance of Partial Least Squares (PLS) and Multivariate Curve Resolution-Alternating Least Squares (MCR-ALS) models, and assess food authenticity using non-invasive spectroscopic methods. For that, original goat cheese samples were adulterated with two adulterants: cow cheese and palm oil. Different ratios of two types of cow cheese (25%, 50%, and 75%) and one type of palm oil (10%, 30%, and 50%) were mixed, resulting in 27 adulterated and 6 pure samples. Spectral images were obtained using the FX10 hyperspectral system (Specim, Finland) with a spectral resolution of 5.5 nm, spectral sampling per pixel of 2.7 nm, and a spectral range of 400 to 1000 nm (VNIR). The data was preprocessed using Savitzky-Golay 1st derivative. Differences among original goat cheese and cow cheese was detectable around 500 nm, while palm oil was detectable around 930 nm. PLS models for palm oil showed one latent variable, with R^2 = 1.0, and RMSEP = 4.2%. MCR-ALS models for palm oil showed two components, with R^2 = 0.95 and RMSEP = 16.2%. For cow cheese, PLS models had one latent variable, with R^2 = 0.96 and RMSEP = 4.3%. MCR-ALS models for cow cheese had two components, with R^2 = 0.27 and RMSEP = 28.0%. PLS provided better models and predictions for both adulterants, while MCR-ALS offered better distribution maps despite higher errors. Additional samples and augmented data could enhance model performance. While the proof of concept demonstrates the method's potential, further refinement of training and prediction sets is necessary before implementation.

SYMPOSIA: Hands-on session on MEDIFIT digital solutions

EPCIS 2.0: A Symphony of Connection, Visibility, and Traceability

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Modern global supply chains face challenges that demand clear visibility and efficient tracking. Our presentation, titled "EPCIS 2.0: A Symphony of Connection, Visibility, and Traceability," delves into the newly released Electronic Product Code Information Services (EPCIS) 2.0. This updated system stands out as a powerful tool that aids businesses in keeping a close eye on their products and in effortlessly connecting diverse data points throughout their journey.

One of the standout features of EPCIS 2.0 is its embrace of modern data structures and communication methods. The inclusion of JSON Linked Data and RDF (Resource Description Framework) ensures richer, structured data representation, enabling effective and intuitive data interchanges. This not only facilitates easier data integration but also promotes interoperability across various systems in the supply chain. Furthermore, its RESTful service API enhances communication with external systems, ensuring real-time tracking and updates.

The true strength of EPCIS 2.0 is revealed in its compatibility with the Internet of Things (IoT). Beyond the traditional monitoring of temperature for temperature-controlled goods, its sensorReport function can accommodate a broad spectrum of measurements. This includes detailed analytical lab results, such as spectroscopy readings, chemical compound analyses, and even counts of biological organisms. The depth and breadth of these capabilities are virtually limitless. In the context of food safety and authenticity, such detailed data is not merely advantageous—it's essential. With these capabilities, EPCIS 2.0 offers stakeholders unparalleled insight into products, ensuring that what they're handling, selling, or consuming is of the highest quality and genuine provenance at every stage of the supply chain.

Developing a Web-Based Solution for Executing Predictive Models: Harnessing FSKX and Singularity Containers

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FSKX (Food Knowledge Exchange Format) is a standard used to share scientific models that include data, metadata, and execution code. Our aim is to distribute these models globally and provide a dependable method to perform simulations. In the past, users had to replicate the precise environment needed for the models, such as installing specific R versions and finding compatible libraries—challenges even for centralized services like the one provided by the BfR (German national institute for risk assessment).

To manage the diverse and complex models, we turned to containerization technologies like Sylabs Singularity, Docker, and Podman. These tools can create distinct runtime environments for each model.

We propose to develop a web service, hosted in the cloud, that automatically crafts a container with all necessary software and libraries to run a specific FSKX model. On demand, the service will launch this container with user-defined parameters to execute the simulation and provide results, then discard the container post use. This solution is built to accommodate an unlimited variety of FSKX models without software conflicts.

The FSKX Runtime Service offers an API, enabling applications to add new models or execute simulations in their designated containers. It also integrates with the EPCIS 2.0 (https://openepcis.io/docs/) event repository by adopting established communication protocols for information sharing.

EPCIS 2.0 allows for the capture and dissemination of information regarding events such as the availability or simulation of a model.

A subscription service is central to EPCIS 2.0. Users can set queries and endpoints to receive automatic updates when new events meet their criteria.

The FSKX Runtime Service utilizes this subscription model. It automatically sets up queries and endpoints when a new model is registered, allowing automatic model execution based on received events.

Leveraging EPCIS events simplifies the communication between applications and the FSKX Runtime Service, enabling external partners to build applications without deep knowledge of the API or its current location. Control over shared information is retained by the original sharers, while the EPCIS repository acts as a persistent database for FSKX models, including their simulations and results.

MicroHibro: FSKX in EPCIS integration for advanced food safety and quality management

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MicroHibro is a web-based tool crafted to enhance food quality and safety. Developed by the PAID AGR-0170 (HIBRO) team at the University of Córdoba (Spain), it has garnered support from various regional, national, and international projects. This tool seeks to overhaul the management of food safety and quality, providing assistance to industries, researchers, and official food control agents. Beyond its practical applications, MicroHibro serves as an educational resource, simplifying the dissemination of fundamental concepts in predictive microbiology and Quantitative Microbial Risk Assessment (QMRA).

The tool comprises a substantial database housing diverse predictive models based on various food matrices and environmental conditions. These models are accessible to different users, addressing a key challenge faced by the food industry and control agents—ensuring access and verification of information related to these models. To tackle this challenge, Microhibro addresses it by sending growth models and predictions as standardized events to the EPCIS repository in the FSKX format. This approach ensures transparency, accessibility, and provides actionable insights for authorized food control agents.

Microhibro does not just function as a predictive microbiology tool; it can act as a bridge between the food industry and regulatory authorities. Its integration with the EPCIS repository, coupled with advanced search and modeling capabilities, revolutionizes the approach to food safety and quality control. Microhibro guarantees transparency, accessibility, and verification, establishing itself as a trusted partner in safeguarding the safety and quality of food products. The presentation concludes with an invitation to witness Microhibro's groundbreaking technology in action, emphasizing its role as a reliable ally in the pursuit of food safety and quality.

SESSION 1: Innovative authentication analytical methods

Oral Sessions

H-NMR fingerprinting of food and beverages under signal suppression conditions – data quality assurance and quantitation

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Aims: Developing and evaluating protocols for non-targeted analysis of the chemical composition of complex compound mixtures using NMR. We particularly focus on establishing protocols for the analysis of intact food and beverages. Assessing the effects of analyzing samples under signal suppression conditions. Automating methods for estimating performance stability during data acquisition and processing. Constructing methods for signal processing for compound quantitation.

Methods and Results: In a multi-year project, we periodically analyze by NMR several reference samples in a row. Each sample is a mixture of several compounds. Using a combination of vendor and Python in-house developed data processing computer code, we produced a data matrix of signal intensities (peak integrals). Scatterplots of integrals *vs*. measurement date showed an overall trend towards decreasing integral values over the years. One explanation for this data tendency is that instrument sensitivity drops as the NMR spectrometer ages. In intact food and beverages, water is the most abundant molecule. In specific matrices like wine, additional molecules like ethanol are present at concentrations much higher than most of the other metabolites detected by NMR. In spectra of these samples the detection and correct qualitative and quantitative characterization of compounds is problematic. The solution to this problem in removing (suppressing) signals of molecules like water or ethanol during spectra acquisition. However, this method has the disadvantage that the absolute quantitation properties that make NMR a primary quantitation technique are lost. By analyzing the signals in the spectra of the reference samples, we provide a detailed, molecular structure-based interpretation of the analyte–water adduct supramolecular properties. This interpretation provides a theoretical, mechanistic framework that can be extended to other compound matrices for the proper processing of NMR spectra. We combined the results from the periodic measurement of our reference samples with the restauration of the absolute quantitative properties of NMR to determine the absolute concentration of metabolites in beverages.

Conclusions: Periodically measuring our reference samples allow us, after data processing, to evaluate measurement stability over a multi-year period. By checking for results comparability across time, we can evaluate for data quality stability. Furthermore, using the same reference sample spectra, we can perform compound quantitation without requiring the addition of external or internal standards to food or beverage samples.

Significance and Impact of the Study: One-dimensional nuclear magnetic resonance spectroscopy is an effective technique for the non-targeted

analysis of the chemical composition of complex compound mixtures. The methods we develop at BfR have broad applicability for the analytical chemists community working with food and beverages. Our methods can help improve results reliability and exchangeability between laboratories.

Acknowledgement: This work is supported by the PRIMA programme under grant agreement No 1932, project MEDIFIT (Call 2019 Section 1 Agrofood IA).

Development and application of non-target methods in the shelf-life assessment of tomato and strawberry

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Aims: This study aimed to assess the dynamic shelf life of tomatoes and strawberries within the production-distribution chain, employing quality and microbiological models under realistic storage conditions.

Methods and Results: Innovative techniques were utilized to evaluate product quality. Image analysis and Vis-NIR techniques were developed and implemented for fruits stored under varying time, temperature, and relative humidity conditions. The study encompassed critical logistical stages, including harvesting, warehouse storage, packaging, distribution, and retail. To estimate the shelf life of strawberries and tomatoes, a stochastic approach was employed, utilizing the collected data as inputs, along with predictive models describing changes in quality attributes (e.g., weight loss, appearance) and microbial populations (e.g., spoilage and foodborne pathogens) during storage. Shelf life models for tomatoes and strawberries were constructed based on appearance scores ranging from 1 to 5. Additionally, physicochemical and predictive microbiology models were developed for risk assessment, rigorously validated, and refined using experimental data. Finally, these models were implemented in MicroHibro software.

Conclusions: The development and application of non-target methods in assessing the shelf life of tomatoes and strawberries, alongside the utilization of both quality and microbiological models, present a novel and comprehensive approach to evaluating the quality and safety of these fruits. This approach contributes significantly to waste reduction in postharvest stages.

Significance and Impact of the Study: The dynamic shelf life of these fruits can be predicted based on storage conditions, such as temperature and relative humidity, as well as the initial quality of the produce. This knowledge can lead to the development of more effective strategies for reducing food waste and enhancing food safety, benefiting consumers and the environment.

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SESSION 1: Innovative authentication analytical methods

Poster Sessions

Non-targeted spectroscopic analysis of Mediterranean honey for adulteration detection – low-tech vs. high – tech analytical methods

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Aims: Honey is a natural food product that is very popular with consumers and achieves high sales prices. From the perspective of the consumer, the quality and safety of the product is related to its authenticity. A growing number of honey adulterations has been identified in recent years, raising concerns about the authenticity of honey with regard to its botanical or geographic origin as well as adulteration by the addition of sugar. Testing for honey authenticity is important for both regulatory and commercial reasons to reduce common honey fraud, such as false statements or adulteration with additional sugars. Many methods of authentication are well established and have proven to be successful for years, but are time-consuming and not sufficient for the wide range of fraud possibilities. Stable isotope mass spectrometry (IRMS) is suitable for detecting adulteration with sugars from C4 plants, such as sugar cane. The application of IRMS for adulteration with sugars from C3 plants is sophisticated, and new techniques of detection are required. Non-targeted analytical methods are promising methods for authenticity testing of honey. They can be used to determine the geographical and botanical origin or adulteration of sugars from other sources. Non-targeted methods have several advantages over established methods: short acquisition time, non-destructive measurement, and simple sample preparation. The major benefit, though, is that adulterations or false declarations that were previously undetected and unsearched for might be found.

Methods and Results: The investigated honey samples were obtained from project partners in the Mediterranean region as part of the EU project for an Interlinked Digital Platform for Food Integrity and Traceability of relevant Mediterranean Supply Chains (Medifit). The honeys were measured and evaluated by 1H nuclear magnetic resonance spectroscopy (NMR), ATR infrared spectroscopy (FTIR-ATR), dispersive Raman spectroscopy and near infrared spectroscopy handheld SCiO (NIR). The various spectroscopic techniques were taken into account separately but also merged to create models that are more significant. Multivariate statistics and machine learning methods were used to assess the recorded spectra in connection to the botanical and geographic origins as well as the addition of foreign sugars.

Conclusions: The preliminary findings indicate that while low-tech approaches can also give suggestions in advance, high-tech methods are most suited for the detection of adulteration.

Acknowledgement: This work is supported by the PRIMA programme under grant agreement No 1932, project MEDIFIT (Call 2019 Section 1 Agrofood IA).

Discrimination of mediterranean honeys based on their botanical and geographical origin using uv-vis spectroscopy and chemometrics

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Aims: Both the botanical and the geographical origin of honey have a significant impact on its quality characteristics, including specific sensory attributes and nutritional value. The aim of the present study was to differentiate Mediterranean honey samples with regards to their botanical and geographical origin, using UV-vis spectroscopy, combined with multivariate statistical analysis.

Methods and Results: A total of 151 commercial honey samples, and specifically thyme, pine, and polyfloral honeys, were gathered from different Mediterranean countries (Greece, Malta, Spain, Tunisia, and Turkey). For all samples, UV-vis spectra were acquired using a UV-vis spectrometer (UV-1700 spectrophotometer, Shimadzu Corporation, Japan) in the range of 190 – 900nm, after appropriate dilution. After spectra pre-processing, Principal Component Analysis (PCA) was used for dimensionality reduction and then Random Forest (RF), Partial Least Squares – Discriminant Analysis (PLS – DA), and Data Driven – Soft Independent Modelling of Class Analogies (DD-SIMCA) was utilized for the classification using the spectral range of 220 – 550 nm. The successful differentiation of both geographical and botanical origins was accomplished, with an accuracy over 90% for most models.

Conclusions: The results confirmed that UV-vis spectral data combined with chemometrics could be successfully used to predict the botanical and geographical origin of honeys.

Significance and Impact of the Study: The findings of the study point out that UV-vis spectroscopy has great potential for determining the geographical and botanical origin of Mediterranean honeys in a quick and non-destructive manner, as also having the advantage of being simple, inexpensive, and fast.

Acknowledgments: This research is part of the PRIMA programme. Grant agreement No 1932, project MEDIFIT (Call 2019 Sec. 1 Agrofood IA).

Application of FTIR spectroscopy for the detection of honey adulteration

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Aims: Honey has been characterized as a functional food, having high commercial value and, therefore, it is a target for adulteration worldwide. The objective of the present study was to detect the honey adulteration with sugar syrups and colorants using FT-IR spectroscopy combined with multivariate statistical analysis.

Methods and Results: A total of 213 honeys were used, including 155 commercial honey samples (thyme, pine, and polyfloral honeys) collected from different countries of Mediterranean (Greece, Malta, Spain, Tunisia, and Turkey) and 58 adulterated Greek thyme honey samples by adding syrups and colorants. For all samples, FTIR spectra were acquired using a Jasco FTIR 6700 spectrophotometer equipped with a 3-reflection ATR diamond in the region of 4000 – 400 cm-1. Regarding spectra pre-processing, different algorithms were evaluated, such as smoothing with Savitzky-Golay, standard normal variate (SNV), Savitzky-Golay first and second derivative. Principal Component Analysis (PCA) along with Random Forest (RF) and Data Driven-Soft Independent Modelling of Class Analogies (DD-SIMCA) were used to detect the adulterants in the honey samples. Both one-class (DD-SIMCA) and multi-class (RF) classification methods produced good results, achieving an accuracy over 90% for most models.

Conclusions: The results demonstrated that FTIR spectra combined with chemometrics could be used for the detection of honey adulteration with the addition of sugars and colorants.

Significance and Impact of the Study: The findings of the present study will help improve the design of a rapid authentication system for determining the adulteration of honeys which is very important in order to protect the consumers.

Acknowledgments: This research is part of the PRIMA programme.
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Application of bacteriophages for the biocontrol of *Salmonella Typhimurium* in natural casings used for traditional fermented meat products

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Aims: The study aimed to investigate the application of bacteriophages for the biocontrol of *Salmonella Typhimurium* in natural pork casings used for traditional fermented meat products at different temperatures.

Methods and Results: Samples of natural pork casings were cut into 2 × 2 cm2 pieces and rehydrated with three consecutive washes in sterile distilled water. Subsequently, the samples were drained and inoculated with ca. 4.54 × 106 cfu/g of *S. Typhimurium* CECT4594. Then, the samples were immersed in sterile distilled water to simulate a new washing process containing a commercial solution of SALMONELEXTM lytic bacteriophages with ca. 9.22 × 109 pfu/mL. The samples were homogenized for 10 s in the phage-containing solution, then drained again and stored at 10 and 25 °C for 48 h. *Salmonella* viable cells and phage concentration were determined in the natural pork casings and the simulated washing water. Control samples were prepared by inoculating the pathogen or phages individually. Experiments were performed in duplicate. At 10 °C, a reduction of 1.15 log in *Salmonella* was observed in the casing after washing in the phage-containing solution after 48 h. In the washing water, the pathogen concentration remained ca. 1.22 log during the 48 h. At 25 °C, washing the casings with phage solution was unable to reduce *Salmonella* count, reaching ca. 9.01 × 107 cfu/g after 48 h. In the washing water, a slight reduction of the pathogen was observed (> 0.5 log) during the first 2 h, but an increase in the pathogen concentration was observed during the remaining storage period, reaching 1.52 × 104 cfu/mL. At both studied temperatures, the concentration of phages in the casings and in the wash water remained ca. 9 × 109 pfu/g/mL, as well as for the control samples. On the other hand, at 25 °C, pathogen growth was observed in control samples, reaching ca. 1.05 × 108 cfu/g.

Conclusions: Washing the natural pork casings with SALMONELEXTM demonstrated efficacy in reducing *Salmonella* at 10 °C in 48 h, while at 25 °C washing process failed to reduce the presence of the pathogen in the casings. These results suggest that the effectiveness of phages in reducing *Salmonella* in pork casings is temperature dependent and may be less effective at higher temperatures.

Significance and Impact of the Study: This study highlights the importance of considering temperature conditions when using phages for the

biocontrol of *Salmonella* in natural pork casings used for the stuffing of traditional fermented meat products.

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Microwave-Assisted Extraction (MAE) of Bioactive Extracts from Avocado (*Persea americana*) leaves: optimization and characterization using response surface methodology (RSM)

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Aims: Optimization of the extraction of phenolic compounds by Microwave Assisted Extraction (MAE) and from avocado leaves (*Persea Americana*).

Methods and Results: in this study, Soxhlet extraction was performed on freeze-dried ground leaves in contact with different solvents at boiling temperature for 5 hours. Nine extracts were obtained by using different hydroalcoholic mixtures: 75%, 50%, 25% water: ethanol/methanol (v/v) to screen the most suitable solvent for MAE. Besides, MAE was optimized using Response Surface Methodology (RSM) with a Box-Behnken design to determine the optimal extraction for the following factors: temperature, solvent ratio, and time. Several Microwave Extraction were performed at different temperatures (30,50 and 70º), ratios of 50% ethanol (v/v) solvent (1:5, 1:12.5 and 1:20), extraction times (5, 12 and 20'). The extracts were characterized for Total Phenolic Content (TPC) using the Folin-Ciolcalteu method and the antioxidant capacity was assessed by using ABTS and DPPH methods. An antimicrobial test was conducted for those extracts showing high antioxidant capacity against foodborne pathogens and the Minimum Inhibitory Concentration (MIC) was estimated for several strains of the foodborne pathogens *Listeria spp*., *Salmonella* spp., *Escherichia coli* and *Staphylococcus aureus*. The results from the chemical characterization signalled 50% ethanol as the most suitable solvent due to its high yield (39,64±2,64%), TPC values (1491,59±12,95 GAE/g) and antioxidant activity for scavenging Activity (56±1,21%) and antioxidant power (73±0,80%). Regarding the MAE extracts, it was observed that ratio l:s was the most influential factor. The optimum values were 20,7º, 1:15,8 and 12,77' with which the model was validated. Only MIC was identified for *Listeria* spp. and *S. aureus* strains. For Soxhlet, the MIC values were 5 and 2.5 mg/ml, respectively, while for MAE, the values corresponded to 6 and 3 mg/ml.

Conclusions: this study demonstrates that, leaf residues of avocado pruning can be a valuable resource of polyphenolic compounds with remarkable antioxidant and antimicrobial properties. The extraction of these beneficial components can be optimally achieved through the application of Microwave-assisted extraction (MAE).

Significance and Impact of the Study: this study demonstrates that byproducts from the avocado are a valuable reservoir of bioactive compounds with an interesting application in the food industry for extending the shelf life of food products. Additionally, a more environmentally friendly method was developed through the optimization of MAE, presenting not only a more sustainable but also more cost-effective approach. These findings present for the avocado industry an opportunity to adopt a bioeconomy strategy by the utilizing the bioactive fraction of the leaves.

SESSION 2: Quality and safety of Mediterranean products

Oral Sessions

Influence of dietary fiber components on trace elements bioaccessibiliry in turnip tops (*Brassica rapa*)

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Aims: Meat and dairy products in the food industry represent a significant portion of anthropogenic greenhouse gas emissions. As a consequence of this, a larger number of consumers are being encouraged to consume more vegetables. Turnip tops (Brassica rapa) is an economically important specie which is grown in northwest Spain and Portugal. In recent years, a breeding program in B.rapa subsp. rapa has been developed in the south of Spain to obtain varieties adapted to the environmental conditions of Mediterranean area. Turnip tops and other cruciferous vegetables have also proven to be an excellent dietary source of some trace elements, with high bioaccessibility, due to their low oxalate content, among other antinutritional factors. This bioaccessibility could be increased even further when they are formulated as ingredients with other dietary components (fiber fractions).

Methods and Results: The aim of this work was to study the influence of dietary fiber components (pectins; arabic gum and cellulose) on the trace element bioaccessibility (Fe, Mn, Ni, Se and Zn) in turnip tops grown in Mediterranean conditions. Dietary fiber fractions were used in different proportions (5; 15 and 25%). Bioaccessibility can be defined as being the fraction of a micronutrient or bioactive compound that remains soluble in the intestine lumen, after having subjected the food to a simulated gastrointestinal digestion in which the physiological conditions of the stomach and small intestine are reproduced. Results showed that pectin increased trace element bioaccessibility for Fe (from 28.4 to 47.5 µg/g); Mn (from 21.9 to 26.5 µg/g); Se (from 9.2 to 38.0 µg/g); and Zn (from 16.7 to 47.5 µg/g). Arabic gum also had a positive effect upon trace element bioaccessibility for Fe (from 28.4 to 34.5 µg/g); Mn (from 21.9 to 29.1 µg/g); Se (from 9.2 to 34.6 µg/g); and Zn (from 16.7 to 25.5 µg/g). Both fractions are considered soluble dietary fiber. This fiber has the capacity to uptake cations, keeping them soluble in the intestinal lumen and preventing their precipitation as insoluble salts. On the contrary, insoluble dietary fiber such as cellulose decreased the bioaccessibility of some of the trace elements studied. It was decreased for Fe (from 28.4 to 8.1 µg/g); Mn (from 21.9 to 17.0 µg/g); and Zn (from 16.7 to 16.0 µg/g).

Conclusions: Soluble dietary fiber increases the bioaccessibility of some trace elements present in cruciferous vegetables, so it can be used as an ingredient to improve its nutritional value.

Significance and Impact of the Study: Development of new foods with functional ingredients to promote a healthy and environmentally sustainable diet.

Honey Value Chain and MEDIFIT Project

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Aims: Development and implementation of innovative solutions, technological tools, digital solutions, and protocols are crucial for food safety on a global scale. Focusing on products with high added-value and nutritional value is significant for biodiversity conservation. In this context, the MEDIFIT project developed an interlinked digital platform for food integrity and traceability of relevant Mediterranean supply chains.

Methods and Results: We took part in all work packages in the MEDIFIT project, which supports sustainability and quality in beekeeping and honey production. Our support to this project, as SBS BİLİMSEL BİO ÇÖZÜMLER SAN. TİC. A.Ş. was to supply honey samples from Türkiye, including four pine honey, 15 polyfloral flower honey, and one thyme honey. We carried out the quality tests in these honey samples and compared the results with other project partners. We developed recommendations for improved policy instruments to promote food traceability and safety. In collaboration with our partners conducted detailed analysis and fieldwork with stakeholders in value chains of honey.

Conclusions:

Significance and Impact of the Study: MEDIFIT project is a pioneering tool on improving traceability, authenticity control of Mediterranean honey integrating innovative analytical methods and digital technologies.

Value Chain Analysis of Sheep Dairy Sub-sector in North West Tunisia

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Aims: Sheep dairy processing from local dairy sheep breed, Sicilo-Sarde, is a booming micro-sector in Tunisia, leading to a socio economic development. Moreover, this breed is actually perceived as climate resilient animal. This research aimed at analyzing the current situation of the sheep dairy value chain in Béja region (North West of Tunisia), where 85% of the entire sheep flocks are actually located.

Methods and Results: Qualitative and quantitative data were collected from different stakeholders from production to commercialization through face-to-face interviews (n=38) and two workshops. The data obtained were analyzed using descriptive analysis (IBM SPPS v. 22). At the production level, the management of dairy sheep farming is essentially extensive and traditional in micro and small family farms, whereas semi-intensive production system is more common in large farms. At the processing level, there are three semi industrial processing units specializing in sheep milk processing, in addition to artisanal workshops. The processing capacity varies between 800-1500 L milk/day. Interestingly, processors are also breeders, and have set up an integrated system: from production to marketing, in order to control the entire supply chain. In terms of marketing, these cheeses are thus mainly retailed by the processors themselves (100%), on site or in their own stores, or to restaurants/hotels/guest houses (75%), and retailers from Béja or from other regions. We have also identified support and backing structures involved in the sheep value chain. Constraints and opportunities of Northern sheep dairy value chain were addressed through a SWOT analysis. Main strengths are: emerging demand for sheep cheese, a positive image of dairy products (terroir, natural, healthy...), artisanal know-how, upstream/downstream integration and geographic grouping of breeders in the Béja region (GDA-EBN), as well as the development of local eco-tourism. Nevertheless, main weaknesses include: increasing feed price, low milk production due to a weak management and inbreeding, lack of qualified labor force, a poor marketing, competition from informal sector and weak governance.

Conclusions: In conclusion, our findings and recommendations may be of special interest for policy makers, stakeholders and other actors to promote Tunisian sheep dairy value chain development.

Significance and Impact of the Study: Total dairy consumption in Tunisia is expected to grow faster than production, leading to an increase in dairy imports, and weakening self-sufficiency and thus impairing food security. In this context, recommendations issued from this study will support the development of

sheep milk dairy chain value in Tunisia leading to enhance local economic growth and development, food security and nutrition while reducing poverty.

Acknowledgement: This work was part of PRIMA-MEDIFIT project (2020-2023) supported by EU program for Research and Innovation solutions in the Mediterranean region.

Exploring agri-food residues as source of bio-protective microorganisms for circular application in vegetable products: an example of strawberry and tomato

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Aims: The agri-food sector is recognized worldwide as one of the industries that contributes most to waste generation. This agricultural waste can be reused to obtain useful compounds that can be introduced into the food industry to improve processes and products. In this context, exploiting the biological fraction of agricultural residues is beneficial from a circular and bioeconomy perspective and desirable since these microorganisms are expected to better fight against phytopathogens and spoilage microorganisms as they are part of the same microbial ecosystem. Therefore, the aim of this work was to carry out an exhaustive review of the scientific literature to identify the microorganisms with bioprotective capacity present in the microbiota of strawberry and tomato plants and to evaluate the different methods of application of bioprotective microorganisms.

Methods and Results: An exhaustive review has been developed to explore the agricultural residues of tomato and strawberry as sources of bacteria with bio-protective potential. The results demonstrate that the microbiota of both vegetables host different microbial groups relevant to food bio-protection such as Bacillus spp., Pseudomonas spp., and to a lesser extent, Lactic Acid Bacteria. Nevertheless, there are several limitations related to post-harvest application, such as impaired cell viability and functionality because of the environmental stress and harsh conditions of the food matrix, so we suggest that microorganisms be introduced at an earlier stage, during pre-harvest. Microbial cultures having both bio-control and bio-protective properties should be considered. Their application can be enhanced by microencapsulation, lyophilization, or by incorporating them into cellulose-based coatings. The approach is expected to mitigate plant disease and alleviate the impact of related spoilage and pathogenic microorganisms, thereby improving produce shelf-life.

Conclusions: The work highlights the potential of agricultural residues as sources of functional microorganisms that can be introduced into the food industry to improve food quality and safety. One aspect to be highlighted is the importance of selecting suitable technological methods to enable microorganisms to deploy their bioprotective mechanisms in real food systems.

Significance and Impact of the Study: The review suggests new opportunities for developing a bioeconomy and circular approach in the sector of

strawberry and tomato, in the Mediterranean region, by valorizing the biological fraction of agricultural residues.

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SESSION 2: Quality and safety of Mediterranean products

Poster Sessions

Comparison of algerian and imported honeys on the basis of quality parameters

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Aims: To compare Algerian and imported honeys on the basis of the results of electrical conductivity, moisture, degrees brix (°Bx), pH, free acid, invertase, acid phosphatase, proline and total carotenoid.

Methods and Results: Sampling comprised 6 Algerian and 6 imported honeys. Analytical determinations were done by official or equivalent procedures. Algerian samples showed the highest electrical conductivity (mean: 0.35 mS/cm; range: 0.22-0.56 mS/cm), degrees brix (mean: 83 °Bx; range: 0.22-0.56 °Bx), pH (mean: 4.21; range: 3.64-4.99), free acid (mean: 29.0 meq/kg; range: 15.0-50.0 meq/kg), invertase (mean: 134.30 U/kg; range: 27.1-207-6 U/kg), proline (mean: 1004.3 mg/kg; range: 184.4-1877.7 mg/kg) and total carotenoid (mean: 19.27 mg β-carotene/kg; range: 7.98-59,07 mg β-carotene/kg), whereas imported honeys exhibited the highest moisture (mean: 17.3%; range: 16.5-18.0%) and acid phosphatase (mean: 58.0 mg P/100 g/24 h; range 56.8-59.4 mg P/100 g/24 h).

Conclusions: The quality of Algerian honeys was considerably better than the quality of imported honeys, so that Algeria should legislate about quality requirements for honeys.

Significance and Impact of the Study: In Algeria there is a large-scale consumption of honey, being the local production not enough to supply total demand. Therefore, Algeria imports honeys from third countries and their quality usually leaves much to be desired due to a lack of national legislation. This study can help establish a National Regulation in Algeria for Algerian honeys.

Phenolics' extracts of algerian Spurge (*Euphorbia* sp.), Jujube (*Ziziphus* sp.) and multifloral honeys

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Aims: To help characterize spurge (*Euphorbia* sp.), jujube (*Ziziphus* sp.) and multifloral Algerian honeys by assessing on honey extracts, total phenolics (TPC), total flavones/flavonols (TFCQ), total flavanols (TFCC) and o-diphenols (o-D) that are related to antioxidant activities.

Methods and Results: The study was carried out with 12 Algerian honeys, there being 4 spurge, 4 jujube and 4 multifloral samples. Extracts were obtained using an acidic solution of honey (100 mg/ml) that was slowly filtered through a column filled with Amberlite XAD-2 resin preconditioned with methanol and distilled water. Polar compounds were removed with 250 ml acidified water (HCl, pH 2), and subsequently rinsed with 300 ml neutral distilled water. Phenolics were eluted from the sorbent with 250 ml methanol and then analysed. Considering the monofloral honeys, jujube samples showed the highest TPC (average: 19.7 mg gallic acid/100 g; range: 12.3-32.1 mg gallic acid/100 g) and TFCC (average: 30.9 mg catechin/100 g; range: 26.9-38.7 mg catechin/100 g), whereas spurge honeys exhibited the highest TFCQ (average: 13.2 mg quercetin/100 g; range: 4.0-20.5 mg quercetin/100 g) and o-D (average: 11.8 µg cathecol/100 g; range: 2.8-32.6 µg cathecol/100 g). In general, multifloral honeys presented the highest TPC (average: 22.1 mg gallic acid/100 g; range: 16.5-28.0 mg gallic acid/100 g), TFCC (average: 34.5 mg catechin/100 g; range: 26.6-47.8 mg catechin/100 g) and o-D (average: 22.3 µg cathecol/100 g; range: 7.2-53.3 µg cathecol/100 g).

Conclusions: This study shows that Algerian honeys exhibit an interesting antioxidant potential.

Significance and Impact of the Study: Algerian honeys are increasingly gaining more prestige in the markets. Among Algerian monolforal honeys, spurge (*Euphorbia* sp.) and jujube (*Ziziphus* sp.) are particularly appreciated by the consumers. Characterization of Algerian honeys, establishing a legal frame for them is of paramount importance to boost their commercialization.

SESSION 3: Predictive tools for food integrity from farm to fork

Oral Sessions

Has the digital age arrived in the official control of food safety in the retail sector?

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Aims: The aim of this study was to assess the use of a digital environment during official food safety inspections of retail establishments by competent authorities (CA) in European Union (EU) countries. We understand a digital environment as the context in which digital tools (apps or programs) and devices (smartphones or tablets) are used to record, analyse or transmit information.

Methods and results: A structured and electronic questionnaire was developed and sent to the CAs. The questionnaire asked about the reasons for using a digital environment during inspections, the process of its development and implementation, the inspection processes carried out through such an environment and the results obtained. In addition, for those CAs that did not use a digital environment, the questionnaire asked about the reasons for not using one. A total of 88 national, regional or local CAs from 15 EU countries replied to the questionnaire. Of these, 62.5% (55/88) used a digital environment, mainly to harmonise data collection and reporting. CAs use a digital environment to automate processes related to the management of official controls and the generation of inspection results, but to a lesser extent to automate decision making during inspections. Of the CAs not using a digital environment (37.5%; 33/88), the two most indicated reasons for not using such an environment were technological constraints and lack of economic resources.

Conclusions: There are many CAs in the EU that are already using a digital environment, with the main motivation being to improve the consistency of controls by standardising the collection of information during inspections. However, there are obstacles to digitalisation related to structural barriers of CAs that may slow down the integration of digital technologies to support inspections.

Significance and impact of the study: This is, to our knowledge, the first study to investigate the use of digital technologies during inspections in the EU. Knowing the benefits, results and barriers of using a digital environment during inspections can help policy and decision makers of CAs in the process of digitalising inspections, as well as finding solutions to the limitations of traditional inspections to better improve the consistency and effectiveness of official food control, a prerequisite to ensure effective and useful traceability of activities of official food control along the food chain.

Making FSKX Compliant Predictive Models Accessible from with ChatGPT

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Aims: This study seeks to provide a proof of concept for a chatbot able to trigger the execution of an FSKX compliant model file, returning generated results, including visualization of prediction outcomes. The project also aims to demonstrate the chatbot's ability to engage in dialogue where relevant model execution input information is missing.

Methods and Results: To fulfill its objectives, the research addresses potential access hurdles to modeling results through a chatbot user interface, considering a seamless and efficient integration of predictive models into systems like ChatGPT. It assesses infrastructural requirements like compute resources, technological constraints such as matching model execution environment accessibility, and more general questions, like guaranteeing the correct mapping of user input to the respective model input parameter.

Conclusions: The research provides insight into optimizing future FSKX exchange formats for autonomous execution of FSKX models. The proposed chatbot solution seeks to eliminate current access barriers to modeling results while integrating predictive models into systems like ChatGPT, thus addressing existing knowledge gaps in large language models.

Significance and Impact of the Study: The study offers a transformative solution allowing researchers to make their models accessible via emerging technologies like ChatGPT and other large language models. This enhances the various benefits the FSKX exchange format provides to modelers and model users, representing a significant leap towards making predictive modeling more easily accessible and usable across various research domains.

Characterized logistic chain and its optimization by using an innovative food cloud system supported by predictive microbiology models

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Aims: In Biofreshcloud project, we study a dynamic programming model which was studied previously in order to maximize the total profit of the retailers. Based on the classical version of the problem we intend the maximize the total revenue by improving the total freshness of the fruits that are sold to the customers or discarded (or donated due to excess stock). The problem of study is a stochastic problem, i.e. it is consist of different replenishment (service) and demand (arrival) components.

Methods and Results: Each component has a certain probability of event occurrence which could correspond to the arrival of a customer/lot of product to a particular location that is either a distribution center (DC) or store or the sales of a product. The optimal solution maximizes the total revenue (in consideration of remaining shelf life) of the sold or discarded items and is obtained by stochastic dynamic programming for discrete time intervals by evaluating the state of the system in the perception of immediate gain and future expected gain. These problems have been widely studied by several authors for more than 40 years and the event-based dynamic programming approach has been found to be useful in order to identify the structure of the optimal policies determined by thresholds such as protection levels, price, base stock levels or switching curves. In order to present an example, consider the classical single item inventory management problem without replenishment (also known as single leg airline revenue management problem) where a certain number of inventory items have to be sold over a fixed time horizon to different classes of customers that are distinguished by the prices they are willing to pay. The demand is uncertain and the probability of selling to any customer class is estimated from the historical data. The objective of the firm is to maximize expected revenue over the sales horizon. The optimal actions are obtained for discrete time intervals by evaluating each possible inventory status for the classical problem and the optimal action for each stage and state does not depend on the decisions of other stage and states. Therefore, the objective function (value function) is obtained at each stage and state separately. Mathematical properties of the value function such as concavity, supermodularity (submodularity) and increasingness (decreasingness) are used to define the optimal policy. The optimal rationing policy defines the optimal sales decision for each stage and state independently and has a monotone structure and defined as a threshold type, i.e. to sell to the lower classes if the inventory level is higher than the protection level at the given time.

As one can already see, if the time left is short enough, then it is optimal to satisfy demand from all customer classes, i.e., the protection level is zero. Similarly, when the time left is long enough then it may be optimal to sell only to the highest paying class. A replenishment component can be added to the model without violating the structure of the optimal rationing policy, and the optimal replenishment policy (set of all optimal actions defined for each stage and state) is characterized by base stock level. Therefore, the optimal controller does not make a decision to produce unless the number of inventory items falls below a certain level (base stock). Such kind of a structure that governs the optimal policy enables managing the operations easily and improves the solution time of the problem considerably.

Our problem model is based on this conventional problem of almost 40 years, but hereby we build a much complex model incorporating microbial growth models in order to model an objective function attaining the total freshness of the product sold. As discarded products are incorporated to the model as zero reward the model inherently reduces the total waste in the system.

Conclusions: The problem contains the food chain stages of fruits passing from the following stages: (1) Harvesting (2) wholesaling (3) Distribution centers and (4) Store selling. Practically, the wholesaling stage is not a physical stage and wholesalers provides a communication between the DCs of the supermarket chains and the growers. Hence the products are transported to the distribution centers as soon as a commissioning is carried out by the wholesaler. Considering that the products are highly affected by the external environment, especially in summer, critical measurement points are: (1) DM quality input control (2) Interim inspection for products stored in DM for more than 7 days and (3) The control to be carried out while being shipped to the store.

The problem is to reduce the food waste of the tomato which is nearly 10% at the beginning. The waste of the products occurs upon the end of the shelf life of the product, largely due to the supply-demand difference in the store. In the project a decision chart will be proposed based on the monitoring and the control system developed during the project.

The pricing algorithm is established according to operational rules: There are three types of discounting decision according to company rules: No discount, 25% discount and 50% discount. A sample fragment of decision chart is given as follows:

PARAMETERS						DSS RECOMMENDATION	
Remaining time to closure	Remaining time to store delivery	Product lot (kg)	Product lot (rem. Shelf life)	Product lot (kg)	Product lot (rem. Shelf life)	Lot 1 discount	Lot 2 discount
5 hours	10 hours	20	5	40	7	0%	0%
5 hours	10 hours	40	5	40	7	0%	0%
5 hours	10 hours	60	5	40	7	25%	0%
5 hours	10 hours	80	5	40	7	25%	0%
5 hours	10 hours	100	5	40	7	50%	0%

Significance and Impact of the Study: In the EU, around 88 million tonnes of food waste are generated annually with associated costs estimated at 143 billion Euro and 170 million tonnes of CO2 are emitted during the production and disposal of EU food waste. Our problem model is based on this conventional problem of almost 40 years, but hereby we build a much complex model incorporating microbial growth models in order to model an objective function attaining the total freshness of the product sold. As discarded products are incorporated to the model as zero reward the model inherently reduces the total waste in the system, which is of a global problem.

Survey on the use of predictive models and software tools in the official control of foods in Spain

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Aims: Official food regulation has a fundamental role in the protection of public health and food safety in a country, highlighting the importance of constant surveillance of food quality and safety. In this sense, predictive microbiology is offered as an innovative tool that changes the way official food regulation is carried out, by allowing a faster response to the behaviour of microorganisms and facilitating the implementation of control measures. This work aims to analyse the level of adoption and knowledge of the Spanish official control of predictive microbiology in its routine controls, highlighting the needs of the sector in this aspect and being able to evaluate it from the MEDIFIT project approach.

Methods and Results: For the study, a survey was carried out during June-September to different official control agents asking about the use of predictive microbiology tools and their assessment of these tools. A total of 281 responses were obtained from agents from different parts of Spain. It could be seen that there was a correlation between age and province of work with respect to knowledge of predictive microbiology, with greater knowledge in agents aged between 50 and 60 from the province of Granada, while use was greater in people who had been working in the sector for more than 20 years and who belonged to the province of Barcelona. More than a third of respondents felt that there were not enough predictive tools, with Combase being the most widely used, followed by Microhibro. The main purpose of using these tools is for auditing purposes, as they simplify the work. The main area of interest of the respondents with the use of predictive modelling is in life cycle studies during the production stage, however, half of them consider that there are not enough models in their tools. Finally, the intention to integrate predictive modelling into traceability systems was assessed and confirmed by all respondents.

Conclusions: This study highlighted the need to improve the accessibility and availability of control agents to predictive models, which can be improved through information exchanges between different applications, using reference standards. This will improve logistics and traceability systems in food industries.

Significance and Impact of the Study: this study has practical implications for the official food control sector in Spain. It not only assesses the current state of adoption and knowledge but also identifies areas for improvement, making it a valuable resource for policymakers, researchers, and industry professionals seeking to enhance food safety and quality through predictive microbiology.

Subscribing to EPCIS 2.0 Events

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Aims: The primary objective of our study was to explore the transformative potential of integrating WebSocket and Webhook subscriptions into EPCIS 2.0.

A webhook is a method for one web server to provide real-time information to another server, immediately after a specified event has occurred. Essentially, it's an HTTP callback or a HTTP POST request that is made to a pre-defined URL. Webhooks are perfect for server-to-server communication, but don't work for server-to-client communication in modern web applications. This is where WebSockets bridge this gap by enabling continuous two-way communication between a client and server. Ideal for real-time data exchange without needing to reload or resend requests. Given the increasing complexities and demands of modern supply chains, especially in the food sector, we aimed to achieve better real-time monitoring and alerting capabilities. This emphasis was especially targeted towards early detection of potential adulteration or health hazards associated with food products.

Methods and Results: We examined the EPCIS 2.0 Query Subscription mechanism that incorporates WebSockets, a technology that establishes a continuous communication channel, especially crucial when static server URLs are restrictive.

Although static server URLs are stable, they can restrict flexibility for applications in dynamic settings and potentially increase costs and configuration challenges. To satisfy different scenarios, server-to-client and server-to-server, we also configured Webhook subscriptions to act as a mechanism to automatically dispatch instant alerts to predefined server endpoints when specific, predetermined events occur. The integration of WebSocket's streaming subscriptions function similarly to push notifications on mobile devices, delivering nearly instantaneous alerts the moment an EPCIS event was captured. This mechanism became a key component for robust real-time monitoring of the supply chain. Within the EPCIS 2.0 Standard, the scheduled subscription mechanism relies on periodic triggers from a job scheduler, making it well-suited for extended operations or batch data processing. Webhook Subscriptions, pointing to a static server endpoint, demonstrated efficiency in quickly notifying other server-side business applications of key events.

Conclusions: The successful incorporation of WebSocket and Webhook into the EPCIS 2.0 framework has undeniably elevated its real-time communication capabilities. Stakeholders in the food supply chain can now receive timely alerts, enabling them to take swift action when necessary, ensuring they are equipped with the most current information, especially in cases hinting at potential adulteration or health concerns related to food products.

Significance and Impact of the Study: EPCIS 2.0's enhanced communication framework is not just a technical upgrade; it's a significant stride towards ensuring the safety, authenticity, and integrity of food products within supply chains, with the potential to save lives and reinforce brand trust.

SESSION 3: Predictive tools for food integrity from farm to fork

Poster Sessions

ALLIANCE: Preventing Fraud in the Food Supply Chains of Food Bearing Quality Labels

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Aims: Enhancing food safety necessitates the use of innovative solutions that can strengthen the already existing fraud prevention and fighting mechanisms used in the food supply chains. ALLIANCE is a novel project that combines emerging digital technologies towards detecting and preventing food fraud in quality-labelled food products, while continuously collecting performance measurements from supply chains and applying analytics in order to assist farmers, producers, processors, retailers, authorities and policy makers to assess risks, determine critical control points within the Food Supply Chains, be able to identify and predict food fraud vulnerabilities and plan preventive interventions.

Methods and Results: By examining the food fraud landscape and proposing systemic solutions that move beyond current practices through novel cost-effective methods and tolls that can detect adulteration on the spot and provide trusted interoperable quality labelled FSCs:

- Blockchain-enabled traceability with increased data integrity
- Advanced spectroscopy for identification of adulteration and provenance of food
- Rapid testing for authenticity validation and proof of geographical origin
- Vulnerability risk assessment in the food supply chains.

Conclusions: The implementation and the application of the ALLIANCE's framework require the collaboration among food scientists, food producers and food associations, food processing industries, logistic companies, retailers and supermarkets, data scientists for analytics, information and technology companies, social scientists for user engagement and awareness, telecom providers for connectivity issues, legal and regulatory experts as well as stakeholders in public food policy and EU regulations. To this end, the deployment of the ALLIANCE framework has been designed to run in seven different Pilots in six EU countries and in Turkey:

- PDO/PGI Extra virgin olive oil for authenticity validation - IT
- PDO feta cheese increased traceability - GR
- Fighting fraud and adulteration in organic honey - FR
- On-site verification of authenticity of PGI Faba beans -ES
- Food fraud in PGI Lika potatoes - HR
- Rapid pesticide fingerprinting for organic pasta - IT

- Improved traceability of PDO Arilje raspberries FSC -SRB

Significance and Impact of the Study: ALLIANCE will provide innovative solutions that will act as authenticity enablers within food supply chains to re-establish quality-labeled food products lifetime management with easy-to-be adopted innovations that safeguard food supply chain systems' integrity and transparency, ensure data veracity, simplify processes, protect uniqueness of the organic, PDO, PGI, and GI food products, increase consumers' confidence and trust, protect brands from illicit trading of counterfeited and adulterated food products and unlawful competition.

Watson: Preventing food fraud through digital and intelligence-based technologies

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Aims: Food fraud poses significant risks to the integrity and safety of the agri-food supply chains, necessitating the adoption of digital technologies and intelligence-based systems for prevention. There is a growing incidence of food fraud, but limited authenticity testing methods and traceability systems contribute to a gap in identifying and preventing it. This paper aims to provide valuable insights regarding food fraud for industry stakeholders, researchers, and policymakers striving to enhance the integrity and safety of the global food supply chain. This paper offers a comprehensive framework, part of an ongoing EU project (Watson), which integrates various digital and intelligence-based technological solutions and can effectively be applied in multiple food chains to prevent fraud.

Methods and Results: The beginning of this paper is dedicated to giving an overview of the current state of food fraud prevention systems, especially the existing approaches and limitations. Then, the Watson project's primary objectives, key pillars, and emerging technologies are introduced. The main content of this paper is to analyse the framework's technological solutions, highlighting their interconnectedness and role in ensuring food products' traceability, authenticity, and safety throughout the supply chain. Multiple digital and intelligence-based technologies, such as portable DNA-based devices, multi-sensor scanning devices, the IoT platform, the blockchain platform, mobile Apps, and the digital passport, will be involved at different supply chain stages to prevent food fraud. In addition, an early warning system based on robust and explainable artificial intelligence will also be established in this food fraud prevention framework. Overall, the Watson project will build an effective food authenticity and traceability framework based on digital technologies for preventing food fraud in supply chains. The following steps are implementing the framework, emphasising the need to enhance fraud prevention systems further and validating the solutions in specific agri-food chains.

Conclusions: This study emphasises the importance of increasing transparency and traceability in food supply chains to address food fraud. Different types of food fraud, such as mislabelling, substitution, and counterfeiting, can be targeted and prevented with the help of digital technologies. Intelligence-based platforms such as blockchain, IoT systems, and early warning systems will significantly enhance the food traceability system.

Significance and Impact of the Study: This research raises consumer awareness regarding food safety and value, ultimately leading to healthier lifestyles and sustainable food ecosystems. By addressing the current condition in the food supply chain and continuously improving the presented framework, the integrity, authenticity, and safety of the global food supply chain can be collectively enhanced, ultimately protecting consumers and fostering trust in the food industry.

Can analytical results along with inspection data be used as a food safety decision tool?

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Aims: Explore the relationship between the non-compliances with the law detected in food safety inspections carried out with digital tools and the presence of *Listeria* spp. (*Listeria*) on food contact surfaces in retail establishments of Barcelona. Our general hypothesis was that inspection non-compliances have a direct relationship with Listeria detection on environmental samples, and thus digital control data can be used to assist in real-time decision-making during control activities.

Methods and Results: In 2023, food contact surfaces were sampled for *Listeria* surveillance from 17 retail establishments selected among those that packaged sliced deli meats for non-assisted sale. Additionally, 51 non-compliances of the digital inspection protocol were selected, as risk factors in relation to *Listeria*. Risk factors belonged to the following categories: conditions of the premises and equipment, general cleanliness, food processing and self-controls. Occurrence of those risk factors among establishments with positive or negative samples is described.

The prevalence obtained was 47% (8/17 establishments with one or more positive samples out of three). The total number of risk factors observed in both type of establishments was similar. Nevertheless, two of the risk categories were most noticed among the establishments with positive samples: conditions of the premises and equipment and general cleanliness. Finally, seven specific risk factors were observed at higher rates in positive establishments. They are related to maintenance and suitability of materials, degree of order and cleanliness, food identification and cross contamination in the sales area.

Conclusions: The small volume of the sample studied (n=17) does not allow to establish any statistically significant association between the non-compliances of the inspection protocol considered risk factors and the detection of Listeria on food contact surfaces. However, there are seven risk factors with high rates of occurrence in establishments with positive surfaces.

Significance and Impact of the Study: This is a preliminary study to evaluate the predictive value of the application of digital technology in inspections to food establishments with the aim to improve decision-making in risk management, identifying which of the non-compliances observed in routine inspections can be associated with the presence of food hazards.

EPCIS-based Model Repository: A Strategy for Advanced Food Inspection in Andalusia

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Aims: The main objective of this work is to create an EPCIS-based Model Repository of bacterial growth models to be used by food companies according to the characteristics of their products and to be able to justify the safety of their products to inspections and official control.

Methods and Results: A bibliographic search was carried out in different databases (WoS, Elsevier, PubMed...), together with the experience of the research group, of different products, as well as their physicochemical characterization to group similar foods with respect to pH, aW and storage temperature. Data from other databases such as MicroHibro, Combase and Open Food Safety were also included in this repository. A decision tree was also developed that companies can follow to correctly select the appropriate predictive microbiology model. The proposed decision tree can help the systematization or protocolization of the selection process can reduce deviations or biases and allow the selection of the most appropriate model, considering whether it was developed for that particular microorganism, whether the food allows its growth, whether the model has been developed in broth, in a model or real matrix, or whether it has been previously validated in similar foods. After data extraction and implementation of the model, its transformation to a standardized format such as FSKX (Food Safety Knowledge Exchange) is required so that it can be used in different programming languages and subsequently applied. This format allows harmonizing the exchange of knowledge as well as the corresponding metadata. The standard will allow creating information objects that can be made available in a FAIR (findability, accessibility, interoperability and reusability) way and is ready-to-use. In this way, companies can offer these results to food inspection services and official control.

Conclusions: The use and correct application of predictive microbiology models saves work, time and money for food operators. The implementation of these models is a first step towards digitization and modernization in terms of food safety for the industry. The transformation of this data and its grouping within the database into a standard format makes it accessible and tangible, not only for companies, but also for inspection and consumers.

Significance and Impact of the Study: Food risk assessment, process control in food production and the development of new products are nowadays supported by the application of mathematical models. An EPCIS repository is an

append-only database because events are snapshots of the state of a supply chain. This is important to ensure transparency, accountability and traceability.

QUANTIFICATION THE PROBABILITY OF GERMINATION OF *Botrytis cinerea* USING AN ACID-BASED MODEL SYSTEM OF STRAWBERRY

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Aims: *Botrytis cinerea* is the main fungus responsible for strawberry post-harvest decay. Understanding the factors affecting its germination is crucial to control its growth and reduce the amount of fruit waste. The aim of this study was to evaluate and model the effects of storage temperature and water activity (aw) on *B. cinerea* germination in strawberry, simulating real-life scenarios of product quality and storage over its shelf-life.

Methods and Results: The effects of storage temperature (5, 10, 15, 20 and 25 ºC) and aw (0.920 to 0.998) on *B. cinerea* germination were evaluated in a strawberry model medium (pH = 3.7) based on Potato Dextrose Agar, modified using acids naturally present in the fruit (citric, tartaric, malic, shikimic and fumaric). Glycerol was used to adjust the aw of the medium to values set at the experimental design. *B. cinerea* conidia (105 conidia/mL) were inoculated in cylinders placed into Petri dish plates containing the modified model medium. Inoculated plates were stored at different temperatures and conidia germination was monitored under microscope (x100) for up to 30 days.

B. cinerea germination was significantly affected by aw at all temperatures tested. An asymmetric model was fitted to the percentage of germinated spores (Pt) as a function of time under the evaluated conditions to estimate the maximum percentage of viable spores (Pmax, %) and the germination time where Pt = Pmax/2 (τ, days). Pmax varied from 0.45 (T=5°C, aw=0.932) to 1.0 (multiple conditions). Log(τ) decreased linearly by increasing aw at a given temperature. The τ values increased by decreasing storage temperatures from 15 to 5°C, whereas increasing temperatures from 15 to 25°C did not significantly affect its values at a fixed aw. Overall, the τ values ranged from 0.4 days (T=25°C; aw=0.998) to 10.2 days (T=5°C, aw=0.932). In addition, the effect of aw on the rate of fungal conidia germination (μ) was determined. Results showed that the germination rate of B. cinerea is significantly affected by aw.

Conclusions: The *B. cinerea* germination in strawberry can be delayed by lowering storage temperatures, while fruits with higher aw favour its germination during shelf-life. The models developed in this study help managing

strawberry storage temperature depending on its aw to delay *B. cinerea* germination, avoiding post-harvest waste.

Significance and Impact of the Study: this study addresses the issue caused by *B. cinerea* on strawberry by understanding the effect of temperature and aw on the fungal germination. Findings enable managing storage conditions to significantly minimize post-harvest waste, advancing more efficient and sustainable fruit production practices.

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