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BOOK OF ABSTRACTS

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PREFACE

Dear Colleagues,

The AgroStat biannual series of conference are driven by the Agro-Industry Group of the French Statistical Society (SFdS), which is a non-profit organisation bringing together researchers, engineers, teachers and statistics users (<https://www.sfds.asso.fr>). The 16th Edition of the AgroStat Conference (AgroStat 2024) will take place from the 3th to 6th September 2024 in the city of Bragança, Portugal, hosted and organised by the Polytechnic Institute of Bragança (IPB).

Bragança is a typically-Portuguese old town (Romanic origin dates back to the 10th century), located by the Natural Park of Montesinho – one of the wildest forest zones of Europe – and the Douro Valley – the third oldest protected wine region in the world; and surrounded by traditional villages of a distinctive rustic beauty. Bragança houses several traditional industries producing a myriad of local foods, such as cheese, fermented meats, wine, chestnuts and honey, which provide substantial economic sustainability to the region.

The AgroStat 2024 conference will reunite internationally recognised researchers and industrial organisations representatives, to take stock of advances in statistics, express their needs and to anticipate future challenges. The AgroStat 2024 conference will provide engineers, modellers, statisticians, developers and end-users, a unique opportunity to exchange knowledge and prospects around novel statistical methods applied to agri-food and sensory sciences. We expect to gather a significant number of delegates to participate in a comprehensive scientific programme that includes 5 keynote lectures, and oral communications, allocated in sessions focusing on the following themes: Sensometrics, Chemometrics, Experimental designs, Process control, Risk analysis, Big Data and Software tools.

AgroStat 2024 will feature special sessions dedicated to Predictive microbiology and Meta-analysis, to encourage food modellers to present the latest scientific approaches for data synthesis, databases and tools developed for the advancement of predictive modelling towards ensuring safety and quality of foods. Notwithstanding, all of the conference themes can be addressed in their theoretical aspects and through applications.

Finally, a session dedicated to the current EU PRIMA-funded project, “Productivity, Adaptiveness, Sustainability and Profitability of Agro-pastoral Systems in Mediterranean Countries” (PAS-AGRO-PAS: <https://pas-agro-pas.esa.ipb.pt/>) will be also opened up for the online participation of young researchers of the consortium.

Three pre-conference workshops will take place during the day before the scientific programme, that is, on the 3rd September 2024. In addition to the rich scientific programme, AgroStat 2024 delegates will have an exceptional opportunity to appreciate the rich culture and traditions of Bragança, by engaging in an attractive social programme that includes welcome reception, tasting of regional foods and gala dinner.

On behalf of the Organising Committee, we look forward to meeting you in Bragança, a historical and charming town located in the Northeast of Portugal.

Vasco Cadavez

Ursula Gonzales-Barron

Pascal Schlich

The AgroStat 2024 Chairs

ACKNOWLEDGMENT

The IPB Chairs acknowledge that “Session 10: EU PRIMA Online Session” was funded by PRIMA project “*Productivity, Adaptiveness, Sustainability and Profitability of Agropastoral Systems in Mediterranean Countries*” (PAS-AGRO-PAS; PRIMA/0014/2022).





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PLENARY LECTURES

Time: 9:15 - 10:10

Date: 4th September 2024

FLEXIBLE HANDLING OF DEPENDENCE FOR SIGNAL IDENTIFICATION USING FUNCTIONAL ANOVA

David Causeur

L'Institut Agro Rennes-Angers, France

Technologies such as Near Infrared Spectroscopy (NIRS), mass spectrometry or hyperspectral imaging are now routinely used to address a variety of issues in food science. For example, NIRS is especially implemented for a rapid and non-invasive evaluation of the quality of food products. Such technologies generate high-throughput data, functional in nature and showing strong dependence across discretized observations, which optimal handling for the usual statistical tasks of testing and prediction is an open question. Originally, this research work is not motivated by issues in food science but in neuroscience, where Functional near infrared spectroscopy (fNIRS), using the absorption of near infrared light by hemoglobin to record changes in blood oxygenation, is used to measure functional brain activity. For designs in which subjects are instructed to execute a specific mental task under different experimental conditions with pre-determined levels for covariates, fNIRS provides real-time cerebral hemodynamic responses for studying neural correlates of task-related experimental variables. Data obtained from such designs are discretized observations of the hemodynamic curves on a high-resolution time scale.

The presentation will first start by questioning the gain in using statistical approaches with ad-hoc handling of dependence, with respect to "lazy" procedures ignoring dependence. In a second part, testing for overall group mean differences among curves or, more generally, relationships between curves and explanatory variables will be addressed by using functional Analysis of Variance (fANOVA) procedures in a general multivariate linear regression framework where additional assumptions are made to account for the regularity of mean curves and for the strong time-dependence across residuals.

How time dependence is modeled in such fANOVA testing procedures is crucial as it must account for the interplay between the pattern of regression parameter curves and the distribution of the time correlations. To address the challenging issue of identifying time points for which the association signal is nonzero, we propose a fANOVA testing procedure which not only flexibly handles dependence but also gives rise to optimal signal detection procedures.

Keywords: Functional data; fNIRS; Dependence in high dimension; Penalized estimation

Time: 14:00 - 14:50

Date: 4th September 2024

**DESCRIPTIVE TEMPORAL SENSORY EVALUATION WITH CONSUMERS:
ADVANTAGES AND LIMITATIONS**

Michel Visalli

Chemosens Platform, France

The transformation of food in the mouth and the release of aromatic and sapid molecules leads to temporal changes in the sensory perception of consumers. This dynamic of sensory perception has been studied for many years using temporal sensory analysis methods. Initially, these methods were developed with trained panels, but over the last years, they shifted from quantitative to qualitative measurements, resulting in rapid methods which can be applied with consumers. While this evolution is desirable to make measurements more representative of perception of consumers, it was likely driven more by practicalities than by scientific considerations. Indeed, rapid methods compromise between costs, ecological validity and relevance of data collection.

This presentation will address different aspects related to data collection and analysis. First, the main results of a systematic scoping review of the literature will be presented, focusing on methodological findings relating to multi-attribute temporal sensory evaluation methods. Second, the granularity of temporal sensory data will be questioned through the presentation of the results of several studies based on data collected using a new method collecting data retrospectively to the tasting and summarizing perception in three periods. Third, the performances (validity, reliability, temporal resolution and discrimination ability) of the temporal methods will be compared using data collected on controlled temporal stimuli delivered in the mouth using a gustometer. Finally, recommendations will be made to help practitioners choose the most appropriate rapid method of collecting temporal data based on their problem, to implement it effectively with consumers, and finally to analyze the temporal data in such a way as to be able to draw robust conclusions.

Keywords: TDS; TCATA; Validity; Discrimination; Repeatability

Time: 9:00 – 10:00

Date: 5th September 2024

**THE PRESENT AND THE FUTURE OF FOOD SAFETY RISK
ASSESSMENT**

Moez Sanaa

World Health Organization, Switzerland

The future of risk assessment lies at the intersection of scientific innovation, ethical imperatives, and societal expectations. As we negotiate a fast-changing landscape impacted by advances in technology and environmental problems, conventional paradigms are being reinvented to suit the complexity of the modern world. In this period of profound shifts, a novel frontier arises, marked by the New Approach Methodologies (NAMs) based on *in silico* and *in vitro* approaches, mechanistic information (e.g. adverse outcome pathways, impact of regulated products), artificial intelligence, and omics/bioinformatic approaches. This change marks the transition from resource-intensive, animal-based models to more integrated, efficient, and mechanistically driven evaluations based on interdisciplinary collaboration.

Considering the increasing complexity of food safety issues, implementing integrated methods is critical. Through a 'One Health' perspective, we address chemical and microbiological hazards, as well as the emerging problem of antimicrobial resistance, while taking social and environmental concerns into account. This comprehensive strategy strengthens our defences against complex problems, ensuring the resilience and sustainability of our food systems and the health of future generations.

Keywords: One Health; NAMs; Antimicrobial resistance

Time: 14:00 - 15:00

Date: 5th September 2024

BAYESIAN PRACTICES IN FOOD SAFETY RISK ASSESSMENTS: TRICKS AND TREATS

Jukka Ranta

Finnish Food Authority

Probabilities are inherent in quantitative food safety risk assessments. This has resulted in numerous modeling applications with simulations of variability and/or uncertainty, both of which can be represented by probability distributions. Whereas variability may be described with common parametric distributions deemed appropriate for purpose, it is yet less obvious how to construct uncertainty distributions for them. Among other approaches, Bayesian methods have been applied for this over 20+ years, either for individual parameters separately, or as full Bayesian multidimensional inference. Although examples are found in research papers, applications in food authorities are less than routine. With increasing computational possibilities to simulate uncertainty and variability, there is yet very little guidance on what level of detail is needed, or whether to take a simple or more advanced approach and how. Often, Bayesian methods are placed among 'refined methods' in higher tiers of assessment yet-to-become, with little concrete guidance. A limiting factor is lack of resources and available tools for food safety risk assessors, since a posterior distribution is often nontrivial to solve. Yet, a cumulative toolbox of models as a library (e.g. RAKIP) and new shiny apps could provide their faster application in government food safety risk assessments. A few examples will be discussed where

Bayesian methods could be 'fit for purpose', touching dose-response models, dietary exposure assessments, and classification, and how they could be made more accessible.

Keywords: Bayesian; Quantitative risk assessment; Food safety; Probability; Variability; Uncertainty; Simulation

Time: 9:00 – 10:00

Date: 6th September 2024

REMOTE SENSING DATA IN THE DEFINITION OF MANAGEMENT ZONES IN PRECISION AGRICULTURE

Maria Teresa Godinho

Instituto Politécnico de Beja, Portugal

Specific-site management (SSM) is the management of agricultural crops at a spatial scale smaller than that of the whole field. SSM techniques are relatively new in agriculture – its implementation, in the 1980's, begun as a response to the need to control costs in large scale mechanized agriculture. Since then, its focus has evolved and now SSM techniques are also recognized and recommended for their contribution to a sustainable agricultural that does not marginalize profit. Specific-site management methods require within field spatial variability to be identified and measured. The problem of identifying and delineating areas with different properties is designated as the management zone delineation problem (MZsP).

This talk addresses precisely the MZsP. Namely, we show how to use remote sensing data to delineate management zones through triclustering techniques. In our algorithm, these techniques are applied to mine spatio-temporal clusters from time series of remote sensing data. Then, each cluster represents a behaviour pattern for a particular subset of spatio coordinates through a specific set of times. The temporal component of this analysis permits MZs dynamics to be characterized within timeframes in the growing season.

Data from maize and vineyard crops in Alentejo have been used to assess the suitability and accuracy of the algorithm with good results.

Keywords: Precision agriculture; Big data triclustering

PRESENTATIONS

Session 1: Experimental Designs

Time: 10:10 - 10:50

Date: 4th September 2024

SPACE FILLING DESIGN FOR TRAINING DATASET REDUCTION

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Models as neural networks require numerous data for the training step. In order to reduce the number of data points, Design Of Experiments (DOE) can be used and more particularly Space Filling Design (SFD) have been tested to select the subset of experimental points. Two case studies in spectroscopy have been simulated to evaluate the relevance and the limits of this approach.

Keywords: Design of experiments; Space filling design; WSP algorithm; Spectroscopy

PREDICTING THE STABILITY OF COMPLEX DISPERSED SYSTEMS USING PHYSICAL AND CHEMICAL TECHNIQUES AND BUILDING MATHEMATICAL MODELS

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The physicochemical stability of cosmetic emulsions is crucial for their marketability. This study aims to anticipate emulsion stability by combining innovative experimental techniques such as rheology, turbidimetry, granulometry, microscopy, and texture analysis with in-depth data analysis. Stable and unstable formulas were compared, revealing that granulometry, rheology, and turbidimetry effectively distinguish between them. The results were then studied using experimental design

Keywords: Emulsion stability; Cosmetics; Rheology; Design of Experiments

Session 2: Food Safety Modelling

Time: 11:10 – 11:50

Date: 4th September 2024

STATISTICAL ANALYSIS OF ECOPHYSIOLOGY AND MYCOTOXIN PRODUCTION IN FUSARIUM SPECIES: KEY FINDINGS

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Fusarium head blight (FHB) poses a significant threat to wheat production and food safety. Various fungal species within the *Fusarium* genus are responsible for FHB. These species emit different mycotoxins harmful to human and/or animal health. Hence, understanding the ecophysiology of these species is crucial for predicting their distribution with climate change in France.

In our study, we analyzed data from an in vitro experiment involving 25 strains from five different *Fusarium* species. These strains were grown under various water and temperature conditions. We determined their growth probabilities using a logistic regression model and developed growth kinetics models (sigmoid curves) to estimate how the different growths varied between species in their response to environment. Furthermore, in a subset of environmental conditions, we measured the production of mycotoxins emitted by the different species to assess how it was (differently across species) affected by environmental conditions. Finally, we used a principal component analysis on the ranks to explore the relationships between the growth parameters and toxin production.

The growth probability analysis revealed species with varying sensitivities to temperature and water conditions, with for instance the growth probability of *F. Langsethiae* being insensitive to temperature and other species' growth probability being jointly affected by temperature and water activity. The interspecific diversity had a small influence on the growth parameters, these being more affected by the environmental conditions. The water activity increased the quantity of toxins produced but the effect of temperature varied between species. Samples characterized by early and rapid growth were those with higher toxin production.

This study is the first to investigate the influence of 24 combinations of abiotic factors on the growth and toxin production of 25 strains across 5 distinct *Fusarium* species. The next

steps of our work include linking this in vitro experiment data to in vivo data. To achieve this, we have established a dataset comprising 1500 samples of different mycotoxins concentrations in wheat, covering various climatic regions in France. This poses challenges in terms of function-to-scalar regression, which we aim to address using statistical techniques such as dimension reduction and penalized regressions.

Keywords: *Fusarium*; Ecophysiology; Mycotoxins; Growth modelling

MODELING THE INACTIVATION AND SURVIVAL OF FOODBORNE PATHOGENS IN TRADITIONAL MOROCCAN FOODS: MERGUEZ SAUSAGE AND AMLOU SPREAD

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Foodborne illnesses caused by pathogens such as *Salmonella* and *Escherichia coli* remain a significant public health concern, particularly in traditional foods with artisanal production chains. This study aimed to develop predictive models for the inactivation of *Salmonella* spp. in a simulated Merguez sausage (Merguez) and the survival of *E. coli* in a simulated traditional Moroccan spread (Amlou). A Doehlert matrix design and response surface methodology were employed to investigate the effects of multiple factors on pathogen behavior. For Merguez, a response surface model accurately predicted *Salmonella* inactivation based on oregano essential oil, pH, temperature, and water activity, with a root mean square error (RMSE) of 0.14 and 0.09 for the scale and shape parameters, respectively. For Amlou, the quadratic model showed a good fit for predicting *E. coli* death rate (RMSE = 0.0095) based on argan oil, sugar, and peptone concentrations. The models highlight the importance of food matrix formulations on pathogen inactivation/survival and can contribute to developing efficient control measures in the food industry.

Acknowledgments: The authors are grateful to EU PRIMA programme and the Moroccan Ministry of Higher Education, Scientific Research and Innovation (MESRSI) for funding the ArtiSaneFood project (PRIMA/0001/2018).

Keywords: *Salmonella*; *Escherichia coli*; Response surface methodology; Traditional foods; Amlou spread; Merguez sausage

Session 3: Meta-analysis

Time: 11:50 – 12:30

Date: 4th September 2024

A SYSTEMATIC REVIEW AND META-ANALYSIS OF ANISAKIDS OCCURRENCE IN EUROPEAN COUNTRIES

Sabrina El Metennani^{1,2}, Anne Thebault^{3*}, Laís Carvalho^{1,2}, Ana Sofia Faria^{1,2}, Vasco Cadavez^{1,2}, Ursula Gonzales-Barron^{1,2}, Pauline Kooh³

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Anisakids, parasitic nematodes, pose a significant health risk to consumers of raw or undercooked fish. These parasites can cause anisakiasis, a gastrointestinal illness characterized by severe abdominal pain, nausea, and vomiting. While wild-caught fish are known carriers of anisakids, the aquaculture industry has also raised concerns about the potential presence of these parasites in farmed fish. The main objective of this systematic review is to compile the occurrence of the zoonotic nematodes anisakids, mainly belonging to the genera *Anisakis*, *Contracaecum*, and *Pseudoterranova*, in European countries.

In total, 265 publications provided data on wild-caught fish, 11 publications focused solely on aquaculture, and an additional 9 publications included data on both aquaculture and wild fish. A preliminary analysis of the aquaculture studies (n=18) showed various numbers of records in countries like Italy (6) and Norway (3). This same set of studies included records for all three genus of the parasites of interest and showed that fish can be analyzed either entirely or by separating viscera from fillets.

The first analysis focusing on *Anisakis* in organ-sampled fillets from aquaculture showed an estimated overall prevalence of 1.72% (95% CI: 0.79%-3.71%) and revealed various detection and identification methods used in this subset. These methods included morphological (visual inspection including candling) or microscopic examination, artificial digestion followed by a morphological (or microscopic) examination, press/UV morphological examination and molecular methods. These initial analyses showed no significant influence (p-value > 0.05).

These findings underscore the need for further investigation into the factors contributing to the prevalence of *Anisakis*. This research is part of the Pathogens in Foods project and is funded by EFSA (GP/EFSA/BIOHAW/2023/05). This abstract is published under the sole

responsibility of the authors, and EFSA is not responsible for any use that may be made of the information it contains.

Keywords: Anisakids; Europe; Fish; Contamination

CAPABILITY OF AUTOCHTHONOUS LACTIC ACID BACTERIA SUPERNATANT FROM DAIRY FOODS TO INHIBIT *SALMONELLA ENTERICA*: A META-REGRESSION STUDY

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This systematic review aimed to assess the antimicrobial activity of lactic acid bacteria (LAB) supernatant against *Salmonella* (*S.*) *enterica* serovar Typhimurium, a common contaminant of dairy products. A comprehensive search of PubMed, Scopus, and Web of Science databases yielded 14 relevant studies, providing 100 observations.

Multilevel fixed-effects meta-analysis regressions were conducted to analyze mean inhibition diameters resulting from the supernatant of LAB and to explore the influence of moderators such as susceptibility method, agar medium, and incubation time on in vitro assay results. Using the 'metafor' package in R 4.1.2, meta-analysis models and graphs were constructed. The primary outcome measured was the mean inhibition zone diameter (ID) and its standard error (SE).

Results from the initial fixed model, employing a pathogen concentration of 7 log CFU/mL and an incubation time of 24 hours, indicated that *Lactococcus* (12.76 ± 1.194 mm) exhibited the highest inhibition values against *S. enterica*, followed by *Lactobacillus* (12.36 ± 1.148 mm) and *Enterococcus* (12.00 ± 1.195 mm). A second model considered the susceptibility method as a moderator, revealing that the well diffusion test yielded higher inhibition values compared to spot and disk diffusion tests ($p=0.009$). This discrepancy could be attributed to the superior diffusion of supernatant in the well test compared to the disk test, owing to mechanical perforation of the agar versus solely diffusion. The best-fit regression model for *S. enterica*, incorporating susceptibility method, agar medium and incubation time, explained 52.3% of the total variance. Notably, a positive and significant correlation between incubation time and inhibition values was observed ($p<0.001$), with longer incubation periods (e.g., 72 hours) resulting in higher inhibition values. The tendency of pH and inhibition diameter values had a significant effect ($p<0.001$), for instance, *Lactobacillus* displayed higher inhibitory activity at more acidic pH (ID=25 mm) compared to neutral pH (ID=15 mm).

Overall, the inhibition of *S. enterica* by *Lactobacillus* highlights the potential of probiotic lactobacilli in promoting gastrointestinal health and preventing foodborne illnesses.

Incorporating *Lactobacillus*-containing foods or probiotic supplements into the diet may enhance the natural defences against *Salmonella* and other pathogenic bacteria in the gut.

Keywords: Antimicrobial peptides; Hurdle technology; Cheese; Bacteriocinogenic

Session 4: Sensometrics I

Time: 14:50 - 15:50

Date: 4th September 2024

CATEGORICAL FUNCTIONAL DATA ANALYSIS APPLIED TO TEMPORAL DOMINANCE OF SENSATIONS DATA

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Sensory analysis is a multidisciplinary field aiming at describing sensory perception and appreciation of food and non-food products by consumers. It features several experimental protocols including temporal ones. Among them, Temporal Dominance of Sensations (TDS) involves subjects indicating the dominant sensation among a list of descriptors (the categorical states of the stochastic process) at each moment throughout the tasting of an intake of the product.

Categorical functional data analysis extends the traditional functional data analysis to temporal categorical data, making it particularly relevant for TDS data. CFDA is now supported by a R-package (CFDA). Applied to TDS data, it produces a PCA-like map of the sensory evaluations of the products by the subjects (the trajectories) based on the sequences of sensations perceived. Each axis represents leading temporal patterns and the coordinates of sensory evaluations on these axes depict their main temporal characteristics. Then, those coordinates can be used as inputs for further statistical analyses such as clustering of subjects or discriminant analysis of products, both based on temporal perception.

This paper shows the application of CFDA on both a pedagogical dataset and a TDS dataset wherein subjects were connected to a gustometer delivering controlled temporal stimuli in the mouth of the subjects. Additionally, it discusses further opportunities and challenges associated with the application of functional data analysis to different other kinds of sensory data

Keywords: Categorical Functional Data Analysis; Temporal Dominance of Sensations

ON THE REPRESENTATION AND ANALYSIS OF TEMPORAL DOMINANCE OF SENSATIONS DATA

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Temporal Dominance of Sensations (TDS), introduced around twenty years ago, has established itself as the standard for multidimensional temporal sensory evaluation. Although initially designed for trained panels, a method for monitoring subject's performances had long been lacking until Frascolla et al. (2023). However, TDS was quickly able, by simplifying itself, to become feasible by consumers, opening up the possibility of segmenting the latter on the basis of their temporal sensory perception of products rather than on the traditional one of their preferences.

A large number of methods have been proposed to represent and analyze TDS data. TDS curves remain by far the most used representation method, sometimes accompanied by the analysis of dominance durations using uni- or multi-dimensional linear models. However, these inferential analyses of dominance durations often sacrifice the temporal aspect of the data. These classic methods based on the curves of dominance proportions and on dominance durations do not integrate the probabilities of transition from one descriptor to another, nor do they model the laws of dominance durations. These two elements are the basis of the approach based on semi-Markovian processes proposed by Lecuelle et al. (2018), which nevertheless remained confidential.

Recently, another descriptive multidimensional approach, rather than inferential, but taking the temporal aspect into account, based on the functional analysis of qualitative variables was proposed (Peltier et al, 2023). This approach, like the previous one, make it possible to segment consumers on the basis of their temporal perception of one or more products; these two approaches therefore deserve to be compared in practice. Between these two relatively sophisticated approaches and the excessive simplicity of TDS curves, Visalli et al. (2024) proposed another representation of TDS data emphasizing, on the one hand, the times at which each descriptor is perceived, and on the other hand the times at which each of these perceived sensations ends. On these two aspects, the authors proposed an inferential approach by resampling. This presentation will discuss these developments, focusing on highlighting the prospects for the development and dissemination of these methods.

Keywords: TDS; Temporal perception; Temporal graph; Temporal qualitative data; Stochastic processes

NONLINEAR PLS-BASED APPROACHES APPLIED TO EXTERNAL PREFERENCE MAPPING – A REVIEW

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In the context of product development and optimization, preference mapping encompasses a variety of methods applied to preference data to understand better consumer preferences. This paper focuses on External Preference Mapping (PrefMap), which aims to relate preference and sensory data to identify drivers of liking and their optimal value associated with an ideal product. Classically, PrefMap consists of two steps: 1) determining a perceptual space of products using a small number of latent variables, followed by 2) building a predictive model that regresses liking scores on the latent variables obtained.

While this perceptual space is typically constructed by a Principal Component Analysis performed on sensory attributes, the use of Partial Least Squares (PLS) allows both sensory and preference data to be considered. However, in its original form, PLS only takes into account the linear part of the relationship between the two sets, which can be a limitation for PrefMap. Therefore, to account for some non-linear relationships, several variants of PLS have been proposed, such as Quadratic PLS, PLS-Spline, and PLS on the matrix augmented by the squared predictors (X2PLS). To avoid collinearities among predictors in X2PLS, we propose its adaptation, which consists in orthogonalizing the squared predictors with respect to their linear part. A notable advantage of (O)X2PLS lies in the absence of hyperparameters, which makes it easy to implement and less subject to overfitting.

After reviewing the different strategies mentioned above, they are compared by varying the complexity of the predictive model involved in the second step (from vectorial to quadratic). In particular, their standardized explained variance is examined on about fifteen data sets. Finally, specific outputs that take advantage of (O)X2PLS approaches are proposed to facilitate the interpretation of the results and to guide practitioners in product optimization.

Keywords: Preference mapping; Partial Least Squares regression; Principal Component Analysis; Variable importance in the projection; Orthogonal polynomials

Session 5: Sensometrics II

Time: 16:10 – 17:10

Date: 4th September 2024

PRINCIPAL COMPONENT ANALYSIS WITH OPTIMAL SCALING: A WAY TO INTEGRATE SENSORY ANALYSIS, PHYSICO-CHEMICAL MEASUREMENTS AND EXPERIMENTAL FACTORS

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Most multivariate statistical methods have been developed for quantitative/numerical data, while it is often the case that qualitative variables are collected at the same time. These qualitative/categorical variables can be either nominal, with a finite number of modalities identified by labels, or ordinal, where the modalities are ordered. To deal with mixed types of variables, an attractive strategy is to assign numerical values to the modalities. This operation of quantification or scaling can be carried out to optimize a criterion related to the objective of the data analysis, i.e. supervised or unsupervised. For an overview of the various approaches to optimal scaling that have been proposed in the past, see Abdi et al. (2024). In this presentation, we consider an exploratory analysis of the relationships between variables of mixed types, more specifically PCA-OS (Principal Components Analysis with Optimal Scaling), also known as the PRINQUAL procedure in SAS software.

By way of illustration, part of the data from a collaborative project (Redlosses Project) is considered. Seventy-two samples of industrially produced sausages, from six campaigns, were characterized by a trained panel in terms of olfactory off-odours attributes among which global alteration, fermented fruit, fermented meat and sour/pungent. In each campaign, meat doughs were prepared with normal or half dose of lactate and three gas mixtures for packaging were tested: normal air, 50%CO₂-50%N₂ and 70%O₂-30%N₂. The experimental factors "Lactate Dose" and "Packaging" were crossed and the sausages were sampled on the 7th and 15th day of storage.

Taking simultaneously account of categorical variables (Lactate Dose, Packaging and Time) and numerical sensory variables, the results of a Factorial Analysis for Mixed Data5 (combining Principal Component Analysis and Multiple Correspondence Analysis) and PCA-OS will be compared and discussed. The fundamental difference between the two types of methods will be illustrated: The former provides multiple scalings for each categorical variable, whereas PCA-OS results in a single scaling transformation. The Redlosses project database also includes physico-chemical and Volatile Organic

Compound measurements. All these data blocks can be submitted to the MBPCA-OS method, extension of the PCA-OS method to the multiblock framework.

Keywords: Exploratory multivariate analysis; Mixed data; Optimal scaling; Experimental design; Sensory analysis; Meat spoilage

APPLICATION OF UNFOLDING ANALYSIS TO PALATABILITY VERSUS TESTS

Julien Rogues

SPF - Symrise Pet Food, France

The Bradley-Terry model is a well-established method for analyzing paired comparison data, typically used to rank items based on preference. However, this model assumes a uniformity in preferences that might overlook nuanced individual differences. Unfolding analysis, on the other hand, is adept at capturing such individual variations by representing both subjects (pets) and objects (pet foods) in a common space, allowing for a more detailed understanding of preference structures. The study aims to explore the application of unfolding analysis in the context of paired comparisons to assess pet food preferences, with an emphasis on understanding individual variations.

A series of experiments were conducted where various pet foods were compared in pairs by pets. The preferences were analyzed using the Bradley-Terry model to establish a general ranking of the pet foods palatability level. Subsequently, unfolding was applied to the same data to map out the preferences in a multidimensional space. This approach revealed significant insights into individual variations in preferences that were not apparent from the Bradley-Terry analysis alone. The results indicated that while there was a consensus on certain popular pet foods, individual preferences varied widely, influenced by specific factors. The unfolding analysis provided a visual representation of these preferences, highlighting clusters of pet foods that were similarly preferred by certain groups of pets, thus offering a more nuanced understanding of the data.

The study advocates for the use of unfolding analysis in conjunction with the Bradley-Terry model to obtain a comprehensive view of preference data. By doing so, researchers can better understand the diverse needs and preferences of pets. This dual approach allows for the identification of niche markets and the development of targeted products that cater to specific segments of pets, thereby enhancing customer satisfaction and loyalty. Overall, the integration of unfolding analysis with Bradley-Terry paired comparisons represents a significant advancement in preference measurement, emphasizing the importance of accounting for individual variations to obtain a complete and accurate picture of consumer preferences. This methodology can be applied beyond pet food preferences to other areas where preferences are measured with paired comparisons and understanding individual differences is crucial.

Keywords: Unfolding; Pet; Preferences

INVESTIGATING SENSORY-INSTRUMENTAL RELATIONSHIPS IN A SUBSET OF TEST-CONTROL PAIRED COMPARISONS BY PARTIAL LEAST SQUARES REGRESSION

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Relationships between sensory and instrumental variables are often investigated using partial least squares regression (PLSR). We describe the conventional PLSR solution. Next, we describe two new approaches for conducting PLSR based on paired comparisons of objects. First, we describe the PLSR of all paired comparisons. Conducting PLSR of all paired comparisons is equivalent to the conventional solution in the sense that both analyses yield the same regression coefficients. Next, we consider a case where multiple test formulations are compared with one control formulation. In this case, the test-control paired comparisons are of primary interest and the test-test paired comparisons are of lesser interest. Conducting PLSR of the relevant subset of paired comparisons yields regression coefficients that differ from the conventional PLSR solution. Compared to the conventional PLSR solution, the PLSR of the relevant subset of paired comparisons explains the test-control paired differences well. However, the PLSR of the relevant subset of paired comparisons does not always give better prediction accuracy. Findings are illustrated using a published data set including instrumental and sensory evaluation of French cabernet franc wines.

Keywords: Partial least squares regression; PLSR; Projection to latent structures; Sensory evaluation; Paired comparisons

Session 6: Predictive Microbiology and Risk Assessment

Time: 10:00 – 11:00

Date: 5th September 2024

THE MULTI-OBJECTIVE DATA-DRIVEN APPROACH: A ROUTE TO DRIVE PERFORMANCE OPTIMISATION IN THE FOOD INDUSTRY

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Although standardized, the food industry is subject to many sources of variability resulting from the natural variability of raw material, human perception and intervention in the

process, capabilities and maintenance of processing tools, etc. Altogether, they affect the reproducibility of final product characteristics representing deviations to standard, the production yield impacting the economic performance of the food manufacturing process, etc. In other words, the overall performance of a manufacturing process can be defined by considering several types of indicators such as economic, quality and environmental indicators. In order to improve the overall performance of a food manufacturing process, it is necessary to identify all sources of variability: in this view, having a global vision of all the measurements collected throughout the process could constitute a powerful lever for optimising production.

In this work, a multi-objective and data-driven approach is used to optimise the overall performance of the cheese manufacturing plant. In the industry, performance objectives are often conflicting, and need to be taken into account simultaneously, as proposed by this method. Machine learning method is implemented to model and explain the variability of each indicator defining the overall performance by using all the parameters collected over the course of one year. Several optimisations were implemented by changing the input parameters (composition of the raw milk) in order to understand how to adapt the process to several given situations.

Comparison of the optimisation scenarios reveals a need to adapt the manufacturing process to different conditions. Implementing a multi-objective approach to optimise overall performance provide industries a powerful decision support tool for controlling their process. To sum up, the development of a multi-objective method for maximizing the overall performance of complex processes through machine learning represents a major breakthrough for the food industry

Keywords: Multiobjective optimisation; Dairy industry; Global performance; Machine Learning

MODELING THE GROWTH DYNAMICS OF *STAPHYLOCOCCUS AUREUS* IN MOROCCAN JBEN SOFT CHEESE UNDER DIFFERENT STORAGE TEMPERATURES

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Understanding the growth behavior of pathogens in food products is critical for food safety. This study investigated the growth dynamics of *Staphylococcus aureus* CECT 976 in Jben goat's milk soft cheese made without starter culture, and stored at 8°C, 20°C and 37°C.

Lab-scale goat's Jben soft cheese samples were prepared following traditional methods and inoculated with *S. aureus* strain. Kinetic parameters such as initial and maximum microbial concentrations (SA₀, SA_{max}) and maximum growth rate (μ_{max} SA) were

estimated using Lotka-Volterra and Jameson-effect models considering the inhibitory effect (a_{21}) of indigenous lactic acid bacteria (LAB) on *S. aureus*.

The results showed significant temperature-dependent differences in *S. aureus* and LAB growth rates and maximum concentrations. At 8°C, *S. aureus* had a lower SA_0 and SA_{max} concentration, and a slower μ_{max} SA (1.054 days⁻¹, 1.089 days⁻¹ for Lotka-Volterra and Jameson-effect models). At 37°C, *S. aureus* showed a significant increase in μ_{max} SA (14.97 days⁻¹, 22.24 days⁻¹) and an increase in SA_{max} . Although the root mean square error (RMSE) and mean absolute error (MAE) values were lower for the Lotka-Volterra model, the fact that a_{21} was not found significant at any temperature suggested that the Jameson-effect model was a more parsimonious model. Thus, square-root secondary models for the maximum growth rate of *S. aureus* and LAB were developed from the Jameson-effect fitted values; and subsequently these two relationships were validated against growth data obtained at 30 °C.

These results provide insights into the temperature-dependent growth kinetics of *S. aureus* in goat's Jben cheese, which is a first step for ensuring the safety of these regional dairy products.

Keywords: Jben cheese; Microbial modeling; Predictive microbiology; Jameson effect; Lotka-Volterra; Lactic acid bacteria

BIOPROTECTIVE EFFECT OF LACTIC ACID BACTERIA AGAINST LISTERIA MONOCYTOGENES IN HEAT-TREATED RECONSTITUTED MILK

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Lactic acid bacteria (LAB) play an important role in fermented products, by promoting desirable organoleptic properties, and by their antimicrobial properties limiting the growth of pathogenic bacteria. The objective of this study was to determine the growth kinetics of *Listeria monocytogenes* (LM) in heat-treated reconstituted milk, as affected by selected LAB strains *Leuconostoc mesenteroides*, *Lacticaseibacillus paracasei* and *Loigolactobacillus coryniformis* isolated from goats' milk cheeses.

Challenge tests of each LAB strain in monoculture and in coculture with LM in milk adjusted to three initial pH levels (5.5, 6.0 and 6.5) were performed. Inoculated milk samples were left to ferment at 12°C for 8 days. A pH-driven dynamic growth model was fitted in separate to the LM and LAB experimental curves from both monoculture and coculture experiments; and a Jameson-effect growth model was fitted only to the coculture growth curves. In monoculture, *L. mesenteroides*, when compared to the other LAB strains, showed the highest growth rates at the three initial pH levels; whereas in coculture,

this strain was able to better control the growth of LM, by decreasing their growth rates [day^{-1}] to 1.469 ± 0.205 at pH 5.5; 2.293 ± 0.284 at pH 6.0 and 1.552 ± 0.132 at pH 6.5. *L. paracasei* and *L. coryniformis* strains were only able to inhibit and reduce the growth of LM at pH 5.5. In relation to the maximum concentration of LM (LMmax), *L. mesenteroides* was again the most effective at all initial pH tested. The LMmax [log CFU/ml] values were reduced to 15.05 ± 0.367 ; 16.32 ± 0.204 and 16.91 ± 0.132 at pH 5.5; 6.0 and 6.5, in comparison to the values 20.85 ± 0.060 ; 21.10 ± 0.212 and 21.31 ± 0.085 , obtained in monoculture, respectively. This indicates that this particular strain of *L. mesenteroides* has a broader and more inhibitory effect on LM growth across different pH levels, whereas *L. paracasei* and *L. coryniformis* are only effective in more acidic conditions (pH 5.5).

These research results provide valuable insights into the use of LAB as a natural biopreservative for controlling LM in dairy products, thereby enhancing food safety.

Keywords: Biopreservation; coculture; Monoculture; pH; Growth kinetics; Modelling; Predictive microbiology

Session 7: Process Control

Time: 11:30 – 12:30

Date: 5th September 2024

A DESIGN OF EXPERIMENTS APPROACH TO IMPROVE THE ANTIBACTERIAL EFFECT OF PROTEIN HYDROLYSATES

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Foodborne pathogens pose a significant risk to public health and seriously impact economy, motivating the development of effective antimicrobial strategies. In the context of increasing demand for minimally processed and environmentally friendly preservatives for food and pet food, the release of bioactive peptides through protein hydrolysis have sparked enthusiasm among the scientific community. This study focuses on determining the inhibitory effects of four food-derived protein hydrolysates on key foodborne pathogens and understanding the impact of the conditions of hydrolysis on their efficacy.

A fractional factorial design was used in a first step to screen the effects of temperature, pH, enzyme-to-substrate ratio and raw material-enzyme combinations. The impact of each factor on pathogen inhibition was assessed and ranked. Then, significant factors from the screening phase were optimized using a Box-Behnken design. This involved a three-level

design focusing on temperature, pH, and enzyme-to-substrate ratio. The antibacterial efficacy of each hydrolysate was tested against *Listeria innocua*, *Salmonella enterica*, *Escherichia coli* and *Staphylococcus aureus* and characterized by the percentage of inhibition (24, 48, and 72 hours). All the statistical analysis were performed using R Software 4.2.2.

The initial screening indicated that pH influences the antimicrobial activity of the hydrolysates and highlights the interest for 3 enzymes-raw materials combinations from the 4 combinations initially tested. Optimal conditions identified via Box-Behnken design were specific regarding the strain studied and the combination raw materials/enzyme. Specifically, a combination of 3 parameters tested (pH, temperature and ratio enzyme/substrate) showed a strong influence on the inhibition of *E. coli*. An optimum point could be identified to reach a point close to a positive inhibition, primary target of the study.

This exploratory work confirms the potential of these hydrolysates to be used as new antimicrobial agents. The optimized conditions depending on the foodborne pathogens and the combination raw materials/enzyme provided specific guidance to improve the inhibition of these bacteria. These findings lay the groundwork for future research and industrial application to enhance food safety. Complementary studies regarding the variability of the measures will allow us to improve results of inhibition before evaluating their effect in vivo once incorporated into food matrices.

Keywords: Protein hydrolysates; DoE; Foodborne pathogens

CHEMICAL AND MICROBIOLOGICAL COMPARISON OF READY-TO-EAT, DRY FERMENTED SAUSAGES FROM NORTHERN PORTUGAL

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Chouriço de carne is a typical Portuguese ready-to-eat dry fermented sausage, produced with wine-marinated pork meat, fat, and seasonings. It's still traditionally produced in certain rural areas of Northern Portugal, where artisanal producers rely on effective spontaneous fermentation and generational knowledge about smoking and drying to suppress pathogen development, ensuring the microbial safety and desired organoleptic properties of *chouriço*.

The aim of this study was to evaluate selected physicochemical and microbiological properties of *chouriço de carne* traditionally produced in northern Portugal, and to understand the associations between these attributes. Water activity (*aw*), moisture, pH, ash, protein, fat, carbohydrates, counts of mesophiles, lactic acid bacteria (LAB), *Staphylococcus aureus*, *Clostridium* spp., as well as detection of *Listeria* spp. and *Salmonella* spp., were determined for 14 producers, 5 sausages per each. The data generated by these variables was subjected to principal component analysis (PCA), cluster analysis and factor analysis.

PCA analysis generated three components which accounted for 60% of data variation: PC1 (26%) positively correlated to moisture and protein and negatively to fat and pH, describes sausages with more meat in formulation; PC2 (19.3%) highly correlated to LAB, characterizes a longer/rapid fermentation; and PC3 (14.5%), which associated negatively to ash, and positively to *aw*, and to a lesser extent, to *Clostridium* spp. and *S. aureus*, defines sausages with poorer hygiene.

Cluster analysis identified three groups within the quality maps: i) *chouriços* with high moisture, more meat and more acidic; ii) sausages with low moisture, more fat, and potential hygiene faults; and iii) *chouriços* with very low moisture, more meat, and less acidic. Slightly different to PCA, factor analysis yielded a varimax-rotated three-factor analysis that explained 65% of the data; PC1 (23.5%) depicts *chouriços* with low pH but high moisture, while PC2 (20,8%) describes sausages with more meat in formulation, and PC3 (20,6%) longer or rapid fermentation.

Overall, the results present great variability between producers, highlighting the difference in recipes, ingredients and manufacture practices employed amongst enterprises, which contribute to a rich landscape, but the variance between sausages of the same producer accentuates the need for process standardization and better microbiological control.

Keywords: Dry fermented sausage; Pathogens; *Clostridium*; *Staphylococcus aureus*; *Salmonella*; *Listeria*; pH; Fat; Protein; Moisture; Principal component analysis; Cluster analysis; Factor analysis

OPTIMISATION OF MICROBIOLOGICAL, PHYSICOCHEMICAL AND TEXTURAL QUALITY ATTRIBUTES OF GOAT'S MILK KEFIR

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Kefir is a popular probiotic drink known for its fermented, acidic, and slightly alcoholic properties. This study aimed to determine key processing variables, namely, the ratio of kefir grains/milk, incubation temperature, and incubation time, that optimise the quality of goat's pasteurised milk kefir.

Fourteen kefir treatments built upon three grain/milk ratios (0.5%, 1%, and 1.5%), three incubation times (16 h, 20 h, and 24 h), and three incubation temperatures (15 °C, 20 °C, 25 °C) were carried out, according to a Box-Behnken design with three central points, to determine the best triplet variables regarding these properties: pH, acidity (% of lactic acid), syneresis (%), mesophiles and lactic acid bacteria concentration, firmness, consistency, cohesiveness and viscosity index. Response surface analysis was applied to each of the quality attributes.

It was found that all the quality properties were affected by the three factors, having in all cases significant effects ($p < 0.05$) for the first-order estimation. Kefir acidity was maximised at 0.66%, 25.3 °C, and 22.8 h; although the temperature had a much greater effect than time, and in turn, the latter had a greater effect than the grains/milk ratio. In terms of the textural properties, firmness, and viscosity index could be maximised at the conditions of 1.07%, 19.9 °C, and 17.4 h; and 1.28%, 18.5 °C, and 20.4 h, respectively. At an incubation temperature of 25 °C, the syneresis was found between 38.5 – 39.9%; the lower (4.46 – 4.49%) was attained at 15 °C. Lower incubation temperatures or longer incubation times can also produce kefir with the desired acidity and textural quality of hardness and consistency, only if the ratio is increased ($>1.0\%$). ~

Thus, this study has been instrumental in understanding the effects of the three key processing variables and helped in the determination of the variables to obtain goat's milk kefir of good technological quality for subsequent studies.

Keywords: Kefir grains; Box-Behnken; Acidity; Hardness; Viscosity; Lactic acid bacteria

Session 8: Artificial Intelligence & Big Data

Time: 15:00 – 16:00

Date: 5th September 2024

TIME SERIES PREDICTION FOR RAW MATERIAL PRICES

Pierre Barbe

SPF - Symrise Pet Food, France

Predicting future price movements is crucial for Symrise purchasing teams to efficiently plan and negotiate with suppliers. Accurate price forecasts enable organizations to optimize their procurement strategies by mitigating risks associated with price volatility.

In this study, we evaluate models for predicting ingredients price time series using historical prices and time series covariates. To capture temporal dependencies and the influence of external factors on price movements, we both explore machine learning models as recurrent neural networks (RNNs), including long short-term memory (LSTM) networks, and parametric models as SARIMAX models. Time series covariates such as

trading volumes, macroeconomic indicators, ingredient drivers prices and other relevant exogenous variables are incorporated to enhance prediction accuracy. Model performance measures are performed by making retrospective comparisons between real price evolutions and predicted evolutions. The best prediction model is implemented in a Shiny application which supports purchasing teams for planning their procurement.

Keywords: Time series; Machine learning; Deep learning

LEVERAGING LARGE LANGUAGE MODELS FOR CONSUMER REVIEW SUMMARY IN COSMETIC INDUSTRY

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This study aims to develop an application utilizing large language models (LLMs) to summarize consumer reviews in the cosmetic industry. The goal is to extract meaningful insights regarding customer sentiments, preferences, and trends over time. The skincare and makeup industries are filled with diverse products and brands, making consumer reviews essential for performance analysis and understanding benefits. However, handling the extensive data poses significant challenges. This study introduces a tool that uses LLMs like GPT and natural language processing (NLP) techniques to effectively process and summarize large datasets of consumer reviews.

A database comprising approximately six million reviews gathered from various online platforms was used: it underwent rigorous preprocessing, including cleaning and normalization, to ensure suitability for analysis. The application leverages NLP techniques and LLMs, employing prompt engineering to generate tailored summaries based on user-defined parameters such as brand, product type, market, years, and specific areas of interest.

To enhance user interaction, an approximate string matching algorithm was integrated to facilitate flexible recognition and adaptation to diverse user inputs. Upon defining parameters, the application interfaces with an API linked to the LLM to generate a summary text, with visual sentiment indicators, categorizing topics as positive or negative through sentiment analysis, thereby providing a clear overview of consumer perception.

This application demonstrates the capability of LLMs to distil actionable insights from vast consumer feedback within the cosmetic industries. It showcases the value of NLP in comprehending consumer sentiments and market trends. Beyond research, this tool holds promise for direct consumer benefits and enterprise applications. Product formulators can gauge consumer reception, while businesses can refine strategies based on real-time feedback.

Keywords: Large Language Models; Natural language processing; Consumer reviews; Cosmetic; Prompt engineering

ARTISANER: AN ONLINE GENERIC PROCESS RISK MODEL FOR SAUSAGE-MAKING

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Artisanal fermented foods may pose health risks to consumers as they are often produced with variable, mostly non-standardised productive processes, and are generally consumed without any cooking. The PRIMA-funded ArtiSaneFood project (<http://www.ipb.pt/artisanefood/>) researched bio-intervention strategies, such as the application of natural extracts and starter cultures, that could control the growth of selected pathogens in such products. Within this context, an online generic process risk model (PRM) for sausage-making was developed as an R shiny tool (ArtisaneR), with the objective of estimating, through Monte Carlo simulation, the prevalence and concentration of *Salmonella* spp., *Staphylococcus aureus* or *Listeria monocytogenes* along the sausage-making processing stages, from mixing of ingredients to packaging. Running the PRM requires input data on the process variables, the probability and level of contamination in main ingredients and casings, probability of cross-contamination, kinetic parameters of the pathogen under study in the sausage matrix, and the effect of bio-preservative(s) on the numbers of the pathogen.

The PRM consists of six functions: (1) generation of contaminated lots, whose contamination levels are dictated by the levels in meat, fat and spices, and the recipe; (2) stuffing, which simulates potential cross-contamination of batter from casings; (3) biointervention, which models the level of microbial reduction due to the addition of extracts or starter cultures; (4) maceration, which models microbial growth during maceration or early fermentation; (5) maturation, which optionally simulates the death of the pathogen based on a pH-driven dynamic model; and (6) packaging, which groups the sausages into packages of finished product.

The ArtisaneR shiny involves 34 parameters for the baseline scenario and 37 for the bio-intervened scenarios; and displays summary statistics and distributions at both lot level and individual level (sausage/package) at each of the five panels corresponding to a processing stage. ArtisaneR has been customised for Portuguese alheira sausage, Spanish salchichón and Moroccan/Tunisian merguez sausage; and is freely available at: <https://pif.esa.ipb.pt/shiny/artisanefood/prmodels/sausage>, with a fully documented manual in the *About* section of the tool. With minimal training, ArtisaneR can be exploited by regional producers of fermented sausages, or can be used as an educational tool in food safety courses.

Keywords: Exposure assessment; Shiny; Simulation; Interactive tool; Regional producers; Fermented sausages

Session 9: Software and packages – corneR

Time: 16:20 – 17:20

Date: 5th September 2024

DEVELOPMENT OF A PYTHON LIBRARY THAT INTEGRATES INFORMATION FROM THE KEGG DATABASE TO ANALYZE BIOLOGICAL PATHWAYS

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Python libraries are a set of modules and packages that store previously developed functions for specific solutions. They have the functionality of reusing code, increasing development, and avoiding writing the same pipelines for analysis from scratch. The Kyoto Encyclopaedia of Genes and Genomes (KEGG) database integrates genomic, chemical, and systems data, as well as containing different bioinformatics tools. It allows for integrated analysis of metabolic pathways, genetic regulation, and molecular interactions, facilitating understanding of complex biological processes. The aim of the work developed was to create a Python library that could analyze pathways by making requests to the KEGG database.

The library “PathExplorer” was developed following the steps: (1) creating the storage file; (2) setting up a virtual environment to maintain code reproducibility across different machines; (3) establishing the library structure; (4) developing the library's functionalities; (5) testing the developed functions; and (6) final installation of the library. This library includes functions capable of interpreting biological data, mapping genes in pathways, conducting enrichment analysis, and providing graphical visualization of different metabolic pathways. Thus, the created library can play an important role in different scientific research, such as bioinformatics, biomedical and pharmaceutical research, where analysis and visualization of pathways can generate important conclusions to drive innovation.

Keywords: Bioinformatics; Data visualization; Pathway mapping; KEGG gene mapping

PATHOGENS-IN-FOODS DATABASE - SYSTEMATICALLY ORGANIZED PATHOGEN OCCURRENCE DATA IN EUROPEAN FARM-TO-FORK FOOD CHAINS

Ana Sofia Faria^{1,2}, Zineb Bradai^{1,2}, Enzo Dornelles Italiano^{1,2}, Anne Thebault³, Pauline Kooh³, Winy Messens⁴, Vasco Cadavez^{1,2}, Ursula Gonzales-Barron^{1,2,*}

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Research focused on the occurrence of pathogens in foods along the farm-to-fork chain is crucial for developing meta-analyses, risk assessment models and management strategies by food safety authorities, but the existing data, although vast, is often scattered and lacks standardization. The Pathogens-in-Foods (PIF) database seeks to address these shortcomings by systematically compiling occurrence data of fourteen pathogens, among them bacteria (*Bacillus cereus*, *Campylobacter* spp., *Clostridium perfringens*, *Listeria monocytogenes*, *Salmonella* spp., Shiga toxin-producing *Escherichia coli*, *Staphylococcus aureus*, *Yersinia enterocolitica*), viruses (Hepatovirus A, Norovirus, Orthohepevirus A) and parasites (*Cryptosporidium* spp., *Giardia* spp., *Toxoplasma gondii*), in randomly surveyed foods from primary production sites, manufacturing, retail, and restauration in Europe.

By applying a predetermined systematic literature search protocol to e-bibliographic databases, trained reviewers periodically retrieve primary studies containing pathogen occurrence data. After relevance screening and quality assessment, data from approved studies is extracted into PIF following its categorized insertion system, which is structured into general study characteristics, pathogen identification, detection/enumeration methodologies, food classification (harmonized with EFSA's FoodEx2, including aquatic species nomenclature), and prevalence and/or enumeration results.

Presently, PIF includes close to 1500 primary studies and 7500 data entries, but very soon, it will incorporate occurrence data on Anisakids in aquatic-based foods produced and/or commercialised in Europe. To this end, the catalogue "Nematodes" has been created inside the "Parasites" section, and an ad-hoc categorization protocol has been implemented, with novel detection/enumeration methodologies' trees, geographical fishing areas and production method (aquaculture/wild).

PIF has an interactive interface (<https://pif.esa.ipb.pt/>) for intuitive data extraction and is capable of generating dynamic graphics and summary statistics from available data. Accessible to researchers and policymakers, PIF provides consistent, quality-evaluated data for use in microbiological risk assessment and establishing future food safety guidelines.

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Keywords: Pathogen; Europe; Food safety; PIF; Risk assessment; Systematic review

PATHOGENS-IN-FOODS (PIF) DATABASE – DEVELOPING INTERACTIVE OCCURRENCE DATA AND META-ANALYSIS DASHBOARDS WITH SHINY R PACKAGE

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Pathogens-in-Foods (PIF) is a database of systematically formatted occurrence data (prevalence and enumeration) of some of the most important microbiological hazards (bacteria, viruses, and parasites) in foods randomly surveyed throughout European farms, processing facilities, retail establishments and restauration. PIF is also a dynamic web application, designed for intuitive access and meta-analysis, and features interactive dashboards (<https://pif.esa.ipb.pt/>) developed using the Shiny and Flexdashboard packages in R software.

With over 6,000 entries of bacteria occurrence data in PIF, users can quickly access this data through the “Explore Database” on the previous website to reach the dashboards “Overview”, “By Country”, “By Bacterium”, “By Food Category” and “Meta-Analysis”. “Overview” provides a more general analysis and visualization of selected occurrence trends across countries, in time, and boxplots illustrating occurrence data by categories (including food subcategories and food chain stages), while sections “By Country”, “By Bacterium”, and “By Food Category” provide the user with a distribution of observations, prevalence in time and prevalence dispersion, while also allowing to delve deeper into the food categorization. The “Meta-Analysis” dashboard provides occurrence data according to regions, bacteria, and food categories and subcategories, and generates visualization charts for that data such as Forest plot, Galbraith plot, Funnel plot, and Residuals plot.

For instance, a meta-analysis of 26 studies revealed a *Salmonella* spp. incidence of 7.77% (95% CI: 3.93-14.79%) in poultry meat food across EU countries, with significant heterogeneity among studies ($Q = 336.2786$, $p < 0.0001$). In another analysis involving 68 studies, *Listeria monocytogenes* incidence in EU raw milk was estimated at 3.15% (95% CI: 2.17-4.54%), with a significant heterogeneity observed ($Q = 873.5166$, $p < 0.0001$).

Pathogens-in-Foods (PIF) shiny tool enables users to explore and analyse microbiological hazard data comprehensively.

Keywords: Microbiological hazards; Data visualization; Web application; Dynamic reports; R

A CENTRALISED DATABASE AND E-PLATFORM FOR IMPROVED PRODUCTIVITY AND SUSTAINABILITY OF AGROPASTORAL SYSTEMS

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The PAS-AGRO-PAS project aims to develop an integrated digital platform to enhance data sharing and decision-making among Mediterranean agro-pastoralists, technicians, and policymakers. The objectives are: (1) to construct a centralized database for storing and analyzing project data; (2) to create the PAS-AGRO-PAS e-platform, providing access to agricultural data, life cycle assessments (LCAs), predictive models, simulation scenarios, and web applications; (3) to deploy the e-platform to build capacities, share knowledge, and raise consumer awareness; and (4) to facilitate the transition to "Agriculture 4.0."

Our approach involves using MongoDB for data storage, which is ideal for managing diverse datasets. The frontend, developed in React.js, offers a user-friendly interface with CRUD functionalities for submitting details into the database. The backend, implemented in Node.js, leverages a microservices architecture to ensure scalability and efficiency. The website, hosted on an Apache server, guarantees secure access. Additionally, the data analysis system, based on RStudio and Shiny server, facilitates database queries and dynamic reporting, enhancing data-driven decision-making. The integration of e-commerce and data analysis tools within the e-platform supports the commercialization of agro-pastoral products and provides valuable insights through real-time reporting and analysis. As a result, the centralized database and e-platform allow partners to feed and access data seamlessly, thereby enhancing collaboration. This initiative is expected to empower agro-pastoralists, optimize resource use, and foster knowledge exchange among stakeholders.

By incorporating advanced data analytics and predictive modeling, the platform will enable users to make more informed decisions that can lead to improved productivity and sustainability. Ultimately, the PAS-AGRO-PAS e-platform aims to revolutionize Mediterranean agro-pastoralism by improving data accessibility and supporting sustainable agricultural practices. This transition towards Agriculture will not only enhance the efficiency and productivity of agro-pastoral systems but also promote sustainable development and resilience in the agricultural sector. The comprehensive approach of the PAS-AGRO-PAS project ensures that the platform will serve as a vital tool for modernizing agricultural practices, increasing transparency, and facilitating informed decision-making processes among key actors in the Mediterranean region.

Keywords: Decision-making; Pastoralism; Agricultural data

Session 10: EU PRIMA Online Session – The PAS-AGRO-PAS project

Time: 10:00 – 12:00

Date: 6th September 2024

MODELING THE GROWTH OF *LISTERIA MONOCYTOGENES* IN SOFT GOAT'S CHEESE "JBEN" UNDER VARIOUS STORAGE TEMPERATURES

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Outbreaks of listeriosis have been associated with cheese consumption. This study focused on goat's Jben, a traditional Moroccan dairy product, to evaluate and model the growth of *Listeria monocytogenes* at different storage temperatures (4–40 °C). Lab-scale Jben samples were prepared using a traditional Moroccan recipe and inoculated with a three-strain cocktail of *L. monocytogenes* at approximately 2 log cfu/g. These inoculated samples (pH = 5.85 ± 0.05, aw = 0.92 ± 0.001) were stored under various isothermal conditions (4, 20, 25, 30, 35, and 40 °C) and analyzed microbiologically using plate count methodology to quantify pathogen levels. Predictive microbiology models, based on mathematical equations, were used to estimate microbial behavior in the product. The Baranyi model was applied to describe the growth kinetics of cheeses stored at constant temperatures and was integrated with the Ratkowsky model through global regression analysis. This approach correlated *L. monocytogenes* concentrations with storage temperature and time.

Results indicated that the growth potential of *L. monocytogenes* increased with higher storage temperatures. Analysis was performed using MATLAB, and the estimated Ratkowsky model parameters were $a = 0.0066 \text{ Log cfu/h}\cdot\text{°C}$, $b = 0.1683 /\text{°C}$, $T_{\min} = 2 \text{ °C}$, and $T_{\max} = 49.3 \text{ °C}$. Growth rates, fitted with the extended Ratkowsky square root model, ranged from 0.001 to 0.0345 log cfu/h at temperatures from 4 to 40 °C. The proposed model aims to predict *L. monocytogenes* growth across a broad range of storage temperatures, providing a basis for informed decisions regarding the microbiological safety of Jben.

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Keywords: Soft goat cheese; *L. monocytogenes*; Predictive microbiology

MODELING THE INHIBITION OF *LISTERIA MONOCYTOGENES* GROWTH IN FISH PRODUCTS WITH LACTIC ACID BACTERIA STRAINS

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The present study aimed to evaluate the potential of several lactic acid bacteria strains, isolated from fish products, as bioprotective cultures against *Listeria monocytogenes* in vacuum-packed, cold-stored fish products. These strains demonstrated their ability to control the growth of *L. monocytogenes* over 21 days of storage and to lower the pH of the medium. To explain the inhibitory effects of the selected lactic acid bacteria on *L. monocytogenes*, microbial interaction was assessed using adapted mathematical models. The kinetic parameters of growth for both microorganisms in monocultures and cocultures were estimated.

The results demonstrate the efficacy of the studied strains in controlling pathogen growth in fish products, achieving an inhibition rate exceeding 40%. The proposed modeling approach aims to reduce the risk of listeriosis associated with the consumption of cold-stored products. It can contribute to establishing a strategy based on bioprotective cultures for fish products.

Keywords: Lactic acid bacteria; Biopreservation; Fish products; *Listeria monocytogenes*; Modeling

ADVANCEMENTS IN BIOMETRIC TECHNIQUES FOR MOROCCAN ARGAN GROVE GOATS

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Biometrics, the science of identifying individuals based on unique physical or behavioral traits, has gained prominence in various fields, including agriculture and animal husbandry. This study highlights the use of biometric techniques in goats, focusing on their importance for breed identification, health monitoring, and livestock management. Goats possess distinctive biometric features such as facial patterns, iris structures, ear shapes, and body measurements, which can be effectively utilized for individual identification. Employing advanced technologies like image processing, machine learning, and 3D scanning allows for the precise and non-invasive capture and analysis of these traits.

Biometric systems offer significant benefits, including enhanced traceability, improved breeding programs, and the prevention of livestock theft and fraud. Moreover, biometric data play a crucial role in health monitoring by enabling early disease detection and optimizing management practices. This emerging field promises to advance goat production systems, contribute to animal welfare, and promote sustainable livestock management practices.

Future research aims to refine the accuracy of biometric identification systems and integrate biometric data with other agricultural technologies for comprehensive livestock management solutions. This work underscores the potential of biometric technologies to revolutionize goat farming, particularly in Moroccan argan groves, fostering advancements in breed improvement, health surveillance, and overall livestock management.

Funding: The authors express their gratitude to the EU PRIMA programme and the Moroccan Ministry of Higher Education, Scientific Research and Innovation (MESRSI) for their support of the PRIMA Pas-Agro-Pas project [grant number PRIMA/0016/2022].

Keywords: Biometric identification; Goats; Animal welfare; Sustainable livestock management

EVALUATION OF THE SAFETY AND QUALITY OF THE TUNISIAN AGRO-PASTORAL DAIRY PRODUCT "SMEN"

Zeineb Jrad

This study was carried out to determine the typicality of agropastoral dairy product from Béni Khédache region of southern Tunisia, which is Smen, prepared in the traditional way. Smen is a spontaneously fermented clarified butter fat produced in households. For the first time, this study aimed to evaluate the nutritional value, microbial quality, sensorial properties and oxidative stability of goat milk Smen.

To reach this goal, Smen samples (final dairy products) from goat raised in agropastoral systems, were collected and analyzed. The results showed that Smen presented a low pH and aw values (5.25 ± 0.19 and 0.619 ± 0.01 , respectively) but were very viscous (366.66 ± 35.11 cP) and fatty ($91.474 \pm 0.96\%$ of fat content). The evaluation of colour parameters showed the yellow intensity of Smen samples ($b^* = 38,66 \pm 0,04$). The resistance to oxidation of Smen samples was studied by measuring Peroxide value (PV), Thiobarbituric acid (TBA), Free Fatty Acid (FFA), Specific absorptivity at 232 and 270 (K232 and K270) values and oxidation induction time in the Rancimat. Results illustrated that it has moderate stability due to its manufacturing process and to the addition of a mixture of herbs called “natural preservative”.

The characterization of the mixture confirmed its contribution to the quality of the Smen studied. Smen is a microbiologically safe product, and lactic acid bacteria (LAB) are the dominant microorganisms. Likewise, the hedonic test demonstrated consumer's attraction to artisanal products.

Keywords: Agropastoral system; Goat; Oxidative stability; Typicity

OPTIMIZATION OF PHENOLICS EXTRACTION FROM GRAPE MARC USING RESPONSE SURFACE METHODOLOGY

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The wine industry induces a huge quantity of by-products, such as grape marc, e.g., the pomace skins, pulp and seeds, which contains bioactive compounds of interest. In this study, the optimization of extraction of phenolic compounds from grape marc based on a Box Behnken design was investigated.

Two grape varieties were used separately: “Chardonnay” (white variety) and “Syrah” (red variety). The response surface methodology was used to optimize the extraction conditions based on three independent variables: temperature (70 °C, 80 °C and 90 °C); time (10 min, 20 min and 30 min) and solvent (65 %, 75 %, and 85 % ethanol). The total phenolic content, as well as the antioxidant activity (assessed by the ABTS and DPPH assays) were determined. The characterization of the grape marc extracts obtained with the best extraction conditions was performed using Ultra-High-Performance Liquid Chromatography-Mass Spectrometry (UHPLC-MS).

The statistical analyses showed that the independent variables solvent and temperature exerted a significant effect on the obtained results. The models obtained from the response surface methodology for total phenolics and antioxidant activity content presented coefficients of regression ranging from 0.915 to 0.996. The optimal extraction condition resulting in the highest contents of total phenols and antioxidant activity was determined for both grape marc varieties. UHPLC-MS analysis of the optimal extract revealed the identification of 21 phytochemical components, including phenolic acids, flavonols and anthocyanins.

Applying green extraction combined with response surface methodology allowed to optimize the recovery of bioactive compounds from grape marc. Cytotoxicity assays are in progress to determinate the safe range of concentration that could be used in further food and pharmaceutical applications.

Keywords: Grape marc; Design of experiment; Response surface methodology; Phenolic extraction; Antioxidant activity

ANTI-LISTERIA EFFECT OF CITRUS PEEL EXTRACT IN FERMENTED MILK MODEL

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Listeria monocytogenes is a ubiquitous microorganism that can contaminate ready-to-eat foods since there is no bactericidal treatment between production and consumption. This pathogen has been identified as a potential contaminant in dairy products during post-processing steps. The objective of this work was to study the antibacterial effect of *Citrus limon* peel extract on *L. monocytogenes* in a fermented milk model. Fermented milk was elaborated by using *L. paracasei* OWS 23 isolated and identified from spontaneous fermented milk. After fermentation, samples were individually inoculated with *L. monocytogenes* at ~5 log CFU/mL, freeze-dried *Citrus limon* extract was added at 2 folds Minimum Inhibitor Concentration level (2.5% (w/v)). The milk sample was stored at 4°C during 7 days. Kinetic curves of *L. monocytogenes* growth were adjusted with Weibull and Baranyi & Roberts models.

The correlation coefficient and standard error of fit were ranked from 0.7 - 0.95 and 0.18 - 0.28, respectively. The time required for a first tenfold reduction of the *L. monocytogenes* population (δ) at 4 °C from Weibull model was around 142.8 h in fermented milk without citrus lemon extract and 44.09 h in fermented milk supplemented with *Citrus limon* extract. The total reduction of *L. monocytogenes* assessed using Baranyi and Roberts model was 1.005 log CFU/mL in fermented milk without *Citrus limon* extract and 2.28 log CFU/mL in samples supplemented with citrus limon extract. *Citrus limon* extract may be considered as a promising natural bio-preservative that can be used in fermented milk.

Keywords: Fermented milk; *Listeria monocytogenes*; *L. paracasei* OWS 23; *Citrus* peel extract; Modelling

RECOVERY OF DIETARY FIBER AND POLYPHENOL FROM RED GRAPE MARC AND ASSESSMENT OF THEIR ANTIBACTERIAL ACTIVITY AND POLYPHENOL COMPOSITION

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Grape marc, a winemaking byproduct composed by the skins, seeds and pulp of grapes, constitutes an available, valuable and renewable source of bioactive ingredients such as antioxidants and dietary fibers. It is a fermentable material and induces environmental damage. Its valorization is crucial to avoid pollution and ensure sustainable development. The aim of this work is to optimize the extraction of soluble dietary fiber and to recover antioxidant phenolics from Syrah red grape marc.

A Central composite design of seventeen experiments was used to develop an optimized process allowing simultaneous extraction of dietary fibers and phenol recovery from "Syrah" grape marc. The response surface methodology was used to optimize aqueous extraction conditions of the dietary fiber based on three independent variables: temperature (80-100°C); time (30-90 min) and the grape marc/solvent ratio (1:25-1:50). The total phenolic content was recovered after soluble dietary fiber precipitation and individual phenolic compounds of the grape marc extract obtained with the best extraction conditions were identified by UHPLC-DAD-ESI/MSn. Antibacterial activity of this latter extract was evaluated against pathogenic microorganisms (two Gram + and two Gram – bacterial strains).

The statistical analyses showed that the independent variable grape marc/solvent ratio has a significant effect on the yield of soluble dietary fibers. The optimal extraction condition resulting in the highest yield of soluble dietary fibers was determined and validated. The content of total phenols of the recovered solvent was determined. UHPLC-DAD-ESI/MSn analysis of the recovered individual phenolic compounds showed the identification of 21 phenolic compounds belonging to the classes of phenolic acids, flavonoids and anthocyanins. Syrah grape marc extract showed also a potential antibacterial activity against both Gram+ and Gram- bacteria.

The findings suggest an integrated green process allowing a simultaneous recovery of dietary fibers and polyphenols from red grape marc. Recovered antioxidant and soluble dietary fibers could be use in functional food formulation and nutraceutical development.

Keywords: Red grape marc; Design of experiment; Response surface methodology; Phenolic extraction; Soluble dietary fibers; Antibacterial activity

MATHEMATICAL MODELLING OF DRYING KINETICS OF DATE SEEDS AND ASSESSMENT OF PHYTOCHEMICAL CONTENTS AND ANTIBACTERIAL POTENCY

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The date palm (*Phoenix dactylifera* L.) belongs to the palm family (*Arecaceae*), is one of the major fruit crops produced in arid and semi-arid regions of the world such as North Africa and the Middle East. The aim of this work is to determine the drying kinetics of

Tunisian Deglet Enour date seeds and the effect of drying temperature on its main phytochemical contents.

Drying kinetics of date seeds were conducted at four temperatures (50, 60, 70 and 80 °C). Eight models available in the literature were used to describe experimental drying kinetics. The statistical parameters (correlation coefficients and standard errors) showed that the approximation of diffusion model could be used to fit the experimental drying curves. The effect of the drying temperature on the phytochemicals of date seeds extract (water-acetone- ethanol, v/v/v) was also investigated. The antibacterial effect of the extract of the dried seeds was investigated.

The extract of dried date seeds at 60°C had the highest total phenols (6.6 ± 0.09 g GAE/100 g DM), total flavonoids (5.64 ± 0.14 g QE/100 g DM), total tannins (9.73 ± 0.16 g CE/100 g DM) and total carotenoid contents (0.65 ± 0.002 mg β -carotene E/100 g DM). Furthermore, the extract of date seeds dried at 60 °C shows an interesting antibacterial activity against eight foodborne pathogens. These results highlight the potential use of Tunisian date seeds as cheap, natural interesting source of bioactive and antibacterial agent.

Keywords: Date seeds; Drying; Mathematical modeling; Phytochemical contents; Antibacterial potency

