Book of Abstracts

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Webinar

NOVEL FOOD

based on new ingredients, materials and processes

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1° Novel Food Webinar: Novel foods based on new ingredients, materials and processes

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Abstracts

Food fermentation: ancient approach for sustainable future

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Fermentation is one of the ancientness technologies, man has used since the beginning of his civilization. Following the domestication of the animals, first evidence of dairy products was found in Iraq, dating back to 7000 bC, while Egyptians (4000 bC) used fermentation for beer and wine production. In China, about 300 bC, vegetables were fermented to prolong their shelf-life. Only at the end of 19th century, when Luis Pasteur linked the fermentation to microbial activity, the possibility to exploit this process in food production became evident. In the last century, fermentations have been fundamental to produce a wide range of foods, very well connected to local cultures, starting from milk, meat and plant raw materials, which represent an important part of the human diet. Throughout fermentation it is possible to transform perishable raw materials to final products which maintain/improve the nutritional profile and are safer by the microbiological point of view.

Recently, food fermentations have been attracted a lot of interest from consumers, following an intense communication by (social) media. Especially plant based fermented foods are promoted as healthy foods, also because putatively able to carry probiotic bacteria.

Nevertheless, fermentation is nowadays considered a very suitable process for the production of foods. It needs low inputs in terms of energy and does not produce waste, thereby adhere to the criteria requested today for a sustainable food system. Moreover, it can be adopted to give a second life to waste (called secondary raw materials) and to ideate new foods, answering to specific needs such as the transition from animal to plant based diets. In this context, fermented foods starting from protein-rich raw materials can be considered an opportunity.

Role of lactic acid bacteria on the nutritional quality of cereal-based fermented foods

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Lactic acid bacteria are the main actors of the fermentation of traditional cereal-based fermented foods. In addition to the improvement of the global nutritional quality of fermented foods such as a better digestibility of proteins or the synthesis of essential amino acids, they can also participate to a better bioaccessibility or to an increased concentration of some micronutrient in the food.

Micronutrient deficiencies are associated with poor growth performance, impaired cognitive development and higher risks for morbidity and mortality from infectious diseases. If deficiencies are more prevalent in developing countries, some micronutrients, such as iron or vitamin B12, are also of importance in industrialized countries, especially in population aiming at reducing their animal products intake for personal choices or environmental reasons. The demand for healthier food requires the development of innovative products taking into account the expectations, purchasing power, and preferences of consumers while at the same time meeting nutrient requirements. The use of material of plant origin such as cereals, directly contribute to improvement of diet through diversification due to their interesting contents in dietary fibers, antioxidants, vitamins and minerals, when eaten as whole grains.

Many lactic acid bacteria improve the bioavailability of minerals through the hydrolysis of different compounds (phytates, polyphenols) chelating minerals in the food matrix. Lactic acid bacteria can also directly synthesize vitamins and can be used as a strategy of food fortification, by fermentation. The fermented cereal based product using vitamin producing bacteria could even compete with animal-based foods as a source of certain vitamins.

Positive interactions between lactic acid bacteria: a Must-have to develop new fermented foods

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The adage “in unity is strength” also applies to fermented foods: the association of lactic acid bacteria (LAB) strains brings benefits to their organoleptic properties and potential health benefits. Such functionalities can depend on positive interactions, as observed between LAB in yogurt. Finding ways to create new functional associations of LAB strains is challenging, especially in the context of the food transition where new resources, notably proteins, are increasingly used. The objective of this PhD work was to understand how to promote positive interactions between LAB, on the basis of their nitrogen metabolism, to conceive new food applications. The interactions were studied in cocultures that associated a proteolytic ($prot^+$) and a non-proteolytic ($prot^-$) strain. These $prot^+$/$prot^-$ pairs were first grown in a model medium containing milk and lupin proteins as sole nitrogen nutriments, in which the growth of $prot^-$ strain thus depended on the peptides and amino acids released by the $prot^+$ strain. Strong, weak, or no positive interactions were observed between $prot^+$ and $prot^-$ strains. Peptidomics results showed that the release of branched-chain amino acids either free or within peptides was important in the positive interactions observed. We then studied the impact of these interactions in alternative yogurts made from milk and lupin, characterized for their physical and sensory properties. Positive interactions between LAB led to diversified functionalities of alternative yogurts, such as flavour compound and organic acid formation, and texture improvement. This work brings new knowledge on the interactions between LAB, which is useful in designing future fermented foods.

Sensory and consumer insights for legume-based ingredients and fermented foods

Anne Saint-Eve

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The growing population is demanding new healthy, sustainable solutions for foods and beverages. The use of pulses in foods would contribute to the evolution of this offer. However, their bitterness, astringency and "beany" aromatic notes and their persistence are obstacles to their use.

In different projects developed in UMR SayFood, we aimed to understand i) the role of pulse composition (volatile and non-volatile compounds) on perceptions and ii) the role of processing conditions on functional and flavor properties of protein-rich ingredients and iii) the role of formulation of a plant-based fermented product combining animal and plant raw materials on environmental impact, perception and consumer behavior when faced with these new foods.

For this, original and multidisciplinary strategies combining sensory analysis (sensory profiling and consumer tests), physico-chemistry (compositions in volatile compounds, peptides, phenolic acids, flavonoids, terpenoids and also functional properties), environmental impact measurements (life cycle assessment) and statistics were set up.

These works showed the major role of process conditions played in pulse ingredient properties and in formulated foods. They open up new arena for inter-disciplinary study based on nutritional (anti-oxidant and anti-nutritional aspects), sustainability, functionality and sensory considerations of plant products as potential ingredients for industrial food applications.

Microalgae: Alternative protein-rich sources and more

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The global food system is the single biggest contributor to biodiversity loss, deforestation, drought, freshwater pollution, and the collapse of aquatic wildlife. It is the second-biggest contributor to climate change, after the energy industry. In 2017, the GHG emissions in the EU were 1.5 Gt CO_2-eq of which 12-17% came from meat production. Hence, the search for protein sources that constitute a safe, nutritious, and sustainable alternative to meat are urgently needed. Microalgae are a protein rich biomass that can be grown in non-arable land, using seawater (in the case of marine species) using inorganic or organic carbon, nitrogen and phosphorous nutrients and light as energy source. Their environmental footprint is thus expected to be far less than that of meat production. Additionally, microalgal strains can be improved using non-GMO methods and cultivation methods can be controlled to increase protein content and induce the production/accumulation of micronutrients such as polyunsaturated fatty acids, pigments, minerals, and vitamins that are considered bioactive. Although food supplemented with microalgae already exist in the market, some organoleptic characteristics as a strong odour and colour hamper their incorporation at nutritionally relevant amounts. However, the same strategies designed to increase protein and bioactives can be used to overcome these constraints.

Reuse of brewing by-products to produce protein-rich ingredients for food industry

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The most abundant brewing industry by-products are brewer's spent grain (BSG) and yeast (BSY). The high production of beer around the world arises a huge amount of those by-products that contain considerably content of proteins, 35-60% and 19-30%, respectively. The reuse of those brewing by-products as raw materials to produce profitable ingredients for food industry emerged at the beginning of the 21st century as a way of handling waste, which is highly encouraged in The Sustainable Development Goals of United Nations. However, so far, they are still undervalued, despite being sources of proteins that can be hydrolysed to obtain peptides with ACE-inhibitory and antioxidant activities. Efficient, and scalable production methods for production of BSY autolysates and BSG hydrolysates by using BSY proteolytic enzymes will be described, together with evaluation of their bioactivity after gastrointestinal digestion/absorption. An i*n vitro* digestion model was applied to assess the stability of autolysates/ hydrolysates (<5 kDa fractions) by oral administration, while peptides' stability and transport across epithelial cells (from the gastrointestinal tract) was estimated using a differentiated co-culture of Caco-2/HT29-MTX that mimics essential aspects of the intestinal epithelial barrier. The protective ability of <5 kDa fractions against oxidative stress on those cell lines were also evaluated. All <5 kDa hydrolysates (1 mg/mL) exerted a protective effect against oxidative stress inhibiting intracellular reactive oxygen species (ROS) generation, being well absorbed at the gastro-intestinal tract and maintaining their *in vitro* bioactivity, supporting its potential as functional ingredients or nutraceuticals with antioxidant and antihypertensive abilities.

Functional Foods Design: from idea mining to human intervention studies

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Functional food can be scientifically defined as those that have a potentially positive effect on health beyond basic nutrition, helping the promotion of optimal health conditions and reducing the risk of non-communicable diseases. However, in some countries, the definition is supported by a regulatory framework that sets basic principles for their commercialization and for obtaining a health claim. Furthermore, scientists worldwide have devoted much effort to develop potentially functional food by adding bioactive-rich extracts in conventional foods and testing their in vitro bioactivities. Phenolic compounds – including anthocyanins and other flavonoids-, methylxanthines, carotenoids, and alkaloids are the main target of current research. Considering the framework (EC 1924/2006) set out by the European Food Safety Authority (EFSA), functional foods and potential ingredients to "functionalize" foods should be sufficiently characterized, safe for consumption, and provide physiological effects when consumed regularly at a normal dose. Thus, to increase the awareness of the required steps to assess the effectiveness of potential food candidates, the detailed definition, in vitro, in vivo, and human intervention studies are explained. An illustrative summary of the required steps is provided together with real-world examples from the market and from scientific literature. These examples focus on food added with bioactive substances, i.e from extraction technologies and in vitro testing using different protocols and media to human clinical trials to efficacy testing.

Environmental and technological factors affecting bioactive compounds content in fruit and vegetables

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Consumers' awareness towards food nutritional and sensory quality has increased in recent years. Therefore, the attention towards bioactive phytochemicals is constantly increasing. Most of these substances are plant secondary metabolites produced beside the primary metabolic pathways (associated with the plant growth and development) and play a key role in the interaction between plant and environment. Together with other compounds such as ascorbic acid, they are responsible for plant antioxidant properties.

Since the traditional plant breeding was focused on yield-related parameters, the biosynthetic routes related to secondary metabolism are in many cases still to elucidate.

Meteorological conditions affect the biosynthesis of many antioxidant compounds. Low rainfall and high temperatures tend to decrease the ascorbic acid, carotenoid, and phenol contents. The potential effects of the growing system on the concentration of antioxidants in fruit and vegetables are not fully known. Some studies report more vitamin C, phenolic compounds, essential amino acids and sugars in organic products. Organic cropping involves exposure to stresses potentially increasing some phytochemicals.

Postharvest handling can enhance fruit antioxidant properties. Keeping apples in a low-oxygen environment before storage may increase glutathione production essential to restore the reduced ascorbic acid form and maintain the fruit antioxidant capacity. The composition of the storage atmosphere can enhance antioxidant activity of pear or apple peel.

Processing techniques produce changes in the level of phytochemicals, and methods involving thermal treatment are often detrimental to nutritional quality. Many studies are dedicated to the "mild" technologies which could better preserve the nutritional and sensory quality.

Importance of the optimization procedures for the extraction of bioactive ingredients and its applications at industrial level

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In recent years, the development of bioactive ingredients has increased. On the one hand, natural ingredients have experimented an increasing demand rather than the use of synthetic ingredients as they are safer, eco-friendly, they possess a wide spectrum of action and they avoid some of the side-effects associated with synthetic additives [1–3].

On the other hand, these target compounds are mostly extracted from very diverse natural matrices and use different extraction techniques and conditions to improve production yields. From a technological point of view, extraction techniques have experienced huge development and the most advanced (SFE, PLE, MAE, UAE, etc.) have been proposed for scaling up processes. However, this wide diversity of variables, makes it difficult to establish comparations, mainly because of the wide variety of biological matrices, their nature, and composition and the respective variations between them [4]. Therefore, the optimization of the extraction processes is essential for the development of efficient and environmental-friendly extraction procedures in a cost-effective way. In this context, some mathematical tools such as the response surface methodology (RSM) and other models are being developed to figure out which method and experimental conditions maximize the extraction efficiency and so, take control of the complete extraction process that can be used by the industry to select the conditions that make the process more profitable.

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The Power of Whole Grains

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Whole grains are essential part of healthy diet and growing evidence shows that whole grain consumption reduces risk of chronic diseases, including cardiovascular diseases, inflammatory bowel diseases and some cancers. Part of traditional Latvian died includes rye, barley and oat. Recently research of bioactive compounds of rye, hulles out, hulles barley and triticale is increasing in Latvia. There first human studies about possible protective effects. Food sources of fiber, lignans, alkylresorcinols were studied. Potential anticancer activity of rye bread was investigated in an intervention study with prostate cancer patients. In addition, possible differences in metabolism in alkylresorcinol metabolites in prostate cancer patients and controls were studied. Another study investigates potential nutritional benefits of hull-less oats in patient with inflammatory bowel diseases and found potential anti-oxidative activity of hull-less oats. Further hull-less oats were accepted by taste feeling. Consecutive study investigated postprandial glycaemic and insulinaemic responses after consumption of activated wheat and triticale grain flakes in order to help manage metabolic syndrome. Still far findings seem promising for further research of whole grains in Latvia by purpose for evidence based encourage to use traditional wholegrains, like rye, oats, barley and creating new functional grain foods for prevention of metabolic syndrome, cancer and gastrointestinal diseases.

Repurposing brewers' spent grain: tailored bioprocessing to improve its antioxidant properties

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Brewers' spent grain (BSG), the main by-product of the brewing industry, contains high concentration of fibers, proteins, and polyphenolic compounds. However, despite its potential, BSG is used as low value feed or discarded as waste. Aiming at promoting its use in functional foods, thirty-two LAB were screened for the ability of improving BSG antioxidant properties during fermentation. *Lactiplantibacillus plantarum* PU1, H46 and PRO17 caused the most relevant increases and were selected for further experiments. A biotechnological protocol for BSG treatment was set-up and optimized through the addition of a commercial xylanase. Bioprocessed BSG (bBSG) showed high inhibition of linoleic acid oxidation, comparable to that of butylhydroxytoluene, and protective effect on human keratinocyte cell lines, comparable to that of α-tocopherol. Hence, the phenolic profile of raw and bBSG was investigated through RP-HPLC-ESI-QTOF. The enzymatic treatment caused the release of 25% of the total bound phenols (mostly phenolic acids and their oligomers) in free forms. Whereas the strains metabolic activity led to the increase of dihydrocaffeic and phloretic acids in bBSG. Potentially bioactive peptides, showing the typical chemical features of antioxidant sequences, were also purified and identified in BSG fermented with *Lb. plantarum* PU1. Peptides encrypted in native barley and maize proteins were released thanks to the proteolytic activity of the lactic acid bacteria used as starter for fermentation.

bBSG, treated with xylanase and fermented with *Lb. plantarum* PU1, was used as ingredient in pasta making, at 15% substitution level of semolina. Bioprocessing improved the technological properties of fortified pasta since the degradation of BSG arabinoxylan structure resulted in the release of the components entrapped into the cellular compartments and a more homogeneous protein network. Moreover, after *in vitro*-mimicked digestion, bBSG pasta showed protective effect towards induced oxidative stress in Caco-2 cells cultures, thus confirming the great potential of bBSG as health-promoting food ingredient.

Antioxidant and Antiradical Properties of Pomegranate Juice

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Insufficient antioxidant capacity in the body creates the possibility of oxidative stress. The stress-forming components are active forms of oxygen and nitrogen, as well as free radicals. Pomegranate juice could be a good addition of antioxidants to the body's internal antioxidant potency - mainly hydrophilic antioxidants. Differences in antioxidant and antiradical properties of freshly squeezed and industrially produced pomegranate juice.Determination of the total amount of antioxidants, evaluation their ability to reduce the potential of free radicals, and thus the amount of oxidative stress, analyzing both freshly squeezed pomegranate juice, which is freely available, and industrially produced juice.The research was performed in the Biochemistry Scientific Laboratory of Riga Stradiņš University. Five pomegranates from Spain, Turkey, Azerbaijan, South Africa and Egypt purchased at Riga Central Market and stores; four industrially produced pomegranate juices from Azerbaijan, Turkey, Georgia and Ukraine were analyzed. Folin-Ciocalteu reagent was used to determine the total polyphenol content [1]. The antiradical capacity in pomegranate juice samples was determined using DPPH method [2]. Determination of the ability of antoxidants to reduce the trivalent iron ion Fe^{3+} into iron (II) ion Fe^{2+} performed using FRAP method [3]. The data obtained in the study were processed and analyzed using MsExcel program.The total content of phenolic compounds, antioxidant activity and their ability differ between pomegranates from different growing regions, as well as between industrially obtained juices from different countries - the effect is due to several factors. Higher values in all three methods were obtained for juices from South Africa, Turkey, Spanish pomegranates and commercially available juices from Turkey, Georgia and Azerbaijan.

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Cytinus hypocistis (L.) L. and it's great bioactive potential

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Plant-derived compounds have been extensively investigated to find novel active compounds as templates to mitigate the relative void of combinatorial chemistry, offering the potential to discover innovative structures that can lead to effective agents for various purposes [1]. *Cytinus hypocistis* (L.) L. is a wild edible parasitic plant on numerous members of the Cistaceae family. Although its biological properties were potentially attributed to its hydrolysable tannin content, its chemical composition was largely unknown, and the active substances not yet identified [2,3]. Thus, to decipher its potential applications, this work aimed at studying the bioactive properties and chemical composition of *C. hypocistis*. The plant material was collected in Castro Daire, Portugal. After lyophilisation, four different hydroethanolic extracts (whole plant, nectar chamber of the flower, petals, and stalks) were prepared and used for further analysis. The proximate composition was evaluated by AOAC official procedures; free sugars were determined using HPLC-RI, while organic acids were determined using UPLC-DAD [4]. Phenolic compounds were analysed by HPLC-DAD/ESI-MS^n [4-6]. *C. hypocistis* extracts were tested for their antioxidant (OxHLIA and TBARS), antibacterial (MIC and MBC), anti-inflammatory (murine macrophage - RAW64.7), and wound healing (migration capacity of HaCaT cells) properties. Enzyme inhibitory properties for α-amylase, SARS-CoV-2 chymotrypsin-like protease, and tyrosinase were also evaluated. *C. hypocistis* study unveiled its nectar as a balanced source of nutrients. A correlation between its hydrolysable tannin content and bioactive properties was also established. Extracts exhibited broad-spectrum antibacterial activity and good anti-inflammatory, antioxidant, and wound healing properties, together with the capacity to inhibit tyrosinase, α-amylase, and SARS-CoV-2 chymotrypsin-like protease. These results are significant evidence of the versatile profile of this plant. For bioactivity validation and mechanism investigation, further studies on fractionation, isolation, and compound characterisation are required.

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Chestnut shells as new potential active ingredient: An exploratory approach employing eco-friendly techniques

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Castanea sativa is an outstanding species that represents a valuable natural resource for rural populations. *C. sativa* shells (CSS), an abundant agro-industrial by-product generated during chestnut peeling process, is commonly discarded, or used as fuel. Nevertheless, CSS produced are not depleted by this application and huge amounts are still available, being particularly rich in bioactive compounds (polyphenols, vitamin E, lignin, and oligosaccharides) that reinforce the potential of shells' valorisation as natural antioxidants with antiaging and nutraceutical properties. The application of a suitable extraction technique is required for the isolation of bioactive compounds, being green extraction technologies outstanding for the industrial recovery of chestnut shells' bioactive compounds. Recently, the richness in bioactive compounds of CSS extracts obtained by different green methodologies, namely ultrasound-assisted extraction (UAE), subcritical water extraction (SWE) and supercritical fluids extraction (SFE), was highlighted by our research group. These different extracts could be used as active principles by cosmetic industry, but the validation as new ingredient is imperative and should consider the legislation principles. The evaluation of the hyaluronidase and elastase inhibitory activities, the *in-vitro* cytotoxicity on dermal cells, the absence of irritancy on 3D skin validated models and the ex-vivo skin permeation (using Franz cells coupled to human skin) demonstrated the potential antioxidant and antiwrinkle effects of these extracts. Finally, an *in-vivo* patch test confirmed the absence of irritation in humans, leading to the development of a outstanding cosmetic formulation. This is the first study that validated by *in-vitro* and *in-vivo* assays, and in accordance with the European Regulation 1223/2009, a new cosmetic ingredient extracted from chestnut shells, a food byproduct.

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Fiber substitution in common foods and their impact on human metabolism

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The Western diet contains many energy-dense products providing a lot of calories within only a small volume. Also, it is poor in dietary fibres. Fibers in turn, have significant benefits on human health. Until now, fibers were predominantly provided by whole grain products. New technologies, however, allow the use of various fiber types for supplementing foods to mimic a certain texture or taste.

Convenience products are a growing market due to changing habits in the population. Products must therefore be designed to provide a sufficient amount of essential nutrients, but also should aim to meet criteria for a health promoting diet. Here we report the development of sensorially appealing, fibre-enriched convenience foods which provided less calories per dish. Beside the acceptance of such reformulated products we were also interested in potential positive metabolic effects in acute placebo-controlled interventions.

From our results we can conclude that it seems feasible to enrich popular convenience products with dietary fibres to markedly reduce energy content without loss of sensory qualities or reduced satiation. This suggests that development and promotion of healthier convenience foods may be a useful strategy against obesity and other diet-related diseases.

Environmental sustainability in the food sector: the role of the Life Cycle Assessment

Prof. Maurizio Cellura – Prof. Sonia Longo, UNIPA, Italy

The food sector is one of the most energy-intensive sectors, and thus a significant contributor to global warming potential, accounting for about 20% of the total consumption of fossil fuels in the European Union. In addition, it causes 20-30% of the environmental impact of private consumption, and more than 50% of the impact from eutrophication. Thus, sustainable actions in the food sector are of paramount importance for reducing greenhouse gas emissions and fighting the climate change.

In this context, the talk introduces the Life Cycle Assessment (LCA) methodology, a reliable tool for assessing the energy and environmental footprint of food products and defining eco-design criteria for reducing the environmental impacts. Furthermore, some experiences on the application of LCA will be described, in order to show the potential and the applicability of this tool.

Arguments in alternative protein-rich foods source choice: are insects available?

Francesco Porcelli, University of Bari (UNIBA), Italy

Insects have been a critical food protein source in tribal or hunter-gatherer societies, that a sizeable anecdotal literature reports. Today the concern for the food shortage and the sustainability of protein production pushes the interest in food insect proteins. The availability of insect proteins and the opportunity for their use primarily lies in particularities of the selected insect species. Lifestyle, mainly detritivorous and sarcosaphrophagous diet, largely influences the safety of the protein source. Holometabolous pupa offers the chance for a safe and technologically manageable protein parcel, but several larvae host a huge undesirable gut content. Insect microbiota is complex enough, including ecto- and endosymbionts influencing the food insects in many ways while living or stored. Endosymbionts pose lesser or any threats to humans, but insects carry or vector ectosymbionts that can be hazardous, including human and animal pathogens. Exoskeleton deserves a topic for discussion because of the hardness, total weight, and effect in the structure of the protein product. Species attitude to mass-rearing and breeding considers sustained overcrowding with near-to-zero cannibalistic tendencies. Also, favourable behaviours as metamorphosis blockage exist in dense populations of selected species. Moreover, the mass rearing practices rarely investigate the fermentative rearing environment that many species prefer. The webinar chapter discusses the interest in insect food proteins, including the insect favourable organic matter conversion index. Few rearing examples suggest the need and the impact of insect-associated microorganisms for selected protein-source species. Simple techniques permit evaluating protein/fat contents of larvae, prepupae/pupae and adults.

How fermentation can improve the acceptability of new pea protein-based foods?

Sophie Landaud, INRAE-AgroParisTech-Université Paris-Saclay, UMR Sayfood, France

The demand for plant-based products is on the rise as consumers are increasingly becoming health-conscious and are seeking ingredients of non-dairy alternatives. One crucial challenge faced by food researchers is therefore the need to increase the use of sustainable plant proteins that have satisfactory nutritional and sensorial properties.

Due to their high protein content, techno functional properties and low cost, pea (*Pitsum sativum* L.) offers a great opportunity to develop an alternative plant protein source that will meet nutritional needs, in an affordable and sustainable way. However, the presence of off flavors notes described as “beany,” “green,” and “vegetal,” is a limiting factor for their consumption.

To overcome this problem, we develop strategies using fermentation as a mean to degrade these off-flavors or to mask them. Microbial consortia were then design to develop new and diversified products. We studied a first way by the co-fermentation of lactic acid bacteria and yeasts to develop yogurt-like products with high pea-protein content with improved sensory perception. These acidified products will be then consumed as new plant based yogurts or will be dried to develop new food ingredients.

A second way was to design de novo a more diverse microbial consortia by selecting strains that were representative of different phylogenetic groups and that had been isolated from animal and plant fermented foods. These strains then had to colonize pea-protein-based products, to compete with undesired endogenous microorganisms and to produce aromatic compounds. These will lead to new products with untargeted sensory perception.

These studies allowed us to develop innovative fermentation processes. Nevertheless, we still need to investigate in deep the mechanisms of matrix-microorganism and microorganism-microorganism interactions in order to better understand and control the development of healthy and palatable plant protein-rich fermented foods.

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