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Meeting Abstracts

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Plant Cellular Agriculture: A Symbiotic Platform for Functional Foods and Nutraceutical Innovation

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Abstract

The rapid rise of cellular agriculture has largely been framed through a "replacement" paradigm, positioning lab-based production as a disruptive substitute for conventional farming. While technologically ambitious, this model risks social exclusion, economic concentration, and weakened food sovereignty. In the context of functional foods and nutraceuticals, an alternative is proposed: a symbiotic, plant callus–based platform designed to complement—rather than replace—traditional agriculture. Plant callus, an undifferentiated mass of plant cells cultured in vitro, functions as a programmable chassis for the controlled production of high value bioactive. Instead of targeting bulk commodity markets, this approach prioritizes low-volume, high-value functional ingredients and nutraceutical compounds, including standardized phytochemicals, carotenoids, antioxidants, and specialty metabolites. By focusing on purity, consistency, and tailored nutritional profiles, callus-based systems address key industry demands for reproducibility and traceability in health-oriented products. Central to this model is an integrated circular bioeconomy in which agricultural side-streams serve as low-cost feedstock for decentralized bioreactors. This strategy reduces environmental burdens while positioning farmers as essential partners and suppliers, creating diversified rural revenue streams. To ensure equitable innovation, decentralized governance and open innovation frameworks aligned with access and benefit-sharing principles are advocated, thereby mitigating risks of technological concentration and digital biopiracy. Finally, a "culinary co-design" approach is proposed to enhance societal acceptance and cultural integration of novel functional ingredients, reframing cellular systems as tools for solving locally defined nutritional and formulation challenges. By shifting the focus of cellular agriculture toward symbiosis, circularity, and nutraceutical specialization, this framework offers a pragmatic and ethically grounded roadmap for developing next-generation functional foods that enhance resilience, equity, and food sovereignty.

Functional Enrichment of Fermented Milk with Nanovesicle-loaded *Vitis vinifera* Leaf Extract

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Abstract

The growing interest in sustainable nutrition and health-oriented foods has driven the development of functional products enriched with naturally occurring bioactive compounds. In this context, agro-industrial by-products have emerged as valuable and sustainable sources of phytochemicals, and grapevine leaves, produced during routine vineyard pruning, represent a widely available agricultural residue. Nevertheless, the incorporation of plant-derived bioactive into food products is often challenged by issues related to their chemical instability and limited bioavailability. To address these limitations, nanotechnology-based

delivery systems have gained increasing attention. Phospholipid nanovesicles represent an effective strategy to protect sensitive compounds, thereby facilitating their successful integration into functional food formulations. In addition, selecting an appropriate food matrix is essential to preserve their functionality and promote their delivery. Fermented dairy products such as kefir, known for their probiotic content, nutritional value, and high consumer acceptance, represent an ideal vehicle for functional ingredients. In this study, grapevine leaves from *Vitis vinifera* L. cv. Monica, a traditional Sardinian cultivar, were valorized by evaluating the chemical composition and antioxidant properties of their extract, its encapsulation within phospholipid nanovesicles, and its incorporation into a fermented goat milk beverage. The extract showed a high total polyphenol content and strong antioxidant activity, while high-performance liquid chromatography coupled with diode-array detection analysis revealed a rich phenolic profile dominated by quercetin-3-O-glucuronide and peonidin-3-O-glucoside. Nanovesicles displayed suitable physicochemical characteristics and encapsulation efficiencies, preserving the antioxidant properties of the extract. When incorporated into kefir at increasing concentrations, the nanovesicle-loaded extract enhanced the antioxidant capacity of the beverage in a dose-dependent manner without altering its rheological properties.

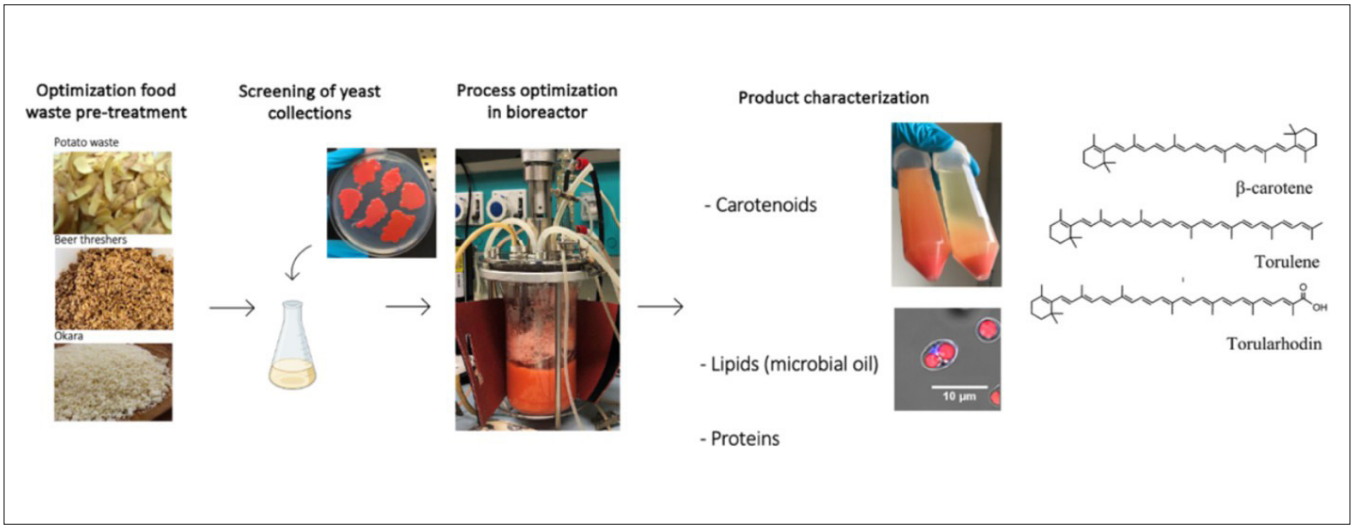
Agri-food Residues and Waste Cooking Oil as Sustainable Feedstocks for Microbial Carotenoid and Lipid Production

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Abstract

The global market of carotenoids, commonly included in different formulations such as colorants and sources of antioxidants and vitamin A, is growing significantly together with the attention in their sustainable and green synthesis. Yeast-based biotechnological production of carotenoids emerges as a valuable strategy, also fitting the circular economy pillars when low-cost feedstocks are used as main components of culture media. In this study, bioprocesses utilizing red yeasts were developed using cost-effective agro-industrial residues, such as soy okara. Its enzymatic pre- treatment using commercial enzyme blends was optimized to obtain balanced and effective fermentation media in terms of carbo and nitrogen sources (Figure 1). The high-performance liquid chromatography screening of red yeast collections (including *Rhodosporidium* or *Rhodotorula* genera) revealed strains naturally rich in b-carotene but also in torulene and torularhodin, uncommon but potent carotenoids not yet commercially available. Finally, a fermentation process performed by *Rhodotorula paludigena* CBS 6565 in 2 L bioreactor was developed, in which the incorporation of waste cooking oil and syrup from candied fruit manufacture boosted the production of 264 mg/L of carotenoids, characterized by the presence of b-carotene (140 mg/L) and torularhodin (72.5 mg/L). In addition, yeast cells accumulated lipids up to 56% of cell dry weight, corresponding to 18 g/L, highlighting the potential for integrated production of microbial oil and carotenoids. Overall, this study underscores the synergy between agri-food waste valorization and the sustainable production of yeast biomass naturally enriched in carotenoids and lipids, to be used as multifunctional source of high value products.



Physicochemical Analysis of Kombucha Fermentation

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Abstract

Kombucha fermentation was conducted using a 0.5% w/v black tea medium enriched with 10% w/v sucrose and 2.5% w/v glucose, inoculated with a 1% wet w/v heirloom symbiotic culture of bacteria and yeast (SCOBY). The fermentation process was monitored over a two-week period, with measurements taken every two days. Physicochemical parameters including pH, optical density (600 nm) and mid-infrared spectral analysis (FTIR) were evaluated. A continuous decrease in pH was observed, from 4.762 to 2.508, confirming organic acid production throughout fermentation. Optical density showed a slight increase during the first 48 h around a 5-fold increase relative to the initial value associated with microbial growth, as SCOBY cells remained suspended and dispersed in the liquid phase, together with fine particles of microbial cellulose produced by acetic acid bacteria. This is followed by a gradual decline of about 3-fold from 48 h to 144 h, which may be attributed to nutrient depletion, increased medium acidity, aggregation or precipitation of microbial metabolites, and the adhesion of microbial cells and cellulose producing bacteria to the biofilm. After 144 h optical density remained constant. Principal component analysis (PCA) of attenuated total reflection-FTIR data (650 - 4000 cm^{-1}) showed clear separation between tea, initial and fermented kombucha samples with PC1 and PC2 explaining 85.7% of variance in total. These changes may reflect sugar consumption, organic acid formation, ethanol production, and polyphenol transformations during fermentation. Overall, the results indicate significant physicochemical changes during kombucha fermentation, driven by microbial activity and biochemical transformations.

Exploring Extremotolerant Microorganisms as Sustainable Nutritional Resources for Deep Space Exploration

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Abstract

Ensuring a nutritionally complete diet is a major challenge for long-duration space missions, where reliance on Earth resupply is limited. Bioregenerative life support systems (BLSS), such as ESA's micro-ecological life support system alternative, aim to sustain astronauts through resource recycling and plant-based food production. However, such systems may not fully satisfy human micronutrient requirements. In this study, an in silico nutritional assessment of crop-based BLSS diets was performed to identify potential deficiencies. The analysis revealed gaps in essential micronutrients, including cobalamin (vitamin B_{12}), riboflavin (vitamin B_2), and calciferol (vitamin D). To address these limitations, a screening of microorganisms was conducted to evaluate their genomic potential for the biosynthesis of these nutrients. Candidates were further filtered based on safety considerations, including inclusion in the European Food Safety Authority qualified presumption of safety and novel food lists. Microorganisms were then prioritized according to their biosynthetic capabilities, metabolic versatility, and potential robustness under space-relevant stressors. Focus was given to extremophiles, which can act as biological buffers within BLSS, stabilizing micronutrient production under the fluctuating stresses of extraterrestrial environments through enhanced DNA repair, antioxidant defenses, and metabolic stability. The outcome of this work is a ranked selection of microbial candidates capable of complementing plant-based BLSS diets by providing essential micronutrients. These organisms represent promising components for integration into closed-loop life-support systems, potentially enhancing both nutritional quality and system resilience. This approach supports the development of sustainable and self-sufficient food production strategies for future human exploration of deep space, bridging microbial biotechnology and space nutrition.

Bioavailability and Multifaceted Antioxidant, Antimicrobial, and Immunomodulatory Activities of Black Chokeberry (*Aronia melanocarpa*) Polyphenols

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Abstract

Black chokeberry (*Aronia melanocarpa*) is a polyphenol-rich fruit exhibiting exceptionally high antioxidant activity *in vitro* and a broad spectrum of health-promoting effects, including antidiabetic, cardioprotective, hepatoprotective, antimutagenic, and anticarcinogenic actions. Although the bioavailability of aronia polyphenols appears limited, accumulating evidence demonstrates meaningful *in vivo* activity. Beyond direct radical scavenging, *in vivo* antioxidant effects include suppression of reactive oxygen and nitrogen species formation, inhibition of prooxidant enzymes, restoration of endogenous antioxidant systems, and modulation of cellular signaling pathways regulating antioxidant responses. Complementary experimental data on various polyphenolic preparations - crude extract, purified anthocyanin-standardized extracts, proanthocyanidins, and isolated compounds such as chlorogenic acid, cyanidin-3-O-galactoside, epicatechin, rutin, and quercetin - highlight substantial variability in biological activity. Minor constituents, particularly quercetin and epicatechin, exhibited the highest oxygen radical absorbance capacity and total radical-trapping antioxidant parameter antioxidant capacities, while proanthocyanidins emerged as the dominant contributors to the antioxidant potential of fresh fruits. Polyphenols showed minimal effects on spontaneous neutrophil chemiluminescence and only modest modulation of phorbol 12-myristate 13-acetate-activated responses, whereas quercetin and rutin significantly reduced opsonized zymosan particles-activated chemiluminescence. Antimicrobial assays against ten pathogens further identified proanthocyanidins as the most potent antimicrobial agents. Together, these findings provide an integrated perspective on chokeberry polyphenols, outlining both their mechanistic diversity and the remaining gaps in understanding there *in vivo* antioxidant and immunomodulatory actions.

Nanoplastic Identification in Food Samples using Electrochemical Sensor Array

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Abstract

The release of micro and nanoplastics (NPs) from food packaging has become a growing concern due to their potential environmental and health impacts. Current analytical methods mainly rely on spiked samples and often suffer from poor sensitivity caused by weak sensor–particle interactions and diffusion limitations. In this work, we report a highly sensitive electrochemical sensor array integrated with frequency-dependent electrokinetic enrichment for rapid detection and quantification of multiple NP types in real food-related samples. The platform employs hydrogen titanate nanotube (HTNT)-modified electrodes combined with dielectrophoretic enrichment to selectively detect polystyrene, polyethylene, polypropylene, and polyethylene terephthalate released from commercial food packaging and drinking water bottles. Selective adsorption of NPs onto HTNTs, supported by computational interaction studies and Raman spectroscopy, generated characteristic differential pulse voltammetry responses under optimized alternating current frequencies. The method achieved an ultra-low detection limit of 0.1 pg mL^{-1} with a working range from 0.1 pg mL^{-1} to 1 ng mL^{-1}, exceeding the sensitivity of conventional electrochemical sensors by more than three orders of magnitude. Distinct frequency-dependent electrokinetic signatures in the 500 kHz^{-2} MHz range enabled simultaneous identification and quantification of different NP types within 25 min. The results were validated using Raman spectroscopy and nanoparticle tracking analysis. Importantly, the sensor successfully quantified NPs in non-spiked extracts from commercial food packaging, including complex beverage matrices such as tea and milk. This study demonstrates a practical and rapid strategy for real-sample NP analysis relevant to food chemistry and safety monitoring.

Bioactive Compounds from Agro-industrial Residues: Biotechnological Strategies for Functional Food Preservation and Sustainable Packaging

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Abstract

Bioactive compounds derived from natural sources have gained increasing attention due to their potential applications in food preservation, functional foods, and sustainable packaging. Agro-industrial residues, particularly those from coffee and other plant-based production chains, represent an abundant and underutilized source of valuable metabolites with antioxidant and antimicrobial properties. Through integrated approaches combining bioinformatics, molecular biotechnology, biochemical characterization, and materials engineering, it is possible to identify, isolate, and incorporate these compounds into functional matrices. This presentation will discuss recent advances in the discovery and application of bioactive molecules obtained from agricultural residues, focusing on their incorporation into cellulose-based biomaterials for the development of bioactive and

biodegradable food packaging. These functional materials demonstrate the ability to inhibit microbial growth, reduce oxidation, and extend food shelf life while contributing to environmental sustainability. Additionally, strategies for scaling up production, functional validation, and industrial translation will be addressed. These advances highlight the role of biotechnology in transforming low-value residues into high-value functional materials, supporting the development of safer, longer-lasting, and more sustainable food systems.

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