



29th EFFoST
Conference

**Food Science Research and
Innovation: Delivering sustainable
solutions to the global economy and
society**

10-12 November 2015 | Athens, Greece

CONFERENCE PROCEEDINGS-VOLUME I



www.effostconference.com



Edited by:

Dr. Efimia Dermesonlouoglou, Dr. Virginia Giannou, Dr. Eleni Gogou & Prof. P. Taoukis
National Technical University of Athens, School of Chemical Engineering, Athens, Greece

Copyright © NTUA, School of Chemical Engineering, Athens 2015
ISBN: 978-618-82196-1-8

CONTENTS

[PL.01]	Food science & engineering for a more sustainable food supply	1
[PL.02]	A strategic research and innovation agenda for very small traditional food processor	2
[PL.03]	Food Research in Horizon 2020	3
[PL.04]	The European Research Council (ERC) support for life sciences-An opportunity for food scientists in frontier research	4
[PL.05]	Perspectives from the industrial sector to the societal challenges for food research in HORIZON 2020	5
[PL.06]	Long term research and innovation priorities for the European Agrifood Industry	6
[PL.07]	ILSI Europe and it's scientific programme	7
[PL.08]	Beyond Fire and Ice–Consideration of Nanoscale Science and Nanotechnology-Enabled Nonthermal Processes to Improve Food Safety	
[PL.09]	IUFoST Global Food Safety Curricula Initiative	8
[INV.01]	Sustainability challenges in food processing (0796)	9
[INV.02]	Towards more efficient manufacturing processes: Challenges and solutions (0786)	10
[INV.03]	Integrating fingerprinting and kinetics in food processing and preservation research on plant based food systems (0686)	11
[INV.04]	Changes, challenges and opportunities promoted by the nonthermal processing of food (0780)	12
[INV.05]	Processing of mechanically and thermally sensitive functionalized food-microstructures by coupled, stress-controlled dynamic membrane dispersing, spraying chilling and cold extrusion sintering (0213)	13
[INV.06]	Effect of food intrinsic characteristics on microbial growth dynamics in/on fish-based model systems at suboptimal temperatures (0373)	14
[INV.07]	Formulating with cereal soluble fibers: Challenges and opportunities in developing functional products (0632)	20
[INV.08]	The comparison of LAOS behavior of structured food materials (suspensions, emulsions and elastic networks) (0655)	21
[INV.09]	Developing a collaborative innovation system (0773)	27
[INV.10]	Edible coatings for the development of sustainable foods with enhanced safety, quality and functionality (0748)	28
[INV.11]	Construction of foams for targeted food production (0642)	29
[INV.12]	Key needs in food science and technology-with special emphasis to food engineering (0068)	30
[INV.13]	From food engineering to product engineering (0264)	31
[INV.14]	From open innovation to enginomics - paradigms change (0398)	32
[INV.15]	Innovation in the European food industry: Challenges, opportunities and barriers (0768)	38

[INV.16]	Innovative uses of structural relaxations in food engineering (0633)	39
[INV.17]	3D Food Printing-An overview (0712)	40
[INV.18]	Future challenges of emerging technologies (0839)	41
[INV.19]	Detection of food frauds: Looking for the unknowns!? But quality assured! (0706)	42
[INV.20]	The role of microbial risk assessment in EU food safety regulation (0838)	43
[INV.21]	Innovative food packaging: Active, intelligent, bio-based and eco-efficient materials and technologies (0837)	44
[O01.1]	Scale of manufacturing: A case study (0270)	45
[O01.2]	Characterization of extrusion processing to design sustainable and functional food systems (0057) ...	46
[O01.3]	Increase in energy efficiency of the chocolate cooling process by molds with structured surfaces (0360)	47
[O01.4]	Refrigerated warehouses as intelligent hubs to integrate renewable energy in industrial food refrigeration and to enhance power grid sustainability (0688)	48
[O01.5]	Processing of edible insects: Production, fractionation and characterization of flours from meal worm (<i>Tenebrio molitor</i>) and black soldier fly larvae (<i>Hermetia illucens</i>) (0411)	54
[O01.6]	High purity vegetable protein concentrates for niche and global markets. A techno-functional approach (0835)	55
[O02.1]	Preservation of sensitive biological products: An insight into conventional and upcoming drying techniques (0271)	57
[O02.2]	An advanced modeling and experimental validation of single droplet drying process (0058)	58
[O02.3]	Spray-dried oil body powder (0281)	64
[O02.4]	Microbial decontamination of model particles and food powders by novel vacuum-steam-vacuum treatment (0295)	69
[O02.5]	Microwave puffing of starch pellets (0262)	70
[O02.6]	Thermal mixing via acoustic vibration during continuous flow cooling of viscous food products (0590)	76
[O03.1]	Novel colorimetric sensors and nanoprobe for the characterization of food antioxidants (0432).....	77
[O03.2]	An online NP-HPLC-DPPH method for the determination of the antioxidant activity of condensed polyphenols from different chocolate manufacturing stages (0023)	82
[O03.3]	Antioxidant activity of water extracts of oat fiber obtained with microwave assisted extraction (0645)	86
[O03.4]	Application of Fourier transform infrared spectroscopy (FTIR) and chemometric analysis to discriminate Turkish noodle enriched with legume hydrocolloids (0550)	88
[O03.5]	Interactions between polyphenols and polysaccharides: Mechanisms and consequences in food processing and digestion (0533)	90
[O03.6]	Study of the synergy between free and bound antioxidants (0274)	96

[003.7]	Anti-tumor potential of bioactive component crocin found in Saffron (<i>Crocus Sativus</i>) against angiogenesis process (0674)	97
[004.1]	Design and exploitation of a new experimental device to forecast the degradation of nutritional quality and the inactivation of microorganisms in canned vegetables (0093)	98
[004.2]	A 1H-NMR-based metabolomics application to the analysis of Caciotta cheese ripening (0211)	104
[004.3]	Predicting storage and quality properties in modified atmosphere packaging for mushrooms (0332)	106
[004.4]	Flavour characterisation of tomato using heat pump drying system (0240)	107
[004.5]	Shelf-assessing the prediction boundaries of an oxidation model (0454)	110
[004.6]	Internet of things based food safety system targeting transport and distribution (0569)	114
[005.1]	Energy saving potential of emerging technologies in milk powder production (0051)	119
[005.2]	Environmental evaluation of European skimmed milk powder (SMP) processing production plant with the use of life cycle assessment (LCA) (0554)	120
[005.3]	Sustainability of meat substitutes: A path to future foods? (0162)	126
[005.4]	Potential innovations for the traditional durum wheat food sector (0304)	132
[005.5]	Sustainability analysis of brewing with malted and unmalted barley (0076)	138
[005.6]	Improving the confectionary supply chain: Evaluation of environmental impacts of ice cream (0130)	139
[005.7]	Identification of exergy inefficient locations in industrial food production chains (0434)	143
[005.8]	Environmental sustainability of ultra-high pressure homogenization application for liquid foods (milk case study) (0685)	144
[006.1]	Hurdle technology to improve organoleptic aspects of broccoli in pressure-assisted thermal sterilisation (PATS) (0404)	149
[006.2]	Product-specific impact of plasma processed air as a pre-drying procedure for dried fruit and vegetables (0412)	150
[006.3]	PEF treatment for the valorization of tomato by-products (0611)	151
[006.4]	Potential application of UHPH process in the physicochemical stabilization of tiger-nuts milk (0287)	153
[006.5]	Continuous flow microwave processing: From concept to commercialization (0717)	154
[006.6]	Inactivation of <i>Alicyclobacillus acidoterrestris</i> in apple juice under ultraviolet irradiation treatments (0086)	159
[007.1]	Controlled bacterial release from water-in-oil-in-water ($W_1/O/W_2$) emulsions (0221)	164
[007.2]	Physical and microstructural properties of amorphous co-milled sugars and aroma compounds (0659)	165
[007.3]	Inter-relationship of flavour and microstructure as a function of the processed vegetable (0681).....	166
[007.4]	Investigating the role of calcium in casein matrix formation and functionality (0564)	167

[O07.5]	Effect of freezing on starch microstructural changes during heating at high rates using in situ hot-stage video-microscopy and differential scanning calorimetry (0318)	168
[O07.6]	Microstructural characterisation of rice bran wax oleogels-in-water emulsions (0321)	169
[O08.1]	Influence of feed gas composition and specimen surface structure on the mechanisms of <i>Bacillus subtilis</i> spore inactivation related to direct cold atmospheric pressure plasma treatment (0053)	171
[O08.2]	Treatment with high hydrostatic pressure and supercritical carbon dioxide against <i>Alicyclobacillus acidoterrestris</i> spores in apple juice (0092)	172
[O08.3]	Stress-induced evolution of resistance and resuscitation speed in <i>E. coli</i> O157:H7 (0379)	178
[O08.4]	A decision support tool based on microbial safety prediction for a better dimensioning of modified atmosphere packaging (0621)	179
[O08.5]	Modelling of the microbial inactivation by high hydrostatic pressure freezing (0573)	187
[O08.6]	Growth potential of <i>Listeria monocytogenes</i> during storage of various cheeses and subsequent tolerance after simulated digestion (0358)	193
[O09.1]	Chicory root fibre - From by-product to food ingredient (0021)	197
[O09.2]	Converting rice bran into a high-value food ingredient (0081)	203
[O09.3]	Research and innovation focusing on by-products of grapes and wines (0257)	208
[O09.4]	Polyphenol-rich nanoparticles from olive pomace extracted by high pressure and temperature reactor using supercritical assisted atomization (0543)	210
[O09.5]	Green leaves as a food source: Processing towards functional fractions (0072)	212
[O09.6]	Extractability and characteristics of proteins deriving from wheat DDGS (0118)	214
[O09.7]	An approach to turn grape pomace into a valuable food (0147)	218
[O09.8]	From industrial waste biomass to valuable chemical compounds: Furfuryl alcohol and tetrahydrofurfuryl alcohol (0606)	225
[O10.1]	Process analytical technology implementation in the food industry: The MUSE-Tech project (0747)	231
[O10.2]	Application of a multisensor device to control part of the bread production process (0746)	232
[O10.3]	Application of a multisensor device to control part of the beer production process (0751)	233
[O10.4]	Monitoring food pathogens by nanowire MOS gas sensor array (0292)	240
[O10.5]	Oxygen solubility in oils: Original measurement using a non-invasive optical sensor (0399)	242
[O10.6]	Non-invasive monitoring of drying processes: Case of laser light backscattering and moisture content (0566)	243
[O10.7]	Metabolomic approach to optimize formulation and fermentation process of functional bakery products (0698)	244
[O10.8]	Application of multisensor device to control frying process: Preliminary results (0793)	245
[O11.1]	Electrostatic pectin-pectin interactions and in vitro bioaccessibility of calcium and iron in particulated tomato-based suspensions (0157)	249

[O11.2]	Effect of vacuum frying on starch gelatinization and its in vitro digestibility in starch-gluten matrices (0313)	256
[O11.3]	Separation of biologically-active bovine immunoglobulins from milk and colostrum (0246)	257
[O11.4]	Novel utilization of milk-based ingredients in salt reduced fish pudding (0253)	258
[O11.5]	Use of nutrient profiling to identify healthy versus unhealthy snacks (0509)	264
[O11.6]	Structural and functional characterization of hemp seed protein-derived acetylcholinesterase-inhibitory peptides (0402)	270
[O12.1]	Swelling, what else? Mass transport mechanisms in osmotically imbalanced multiple W/O/W food emulsions (0337)	276
[O12.2]	Interfacial engineering of complex emulsion for modulation of salt perception (0125)	277
[O12.3]	Essential oil nanoemulsions to prolong the shelf life of solid food products (0702)	278
[O12.4]	Processing of an eco-friendly nanoemulsion by high-pressure homogenization to protect a bioactive extract of jackfruit pulp (<i>Artocarpus Heterophyllus</i>) (0190)	279
[O12.5]	Towards structured granules with tailored dispersibility by controlling wet powder screen extrusion (0263)	283
[O12.6]	Modeling and simulation of peristaltic flows in a human stomach (0084)	284
[O12.7]	Structural changes of wheat proteins during high moisture extrusion processing of meat analog products (0059)	285
[O13.1]	New horizon for food engineering (0631)	286
[O14.1]	Effect of glutaraldehyde and oleic acid content on secondary structure of zein during film formulation (0229)	287
[O14.2]	Impact of novel bioactive edible coatings enriched with limonene on the postharvest quality of limes (0066)	292
[O14.3]	Quality changes of mangoes treated with different wax nanoemulsion coating formulations (0152)...	298
[O14.4]	Novel bio-based materials for use in the food & beverage industry (0845)	304
[O14.5]	Encapsulation of carvacrol in electrospun zein nanofibers (0559)	306
[O14.6]	Determination of properties of oxygen and water vapor permeability and glass transition temperature of edible films based upon HPMC, carrageenan, glycerol and cellulose nanofibers (0054)	312
[O15.1]	Particle interactions with foam and foam-like structures (0197)	315
[O15.2]	Engineering of dough and bread structuration; interest of pressure modulation during mixing and impact on dough porosity during resting, sheeting and fermentation and on the structure of baked bread (0492)	320
[O15.3]	On the hybrid modelling of simultaneous heat and mass transfer in foams (0537)	321
[O15.4]	Non-destructive 3D imaging analysis of foam structures using fast laboratory micro-CT (0579)	322
[O15.5]	Aroma release from milk protein-based model foam systems (0704)	323
[O15.6]	Influence of high isostatic pressure on the foaming properties of food proteins (0707)	328

[O16.1]	Fermentation - A powerful method to overcome soybean allergenicity (0154).....	329
[O16.2]	Entrapment of cross-linked enzyme aggregates of L-arabinose isomerase in alginate beads for production of D-tagatose (0300)	336
[O16.3]	Production of synbiotic fermented soymilk from vegetable soybean (0353)	337
[O16.4]	Melatonin and derived tryptophan metabolites produced during alcoholic fermentation by different yeast strains (0467)	341
[O16.5]	Microbial fermentation of plant raw materials affected by PEF pre-treatment (0652)	346
[O16.6]	Bioactive properties of egg yolk protein by-product (0133)	347
[O16.7]	Natural functionalization of bioactive milk proteins via Maillard reaction and its impact on antioxidant capacity and digestibility (0201)	348
[O16.8]	Development of ohmic cells dedicated to the baking of crust less bread (0612)	349
[O17.1]	Intensified processing of protein-polysaccharide-conjugates via extrusion (0091)	354
[O17.2]	Structural strength and crystallization in amorphous food models at low water activities (0443).....	355
[O17.3]	The multiscale nature of food science and technology (0663)	361
[O17.4]	Alternative paradigms for food sterilization (0689)	362
[O17.5]	Texture & mouthfeel research for optimum food design: A multi-scale approach in food microstructure and functionality (0770)	363
[O17.6]	Stabilization of açai juice using mechanical treatments (0695)	364
[O18.1]	Complexity in the virtualization of food processing and optimization (0244)	370
[O18.2]	On the numerical strategies to virtualize food heating in a continuous free-running oscillator RF system (0740)	374
[O18.3]	Estimation of dielectric properties of osmo-dehydrated foods by inverse numerical technique (0209)	375
[O18.4]	Computational modelling of end-over-end (EOE) retort processing for canned foods with particulates (0278)	382
[O18.5]	Computational modelling of reciprocal-agitation retort process for canned liquid foods (0290)	388
[O18.6]	Seeding-induced crystallisation in highly concentrated system (0383)	394
[O18.7]	Coalescence and agglomeration of skim milk particles during spray drying (0393)	395
[O18.8]	Experimental investigations and modelling of hot air drying of sliced tomatoes (0424)	396
[O19.1]	3-D printing of artificial plant tissue for innovative food manufacturing: Bio-ink formulations for the printing of porous structure (0317)	409
[O19.2]	Structural-mechanical analysis of cookies produced by conventional and 3D printing techniques (0386)	415
[O19.3]	Structure design of 3D printed cookies in relation to texture (0387)	420
[O19.4]	The role of gelation dynamics in food printing (0715)	426
[O19.5]	Process control in 3D food printing (0713)	427

[O19.6]	Successfully developing food products using 3D printing technologies: Challenges, opportunities and future outlook (0710)	428
[O20.1]	Structuring food for improving nutrient bioavailability: The case of dairy gels (0541)	432
[O20.2]	The biopolymer toolbox to tailor lipid digestion-From Interfacial design to in vivo studies (0334)	434
[O20.3]	The effect of dietary fibre on the in vitro digestion of cereal foods (0557)	435
[O20.4]	In-vivo versus in-vitro digestion: Validation of the COST Infogest digestion protocol (0578)	436
[O20.5]	Engineering digestion: In vitro & in silico methods for studying human digestion (0470)	437
[O20.6]	Food for the ages: Application of dynamic in vitro digestion models to evaluate the differential digestive fate of proteins and emulsions in infants, adults and the elderly (0141)	442
[O20.7]	In vitro static digestion in the newborn: Proposition of a protocol for infant formula (0602)	443
[O20.8]	Impact of surface adsorption on in vitro digestibility of food preservatives (0546)	449
[O21.1]	High pressure processing (HPP) assisted enzymatic hydrolysis - An innovative approach for the reduction of soybean allergy (0151)	450
[O21.2]	Delineating the bioactivity and colonic fermentation of bovine lactoferrin-fructo-oligosaccharide mixtures in adults or infants via the Maillard reaction (0140)	457
[O21.3]	Novel angiotensin I-converting enzyme (ACE) inhibitory peptides from bovine connective tissue: Purification and characterization (0575)	458
[O21.4]	Gas-solid interactions of cold atmospheric pressure plasma with complex food matrices (0577)	464
[O21.5]	Shelf-life extension of pomegranate arils with chitosan-ascorbic acid coatings (0296)	469
[O21.6]	Effect of electrical field strength applied by PEF on the shelf life of fresh fruit smoothie: Trade-off between yeasts and moulds (0581)	470
[O22.1]	Virtual engineering of food processes: A powerful design, diagnosis, prognosis and optimization tool based on modelling and simulation (0514)	471
[O22.2]	Operational state related simulation of the electrical power consumption of food packaging plants (0430)	472
[O22.3]	Modelling salt diffusion in cereal doughs: An innovative application of 3D images from X-ray micro-tomography (0644)	479
[O22.4]	Radiation heat transfer in an oven register: Modelling aspects and the experimental validation (0539)	483
[O22.5]	Modelling of the kinetics of high hydrostatic pressure assisted hydrolysis (0549)	484
[O22.6]	Process optimization of systems for energy-efficient and mild product drying by means of numerical modelling (0571)	489
[O22.7]	On the development and validation of a 3-D thermal Lattice Boltzmann solver (0547)	490
[O23.1]	High throughput electro-hydrodynamic processing in food encapsulation and food packaging applications (0160)	491
[O23.2]	Encapsulation efficiency and physico-chemical properties of a selenomethionine-loaded chitosan nanoparticles formulation for oral delivery (0325)	492

[O23.3]	Spray-dried vitamin-loaded particles: Structure & hydration properties (0468)	493
[O23.4]	Microencapsulation of vanillin by layer-by-layer electrostatic deposition technique (0123)	495
[O23.5]	Microencapsulation of a probiotic <i>Lactobacillus paracasei</i> strain by complex coacervation and subsequent ionotropic gelation (0592)	496
[O23.6]	Effect of drying method on agricultural products' properties (0502)	501
[O23.7]	Microencapsulation with biopolymers of active and natural compounds with food, biomedical and technological interest (0064)	507
[O23.8]	Encapsulation of astaxanthin using protein-polysaccharide conjugates as emulsifier and coating materials to form pH and heat stable dispersions (0605)	513
[O24.1]	Interactions between whey protein and pectin in model system (0024)	514
[O24.2]	Membrane distillation for milk concentration (0052)	521
[O24.3]	Transglutaminase treatment of milk with amaranth added: Effect on the structure properties of stirred yoghurt (0369)	527
[O24.4]	Understanding CO ₂ production and transfer during cheese ripening (0409)	537
[O24.5]	Potential application of phage for detection and biological control of food borne pathogens; the case of <i>Mycobacterium avium</i> subspecies paratuberculosis (0289)	543
[O24.6]	Pulsed light vs. allergenicity: Applications in dairy ingredients (0449)	548
[O24.7]	Biodiversity of wild lactic acid bacteria isolated from raw donkey milk: Assessment of their technological properties, bacteriocin production, safety evaluation and probiotic potential (0629)	554
[O24.8]	The effect of cross linking of milk proteins in stirred yoghurt by an oxidoreductase on gel structure and sensory perception (0535)	557
[O25.2]	Nonthermal processing technologies as elicitors to induce the biosynthesis and accumulation of nutraceuticals in plant foods (0224)	562
[O25.3]	Physiological response of fruits processed by moderate- intensity pulsed electric fields (0288)	563
[O25.4]	Non-thermal plasma – An alternative technology for the decontamination of dry food surfaces (0585)	564
[O26.1]	Food loss and waste reduction in a context of growing urbanization (0526)	565
[O26.2]	Reduction of water and energy usage in vegetable processing by use of pulsed electric fields – A case study (0792)	568
[O26.3]	Environmental impacts and energy and emissions reductions from food catering (0335)	569
[O26.4]	Chemical-free neutralization of caustic peeled tomato slurry to reclaim wastes: A water conservation initiative (0458)	575
[O26.5]	A study of strategies to reduce energy use for internal environmental conditions in supermarkets (0323)	581

[O26.6]	Experimental and numerical study on the performance of CO ₂ refrigeration for supermarket applications (0235)	588
[O27.1]	Multispectral Imaging (MSI); a promising method for the detection of minced beef adulteration with horsemeat (0525)	594
[O27.2]	Prove authenticity of grated Parmigiano-Reggiano cheese by small sensor system (S3) (0173)	595
[O27.3]	Evaluating the flavor authenticity of thermal and high pressure processed apple juice by headspace gas chromatography- mass spectrometry fingerprinting (0180)	597
[O27.4]	Concept and pilot studies for the automated food control of online distributed foodstuff (0626)	603
[O28.1]	The overview of migration, poverty and food safety risks in developing countries (0584)	607
[O28.2]	Isolation and identification of potential probiotic bacteria from South African Saanen goats' milk (0116)	611
[O28.3]	Developing and testing the acceptability of therapeutic food for the management of severely malnourished children (0033)	612
[O28.4]	In-vitro digestibility and other functional properties of starches from bambara landraces (0298)	618
[O28.5]	Malnutrition in Madagascar: Understanding food representation and practice to facilitate the appropriation of local food resource by consumers (0061)	619
[O28.6]	Production of probiotic whey drink from released liquid whey of Jordanians soft cheeses (0039)	625
[O29.2]	Utilization of pulsed light for enzyme inactivation and conformational structure change of whey protein (0551)	631
[O29.3]	Impact of high pressure/temperature treatment on structure modification and functional sensory properties of frankfurters batter (0307)	632
[O29.5]	Hyperbaric storage preservation at room temperature of two commercial ready-to-eat pre-cooked foods at room temperature using an industrial scale pressure equipment (0664).....	634
[O30.1]	Reduction of energy in baking ovens; an overview of LEO ("Low Energy Oven") European project based on infra-red technology and on water spraying to replace steam injection during baking (0560)	639
[O30.2]	COLDμWAVE - Investigation of microwave blanching of vegetables (0455)	640
[O30.3]	BAKE4FUN, a European project for SME benefit to design and validate functional bakery products (0700)	641
[O30.4]	SUCCIPACK: Development of active, intelligent and sustainable food packaging using polybutylene succinate (PBS) (0462)	642
[O30.5]	Analysis of needs for innovation in small scale mushroom enterprises: TRAF00N Project (0177)	644
[O30.6]	The FOOD-STA project: Improving higher education and continual professional development to face future challenges of the European food industry (0212)	645
[O31.1]	Comprehensive evaluation of the global clean label phenomenon: Implications for consumers, manufacturers and regulators (0711)	651
[O31.2]	The worldwide mycotoxins regulations in cereals (0766)	655

[O31.3]	Mycotoxin reduction: Biological based and practical methods to reduce exposure (0826)	657
[O31.4]	Evaluation of polyurethane foam materials as air filters against fungal contamination (0341)	659
[O32.1]	Improving the quality of vacuum packed fresh Norwegian salmon through active packaging solutions in the form of absorbing and CO ₂ -emitting pads (0328)	661
[O32.2]	Developing suitable smart TTI labels to match specific shelf life monitoring requirements: The case of different seafood products (0701)	663
[O32.3]	Use of palladium based oxygen scavenger to prevent discoloration of ham (0085)	669
[O32.4]	Influence of the surface hydrophobicity of the carrier material on the inactivation of bacterial spores with gaseous, condensing hydrogen peroxide (0247)	670
[O33.1]	Healthy food design: New strategies and opportunities (0829)	671
[O33.2]	Connecting and communicating with consumers in new product development-Connect2Innovate (0784)	672
[O33.3]	Facilitation of communication in new food product development-community building between food technologists, consumer researchers, industry and academics (0819)	672
[O33.4]	TRADEIT: Supporting innovation and SME food producers (0823)	675
[O33.5]	Creating a multidisciplinary platform to address the main challenges in food innovation-Connect2Innovate (0801)	672

Production of synbiotic fermented soymilk from vegetable soybean

Carolina Battistini^a, Beatriz Gullón^b, Eliana Paula Ribeiro^a, Leo Kunigk^a, Ana Maria Pereira Gomes^b,
Cynthia Jurkiewicz^a

^aMaua Institute of Technology, São Caetano do Sul, Brazil (cynthia@maua.br)

^bCBQF – Faculty of Biotechnology, Catholic University of Portugal, Porto, Portugal

ABSTRACT

Vegetable soybeans [*Glycine Max* (L.) *Merril*] are harvested while seeds are immature which have some advantages over mature soybean, such as sweeter flavor and less content of indigestible oligosaccharides, stachyose and raffinose. Considering those beneficial characteristics the aim of this work was to study the fermentation process of soymilk from vegetable soybean and evaluate the influence of prebiotics, inulin and fructooligosaccharide, on physical-chemical and microbiological properties of the fermented beverage. Soymilk was produced by soaking 50 g of freeze-dried vegetable soybeans cultivar BRS-232 in 455 g of water for 10 minutes. The mixture was heated at 85 °C and blended for 3 minutes. The slurry was stirred for 5 minutes, filtered and the soymilk supplemented with 4 g·ml⁻¹ fructooligosaccharides (FOS) or inulin, or a mixture of both. Fermented soymilk without the addition of prebiotic was also prepared. The four formulations were produced in triplicate. Soymilks were inoculated with 0.02% of a freeze-dried ABT-4 culture, containing *Lactobacillus acidophilus* La-5, *Bifidobacterium animalis* subsp. *lactis* Bb-12 and *Streptococcus thermophilus*, incubated at 37 °C until pH reached 4.8 and stored at 5 °C for 28 days. Prebiotics had no effect on time needed to reach pH of 4.8 in soymilk that was obtained in 3.2 ± 0.2 h. Lactic acid production was 15 % higher in fermented soymilk with inulin during storage. Viable cell numbers of *B. animalis* remained above 10⁸ cfu/mL in the fermented soymilk during storage while *L. acidophilus* decreased by 1 log cfu/mL in the same period. The content of stachyose and raffinose decreased after fermentation by 28.5% and 39.5 % respectively. Soymilk made with vegetable soybeans has a great potential as a vehicle to deliver probiotics to consumers. The total count of probiotics was higher than 10¹⁰ cfu in a daily portion of 100 mL of the fermented beverage.

Keywords: Vegetable soybean; Fermented soymilk; Prebiotic; Probiotic

INTRODUCTION

A probiotic fermented soymilk combines the beneficial properties of soy with the health benefits of probiotic microorganisms. The fermentation of soymilk is usually carried out by a mixture of a probiotic culture with a yogurt culture, so the acidification rate is increased and the sensory characteristics of the product is improved (Champagne et al., 2009; Saad et al., 2013; Xiao, 2008). Prebiotic ingredients, such as inulin and fructooligosaccharides, may also improve the activity and survival of probiotic bacteria in fermented soymilk (Bedani et al., 2013; Rinaldoni et al., 2012). Moreover, the combination of prebiotics and probiotics results in a synbiotic effect on gut microbiota (Ramchandran & Shah, 2010).

Vegetable soybean [*Glycine Max* (L.) *Merril*] is a popular food that is consumed in Asia, the United States and other countries, mainly as a snack or in salads. It is a soybean that is harvested while the seeds are at approximately 80 % of maturity, such that it has a green color and a soft texture (Saldivar et al., 2010; Song et al., 2003; Wszelaki et al., 2005). These immature seeds have advantages over mature soybean, including improved sensory attributes and nutritional value, such as sweeter flavor and less contents of stachyose and raffinose, resulting in better digestibility (Huang et al., 2014; McWilliams et al., 2004; Saldivar et al., 2011). Although there are many studies about fermentation of soymilk by probiotic microorganisms, little is known about the behavior of those bacteria in soymilk produced from vegetable soybean.

The aim of this study was to evaluate the fermentation process of soymilk from vegetable soybean by probiotic microorganisms and yogurt culture and evaluate the influence of prebiotics, inulin and fructooligosaccharide, on physical-chemical and microbiological properties of the fermented beverage.

MATERIALS & METHODS

Soy milk, from vegetable soybeans, cultivar BRS232 (Embrapa Soybean, Brazil), was produced by soaking fifty grams of freeze-dried vegetable soybeans in 455 g of water at room temperature for 10 minutes. The mixture was heated at 85 °C and blended for 3 minutes. The slurry was stirred at 85 °C for 5 minutes and filtered in a 0.5-mm conical sieve to obtain the soy milk.

The prebiotics, 4 g·mL⁻¹ of fructooligosaccharides (FOS) (Orafti® P 95, Beneo Latinoamericana), 4 g·mL⁻¹ of inulin (Orafti®GR, Beneo Latinoamericana) or a mixture of 4 g·mL⁻¹ FOS and 4 g·mL⁻¹ inulin were added to soy milk and pasteurized at 75°C for 15 seconds. The soy milk supplemented with prebiotic was cooled at 37 °C, inoculated with 0.02% of a freeze-dried ABT-4 culture (Christian Hansen, Denmark) containing *Lactobacillus acidophilus* La-5, *Bifidobacterium animalis* subsp. *lactis* Bb-12 and *Streptococcus thermophilus* and incubated at 37 °C until the pH reached 4.7 – 4.8. The fermented beverages were stored at 5 °C for 28 days. All treatments were replicated three times.

Lactic acid were determined according to Rivas et al. (2012) using an Agilent 1200 series HPLC instrument with a refractive index detector (Agilent, Waldbronn, Germany). The contents of oligosaccharides, stachyose and raffinose, were determined using a 1100 series Hewlett-Packard chromatograph equipped with a refractive index detector (Rivas et al., 2012).

Viable cells numbers of *Lactobacillus acidophilus*, was determined by surface-plating 20 µL of diluted samples in M-MRS agar (formulated MRS agar containing 20 g·L⁻¹ of maltose instead of glucose). Plates were incubated at 37 °C for 48 h under aerobic conditions (Lima et al., 2009). *Bifidobacterium animalis* was monitored by surface-plating 20 µL of each dilution in De Man Rogosa Sharpe (MRS) agar containing 0.2 g·L⁻¹ of bile salts, 0.3 g·L⁻¹ of sodium propionate, 0.5 g·L⁻¹ of cysteine - HCl and 0.2 g·L⁻¹ of lithium chloride. Plates were incubated at 37 °C for 48 h under anaerobic conditions (GasPak™, BD BBL™, EUA) (Lima et al., 2009). *Streptococcus thermophilus* were determined by surface-plating 20 µL of each dilution in M17 agar supplemented with 5 g·L⁻¹ lactose and plates were incubated at 37 °C for 48 h under aerobic conditions (Richter & Vedamuthu, 2001).

RESULTS & DISCUSSION

The addition of prebiotics, fructooligosaccharides or inulin or their combination to soy milk did not influence the fermentation time. The time needed to reach pH of 4.8 ranged from 3.1 to 3.3 h, with no significant difference ($p > 0.05$) between data (Table 1). All beverages presented a significant ($p < 0.05$) increase in lactic acid content during 28 days of storage. The highest increase in lactic acid content (0.48 g/L) was observed in beverage containing inulin (Table 1). The production of lactic acid can be attributed mainly to *Streptococcus thermophilus* that is a homofermentative species and produces lactic acid to a higher extent than probiotic bacteria in soy milk (Wang et al., 2003).

Table 1. Fermentation time of soy milk and lactic acid content in the fermented beverage after 1 and 28 days of storage at 4 °C. Soy milk with no prebiotic (Control), with Fructooligosaccharide (FOS), with Inulin and with FOS and Inulin.

	Prebiotic			
	Control	FOS	Inulin	FOS + Inulin
Time to reach pH 4.8 (h)	3.33 ± 0.22 ^a	3.22 ± 0.13 ^a	3.19 ± 0.10 ^a	3.13 ± 0.05 ^a
Lactic acid (1 day)	2.09 ± 0.13 ^a	1.79 ± 0.04 ^b	2.11 ± 0.14 ^a	2.13 ± 0.06 ^a
Lactic acid (28 days)	2.24 ± 0.03 ^b	2.28 ± 0.16 ^b	2.59 ± 0.12 ^a	2.42 ± 0.07 ^a

Values are expressed as mean ± Sd. ^{a,b}Different letters in a row denote significant difference between trials ($p < 0.05$).

The addition of FOS and/or inulin in soy milk had no significant ($p > 0.05$) effect on *Streptococcus thermophilus* and *Bifidobacterium animalis* viability in fermented beverages. The *Bifidobacterium animalis* Bb-12 viability in fermented vegetable soy milk was greater than *L. acidophilus* La-5. At the end of 28 days of storage, the viable cell number of *B. animalis* was higher than 8 log cfu·mL⁻¹ in all of the fermented beverages, regardless of the presence or absence of prebiotic (Figure 1). The decrease in *Lactobacillus acidophilus* population in fermented soy milk during storage was significant ($p < 0.05$) and higher than 1 log cfu·mL⁻¹ for all treatments. In general, beverages with inulin and/or FOS presented significantly ($p < 0.05$) lower counts (approximately 0.2 log cfu·mL⁻¹) compared to beverages without prebiotics (Figure 1).

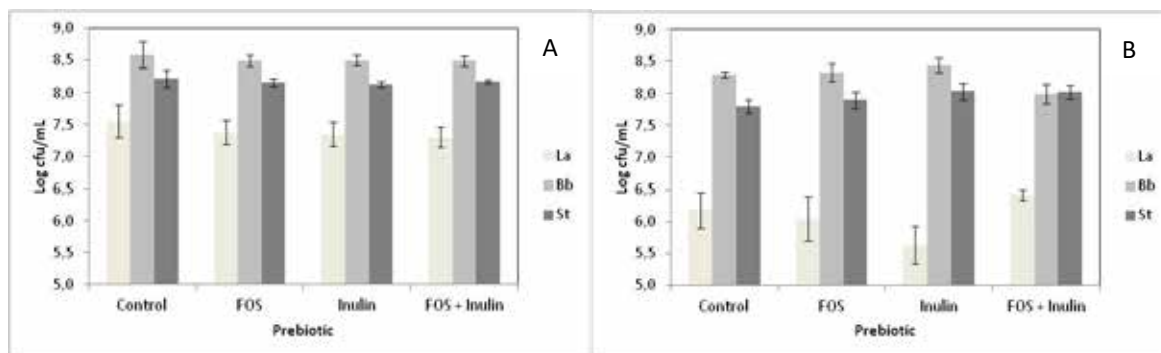


Figure 1. Viable counts of *L. acidophilus* (La), *B. animalis* (Bb) and *S. thermophilus* (St) in fermented soymilk with no prebiotic (Control), Fructooligosaccharide (FOS), Inulin and a mixture of FOS and Inulin. A: after 1 day of storage. B: After 28 days of storage.

Oligosaccharides content in soymilk without prebiotic before fermentation were 0.63 g/L and 0.38 g/L of stachyose and raffinose, respectively (Figure 2). After fermentation of soymilk the content of stachyose and raffinose decreased significantly ($p < 0.05$) to 0.48 g/L and 0.22 g/L, respectively. The hydrolysis of these α -galacto-oligosaccharides requires the enzyme α -galactosidase which hydrolyses α -galactosidase bonds (Scalabrini et al., 1998). *Bifidobacterium* spp., *Lactobacillus acidophilus* and *Streptococcus thermophilus* have α -galactosidase activity, however the utilization of these sugars varied with the culture species and strains employed (Farnworth et al., 2007; Wang et al., 2003). Donkor et al. (2007) reported that *S. thermophilus* reduced raffinose in soymilk by 64.5%, whereas stachyose was metabolized by over 40% for most of the strains evaluated. Hou et al. (2000) observed that *Bifidobacterium* reduce raffinose by 39% and stachyose by 65% after 48 h of fermentation of soymilk. In the present study, the reduction of raffinose and stachyose was $41 \pm 5\%$ and $23 \pm 2\%$, respectively. The short fermentation time in our work may have led to a lower reduction in oligosaccharides content.

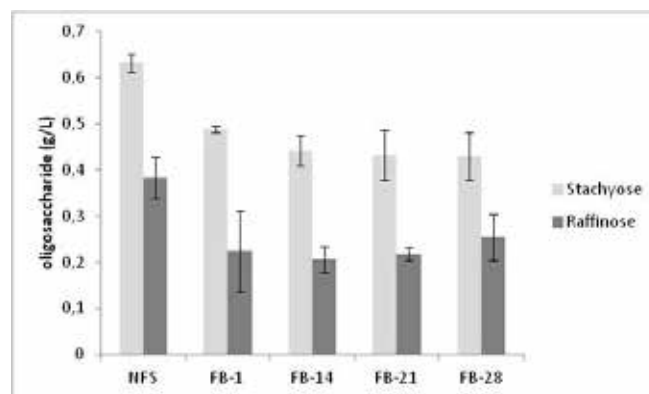


Figure 2. Oligosaccharides content in the soymilk produced with vegetable soybeans and in the fermented beverages (FB) during the storage period. Not fermented soymilk (NFS); FB with 1 day of storage (FB-1); FB with 14 days of storage (FB-14); FB with 21 days of storage (FB-21); FB with 28 days of storage (FB-28).

CONCLUSION

The results demonstrated that fermented soymilk from vegetable soybean is a very promising product as a vehicle for probiotic bacteria, as well as soy product with a lower content of nondigestible oligosaccharides.

ACKNOWLEDGEMENTS

Maua Institute of Technology and Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP) for financial support. Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and Santander Bank for scholarship.

REFERENCES

- Bedani, R., Rossi, E. A., & Saad, S. M. I. (2013). Impact of inulin and okara on *Lactobacillus acidophilus* La-5 and *Bifidobacterium animalis* Bb-12 viability in a fermented soy product and probiotic survival under in vitro simulated gastrointestinal conditions. *Food Microbiology*.
- Champagne, C. P., Green-Johnson, J., Raymond, Y., Barrette, J., & Buckley, N. (2009). Selection of probiotic bacteria for the fermentation of a soy beverage in combination with *Streptococcus thermophilus*. *Food Research International*, 42(5-6), 612–621.
- Donkor, O. N., Henriksson, A., Vasiljevic, T., & Shah, N. P. (2007). α -Galactosidase and proteolytic activities of selected probiotic and dairy cultures in fermented soymilk. *Food Chemistry*, 104(1), 10–20.
- Dornbos Jr, D. L., & McDonald Jr, M. B. (1986). Mass and Composition of Developing Soybean Seeds at Five Reproductive Growth Stages. *Crop Science*, 26(May-June), 624–630.
- Farnworth, E. R., Mainville, I., Desjardins, M. P., Gardner, N., Fliss, I., & Champagne, C. (2007). Growth of probiotic bacteria and bifidobacteria in a soy yogurt formulation. *International Journal of Food Microbiology*, 116(1), 174–181.
- Hou, J.-W., Yu, R.-C., & Chou, C.-C. (2000). Changes in some components of soymilk during fermentation with bifidobacteria. *Food Research International*, 33(5), 393–397.
- Huang, M., Wang, Q., Zhang, M., & Zhu, Q. (2014). Prediction of color and moisture content for vegetable soybean during drying using hyperspectral imaging technology. *Journal of Food Engineering*, 128, 24–30.
- Lima, K. G. D. C., Kruger, M. F., Behrens, J., Destro, M. T., Landgraf, M., & Gombossy de Melo Franco, B. D. (2009). Evaluation of culture media for enumeration of *Lactobacillus acidophilus*, *Lactobacillus casei* and *Bifidobacterium animalis* in the presence of *Lactobacillus delbrueckii* subsp *bulgaricus* and *Streptococcus thermophilus*. *LWT - Food Science and Technology*, 42(2), 491–495.
- McWilliams, D. a., Berglund, D. R., & Endres, G. J. (2004). Soybean - Growth and Management Quick Guide. *NDSU Extension Service, North Dakota State University*, (August), 1–8.
- Ramchandran, L., & Shah, N. P. (2010). Influence of addition of Raftiline HP?? on the growth, proteolytic, ACE- and ??-glucosidase inhibitory activities of selected lactic acid bacteria and *Bifidobacterium*. *LWT - Food Science and Technology*, 43(1), 146–152.
- Richter, R. L., & Vedomuthu, E. R. (2001). Milk and Milk Products. In *Compendium of methods for the microbiological examination of foods* (pp. 483–495). Washington DC: American Public Health Association.
- Rinaldoni, A. N., Campderrós, M. E., & Pérez Padilla, A. (2012). Physico-chemical and sensory properties of yogurt from ultrafiltered soy milk concentrate added with inulin. *LWT - Food Science and Technology*, 45(2), 142–147.
- Rivas, S., Gullón, B., Gullón, P., Alonso, J. L., & Parajó, J. C. (2012). Manufacture and properties of bifidogenic saccharides derived from wood mannan. *Journal of Agricultural and Food Chemistry*, 60(17), 4296–4305.
- Saad, N., Delattre, C., Urdaci, M., Schmitter, J. M., & Bressollier, P. (2013). An overview of the last advances in probiotic and prebiotic field. *LWT - Food Science and Technology*, 50(1), 1–16.
- Saldívar, X., Wang, Y. J., Chen, P., & Mauromoustakos, a. (2010). Effects of blanching and storage conditions on soluble sugar contents in vegetable soybean. *LWT - Food Science and Technology*, 43(9), 1368–1372.
- Saldívar, X., Wang, Y.-J., Chen, P., & Hou, A. (2011). Changes in chemical composition during soybean seed development. *Food Chemistry*, 124(4), 1369–1375.
- Scalabrini, P., Rossi, M., Spettoli, P., & Matteuzzi, D. (1998). Characterization of *Bifidobacterium* strains for use in soymilk fermentation. *International Journal of Food Microbiology*, 39(3), 213–219.
- Song, J. Y., An, G. H., & Kim, C. J. (2003). Color, texture, nutrient contents, and sensory values of vegetable soybeans [*Glycine max* (L.) Merrill] as affected by blanching. *Food Chemistry*, 83(1), 69–74.
- Wszelaki, a. L., Delwiche, J. F., Walker, S. D., Liggett, R. E., Miller, S. a., & Kleinhenz, M. D. (2005). Consumer liking and descriptive analysis of six varieties of organically grown edamame-type soybean. *Food Quality and Preference*, 16(8), 651–658.
- Xiao, C. W. (2008). Health effects of soy protein and isoflavones in humans. *The Journal of Nutrition*, 138(6), 1244S–1249S.