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Review Article

EMERGING APPLICATIONS OF FERMENTED FRUIT ENZYME BEVERAGES AS NUTRACEUTICAL, FUNCTIONAL FOOD, AND DESIGNER FOOD PRODUCTS: A REVIEW

Ashwani Kumar [1]*, Anuradha Saini [2], Meenakshi [3], Shiva Bhardwaj [2], Amit Panwar [2]
[1]Dean, Faculty of Biosciences, Shri Ram College Muzaffarnagar, UP-251001, India
[2]Student of Biosciences, Shri Ram College Muzaffarnagar, UP-251001, India
[3]Assistant Professor, Faculty of Biosciences, Shri Ram College Muzaffarnagar, UP-251001, India
*Corresponding Author Email: ashipbtech81@gmail.com

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ABSTRACT

In the past, the beneficial effects of fermented fruits were unknown, and so people primarily used fermentation to preserve fruits, enhance shelf life, and improve flavor. Fermentation of fruits has been adopted over many generations, primarily due to their commercial significance. Edible tropical fruits such as, cashew apple, mangoes, papaya, pineapple, litchi, guava, bael, banana, pomegranate, jamun and palm etc. with high export potential have their origin in the tropics and require rather suitable climatic conditions; and can not tolerate environmental stress. Most of the tropical fruits are important sources of antioxidants, vitamins and minerals and form a very healthy part of a diet. An effective utilisation of inferior grade and over-ripe fruits and processing them into fermented beverages has been revealed as a new and promising alternative to generate extra revenues whilst conducting a sustainable exploitation of wastes. In addition, microorganisms contributing to the fermentation process have recently been associated with many health benefits, and so these microorganisms have become another focus of attention. This paper reviews the production techniques and beneficial health effects of different fermented fruits. Scientific advances in the emerging area of functional beverages; as they provide a health benefit beyond the basic nutritional functions also reported in this paper.

Keywords: Fruit Fermentation, Functional food, Fruit enzymes, Neutraceutical, Designer food

INTRODUCTION

The post-harvest shelf life of maximum of fruits is very limited due to their perishable nature. In India more then 20–25 percent of fruits are spoiled before utilization. Despite being the world's second largest producer of fruits and vegetables, in India only 1.5 percent of the total fruits and vegetables produced are processed. Fruits are mainly water (75–90%), most located in vacuole causing turgor to the fruit tissue, and fruit juice is prepared by mechanically squeezing or macerating fresh fruits without the application of heat or solvents. Fruit cell wall consists of crystalline cellulose microfibrils embedded in an amorphous matrix of pectin and hemicelluloses[1.] Food preservation ensures conservation and better utilization of fruits and vegetables through avoiding the glut and utilizing the surplus during the off-season. It is necessary to employ modern methods to extend storage life for better distribution and also processing techniques to preserve them for utilization in the off-season[2.] The fruit can be preserved by converting it into products like jam, jelly, fruit bar, juice, pickle, murabba etc. to prolong their utilizable lifespan. Fruit juice preparation is one of the easiest ways to preserve fruit. The availability of nutritious components from fruits and vegetables to a wide range of consumers is thus facilitated throughout the year by the marketing of their juices. The production process of fruit and vegetable juices includes steps like extraction, clarification, and stabilization[3].

Fermented fruits- Keeping fruits and vegetables fresh to maintain their nutrient values needs special caution and can become demanding if without a proper refrigerating system. It seems that the practice of fruit and vegetable fermentation may have evolved from ancient times to keep the collected food fresh for longer periods of time, especially when natural resources and harvestings are limited. Fermented fruit juice is one of the functional fermented foods and has many health benefits. Epidemiological evidence has been provided showing that constituents in fruits are beneficial to human health and contribute to the prevention of degenerative processes caused by oxidative stress[4]. Fruits contain many different dietary phytonutrients with strong antioxidant capacities; such as: phenolics, which include flavonoids and phenolic acids; carotenoids; and vitamins. Dietary intake of plant phenolics are inversely related to coronary heart disease and act as anti-ulcer, antispasmodic, anti-secretory, or anti-diarrheal agents in the gastrointestinal tract. Certain flavonoids have been shown to inhibit the activity of free radical generating enzymes aldose reductase, which cause diabetic cataracts and tumour growth in modelled systems. The mineral profile of fermented fruit juices has also been proposed as a possible fingerprint that could be used to characterize fermented fruit juices based on their geographical origin[5]. Fruits like guava and pomegranate are easy to culture, possess high nutritive value and its products like juices, beverages nectars, etc. are largely appreciated by the consumers. In general fruit fermented fruit juices are processed in the same way as wine made from grapes and significant compositional changes take part during wine making. Likewise phenolic compounds are not only health promoting bioactivities but also greatly contribute to the sensory properties of stuff by alternating colour taste[6]. Fruit juices contain water and 20% carbohydrates, 1% organic acids and trace amounts of vitamins, minerals and nitrogenous compounds. The sugars, organic acids and phenolics give the juice its flavour, while the vitamins, minerals and nitrogenous compounds are, in many cases, essential to yeast growth and fermentation. Fermented fruit juice has a similar composition, but has much lower levels of sugar (none in dry wines), 8-13% alcohol and a greater range of minor components[7].Papaya is the fruit of the plant *Carcica* papaya. It is native to the tropics of the Central and northern South America and is now cultivated in many tropical regions including India, Australia, Malaysia, Indonesia, the Philippines, and Hawaii. Fermented papaya preparation (FPP) has been reported to possess free radical scavenging and antioxidative properties[8].

Nutraceutical Fruits- The potential of food as prophylactic and therapeutic agent versus diseases have now begun to be acknowledged. The fascinating facts have been revealed about effect of dietary factors on certain molecular systems and mechanisms that take care of mental activity in recent years.A diet that is high in omega-3 fatty acids is earning accolades for reinforcing cognitive activity in humans[9] and upregulating genes that are vital for sustaining synaptic activity and agility in rodents[10].Eventually,diets that are rich in saturated fat are turning culprits for lowering molecular scaffolds that help cognitive function and elevating the danger of neurological dysfunction in humans[11] as well as animals[12]. Thus, a combination of nutrition and exercise is recommended to undo these probable ill health outcomes. This is further corroborated by information available in the literature[13]. Nutraceutical is hybrid of nutrition and pharmaceutical and was introduced in 1989 by Stephen L. DeFelice, founder and chairperson of the Foundation of Innovation Medicine, and definedas "Food, or parts of food, that provide medical or health benefits, including the prevention and treatment of disease"[14,15.] Functional foods, according to their generally accepted definition, are "any food or food ingredient that may provide a health benefit beyond the traditional nutrients it contains"[16]. Plenty of studies are about fruitful influences of nutraceuticals like antioxidant, mushrooms, vitamins, essential amino acids, phytochemicals, and polyunsaturated fatty acids in pediatric foods upon the budding immune response[15,17]. Fruits and fruit juice were used for cognition and brain health. Keservani and coworkers reported the use of various fruits for brain health because of medicinal value of fruits[18,19.] Keservani and Sharma reported the role of vitamin C and polyphenols found in citrus fruits and blueberries in mental performance[20].

Designer food- Designer food refers to the food that is designed to have some health benefits other than its traditional nutritional value. 'Designer food', 'functional food' and 'fortified food' are synonym, which refers to the food fortified or enriched with nutrient content already present in them or other complementary nutrient. The term was introduced in Japan in 1980s for referring processed food containing nutrient conferring of some additional health benefits apart from its own nutritional value[21].

Functional fruits- Diffusion of functional foods throughout the market has blurred the distinction between pharma and nutrition[22.] The idea of health-promoting foods is not new: Hippocrates wrote 2400 years ago "Let food be thy medicine and medicine be thy food"[23.] Asian communities were familiar with the concept of functionality of food products and herbs[24.] Several critical factors have been recognized as the key factors leading to the diffusion of functional foods: health deterioration, due to busy lifestyles, low consumption of convenience foods and insufficient exercise; increased incidence of self-medication; increased awareness of link between diet and health due to information by health authorities and media on nutrition; and a crowded and competitive food market[25.] Aboveall, the various stakeholders have perceived the economic potential of functional food products as an important part of public health prevention strategies. Some authors reported that anannual reduction of 20% in health care expenditure is possible through widespread consumption of functional foods[26]. Nowadays, the range of functional foods includes products such as baby foods, baked goods and cereals, dairy foods, confectionery, ready meals, snacks, meat products, spreads, and beverages[27]. In particular, beverages are by far the most active functional foods category because of (i) convenience and possibility to meet consumer demands for container contents, size, shape, and appearance; (ii) ease of distribution and better storage for refrigerated and shelf-stable products; (iii) great opportunity to incorporate desirable nutrients and bioactive compounds[28,29,30]. The different types of commercially available products could be grouped as follows: (1) dairy-based beverages including probiotics and minerals/ω-3 enriched drinks, (2) vegetable and fruit beverages, and (3) sports and energy drinks.

Functional foods - Historically, various terms have been used interchangeably to designate foods for disease prevention and health promotion. The term designer food, coined in 1989, is used to describe foods that naturally contain or are enriched with nonnutritive, biologically active chemical components of plants that are effective in reducing cancer risk. The word Nutraceuticals was introduced also in 1989 by the U.S. Foundation for Innovation in Medicine to refer to "any substance that is a food or a part of a food and provides medical or health benefits, including the prevention and treatment of disease"[31.] On the other hand, the concept of functional food was first introduced in Japan in the mid-1980s for foods containing ingredients with functions for health (FOSHU, food for specified health use)[32]. FOSHU is defined by the Japanese Ministry of Health, Labor and Welfare as "foods which are expected to have certain health benefits, and have been licensed to bear a label claiming that a person using them for specified health use may expect to obtain the health use through the consumption thereof"[33]. In the U.S., functional foods are defined as "foods and food components that provide a health benefit beyond basic nutrition"[34]. Thinned stone fruits are a source of polyphenols and antioxidant compounds[35.] In China, "health (functional) food means that a food has special health functions or is able to supply vitamins or minerals[36]. In Europe, the interest in functional foods started in the latter half of the 1990s. The European Commission generated an activity called Functional Food Sciencein Europe (FuFoSE) to explore the concept of functional foods through a science-based approach. As a result ,the European Commission stated that''a food product can only be considered functional if together with the basic nutritional impact it has beneficial effects on one or more functions of the human organism thus either improving the general and physical conditions or/and decreasing the risk of the evolution of diseases[37]. Therefore, a functional food can be: an unmodified natural food; a food in which a component has been enhanced through special growing conditions, breeding, or biotechnological means; a food to which a component has been added to provide benefits; a food from which a component has been removed by technological or biotechnological means so that the food provides benefits not otherwise available; a food in which a component has been replaced by an alternative component with favorable properties; a food in which a component has been modified by enzymatic, chemical, or technological means to provide a benefit; a food in which the bioavailability of a component has been modified; or a combination of any of the above[38] .

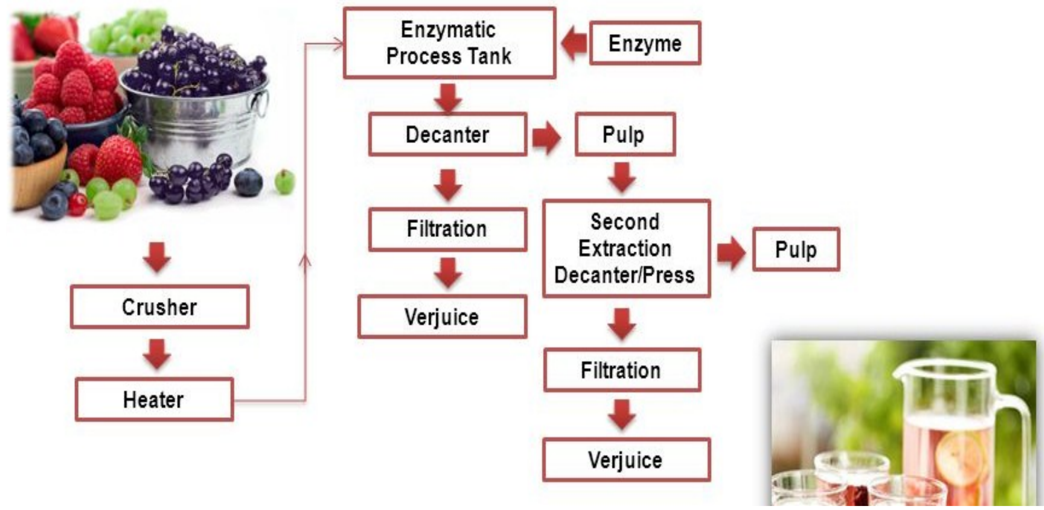

Fig 1: Scheme for the fruit processing

FRUIT ENZYMES AS HEALTH SUPPLIMENTS

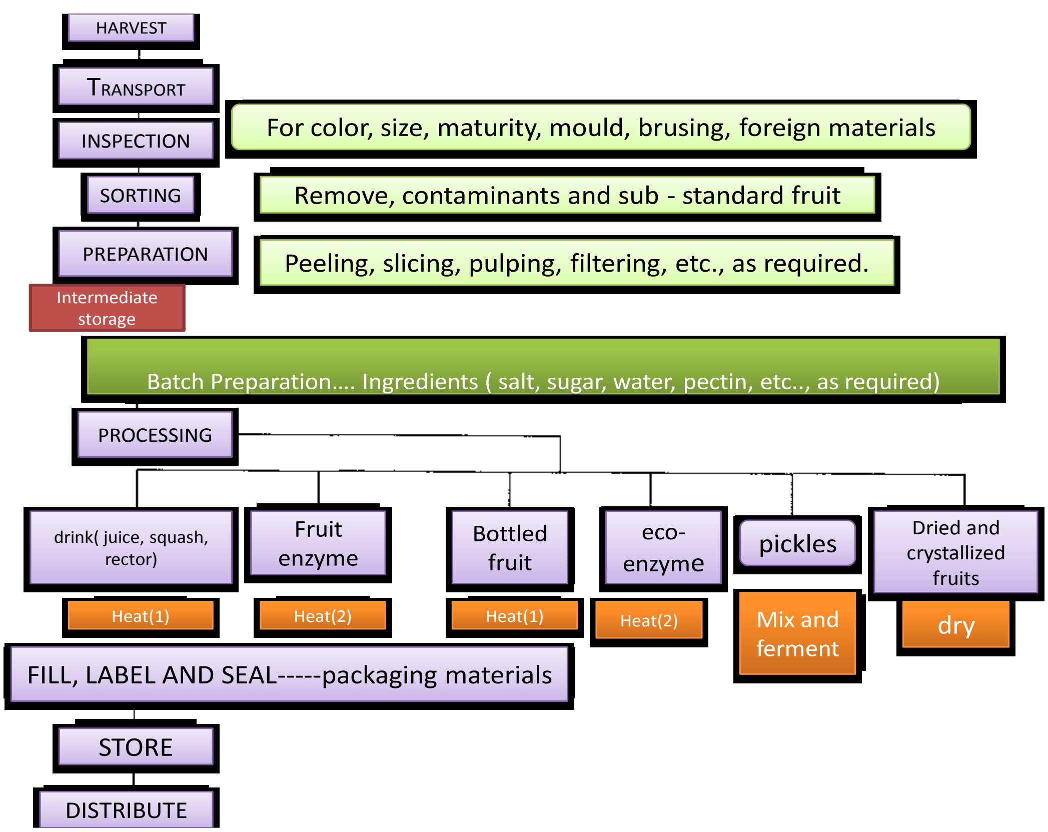

Fig 2: Different techniques for fruit fermentation and processing

Foliar sprays of three plant resistance inducers, including chitosan (CH), potassium sorbate (PS) (C6H7kO2), and potassium bicarbonates (PB) (KHCO3), were used for resistance inducing against *Erysiphe cichoracearum* DC (powdery mildew) infecting okra plants. CH at 0.5% and 0.75% (w/v) plus PS at 1.0% and 2.0% and/or PB at 2.0% or 3.0% recorded as the most effective treatments. The highest records of reduction in powdery mildew were accompanied with increasing in total phenolic, protein content and increased the activity of polyphenol oxidase, peroxidase, chitinase, and β-1, 3-glucanase in okra plants[39]. The effects of refined pectin and mango pulp on macronutrient digestion and small intestinal enzyme activity were studied in grower pigs. Diets based on wheat starch with and without apple pectin or dried mango fruit pulp were fed to 30 grower pigs for 21 days. The data suggests that pectin has a significant effect on digestive enzyme activity and subsequent influence on macronutrient digestion[40].

Cabernet gernischt (CG) is a famous Chinese wine grape cultivar, the red wine of which is known for its green trait, especially when produced from grapes cultivated in regions with monsoon climate. To modify CG wine aroma, three enzyme preparations (H. uvarum extracellular enzyme, AR2000, and pectinase) were introduced in different winemaking stages with *Saccharomyces cerevisiae*. Partial least-squares regression revealed that the green trait was due mainly to varietal compounds, especially C6 compounds, and could be partly weakened by fermentative compounds[41]. P-Synephrine is one of the main active components of the fruit *of Citrus aurantium* (bitter orange). The purpose of the study was to measure the action of p-synephrine on hepatic enzyme activities linked to carbohydrate and energy metabolism and the levels of adenine mononucleotides. P-Synephrine increased the activity of glycogen phosphorylase in vivo and in the perfused liver[42]. This study evaluated the effects of grinding at atmospheric pressure (control), under vacuum (~2.67 kPa), or with modified atmosphere (N2 and CO2) on the browning, antioxidant activity, phenolics, and oxidative enzyme activity of apples as a function of time. Least changes were obtained with vacuum grinding, particularly in terms of preventing enzymatic browning and oxidation of antioxidants apples[43].*Rosellinia necatrix*, causing root rot disease is a very destructive pathogen of woody plants and is responsible for yield losses to a large number of fruit trees. Out of 47 single spored transformants analyzed, only 33 showed hygromycin gene amplification using PCR and only 19 transformants showed single gene integration in southern hybridization, which accounted for single gene integration percentage of 42%, highest amongst all the previous reports on *Rosellinia necatrix* transformations[44].

Arabidopsis N-glycan processing mutants provide the basis for tailoring recombinant enzymes for use as replacement therapeutics to treat lysosomal storage diseases, including N-glycan mannose phosphorylation to ensure lysosomal trafficking and efficacy. Functional recombinant human alpha-L-iduronidase enzymes were generated in seeds of the *Arabidopsis thaliana* complex-glycan-deficient (cgl) C5 background, which is deficient in the activity of N-acetylglucosaminyl transferase I, and in seeds of the Arabidopsis gm1 mutant, which lacks Golgi α-mannosidase I (GM1) activity[45].Glandular hair constituents of *Mallotus philippinensis*, Muel fruit act as tyrosinase inhibitors. The glandular hair extracts from the fruit rind of *Mallotus philippinensis,* Muel is employed to treat various skin infections. Hence the present study inspected on the anti-melanogenic activity of *Mallotus philippinensis* constituents. Fluorescence and circular dichroism study implicated conformational change in secondary and tertiary structure of tyrosinase[46]. Neofunctionalization of "Juvenile Hormone Esterase Duplication" in Drosophila as an odorant-degrading enzyme towards food odorants. Odorant degrading enzymes (ODEs) are thought to be responsible, at least in part, for olfactory signal termination in the chemosensory system by rapid degradation of odorants in the vicinity of the receptors[47].

Complex Enzyme-Assisted Extraction Releases Antioxidative Phenolic Compositions from Guava Leaves. In this study, in order to enhance the bioavailability of insoluble-bound phenolics from guava leaves (GL), the ability of enzyme-assisted extraction in improving the release of insoluble-bound phenolics was investigated. Compared to untreated GL, single xylanase-assisted extraction did not change the composition and yield of soluble phenolics, whereas single cellulase or β-glucosidase-assisted extraction significantly enhanced the soluble phenolics content of PGL[48]. Association between single nucleotide polymorphisms in the antioxidant genes CAT, GR and SOD1, erythrocyte enzyme activities, dietary and life style factors and breast cancer risk in a Danish, prospective cohort study. Exposure to estrogens and alcohol consumption - the two only well-established risk factors for breast cancer - are capable of causing oxidative stress, which has been linked to progression of breast cancer. Our results showed that genetically determined variations in the antioxidant enzyme activities of SOD1, CAT and GSR were not associated with risk of breast cancer[49]. Succinic acid production from fruit and vegetable wastes hydrolyzed by on-site enzyme mixtures through solid state fermentation. In this study, a novel biorefinery concept of succinic acid (SA) production from fruit and vegetable wastes (FVWs) hydrolyzed by crude enzyme mixtures through solid state fermentation was designed. Enzyme complex solid mashes from various types of FVWs were on-site produced through solid-state fermentation by *Aspergillus niger* and *Rhizopus oryzae*[50].

Effects of ultraviolet light emitting diodes (LEDs) on microbial and enzyme inactivation of apple juice. In this study, the effects of Ultraviolet light-emitting diodes (UV-LEDs) on the inactivation of E. coli K12 (ATCC 25253), an indicator organism of E. coli O157: H7 and polyphneoloxidase (PPO) in cloudy apple juice (CAJ) were investigated. The clear (AJ) and cloudy apple juice were exposed to UV rays for 40min by using a UV device composed of four UV-LEDs with peak emissions at 254 and 280nm and coupled emissions as follows: 254/365, 254/405, 280/365, 280/405 and 254/280/365/405nm. UV-LEDs at 254nm achieved 1.6±0.1 log10 CFU/mL inactivation of E. coli K12 at UV dose of 707.2mJ/cm2[51]. The *Caenorhabdits elegans* mRNA decapping enzyme shapes morphology of cilia. Cilia and flagella are evolutionarily conserved organelles that protrude from cell surfaces. In *Caenorhabditis elegans*, cilia display morphological diversity of shapes (single, dual rod-type and wing-like and highly-branched shapes). Here we show that DCAP-1 and DCAP-2, which are the homologues of mammalian DCP1 and DCP2 mRNA decapping enzymes, respectively, are involved in formation of dual rod-type and wing-like shaped cilia in *Caenorhabditis elegans*[52].

Measurement of Tricarboxylic Acid Cycle Enzyme Activities in Plants. Mitochondria are vital cytoplasmic organelle of eukaryotic cells responsible for oxidative energy metabolism and the synthesis of intermediates utilized invarious other metabolic pathways. The functions of mitochondrion are the oxidation of organic acids by the tricarboxylic acid (TCA) cycle and the synthesis of ATP by the oxidative phosphorylation in the mitochondrial electron transport chain[53]. The protective effect of acerola (*Malpighia emarginata*) against oxidative damage in human dermal fibroblasts through the improvement of antioxidant enzyme activity and mitochondrial functionality. The chemical composition analyses showed a high content of vitamin C, total polyphenols, β-carotene and folates in the acerola fruit. From the HPLC-DAD/ESI-MSn analyses, two anthocyanins (cyanidin 3-O-rhamnoside and pelargonidin 3-O-rhamnoside), three hydroxycinnamoyl derivatives (caffeoyl hexoside, dihydrocaffeoylquinic acid and coumaroyl hexoside) and fifteen flavonols (mostly glycosylated forms of quercetin and kaempferol) were detected[54]. Effects of concentration of corn distillers dried grains with solubles and enzyme supplementation on *Cecal microbiota* and performance in broiler chickens. With the increasing production of ethanol for biofuels, a by-product of corn-based ethanol fermentation, dried distillers grains with solubles (DDGS) is finding its way into the feed of agricultural animals. We assessed the changes in the *Cecal microbiota* of broilers feed rations supplemented with DDGS (five concentrations: 0, 6, 12, 18 and 24% w/w) with and without presence of digestive enzymes[55].

Effects of pulse electric field (PEF) on antioxidant activity of pine nut (*Pinus koraiensis*) peptide were discussed using H2O2-induced HepG2 cells and changes of peptide structures were measured by MIR, NMR and CD spectra. The PEF-treated QDHCH has better protective oxidative stress inhibitory of 74.22±3.70%, and the T-SOD, CAT, GSH-Px and GSH-Rx activities in cells were significantly increased by 91.92, 7.98, 18.5 and 18.79U/mg prot, while the MDA content was decreased to 8.45±0.71U/mg prot compared with H2O2 damaged group[56]. Postharvest withering of grapes strongly affects the content and extractability of phenolic compounds in the production of sfursat, fortified and passito wines. This work evaluated the effectiveness of enzymes applied individually and/or in multi-enzyme blends, on the extraction of anthocyanins, oligomeric flavanols and polymeric flavanols from withered grape skins during simulated maceration[57]. The objective of this study was to investigate the effects of phosphogypsum (PG) amendment on the physiochemical proprieties of saline and agricultural soils along with the growth, productivity and antioxidant enzyme activities of tomato plants *(Solanum lycopersicum L.)* grown on the amended soils under controlled conditions. For both soils, PG amendment led to an increase in Calcium (Ca) and sodium (Na), and a decrease in potassium (K) in plant tissues[58]. Enzymatic saccharification of lignocellulosic residues using cellulolytic enzyme extract produced by *Penicillium roqueforti* ATCC 10110 cultivated on residue of yellow mombin fruit. The aim of this work was to enzymatic saccharification of food waste was performed by crude enzymatic cellulolytic extract produced by *Penicillium roqueforti* cultivated in yellow mombin residue. The temperature and substrate (*sugarcane bagasse*) concentration parameters were optimized using a Doehlert Design and, a maximum sugar yield of 662.34±26.72mgg-1 was achieved at 62.40°C, 0.22% (w/v) of substrate, with the addition of Mn2+[59].

Tomato UDP-Glucose Sterol Glycosyltransferases, A Family of Developmental and Stress Regulated Genes that Encode Cytosolic and Membrane-Associated Forms of the Enzyme. Sterol glycosyltransferases (SGTs) catalyze the glycosylation of the free hydroxyl group at C-3 position of sterols to produce sterol glycosides. Expression of recombinant SlSGT proteins in *E. coli* cells and *N. benthamiana* leaves demonstrated the ability of the four enzymes to glycosylate different sterol species including cholesterol, brassicasterol, campesterol, stigmasterol, and β-sitosterol, which is consistent with the occurrence in their primary structure of the putative steroid-binding domain found in steroid UDP-glucuronosyltransferases and the UDP-sugar binding domain characteristic for a superfamily of nucleoside diphosphosugar glycosyltransferases[60]. The importance of the P450 enzyme CYP1B1 in both cancer therapy and prevention are reviewed and evidence is discussed, which provides strong biological plausibility for the therapeutic merits of this approach. The significant resistance to chemotherapy among common cancers, and the realization that in many cases chemotherapy leaves behind drug-resistant cancer cells that eventually cause recurrence and metastatic disease, has recently prompted the search for natural compounds that would circumvent this problem[61]. Nitric oxide (NO) is extensively involved in various growth processes and stress responses in plants; however, the regulatory mechanism of NO-modulated cellular sugar metabolism is still largely unknown. These S-nitrosylation modifications led to a decrease in cellular glycolysis enzymes and ATP synthase activities as well as declines in the content of acetyl coenzyme A, ATP, ADP-glucose and UDP-glucose, which eventually caused polysaccharide-biosynthesis inhibition and monosaccharide accumulation[62].

Polyphenol oxidase (PPO) was extracted and characterized from ripe fruit of *Mauritia flexuosa*. Buriti PPO showed optimum activity at pH 7.0 and 35°C, with complete inactivation in between 2.0≤pH>10, using catechol as substrate. These results demonstrate that the enzyme has heat stability at higher[63]. Enzyme activities and gene expression of starch metabolism provide insights into grape berry development. The starch metabolism shares a certain role in the carbohydrate metabolic pathways during grape berry development, and is regarded as an important transient pool in the pathway of sugar accumulation. The results indicated that starch granules in grape berry were located at the chloroplast in the sub-epidermal tissues, acting as the temporary reserves of photosynthetic products to meet the needs for berry development[64]. Gene Duplication Leads to Altered Membrane Topology of a Cytochrome P450 Enzymin Seed Plants. Evolution of the phenolic metabolism was critical for the transition of plants from water to land. A cytochrome P450, CYP73, with cinnamate 4-hydroxylase (C4H) activity, catalyzes the first plant-specific and rate-limiting step in this pathway. Its N-terminus forms a single membrane spanning helix and its properties and length are highly constrained. The second is characterized by an elongated and variable N-terminus, reminiscent of ancestral CYP73s. Using as proxies the Brachypodium distachyon proteins, we show that the elongation of the N-terminus does not result in an altered subcellular localization, but in a distinct membrane topology[65].

Leucas cephalotes has been used by many tribes to treat variety of diseases and known to have many essential secondary metabolites. Ethanolic extracts have been evaluated for antihyperglycemic activity and hexane extract have been analyzed for FA identification. Nineteen FAs have been identified in all parts of *Leucas cephalotes* in which palmitic acid; oleic acid, linolenic acid, and linoleic acid were major FAs[66]. Starch granules, starch and amylopectin content were found to increase during banana fruit development, but decline during storage. The SS activity started to increase later than amylopectin and starch content. Secondly, four putative SS genes were cloned and characterized from banana fruit. Among them, MaSSIII-1 showed the highest expression in banana pulp during fruit development at transcriptional levels. Further Western blot analysis suggested that the protein was gradually increased during banana fruit development, but drastically reduced during storage. Lastly, over expression of MaSSIII-1 in tomato plants distinctly changed the morphology of starch[67].Chemical constituents, radical scavenging activity and enzyme inhibitory capacity of fruits from *Cotoneaster pannosus Franch*. *Cotoneaster pannosus* (Rosaceae) is a semievergreen shrub, producing globose dark red pomes, native to China and widely used as an ornamental plant all over the world. Both the polar and apolar fruit extracts showed noteworthy radical scavenger activity and inhibitory effects against monoamine oxidase A (MAO-A), tyrosinase (TYR) and α-glucosidase, making *Cotoneaster pannosus* red pomes a promising candidate ingredient in functional foods and dietary supplements[68]. Exploiting the Genetic Diversity of Maize Using a Combined Metabolomic, Enzyme Activity Profiling, and Metabolic Modeling Approach to Link Leaf Physiology to Kernel Yield.Correlation studies and metabolic network analyses allowed the description of a maize ideotype with a high grain yield potential. Such an ideotype is characterized by low accumulation of soluble amino acids and carbohydrates in the leaves and high activity of enzymes involved in the C4 photosynthetic pathway and in the biosynthesis of amino acids derived from glutamate[69].

Cashew immature and ripe peduncles (*Anacardium occidentale L.)* from orange- and red-colored clones CCP 76 and BRS 189, respectively, were prepared as juice or fibrous fraction and submitted to UPLC-MS analyses, while the soluble fraction was also submitted to enzymatic evaluation. The phenolic biosynthetic pathway was evaluated in juice samples and phenylalanine ammonia-lyase activity decreased significantly during the development, although it was much higher in ripe CCP 76. UDP-glycosyltransferases activity differed between clones[70]. Japanese apricot (*Prunus mume Sieb.et Zucc.)* is an important ornamental plant in China. In our study, RNA-seq technology was employed to characterize the transcriptome response to the mutation of "Fuban Tiaozhi" associated with petals variegation in Japanese apricot. As a result, 4,579,040 (white-flowered, WF) and 7,269,883 (red-flowered, RF) reads were mapped to P.persica genes, while 5,006,676 (WF) and 7,907,436 (RF) were mapped to P. persica genomes. There were 960 differentially expressed genes (DEGs) identified. Gene ontology analysis showed that these genes involved in 37 functional groups including 19 biological processes, 10 cellular components and eight molecular functions.We found that UDP-glucose: flavonoid 3-O-glucosyltransferase (UFGT) gene showed differential expression pattern[71]. Changes in sugar content and related enzyme activities in table grape *(Vitis vinifera L.)* in response to foliar selenium fertilizer. Spraying selenium (Se) fertilizer is an effective method for Se-enriched fruit production. This study was conducted to identify the effects of Se fertilizer on sugar metabolism and related enzyme activities of grape berries.Acid invertase (AI) activity, total soluble sugar and Se content in berries, and photosynthetic rate in leaves produced under Se fertilizer treatments were higher than that of control[72]. The objectives were to determine the standardized ileal digestibility (SID) of AA and NE value of cold-pressed soybean cake (CP-SBC), and the effect of extrusion or adding multi-enzyme to CP-SBC diet for growing pigs. Eight ileal-cannulated pigs (initial BW = 79.7 ± 3.97 kg) were fed 4 diets in a replicated 4 × 4 Latin square design to give 8 replicates per diet[73].

Study on optimization of process parameters for enhancing the multi-hydrolytic enzyme activity in garbage enzyme produced from preconsumer organic waste. Garbage enzyme produced from 6g pineapple peels. 4g citrus peels pre-treated with ultrasound for 20min shows higher hydrolytic enzymes activity. Simultaneously statistical optimization tools were used to model garbage enzyme production with higher activity of amylase, lipase and protease. The maximum activity of amylase, lipase and protease were predicted to be 56.409, 44.039, 74.990U/ml respectively at optimal conditions (pH (6), temperature (37°C), agitation (218 RPM) and fermentation duration (3days)[74]. Impacts of sorghum grain composition and microstructure. Brewing lager beers from unmalted sorghum traditionally requires the use of high temperature mashing and exogenous enzymes to ensure adequate starch conversion. The low temperature mash generated worts of comparable quality to those resulting from a traditional energy intensive mash protocol. Whilst brewing sorghums were of lower protein content, protein per se did not correlate with mashing performance[75]. DWF4 and CPD are key brassinosteroids (BRs) biosynthesis enzyme genes. In PeCP/DW-TL, their expressions were all relatively reduced. Additionally, the expression of PeDWF4 and PeCPD differentially made the expression levels of AtDWF4, AtCPD, AtBR6OX2, AtFLC, AtTCP1 and AtGA5 change in the TLs. The total BRs contents were PeDWF4-TL greater than PeCP/DW-TL greater than WT greater than PeCPD-TL. These results imply that PeDWF4 is functionally not exactly the same as PeCPD and there may be synergistic and antagonistic effects in physiology between both of them in the regulation of plant growth and development[76].

The sphingolipid biosynthetic enzyme Sphingolipid delta8 desaturase is important for chilling resistance of tomato. In control plants, SlSLD was highly expressed in the fruit and leaves in response to a chilling treatment. The degree of chilling damage was greater in SlSLD-silenced plants than in control plants, indicating that SlSLD knock-down significantly reduced the chilling resistance of tomato. Together, these results show that SlSLD is crucial for chilling resistance in tomato[77]. Biochemical characterization and synergism of cellulolytic enzyme system from *Chaetomium globosum* on rice straw saccharification. In this study, a lignocellulose-degrading enzyme system of *Chaetomium globosum* BCC5776 (CG-Cel) was characterized for its activity and proteomic profiles, and synergism with accessory enzymes. The highest cellulose productivity of 0.40 FPU/mL was found for CG-Cel under the optimized submerged fermentation conditions on 1% (w/v) EPFB (empty palm fruit bunch), 2% microcrystalline cellulose (Avicel®) and 1% soybean meal (SBM) at 30 °C, pH 5.8 for 6 d. CG-Cel worked optimally at 50-60 °C in an acidic pH range[78].

In vitro growth and cell wall degrading enzyme production by Argentinean isolates of *Macrophomina phaseolina*, the causative agent of charcoal rot in corn. In this work, we explored the in vitro production of plant cell wall-degrading enzymes pectinases, cellulases, hemicellulases by several Argentinean isolates of *Macrophomina phaseolina*, and assessed the pathogenicity of these isolates as a preliminary step to establish the role of these enzymes in *Macrophomina phaseolina*-maize interaction. The isolates were grown in liquid synthetic medium supplemented with glucose, pectin, carboxymethylcellulose or xylan as carbon sources and/or enzyme inducers and glutamic acid as nitrogen source[79]. In vitro inhibitory activities of selected Australian medicinal plant extracts against protein glycation, angiotensin converting enzyme (ACE) and digestive enzymes linked to type II diabetes. Extracts of five selected plant species were investigated: *Petalostigma pubescens, Petalostigma banksii, Memecylon pauciflorum, Millettia pinnata* and *Grewia mesomischa*. Enzyme inhibitory activity of the plant extracts was assessed against α-amylase, α-glucosidase and angiotensin converting enzyme (ACE). Antiglycation activity was determined using glucose-induced protein glycation models and formation of protein-bound fluorescent advanced glycation endproducts (AGEs). Antioxidant activity was determined by measuring the scavenging effect of plant extracts against 1, 1-diphenyl-2-picryl hydrazyl (DPPH) and using the ferric reducing anti-oxidant potential assay (FRAP)[80].

Salicylic-Acid-Induced Chilling- and Oxidative-Stress Tolerance in Relation to Gibberellin Homeostasis, C-Repeat/Dehydration-Responsive Element Binding Factor Pathway, and Antioxidant Enzyme Systems in Cold-Stored Tomato Fruit. Mature green tomatoes *(Solanum lycopersicum*) were treated with 0, 0.5, and 1 mM SA solution for 15 min before storage at 4 °C for 28 days. In the SA-treated fruit, the upregulation of GA biosynthetic gene (GA3ox1) expression was followed by gibberellic acid (GA3) surge and DELLA protein degradation. CBF1 participated in the SA-modulated tolerance and stimulated the expression of GA catabolic gene (GA2ox1)[81]. Stones from olives and Prunus genus fruits are cheap and sustainable sources of proteins and could be potential sources of bioactive peptides. The main limitation to the use of these seeds is the presence of amygdalin. Moreover, antioxidant, angiotensin I converting enzyme (ACE) inhibitor, and hypocholesterolemic properties will be evaluated in hydrolysates obtained from these seeds. Despite some seeds contained amygdalin, all protein isolates were free of this substance. The highest antioxidant and ACE inhibitor capacities were observed for the Prunus genus seed hydrolysates[82]. Thay have previously characterized VPE genes (SlVPE1-5) during fruit development in tomato and discovered that the VPE enzyme activity negatively interfered with sugar accumulation in mature fruits. Comparative proteomic analysis demonstrated that acid invertase was one of the molecular targets of SlVPE5, which is involved in the hydrolysis of sucrose[83].Pomegranate peel extract attenuates oxidative stress by decreasing coronary angiotensin-converting enzyme (ACE) activity in hypertensive female rats. The influence of pomegranate consumption was examined on systolic blood pressure (SBP), angiotensin-converting enzyme (ACE) coronary activity, oxidative stress, and vascular morphology. Four- or 28-wk-old SHR model rats were treated for 30 d, with terminal experimental animal age being 8 and 32 wk, respectively, with either pomegranate extract (SHR-PG) or filtered water.This finding was demonstrated by marked reduction in coronary ACE activity, oxidative stress, and vascular remodelling[84].

Lifestyle predictors of oxidant and antioxidant enzyme activities and total antioxidant capacity in healthy women: a cross-sectional study. The aim of this study was to identify demographic and modifiable lifestyle factors that may be related to endogenous oxidant and antioxidant activity measured in blood specimens from putatively healthy women recruited at the Roswell Park Cancer Institute (Buffalo, NY, USA). Total glutathione (TGSH), catalase (CAT), CuZn-superoxide dismutase (CuZn-SOD), glutathione peroxidase (GPx), glutathione reductase (GR), and myeloperoxidase (MPO) activity, and total antioxidant capacity (TAC) were measured in 124 healthy women, and associations with epidemiological factors were tested using general linear models[85]. Gene Cloning, Expression and Enzyme Activity of *Vitis vinifera* Vacuolar Processing Enzymes (VvVPEs). Vacuolar processing enzymes (VPEs) have received considerable attention due to their caspase-1-like activity and ability to regulate programmed cell death (PCD), which plays an essential role in the development of stenospermocarpic seedless grapes ovules. To characterize VPEs and the relationship between stenospermocarpic grapes and the VPE gene family, we identified 3 *Vitis vinifera* VPE genes (VvβVPE, VvγVPE, and VvδVPE) from the PN40024 grape genome and cloned the full-length complementary DNAs (cDNAs) from the *'Vitis vinifera* cv. Pinot Noir' and *'Vitis vinifera cv*. Thompson Seedless' varietals.The results of quantitative real-time PCR (qRT-PCR) suggested that VvβVPE in seeded grapes increased significantly at 30 days after full-bloom (DAF), closeto the timing of endosperm abortion at 32 DAF. These results suggested that VvβVPE is related to ovule abortion in seedless grapes[86].

Influence of γ-irradiation of barley seeds (Nur variety) at the doses of 8-50 Gy on catalase, pyruvate kinase, glucose-6-phosphate dehydrogenase, and guaiacol peroxidase activities was studied in the seedlings on the 3, 5 and 7 days after germination. It has been shown that activities of the studied enzymes increase in the dose range that causes the growth stimulation in the seedlings (16-20 Gy)[87]. Polyvinylpolypyrrolidone reduces cross-reactions between antibodies and phenolic compounds in an enzyme-linked immunosorbent assay for the detection of ochratoxin A. Pistachios represent a food matrix rich in phenolic compounds potentially contaminated with OTA, and were used to model OTA cross-reactivity. HPLC methods were used to confirm that PVPP does not interact with OTA and levels of gallic acid and catechin remaining in pistachio extracts decreased with increasing PVPP application[88]. Rice Endosperm Starch Phosphorylase (Pho1) Assembles with Disproportionating Enzyme (Dpe1) to Form a Protein Complex that Enhances Synthesis of Malto-oligosaccharides. Prior evidence has suggested that the rice enzyme, OsPho1, may have a physical/functional interaction with other starch biosynthetic enzymes. Pulldown experiments showed that OsPho1 as well as OsPho1 devoid of its L80 region, a peptide unique to higher plant phosphorylases, captures disproportionating enzyme (OsDpe1).This heterotypic enzyme complex, determined at a molar ratio of 1:1, was validated by reciprocal co-immunoprecipitation studies of native seed proteins and by co-elution chromatographic and co-migration electrophoretic patterns of these enzymes in rice seed extracts[89].

Two angiotensin-converting enzyme-inhibitory peptides from almond protein and the protective action on vascular endothelial function. Almond protein was hydrolyzed using a two-stage alcalase-protamex hydrolysis process, and the hydrolysates were subjected to a series of separations, ultrafiltration, gel filtration chromatography, and reversed-phased preparative chromatography, to obtain the active peptides. Then the effect of two ACE inhibitory peptides on the endothelial function of HUVECs was evaluated. Results showed that the two potent ACE inhibitory peptides significantly regulated the release of nitric oxide and endothelin in HUVECs[90]. Determination and optimization of Vitamin B complex in xylanase enzyme treated polished rice by response surface methodology. Xylanase enzyme was produced from *Aspergillus awamori* MTCC 9166. Brown rice was treated with 60-100% enzyme (40 ml of buffer -undiluted) for 30 to 150 min (with variation of 30 min) at 30 degrees C to 50 degrees C (with variation of 5 degrees C) to attain a saturated moisture level of 35.5 g100 (-1) g .The enzyme acted upon selective degradation (polishing time 10-50 sec) of bran layer facilitating retention of more vital nutrients along with the vitamins[91].

Evaluation of enzyme treatment conditions on extraction of anthocyanins from *Prunus nepalensis L.* The study was designed to investigate the effect of enzyme assisted extraction of anthocyanins from Sohiong fruit *(Prunus nepalensis)* under varied time, temperature and treatment conditions. Cellulase treatment (10% E/S) for 180min at 4°C exhibited highest yield of 984.40±3.84mg C3G/100gdm which accounts to 14.61% higher yield when compared to conventional method (858.84±6.88mg C3G/100gdm). The study provides an economical alternative for commercial extraction of anthocyanins from Sohiong fruit which can be used as a colourant for various foods and other products[92].The major complications in fruit juice quality improvement are the presence of polysaccharides components in the form of disrupted fruit cell wall and cell materials. In this context, magnetic tri-enzyme nanobiocatalyst was prepared by simultaneously co-immobilizing three enzymes; α-amylase, pectinase and cellulase onto amino-functionalized magnetic nanoparticle by 60mM glutaraldehyde concentration with 10h cross-linking time for one pot juice clarification. The prepared nanobiocatalyst was characterized by FT-IR, SEM and XRD. Finally, the clarification of apple, grapes and pineapple juices using magnetic tri-enzyme showed 41%, 46% and 53% respective reduction in turbidity till 150min treatment[93].

The addition of exogenous NSP-ase showed a significant improvement ($p < 0.01$) in feed gain Supplementation of NSP-ase at the 25% inclusion level could not, however, sustain the beneficial effect, which was possibly due to excessively high dietary CF[94.] Inhibition of human and rat CYP1A1 enzyme by grapefruit juice compounds. Cytochrome P4501A1 is involved in the metabolism of carcinogenic polycyclic aromatic hydrocarbons. The human and rat CYP1A1 differ by 21% in amino acid sequence, including the active site of the enzyme. Additionally, naringenin exerted a mixed type inhibition effect on rat CYP1A1. Computational docking showed that inhibitors might block the oxidation of 7-ethoxyresorufin by binding to the CYP1A1 active site. Our results demonstrate the differences in CYP inhibitory mechanisms for the same molecule when CYP from different species are considered[95]. Compared with 'AL', the transcript levels of citrate biosynthesis- and utilization-related genes and/or the activities of their respective enzymes such as citrate synthase, cytosol aconitase and ATP-citrate lyase were significantly higher in 'HAL'. Nevertheless,the mitochondrial aconitase activity, the gene transcript levels of proton pumps, including vacuolar H(+)-ATPase, vacuolar H(+)-PPase, and the juice sac-predominant p-type proton pump gene (CsPH8) were significantly lower in 'HAL'. These results implied that 'HAL' has higher abilities for citrate biosynthesis and utilization, but lower ability for the citrate uptake into vacuole compared with 'AL'[96]. Continuous microwave pasteurization of a vegetable smoothie improves its physical quality and hinders detrimental enzyme activity. A better color retention of the microwave pasteurization- treated smoothie using high power/short time than in conventionally processed sample was evidenced by the stability of the hue angle Lower residual enzyme activities from peroxidase, pectin methylesterase and polygalacturonase were obtained undermicrowave heating, specifically due to the use of higher power/shorter time[97]. Delaying harvest time coupled with periods of heavy rainfall caused sprouting in the wheat kernels, observed as a drop in Falling Number and an increase in α-amylase activity. The appearance of α- and β-amylase, peptidase, and endoxylanase activity during field sprouting was independent from each other. Consequently, Falling Number could not be used to predict activity of other hydrolytic enzymes[98].

FRUIT PRODUCTS AS NATURAL SUPPLIMENTS

Food manufacturers have made public statements and voluntary commitments, such as the Healthier Australia Commitment (HAC), to improve the nutritional quality of foods[99]. Marketing messages accompanying online selling of low/er and regular strength wine and beer products in the UK: a content analysis. The current study compares the main marketing messages conveyed by retailers and producers for low/er and regular strength wine and beer products. Four themes were identified: (a) suggested occasions for consumption, (b) health-related associations, (c) alcohol content, and (d) taste. Compared with regular strength products, low/er strength equivalents were more often marketed in association with occasions deemed to be suitable for their consumption including lunchtimes[100]. In this study, chitooligosaccharide (COS) and glycine (Gly) were selected to prepare Maillard reaction products, which were designated COS-Gly-MRPs. Using ferric reducing antioxidant power (FRAP) as a response, the optimal reaction conditions, i.e., a time of 107 min, temperature of 121 °C, pH of 6.0, and nCOS:nGly = 2.5:1, were obtained by one-variable-at-a-time method and by response surface methodology. The resulting COS-Gly-MRPs exhibited much stronger antioxidant activity than their substrates[101]. Expansion of the range of anthocyanin food colorants from unconventional vegetal primary products. The purpose of work to study the content of anthocyanins and other biologically active substances in residues of fruits of Sanberri from receivingjuice and mash. It is established that residues contained over 70% solids, more than 60% of dietary fiber, to 55.4 mg/% of ascorbic acid and up to 90.0 mg/% of anthocyanins. Furthermore, they possessed high antioxidant activity (156.8-399.4 mg/% dihydroquercetin equivalent) that allowed recommending them as raw materials for receiving natural food colorants[102].

The study included 45 patients (aged 35 to 69 years) with type 2 diabetes with concomitant obesity I-III degree. The study was conducted in two stages. The first phase evaluated the effect of jelly intake on postprandial glycemia with determination of blood glucose levels on an empty stomach and 30, 60, 120 and 180 minutes after consumption of fruit jelly with maltitol, pectin and sublimated raspberry juice and traditional marmalade with fructose (control), containing 25g of digestible carbohydrates. In the second phase the effectiveness of combination therapy during 2 weeks of the inclusion of fruit jelly with a modified carbohydrate profile in a standard hypocaloric diet (1550 kcal/day) has been assessed. It has been shown that the dynamics of postprandial glycemia in patients with typeII diabetes after the consumption of fruit jelly with a modified carbohydrate profile was comparable to the dynamics of blood glucose after eating traditional marmalade with fructose[103]. Berries and other natural products in the pancreatic cancer chemoprevention in human clinical trials. Due to the lack of efficient early diagnosis and rapid disease progression, PDAC patients have a 5-year survival rate of just 5%. Epidemiological studies suggest that smoking, obesity, type II diabetes, and pancreatitis are common risk factors for PDAC development. By contrast, high intake of fresh fruit, vegetables, and nuts rich in phytochemicals could reduce PDAC risk. This review summarizes the human clinical studies that have used berries or other natural products for chemoprevention of PDAC. Developing chemopreventive agents against PDAC would be tremendously valuable for the high-risk population and patients with premalignant lesions[104].

Female rats were randomly divided into five groups: healthy control, dyslipidaemic control and dyslipidaemic experimental receiving acerola, cashew or guava processing by-products. Fruit processing by-products were administered (400 mg/kgbody weight) via orogastric administration for 28 consecutive days. Acerola, cashew and guava by-products caused body weight reduction (3·42, 3·08 and 5·20 %, respectively) in dyslipidaemic female rats. Dyslipidaemic female rats receiving fruit by-products, especially from acerola, presented decreased faecal pH, visceral fat, liver fat and serum lipid levels, as well as increased faecal moisture, faecal fat excretion, faecal Bifidobacterium spp. and Lactobacillus spp. counts and amounts of organic acids in faeces[105]. Low-Carbohydrate, High-Protein, High-Fat Diets Rich in Livestock, Poultry and Their Products Predict Impending Risk of Type 2 Diabetes in Chinese Individuals that Exceed Their Calculated Caloric Requirement. In this paper, we aimed to investigate the association of low-carbohydrate, high-fat and high-protein diets with type 2 diabetes (T2D) risk in populations consuming extra calories and those with normal caloric intake. A total of 3644 subjects in the Harbin People's Health Study (Cohort 1, 2008-2012) and 7111 subjects in the Harbin Cohort Study on Diet, Nutrition and Chronic Non-Communicable Diseases (Cohort 2, 2010-2015) were analyzed, with a median follow-up of 4.2 and 5.3 years, respectively[106]. Quality of fresh-cut products as affected by harvest and postharvest operations. It is well known that harvest and postharvest handling of fresh produce has a paramount impact on its quality and storage, but most of the existing literature focused on these impacts only related to fresh produce as destined to final consumers. In fact, current harvest methods and postharvest technologies have improved fruit and vegetable handling and distribution processes by slowing down physiological processes and senescence[107].

The aim of this paper is to work out a methodological approach for the evaluation nutritional sustainability of typical agro-food products, representing the Mediterranean eating habits and included in the Mediterranean food pyramid. The first macro-indicator called "business distinctiveness" takes into account the application of different regulations and standards regarding quality, safety and traceability as well as the origin of raw materials. The second macro-indicator called "nutritional quality" assesses product nutritional quality taking into account the contents of key compounds including micronutrient and bioactive phytochemical. For each indicator was set-up a 0-10 scoring system; from 0 (unsustainable), to 10 (very sustainable) with 5 as a sustainability benchmark value[108]. This systematic review was carried out to identify which naturally-occurring agents and constituents isolated therefrom have effects in preventing bone loss in a ligature-induced periodontitis model. 294 articles were found, of which 15 met the inclusion criteria. The selected studies tested a multi-herbal formulation; extracts (leaves, barks or fruit) of different plant species; and propolis. The most usual dosing protocol consisted of 3-times-a-day, 11-day treatment. The combined gel of *Myracrodruon urundeuva* (5%) and *Lippia sidoides* (0.5%) was the most active treatment, reducing 45-65% bone loss in the region of molars as compared to 73.4% of doxycycline (gold-standard). *Ginkgo biloba* extract (28-56 mg/kg) and propolis (100-200 mg/kg) prevented bone destruction by 50% and 40-44%, respectively[109].

The stability of two *Alternaria* mycotoxins, alternariol (AOH) and alternariol monomethyl ether (AME), has been investigated during the food processing of tomato products simulating commercial processing conditions. It was observed that time of storage significantly reduced the initial concentration of AOH, but only if tomatoes were stored at 35 °C. The washing step achieved the highest reduction of AOH and AME. This reduction was even more efficient when using sodium hypochlorite solutions. Finally, during the heat treatment (80-110 °C), results showed that heating tomato samples at 100 and 110 °C, significantly affected AOH stability, though AME seemed to not be affected by these thermal processes[110]. Determination of free, esterified, glycosylated and insoluble-bound phenolics composition in the edible part of araticum fruit (*Annona crassiflora Mart*.) and Phenolics present in the free, esterified, glycosylated and insoluble-bound forms of araticum pulp, peel and seed were for the first time characterized and quantified using HPLC-ESI-MS/MS. Levels of total phenolics, flavonoids, condensed tannins and antioxidant activities from araticum fruit followed the order peel > pulp > seed. Extracts were found to contain contrasting levels of phenolics that were specific to each fruit part. From 10 phenolics quantified in araticum fruit, catechin and epicatechin were the major ones from pulp and peel, whereas seed displayed caffeic acid, catechin and epicatechin as its main phenolics[111].

The consumption of processed mushrooms may play an important role in preventing diseases associated with vitamin D deficiency. We determined the effects of 2 kinds of freezing (blast, cryogenic), canning (mild and strong brine), and drying (air-drying, freeze-drying) on the retention of vitamin D2 and ergosterol in *Agaricus bisporus*. After 12 months of storage, canned mushrooms retained the largest amount of vitamin D2 and ergosterol, whereas the smallest amount was retained in dried mushrooms. Cryogenic freezing resulted in higher levels of vitamin D2, whereas ergosterol levels were higher using air-blast freezing[112]. Chemometric techniques have seen wide application in biological and medical sciences, but they are still developing in the food sciences. Extracts of three citrus fruit varietals aged over four time points that corresponded to noted changes in sensory attributes were chemically profiled and modeled by two discriminatory multivariate statistical techniques, projection partial least-squares discrimant analysis (PLS-DA) and machine learning random forest (RF). Age-associated compounds across the citrus platform were identified[113].

The field investigation was designed to determine whether their active ingredients (AIs) were transferred from raspberry plants to beehives located in the immediate neighbourhood of the crop and to what extent they were transferred. Every week for 2 months, samples of soil, raspberry leaves, flowers and fruits, worker bees, honeybee brood, and honey were collected and analysed for the presence of propyzamide, chlorpyrifos, iprodione, pyraclostrobin, boscalid, cypermethrin, difenoconazole, azoxystrobin, and pyrimethanil residues[114]. 25 years of EU quality schemes for agricultural products and foodstuffs across EU Nowadays consumers are increasing their attention to the quality and origin of products they consume. This paper provides an overview of the last 25 years of EU quality schemes (Protected Designation of Origin (PDO), Protected Geographical Indication (PGI) and Traditional Speciality Guaranteed (TSG)) on agricultural products and foodstuffs across the 28 EU Member States. According to the results, it was possible to conclude that Southern European countries have the highest number of registered products. The most used EU quality scheme is PGI, followed by PDO[115]. We compared the recovery of carotenoids and their efficiency of micellarization in digested fruits, vegetables, egg yolk, and salmon and also in mixed-vegetable salads with and without either egg yolk or salmon using the static INFOGEST method22 and the procedure of Failla et al.16 Carotenoid stability during the simulated digestion was ≥70%. The efficiencies of the partitioning of carotenoids into mixed micelles were similar when individual plant foods and salad meals were digested using the two static methods[116].Consumers' perceptions of biocidal products in households. The aim of this study was to evaluate consumers' use and understanding of biocidal products in order to identify starting points for minimising their exposure to these products and reducing possible emissions to the environment. In a case study, standardised questionnaires were used to interview consumers in 133 households in three neighbourhoods in Northern Germany, representing the urban-rural typologies in Europe: predominantly urban, intermediate and predominantly rural regions[117].

FERMENTED FRUITS AND VEGETABLES FOR HUMAN NUTRITION

As world population increases, lactic acid fermentation is expected to become an important role in preserving fresh vegetables, fruits, and other food items for feeding humanity in developing countries. However, several fermented fruits and vegetables products (Sauerkraut, Kimchi, Gundruk, Khalpi, Sinki, etc.) have a long history in human nutrition from ancient ages and are associated with the several social aspects of different communities. These conditions are more critical in tropical and subtropical countries which favour the growth of spoilage causing microorganisms. Lactic acid fermentation increases shelf life of fruits and vegetables and also enhances several beneficial properties, including nutritive value and flavours, and reduces toxicity[118].Genotypic and phenotypic characterization of *Lactobacillus plantarum* strains isolated from Thai fermented fruits and vegetables. Ten *Lactobacillus plantarum* strains originally isolated from Thai fruits and vegetables fermentation were characterized by various phenotypic and genotypic methods. The phenotypic analysis using the method of carbohydrate fermentation patterns (API50CHL) revealed that the isolates belonged to the *Lactobacillus plantarum* species. This was further confirmed by 16S rRNA gene sequencing. Multilocus sequence typing (MLST) revealed a strongly clonal population structure and a low genotypic diversity in this collection[119].

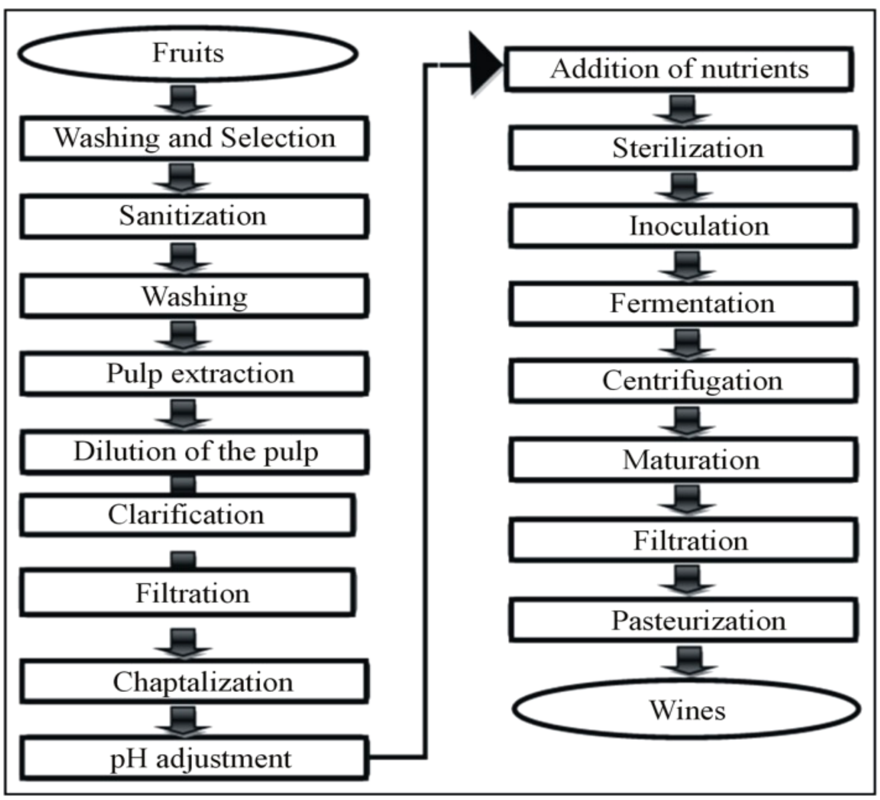

Fig 3: General flow for fruit beverage production

FRUITS AS NEUTRACEUTICAL AGENTS

In recent years, the fruits of native Brazilian plant species with anti-inflammatory property have gained prominence due to their properties comparable to traditional medicines.Our results revealed that the fruit exhibits flavonoid derivatives and stilbenes, as trans-piceatannol and resveratrol, as main secondary metabolites[120].

Chemical constituents, radical scavenging activity and enzyme inhibitory capacity of fruits from *Cotoneaster pannosus* Franch. *Cotoneaster pannosus* (Rosaceae) is a semievergreen shrub, producing globose dark red pomes, native to China and widely used as an ornamental plant all over the world. Despite its extensive cultivation, little information is available on the chemical composition and biological activities of its fruits. In this work, the analysis of the chemical composition of *Cotoneaster pannosus* fruits, in terms of phenolic components, carotenoids and ascorbic acid by HPLC/DAD, HPLC/ESI-MS and MS/MS as well as in terms of macro- and micro-nutrients was performed[121].An improved method for extraction of nutraceutically important polyphenolics from *Berberis jaeschkeana* C.K. Schneid fruits. *Berberis jaeschkeana* fruits, source of nutraceutically important polyphenolics were investigated. A total of 32 experimental run were conducted under Plackett-Burman and central composite design. Microwave power, methanol and HCl concentration significantly ($p<0.05$) affect extraction of polyphenols under linear, quadratic and interactive effect. The model showed good fitness with significant ($p<0.05$) model F-value and a non-significant lack of fit. Under optimum microwave assisted extraction (MAE) condition the total phenolics, flavonoids, tannins and antioxidant activity were in closed context with predicted values[122].

The market of plant-based nutraceuticals and food supplements is continuously growing due to the increased consumer demand. Therefore, the aim of the present study was to investigate the absorption profile of the (poly)phenolic compounds contained in three different plant-based food supplements, made of 36 different plant matrices, which were consumed by 20 subjects in an open one-arm study design. Blood samples were collected at baseline and 1, 2, 5, and 10 h after capsule intake[123]. Effects of solvents and extraction methods on the content and antiradical activity of polyphenols from fruits *Actinidia arguta*, *Crataegus monogyna*, *Gaultheria procumbens* and *Schisandra chinensis*. In line with the current tendency towards the production of the so-called safe foods, the use of environmentally-friendly methods for the extraction of polyphenols from fruits has been sought. Citric acid is a good solvent in the preparation of phenolic compounds for the food and pharmaceutical industries because it is a natural antioxidant and is non-toxic for the environment. For the extraction, aqueous solutions of citric acid (CAE) and methanol (ME) were used. The following were determined in fruit extracts: the content of total phenols (TP) and anthocyanins (A), and antiradical activity (DPPH and ABTS[124].

Acetaminophen (APAP)-induced acute liver failure (ALF) is a serious health problem in developed countries. N-acetyl-L-cysteine (NAC), the current therapy for APAP-induced ALF, is not always effective, and liver transplantation is often needed. *Opuntia spp.* fruits are an important source of nutrients and contain high levels of bioactive compounds, including antioxidants. Rat hepatocyte cultures were exposed to 20mmol/LAPAP, and necrosis was assessed by LDH leakage. *Opuntia robusta* had significantly higher levels of antioxidants than *Opuntia streptacantha*[125]. Wild edible fruits contribute significantly to the nutritional security of mankind across the globe. Bioactive compounds and antioxidant potential of 10 wild edible fruits reveal that *Terminalia chebula*, *Phyllanthus emblica* and *Myrica esculenta* are the richest source of total phenolics; *Pyaracantha crenulata*, *Terminalia hebula* and *Berberis asiatica* for flavonoids; *Phyllanthus emblica*, *Morus alba* and *Ficus palmata* for ascorbic acid, anthocyanins, and Morus alba for β-carotene. Phenolic compounds, i.e. Gallic acid, catechin, chlorogenic acid, caffeic acid and p-coumaric acid varied among species and found the maximum in *Terminalia chebula* and *Phyllanthus emblica*[126].

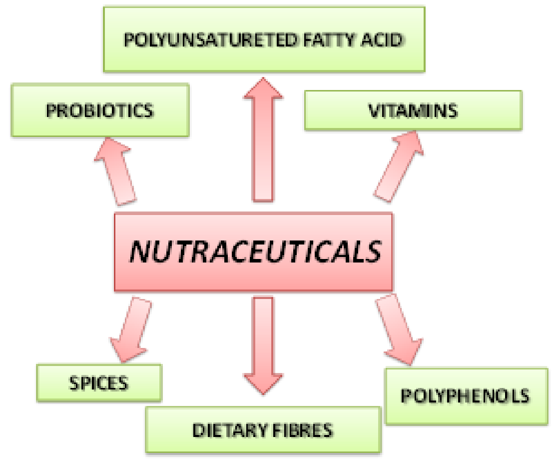

Fig 4: Sources of Neutraceuticals

In this paper the diversity of fruit quality within nine loquat cultivars, including five international affirmed cultivars (Algerie, *Golden Nugget, Peluche, Bueno, El Buenet*) and four local cultivars (*Sanfilippara, Nespolone di Trabia, BRT20 and Claudia*), were investigated in order to discriminate the variation in pomological characteristics, sensory profile, and antioxidant properties.The results of this trial provide useful information on the pomological traits and the not yet known specific nutritional and functional properties of loquat fruits[127].

CONCLUSION

As the mechanisms underlying the beneficial effects of designer and fermented fruit beverages are becoming more visible with accumulating results from clinical and animal studies, fermented fruits are gaining popularity among consumers for their possible therapeutic and high marketing value. To our knowledge, further studies should conducted to design a second generation of functional and fermented fruit based beverages could be: (i) the identification and quantification of promising bioactive compounds, (ii) the standardization of bioactive compounds, (iii) the selection of starters able to produce bioactive compounds, (iv) the application of natural biopreservatives to improve the image of naturalness of the functional beverages, (v) the development and validation of standard methods to enhance and ensure the levels of selected phytochemicals and other biologically active compounds in raw and processed products, (vi) the establishment of proper dosage and delivery systems, (vii) the investigation of bioavailability and metabolism of functional ingredients, (viii) the study of safety aspects related to functional beverage consumption, (ix) the formulation of value added products based on traditional fermented beverages, (x) and finally the examination of regulatory issues. As more studies are published in the future, it would be possible to conduct a meta-analysis that may be helpful in confirming the beneficial effects of fermented fruit beverages and functional foods. The future of functional food and fruit beverages depends on the unequivocal demonstration of their efficacy in promoting health. Thus, a joint venture between food producers and researchers is advisable, as a tool to provide scientific evidence of many health claims.

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