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Utilization of Agro Waste for Beneficial Product Formulation

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ABSTRACT

In the past few years, we have been very familiar with the waste hierarchy concept of the 3 R's, Reduce, Reuse and Recycle. This review article aims to suggest a possible way to reuse the agro-waste sector. It will focus on the zero waste food industry. While consuming our day-to-day food unknowingly we throw away some of the important portions of fruits and vegetables which can help us fight diseases and stay healthy. Therefore, we need proper management to utilize these beneficial components present in those fruit scrapes. An abundant amount of food waste is been produced during the processing of food from the different food industries. In addition to this, agro wastes like peels, seeds, etc. are also generated from fruit and vegetable agriculture. This paper mainly focuses on the agro-waste of the food industry, which can be consumed when the bioactive compound is extracted and is available as a functional food. The bioactive compounds have the potential to control blood pressure, diabetes, inflammation, etc. Thus, by incorporating these bioactive compounds we can enhance the quality of food. Recently functional food is consumed by a large population for its beneficial effect on our body.

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1 Introduction

Agricultural wastes or agro wastes refer to the waste products produced directly from agricultural activities throughout the processing as well as the growing of raw agricultural harvests such as vegetables, flowers, fruits, crops, etc. These agricultural wastes eventually contain various materials that are beneficial to humans. Numerous studies have already revealed that various types of agro-waste like peels, husks, etc. of fruits possess natural antimicrobial properties (Sadh et al. 2018). The increasing practice of agricultural production generated a large number of agricultural crop residues, by-products, etc. In accordance with the increasing farming system in developing countries, the production of agricultural waste is also increasing (Obi et al. 2016). These huge amounts of agricultural wastes and biomass produced from agriculture-based industries were burnt or naturally transformed into organic compost in the previous days (Upadhyay and Harshwardhan 2017).

1.1 Global Scenario of waste generated from Food and By-products

Annually throughout the world, a huge number of by-products and food wastes were generated from food industries and various other sources during food processing, storage, transportation, etc (Helkar et al. 2016). These agro wastes like trimmings, bagasse, peels, stems, shells, bran, seeds, damaged fruits, etc. possess a greater nutritional value in comparison to the actual final product (Torres et al. 2018). Nowadays a significant amount of by-products and wastes are produced as a result of the increasing demand for minimally processed fruits (Torres et al. 2018). These by-products and food wastes contain several valuable components like polysaccharides, fats, proteins, flavor compounds, fibers, phytochemicals, and bioactive composite which are valuable to health (Helkar et al. 2016). Therefore, the initiative has been taken to minimize the costs associated with their disposal and ensure their sustenance in the environment as these residues and by-products have added nutritional value in them (Lima et al. 2018). By proper utilization of these by-products and making functional food ingredients and functional food products, sustainable and stable economic growth of food industries is possible with increment in income (Helkar et al. 2016).

1.2 India's hunger and malnutrition

One of the major causes of malnutrition in India is economic inequality. The diet of people below the poverty line is poor in both quality and quantity. The problem of hunger and malnutrition arises not from the non-availability of food or agro product but unawareness of various agro by-product utilization as well as the inaccessibility of the available food. Therefore, we require alternative nutritional sources to accomplish these nutritional

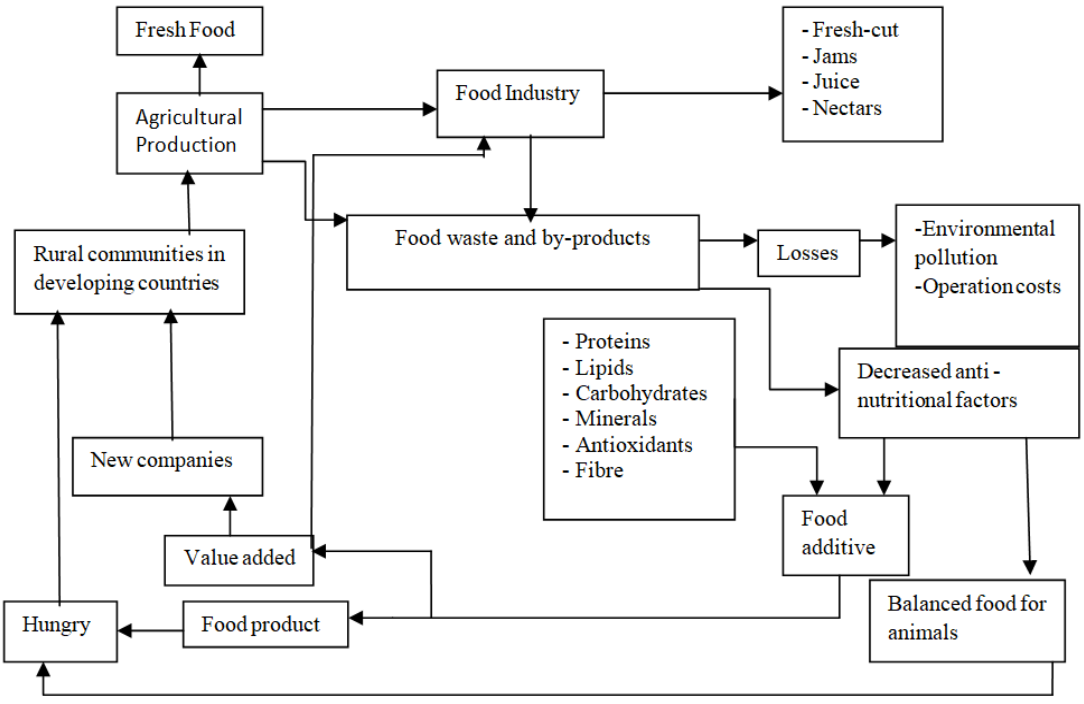

Figure 1 Hypothetical illustration of the utilization of food waste generated by-products which can lead to significant minimization of hunger (Torres et al. 2018).

problems of society. Food wastes and by-products generated from food industries are enriching in proteins, bioactive compounds, lipids, starch, micronutrients, and dietary fibers, etc. In developing countries, a large amount of agro wastes and by-products remain produced (Torres et al. 2018). To mitigate the problem of protein deficiency and associated malnutrition in any developing country (Helkar et al. 2016) like India, it is high time to focus on these agro wastes and turn these huge potential by-products or agro wastes into wealth. During industrial processing of several fruits (eg-pineapple), it has been observed that most of the fruit is discarded as residue. The high quantity of waste produced from fruits and vegetables during their processing as residues are then processed to extract its beneficial components (Sagar et al. 2018). Proper utilization of industrial by-products, which can serve as raw material for the functional food industry, can improve severe health conditions, reduce nutritional problems, can provide an economic advantage to the industry, and can minimize the factors contributing to the mismanagement of waste (Helkar et al. 2016). The conceptual diagram of the utilization of food waste and by-products is represented in Figure 1.

2 Agro waste produced from Industries

Among the numerous sources of agro-waste producers, the food industry plays a pivotal role. Some important fruits and vegetables used in processing in developing countries are tropical and sub-tropical fruits like banana, mango, grape, etc., and vegetable crops tomato, pumpkin, etc.

2.1 Fruit Industry

2.1.1 Banana (*Musa acuminata*)

According to the total production (56.4 million metric tons), banana ranks fourth behind rice, corn, milk. It is used broadly because of its nutritional importance. Banana is cultivated in over 122 countries worldwide (Ehiowemwenguan et al. 2014). In past, there are many studies show that parts of bananas can be utilized to treat various diseases. The agro-waste part of the banana is its peel that has antibacterial activity against microorganisms (Kapadia et al. 2017). The peel and pulp of fully ripe bananas possess antifungal (prevent fungus disease in tomato plants) as well as antibiotic principles (against *Mycobacterium*) (Ehiowemwenguan et al. 2014). Many enzymes like polyphenol oxidase and gelling agent pectin are present in a banana skin. The extract of banana peel is also used individually or in combination in cream or ointment, helping to mitigate pain, itching, and swelling (Chabuck et al. 2013). Dopamine, norepinephrine, serotonin are found in the ripe peel and pulp. Dopamine and norepinephrine help to increase blood pressure whereas serotonin stimulates intestinal smooth muscle (Ehiowemwenguan et al. 2014).

2.1.2 Mango (*Mangifera indica*)

Mango is the most abundant tropical seasonal fruit consumed both in fresh or processed form throughout the world. About 25% of its production is used extensively to make puree, pickles, jam, jelly, juice, etc (Liu et al. 2017). Skins of mango are the most important by-products of mango processing. The by-products of mango have been efficiently utilized. A significant amount of phytochemicals, hemicellulose, cellulose, pectin, protein, lipids, polyphenols, carotenoids, etc. are present in mango waste, therefore they can be used in the production of nutraceuticals as well as a functional food (El-Faham et al. 2016).

2.1.3 Grape (*Vitis vinifera*)

The grape is widely cultivated because of its high nutritional content, good taste, and economically significance in making juice, jam, wine, and raisins (Nile et al. 2013) and for other multipurpose use (Shah et al. 2019). Almost 75% of the production is being used for manufacturing wine. The wine industry generates solid waste like peels, seeds, and stalks which contribute up to 20% of the total biomass (Amorim et al. 2019). The phytochemicals extracted from the juice, seed, skin of grapes are carotenoids, melatonin, phenolics, flavonoids, stilbenes. These phytochemicals have potential antioxidant, anti-apoptotic, anti-inflammatory, anticancer as well as antimicrobial activity. These compounds also possess cardioprotective, hepato-protective effects (Yang and Xiao 2013). Phytochemicals such as tannins, epicatechin, anthocyanins, catechin, flavonols, flavan-3-ols, epigallocatechin, gallocatechins, and epicatechin gallate, proanthocyanidins (typically hexamers), or procyanidins obtained from grapefruit have been reported for their bioactive properties. Acylated procyanidins, an ester of gallic acid was obtained from grape seeds extract (GSE) (Imran et al. 2017)

2.1.4 Pineapple (*Ananas comosus*)

Pineapples are an economically significant fruit worldwide. Large amounts of solid as well as liquid wastes are produced from the pineapple canning industry that causing disposal problems (Li et al. 2014). Researchers have made efforts to process these wastes to minimize the problems associated with disposal and to ensure their sustenance (Lima et al. 2018). The peel waste generated from pineapple cannery can serve as a well off source of various bioactive compounds that bears antioxidant activities (Table 1). Bromelain extracted from fruit, stem, peel of pineapples (Li et al. 2014) is a mixture of various enzymes like endopeptidases, glycoprotein, glycosidase, carbohydrates, cellulases, protease inhibitors (Pavan et al. 2012). The glycoprotein (proteolytic enzyme) is the primary ingredient in crude bromelain, which is present along with other insoluble materials, such as organic acids, minerals, colored pigments, an inhibitor of protease, and organic solvents (Rathnavelu et al. 2016). Due to its various biochemical

Table 1 Antioxidant activity of pineapple

	Water content(% w/w)	Ethanol (% v/v)	Yield (% w/w)	Antioxidant activity(mg.ml-1)	Total Sugar (%w/w)
Fresh PPW	85.5	0	5.16	0.2 ± 0.009	3.69
		15	6.48	0.4 ± 0.004	7.51
		35	6.57	0.4 ± 0.003	7.16
		55	6.94	0.5 ± 0.020	7.40
		75	5.70	0.6 ± 0.040	6.23
		95	4.18	0.6 ± 0.001	5.65
Dried PPW	5.43	0	24.67	0.8 ± 0.050	ND
		15	30.95	1.3 ± 0.090	
		35	28.93	1.2 ± 0.001	
		55	45.38	0.9 ± 0.070	
		75	30.09	0.9 ± 0.070	
		95	30.37	1.2 ± 0.110	

ND= Not determined PPW= Pineapple peel waste (Saraswaty et al. 2013)

Table 2 Nutrient content of pomegranate peel (per 100g)

Composition	Content
Total solid	94.50
Water content	5.40
Entire sugar	17.70
Reducing sugars	4.34
Protein	4.90
Crude fibre	16.30
Fat content	1.26
Ash	3.40

(According to Khan et al. 2017)

and different pharmacological beneficial properties, this is used as a potential therapeutic agent.

2.1.5 Pomegranate (*Punica granatum*)

Pomegranates (*Punica granatum*) have a prominent medical history and possess remarkable medicinal properties (Bassiri-Jahromi 2018). The nutrient content of Pomegranate fruit peel, which is referred as the solid waste produced in a large quantity at the time of processing, is depicted in Table 2 (Fourati et al. 2019). The extracted and isolated bioactive compounds and by-products are rich in antioxidants of the polyphenolic class, which include tannins and flavonoids (Khan et al. 2017). Ellagitannins and anthocyanins are the bioactive compounds, which makes pomegranate an important fruit by protecting against inflammatory diseases and also have radical (free) scavenging activity (Sorrenti et al. 2019), anti-metastatic, anti-proliferative and anti-invasive, anticancer, antiviral effects as reported previously. Approximately every part of the pomegranate including the fruit juice, peel, flowers, arils, bark, phytochemicals has been tested for antimicrobial activities (Bassiri-Jahromi 2018). Pomegranate by-products, punicalagin can inhibit the growth of pathogenic *Escherichia coli*, *Staphylococcus aureus*, *Clostridium perfringens*, *Pseudomonas aeruginosa*, etc. Moreover, a significant increase was found in the population of useful bacteria including *Bifidobacterium* sp. and *Lactobacillus* sp.

2.2 Vegetable agriculture

Biological wastes are abundantly generated in a prominent amount from the agro-food industries as well as from vegetable agriculture.

2.2.1 Corn silk

Corn silk is the agro-waste produced from corn and is used as a medicine. The stigmas of the maize flowers (female) are referred as corn silk. Fresh CS looks like soft silk threads of 10-20 cm in

Table 3 Tocopherol and carotenoid analysis in various parts of pumpkin in *C. pepo* and *C. moschata*

Tocopherol and carotenoid	Part	*C. pepo*	*C. moschata*
α Tocopherol	Peel	4.45 ± 0.75	6.15 ± 2.19
	Flesh	1.40 ± 0.01	1.54 ± 0.99
	Seed	21.33 ± 3.36	25.74 ± 0.73
γ Tocopherol	Peel	0.66 ± 0.09	ND
	Flesh	ND	0.52 ± 0.01
	Seed	61.65 ± 17.66	66.84 ± 4.90
β carotenoid	Peel	39.48 ± 0.24	68.30 ± 2.02
	Flesh	1.48 ± 0.05	5.70 ± 1.50
	Seed	17.46 ± 18.29	7.15 ± 1.50
β cryptoxanthin	Peel	0.15 ± 0.02	0.13 ± 0.03
	Flesh	ND	ND
	Seed	0.16 ± 0.16	ND

ND- Not Determined (According to Rahman et al. 2019)

length and it can be light green or yellow-brown. The main constituents of CS are vitamins, carbohydrates, proteins, minerals (eg.-potassium, calcium), fiber, etc. (Guo et al. 2009). Corn silk tea has the potential to improve health conditions such as reducing edema, decreasing inflammation, improving obesity, lowering blood pressure, and therefore used for the treatment of hypertension (Shi et al. 2019).

2.2.2 Papaya (*Carica papaya*)

Carica papaya is also known as 'papaya' (Roshan et al. 2014) is referred to as the powerhouse of nutrients. Papaya generally requires one year to grow, which has made it an outstanding choice from a socioeconomic viewpoint in countries that produce it (Oliveira and Vitória et al. 2010). Papaya is rich in powerful antioxidants, vitamin B, vitamin E, vitamin C, vitamin A, fibre, magnesium (Aravind et al. 2013). Papaya or papaya seeds is used to treat male fertility. Papaya fruits contain lycopene (Alotaibi et al. 2017). The digestive enzyme-papaintha present in papaya is effective against trauma, allergies, sports injuries. The nutrient content of papaya helps to improve the cardiovascular system and prevent colon cancer (Aravind et al. 2013).

2.2.3 Tomato (*Solanum lycopersicum)*

Tomato (*Solanum lycopersicum*) is a widely eaten vegetable either in fresh or processed form and is included in the family Solanaceae (Isah et al. 2014). Phytonutrients, fibre, vitamin C, A, B complex, and 14 types of carotenoids are mainly present in tomato fruit. The redness of tomatoes is because of the occurrence of lycopene. The carotene present in tomatoes can impart orange coloration. The strong red color in tomatoes is an indication of the presence of a high quantity of lycopene. Several important components like phytoene, lycopene, gamma-carotene, neurosporene and phytofluene are derived from tomatoes. The antioxidant property of lycopene helps to mitigate prostate cancer as well as other cardiovascular diseases (Sidhu et al. 2017; Giovannucci et al. 2002).

2.2.4 Pumpkin (*Cucurbita spp*.)

Pumpkin (*Cucurbita spp*.) is coming from the family *Cucurbitaceae* and is cultivated and consumed throughout the world for its agricultural, commercial, and decorative uses (Amin et al. 2019). The agro-waste i.e., pumpkin seeds discarded at the time of processing has significant nutritional values. They provide an excellent source of protein and the best quality oil having a unique aromatic flavor (Devi et al. 2018). In addition, they are also good sources of minerals, mono-unsaturated fatty acids, dietary fibre, and health-benefiting vitamins. Decreasing sodium intake and consuming adequate potassium is important for treating high blood pressure (Rahman et al. 2019). Pumpkin seeds are generally consumed as a raw, cooked, or roasted form which is enriched with minerals mainly zinc, phosphorous, magnesium, potassium, and selenium. These compounds help the prevention of diseases such as arthritis, cancer, prostate, etc. Therefore, seeds are referred as regarded valuable for the food industry because of their valuable constituents like fibres, protein, minerals, phytosterols, fatty acids (Patel 2013). The antioxidants vitamin E, vitamin C, carotenoids, and tocopherol have therapeutic effects to improve eye health and prevent degenerative damage. The tocopherol and carotenoid content of pumpkin are shown in Table 3. A decrease in risk and progression of age-related macular degeneration has been shown with a higher intake (3 or more servings per day) (Rahman et al. 2019). Different pumpkin extracts containing antioxidant activity helps in the treatment of diabetics, vascular injury, etc. (Yadav et al. 2010).

2.2.5 Oyster Mushroom

During packaging, the ends of the mushroom are left out for cleaner packaging purposes. However, these thrown portions of mushroom contain an equal amount of vitamin D and active compounds as the body of the mushroom. They can be collected for more utilization of the compounds. In recent times, mushrooms are included efficiently in the normal human diet. Therefore, consumption of certain types of species increases. The genus

Pleurotus generally refers to as Oyster mushroom, comprises about 40 different species (Deepalakshmi and Mirunalini 2013). Some bioactive compounds like polysaccharides; polysaccharide-proteins; polysaccharopeptides; functional proteins such as pleuron glycoprotein, nebrodeolysin, ubiquinone-9 ubiquitin-like peptide; proteoglycans and lectin, glucans, etc are extracted from genus Pleurotus (Oloke and Adebayo 2015). Unsaturated fatty acids are present in mushroom fruiting bodies. One of the pivotal components responsible for the dry matter of mushrooms is protein however protein content of the sample can vary (Wani et al. 2010). It has low-fat content in comparison to protein and carbohydrates. It is reported that a small amount of vitamin C is present in mushrooms, the wild variety of mushrooms possess different types of vitamins (Ghosh et al. 2019).

3 Bioactive Compounds present in Food waste and its Disease Management

3.1 Norepinephrine

Norepinephrine, found in the banana peel is a bioactive compound. Noradrenaline (norepinephrine) is a neurotransmitter found in both the central nervous system and peripheral nervous systems i.e., in cell bodies of the pons and medulla (Sagar et al. 2018). The main function of noradrenaline is associated with the fight-or-flight response where the body is ready to react to an emergency. Depletion of norepinephrine resulted in depression, which is contributing to significant potential morbidity, mortality, suicide, medical illness, etc. (Moret and Briley 2011). Noradrenaline belongs to the catecholamine class is derived from phenylalanine and tyrosine. It serves as a drug for blood pressure, regulates flexor muscles, and is distributed in the medulla oblongata as well as in the dorsal vagal nucleus (Terbeck et al. 2016). Recent reviews have explored the role of the noradrenergic system in emotional memory (Tully and Bolshakov 2013).

3.2 Angiotensin

Angiotensin is extracted from corn silk. It is mentioned in folk medicine that corn silk tea is used for anti-hypertensive healthcare. Angiotensin-converting enzyme (AcE) helps to maintain homeostasis of blood pressure (Li et al. 2019). The first angiotensin-converting enzyme (AcE) inhibitor is Captopril; which drug is used widely in different types of cardiovascular (CV) diseases. Losartan was the first angiotensin receptor blocker (ArB). Both ArBs and AcE inhibitors are commonly used in patients with heart disease, hypertension, diabetes, chronic kidney disease, and coronary artery disease (Messerli et al. 2018).

3.3 Proanthocyanidins

From grape skin and seed, a broad class of potential bioactive compound or polymerized polyphenol component named Proanthocyanidin (PC) is isolated. PC is well known for its free radical scavenging activity (Jing et al. 2015) and thereby provides protection against different neurodegenerative diseases as well as cardiovascular diseases like atherosclerosis, restenosis, and heart failure following angioplasty. Oxidative stress is the primary step, due course of time, it develops various vasculopathies, neurodegenerative diseases (epilepsy, Parkinson's disease, Alzheimer's disease), cardiovascular diseases, etc. (Yang et al. 2018). Experimental evidence both in *in-vivo* and *in-vitro* models explored the beneficial antioxidant property of grape seed proanthocyanidins extract (Dixon et al. 2004).

3.4 Carotenoids

Carotenoids is a major bioactive compound of mango enriched with vitamin A. It is a fat-soluble pigment that consists of greater than 700 compounds that are required for the different coloration (red, orange, and yellow). Most carotenoids are chemically hydrocarbons that consist of 40 carbon atoms and two terminal rings (Mezzomo and Ferreira 2016). They are mostly derived from dark green leafy vegetables, colored fruits, etc (Gouado et al. 2007). Carotenoids help in quenching singlet oxygen, removing peroxy radicals, inhibiting cell proliferation, modulating carcinogen metabolism, immune response (Mezzomo and Ferreira 2016). Studies showed that Carotenoids are highly lipophilic molecules and perform as an antioxidant agent by inhibiting the incidence of diverse ROS-mediated disorders by scavenging ROS. By preventing the oxidation of membrane structures Lipoproteins, their major transporter mitigates the mortality (Fiedor and Burda 2014). The chemical structure of Carotenoids reveals functional conjugated double bonds, which are prone to be attacked by electrophilic compounds (Venkateswarlu and Reddy 2014). It is reported that with the increasing uptake of carotenoid-rich food, the risk of occurrence of different types of cancer, atherosclerosis, and other diseases is reduced (Fiedor and Burda 2014).

3.5 Papain

The papain is a natural enzyme (proteolytic) extracted from the latex of papaya's unripe fruits that digest protein and is used as a meat tenderizer, as digestive medicine, in pharmaceutical, tanning, and brewing, and in the manufacturing of chewing gum (Foda et al. 2016). Extensive proteolytic activity is shown towards proteins, polypeptide chains, amino acid esters, etc. Mostly the peptide bonds formed between the basic amino acids (eg. - lysine, arginine, histidine), leucine, glycine are cleaved by Papain (Olmoss 2012). The conditions of acidity for the optimum action of papain are found to be pH 10 (Frankel 1917). The cross-linkages of collagen which give stability to the collagen fibrils are hydrolyzed by Papain and thus they become weaker upon exposure to papain gel. In dental care, dentin papain-based gel is used as a useful bioactive

compound for the removal of chemomechanical dental caries. Sports injuries, allergies, etc can also be cured by using Papain (Olmoss 2012).

3.6 Tocopherol

The methyl-substituted derivatives of tocol are termed as 'Tocopherol'. Tocotrienols with an unsaturated isoprenoid sidechain and tocopherols with a saturated side chain are collectively called as tocols and are found in edible oils (Rizvi et al. 2014). Common salad oil is pumpkin seed oil. It is a rich dietary source of Tocopherol. Tocopherol is a class of organic compounds many of which have vitamin E. Pumpkin seed oil helps in the reduction of prostate size, lowering hypertension and hypercholesterolemia as suggested in some research (Stevenson et al. 2007). A diet rich in pumpkin seeds can lower the levels of different types of cancer. There are also potential health benefits to be gained from the different carotenoids pigments found in pumpkin seed oil (Dar et al. 2017). Cardiovascular functions are found to be improved by gamma tocopherol. The vessel-relaxing nitric oxide generated by the action of the enzyme nitric oxide synthase helps to improve endothelial function. Here tocopherol helps in this process by enhancing the function of nitric oxide synthase (Rizvi et al. 2014). The antioxidant potential of tocopherols plays a significantly important role in the therapeutic effects of pumpkin seed oil. The pumpkin seed oil in roasted form contains higher levels of alpha and gamma-tocopherol as compared to the roasted sunflower oil (Stevenson et al. 2007). Due to its free radical scavenging activity, it helps to reduce mutations, inhibit cancer cell progression by blocking the cell cycle process in different ways (Rizvi et al. 2014). Tocopherols and especially their oxidation product tocopheryl quinone helps in the inhibition of platelet aggregation so can be used as anticoagulants (Brigelius-Flohé et al. 2002).

3.7 Bromelain

Bromelain commercially obtained from the fruit or stem of the pineapple, it belongs to a protein-digesting enzyme that contains different thiol endopeptidases and other different components like peroxidase, escharase, phosphatase, etc. Bromelain possesses antithrombotic, anti-inflammatory activities (Pavan et al. 2012). Pineapple juice uptake helps in the reduction of blood cholesterol (Debnath et al. 2012). Bromelain has comprised of sulfhydryl proteolytic enzymes which have protein-digesting and milk-clotting and coagulating properties (Orsini 2007). Blood coagulation, inflammation, and certain types of the tumor may all be reduced by therapeutic doses of bromelain when taken as a dietary supplement (Joy 2010). It may also help to ease arthritis pain, heal the early stages of an injury, prevent and treat sports injuries, joint aches, tendonitis (Debnath et al. 2012).

3.8 Ellagitannins

Ellagitannins are comprised of a complex class of polyphenols characterized by one or more hexahydroxydiphenoyl (HHDP) moieties esterified with sugar, usually glucose (Klewicka et al. 2016). With over 500 compounds reported, they represent the largest group of tannins. They are easily labilized in solution. Upon hydrolysis with acid and/or base, their hexahydroxydiphenoyl (HHDP) group converted into the gallic acid dimeric derivative, ellagic acid after spontaneous rearrangement (Erukainure et al. 2018). The antimicrobial potential is exhibited by ellagitannins. In an instance, they inhibit the activity of methicillin-resistant *Staphylococcus aureus*. Ellagitannins and ellagic acid inhibit cancers of the mouth, breast, esophagus, etc., and reduce inflammation by reducing the level of pro-inflammatory cytokines IL-6 and increasing IL-10, anti-inflammatory cytokines which can hamper the initiation of carcinogenesis (Lipińska et al. 2014).

3.9 Lycopene

Lycopene is a red-colored predominant carotenoid pigment, phytochemical found in tomatoes and other red fruits that possess potential antioxidant activity (Alda et al. 2009). 2.5 times higher lycopene levels are present in the tomato skin than the pulp and its core. At the time of processing of tomatoes, most of the portion is lost as skin and seeds (Knoblich et al. 2005). Increased lycopene intake promotes the reduction of the incidence of prostate cancer (Elbadrawy and Sello 2011). Lycopene has several different cardiovascular beneficial effects, such as an anti-inflammatory (Mozos et al. 2018), antioxidative, cardioprotective, etc.

3.10 Lovastatin

Lovastatin is clinically useful as a potent anti-hypercholesterolemic agent. It can reduce serum cholesterol levels by inhibiting its synthesis or increasing the number of LDL (low-density lipoprotein) receptors and their catabolism and also slows the progression of atherosclerosis (Hunninghake et al. 1987; Schimmel et al. 1997). Lovastatin treatment had shown to the prevalence in patients with Alzheimer's disease. Upon injection with a high dose of lovastatin, the results revealed that the high dosage stimulated high bone formation both *in-vivo* and *in-vitro*, and also the injection of lovastatin at particular sites heal the femoral fractures and decreased the cortical fracture gap (Radha and Lakshmanan 2013).

4 Production of Functional Food by Utilizing Isolated Bioactive Compounds

All foods are considered as somewhat functional food as they are responsible for the taste, smell, and quality of food. Nowadays lots of experiments are performed to boost their inherent qualities as

Table 4 Functional food currently in the Indian market

Company name	Product description	Base product	Main components	Health claims
Yakult	Probiotic drink	Fermented milk	Skimmed milk, glucose-fructose syrup, live *Lactobacillus casei*	Helps in digestion and build immunity
Amul	Probiotic yogurt and drink	Yogurt	Probiotic yogurt or dahi	Improves intestinal microflora and aid better digestive health
Dabur	Chaywanprash	Jam	Amla, giloy, and more than 40 other natural ingredients	Strengthens body internal defense mechanism
Himalaya	Green tea Tulasi	Tea	Tulasi, black pepper, mint, cardamom, fennel, and ginger	Aids digestion and relieves flatulence
Nestle	Magi vegetable multigrain noodle	Noodle	Ragi, corn, jowar, and wheat	High protein content
Kellogg's	Kellogg's K	Cereal	Wheat, rice, oats, honey	Naturally cholesterol free, 8 essential vitamins, only 2% fat, high vitamin B complex
Britannia	High fibre biscuits	Biscuits	Wholesome wheat	Source of protein and fibre, low-fat food
ITC sun feast	Marie light	Biscuits	Enriched with natural wheat fibre with 0% trans-fat and 0% cholesterol	Low fat and high in fibre and protein
Fortune	Rice bran fortified oil	Oil	Tocopherols	Cholesterol-lowering potential, prevent or delays heart disease, cataracts, macular degeneration, prostate, and other cancer.

Source: Self-created based on a market survey by authors.

they may become helpful in improving some disease conditions (Hasler 2002).

Functional food can be (i) a natural food, (ii) a food with the added component, (iii) a food with the removed component, (iv) a food with modified components, (v) a food in which the bioavailability has been modified or (vi) any combination of these (Henry 2010). The demand for functional food is ever-growing, especially in the Indian market (Table 4) which is determined by concern about healthy diet, lifestyle, and increase in life expectancy and to enhance the quality of life. Hence, health plays an important role in the research according to the behavior of the consumer towards the functional food (Ali and Rahut 2019).

For a long period, we have overlooked the power of peel from fruits and vegetables. Researchers have found that peels, seeds, and other agro waste parts of fruits contain more percentage of bioactive compounds than the fruit. For proper utilization of these compounds, these can be extracted and added in conventional food like juice, puree, jam, tea, etc. to make them functional food and to boost their quality.

4.1 Norepinephrine

The neurotransmitter norepinephrine extracted from banana peel contains minerals, amino acids, proteins, glycoproteins, and antioxidants. During the processing, it is to be kept in mind to retain both natural norepinephrine and epinephrine in the extract as in Green tea. This helps to increase body thermogenesis. Intake of banana in the form of banana pure or the form of extract has health benefits in humans (Medasani 2013).

4.2 Carotenoid

Mango is the most demanded fruit in India and is also known as the king of fruits. Many industries produce jam, jellies, juice, pickles and generate a lot of mango peel waste too. As this fruit is high in carotenoid and antioxidants but the availability is only for a few months, therefore we can extract the bioactive compounds and put them in the products for making it an improved conventional food.

4.3 Angiotensin

Corn skill is a great source of angiotensin. Angiotensin is a bioactive compound, which has proved to treat cardiovascular diseases. Corn skill tea is very popular in hilly areas as it lowers blood pressure. We can transfer this medicinal property of corn skill into regular tea. If corn skill is added in tea bags then we can naturally cure patients with high blood pressure.

4.4 Proanthocyanidins

The wine industry produces a large amount of grape skin and seed waste. The peel of the grape is rich in proanthocyanidins, which is an antioxidant and reduces oxidative stress-associated diseases. If

this bioactive compound can be extracted and yet again be added to the wine, they can produce wines, which are beneficial for health and reduce cardiovascular disorder, neuron disorder. The proanthocyanidins can also be added to tetra-packed grape juice.

4.5 Papain

Papaya jam and papaya sauce are famous around the world for their extensive proteolytic activity. Papain is a bioactive compound, which is found in a large amount in the papaya skin. The enzyme is widely used to cure dental caries, sports injuries, and allergies. If papain is extracted and added in candies, such candies will be healthy for your teeth. Similarly, for quick recovery from sports injuries, sports person can eat candies for relief from pain.

4.6 Tocopherol

Tocopherol is found in pumpkin oil. Pumpkin oil is beneficial for hypertension, hypercholesterolemia, and arthritis. A good source of vitamin E is pumpkin oil. Pumpkin oil can be used as a dressing on salad as it will enhance the taste and is beneficial for health.

4.7 Bromelain

Bromelain extracted from pineapple is used as a medicine for pain, muscle soreness, and many other conditions as it has benefits on health. The pineapple juice and jam industry only used the pulp and the skin and stem is thrown away. The stem of a pineapple is rich in bromelain. If bromelain can be extracted and added to the pineapple jam and juice it will produce a functional refreshment.

4.8 Ellagitannins

Ellagitannins are found in the skin and seeds of pomegranate and possess antimicrobial activity against bacteria, fungus, viruses. The juice industry produces a lot of waste from pomegranate seeds. The solid waste can be used as refreshment pills as they help to fight against bacteria present inside the mouth.

4.9 Lycopene

Lycopene is a form of carotenoid. Tomato peel is rich in lycopene. Industries, which produce tomato sauce, create a lot of tomato peel waste. If lycopene is extracted and added to sauces like tomato, chili, soya, etc. then this sauce will be beneficial for health.

4.10 Lovastatin

Lovastatin is a drug, which is extracted from the oyster mushroom. In mushroom industries, the end of the stem (stipe) of the oyster mushroom is thrown away. The stipe contains enough amount of lovastatin as the cap (pileus) of the mushroom. If the waste can be collected and lovastatin is extracted, we can produce the low-cost drug for high blood pressure and cardiovascular disease.

5 Scenario of India's Population and Hunger

In the year 2015, the United Nations (UN) take the commitment to accomplishing zero hunger by 2030 which is regarded as an important step towards the Sustainable Development Goals (SDGs). This new commitment needs significant implications, demands a wide array of research besides the conventional analysis of energy intake, and takes into consideration all the necessary nutrients for proper nourishment (Ritchie 2018).

The increment in population was negligible before the year 1921 and therefore is considered as the 'Great Divide' in Indian demographic literature. In between 1911-1921, a marked reduction was observed in the population with an average growth rate of 1.2 percent between the years 1921-1951 and 2.2 percent per annum during the 30 years from 1951 to 1981. There was a threefold increase occurred in India's population in the last 90 years. India's estimated total population from 2014 to 2020 is 1,369 million. Due to overpopulation, comes the crises of food and employment. Foodgrain production increased to 174.4 million tonnes in 1991 from the early 50 million tonnes production in 1950-51. Table 5 represents an increase in population growth and grain production since 1961 (Bhagat 2000).

Table 5 Relation between the increase in population growth and grain production (India, 1961-91)

Year	Population (million)	Food production(million tonnes)	Per capita availability per annum (Kg)
1961	439.2	81.3	185
1971	547.9	103.5	188
1981	683.3	130.8	191
1991	844.3	174.7	207
2001	1027	204.5	199

Source: Census of India, 1971, 1981 and 1991.
Centre for Monitoring India's Economy. India's Agricultural Sector: A Compendium of statistics Mumbai. Economic Survey 2001-02 (Bhagat 2000)

Table 6 Benefits of functional foods to serve the malnutrition children

AGE (Year)	FUNCTIONAL FOOD	BIOACTIVE COMPOUNDS	HEALTH BENEFITS	RECOMMENDED AMOUNT OF INTAKE
0.5 – 1	Milk powder (Rich in vitamin A)	Carotenoid	Increases immune response Healthy eyesight	Once daily
0.5 - 1	Milk powder (Banana flavour)	Norepinephrine	Increase motor skills Increases communication skills Healthy neurons	Once daily
1 - 3	Cerelac (Rich in vitamin E)	Tocopherol	Strong bones Good muscle reflex	Twice daily
1 - 3	Custard (Pineapple flavour)	Bromelain	Increase immunity Quick healing effect	Once daily
1 - 3	Custard	Proanthocyanidins	Neural protection	Once daily
3 - 5	Cerelac	Carotenoid Norepinephrine	Healthy eye Increase motor skill	Twice daily
3 - 5	Biscuits	Tocopherol Lycopene	Increase motor skill Increase immune system	Twice daily

Source: Self-created based on a market survey by authors.

6 Hypothesis to Serve Malnutritional Children

An adequate, nutritious, and balanced diet is vital (Mishra 2012) to mitigate the problem of malnutrition. India right now has self-sufficient food grains. Therefore, there is no problem with limiting the food supply. The problem is due to the food sequestration as well as lack of proper provisioning. Sustainable food security demands (i) sufficient food availability, (ii) adequate resources, (iii) proper utilization of the available foods, adequate water, and good sanitation (Kumar and Kumar 2013). Yet a large number of children suffer from malnutrition. The relative price of food stuffs has remained unchanged over the past 20 years (Saxena 2018).

India has a population of 1.11 million contributing around 17 percent of the world's population. Due to this large population size hunger, malnutrition and food insecurity are evident in India (Acharya 2009). The higher child malnutrition rate in India is contributed by many factors. First, Indian women's nutrition, inappropriate feeding, and rearing practices for young children due to their low social status, the practice of marriage at an early age, low weight of females at the time of pregnancy, and poor education. Underweight women give birth to babies having low birth weight. They are more prone to malnutrition due to inappropriate caring, low social status, poor quality of consumed food, unhygienic lifestyle, bad medical facilities, and difficulty in obtaining food (Saxena 2018). Our hypothesis is to serve the malnutrition children between 6 months to 5 years shown in Table 6, by providing the bioactive compounds in baby food at a cost-effective price. As we can see, the mother is not well nourished so she cannot serve the baby. If our functional baby food can reach every door of nursing mothers then we can lower the amount of hunger in India.

7 Discussions and Conclusion

From various industrial activities, a lot of agro-waste and by-products are generated. For example, during the processing of raw agricultural products, residues or agro wastes are produced. The accumulation of these discarded agro wastes can lead to environmental pollution, which ultimately affects human health. However, by utilizing proper food industrial waste management techniques like "3 R", these wastes can be converted into useful ones. The by-products produced from agro-industries or food industries are considered as a good source of proteins, minerals, amino acids, and bioactive compounds, etc. In an instance, Norepinephrine extracted from the banana peel, carotenoid isolated from mango peel waste, angiotensin comes from corn silk, the drug lovastatin extracted from the waste part oyster mushroom, etc. are some important bioactive compounds that have antimicrobial, antioxidant, anti-carcinogenic, cardio-protective, etc. potential. Therefore, these agro wastes can serve as a raw material for the development of functional foods. By utilizing these by-products efficiently from the food industry, it helps to decrease the negative cost along with the reduction of the amount of environmental wastes and can directly affect the economy of the country. Proper utilization of industrial by-products is needed in developing counties like India to reduce the problem of hunger and malnutrition by increasing the availability of functional food. This can create a zero-waste food industry in the future.

Abbreviation

GSE - Grape Seeds Extract, CS - Corn Silk, PC – Proanthocyanidin, ND - Not Determined, PPW - Pineapple Peel Waste, AcE - Angiotensin-converting Enzyme, ArB - Angiotensin receptor Blocker, TNF - Tumour Necrosis Factor, HHDP – Hexahydroxydiphenoyl, ROS – Reactive Oxygen Species

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