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Agro-industrial waste as source of bioactive compounds and their utilization: A review

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Abstract

Processing of horticultural goods produces a large amount of waste. Huge waste and losses in the food and processing industries are facing economic losses and environmental problems. Agro-industries byproducts can serve as important raw material for development of value added food products. The byproducts from fruits and vegetables can be used as unconventional alternate feed for animals which have best source of digestible nutrients and fulfill the gaps between demand and supply of feedstuffs. It is also used as food additives for formulation of nutraceuticals, pharmaceutical and other functional food. Other agricultural byproducts from cereals and plantation crops are can be utilized as organic residues and processing byproducts for valorization of waste by converting it into most useful products. The use of bioactive compounds extracted from by-products are an important step towards sustainable development. In order to produce value-added products, the use of these low-cost horticultural waste is a novel step in sustainable development.

Keywords: Fruit and vegetable, waste, processing, phenolic compound, fiber

Introduction

The food processing industry, including the processing of fruits and vegetables industry, is the second-largest producer of environmental waste after household sewage treatment systems. Agriculture is still a major source of income in developing countries and from the beginning of the production stage to the end of the consumption area, approximately 1.3 billion tonnes of food grains are destroyed or wasted every year (FAO 2011) [16].

There is a tendency to find new sources of active ingredients, such as plant-based products made from the expected food underestimated (Rodríguez *et al.* 2006) [38]. The obtained by-products are important sources of sugar, minerals, organic fiber, dietary fiber, and phenols, which have a wide range of effects, including antiviral, antibacterial, cardio-protective, and antimicrobial activities (Jasna *et al.*, 2009) [26]. Products made during the processing of fruits and vegetables alone account for 25-30% of losses of horticultural products (Sagar *et al.*, 2018) [39]. By-products of fruit and vegetable industry are reported to have a significant amount of dietary fiber (Andrade, Ferreira, & Gonçalves, 2016; Gouw, Jung, & Zhao, 2017) [5, 21] and phytochemical components (Amaya-Cruz *et al.*, 2015) [4], (Gonçalves *et al.*, 2018) [20].

Cereals is important source protein and carbohydrates, where it also rich in health beneficial components such as dietary fibers, vitamins, minerals, polyphenols, polysterols, etc. The major cereal producing states in India are Rajasthan, Karnataka, Andhra Pradesh, Maharashtra, Uttar Pradesh, Madhya Pradesh, Tamilnadu, Bihar, Gujarat, and Haryana (MOSPI 2020). Cereal processing depends on its area of utilization and targeted application. The wastage generate during cereal processing is majorly effect on the farmer loss, food industry loss and certain environmental problems (Campos, Dave, & Veragara, 2020) [10]. Similarly plantation crops and its byproducts have export prospective and also have significant internal demand in most of industries. The byproduct of plantation crop industries could be used as food ingredients, pharmaceutical, cosmetic and functional component in value added product (panak balentic *et al.*, 2018) [35]. Outer covering is major byproduct produced from various types of plantation crop such as cocoa, coconut, coffee, etc.

Agro processing industry generates large amounts of wastes rich in biologically active compounds. Because they have an impact on the environment and require management or utilization, this problem has become a serious problem. This review highlights the production, waste generation and waste utilization of agricultural crops such as fruits, vegetables, cereal crops and plantation crops.

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Fruits and vegetables processing

Fruits and vegetables are rich in phytochemicals and research has been conducted to extract phenolic compounds, dietary fibers, and bioactive compounds (Galanakis 2012) [19]. Bioactive chemicals that have therapeutic potential can affect energy consumption while reducing pro-inflammatory states, stress, as oxidative well as physical disorders (Siriwardhana *et al.*, 2013)[43]. Epidemiologic studies show that the basic consumption of foods rich in bioactive chemicals has antioxidant activities, including vitamins, phytochemicals, and especially phenolic compounds, like flavonoids and carotenoids, have a positive effect on human health and can reduce the risk of many diseases, such as cancer, heart disease, stroke, Alzheimer's diabetes, cataracts, age-related functional decadence (Hassimotto, Genovese, & Lajolo, 2009) [23], (Siriwardhana *et al.*, 2013) [43].

Waste generation from Fruit and vegetable processing

Fruits and vegetables have the highest wastage rate, part of the harvest is spent every year ((FAO, 2011) [16]. According to the latest statistics, the fruit industry contributes more than 500 million tonnes of waste worldwide (Banerjee *et al.*, 2017) [7].

Phenolic compound from fruit waste:

Peels and seeds of fruits and vegetables contain lots of phenolic compounds (Friedman *et al.*, 1997) [18]. Flavan-3-ols is the largest group of phenolics found on a banana peel (Rebello *et al.*, 2014) [37], Stojkovic (2016) [46] reported significant amount of Chlorogenic acid, Epicatechin and Phloridzin in apple peel. Similarly pineapple peel were found to have numerous polyphenolics such as gallic acid (31.76 mg/100 g dry extracts), catechin (58.51 mg/100 g), epicatechin (50.00 mg/100 g), and ferulic acid (19.50 mg/100 g), respectively (Chengmei *et al.*, 2014) [12]. According to Hamedi, Mohebbi, Shahidi, and Azarpazhooh, 2018) [36] pomegranate peel contains a lot of phenolic substances, including flavonoids (anthocyanins, catechins, and other complex flavonoids) and hydrolyzable tannins (punicalin, pedunculagin, punicalagin, gallic acid, and ellagic acid). Other phytochemicals identified from pomegranate are organic acids and phenolic acids. Papaya seed and peel were reported to have numerous phenolic compounds viz. p-hydroxybenzoic acid, protocatechuic acid hexoside, gallic acid-deoxyhexoside, protocatechuic acid, chlorogenic acid, caffeic acid, caffeoyl hexose-deoxyhexoside, rutin, ferulic acid, p-coumaric acid, kaempferol-3-O glucoside, and myricetin (Hasim Kelebek *et al.*, 2014) [22]. Similarly Carlos-Eduardo *et al.* (2020) [20] have reported availability of vanillic acid in guava seed.

Phenolic compound from vegetable waste:

The chemical content of phenolic varies greatly between skin and pulp. Tomato peel contains a high concentration of polyphenols and ascorbic acid (Valdez-Morales *et al.*, 2014) [47]. Mirjana *et al.* (2010) [30] reported presence of numerous phenolic compounds are tyrosol, vanillic acid, caffeic acid, coumaric acid, and a small amount of trans-cinnamic acid in pumpkin seed oil. Munir *et al.* (2018) [33] has reported dried onion skin as a good source of phenolic compounds. Kallel *et al.* (2014) [28] reported garlic skin as a good source of phenolic compounds such as caffeic, p-coumaric, ferulic, and di-ferulic acids, respectively. Carrot peel contained in Phenolic compound mainly hydroxycinnamic acids and derivatives such as chlorogenic acid, caffeic acid, 3'-caffeoylquinic acid, 4'-p-coumaroylquinic acid, 3', 4'-dicafeoylquinic acid, 3',5'-

dicafeoylquinic acid (Zhang and Hamauzu, 2004) [50]. The seeds and peel of cucumber (*Cucumis sativus* L.) are used in folk medicine as antidiarrheal, detoxification, anti-gonorrhoea, anti-inflammatory, antihypertensive, diabetes and blood lipid regulator, antioxidant, and analgesic (Abu-Reidah, *et al.*, 2012) [1].

Cereal crops processing

The average global production of cereals per year is about 3200 million tons of grains and the major cultivated cereal crops are wheat, maize, rice, sorghum, barley, oats, rye and millets (FAOSTAT 2018) [17]. In India, agricultural crops such as cereals, pulses and legumes plays major role in growth of economy. It is cultivated worldwide in larger quantity because of its economical importance and main staple food as a source of energy in diet.

Cereal processing and waste generation

Cereal grains are converted into most desirable food ingredient by specific process with enhanced flavor, texture, appearance, color and its shelf life. Different processing's of grain used in food industry includes milling, malting, pearling, fermentation, heat processing, extrusion and puffing (Slavin *et al.*, 2010) [44]. Processing of grains with different processing method generates large quantity of byproduct such as bran, germ, hull, husk, fiber and other unwanted parts of crop. All cereals are preferred for consumption after milling therefore the wastage of cereal crops are mostly produced from milling industries. Bran is major byproduct which separates from grain endosperm during milling. It is coarse outer shell of seed with small amount of flour and rich in high fiber and protein content. Germ is another important byproduct produces during wet milling of corn and sorghum where it is primary substance remains with protein rich gluten (Elmekawy *et al.*, 2013) [15]. Various types of cereals shows similar structural morphology in which bran made up outer part of grains and its composition was depends on grain type, shape, size, thickness of pericarp, kernel size, maturity, duration of grain storage, condition of grain storage and machinery used for milling (Alan *et al.*, 2012; Zitterman 2003) [3, 51]. Three year production of major cereal crops in India and their approximate waste generation in percentage.

Utilization of Waste from Cereal processing

Source of bioactive compounds

Cereals and pulses are major source of energy and protein for nourishment of our body. The processing of this grains produce high volume of byproducts includes bran, germ, husk and meal which are rich source of bioactive compounds such as phenolic compounds, carotenoids, phytosterol, saponins, etc. These bioactive compounds are associated with different types of health benefits for human health. Recovering of the bioactive compounds from these byproducts and used as functional component in value added product the utilization of cereal and pulses processing waste (Saini A. *et al.*, 2019) [40].

Energy production

Agricultural crops production is an important source of national income for most of the developing nations. After harvesting of these crops the residues are left, which is often just burn as waste (Manas puri, 2018) [29]. Harvesting and processing of different crops generate large amount of waste which commonly known as biomass and it can be good source of energy or it can be converted into useful products. Crop

waste or residue contain potential source of carbon, nitrogen, potassium, phosphorus, and some mineral which can be further used for production of bioenergy, especially blending of biofuels with conventional fuels for prevent the over-exploitation of fossil fuel and natural energy sources. The biomass of crop residues used for mainly methane production and also used for biofuel such as bioethanol (Sharma *et al.*, 2018) [42]. The dry cereals based waste from rice, wheat and maize raw material are potentially used for production of biofuel such as maize starch are main raw material for ethanol production. Starch and cellulose are biomass generated from agro-industrial byproduct which major raw material for bio-hydrogen production and this biohydrogen is used as fuel for production of electricity through fuel cell (Elmekawy *et al.*, 2013) [15].

Animal feed

Cereal crop residues are valuable source mainly used for animal feeding. Livestock mainly ruminants are mostly depends on biomass than other animals (Wilkinson, 2010) [49]. Cereal processing byproducts are such as bran, germ, husk are greater source of fiber content, minerals, vitamins, polyphenols, polysterol and low in protein, starch and fat. The various types of cereal byproducts can be fed to animal without any process or modification. Rice bran, wheat bran, corn husk and other crops residues are major byproducts generates on harvesting and processing which fulfill nutrient requirements of animals. It will be helps to minimize the cost of feeding and make higher profits to farmer (Wadhwa and Bakshi 2013) [48]. Wheat and rice bran is major alternative feed source for poultry production. Rice husk may be used as source of fiber in animal and poultry feed as food additives (Bodie *et al.*, 2019) [9]. Utilization of agro-industrial cereal crop waste for animal feedstuff can help to saving money by reducing waste discharge, cost of cut waste-management and it also important for prevent pollution of environment. Utilization of cereal crops byproducts for animal feedstuff will serve as a sound basis for most of continued technological progress and management of animal farming (Ajila *et al.*, 2012) [2].

Compost and fertilizer

Instead of burning cereal crop waste or residues it can be used as manure, where high quality manure is produced by composting as organic fertilizer. It will improve the soil fertility as well as reduce the waste which can prevent the environmental pollution. Chemical fertilizers are responsible for spoiling of the soil health but composting will enhance the fertility status of soil along with better yield. Compost manure manufacturing process is inexpensive as compare to chemical fertilizer (Mishra *et al.*, 2017) [31].

Plantation crops processing and waste generation

Plantation crops are those which are high commercial value and cultivated in extensive scale and it plays important role in agricultural economy. Numbers of plantation crops are grown in India in which major crops are cashew, cocoa, coffee, coconut, oil palm, rubber, tea, etc. The export of plantation crop accounts around 27% of total agricultural produces and 4.8% of total exported commodity. Cultivation of plantation crop generates considerable employment on the farm level, in industries as well as off farming activities (Chopra *et al.*, 2016) [13].

Utilization of waste from plantation crop

Spices processing waste utilization

Spices industry produces around 80-90% of residues as waste after processing. These waste materials are not properly utilized for commercial use and application which causes adverse effect on environment (Sowbhagya, 2019) [45]. The spent residues from processing of different spices such as chilli, cumin, coriander, and pepper are excellent source of dietary fibers which can be inexpensive functional ingredient in various value added products. The mustard meal or its residue can be used for prevent the soil born pathogen and prevent nematodes. Other spices waste can utilized as organic fertilizer and pesticides in agriculture (Sowbhagya, 2019) [45]. The functional ingredients from spices byproduct are used in bakery products or functional food formulation.

Cocoa and coffee processing waste utilization

Cocoa processing in chocolate industries produces large amount of cocoa shell as a value added byproduct. Cocoa shell is source of protein, dietary fibers and also enriched with bioactive compounds (Jayola *et al.*, 2018) [27]. Cocoa shell can utilized for making animal feed which provide better nourishment to poultry birds, goat, cattle and other animals. It can also utilize in agriculture as fertilizer, can be used as alternative source of fuel, used as adsorbent, and used as dye and other applications (Panak Balentić *et al.*, 2018) [35]. The waste from coffee processing is another important byproduct in which coffee pulp is produced during wet processing of coffee. Coffee pulp and coffee husk is source of nutrient such as nitrogen, phosphorus and potassium therefore it mainly used in organic fertilizer (Iriundo-DeHond *et al.*, 2019) [25]. Coffee byproducts can utilized for development of animal feed, functional food, biogas, caffeine, pectin, peptic enzyme, and compost for agriculture (Padmapriya *et al.*, 2013) [34].

Areca nut and cashew nut processing waste utilization

During processing of areca nut, various byproducts are obtain such as husk, fiber, sheath, etc which gives more economic returns to areca nut farmers and processors by utilizing it for formation of value added product. Areca nut husk can used as organic matter for making vermi-compost and it gives better recovery in period of three month. Areca nut sheath is used for animal feed or other household application (Annamalai *et al.*, 2017) [6]. Cashew apple is major byproduct of cashew nut processing industries can be utilized for various sustainable application. It rich source of different functional compound which can further use in formulation of value added products (Jayeola *et al.*, 2018) [27]. Cashew apple juice is more nutritious than cashew nut which contains carbohydrates, dietary fibers, vitamin, minerals and many bioactive compounds (Das and Arora, 2017) [14]. It can be utilized for animal feed production, bioethanol production, formulation of probiotic product and development of many more value added products (Barve *et al.*, 2020) [8].

Coconut and sugarcane processing waste utilization

Coconut processing is mainly occurred for extraction of coconut oil. Number of value added byproducts are generating during coconut oil extraction which includes coconut water, coconut shell, coconut husk, etc. (Sangamithra *et al.*, 2013) [41]. Coconut water is potential source of nutrients usually used as beverage for hydration. Coconut shell are utilized as primary ingredient in plywood industry for

manufacturing of glue, it is also used as fuel for household cooking, ironing and a better replaced for bunker oil in boiler operations (Montenegro, 1985) [32]. Sugarcane industry produces byproduct which can be utilized for economical benefits. Bagasses are utilized as fiber rich animal feed after treating bagasse with molasses by fermentation. Press mud is byproduct obtain after juice extraction which can be used as organic fertilizer (Iqbal *et al.*, 2015) [24].

Conclusion

Food processing industries are disposing their waste or byproducts in landfill which create pollution and it is hazardous to environment as well as human health. Agro-industries generate various types of waste in which includes peel, pomace, pulp, bran, germ, etc. and they are rich source of dietary fiber, vitamin, minerals and bioactive compounds. The agro-industrial byproducts are inexpensive source of bioactive compounds and functional compounds which can improve nutritional quality of food. The massive waste of fruit and vegetable, and their ingredients not only causes the loss of edible food, but also waste products, including the organic matters that have huge potential industry benefits and various uses. It is necessary to use novel technology. These should be used to extract the highest levels of bio-active compounds and other compounds of economic value from vegetable and fruit. The use of food processing waste in the production of high-value products has increased the profitability of the food processing industry by reducing the cost of disposal of these products waste and losses.

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