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Abhilash Narayandas
Assistant Professor, Department of Food Technology, JNTU, College of Engineering, Kalikiri, Andhra Pradesh, India

M Sardar Baig
Professor and Head, Department of Food Processing Technology, Dr. NTR College of Food Science and Technology, Acharya NG Ranga Agricultural University, Bapatla, Guntur District, Andhra Pradesh, India

D Gayatri
Assistant Professor, Department of Food Technology, Rajiv Gandhi Degree College, Rajahmundry, Andhra Pradesh, India

M Penchalaraju
PhD, Research Scholar, Department of Food Science and Technology, Pondicherry University, Pondicherry, India

Corresponding Author:
M Penchalaraju
PhD, Research Scholar, Department of Food Science and Technology, Pondicherry University, Pondicherry, India

Valorisation of organic and inorganic waste and by-products from the agricultural food processing industry

Abhilash Narayandas, M Sardar Baig, D Gayatri and M Penchalaraju

Abstract
Waste valorization is a process of reusing, recycling, composting the waste materials and converting them into more useful products. Food waste and by-products, which are normally regarded as not valuable, have great potential for valuable compounds production. Valorisation of these materials means more nutrients or bioactive compounds and addresses environmental issues caused by discarding these "waste" materials. In this paper, the nutritive and economic potential of food waste and by-products and the application of innovative technologies in food waste and by-products valorisation were reviewed. Such technologies improve the perspectives regarding waste utilisation, paving sustainable industrial development, one of the basic pillars for public health.

Keywords: Valorisation, agricultural food, organic and inorganic waste

Introduction
Waste valorisation is a process of reusing, recycling, composting the waste materials and converting them into more useful products. Many waste material and by-products are generating from different food processing industries such as sugar cane industry, fruit processing industry, coffee processing industry, meat industry, fish processing, dairy industry, and oil processing industry. The processing of fruits results in the production of by-products that are rich sources of bioactive compounds, including phenolic compounds. The interest in natural phenolic antioxidants has been raised by suggesting that many of these compounds display antimutagenic, antimicrobial, chemopreventive, antitumour, anti-inflammatory, and apoptotic, neuroprotective, antisickling, anthelmintic, and many other activities. Thus, utilising fruit wastes as sources of bioactive compounds may be of considerable economic benefits and become increasingly attractive. The orange juice industry by-product was used to obtain a high dietary fibre powder that will be used as wall material for encapsulation (Kaderides & Goula, 2017) [6].

Valorisation of waste and by-products from sugar cane industry
Bagasse is a by-product from the sugar cane industry and can prepare pulp, paper, board, feed and ethanol. Molasses is a thick syrup, sugar refinery waste, generated during the sugar making process. Molasses can be used in mixed animal feed, and in the baking and confectionery industry, used in the production of vinegar, citric acid, and other products. Food processing industry in most countries across the world generates a huge quantity of by-products, including pomace, hull, husk, pods, peel, shells, seeds, stems, stalks, bran, pulp refuse, press cakes etc., which have limited use and create considerable environmental pollution. Drying of plant waste is necessary before further exploitation because it is prone to microbial spoilage (Vidyarthi *et al*., 2020) [12].

As a continuous process with high versatility and productivity, extrusion offers a good avenue to incorporate different types of by-products in ready-to-eat snacks and breakfast cereals. Also, incorporating these by-products can improve the nutritional value of extruded products that are otherwise carbohydrate-rich, high glycaemic products, and often consumed by children.

The cost of drying, storage, and transport poses additional economic limitations to waste utilization, and therefore agro industrial waste often is utilized as feed or fertilizer. However, in this way, many valuable nutrients contained in agro-industrial wastes are lost. Therefore, the use of these by-products has become a growing trend in the food industry. One of the motives is to increase the nutritional value of the new product, and another is utilising nutritionally valuable raw materials, thus reducing the total waste. By-products of plant food processing, which are rich in fibre and bioactive compounds, have attracted much attention for their functionality and potential as cheap and valuable food ingredients in recent years, confirmed by numerous investigations (Ačkar *et al*., 2018) [1].

Valorisation of fisheries by-products

Global fisheries production has increased to ~200 MT with aquatic by-products of 20 MT that are a challenge for the fish processing industry and environmental management. Scope and approach: Aquatic by-products are the potential source and treasure house of many healthy and biologically active compounds, which have significant potential to supply new and valuable food ingredients. However, the diversity of available raw materials and the post-harvest stage of materials challenge the scientific community to determine how to use best this resource (Nawaz *et al*., 2020) [8].

According to a 2018 report of Food and Agriculture Organization (FAO), over 20 MT of fisheries by-products (head, skin, fins, bone, red meat, viscera, trimmings and scale) are being generated. Numerous efforts have been developed to use these by-products in the feed, food packaging, fish silage, fertiliser, bio-fuels and to recover more for use as human food. The use of various by-products in human foods is still challenging concerning safety issues and their interactions with other ingredients in foods. Previous studies have revealed the significance of fish by-products (15–30% crude protein, 0–25% fat, and 50–80% moisture) regarding their nutritional value and functional properties.

Collagen can be isolated from fish by-products such as skin, fins, bones and scales. Pang *et al*. (2013) isolated and purified the collagen from skins, scales, fins and bones from various sources with yields was 71, 13, 40 and 13%, respectively. Similarly, Mahbood, (2015) extracted the collagen from fisheries by-products of *Catla catla* and *Cirrhinus mrigala* especially fins and characterised the molecular weight distribution, amino acid composition (glycine (Gly) and alanine (Ala) were the most abundant amino acids) and crude protein content (18–25%).

Redfish meat is also a by-product from fish processing and good sources of protein, can be used for animal feed, preparation of fish protein isolates, and it can be used as a cryoprotectant to reduce the denaturation of proteins during processing and storage and can be used as a supplement in pasta (Nawaz *et al*., 2020) [8].

Generally, fish processing waste as by-products is divided into two types, such as organic waste and inorganic waste. Organic waste is skin, viscera, fish meat (red and white), and a part of the scales, bones, and fins. These organic waste are used as sources for isolation and purification of collagen and gelatine. This collagen and gelatine have a wide range of applications in food processing industries as food additives. An inorganic waste generated from fish processing industry is bones as cooked bones and uncooked bones. This inorganic waste is used for the preparation of bone powder which can be used for bone powder is high in calcium mainly in the form of hydroxyapatite (HA) and calcium carbonate (Kang, Heu, & Kim, 2006) [7].

Table 1: Functional ingredients from fisheries by-products and their potential health benefits

Functional ingredients isolated from fish waste	Fish by-products	Functional property/Health benefits
Omega-3 oils	Salmon and Cod liver oil	Prevention of cardiovascular diseases and brain function in children
Carotenoids	Astaxanthin, Fucoxanthin	Neurodegenerative disease
Vitamins and Minerals	Marine fish	Growth and physiology of the body
Cartilage calcium	Fishbone	Anti-Carcinogenic agent, teeth and bone strength and antitumor agent
Bioactive peptides	Fish protein	Obesity control and Ca-binding activity
Fish protein isolate	Fish muscle, redfish meat	Protein supplement
Taurine	Cod, mackerel	Prevent cardiovascular disease, Alzheimer's disease and Cystic fibrosis
Minerals	Fishbone	Growth and metabolism
Collagen and gelatin	Fishbone, scales, fins	Anti-ageing agent

By-products from other food processing industries

The widespread use of superabsorbent materials (SAMs) in several applications (e.g. personal care hygienic, agricultural, among others) results in a serious pollution issue, due to the considerable amount of disposable materials produced that finally are thrown onto the environment. Furthermore, it is noteworthy that industrial superabsorbent materials are commonly produced from expensive, toxic and non-renewable acrylic compounds with a low degradability rate. Consequently, several studies have been focused on the development of SAMs from exclusively biodegradable sources, such as proteins and polysaccharides. The superabsorbent materials (SAMs) are used in various applications such as for personal care hygienic, agricultural and others and causes the pollution issues, and these SAMs were commonly produced from toxic, non-renewable expensive substances so, that the researches were focussed on the extraction of SAMs from natural biodegradable sources such as proteins and polysaccharides (Álvarez-Castillo *et al*., 2020) [2].

Soya protein is also obtained from wastes of soy oil processing industry, and soya protein is rich sources of glycine, aspartic acid and glutamic acid. Porcelain plasma is obtained from centrifugation of blood from the meat industry, and it can be used as a gelling agent in meat sausages and meat products such as surimi and frankfurters (Álvarez-Castillo *et al*., 2020) [2].

Coffee processing industry

The coffee residues, husk, pulp, skin, coffee wastewater, coffee silver skin, mucilage residues are the waste and by-products from coffee processing industry. These by-products are used for production of bioactive compounds, organic acids, mushrooms, Single cell proteins and other pharmaceutical applications.

Fruit and vegetable processing industry

A large amount of underutilised waste and by-products, which includes peels, skins, seeds, molasses and bagasse were generated from fruit and vegetable processing industry.

Cassava bagasse is a by-product from the production of cassava starch and cassava flour (Manihot esculenta Crantz) and contains fibre material as well as the residual starch not completely extracted during the processing. The industry of orange juice produces as by-product orange bagasse that corresponds to around 50% of the total fruit while in the case of passion fruit, around 40–60% of the total fruit mass ends up as residue consisting of peel and seeds. These by-products can be used for animal feed (low-valued product), but mostly they are simply disposed of in the environment without any type of treatment and are considered an environmental hazard. Some of the citrus peel is used for pectin production (high-valued product), but the market demand for pectin is low compared to the amount of pectin that could be produced from the worldwide supply of citrus by-product. This challenges the food industry to identify ways for better utilisation of these materials aiming the strengthening of a sustainable food system. The use of food by-products contributes to a sustainable food system, decreasing the impact that their disposal on the environment. Different by-products, such as chicory root pulp and apple pulp, are rich in fibre, including pectin.

For cassava bagasse, it was revealed that most of the remaining starch in these by-products was digestible starch. In this case, cassava bagasse can be used as a source of energy and maybe applicable as a substitute to cassava flour, contributing to reduce the amount of waste material. This could have a positive impact mainly for small farmers/ producers, which would increase their income or improve their nutritional status. Fibre isolation (AIS) might be an alternative procedure for further utilisation of cassava bagasse as a food product/ingredient source of fibre. Their characterisation showed a significantly higher concentration of pectin and (hemi) cellulose than the raw by-product. Orange bagasse analyses demonstrated that both samples were very similar in their chemical structure. They were rich in small sugars and pectin. Pectin characterisation showed that HG was predominant in their structure, and they were highly methyl esterified. Characterisation of passion fruit peels showed that they are good sources of fibres, especially pectin and (hemi) cellulose. Regarding pectins, our results suggest that pectins from cassava bagasse, orange bagasse and passion fruit peel are diverse not only in their amount but also in their chemical structure. Here we have demonstrated that the degree of methylation and acetylation vary according to the by-product, as well as the proportion of HG and RG in their structure (Bussolo de Souza *et al*., 2018) [4].

Conclusion
The reuse and recycling of waste material and convert into more valuable products in terms of nutritional value and functional properties of by-products generated from the food processing industry is a challenge for food business operators. This paper as described the different waste material and its sources and reuse, recycling methods to increase the value as from fruit processing, fish processing, coffee processing, oil processing, meat industry, sugar cane industry.

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