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Development of Nutraceutical Products from Dietary Fibers Extracted by the Food Industrial Wastes

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Abstract

The food business is currently growing in researching and producing nutraceutical commodities. Due to customer interest in "healthy" foods, these products gather steam in the food industry. As a result, the biopharmaceutical and food sectors are working to extract natural bioactive. These can be utilized as nutraceutical components, therapeutics, and ingredients in the formulation of food supplements. The significance of food bioactive components has prompted the advancement of an enormous and expected market for fiber rich products.

Dietary fiber comprises noncellulosic polysaccharides, including hemicellulose, pectic compounds, mucilage, lignin, gums, cellulose and a non-carbohydrate constituent resistant enzymatic digestion. Fiber rich foods, such as fruits, nuts, cereals vegetables, are good for health since they have been associated with a decreased risk of various ailments.

Consequently, supplementation of dietary fiber waste has been adopted to improve the fiber content of food sources. This review presents the research findings on diverse food process by products for use as or extraction of nutritional, functional, and novel fiber and its application in a wide range of food products. Efficient by product use substantially influences the national economy and the environment. Therefore, appropriate waste management is essential for the food industry's growth.

Keywords: By products/wastes; Dietary fibers; Nutraceutical; Fruits; Vegetables; Cereals; Nutrition; Dietary fiber waste; Functional foods; Food waste

Introduction

"According to the Food and Agriculture Organization (FAO)" and the literature, around forty percent of fresh vegetables are lost during harvesting and pre retail, and over fifty percent after retail, demanding economical and long term benefits [1]. Fruit and vegetable portions that are edible and inedible are eliminated from the food supply (crops, low deposit, indigenous, hospitableness) [2]. Damage to fruits and foods also occurs during transport, stockpiling, and production, resulting in waste [3]. The numerous types of food waste produced are carcasses, rawhides, feathers, heads, hoofs, internal organs, offal, fat meat pieces, blood, and compost. Wastes from the seafood industry include oils, skins, and bones. The dairy processing industry wastes include milk sludge, whey, casein, and curd from the separation process. In addition, shell brans, seeds, stem peelings after oil extraction, and starch are vegetable derived processing food wastes [4]. When dumped into the environment, these food sector wastes are detrimental to the environment due to their relatively biological instability, poor oxidative stability, optimal enzymatic reactions, increased concentrations of organic matter, high nutritional quality, and increased water reactivity. The bulk of organic waste is disposed of in landfills, with just a low percentage used as livestock feed or fertilizer. The large volume of food waste and the microbial decomposition of these wastes, which raises the costs of the food service industry, may pose a threat to the ecosystem and human and animal health. Furthermore, untreated waste contributes to the "carbon footprint" of vegetables and fruits and the rise in global temperatures [5].

Macro and micronutrients extracted from the food industry as by products can be utilized to formulate nutraceutical supplements and food additives. Dr. Stephen de Felice" introduced the term "nutraceutical" in 1989, merging "nutrition" with "pharmaceutical", and described it as a food that serves as therapeutic and wellbeing advantages, such as disease prevention and treatments. On the other hand, a nutraceutical is defined by health Canada as "a product derived from foods but offered in the form of capsules, powders, or other therapeutic forms not typically associated with foods". It can include supplements, isolated nutrients, nutritional diets, herbal products, genetically modified foods, and processed meals, including soups, drinks, and cereals. Nutraceuticals encompass most therapeutic sites, including anti-arthritic, cough, sleeping problems, cold, digestion, and the prevention of some

malignancies, diabetes, osteoarthritis, hypertension, stress, and cholesterol regulation.

The worldwide nutraceuticals market was worth $413.0 billion in 2020. It is expected to grow to $650.5 billion by 2030, with a CAGR of 3.9 percent between 2021 and 2030. In terms of nutraceuticals market share, the functional food category led in 2020, but functional beverages are predicted to increase fastest during the forecast period as shown in Figure 1. The food industry is already dominated by functional foods, with a CAGR of 7.1 percent from 2015 to 2021. The primary divisions of the global nutraceuticals markets are product category and geography. Geographically, the worldwide nutraceuticals economy is divided into four parts. “North America includes the United States, Mexico, and Canada. Europe includes the United Kingdom, France, and Italy. Asia-Pacific includes China, Japan, India, and other countries. South America, the Middle East, and Africa are all included in the rest of the world”. Bioactive constituents such as phenolic, phytochemicals, and micronutrients are abundant throughout fruits and vegetables tissue. Sometimes the discarded wastes from fruits and vegetables contain antimicrobial and antioxidant contents similar to or even higher than the final product [6].

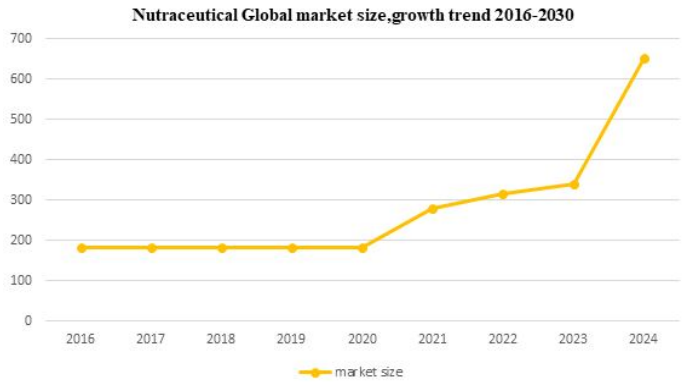

Figure 1: Global increasing market size of nutraceutical products from 2016-2030.

These natural bioactive constituents are currently researched for their potential to prevent and treat severe diseases. These components interact efficiently with the DNA, proteins, and other biological elements to reach optimal effects. Such components may subsequently be utilized to formulate natural medicinal drugs. As a result, consumers are becoming more interested in food bioactive, which positively impacts an individual's health and promotes disease risk mitigation. It has been observed that by products of the fruit and vegetable industries contain a large quantity of dietary fiber [7].

Dietary fiber has a lengthy history, with hipsley coining the word as a non-digestible component of the plant cell wall. There have been various modifications to the definition lately. Botanists define dietary fiber as chemical analyzers that work as part of the plant organs and a consumer component with chemical ingredients that have a favorable impact on human health, dietetics, and nutrition. According to Trowell, et al., "Dietary fiber consists of residues of plant cells resistant to hydrolysis (digestion) by the alimentary enzymes of man”. The constituents of dietary fibers include hemicelluloses, cellulose, waxes, gums, lignin, pectin’s and oligosaccharides.

“The American Association of Cereal Chemists (AACC)” described dietary fiber in 2000 as comestible plant components or carbohydrates that are resistant to digestion and absorption in the small intestines and ferment completely or moderately in the large bowel. Oligosaccharides, lignin, polysaccharides, and other plant components make up dietary fiber. Current dietary fiber consumption guidelines are based on gender, age, and energy intake, with the overall recommendation for an Adequate Intake (AI) being 14 grams per 1000 calories. The recommended daily dietary fiber intake for adult women is 28 g/day and 36 g/day, based on the caloric guidelines of 2000 kcal/day for women and 2600 kcal/day for men. Non-starch polysaccharides, similar carbohydrates (e.g., resistant starches), lignin, and related compounds are included in this AI.

This review summarizes the scientific data from multiple industrial food byproducts for usage or isolation of nutritional, functional, or innovative fiber and its application in various functional products. The bulk of study data and assessments on the utilization of various growing crops as functional food ingredients and the health consequences of dietary fibers are available. However, little is known about food production byproducts as a source of nutrition or functional fiber, their characteristics, and their potential for use in producing other health promoting functional products. Thus, research on fiber rich food industry byproducts, possible applications, and public health has been conducted.

Industrial significance

This study proposes an alternate use for food enterprises' 'waste' that may help them functionally and financially in the long term. Polysaccharides, vitamins, minerals, dietary fiber, and bioactivities are present in many nutritious food wastes. By-products enhanced foods' gelling, thickening, water retention, and binding capacity. Industrial and scientific advancements may improve results and the development of nutraceutical food products, increasing their revenue and ensuring the food industries' sustainable and steady economic growth.

Literature Review

Multiple academic sources contribute to the design of the literature review. The literature review's research design is depicted in Figure 2.

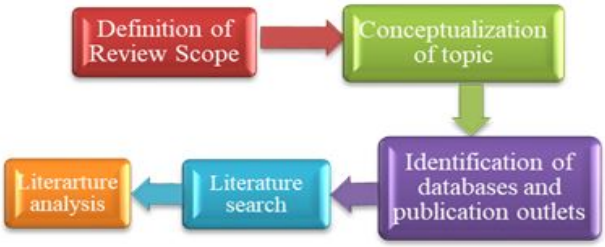

Figure 2: The research design for literature review.

Search strategy

This paper conducted more studies on dietary fibers derived from plant residues and their use in nutraceutical products. The databases were used to find the studies evaluated during the investigation [8]. We sought to find many phrases and synonyms for each of the keywords listed in Table 1 that had credible links.

Table 1: Overview of keywords and publication outlets.

Keywords	Waste/by products, waste as dietary fibers, vegetable/fruit residues/by products/wastes from fruits, dietary fiber, classification, composition, physico-chemical, fruit juices processing, nutrition, nutraceutical, functional foods.
Databases	Google Scholar, Research gate, BMC, NCBI, MDPI, PubMed, and Escholar
Date of publication	Recent (last six years)

Inclusion selection of the study

Two primary criteria were used to select the studies: Discussing the issue of interest and their quality. Finally, the produced articles were chosen manually by looking at the titles and then reading the abstracts published in high impact factor journals. The selected articles were based on the science of dietary fibers, their nutraceutical and functional properties, health benefits, and industrial waste utilization. Articles that did not pertain to the area of research were excluded throughout this procedure.

Following the assessment, the included papers were submitted for literary analysis. The transparency, perspective with which the data findings and conclusions were acquired, and the coherence of the articles were used to evaluate their quality. Finally, the studied data were retrieved and categorized based on the topics of interest.

Exclusion criteria of the study

Articles not related to the research topic, including abstracts, were excluded. Articles not written in the study's native context (English) were also eliminated. Articles that focused on the correlation between dietary fibers and pathologies were omitted. No thesis or dissertation was referenced [9].

Constituents of dietary fibers

Fiber acquired from plants (dietary fiber) and fiber added to food (functional/novel fiber) may be viewed as a total of the dietary fiber received from both sources. Each of these classifications might have a microbiological base for its existence. Non-carbohydrate and carbohydrate fibers are the two forms of plant based fibers available as can be seen in Figure 3. Lignin based cellulose and non-cellulose are the two types of carbohydrates found in nature. Cellulose is a polysaccharide comprised mostly of glucose.

In contrast, hemicelluloses are formed of pentoses and hexoses that are often linked together by methyl uronic acid. On the other hand, hemicelluloses have a lower degree of polymerization than cellulose [10]. As a result, hemicelluloses are less fibrous and more alkaline soluble than fibrous cellulose.

Another method of defining dietary fibers is how well they dissolve in water. Soluble (cellulose) dietary fibers offer fewer calories than hemicellulose. Cellulose and lignin based dietary fibers, which are both soluble (cellulose) (pectin, b-glucans, galactomannans, fructans, oligosaccharides, some guar, hemicelluloses, gums, and mucilage). Insoluble dietary fiber ferments in the colon at a slower rate than soluble dietary fiber [11]. Soluble dietary fibers are rich in oats, psyllium seeds, and flaxseed, but insoluble dietary fibers are found in whole grains and vegetables. Fibers produced from animals or microorganisms, such as chitin, yeast beta-glucan, xanthan gum, and others, may be used. Weight management necessitates the consumption of both insoluble and soluble fibers.

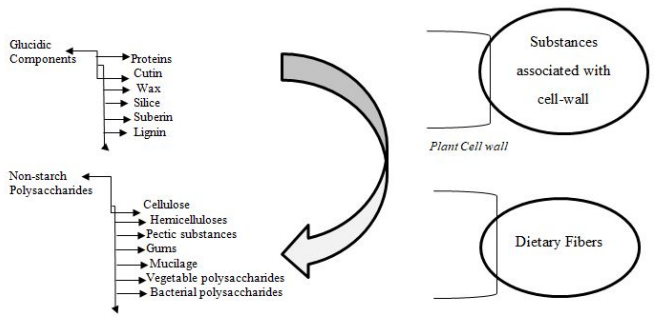

Figure 3: Composition of dietary fibers and associated substances.

Sources of dietary fiber

Cereal based dietary fibers: Dietary fibers are reported from various sources due to the diversity of studies in the field. These are categorized as soluble dietary fibers or dietary insoluble fibers based on the water solubility of the dietary fiber. Cereal grains are a good source of dietary fiber and are most often consumed as staple foods. These sources are wheat, sorghum, corn, barley, maize, oats, and rye. Soluble dietary fiber is abundant in barley and oats, where it is found mainly in the form of glucan in the endosperm and husk portions [12]. These two sources have been found to have high levels of SDF (4%–12%).

In contrast, insoluble dietary fiber from oat bran, maize bran, and wheat bran has a lower potential to ferment in the large intestine. Wheat bran and soybeans have high dietary fiber

content, ranging from 777 g/kg–810 g/kg of total dietary fiber. Brown rice is high in insoluble dietary fiber, with more than 14% insoluble fiber content.

Plant based dietary fibers: Another form of dietary fiber that resists digestion in the small intestine is resistant starch, which is mainly found in legumes. Around 35% of the starch is found in legumes. Dietary fiber is also found in plant based gum products. For example, the guara bean, derived from guar gum, is a resourceful gum substance. Gums include tragacanth, tara gum, xanthan gum, and other sources. These gums have an 800 g/kg–1000 g/kg. In addition, soluble fibers (such as glucan from guar gum, pectin, and gum Arabic) are particularly suited for fecal bacteria in the large intestine.

Fruits based dietary fibers: Fruits waste may be used to recover nutritional fiber from these sources. A significant amount of waste produced by apple and pear juice factories might be utilized in culinary applications. Apple pomace also has considerable fiber in SDF (10.3 percent–16.4 percent). Hemicellulose and cellulose, as well as lignin and pectin, make up the majority of these components [13]. They have a tremendous water-holding capacity when utilized in culinary goods. They may be used in baked goods, cereals, granola bars, meatballs, and dairy and confectionary items. Several studies examined the functional properties of spray dried apple fiber and discovered that it was nutritionally equivalent to wheat and oat bran when used in bread, cookies, and muffins. Similar results were obtained from tests on dietary fiber extracted from kiwi and pear waste processed in ultrafiltration units at kiwi and pear puree production facilities. The pear pomace had 43.9 percent dietary fiber, whereas the kiwi pomace included 25.7 percent.

Pectin predominates as a soluble dietary fiber source in various commodities. Dried figs are an excellent source of micronutrients. Dried figs provide 4.6 g of dietary fiber per two figs, making them a healthy source of fiber.

Utilization of DF in the fruit juice industry: In the juice processing business, the peel and pulp of oranges and grapefruits are the principal sources of dietary fiber. Along with specific uronic acid units, the alcohol insoluble components of these wastes may be separated into alkali and acid SDF, which may be a valuable source of nutritional cellulosic fiber. Citrus fruits are the most significant global category of fruit crops, with an estimated 88 million tons produced globally, only a third of which is processed. In 98% of industrialized crops, tangerine, oranges, limes, lemons, and mandarins fall into this group.

The citrus business generates residues such as pulp, bark, and seedlings. Albedo, or the inner section of the mesocarp, and flavedo make up the shell. Albedo refers to the whitish, gelatinous, and cellulose tissue that makes up the majority of the shells used to extract nutritional fibers. Dietary fiber derived from citrus pomace has a high water holding capacity and a characteristic viscosity. Commercial juicing provides a large amount of revenue to the food industry. Peels and trimmings are among the residues. Polyphenols are abundant in pineapple peel. This powdered drink's dry mix comprised nutritious fiber from peels, citric acid, sugars, a foaming agent, color, and flavor. Peel and pulp are similarly high in dietary fiber.

Waste from peach juice extraction comprises between 31% and 36% of the required daily fiber intake on a dry weight basis. There is more insoluble dietary fiber, but the soluble fiber content is smaller than in cereals. Therefore, it is feasible to use fibrous material with a high water holding capacity in baked foods, extruded items, and dietetic beverages.

By product production in a mango processing facility might range between 40% and 60%. Soluble dietary fiber and insoluble dietary fiber yields are almost comparable. Due to its shear thinning properties and decreased starch digestion, SDF is generated from mango waste. Another source of dietary fiber is the pomace left over after grape juice production, which provides over 77% of the dietary fiber present in juice (on a dry weight basis). The material mainly comprises pectin, hemicellulose, and SDF.

Date flesh and seed have an equal amount of dietary fiber. Therefore, the coarsely ground component of dates may be used to provide dietary fiber to a wide variety of culinary products [14]. It is worth noting that when Saudi date seed fiber is added to baking goods, the organoleptic properties of the control bread result remain the same. Watermelon is the world's second largest fruit crop, and it produces much bio waste, especially rind and seeds, which are a hazard to the environment. Watermelon skin contains citrulline, a non-protein amino acid, pectin, and a polysaccharide. They possess antioxidants and vasodilator properties. Additionally, phenolic compounds are found in greater abundance in the peel of a watermelon than in the flesh Watermelon seeds are high in linoleic acid and low in oleic, palmitic, and stearic acids and minerals (P,K,Na, and Mg).

Vegetables based dietary fibers

Broccoli, a *Brassica* vegetable, is globally popular due to its he alth advantages. Harvesting broccoli yields many byproducts, most edible, with a 60% and 75% waste rate. Broccoli stalks include a variety of pectin sources, phenolic compounds, glucose, mannitol, other polysaccharides, free amino acids, and glucosinolates. *Brassica* vegetables, such as cauliflower, have a high concentration of naturally occurring antioxidants. In addition, the rich glucosinolates in this plant are suspected of having anticancer properties.

Cauliflower leaves and stems include carbohydrates, protein, fat, lipids, and glucosinolates. Cauliflower leaves are an excellent source of nutritious fiber and minerals. Potatoes are the fourth most common crop worldwide in terms of consumption, and they constitute an integral element of the human diet.

Potato peels are a low cost source of significant bioactive compounds, such as secondary metabolites and cell wall components that may be used to enhance the functionality of meals or to substitute for synthetic additives. Potato peels account for around 10% of overall potato waste. Potato peels are rich in glycoalkaloids such as solanine, polysaccharides, quercetin, and rutin. It also contains phenolic compounds such as ferrulic, gallic, p-coumaric, caffeine, and chlorogenic

acids. The most abundant aglycones in the peels of purple and red potato varieties were peonidin, malvidin, and pelargonidin.

The pumpkin (Cucurbitaceae) is a significant source of minerals, including carotenoids. In addition, pumpkin seeds are rich in oil and contain various beneficial compounds [15]. Pumpkin seed oil is high in protein and fatty acids such as stearic, oleic, palmitic, and linoleic acids. However, these fatty acids accumulate in various pumpkin varieties. The most often identified proteins in pumpkin seeds are cucurbitin, albumin, glutelin, and prolamin. Additionally, other nutrients in pumpkin seeds, such as tocopherol, magnesium, and zinc, are abundant in the kernels. Pumpkin peel extracts may be used in bioactive pigments and regenerative skin treatments.

Discussion

Application/utilization of dietary fiber from food waste into functional products

When dietary fibers are incorporated into formulations, it is frequently required to change other constituents, such as hydration, which may need to be increased. In addition, the incorporation of the fibers results in a granular mouth feel, which may result in organoleptic restrictions. Although smaller particle size fibers can address these concerns, they adversely influence other functional characteristics. Insoluble dietary fibers have a variety of applications, including baked foods, meat items, candies, sauces, drinks, and yogurts. Thus, they act as bulking agents and minimize the calorie content [16].

However, it is essential to focus on health. Increased fiber provides nutritional benefits. Due to its propensity to retain water and fat, fiber may increase the yield of cooked meat products (e.g., sausages). Fiber use minimizes cooking fat and water loss while increasing the end product's texture. Researchers have observed that both pure cellulose and microcrystalline cellulose improved the surface of the pork and decreased cooking losses and diameter changes throughout the cooking process. According to these studies, fibers may be utilized to manage the flow of oil and water [17]. A fiber batter may reduce fat retention and boost moisture content after frying (l percent-3 percent).

Numerous studies have been conducted on the capacity of cereal fibers (wheat bran, oat, barley, maize), fruit fibers (citrus, apple), vegetable fibers (pea, sugar beet), and cellulose powders to increase the insoluble fiber content of baked foods. While some flour or fat is substituted with fibers for their nutritional benefit (lower calorie, higher fiber content), some unpurified fiber elements are also employed to flavor or color the product, such as apple pomace. In addition, their water retention, improved fermentability, and textural characteristics are also utilized to determine how they affect the volume of pastes and cakes and the preservation of bread.

Wheat bran and cellulose were substituted for flour in cookies to bake them firmer. To preserve the hardness and texture of baked items, fibrous substances (fruit, sugar beet, wheat bran, cellulose, or potato peel) may be substituted for part of the flour. Adding cellulose to cakes boosted their volume and improved their texture. Due to their texture modifying and freeze thaw stabilizing properties, dietary fibers such as cellulose may be used in surimi or other textured foods. In addition, dietary fiber filaments are nutritionally and technically important in formulating snacks, extruded products and tortillas because they improve stability and yield while decreasing drying time. Additionally, breakfast cereals (extruded or flakes), fruit products, and yogurt increase the Total Dietary Fiber (TDF) content [18].

Dietary fibers may be used in sauces and soups due to their ability to improve the flow characteristics and prevent the formation of lumps in powdered mixes due to their water retention and texture (such as ready to eat sauces, blends of spices, or flavoring agents). Additionally, they may be used in dietary beverages, meal replacements, sports beverages, and morning beverages.

The bioactive components polyphenols and ascorbic acid and the high quantity of dietary fiber make nopal or opuntia a functional food. The prebiotic nature is attributed to a large amount of insoluble and soluble fibers and arabinoxylans found in mucilage, which influence the gut microbiota.

Wet grinding is another process for extracting fibers, wherein the cabbage is pre-crushed with a miller, and the water utilized has a pressure of 4.8 bars. The puree is bleached with citric acid at 1.2 percent concentration and homogenized. Manual wet sieving with distilled water was then performed. The fiber concentration is achieved by freezing and fractionating the resulting paste under pressure. To acquire nutritional fiber, red cabbage has been dried using various methods, including solar drying, hot air oven drying, and freeze drying [19]. According to the findings, the maximum proportion of fibers was extracted from sun dried, baked, and lyophilized cabbage.

Isolated fiber constituents such as resistant starch and b-glucans are also employed to boost fiber content in baked goods, and cereal. In the case of drinks and beverages, dietary fibers enhance viscosity and stability, with soluble fibers being the most commonly utilized since it is more water dispersible than insoluble fibers. These soluble fibers include those derived from grain fractions and multi fruits.

Soluble fibers such as lignocellulosic materials, inulin, guar gum, xanthan gum, and carboxymethyl cellulose are used as functional additives in dairy products. During cheese production, pectin, guar gum, and inulin are added to reduce the percent fat without compromising organoleptic characteristics such as flavor and texture; on the other hand, the addition of dietary fiber to yogurts and ice creams increases the stability of these emulsions. The most frequently added fibers used in marmalade and jams are pectins with varying degrees of esterification, which are derived chiefly from fruits and have a role in the stability of final products. In addition, fiber molecules such as inulin and oligofructose are utilized as sugar substitutes in low calorie confectionery and derivative products.

Functions and benefits of dietary fiber on human health

Dietary habits high in fiber, and rich in cereal crops, vegetables, and fruits are beneficial for the human body because they have been linked to a decreased prevalence of several diseases due to potential benefits such as increasing human fecal, decreasing gastric motility, lowering cholesterol and high glycemic load, and sequestrating substances (carcinogenic/mutagenic) that can be hazardous to the human body. Dietary fiber consumption is linked to a decreased risk of coronary heart disease, peripheral vascular disease, strokes, and a significant risk of diabetes, hypertension, obesity, and CVD. A higher DF consumption has also been linked to reducing serum cholesterol and blood pressure [20]. It also appears to promote immune system function through promoting digestive health and interacting with the microbiome (Table 2).

Table 2: Functions and benefits of dietary fiber on human health.

Functions	Benefits
Increases food consumption, resulting in a shorter time to fullness.	As a consequence, consumption may be lowered.
It forms a gel like material that acts as a reservoir for water when digested.	Blood sugar level variability is minimized.
Carbohydrate intake and a decrease in the rate of glucose absorption.	
Reduces total and LDL cholesterol levels.	Cardiovascular disease is a less probable occurrence.
A hypotensive agent.	This supplement may help alleviate metabolic syndrome and diabetes symptoms and risks.
Accelerates the pace of food digestion.	Regularity is facilitated.
Increased stool/faeces volume.	It may help relieve constipation.
Promotes bacterial fermentation by maintaining a steady pH level in the intestines.	The risk of colorectal cancer may be decreased.
Synthesis of short chain fatty acids.	

Conclusion

Food waste from the food industry is vital since it may be utilized as a raw material to produce functional and nutraceutical products. There has been a constant rise in the demand for innovative functional foods because of their disease curing properties. Utilizing waste for dietary fiber rich components can improve various foods operational and nutritional qualities due to their diverse composition and capabilities. However, because of the enhanced hydration and connection of the fibers with other dietary components, it is frequently required to alter the formulation and processing of fiber enriched meals. According to the food and drug administration, food industry by products will also open up new opportunities in the food and pharmaceutical sector. It will be possible to reduce negative expenses of environmental pollution, extend sustainability in the food industry, and positively impact the country's economy by effectively using by products from the food industry. Therefore, the food industry must take a more active role in promoting a zero waste society.

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Data Availability Statement

Data is already available in the manuscript.

Ethical Approval

Ethical approval is not required.

Ethical Consent

Not required.

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