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Potential use of food wastes in functional foods: A review of microbial safety studies

Gıda atıklarının fonksiyonel gıdalarda potansiyel kullanımı: mikrobiyal güvenlik çalışmalarının bir derlemesi

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Abstract

This review aims to provide an overview of the potential use of food waste in the production of functional foods, focusing on the microbiological safety of food waste. Food is an essential human need, but food waste has become a significant global issue. Effective management, treatment, and recovery of food waste is key to address this challenge. There is now considerable interest in recycling and upgrading food waste. A variety of methods have been developed to effectively control and use these wastes, including the extraction of bioactive compounds from the waste for reintroduction into the food chain. In this context, the study reviewed recent research identified through the keywords "food waste," "functional food," and "food safety." This review examines the role of food waste in functional food development, highlighting both its advantages and the microbiological risks. The findings highlight that food waste from many food industries is considered a cheap source of functional or bioactive compounds. Sugars, proteins, lipids, fibers, vitamins, minerals, and pigments are the main value-added products derived from fruit and vegetable waste. Animal waste contains bioactive peptides from meat and dairy products. The aforementioned ingredients can be transformed into nutraceuticals and functional foods by reintroducing them into the food chain as natural food additives. The review concludes that these natural compounds have the potential to enhance the safety and palatability of foods, while simultaneously addressing any underlying nutritional deficiencies. However, the reintroduction of food wastes into the food chain or food matrices requires a comprehensive evaluation of the optimal recycling and manufacturing practices to ascertain their suitability and safety. Although many food wastes are valorized, few studies have focused on microbiological safety assessments, an important concern that must be addressed to ensure the safety of food products.

Özet

Bu derleme, fonksiyonel gıdaların üretiminde gıda atıklarının potansiyel kullanımına genel bir bakış sunmayı amaçlamakta ve özellikle gıda atıklarının mikrobiyolojik güvenliğine odaklanmaktadır. Gıda, insan yaşamı için temel bir ihtiyaçtır; ancak gıda israfı günümüzde önemli bir küresel sorun haline gelmiştir. Bu sorunun çözümünde gıda atıklarının etkili yönetimi, işlenmesi ve geri kazanımı büyük önem taşımaktadır. Gıda atıklarının geri dönüştürülmesi ve değerlendirilmesine yönelik ilgi son yıllarda artmıştır. Bu atıkların kontrol altına alınması ve yeniden kullanılması için çeşitli yöntemler geliştirilmiştir; bunlar arasında, gıda zincirine yeniden kazandırılmak üzere atıklardan biyoaktif bileşiklerin ekstraksiyonu yer almaktadır. Bu bağlamda, çalışmada "gıda atığı", "fonksiyonel gıda" ve "gıda güvenilirliği" anahtar kelimeleri kullanılarak yapılan güncel araştırmalar gözden geçirilmiştir. Bu derleme, fonksiyonel gıda geliştirilmesinde gıda atıklarının rolünü incelemekte, avantajlarını ve mikrobiyolojik risklerini ortaya koymaktadır.

Elde edilen bulgular, birçok gıda endüstrisinden kaynaklanan atıkların, fonksiyonel ya da biyoaktif bileşiklerin ucuz bir kaynağı olarak değerlendirildiğini göstermektedir. Meyve ve sebze atıklarından elde edilen şekerler, proteinler, lipidler, lifler, vitaminler, mineraller ve pigmentler, başlıca katma değerli ürünler arasında yer almaktadır. Hayvansal atıklar ise et ve süt ürünlerinden elde edilen biyoaktif peptitleri içermektedir. Bu bileşenler, doğal gıda katkı maddeleri olarak gıda zincirine yeniden kazandırılarak nutrasötik ve fonksiyonel gıdalara dönüştürülebilir. Derlemede, bu doğal bileşiklerin, gıdaların güvenilirliğini ve tat kabul edilebilirliğini artırma potansiyeline sahip olduğu, aynı zamanda besin eksikliklerini giderme konusunda da katkı sağlayabileceği belirtilmektedir. Bununla birlikte, gıda atıklarının gıda zincirine veya gıda matrislerine yeniden kazandırılması sürecinde, bu bileşenlerin uygunluğu ve güvenliği açısından optimum geri dönüşüm ve üretim uygulamalarının kapsamlı bir şekilde değerlendirilmesi gerekmektedir. Birçok gıda atığının değerlendirilmesine rağmen, mikrobiyolojik güvenlik değerlendirmelerine odaklanan çalışmalar sınırlıdır. Bu durum, gıda ürünlerinin güvenilirliğinin sağlanması açısından ele alınması gereken önemli bir konudur.

INTRODUCTİON

Recently, people have become more concerned about food safety and sustainability. Factors contributing to this situation include population growth, climate change, water scarcity, farmer distress, and food waste. It is estimated that by 2050, the global population will reach 9 billion, necessitating an increase in food production to meet the demands of this growing population. Furthermore, it is estimated that the global food demand will be 60% higher than it is today. Successful resolution of this challenge will ensure the sustainability of food.

A review of the literature revealed that approximately one-third of all food is lost or wasted as a consequence of various unsustainable practices (1). The terms "food waste" and "food loss" are often used interchangeably, but the concepts are different (2, 3). The term "food loss" refers to the reduction in the quantity or quality of food that can be attributed to the decisions and actions of food suppliers along the supply chain before reaching the consumer. Conversely, food waste refers to the reduction in the quantity or quality of food resulting from the decisions and actions of consumers, retailers, and food services (4). From the initial production stage to the final stage of consumption, over 58 million tons of food waste are generated annually (2), with an estimated market value of 132 billion euros (5). In relation to specific food types, roots, tubers, and oleaginous crops exhibited the highest incidence of losses, amounting to 25% from the post-harvest stage to the distribution stage. Subsequently, fruit and vegetables (30%), meat and animal products (12%), and cereals and pulses (9%) were identified as the most affected food types (6, 7).

The reduction of food loss and waste represents a pivotal strategy for enhancing the efficacy of food system, reducing production costs, and advancing environmental sustainability (8). The conventional method for addressing food waste is incineration or disposal in landfills. However, the incineration or disposal of food waste can result in contamination of the air, water, and soil, as well as of food. In light of these considerations, the European Union (EU) is encouraging a reduction in food waste and exploring novel applications of using food wastes to address these issues, apart from the aforementioned applications. In this context, various techniques have been employed for the efficient utilisation of waste. Such methods include the extraction of essential nutrients from waste, its use as an additive in functional food production, and its use as a raw material for fermentation.

Recent studies have demonstrated that food waste derived from a range of food sectors, including vegetables, fruits, drinks, meat, aquaculture, and marine foods, represents an interesting and potentially cost-effective source of useful or bioactive substances for functional food production (9). The utilisation of bioactive chemicals recovered from food supply chain wastes as new products or raw materials through sustainable extraction technologies will have a beneficial impact on human health, thereby stimulating the development of new value-added companies. Conversely, the reintroduction of recovered food waste biocompounds presents some challenges, including safety, biological instability and the potential for contamination by pathogens or toxins. Consequently, these substances must be regarded as novel foods and undergo safety assessments that may differ according to the existing legislation in other countries concerning the use of food waste (10). The aim of this review is to provide an overview of the potential of food waste in the production of functional foods, with a particular focus on their microbiological safety. This study also examined whether microbial safety assessments have been conducted on these bioactive compounds during their reintroduction into the food chain.

METHOD

In this paper, a literature review was conducted using the following keywords: food waste, functional foods, and food safety. The objective of this study was to examine the literature on the use of food waste in functional food production, with a particular emphasis on microbial safety considerations.

Food Wastes

The Food and Agriculture Organization (FAO) (4) stated that food waste is increasing at similar rates in both developed and developing countries. Products made from food waste have high market potential because they are inexpensive, abundant, and easily accessible. Additionally, food waste contains health-promoting substances, further enhancing the market value of waste-derived products. Fig. 1 presents the food waste types.

Potential Use of Food Wastes in Functional Food Production

Fruit and vegetables wastes

The consumption of fruits and vegetables contributes to the maintanence of nutritional well-being. In this context, fruit and vegetable production has increased in response to population growth and shifts in dietary patterns. The most commonly produced fruits are apples, bananas, citrus fruits, grapes, melons, and pears. The most commonly produced vegetables are brassicas, cucumbers, cabbages, cauliflower, garlic, tomatoes, onions, carrots, and turnips (11). However, most vegetables and fruits are lost or wasted during the post-harvest period due to their susceptibility to microbiological degradation. A significant amount of waste is produced following the extraction of juice or the production of value-added products such as jams, jellies, and marmalades. The majority of this waste is in the form of pomace, a mixture of pulp, peel, seeds, and stalks, which often have a higher concentration of bioactive chemicals than the actual fruit juice. Conversely, the industrial processing of common crops such as potatoes, tomatoes, and carrots results, in the generation of considerable quantities of waste (12). Table 1 presents examples of the fruit and vegetable wastes.

As previously stated, by-products or wastes from fruits and vegetables can be used as innovative ingredients or food fortifiers because of their high bioactive content. To extract bioactive components, traditional extraction methods use chemicals or solvents with the objective of lysing or disrupting the cells or tissues of interest. Such procedures include acid, alkali, and solvent extraction. Furthermore, the use of the significant amounts of chemicals necessary for these processes inevitably has an unsustainable environmental impact. Alternative extraction techniques include ultrasound-assisted extraction, microwave-assisted extraction, accelerated solvent extraction, pulse electric field, high-pressure processing, and colloidal gas aphrons, as well as subcritical and supercritical fluid extraction. These processes can be used separately, as a preliminary step, or in combination with one another to achieve the highest yield and lowest cost (13).

Because of their wide range of possible applications in various industrial sectors, fruit and vegetable wastes can contribute to circular economy. Implementing improved waste management strategies is a key aspect of the transition to a bioeconomy, with the aim of reducing the negative environmental impacts associated with the fruit and vegetable processing

Fig. 1. Food waste types

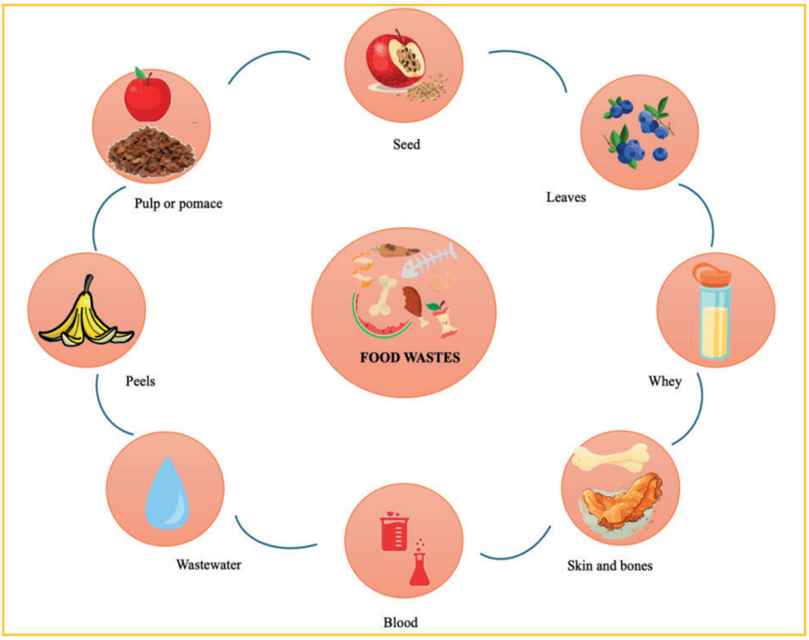

Table 1. Parts of some fruit and vegetable wastes [(Adapted from Kainat et al. (13)]

Fruit and vegetables	Wastes	References
Apple	Pomace, peel, and seeds	
Banana	Peel	
Grapes	Skin, stem, seeds, and pomace	
Orange	Peel	(14)
Onion	Outer leaves	
Tomato	Core, skin, and seeds	
Potato	Peel	
Lemon	Peel and seeds	

industry. Therefore, there is a common interest in discovering innovative strategies for valorizing these substrates. Further innovative valorisation strategies aim to recover high-value ingredients from fruit and vegetable waste, which are used as natural sources of biologically active substances for the formulation of functional foods. As previously stated, the most common way to use waste is to extract useful bioactive substances. Another current strategy is to use them in fermentation (15). Table 2 presents the use of fruit and vegetable waste in different food products, such as bakery foods, meats, snacks, and beverages, as well as their use as prebiotic compounds.

Table 2. Food waste valorisation studies

Food waste	Aim	Results	References
Pineapple peel	Cracker production	Nutritionally enhanced and sensory-acceptable crackers	(16)
Tomato waste	Juice production	Antioxidant capacity against free radicals	(17)
Broccoli pomace	Juice production	High antioxidant activity, higher soluble carbohydrates (lower fiber content) and, high protein content	(18)
Pineapple peels	Fermentation by *Trichoderma viride*	Pineapple peels with *T. viride* produced high protein fungal biomass	(19)
Sea buckthorn waste	Refreshing beverage production using *Saccharomyces cerevisiae*	Enhanced antioxidant, antimicrobial, and nutritional properties	(20)
Mandarin/ orange waste	Fermentation by *Clostridium beijerinckii*	*C. beijerinckii* **produced 0.046 g** of butanol per 1 g of dried strained lees in the culture supernatant	(21)
Orange peel	Wheat dough and bread production	Orange peel powder strengthened the dough elasticity. Wheat dough was changed by affecting the fibre, pectin and polyphenol components	(40)
Jackfruit peel	Cookie production	Jackfruit peel flour significantly affected the sensory, physical and chemical attributes of the cookies	(41)
Mango, apple and banana peels	Prebiotic effect examination	Apple, banana, and mango peel powder (2%) can be used as prebiotics to enhance the growth of lactic acid bacteria	(47)
Apple peel	Cereal-based muffin and apple puree production	The total phenolic content, dietary fiber content, total antioxidant activity, and anti-hyperglycemic properties increased with the incorporation of apple peel powder, specifically in muffin	(48)
Melon peel powder	Functional yoghurt production	Melon peel powder exhibited prebiotic effect and enhanced antioxidant activity. Yoghurt containing 2% melon peel powder had the highest taste and sensory qualities	(49)
Apple pomace	Baked pork production	The use of 0.5% freeze-dried apple pomace was most effective in inhibiting lipid oxidative changes in baked pork	(50)

There are several advantages to the use of fruit and vegetable waste in innovative food formulations. Table 2 presents the extensive research conducted to develop functional foods with enhanced antioxidant activity, nutritional value, and sensory properties using waste. These studies have shown that fruit and vegetable waste can significantly enhance the physicochemical, sensory, nutritional, and bioactive properties of the final products. Nevertheless, in addition to these studies, conducting microbial safety assessments is essential to ensure public health and sustainability.

Dairy industry wastes

The primary source of waste produced following the processing of animal products is the dairy and meat processing industries (12). The dairy industry plays an essential role in the global food industry by providing a range of products that meet the nutritional needs of a vast consumer base. These products include milk, cheese, butter, ghee, and milk powder (23, 42). In 2019, global milk production reached 852 million tons, increasing to 906 million tons in 2020. By 2030, production is predicted to increase by 1.7% per year, reaching 1.020 million tons (22). A range of materials, including proteins, sugars, fats, food additives and cleaning agents, are produced as waste products during dairy processing and are discharged into effluents or sludge. In this context, dairy waste can be broadly categorised into two main types: waste water (effluent) and solid waste. The dairy effluent is characterised by a high organic matter content, which is conducive to the microorganisms growth. This, in turn, enables the production of a range of valuable products via microbial activity. However, the primary waste product of cheese production is whey, which is a significant component of dairy effluent. This effluent contains a substantial source of protein and, through enzymatic hydrolysis, can serve a source of bioactive peptides (24). For instance, the use of hydrolysed whey based medium fermented by LAB as a preservative in bread preparation represents a valuable opportunity to use a natural antifungal agent (25). In their study, they found that using a fermented whey medium for dough preparation resulted in a 0.5–0.6 log CFU/g reduction in *Penicillium expansum* growth and an improvement in the shelf life of 1–2 days in relation to control bread.

The most common methods of treating dairy waste include physicochemical and biological. However, the cost-effectiveness and environmentally friendly nature of biological methods make them a preferred option over physicochemical techniques. On the other hand, the conversion of dairy waste into value-added products aligns with European policies that promote a circular economy and encourage the reduction of waste and sustainable production practices (42). Dairy waste is rich in organic

Table 3. Dairy waste valorisation studies

Waste	Aim	Results	References
Ricotta cheese whey	Sports beverage	Increased vitamin, mineral, antioxidant, and total phenolic compound content	(26)
Sweet cheese whey	Growth medium	Novel strategy for cultivating selected starters with a bio-protective activity by valorizing cheese whey	(27)
Powder whey	Fruit beverage	Angiotensin-converting enzyme inhibitory activity, antioxidant activity, and α-glucosidase inhibition	(28)
Whey protein concentrate	Cookie	Increased protein and mineral content and reduced carbohydrate and calorie intake	(43)

matter and can therefore be used as a substrate for the production of functional foods. Table 3 summarizes studies on the valorization of dairy waste.

As shown in Table 3, whey is a by-product of the dairy industry and is a widely used ingredient in the production of various functional products. Therefore, dairy waste can be used to produce value-added foods, thus supporting a circular economy and reducing the environmental impact of waste disposal.

Meat industry wastes

The livestock slaughtering and meat processing industries represent a significant sector of the food industry. It continues to grow in response to the need to sustain a growing global population with diverse nutritional requirements. Pork, beef, and poultry production has doubled in the last decade and is expected to continue rising until 2050 (44). The world's meat production was around 360 million tons (carcass weight equivalent) in 2022 (45) and is expected to increase by almost 44 million tons by 2030 (46). Meat industry wastes, including horns, blood, bones, skin, and guts, are rich in proteins that can be incorporated into diets. They also include antimicrobial and antioxidant properties associated with hydrolysed peptides. These properties can be effective in extending the shelf life of food (29). Protein-rich meat waste is an attractive material for the production of bioactive peptides with health-promoting properties. A water-insoluble collagen is subjected to hydrolysis under strictly controlled conditions to form gelatin, which can be incorporated into a diverse range of food products. It is a major ingredient in aspic and jelly. In contrast, collagen derived from hides and skins acts as an emulsifier in meat products (30). However, edible fats from meat can be used in bakeries for cooking and frying, and to improve the flavour and texture of foods (31).

The use of bioactive peptides derived from meat industry waste or byproducts with beneficial physiological effects is a promising option for the development of functional foods. It is noteworthy that limited studies have been conducted on the product development and effects of foods with added bioactive peptides. Further research is needed to investigate the improved processing, sensory evaluation, and health benefits of using bioactive peptides from the meat industry as ingredients in functional foods. However, although meat industry wastes could be an important source of nutrients, their safety needs to be investigated (35).

Table 4. Meat industry waste valorisation studies

Product	Waste	Results	References
Nuggets	Chicken and beef liver	**Enhanced nutritional profile of processed foods**	(32)
Forcemeat	Chicken feet and head	Enhanced physical and chemical properties, cost-effective, sustainable	(33)
Yoghurt	Gelatin extracted from bovine heart	The addition of 1.5% gelatin considerably affected the physicohemical properties and texture of the final product	(34)
Sausages	Collagen gel extracted from chicken feet	Collagen-based fat reduction reduced thiobarbituric acid reactive substance levels, with the collagen gel sample showing better antioxidant activity and lower atherogenicity and thrombogenicity indices compared to the hydrolyzed collagen sausage	(51)

Microbial Safety of Food Wastes

The issue of food safety, that is, the assurance that food will not cause harm to the consumer when it is prepared and consumed according to its intended use, remains a significant global concern that affects the health of populations in both industrialised and developing countries. In this context, consumers continue to demand fresh and processed foods that are safe to eat, convenient to consume, promote health and well-being, and have high sensory qualities. Another growing consumer demand is that food products should be produced in an environmentally sustainable way. Food loss and waste are critical issues that impact both food safety and environmental sustainability. Reducing food waste has emerged as a key strategy to ensure food security, minimize environmental impact, and produce sustainable foods.

The recycling and upgrading of food waste, in accordance with the EU Circular Economy Action Plan and European Bioeconomy Strategy, is currently a highly popular approach. As previously stated, this involves the utilisation of valorised waste in a diverse range of applications across various industries, which stimulates the growth of the food sector, increases commercial outputs, and prevents issues associated with improper waste management and its detrimental impacts on the environment.

The most prevalent pollutants in wastes are pesticides, biogenic amines, mycotoxins, pathogens, and heavy metals, despite the obvious benefits of this strategy. All these hazards can cause serious illness; therefore, several factors need to be considered when validating the suitability of food waste for extracting valuable constituents.

Food waste can be stored for several days or weeks when collected, sorted and transported prior to final treatment, and is easily spoiled due to its high organic matter and water content. The presence of pathogens in spoiled food waste is a common occurrence, given that such waste contains biodegradable components that can facilitate the growth of pathogens (Table 5) (56). *Salmonella*, *E. coli* and *Listeria monocytogenes* are the most common foodborne pathogens detected in food wastes (57). Therefore, pathogens are important as the reintroduction of contaminated waste could result in numerous foodborne outbreaks (6).

Pathogen contamination in food waste is typically the result of inadequate hygiene conditions during the production, transportation and storage of the waste. Furthermore, the risk of cross-contamination during the handling and processing of the waste is also considerable. Therefore, the reintroduction of wastes into the food chain necessitates a thorough assessment of the optimal manufacturing and recycling procedures to ensure their microbial safety (10). In the context of functional food production, it is important to assess and reduce pathogen contamination in food waste. This can be achieved through the pre-treatment of wastes using a combination of physical, chemical and biological methods, which effectively reduce the pathogen count. Additionally, microbial safety analyses in accordance with international standards are essential for the safe reuse of wastes.

Table 5. Presence of pathogens in food waste

Food wastes	Potential pathogens	References
Fruit and vegetable wastes	*Salmonella* spp. *E. coli* O157:H7, *L. monocytogenes*	(58)
Dairy wastes	*Staphylococcus aureus*, *L. monocytogenes, E. coli* O157:H7	(59)
Meat industry wastes	*Clostridium perfringens*, *Salmonella* spp. *E. coli* O157:H7, *L. monocytogenes*	(58)

Table 6. Microbiological safety studies in valorised food wastes [(Adapted from Socas-Rodríguez et al. (6)]

Food waste	Extracted compounds	Aim	Safety analysis	Results	References
Fruit (Sweet cherry pits, date, and grape) seeds	Phenolic compounds	Exploring bioactive substances and ensuring food safety	Pesticides, mycotoxins, and heavy metals	Date seeds exhibited high potential for food and pharmaceutical applications	(36)
Coffee silverskin	Fiber, proteins	Use of coffee by-products in cereal-based food	Aerobic mesophilic bacteria, total coliforms, molds and yeasts, *Salmonella* spp., *Escherichia coli,* and *Staphylococcus aureus* counts	The sum of aflatoxins (B_1, B_2, G_1, G_2) are under the established limits for food safety	(37)
Banana peel flour	Fiber, proteins, amino acids, polyunsaturated fatty acids, antioxidants compounds, vitamin K	Preparation of gluten-free products	-	Physicochemical analyses were carried out in the final product	(38)
Snow crab cooking wastewater	Proteins, minerals, aromas, antioxidants	Valorisation potential for food applications	*Bacillus cereus, C. perfringens, E. coli, Salmonella* **spp.**, *S. aureus* counts	Their safety was verified	(39)
Potato peels	Antimicrobials and antioxidants	Extraction of potential antibacterial agents	-	Physicochemical analyses were carried out for final product. Potato peel extracts could be used as natural preservatives or antioxidants, as well as promising anti-sprouting agents	(52)
Potato peels		Lemon carbonated soft drink	Coliform and *E. coli* counts	Microbiological analyses were carried out for final product. Coliform and *E. coli* are not detected in lemon soft drink formulations	(53)

Table 5 presents the wide range of applications in this area, with the main objective being to extract valuable bioactive compounds. However, as the literature review shows, most studies did not include a microbial safety study. The most recent research were listed in Table 5.

This table shows the variation in research methodologies for assessing the microbiological safety of food waste. While most research focuses on the use of food waste to produce functional foods, few include comprehensive safety assessments. For example, Mateus et al. (36) aimed to investigate both the antioxidant properties and the safety of food waste (Sweet cherry pits, date, and grape seeds), with the aim of its safe application according to circular economy practices. To this end, they identified three major chemical contaminants, namely pesticide residues, mycotoxins and heavy metals. Moncalvo et al. (54) assessed the microbiological safety of waste grape skins and extracts for mycotoxin presence. On the other hand, Bouaziz et al. (55) used date seeds in their study to develop a functional chocolate spread enriched with dietary fiber from date seeds and to evaluate the effect of the dietary fiber addition on quality characteristics of the obtained product. However, they did not evaluate the safety of this waste. This lack of microbiological safety assessment is a significant gap, as the safety of these wastes is important for their effective use in food applications. Future research should focus on microbiological safety studies to ensure the reliability and consumer acceptance of food waste-derived products, supporting both sustainability and food safety objectives. However, the ability to differentiate between the controlled growth of specific microorganisms during the processing of food waste and the presence of potentially hazardous conditions that could adversely impact consumer health represents another challenge in the assessment of the microbiological safety of food waste. On the other hand, microbial safety analyses have been conducted on the final product in some studies. While microbial analyses of the final product are valuable, a more comprehensive approach that encompasses all stages of the production process is necessary to ensure microbial safety more effectively. This is a crucial requirement for the safe and sustainable recycling of food waste. However, a review of the literature revealed that there are currently no regulations regarding the microbial quality of food wastes before their utilisation. For example, Beltrán-Medina (37) evaluated the potential use of a coffee silverskin in a cereal-based extruded food product and, prior to its use, characterised and evaluated its safety by chemical composition studies, microbiological determinations, aflatoxin measurements and acute toxicity tests. They noted that, in the absence of specific microbiological regulations for coffee silverskin, the standards for roasted coffee and the official Mexican regulation for cereals and their products were used for comparison. This highlights the need for further research to establish specific regulations for waste products.

CONCLUSION

Food waste management is a major challenge on a global scale, prompting the development of innovative processes and methodologies. Food waste contains valuable compounds such as flavonoids, phenolic compounds, carotenoids, anthocyanins, pectin, proteins, dietary fibres, and enzymes. Functional food production using food waste has been an important research topic in recent years. However, there are challenges for using aformentioned compounds from food wastes, including biological instability and the risk of pathogen contamination. Many studies have revealed that these wastes can provide valuable contributions to the food industry by increasing their nutritional value and functional properties. However, research on the microbial safety of these wastes is very limited. It is critical to evaluate whether food wastes used in functional food production are safe, especially in terms of microorganism contamination. These wastes, when not processed properly, can create a suitable environment for pathogens and may adversely affect the health benefits of the final product. Despite increasing safety concerns in this area, only a limited number of safety assessment studies have been conducted. This problem will lead to the need for specific regulations for the valorisation and safety of food waste. Therefore, ensuring the microbial safety of functional foods produced using food wastes is a great need for applied research in this field, and more in-depth investigations are required. Consequenlty, this study contributes to the existing literature by providing a comprehensive evaluation of the potential of food waste in functional food production, emphasizing both the benefits and the critical microbiological safety considerations, which are often overlooked in previous research.

Author Contribution

Study design: AKP, IS; Drafting the manuscript: AKP, IS; Critical review for content: AKP, IS; final approval of the manuscript; AKP, IS.

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Conflict of Interest

The authors declared that they have no conflict of interest.

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