

Review article

Nutritional value, consumer perspective, environmental benefits and challenges of Upcycled foods in Nigeria

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Received 5 June 2026; Accepted 8 July 2026; Published

Abstract Upcycled foods are emerging as a promising approach to improving food system sustainability by converting food by-products, surplus, or undervalued raw materials into nutritious, safe, and value-added food products. In Nigeria, where post-harvest losses and food insecurity remain significant challenges, upcycled foods present important nutritional, consumer, and environmental opportunities. From a nutritional perspective, many upcycled foods such as products derived from fruit peels, cereal by-products, legumes, and root crop residues are rich in dietary fiber, vitamins, minerals, and bioactive compounds that support human health. This work closes the gap between consumer perception, economic empowerment, and agricultural waste management in a particular, very promising African market. These products can contribute to improved nutrient intake while promoting efficient resource utilization. Consumer perspectives on upcycled foods in Nigeria are gradually evolving, influenced by factors such as affordability, taste, cultural acceptance, awareness, and trust in food safety and quality. While some consumers view upcycled foods as innovative and environmentally responsible, others express concerns related to hygiene, processing methods, and social perceptions associated with consuming food made from “waste.” Environmentally, upcycled foods offer notable benefits by reducing food waste, lowering greenhouse gas emissions, conserving natural resources, and supporting circular economy principles within the agri-food sector. However, several challenges limit their widespread adoption in Nigeria, including inadequate processing infrastructure, limited regulatory frameworks, inconsistent quality standards, low consumer awareness, and technical constraints in ensuring microbiological and nutritional safety. Additionally, small-scale producers often face financial and technological barriers.

Keywords: Upcycled foods, nutritional value, environmental benefits, food security, consumer perspective

1.0. Introduction

Food waste continues to present significant challenges to sustainable food systems worldwide. A large proportion of edible food never reaches consumer tables, instead ending up in landfills, incinerators, or being diverted to animal feed and other non-food uses. This represents not only lost nutrients but also wasted resources such as land, water, and energy used in producing those foods [1]. The emerging concept of upcycled foods addresses this challenge by reimagining how food materials that would otherwise be discarded can be transformed into valuable food products for human consumption [2].

Upcycled foods are defined by the Upcycled Food Association (UFA) as foods that “use ingredients that otherwise would not have gone to human consumption, are procured and produced using verifiable supply chains, and have a positive impact on the environment” [3]. This formal definition was developed in a collaborative process involving academic, non-profit, and industry stakeholders, including representatives from Harvard Law School, Drexel University, the Natural Resources Defense Council, and the World Wildlife Fund. The definition provides a framework for identifying upcycled foods and distinguishing them from general recycled or repurposed food products [3].

Fundamentally, upcycled foods focus on leveraging ingredients that would otherwise be wasted such as surplus produce, by-products of food manufacturing, and imperfect or “ugly” fruits and vegetables and converting them into high-quality food products [4]. Unlike simple recycling, upcycling adds value to the food supply chain by retaining the edible and nutritional aspects of these materials, making them suitable for human consumption and enhancing sustainability outcomes. For example, by using otherwise discarded ingredients like spent grains from brewing or fruit pulp from juice production, manufacturers can create nutritious new foods that contribute both to food waste reduction and to resource efficiency efforts [5].

The concept of upcycled foods is embedded within the wider movement toward a circular food system, an approach that aims at minimizing waste by maximizing the use of all food resources from production to consumption [6]. In traditional linear food systems, a significant portion of food and associated nutrients are lost along the chain. By contrast, upcycling repositions food by-products and surplus items as valuable raw materials, thus conserving resources and reducing environmental pressures such as greenhouse gas emissions contributed by food waste [1].

Labels and certification have also become central to the upcycled food movement. To help build consumer trust and assure product quality, the Upcycled Food Association has developed a certification standard that identifies products with verified upcycled ingredients. Products that meet these criteria can display the Upcycled Certified mark, signaling to consumers that the product contributes to waste reduction and has been produced using safe, traceable methods [7].

The rise of upcycled foods reflects broader concerns about sustainability, climate change, and food security. Organizations such as the UFA emphasize that preventing food waste through upcycling is not only a strategy for environmental preservation but also an economic opportunity. According to UFA reports, a significant share of produced food estimated at 30–40% globally goes unsold or uneaten,

leading to economic loss and environmental harm [8]. By transforming this surplus into edible food products, the upcycled food movement seeks to create new market opportunities, reduce waste, and improve supply chain resilience [9].

Critically, upcycled foods are not limited to niche products or specialty markets. As awareness grows, more manufacturers and retailers are exploring how surplus or by-product ingredients can be integrated into mainstream food products, including snacks, flours, sauces, and beverages. This reflects a shift toward recognizing food waste not as a liability but as a resource with untapped potential [10].

Upcycled foods represent a forward-looking approach to food production and consumption. By revalorizing food materials that would otherwise go to waste, upcycled foods hold promise not only for reducing food waste and environmental impacts but also for contributing to more efficient and sustainable food systems [5]. In order to reduce food waste and conserve resources, this article identifies and promotes upcycled foods as a sustainable, circular economy solution. It creates a framework for turning byproducts into superior food items while emphasizing their nutritional worth and environmental advantages. The originality of this article is found in its comprehensive, regional approach. In the particular and quickly expanding Nigerian market, upcycling uniquely combines consumer psychology, agricultural waste management, and economic empowerment rather than considering it as a simply technical or environmental issue. This work is unique because it examines how low-income populations might obtain affordable, wholesome food from repurposed materials, addressing food security directly rather than only as a luxury sustainability fad. The piece examines Nigerian cultural issues where “recycled” or “by-product” may be viewed as inferior or unclean. This work closes the gap between consumer perception, economic empowerment, and agricultural waste management in a particular, very promising African market.

2.0. Materials and Methods

Among the search engines used to locate relevant literature for this review were Google Scholar, PubMed, and Science Direct. The information was gathered using keywords and phrases such as “upcycled foods,” “food security,” “consumer perspectives of upcycled foods,” “nutritional value,” and “environmental benefits and challenges of upcycled foods.” In order to ensure relevance and quality, the study also excluded data that were not published in a reputable journal or that were not in English. Citation monitoring and current thorough reviews were used to find more references.

2.1. Nutritional Value of Upcycled Foods

The nutritional quality of food is a critical determinant of human health and well-being. In recent years, upcycled foods have gained attention not only for their role in reducing food waste but also for their potential to contribute valuable nutrients to human diets [11]. Many upcycled food ingredients originate from parts of food materials that are often discarded despite being nutritionally rich. These include spent grains from brewing, fruit and vegetable peels, pomace, and cereal residues. Research evidence available on Google-indexed academic and institutional platforms suggests that these materials retain significant nutritional value and can enhance the nutrient den-

sity of food products when properly processed and incorporated [12]. Four agri-food by-products made from powdered broccoli, artichokes, asparagus, and pumpkin were examined in a study by [13]. The resultant powders showed notable levels of antioxidant activity and polyphenols and flavonoids. The findings showed that it is possible to produce nutritionally enriched powders from food byproducts in an industrial setting and incorporate them into staple foods without compromising ultimate acceptance.

2.2. Higher Dietary Fiber and Protein Content

Dietary fiber and protein are essential components of a healthy diet, playing key roles in digestion, metabolic health, and disease prevention. One of the major nutritional advantages of upcycled foods is their high fiber and protein content, particularly when derived from cereal residues, legumes, and vegetable by-products [14]. According to the Upcycled Food Association, many upcycled ingredients come from nutrient-dense food waste streams that naturally contain higher levels of dietary fiber and protein than refined conventional food ingredients [15].

Spent grains generated during brewing processes are among the most widely studied upcycled ingredients. These grains retain substantial amounts of insoluble fiber, protein, and minerals after the extraction of sugars during brewing [16]. Studies reported on PubMed Central indicate that incorporating spent grains into baked goods and snack products significantly increases dietary fiber and protein levels compared to products made solely from refined flour [17]. Higher dietary fiber intake is associated with improved bowel function, reduced risk of cardiovascular diseases, and better glycemic control [18]. According to reports, grape pomace, a byproduct of making wine, is a rich source of phenolic compounds, protein, and dietary fibre [11].

2.3. Enhanced Antioxidant and Health-Related Nutrients

Beyond macronutrients, upcycled foods can serve as important sources of antioxidants and other bioactive compounds that promote health. Many food by-products contain higher concentrations of phytochemicals than the edible portions typically consumed. According to the Society of Chemical Industry (SCI), fruit and vegetable peels, seeds, and pomace are rich in polyphenols, flavonoids, carotenoids, and other antioxidant compounds that are often lost when these materials are discarded [19].

Food upcycling allows these bioactive compounds to be retained and reintroduced into the food supply. Research findings available on Google-indexed journals show that upcycled flours produced from fruit peels and vegetable residues exhibit strong antioxidant activity

and can help reduce oxidative stress when consumed as part of a balanced diet [20]. Antioxidants play a crucial role in neutralizing free radicals, thereby reducing the risk of chronic diseases such as cardiovascular disease, diabetes, and certain cancers [21].

2.4. Nutritional Considerations for Balanced Diets

While upcycled foods offer notable nutritional advantages, research emphasizes that not all upcycled food products are inherently healthier than conventional foods (Table 1). Nutritional quality depends largely on how upcycled ingredients are processed, formulated, and incorporated into final products. According to studies published on PubMed Central, the health benefits of upcycled foods may be reduced if they are added to highly processed products that contain excessive amounts of sugar, salt, or unhealthy fats [22].

Processing methods such as excessive heat treatment or refining can degrade sensitive nutrients, including vitamins and antioxidants. Therefore, careful processing and formulation strategies are required to preserve the nutritional integrity of upcycled ingredients. Researchers recommend that upcycled foods be designed to complement balanced diets rather than serve merely as marketing tools for sustainability claims [23].

2.5. Types of Upcycled Foods and By-Products

Upcycled foods can be classified according to the type of raw material or by-product used (Table 2). Understanding the sources and characteristics of these ingredients is essential for developing nutritious, safe, and acceptable products [2]. In Nigeria, the availability of various food by-products provides significant opportunities for upcycling in both industrial and small-scale food processing [6].

2.5.1. Fruit and Vegetable By-Products

Fruit and vegetable by-products, including peels, pulp, pomace, and seeds, are widely used in upcycled food production. Citrus peels, plantain peels, cassava peels, and yam peels, which are often discarded during processing, are rich in dietary fiber, vitamins, minerals, and bioactive compounds such as polyphenols and antioxidants [29]. For example, cassava and yam peels can be dried and milled into flours that are incorporated into baked goods, snacks, and composite flours, enhancing their nutritional quality while reducing waste. Fruit pomace from juice processing can be used to produce fiber-enriched snacks or powders, which also contribute to gut health and dietary diversification [30].

2.5.2. Cereal By-Products

Cereal by-products such as spent grains, bran, and husks are an-

Table 1. Nutritional Components of Common Upcycled Food Ingredients and Their Health Benefits

Upcycled Ingredient Source	Major Nutrients Present	Key Nutritional Benefits	References
Spent brewery grains	Dietary fiber, protein, minerals (iron, magnesium), polyphenols	Improves gut health, increases satiety, supports muscle maintenance and metabolic health	[16]
Fruit peels (e.g., citrus, banana, apple)	Dietary fiber, antioxidants, vitamin C, polyphenols	Enhances antioxidant intake, supports digestive health, reduces oxidative stress	[24]
Vegetable residues (pomace, pulp)	Fiber, phytochemicals, micronutrients	Promotes gut microbiota activity, improves bowel function, supports immune health	[25]
Cereal processing by-products	Complex carbohydrates, fiber, B-vitamins	Provides sustained energy, improves digestive health, reduces risk of chronic diseases	[26]
Legume by-products (husks, seed coats)	Protein, dietary fiber, minerals	Supports protein intake, improves satiety, aids blood glucose control	[27]
Root and tuber peels (cassava, yam, plantain)	Fiber, minerals, bioactive compounds	Enhances dietary fiber intake, contributes to food security when processed safely	[28]

Table 2. Types of Upcycled Foods, Sources, and Applications

Type of Upcycled Food	Source / By-Product	Nutritional Value / Key Components	Common Applications	References
Fruit and Vegetable By-Products	Citrus peels, plantain peels, cassava peels, yam peels, fruit pomace	High in dietary fiber, vitamins, minerals, polyphenols, antioxidants	Flours for baked goods, snacks, composite flours, fiber-enriched powders	[37]
Cereal By-Products	Spent grains (breweries), wheat bran, rice bran, maize husks	Protein, dietary fiber, essential amino acids	Bread, cookies, extruded snacks, breakfast cereals	[38]
Legume Residues	Bean husks, groundnut shells, lentil hulls	Protein, fiber, micronutrients	Composite flours, cookies, protein-enriched snacks	[39]
Beverage and Dairy By-Products	Spent grains (breweries), whey (cheese/yogurt), fruit pulp (juice production)	Protein, fiber, vitamins, bioactive compounds	Protein powders, snack bars, bakery products, fiber-enriched powders	[40]

other important category of upcycled foods. Spent grains from breweries or cereal processing are rich in protein, fiber, and essential amino acids, making them suitable for inclusion in bread, cookies, and extruded snacks [31]. Wheat bran, rice bran, and maize husks, which are typically discarded or used as animal feed, can be processed into functional ingredients for human consumption. Upcycling cereal by-products not only increases nutrient density but also reduces environmental impact associated with their disposal [32].

2.5.3. Legume Residues

Legume residues, including bean husks, groundnut shells, and lentil hulls, are also valuable for upcycled food production. These residues contain significant amounts of protein, dietary fiber, and micronutrients, which can enhance the nutritional profile of flour blends, snack foods, and protein-enriched products [33]. For instance, groundnut husks can be incorporated into composite flours for cookies or breads, providing both functional and health benefits while reducing agro-industrial waste [34].

2.5.4. Brewery, Juice, and Dairy Industry By-Products

By-products from the beverage and dairy industries, such as spent grains from breweries, fruit pulp from juice production, and whey from cheese or yogurt processing, are increasingly being utilized in upcycled foods. Spent brewery grains are high in protein and fiber and can be incorporated into baked goods, snack bars, and extruded products [35]. Whey, a by-product of cheese making, is rich in protein and can be dried into powder for use in protein-enriched foods and beverages. Fruit pulp residues, often discarded during juice processing, can be converted into fiber-rich powders or incorporated into snacks and bakery products, improving both nutritional content and sustainability [36].

3.0. Global Food Waste Overview

According to the Food and Agriculture Organization (FAO, 2023), approximately one-third of all food produced globally around 1.3 billion tonnes per year is lost or wasted. This includes losses along the entire supply chain, from production and processing to distribution and consumption [1]. The environmental implications of food waste are significant: decomposing food in landfills produces methane, a potent greenhouse gas, contributing to climate change. In addition, wasted food represents a waste of resources such as water, land, and energy, and contributes to biodiversity loss due to unsustainable agricultural practices [41].

Economically, global food waste represents an estimated \$940 billion loss per year, which affects both developing and developed nations. Reducing food waste is thus critical not only for environmental sustainability but also for improving economic efficiency and strengthening food security [42].

3.1. Post-Harvest Losses in Nigeria

In Nigeria, food waste and post-harvest losses are particularly high due to factors such as inadequate storage, poor transportation infrastructure, and limited processing facilities. Fruits, vegetables, cereals, and tubers are the most affected commodities [43]. For example:

- 1. Fruits and vegetables:** Approximately 40–50% of produce is lost before reaching markets due to spoilage and inadequate cold chain systems [44].
- 2. Cereals:** Maize, rice, and sorghum experience losses of 10–20% during storage and processing [45].
- 3. Tubers:** Cassava and yam, which are highly perishable, can experience post-harvest losses of 20–30%, reducing both income for farmers and available food for consumers [46].

These losses exacerbate food insecurity, particularly in low-income populations, and undermine the efficiency of agricultural investments [47].

3.2. Economic and Environmental Impacts of Wasted Food

The consequences of food waste in Nigeria extend beyond nutrition. Economically, post-harvest losses reduce farmers' incomes, decrease the availability of affordable food, and increase prices for consumers. For households, food waste also represents a direct financial loss, particularly in urban areas where food prices are high [43].

Environmentally, wasted food contributes to greenhouse gas emissions, including methane from decomposition, and unnecessary use of land, water, and energy. For example, wasted tubers and cereals consume significant amounts of agricultural inputs without providing nutritional benefits. Additionally, food waste contributes to pressure on waste management systems, including landfills, which are often inadequate in Nigerian cities [48]. Addressing these challenges is critical for improving food system efficiency, promoting sustainable consumption, and supporting initiatives such as upcycled foods, which transform surplus or discarded food into nutritious products [6].

3.3. Nutritional Enhancement through Upcycling

Upcycling food by-products not only reduces waste but also offers opportunities to enhance the nutritional quality of foods. By carefully selecting and processing nutrient-rich by-products, food manufacturers can create products that contribute to improved health outcomes while promoting sustainability [49].

3.4. Fortification Potential of Upcycled Foods

Upcycled foods provide an excellent source of dietary fiber, protein, vitamins, and minerals. Fruit and vegetable peels, cereal bran, and legume husks, which are often discarded, are naturally rich in

these nutrients. Incorporating these by-products into flours, snacks, or bakery products can fortify foods and increase their nutritional density [11]. For example, spent brewery grains are high in protein and fiber, making them suitable for protein-enriched bread or snack bars. Similarly, cassava peel flour can be added to composite flours to enhance mineral content and dietary fiber [50].

3.5. Bioactive Compounds from By-Products

Many food by-products contain bioactive compounds such as polyphenols, carotenoids, and antioxidants, which contribute to health beyond basic nutrition. Fruit pomace, citrus peels, and vegetable residues are especially rich in these compounds [51]. The inclusion of such by-products in food formulations can help reduce oxidative stress, improve immune function, and provide protective effects against chronic diseases such as cardiovascular disorders, diabetes, and certain cancers. Upcycling allows these bioactive compounds to be preserved and delivered in convenient, safe, and palatable forms [52].

3.6. Impact on Gut Health and Chronic Disease Prevention

Dietary fiber from upcycled by-products supports gut health by promoting the growth of beneficial gut microbiota. High-fiber upcycled ingredients, such as fruit and vegetable pomace or cereal bran, can improve digestion, reduce constipation, and enhance nutrient absorption [53]. Additionally, the antioxidants and polyphenols present in by-products may reduce inflammation and oxidative stress, which are linked to the development of chronic diseases. Regular consumption of foods fortified with upcycled ingredients can therefore contribute to long-term health benefits and dietary quality improvements, particularly in populations vulnerable to nutrient deficiencies or diet-related diseases [54].

3.7. Food Safety and Quality Considerations

The production and consumption of upcycled foods present unique food safety and quality challenges (Table 3). While upcycling transforms surplus or by-products into nutritious foods, proper handling, processing, and regulatory compliance are essential to ensure that these products are safe, stable, and acceptable to consumers [7].

3.8. Microbial Risks Associated with Upcycled Ingredients

One major concern in upcycled food production is the potential microbial contamination of by-products. Food residues, peels, spent grains, and pomace may harbor bacteria, molds, or yeasts if not properly collected, stored, or processed [17]. For example, fruit and vegetable peels can carry pathogenic microorganisms such as *Salmonella* or *E. coli*, while cereal and legume residues can develop molds if

moisture levels are high. Ensuring microbial safety requires hygienic handling, rapid processing, and storage under controlled conditions [55].

3.9. Preservation, Processing, and Shelf-Life Challenges

Upcycled ingredients are often perishable, and incorporating them into food products requires technologies that maintain quality and extend shelf life. Drying, milling, extrusion, and pasteurization are commonly used to stabilize by-products and prevent spoilage [56]. However, improper processing can reduce nutrient content, alter sensory properties, or increase the risk of microbial growth. Shelf-life assessment, packaging innovations, and controlled storage conditions are therefore critical for ensuring consistent quality in upcycled foods [57].

3.10. Regulatory Compliance and Safety Certification

Compliance with food safety regulations and obtaining appropriate certifications are essential for consumer confidence and market access. Regulatory authorities may require that upcycled foods meet standards for microbial limits, labeling, allergen disclosure, and traceability [58]. Certification programs, such as the “Upcycled Certified” label, verify that products are produced from safe, high-quality by-products and processed under strict safety protocols. Such regulatory frameworks help standardize practices, promote transparency, and support the growth of the upcycled food industry [7].

4.0. Technological Innovations in Upcycling

Technological innovations play a critical role in scaling up the upcycled food sector. Efficient, cost-effective, and safe processing technologies allow food by-products to be transformed into value-added products, ensuring nutritional quality, safety, and consumer acceptability (Table 4). Innovation also supports small-scale producers and encourages circular economy practices within the food system [57].

4.1. Low-Cost Processing and Preservation Technologies for Small-Scale Producers

Many upcycled food initiatives in Nigeria are carried out by small and medium-sized enterprises (SMEs), which often have limited access to sophisticated equipment. Low-cost processing technologies, such as solar drying, manual milling, and simple pasteurization units, can stabilize perishable by-products like fruit peels, tuber residues, and cereal husks [63]. These methods reduce microbial contamination, extend shelf-life, and retain the nutritional quality of by-products, making them suitable for incorporation into composite flours, snacks, or baked products [64].

Table 3. Food Safety Risks, Challenges, and Mitigation Strategies for Upcycled Foods

Food Safety / Quality Concern	Description of Risk / Challenge	Mitigation Strategy / Solution	References
Microbial Contamination	By-products such as fruit peels, cereal residues, and legume husks may harbor bacteria, molds, or yeasts	Hygienic handling, rapid processing, drying, and storage under controlled conditions	[59]
Perishability and Shelf-Life	Upcycled ingredients are often highly perishable, reducing shelf-life of final products	Use of preservation techniques such as pasteurization, extrusion, milling, and packaging innovations	[60]
Nutrient Loss During Processing	Improper processing may reduce protein, fiber, vitamins, or bioactive compounds	Optimized processing conditions that maintain nutritional quality; cold-chain storage	[57]
Allergen and Toxin Risk	Some by-products may contain allergens or natural toxins	Clear labeling, allergen disclosure, and routine testing of raw materials	[61]
Regulatory Compliance	Lack of standardization may affect product safety and consumer trust	Adherence to national and international food safety regulations; certification (e.g., Upcycled Certified)	[62]

Table 4. Technologies, Applications, and Benefits in Upcycled Food Production

Technology / Innovation	Application in Upcycled Foods	Key Benefits	References
Low-Cost Processing	Solar drying, manual milling, pasteurization of fruit peels, tuber residues, cereal husks	Extends shelf-life, reduces microbial risk, preserves nutrients, suitable for SMEs	[69]
Extrusion	Transforming cereal and legume by-products into snacks, breakfast cereals, or extruded bars	Improves texture, increases versatility, enhances protein and fiber content	[70]
Drying and Milling	Processing fruit and vegetable residues into powders for bakery products, snacks, and flours	Stabilizes perishable by-products, retains nutrients, increases shelf-life	[57]
Fermentation	Fermenting spent grains, legume residues, and vegetable by-products	Enhances bioactive compounds, improves digestibility, extends shelf-life	[71]
Digital Platforms	Mobile apps and online systems connecting farmers, processors, and upcycled food producers	Ensures consistent supply, reduces spoilage, improves logistics, supports smallholder inclusion	[72]

4.2. Emerging Innovations: Extrusion, Drying, Milling, and Fermentation

Advanced processing technologies are increasingly applied to upcycled food production. Extrusion allows cereal and legume by-products to be transformed into high-protein snacks or breakfast cereals with improved texture [65]. Drying and milling of fruit and vegetable residues create shelf-stable powders for bakery and snack applications. Fermentation of by-products, such as spent grains or legume residues, can enhance bioactive compounds, improve digestibility, and increase shelf-life [66]. These innovations not only increase product versatility but also improve sensory appeal and nutritional profiles.

4.3. Digital Platforms for Sourcing Surplus Food

Technology also supports the efficient collection and redistribution of surplus food. Digital platforms and mobile applications connect farmers, processors, retailers, and upcycled food producers, enabling real-time tracking of surplus or by-products [67]. This reduces logistical challenges, minimizes spoilage, and ensures a consistent supply of raw materials for upcycling. Moreover, these platforms help integrate smallholders into commercial value chains, supporting income generation and economic sustainability [68].

4.4. Consumer Perspectives on Upcycled Foods

Consumer perception plays a critical role in the successful adoption and commercialization of upcycled foods. Regardless of their nutritional or environmental benefits, upcycled food products must be accepted by consumers to achieve market sustainability [12]. Research evidence available from Google-indexed journals and industry reports shows that consumer attitudes toward upcycled foods are shaped by awareness, perceived quality, sensory attributes, safety concerns, and marketing communication strategies [12].

4.4.1. Consumer Awareness and Acceptance

Consumer awareness is one of the most important determinants of acceptance of upcycled foods (Table 5). Studies indicate that many consumers are increasingly aware of food waste as a global environmental problem and express willingness to support solutions that reduce waste [73]. As a result, upcycled foods are often viewed positively when consumers understand that such products help prevent edible food from being discarded. However, acceptance is not based on environmental motivation alone. According to research published in Foods (MDPI), consumer acceptance of upcycled foods is strongly influenced by sensory characteristics such as taste, texture, aroma, and appearance, as well as perceived product quality and familiarity [74]. Products that resemble familiar food items, such as bread, snacks, or flour-based products, tend to achieve higher acceptance than unfamiliar or unconventional food formats. The Upcycled Food Association reports that consumers are more likely to purchase upcycled foods when they are clearly labeled, visually appealing, and positioned as high-quality products rather than waste-derived alternatives [75]. Education and transparent communication about sourcing and safety also play a significant role in building trust and encouraging acceptance [76].

4.4.2. Food Neophobia, Cultural Attitudes and Marketing Challenges

Food neophobia, defined as the reluctance to eat new or unfamiliar foods, represents a major psychological barrier to the acceptance of upcycled foods. In Nigeria, cultural attitudes toward food waste and by-products can negatively influence willingness to consume upcycled foods, as consumers often associate discarded materials with poor quality or safety risks. Awareness campaigns, education, and demonstration of safety standards are essential strategies to reduce neophobia and improve familiarity with these innovative products. Research available on Google Scholar and published by MDPI high-

Table 5. Consumer Perspectives on Upcycled Foods and Their Influence on Purchase Decisions

Consumer Factor	Description	Effect on Consumer Acceptance	References
Consumer awareness	Knowledge of food waste issues and understanding of upcycled food concepts	Higher awareness increases willingness to try and purchase upcycled foods	[80]
Sensory attributes (taste, texture, appearance)	Perceived palatability and quality of upcycled food products	Positive sensory experience strongly improves acceptance and repeat purchase	[81]
Food neophobia	Fear or reluctance toward unfamiliar or novel foods	High neophobia reduces willingness to try upcycled products	[22]
Safety and trust	Confidence in food safety, hygiene, and regulatory standards	Greater trust enhances acceptance and purchase intention	[80]
Marketing and labeling	Product framing, sustainability claims, and certification labels	Positive framing and sustainability messaging increase acceptance	[80]
Price perception	Perceived value relative to cost	Consumers may pay a premium if benefits are clearly communicated	[79]
Environmental concern	Consumer concern about food waste and sustainability	Environmentally conscious consumers show higher acceptance	[12]

lights that consumers often associate food by-products with waste, poor hygiene, or inferior quality, which can negatively affect purchase intentions [77]. Marketing language and product framing are therefore crucial. Studies show that emphasizing the term “food waste” can reduce consumer interest, while focusing on positive attributes such as sustainability, nutrition, and innovation improves acceptance [78]. Consumers are more receptive to upcycled foods when they are presented as environmentally friendly, nutritious, and responsibly produced rather than as products made from discarded materials [75].

4.4.3. Price and Purchasing Decisions

Price is another key factor influencing consumer purchasing decisions regarding upcycled foods. Consumer willingness to pay a premium for upcycled products varies across population groups and depends largely on perceived value [79]. It has been shown that consumers are more willing to pay higher prices when upcycled foods are marketed with strong environmental and nutritional claims [11].

However, when upcycled foods are positioned as being made from waste without sufficient explanation of benefits, consumers may perceive them as lower in value and be unwilling to pay premium prices. According to MDPI studies, highlighting sustainability alone is not always sufficient; combining environmental messaging with quality, taste, and health benefits leads to higher purchase intent [2].

4.4.4. Role of Branding, Labeling, and Certification

Effective branding, labeling, and certification are critical in shaping consumer perception and building trust. Studies show that labeling products as “Upcycled Certified” or emphasizing environmental and nutritional benefits increases acceptance and willingness to purchase [7]. Transparent communication about the source of ingredients, safety protocols, and health benefits helps consumers feel confident in trying upcycled products, enhancing market penetration.

4.4.5. Implications for Consumer Adoption

Overall, consumer acceptance of upcycled foods depends on a combination of awareness, trust, sensory quality, marketing communication, and pricing strategies. Evidence from Google-indexed literature suggests that improving public education on food waste, using positive product framing, ensuring high sensory quality, and maintaining transparent labeling are essential for increasing acceptance of upcycled foods [12]. In markets where awareness remains low, such as many developing regions, targeted education campaigns and gradual introduction of upcycled ingredients into familiar foods may help overcome resistance and encourage wider adoption [79].

4.5. Environmental Benefits of Upcycled Foods

Upcycled foods provide not only nutritional and economic ad-

vantages but also substantial environmental benefits (Table 6). As concerns about climate change, resource scarcity, and food system sustainability increase, upcycled foods have emerged as an effective strategy to reduce environmental impacts associated with food production and waste. Evidence from Google-indexed sources highlights three major environmental benefits: reducing food waste, promoting circular economy principles, and mitigating greenhouse gas emissions [78].

4.5.1. Reducing Food Waste

A major environmental advantage of upcycled foods is their capacity to divert edible food from landfills. According to [82], approximately one-third of globally produced food is wasted annually, representing a significant environmental challenge. When food waste decomposes in landfills, it produces methane, a potent greenhouse gas with a global warming potential approximately 28 times greater than carbon dioxide over a 100-year period. By converting surplus food, by-products, and imperfect produce into consumable products, upcycled foods prevent this decomposition and contribute to reductions in methane emissions [1].

In addition to reducing greenhouse gases, minimizing food sent to landfills alleviates pressure on waste management infrastructure. Landfills are limited in capacity, and large volumes of decomposing food increase environmental contamination risks, including leachate generation and groundwater pollution. Upcycled food initiatives thus serve a dual purpose: recovering lost nutrients for human consumption while mitigating the environmental hazards associated with food waste disposal [83].

4.5.2. Promoting Circular Economy Principles

Upcycled foods embody circular economy principles by transforming waste streams into value-added products. A circular economy aims to extend the lifecycle of resources, reduce environmental impact, and minimize extraction of virgin materials [84]. By utilizing food by-products such as spent grains, fruit pomace, and vegetable peels, upcycled food production reduces the need for additional agricultural inputs, including land, water, energy, and fertilizers, which are typically required to produce similar foods from raw ingredients [85].

Moreover, upcycling supports resource efficiency by keeping materials in productive use for as long as possible. For instance, incorporating vegetable residues into flours or snacks preserves the nutritional value and functional components of these materials, which would otherwise be wasted. Such practices reduce the overall environmental footprint of food systems, making food production more sustainable and resilient [86].

4.5.3. Mitigating Greenhouse Gas Emissions

The environmental benefits of upcycled foods are further en-

Table 6. Environmental Benefits of Upcycled Foods

Environmental Aspect	Description	Mechanism of Impact	References
Reducing Food Waste	Diverts edible food from landfills	Prevents decomposition of food waste and reduces methane emissions	[90]
Resource Conservation	Extends lifecycle of food materials	Reduces need for virgin raw materials (land, water, energy, fertilizers)	[91]
Circular Economy Promotion	Converts by-products into value-added products	Keeps food resources in productive use, supporting sustainable supply chains	[92]
Greenhouse Gas Mitigation	Lowers overall GHG emissions	Reduces emissions from both agriculture and landfill decomposition	[93]
Reduced Waste Management Pressure	Minimizes burden on landfill and waste systems	Less food sent to landfills reduces leachate and soil contamination risks	[94]

hanced through their contribution to mitigating greenhouse gas (GHG) emissions. [87] highlights that food production is responsible for a significant proportion of global GHG emissions, including CO₂, methane, and nitrous oxide. By reducing the demand for new agricultural production through the use of by-products and surplus foods, upcycling decreases emissions associated with planting, harvesting, processing, and transportation of conventional raw materials [6].

Furthermore, the reduction in food waste sent to landfills lowers methane generation, a key contributor to climate change. Studies indicate that diverting food from landfills and reintroducing it into the human food chain can meaningfully reduce the carbon footprint of food systems [88]. The environmental benefits are cumulative when upcycled foods are integrated across multiple stages of the supply chain, from farm to processing to retail [89].

4.6. Economic and Social Benefits of Upcycled Foods

Upcycled foods offer significant economic and social benefits in addition to their nutritional and environmental advantages (Table 7). By repurposing food by-products and surplus produce into valuable food products, upcycling contributes to income generation, job creation, and improved food security. These benefits are particularly relevant in developing countries such as Nigeria, where post-harvest losses, unemployment, and limited food access remain persistent challenges [86].

4.6.1. Income Generation and Job Creation

Upcycling initiatives provide opportunities for employment across the food value chain. According to the Global Alliance for Improved Nutrition activities such as processing, packaging, quality assurance, marketing, and distribution of upcycled foods can create jobs, particularly for small-scale enterprises, rural communities, and women-led businesses [57]. By transforming surplus or discarded food into marketable products, upcycling fosters entrepreneurship and generates additional revenue streams for farmers, processors, and retailers [85].

The economic potential of upcycled foods extends to both formal and informal sectors. Small and medium-sized enterprises can capitalize on the availability of low-cost raw materials from food waste to produce high-value products such as flour, snacks, and baked goods [49]. It has been shown that certification schemes and market recognition, such as the “Upcycled Certified” label, can enhance product visibility, allowing businesses to access new consumer markets and justify higher price points, thereby increasing income generation [7]. Furthermore, by developing value-added products, upcycling contributes to rural development and strengthens local economies. In regions where traditional employment opportunities are limited, upcycling

initiatives can serve as a catalyst for economic empowerment, skill development, and inclusive growth [95].

4.6.2. Improved Food Security

In addition to generating income, upcycled foods contribute to improved food security by increasing the availability of nutritious food products. Food security encompasses physical availability, economic access, and utilization of safe and nutritious food. By converting edible by-products and surplus food into consumable products, upcycling helps reduce losses in the food supply chain and provides additional sources of affordable food [86].

Reports from the Food and Agriculture Organization highlight that reducing post-harvest food losses is critical for ensuring food availability in low-income populations [96]. Upcycled foods, such as fruit and vegetable flours, spent grain products, and tuber-based snacks, provide nutrient-rich alternatives that can supplement diets in regions with limited access to fresh produce [97]. Moreover, using local by-products reduces dependency on imported food and stabilizes supply chains, enhancing resilience against food shortages and price volatility [98].

4.7. Policy, Governance, and Institutional Support

The growth of the upcycled food sector in Nigeria depends not only on technological and market innovations but also on effective policy, governance, and institutional support. Addressing food waste, ensuring safety standards, and integrating upcycled foods into national strategies require coordinated action from government agencies, private sector stakeholders, and civil society organizations [101].

4.8. Existing Food Waste and Food Safety Policies in Nigeria

Nigeria has established several frameworks aimed at improving food safety and reducing post-harvest losses, including the National Food Safety and Quality Policy and regulations enforced by the National Agency for Food and Drug Administration and Control (NAFDAC) [102]. These policies cover food hygiene, labeling, storage, and transportation standards, which are relevant for upcycled food production. However, specific guidelines for upcycled foods are currently limited, creating regulatory uncertainty for producers and potential barriers to market entry. Strengthening these policies to explicitly include food by-products and upcycled ingredients would provide legal clarity, protect consumers, and encourage industry growth [7].

4.9. Integration of Upcycled Foods into National Nutrition and Sustainability Strategies

Incorporating upcycled foods into national nutrition, food security

Table 7. Economic and Social Benefits of Upcycled Foods

Benefit Category	Description	Impact Mechanism	References
Income Generation	Creation of revenue streams from food by-products	Farmers and small-scale enterprises convert surplus or discarded food into marketable products	[99]
Job Creation	Employment opportunities along the upcycled food value chain	Jobs in processing, packaging, quality control, marketing, and distribution	[86]
Entrepreneurship	Opportunities for small businesses and rural enterprises	Low-cost raw materials from food waste allow startups to develop value-added products	[5]
Improved Food Availability	Increased supply of edible foods	Surplus produce and by-products are transformed into consumable products, enhancing local food supply	[100]
Affordable Nutrition	Nutrient-rich products at lower cost	By-products retain protein, fiber, vitamins, and minerals, contributing to balanced diets	[97]
Food Security	Supports access to safe, nutritious, and sustainable foods	Reduces dependence on imports, stabilizes supply chains, and mitigates food shortages	[72]

ty, and sustainability policies can maximize their impact. [57] emphasizes that food loss reduction and sustainable consumption are key elements of global nutrition strategies. Upcycled foods can be included in school feeding programs, dietary guidelines, and public nutrition initiatives, promoting the consumption of nutrient-rich, fiber-enriched products. Integration into sustainability policies also aligns with circular economy principles by reducing environmental footprints and enhancing resource efficiency in agriculture [11].

4.10. Public-Private Partnerships and Incentives

Public-private partnerships (PPPs) are essential for scaling up upcycled food initiatives. Collaborations between government agencies, food processors, NGOs, and technology providers can facilitate training, infrastructure development, and market access for producers [103]. Incentives such as tax breaks, grants, and access to low-interest loans can support small and medium-sized enterprises (SMEs) in developing upcycled products. Policy support that encourages innovation, ensures food safety, and provides market linkages will strengthen the institutional ecosystem for upcycled foods in Nigeria.

4.11. Challenges Facing Upcycled Foods in Nigeria

Although upcycled foods offer nutritional, economic, and environmental benefits, their adoption in Nigeria faces several challenges. These challenges range from sensory issues and public perception to regulatory barriers and market development. Evidence from Google-indexed sources highlights these constraints, which must be addressed to realize the full potential of upcycled foods in the Nigerian context [2].

4.11.1. Consumer and Sensory Challenges

One of the main obstacles to consumer acceptance of upcycled foods is related to sensory quality. Upcycled ingredients derived from by-products may alter the taste, texture, aroma, or appearance of food products, which can reduce their overall acceptability. Nigerian consumers, like those globally, often prefer familiar flavors and textures, making it critical for producers to optimize formulations. Incorporating sensory evaluation during product development can help ensure that upcycled foods are appealing and competitive with conventional products.

4.11.2. Public Perception and Safety Concerns

Public perception presents another significant challenge. Many consumers associate food waste with hygiene and safety risks, leading to hesitation in trying upcycled products. Without clear evidence and communication of safety practices, including proper processing, handling, and certification, these perceptions can severely limit market adoption. Public education campaigns and transparent labeling are essential for building trust and demonstrating that upcycled foods are safe, nutritious, and environmentally beneficial.

4.11.3. Regulatory and Supply Chain Barriers

Navigating regulatory frameworks and ensuring a reliable supply of ingredients are additional challenges for upcycled food producers in Nigeria. Food safety regulations, labeling requirements, and policies regarding the use of by-products in human food can be complex and inconsistently enforced. In addition, the supply of raw materials such as fruit and vegetable residues, spent grains, or tuber peels is often seasonal and decentralized, making consistent sourcing and quality control difficult. These supply chain limitations can hinder large-scale production and commercial viability.

4.11.4. Market Development and Awareness

Upcycled foods are still an emerging concept in mainstream Nigerian markets. Limited consumer awareness, a lack of standardized definitions, and insufficient industry-supportive policies constrain growth [12]. Many consumers are unfamiliar with the concept of upcycling, which can affect willingness to pay and acceptance. Creating a structured market strategy, developing certification and labeling systems, and promoting consumer education are essential for building trust, expanding market reach, and encouraging widespread adoption.

5.0. Recommendations

In Nigeria, marketing and educational initiatives for repurposed meals should emphasize price, taste, and health advantages. To fight the stigma attached to "waste" or "expired" foods, their nutritional worth must come first. Targeting well-known and popular product forms is also a good idea. For instance, popular snacks like plantain chips, chin chin, or nourishing porridges should incorporate agricultural waste and recycled fruit peels (like orange or mango).

Nigerian regulatory organizations, such as the Standards Organization of Nigeria (SON) and the National Agency for Food and Drug Administration and Control (NAFDAC), should strive to provide uniform definitions and a certification system tailored to upcycled foods. This would increase institutional trust and set them apart from items that have been repackaged, rejected, or illegally expired. To guarantee consumer safety, precise regulations pertaining to the procurement, management, and processing of byproducts (such as cashew apples, fishery trash, and corn cobs) must be set.

Rather than depending on ineffective supply systems, smallholder farmers should be given incentives and inexpensive technologies to dry, store, and transport excess agricultural yields directly to upcycling processors. Nigerian food scientists and organizations should be encouraged to carry out more research to determine the most practical waste streams. For instance, studies on the extraction of bioactive substances from vegetable peels or the production of chitosan from prawn shells ought to be given top priority. In order to enable indigenous start-ups functioning within the circular economy grow from niche ideas to mass-market food production, the Nigerian government should offer grants, tax exemptions, and microfinance support.

6.0. Conclusion

Upcycled foods represent a promising strategy for addressing food waste while simultaneously providing nutritional, economic, and environmental benefits. By transforming surplus produce and by-products into value-added food products, upcycling contributes to dietary diversification, increased nutrient intake, and the reduction of post-harvest losses. Furthermore, these foods support environmental sustainability by diverting edible materials from landfills, conserving natural resources, and mitigating greenhouse gas emissions associated with conventional food production. Despite these advantages, several challenges must be addressed to scale up adoption, particularly in Nigeria. Consumer perception and sensory acceptability remain key barriers, as many people associate upcycled foods with inferior quality or safety risks. In addition, regulatory uncertainties, inconsistent supply chains for by-products, and limited technological capacity for processing and preservation restrict broader commercialization.

Future efforts should focus on public education campaigns, highlighting the nutritional and environmental benefits of upcycled foods,

as well as clear labeling and certification schemes to build consumer trust. Investment in processing technologies, training for small and medium-scale enterprises, and integration into national nutrition and sustainability policies will also be critical to establish a robust upcycled food sector. Upcycled foods have the potential to form a key component of sustainable food systems in Nigeria and globally. By combining innovation, policy support, and consumer engagement, these foods can contribute significantly to reducing food waste, enhancing food security, and promoting environmentally responsible consumption. The potential for upcycled foods in Nigeria is significant, given the country's high levels of food waste, growing population, and increasing consumer interest in sustainable products. To fully realize this potential, several strategies and recommendations are essential for promoting adoption, improving market penetration, and ensuring the safety and nutritional quality of upcycled products.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

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