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Non-conventional foods as emerging nutritional sources and rich reservoirs of bioactive compounds

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Abstract
Non-conventional food sources are emerging as sustainable alternatives to address global food shortages but also to contribute to improved nutrition, environmental sustainability, and diversification of the food system. These sources include algal biomass, fungal mycelium, insects, lab-grown meat, plant-based dairy alternatives, inulin-rich plants, and underutilized species such as *Prosopis cineraria*. Fungal products like yeast extracts and mycoprotein provide high-quality protein, essential amino acids, and bioactive compounds, while also contributing to desirable sensory properties in food formulations. Edible insects, rich in protein, fats, and micronutrients, are increasingly incorporated into cereal-based products to improve nutritional and functional profile. Algae and seaweeds offer essential fatty acids, vitamins, and minerals, and are used to enhance the functional and health-promoting properties of various foods. Inulin derived from plants such as artichoke serves as a prebiotic, fat replacer and, improving both nutritional and sensory qualities. Their integration into food industries holds significant promise for future food security. The current review highlights the production, processing and nutritional composition of non-conventional food sources.

Keywords: Nonconventional foods, lab grown meats, fungal mycelium, insects

1. Introduction
Energy is a fundamental requirement for survival of human beings, animals, and other living organisms. It is established that the population of world is largely dependent on conventional food production systems and agricultural land as the primary platform for crop cultivation. According to population projections, the world population is expected to reach approximately 11 billion by 2050, raising serious concerns about the ability of existing agricultural systems to meet future food demand. This situation poses a significant risk of food insecurity for upcoming generations. At present, nearly one in ten people worldwide suffers from inadequate access to sufficient and nutritious food, particularly protein and energy rich sources. This challenge is expected to intensify further with the continuous increase in population. In response, scientists and researchers are actively exploring and developing alternative food sources beyond conventional systems. As a result, several non-conventional food sources are gaining increasing attention and popularity among consumers. Non-conventional foods refer are consumed by a limited segment of society. These foods are derived from diverse sources, including algal biomass, yeasts, molds, animal protein isolates, grain and cereal extracts, plants, inulin, seeds, seaweeds, as well as lab-grown meat products and plant-based dairy alternatives [1]. The consumption of non-conventional food products offers a promising approach to addressing pressing challenges such as food security and nutritional deficiencies. In addition to serving as alternative food sources, they provide significant health and functional benefits. The aim of this article is to provide an overview of different non-conventional foods, including their sources, health benefits, consumption patterns, production technologies, and commercial applications. Notably, fungal foods constitute a key segment, offering substantial potential due to their bioactive compounds and diverse technological applications. Fungal foods, including yeasts and mycoproteins, are valued for their high protein content, bioactive compounds, and flavor-enhancing properties [2]. Peanut-based products serve as nutrient-dense options essential amino acids, healthy fats, and rich in proteins, while edible insects provide a highly sustainable source of quality protein, micronutrients, and fats [3]. Inulin, extracted from plants such as artichoke,

functions as a prebiotic and fat replacer, improving both health and food texture [4]. Underutilized plants like *Prosopis cineraria* and *Pachira aquatica* offer significant nutritional benefits, including high protein, fiber, and mineral content [5, 6]. Spent yeast, a by-product of fermentation industries, is a valuable source of proteins and vitamins and is widely used as a flavor enhancer. *Erechtites valerianifolia* is a nutrient-rich unconventional vegetable contributing to dietary diversity. Lab-grown meat represents an innovative approach to meat production through cellular agriculture, offering a sustainable and ethical alternative [7]. Seaweeds and microalgae, including spirulina, are rich in proteins, bioactive compounds, vitamins, and essential fatty acids, making them highly valuable functional ingredients. Additionally, plant-based milk alternatives derived from nuts, cereals, and legumes are increasingly consumed due to their health benefits and lower environmental impact. Collectively, these non-conventional foods present promising opportunities for enhancing nutrition, sustainability, and diversification of the global food system.

The culinary landscape across the world is rich and diverse, encompassing numerous traditional foods that have served as dietary staples in different cultures for centuries. Beyond these commonly consumed conventional foods, there exists an important yet relatively underexplored category known as non-conventional foods. These foods, often referred to as alternative or unconventional food resources, are increasingly attracting attention because of their distinctive nutritional value, environmental sustainability, and potential contribution to improving food security. They offer additional dietary options, particularly for populations living in regions affected by limited resources or recurring food shortages, thereby supporting efforts toward diversified and resilient food systems. However, their widespread adoption faces challenges including cultural resistance, unclear regulatory frameworks, and limitations in large-scale production and availability. Despite these barriers, growing interest in sustainable food systems, along with research, innovation, and entrepreneurship, is helping to improve acceptance and development of non-conventional foods. Overall, they hold significant promise for creating a more sustainable, diverse, and resilient global food future. In this article, the world of non-conventional foods, their benefits, exploring their types, and future usage will be discussed.

2. Production and Processing of Non-conventional Foods

The production and post-harvest processing of non-conventional foods utilize diverse modern technologies to ensure efficiency and safety. As an example, insect farming involves rearing insects under controlled conditions in indoor units or greenhouse systems, followed by harvesting and further processing into edible products [8]. Similarly, algae-based foods are produced with the help of large-scale cultivation in open ponds or specialized systems such as photobioreactors, followed by refining processes to create products like dietary supplements and food additives [9]. Other types of non-conventional foods, including plant-based ingredients derived from traditional medicinal sources, may be obtained through methods such as wild collection, farming, or fermentation to ensure they are safe and suitable for consumption [10]. Ensuring safety, quality, and compliance with regulations is a crucial aspect of processing these foods. This includes establishing appropriate food safety standards, maintaining strict quality control, and securing necessary approvals to meet consumption guidelines. Producers must also address factors like proper labelling, effective packaging, and appealing marketing to attract consumers and build trust [11]. As the industry expands, continued advancements in production methods, along with new business approaches and marketing strategies, are expected to further support the growth and acceptance of non-conventional foods [12].

3. Environmental Benefits of Non-conventional foods

Non-conventional foods present important environmental advantages over conventional food sources. Insect-derived proteins, for instance, require substantially lower inputs of land, water, and feed compared with conventional livestock systems, highlighting their potential as sustainable protein alternatives [13]. Likewise, algae-based food resources can be cultivated using limited natural resources while simultaneously contributing to carbon dioxide sequestration [14]. Several plant-based non-conventional foods originating from traditional medicinal practices are obtained through sustainable approaches such as wild harvesting and agroforestry, which play a vital role in conserving biodiversity and supporting ecosystem stability [15]. The integration of such foods into dietary patterns can therefore contribute significantly to reducing environmental impacts and enhancing the sustainability of global food systems [16].

Non-conventional foods typically require minimal packaging and can often be produced locally, thereby reducing transportation-related emissions and promoting regional economic resilience [17]. The utilization supports waste reduction through the valorisation of by-products and underexploited resources that might otherwise remain unused [18]. As interest in non-conventional food sources continues to expand, ongoing innovations are anticipated to further reduce the overall environmental impact of food systems across all stages, from production to consumption [12].

4. Types of Non-Conventioanl Foods

4.1 Fungal Foods

Among fungal sources, yeasts are single-celled microorganisms that are rich in a variety of nutrients [19]. Yeast extracts are widely recognized for imparting an umami taste and are extensively used in different food products [20]. Table 1 presents the applications of fungal mycelium in food making. The high content of vitamin B in yeast extracts further enhances their nutritional value. It is already demonstrated that replacing up to 50% of salt with yeast extract in crackers resulted in acceptable sensory properties. It is identified 37 aroma compounds in different yeast extracts, with methanol and 2,4-di-tert-butylphenol being the most potent contributors [21]. In addition, novel products like Quorn, derived from the filamentous fungus *Fusarium venenatum*, have gained popularity in European markets [22]. Various substrates, including food waste such as stale bread, have been utilized for fungal growth and cultivation [23]. Fungi such as *A. sojae* and *Aspergillus oryzae* have been used for over 3,000 years in the production of soy sauce and koji, where their enzymatic activity enhances flavour development [24]. Fungal biomass can be effectively used as a novel food ingredient due to its high nutritional value. Cookies were developed using *Pleurotus albidus* mycoprotein flour as a substitute for wheat flour, resulting in improved protein, fibre, and phenolic content, along with enhanced texture and colour [25]. Mycoprotein is considered a high-quality protein source beneficial for human health as it provides essential amino acids. Several studies have reported that consumption of mycoprotein and yeast-based products may help reduce cholesterol levels, mainly Low-Density Lipoprotein (LDL), and improve metabolic health [26, 27, 28, 29]. Furthermore, mycoprotein provides essential amino acids that support muscle protein synthesis and may positively influence glucose regulation [30, 31, 32]. Fungal foods, particularly edible fungi such as mycoprotein, mushrooms, and yeast-derived products, have gained significant attention due to their rich content of bioactive compounds and potential role in disease prevention. These foods are rich sources of dietary fibre, high-quality protein, β-glucans, phenolic compounds, and essential micronutrients, all of which contribute to multiple health-promoting functions.

One of the most important bioactive components in fungal foods is β-glucan, a polysaccharide found in fungal cell walls. β-glucans exhibit strong immunomodulatory, anti-inflammatory, antioxidant, and cholesterol-lowering effects, which contribute to a reduced risk of chronic diseases such as obesity, diabetes, cardiovascular diseases, and certain cancers [33, 34]. The compounds enhance immune responses by activating macrophages and natural killer cells, thereby improving host defence against infections [35]. Similarly, fungal mycoprotein derived from species such as *Fusarium venenatum* has been widely studied as a functional food ingredient. Due to its high fibre and protein content, mycoprotein is also considered a sustainable alternative to animal protein with potential long-term health benefits [36]. In addition, yeast-derived products, especially nutritional yeast and yeast extracts, contain β-glucans, B-complex vitamins, and antioxidants that support immune health, reduce inflammation, and improve gut microbiota balance [37, 38]. These properties are associated with reduced risk of gastrointestinal disorders and improved metabolic health. Overall, fungal foods act as functional bioresources that bridge nutrition and phytomedicine. Their regular consumption has been linked with the prevention of lifestyle-related diseases such as cardiovascular disorders, diabetes, obesity, infections, and inflammatory conditions [39, 40]. Therefore, fungal-derived foods are increasingly recognized as promising natural agents in preventive nutrition and phytomedicine.

Table 1: Applications of Fungal Mycelium as Food Ingredients

Application	Function	Therapeutic / Health Effects	References
Yeast extract as salt replacer in crackers	Flavor enhancement (umami), sodium reduction	Maintains acceptable sensory properties	[41]
Yeast extracts in food products	Umami taste enhancer, aroma development	Improves food acceptability due to key aroma compounds	[20, 21]
Yeast as nutritional ingredient	Source of proteins, B-vitamins, micronutrients	Enhances nutritional value and supports metabolic health	[19, 42]
Mycoprotein (*Fusarium venenatum*)	High-quality protein, meat alternative	Reduces total and LDL cholesterol; improves satiety and glycemic control	[27, 43]
Mycoprotein flour (*Pleurotus albidus*) in cookies	Improves nutritional composition and texture	Increases protein, fibre, phenolics; enhances texture and color	[25]
Fungal biomass as food ingredient	Nutrient enrichment (protein, fibre)	Sustainable protein source with health benefits	[36]
β-glucan from fungal cell walls	Bioactive polysaccharide, immune modulator	Reduces risk of CVD, diabetes, obesity; antioxidant and anti-inflammatory effects	[33, 34]
β-glucan immune function	Activates macrophages and NK cells	Enhances immune response and host defence	[35]
Yeast-derived products (nutritional yeast, extracts)	Source of β-glucans, B-vitamins, antioxidants	Improves gut microbiota, reduces inflammation, supports immunity	[37, 39]
Fungal foods (mushrooms, mycoprotein, yeast)	Functional food ingredients (protein, fibre, phenolics)	Prevents lifestyle diseases (CVD, diabetes, obesity, infections)	[39, 40]
Traditional fermented fungal foods (tempeh, oncom)	Fermentation and flavor development	Improves digestibility and nutritional quality	[44]
Koji fermentation (*Aspergillus oryzae*, *A. sojae*)	Enzymatic breakdown of substrates	Enhances flavor and digestibility of foods like soy sauce	[24]

4.2 Insects

Edible insects have long been recognized as an important component of traditional diets and are consumed at various developmental stages, including eggs, larvae, pupae, and adults. They are widely distributed across diverse ecological environments and represent a readily available and sustainable food resource [45, 46]. Their applications in different food formulations are summarized in Table 2. The consumption of edible insects is particularly common in regions such as Southeast Asia, Africa, Mexico, and certain parts of India, where species such as crickets, bees, flies, and ants are frequently included in local diets [47]. The growing interest in edible insects is largely attributed to their high protein content and superior nutritional profile [48]. Recent studies have increasingly focused on the incorporation of insect-derived flours into cereal-based products to enhance their nutritional quality. Insect flours have been used as partial substitutes for cereal flours in staple foods and snack products at substitution levels ranging from 5% to 40%, with approximately 10% substitution often reported as optimal for maintaining acceptable sensory and technological properties. For example, composite wheat-based breads enriched with insect flours derived from Nauphoeta cinerea, Hermetia illucens, Acheta domesticus, and Tenebrio molitor have demonstrated improved nutritional quality while maintaining satisfactory dough characteristics, [48, 49]. These insect flours typically contain high levels of protein (45-57%) and fat (27-36%) on a dry weight basis, contributing significantly to the enhancement of the nutritional profile of composite bread products.

Notable increases in protein, fat, and fiber contents in insect-enriched bread formulations, with bread containing 10% cockroach flour showing a 49% increase in protein content without negatively affecting sensory attributes such as crumb hardness and overall acceptability [49]. Similarly, [48] observed that the incorporation of cockroach flour did not adversely affect the technological properties of composite bread, although the relatively high fat content of insect flours should be considered during product formulation. Beyond bakery applications, insect flours have also been successfully incorporated into traditional cereal-based foods. For instance, substitution of maize flour with 6.5% Tenebrio molitor larval flour significantly improved the protein, lipid, essential amino acid, and polyunsaturated fatty acid contents of maize tortillas [50]. Likewise, the incorporation of palm weevil larval (Rhynchophorus phoenicis) flour at substitution levels ranging from 10% to 50% in wheat-based biscuits resulted in substantial improvements in protein, lipid, and fiber contents [51]. Collectively, these findings highlight the potential of edible insects as functional ingredients for the development of nutritionally enriched cereal-based food products.

One of the major therapeutic benefits of edible insects is their role in cardiovascular health improvement. Insect lipids, particularly from species such as *Hermetia illucens* and *Tenebrio molitor*, contain a favorable ratio of Polyunsaturated Fatty Acids (PUFAs), which can help reduce LDL cholesterol and support heart health [13, 52]. Edible insects also exhibit strong anti-inflammatory and antioxidant properties due to the presence of peptides, phenolic compounds, and chitin-derived oligosaccharides. The bioactive components help reduce oxidative stress, which is a key factor in aging and chronic diseases such as diabetes and cancer [49]. In addition, insect protein has been shown to support glycemic control and metabolic health. High protein and fibre (chitin) content slows glucose absorption and improves satiety, which may help in the prevention and management of type 2 diabetes and obesity [48, 53]. Emerging studies also suggest that insect-derived bioactive peptides may have antimicrobial and immunomodulatory effects, enhancing gut health and immune response. Chitin and chitosan from insect exoskeletons can stimulate immune cells and promote beneficial gut microbiota balance [53, 54].

Table 2: Functional Applications of Edible Insects in Different Food Systems

Application	Function	Therapeutic / Health Effects	References
Whole edible insects (eggs, larvae, pupae, adults)	Nutrient-rich food source (protein, fat, micronutrients)	Supports general nutrition and food security	[45, 46]
Insect consumption in traditional diets (Asia, Africa, Mexico, India)	Alternative protein source	Enhances dietary diversity and nutrition	[47]
Insect powders in cereal-based products	Nutritional enrichment of foods	Improves protein and micronutrient content	[48]
Insect flour in wheat bread (e.g., *Acheta domesticus*, *Hermetia illucens*, *Tenebrio molitor*)	Protein enrichment, functional ingredient	Increases protein, fat, fibre; maintains acceptable sensory properties	[48, 49]
Cockroach (*Nauphoeta cinerea*) flour in bread	Improves nutritional quality	~49% increase in protein; good sensory acceptability	[49]
Insect flour composition	High nutrient density	Provides essential nutrients and energy	[48]
Yellow mealworm (*Tenebrio molitor*) flour in maize tortillas	Nutritional enhancement	Increases protein, essential amino acids, PUFA content	[50]
Palm weevil larva (*Rhynchophorus phoenicis*) flour in biscuits	Protein and fibre enrichment	Protein ↑86%, lipid ↑30%, fibre ↑64.2%	[51]
Insect lipids (PUFA-rich)	Lipid profile improvement	Reduces LDL cholesterol; cardioprotective effects	[13, 52]
Bioactive compounds (peptides, phenolics, chitin derivatives)	Antioxidant and anti-inflammatory activity	Reduces oxidative stress; lowers risk of chronic diseases	[49]
Insect protein and fibre (chitin)	Glycemic regulation, satiety	Improves glucose control; supports obesity and diabetes management	[48, 53]
Chitin and chitosan from insects	Immunomodulatory, gut health	Enhances immune response; improves gut microbiota	[53, 54]
Edible insects (general functional food role)	Functional food ingredient	Cardioprotective, antimicrobial, metabolic and immune benefits	[13, 54]

4.3 Inulin (From Roots of Artichoke Plant)

Artichoke (*Cynara cardunculus L. subsp. scolymus*), a perennial member of the Asteraceae family, is recognized as an important source of inulin, a bioactive polysaccharide widely valued for its functional and nutritional properties [55, 56, 57, 58]. Inulin extraction from artichoke roots has been successfully carried out using both conventional approaches such as hot water extraction and emerging techniques including ultrasound-assisted extraction [59, 60]. Due to its well-established prebiotic activity, inulin selectively stimulates the growth of beneficial intestinal microorganisms, thereby supporting gut health and contributing to the development of functional foods. Currently, inulin is used as a fat substitute [61, 62] a wall material and carrier for encapsulation of lipophilic compounds [63, 64], a gelling agent [65, 66] and a prebiotic ingredient [67]. It is also used to enhance the nutritional quality of fruit- and milk-based beverages [65, 68] and for the production of edible films [64]. Owing to its fibre content, inulin improves flavour and texture and provides significant advantages in bakery and cereal products compared to other dietary fibres [69].

The incorporation of inulin into food formulations has been widely reported to improve both technological and sensory properties of products. In baked goods, inulin contributes to enhanced crispiness while simultaneously helping retain moisture and maintain product palatability during extended storage. For example, the addition of 20% inulin to rice flour in gluten-free layered cakes significantly increased dietary fiber content while reducing fat levels [70]. Inulin has also been successfully utilized as a fat replacer in non-fat dairy products, where it provides sensory characteristics comparable to those of full-fat counterparts [71, 72]. In addition, inulin also contains short-chain fractions capable of enhancing perceived sweetness by up to 35%, allowing it to partially substitute sucrose in various food applications [73, 74].

The applications of inulin are given in Table 3. Inulin selectively stimulates growth of beneficial gut microbiota, especially *Lactobacilli* and *Bifidobacteria*, which improve intestinal health and suppress pathogenic bacteria. This modulation of gut microbiota is related with improved digestion, enhanced immunity, and reduced gastrointestinal disorders [4, 75]. Inulin has also been extensively studied for its role in glycaemics control and diabetes management. Due to its non-digestible nature, inulin does not raise blood glucose levels and helps improve insulin sensitivity. Clinical studies have shown that inulin supplementation can reduce fasting blood glucose and improve glycaemic response in patients with type 2 diabetes [76, 77]. Another important therapeutic benefit of inulin is its effect on lipid metabolism and cardiovascular health. Regular intake of inulin has been reported to reduce serum triglycerides and LDL cholesterol while increasing HDL levels, thereby lowering the risk of cardiovascular diseases [78, 79]. In addition, inulin contributes to weight management and satiety regulation. It enhances the release of gut hormones such as PYY and GLP-1, which helps in satiety and reduce overall calorie intake, making it useful in obesity prevention strategies [80]. Emerging research also suggests that inulin may have anticancer potential, as fermentation by gut microbiota produces Short-Chain Fatty Acids (SCFAs), particularly butyrate, which has been shown to inhibit colon cancer cell proliferation and promote apoptosis [81]. Overall, inulin demonstrates multiple therapeutic benefits, including prebiotic activity, glycaemic control, lipid regulation, weight management, and potential anticancer effects, making it a valuable functional ingredient in phytomedicine and preventive nutrition.

Table 3: Functional Applications of Inulin in the Food Industry

Application	Function	Therapeutic / Health Effects	References
Inulin from artichoke (*Cynara cardunculus*) roots	Source of dietary fibre (prebiotic)	Supports gut health and beneficial microbiota growth	[56, 57, 58]
Inulin extraction (hot water, ultrasound-assisted)	Efficient recovery of functional ingredient	Enables industrial utilization in food systems	[59, 60]
Inulin as prebiotic ingredient	Stimulates growth of *Bifidobacteria* and *Lactobacilli*	Improves digestion, immunity, and gut health	[4, 75, 82]
Inulin as fat replacer	Mimics fat texture and mouthfeel	Reduces fat intake while maintaining sensory quality	[61, 62, 67]
Inulin in gluten-free cakes (rice flour)	Improves texture, increases fibre	Reduces fat content; enhances dietary fibre intake	[70]
Inulin in dairy products (yogurt, custard)	Improves creaminess, smoothness	Enhances sensory properties of low-fat products	[83, 84, 85, 86]
Inulin in non-fat dairy products	Fat substitute	Provides characteristics similar to full-fat products	[71]
Inulin as gelling agent	Structure formation in foods	Improves texture and stability	[65, 66]
Inulin as encapsulation carrier	Wall material for lipophilic compounds	Enhances stability and delivery of bioactives	[63, 64]
Inulin in beverages (fruit/milk-based)	Nutritional enhancement	Improves functional value of beverages	[65, 68]
Inulin in edible films	Film-forming agent	Improves packaging functionality	[64]
Inulin as sugar replacer	Partial sucrose replacement	Reduces sugar intake	[73, 74]
Inulin and glycemic control	Non-digestible carbohydrate	Reduces blood glucose; improves insulin sensitivity	[76, 77]
Inulin and lipid metabolism	Modulates lipid profile	Reduces triglycerides and LDL; increases HDL	[78, 79]
Inulin and weight management	Regulates satiety hormones (GLP-1, PYY)	Reduces calorie intake; supports obesity prevention	[80]
Inulin and anticancer potential	SCFA (butyrate) production via fermentation	Inhibits colon cancer cell growth; promotes apoptosis	[81]

4.4 Prosopis Cineraria Plant

Prosopis cineraria (L.) Druce is an ecologically and nutritionally important tree species widely distributed in arid and semi-arid regions. Belonging to the family Leguminosae, Prosopis species are recognized as valuable sources of plant-derived proteins and contribute significantly to traditional food systems in regions such as India, South America, and northwestern Mexico. Notably, available literature indicates the absence of toxic or cyanogenic constituents in P. cineraria, further supporting its potential as a safe food resource [87]. The protein content of P. cineraria ranges from 16.5% to 27.25%, although higher protein levels have been reported in related leguminous species such as Acacia nilotica (25.47%) and Acacia senegal (38.89%) [88, 89]. In comparison, legumes and cereals generally contain protein between 10% and 18% [90, 91]. Therefore, *Prosopis* seeds are considered a cost-effective and promising protein source for industrial applications, particularly in developing countries, and may help address protein-energy malnutrition. In addition to protein, *Prosopis cineraria* is rich source of dietary fiber (20.93%) and ash content (5.34%) [93, 94, 95]. It is also gluten-free and provides essential minerals such as calcium, zinc, and potassium, along with amino acids like lysine, making it a valuable ingredient for food product development [96]. The unripe green pods are commonly consumed as vegetables and are also used in the preparation of pickles [95, 97, 98]. The pods consist of three main parts: mesocarp (56%), which is processed into flour, endocarp (35%), which is generally considered waste, and seeds (9%). *Prosopis* flour has been used to develop various food products such as bread, cakes, and chapatis, often by blending it with wheat flour [99]. In addition, *Prosopis* is utilized in the preparation of both fermented and unfermented beverages and syrups, further highlighting its potential in diversified food applications [100, 101, 102]. Table 4 gives the data in tabular format.

Table 4: Applications and Nutritional/Health Significance of *Prosopis cineraria*

Application	Function	Therapeutic / Nutritional Effects	References
Prosopis cineraria as food source (seeds, pods)	Plant-based protein source	Helps address protein-energy malnutrition	[88, 89]
Comparison with cereals and legumes	Nutritional superiority	Provides higher protein than many staple crops	[90, 91]
Dietary fibre content	Digestive health support	Improves gut health and digestion	[93, 94, 95]
Mineral-rich composition	Micronutrient supply	Supports metabolic and physiological functions	[96]
Amino acid profile (lysine-rich)	Enhances protein quality	Improves nutritional value of diets	[96]
Gluten-free nature	Suitable for special diets	Beneficial for gluten intolerance	[96]
Green pods as vegetable/pickle	Direct food consumption	Provides nutrients in traditional diets	[95, 97, 98]
Prosopis flour (mesocarp ~56%) in bakery products	Ingredient in bread, cakes, chapatis	Enhances nutritional quality of cereal-based foods	[99]
Seed utilization (~9% of pod)	Protein-rich fraction	Valuable for food formulations	[99]
Beverages and syrups (fermented/unfermented)	Functional food development	Expands dietary applications and energy sources	[100, 101, 102]
Safety profile (non-toxic, non-cyanogenic)	Safe consumption	No reported toxic compounds	[87]

4.5 Spent Yeast

Spent yeasts, generated as by-products of wine and beer fermentation, represent an important source of functional and bioactive compounds such as yeast extracts and β-glucans. These components are widely applied in the food industry as natural flavour enhancers, particularly in meat and savoury food products. In addition to their flavouring properties, spent yeasts possess significant nutritional value, containing lipids, carbohydrates, minerals (e.g., phosphorus, calcium, and magnesium), and B-complex vitamins [38]. Regulatory frameworks such as Regulation (EU) 2015/2283 further support the application of yeast extracts as natural flavouring agents and enable the use of yeast-derived β-glucans as novel functional ingredients. As a result, yeast-based formulations are increasingly incorporated into soups, sauces, meat products, savoury snacks, and food concentrates. Furthermore, yeast extracts have been shown to enhance the sensory quality of dietetic and reduced-fat or reduced-carbohydrate foods, improving flavour intensity and consumer acceptability [103, 104, 37].

4.6 Lab Grown Meat

Lab-grown meat is a new and promising approach for producing meat products traditionally obtained from livestock such as beef and cattle, and it forms an important part of the emerging field of a cellular agriculture. The main aim of this technological innovation is to reduce the negative impacts of conventional meat production on human health, animal welfare, and the environment. Global meat consumption increased by nearly 60% in between 1990 and 2009, and this technique is expected to continue due to rising income levels in regions such as Asia, Latin America, and the Middle East [105]. Lab-grown meat is produced by culturing adult muscle stem cells within a collagen-based scaffold derived from animal sources. These cells are provided with appropriate nutrients and energy sources to support their proliferation and differentiation into skeletal muscle fibers [106]. To enhance flavor, texture, and tenderness, fat cells are often co-cultured with muscle cells. The developed tissue is then harvested and processed for consumption. Furthermore, cultured meat can be engineered to modify the composition of amino acids and lipids, and it can be enriched with vitamins, minerals, and bioactive compounds, making it a promising functional food [107].

4.7 Seaweeds

Seaweeds and microalgae are found in all coastal regions of the world, ranging from tropical to cold polar environments. Most microalgae are edible and serve as rich sources of essential nutrients, including proteins, essential fatty acids minerals, vitamins, and phenolic compounds that are important for human growth and development. Seaweeds are considered sustainable sources of valuable bioactive compounds, attracting significant interest from the food industry [108, 109]. Their incorporation into bakery, dairy, fish, and both vegetarian and non-vegetarian food products enables the development of novel functional foods with improved nutritional value, quality, and health-promoting properties [110]. Comparison of nutritional characteristics and digestibility of different algal groups, including blue-green, green, red, and brown algae, and reported that brown algae contain the highest levels of dietary fiber but demonstrate relatively lower digestibility in *in vitro* studies [111]. In several regions of the western Pacific, species such as Gracilaria (Rhodophyta) and Caulerpa (Chlorophyta) are traditionally consumed as vegetables and contribute to local dietary practices [112]. Nevertheless, the broader nutritional potential of algae remains insufficiently exploited, largely due to challenges related to nutrient bioavailability and bioaccessibility that limit their effective utilization in human diets [108]. Although many algae species are considered safe for consumption, GRAS (Generally Recognized As Safe) status has been granted only to selected species such as, *Chlamydomonas reinhardtii*, *Auxenochlorella protothecoides*, *Arthrospira platensis*, *Euglena gracilis*, *Dunaliella bardawil*, and *Chlorella vulgaris* [113]. Algal proteins are known to contain all essential amino acids, along with fatty acids such as α-linolenic acid and linoleic acid, as well as various sugars [113]. In addition, omega-3 fatty acids such as DHA and EPA have been identified in several algal species [114]. A well-known example of edible seaweed is *nori*, which is widely used in Japanese cuisine [115]. Yeast extract is a naturally derived ingredient that is easy to produce, highly palatable, and imparts a salty, umami flavor. It is commonly used in food applications to enhance saltiness and improve overall flavor intensity [41]. In rece[nt ye]ars, yeast extract has gained attention as a natural alternative to salt in food formulations [116]. Additionally, cereal-based products are widely consumed due to their affordability, ease of processing, and long shelf life; however, their nutritional quality can be improved. Incorporating algae into cereal-based foods enhances their nutritional and functional properties due to their high content of bioactive compounds.

Pasta, a versatile cereal-based product, is widely recognized for being a good source of carbohydrates, B-group vitamins, and iron. However, it is relatively low in protein and essential amino acids. Therefore, fortification with algae can significantly improve its nutritional profile. Studies have shown that incorporation of fucoxanthin-rich edible algae such as wakame (*Undaria pinnatifida*) at 10% inclusion levels produced pasta that was highly acceptable to consumers, with only a slight algal flavor compared to the control sample. The interaction between starch and algal proteins contributed to improved product quality [117]. Similarly, *Sargassum marginatum*, an Indian brown seaweed, has been used in pasta production, enhancing both functional and nutritional properties [118]. Green algae such as *Monostroma nitidum* have also been used in the formulation of Chinese fresh egg noodles [119]. Bread is another cereal-based product that serves as an effective carrier for algal bioactive compounds. The addition of green algae (*Ulva lactuca*) and 2.5% powdered *Laminaria* has been shown to improve bread quality [120] and similar improvements have been reported in other algal-fortified bakery products [121].

Furthermore, macroalgae contain phycocolloids such as agar, alginates, and carrageenan, which are widely used for their gelling, thickening, and stabilizing properties in food systems [122, 123].

4.8 Spirulina

Spirulina is a filamentous, free-floating, multicellular, prokaryotic cyanobacterium [124]. It contains a high concentration of essential nutrients, including vitamins, minerals, proteins, and fatty acids, particularly omega-3 and omega-6 fatty acids [9]. In addition, spirulina has low levels of total fat and cholesterol compared to many other food sources [124]. It also contains several bioactive compounds such as polysaccharides, phenolic compounds, and phycocyanin, which contribute to various biological activities [125]. The amino acid profile of spirulina protein is considered one of the most balanced among plant-based protein sources [9]. The two main species classified under the genus *Spirulina* are *Arthrospira platensis* and *Arthrospira maxima* [124]. Spirulina is widely regarded as a “superfood” not only due to its rich nutritional composition but also because of its reported antiviral, antibacterial, antioxidant, antidiabetic, anticancer, and anti-inflammatory properties [126]. Its biomass typically consists of 55-70% protein, 15-25% carbohydrates, 6-8% lipids, 7-13% minerals, 3-7% moisture (dry weight basis), and 8-10% dietary fibre [127]. *Arthrospira* species have been classified as generally recognized as Safe (GRAS) by the U.S. Food and Drug Administration (FDA) for use in dietary supplements and human consumption.

4.9 Vegan Milk

The consumption of plant-based dairy alternatives has increased substantially worldwide due to their recognized health benefits and growing consumer awareness regarding diet-related health concerns. These beverages are particularly preferred by individuals with lactose intolerance, cow’s milk allergies, or those seeking to reduce cholesterol intake. It has been estimated that nearly 65% of the global population experiences some degree of lactose malabsorption (U.S. National Library of Medicine, 2020). Consequently, plant-based milk substitutes have attracted considerable research attention regarding both their health benefits and potential limitations. Plant-based milk alternatives are often regarded as beneficial because of their high antioxidant content and favourable fatty acid profiles, which may contribute to reducing the risk of chronic conditions such as diabetes, atherosclerosis, cancer, and cardiovascular diseases [128]. However, despite these advantages, certain nutritional limitations have been reported, including comparatively lower protein content and reduced bioavailability of some minerals and vitamins, as well as potential concerns related to dental health. These limitations are commonly addressed through nutritional fortification strategies to enhance their overall nutritional quality and functional value.

Consumer awareness of health benefits has significantly increased demand for plant-based milk products, with growth estimated at 60-70% in recent years. In 2018, the non-dairy creamer sector grew by 13.1%, while other plant-based products such as ice cream, yogurt, cream, butter, and salad dressings generated approximately 697 million USD. In addition to health benefits, plant-based milk production also offers environmental advantages, including reduced water usage, lower carbon footprint, and mitigation of climate change and ecotoxicity impacts [129].

Among plant-based alternatives, almond milk is widely consumed due to the high nutritional value of almonds, which contain approximately 25% protein, primarily in the form of amandin [130]. Almond milk is typically produced by dispersing partially defatted almond powder in water (8-10%) with a stabilizing hydrocolloid (~0.1%), followed by heating at 90 °C to solubilize the components, as described in patented processes (US 5656321 A). The mixture is then centrifuged to remove coarse particles, homogenized under high pressure, sterilized using Ultra-High Temperature (UHT) processing, and finally packaged aseptically [131].

Oilseeds, particularly peanuts, are also considered promising raw materials for non-dairy beverage production. Peanut milk can be produced using various processing methods, including defatting, roasting, alkali soaking, and steaming to improve product quality [132, 133]. Wet grinding is the most commonly used method, although full-fat and partially defatted peanut pastes have also been successfully applied. Spray-dried peanut protein isolates have also been explored; however, their use is limited due to high production costs [132]. Additional processing techniques such as heating, homogenization, and the use of stabilizers and emulsifiers have been studied to improve stability and consumer acceptability. Oat milk has recently gained popularity due to its nutritional and functional properties, including dietary fiber and phytochemical content. Oats are associated with several health benefits, including anti-inflammatory and hypocholesterolemic effects, particularly in reducing LDL cholesterol [134]. Oats consist of approximately 60% carbohydrates, 11-15% protein, 5-9% lipids, 2.3-8.5% dietary fiber, and 0.54% calcium [135]. However, their high starch content (55-60%), which gelatinizes at 44.7-73.7 °C, makes it difficult to produce a stable liquid beverage [136]. This often results in high viscosity and gel formation during heat treatment, reducing product acceptability. To overcome this issue, enzymatic hydrolysis of starch has been explored to improve fluidity and prevent gelatinization. Optimization of the enzymatic process for oat milk production to obtain improved product stability and quality done [137].

4.10 Pachira Aquatica (Monguba) Seeds

Pachira aquatica (Malvaceae) is an Unconventional Food Plant (UFP) native to Mexico and widely distributed in Brazil, commonly known as monguba. It is characterized by its distinctive flowers, arboreal growth habit, and cacao-like fruit containing multiple seeds [138]. Monguba seeds, known for their chestnut-like flavor and use in traditional medicine, exhibit significant nutritional value, including high levels of sugars (mainly sucrose), essential minerals such as potassium, calcium, magnesium, and zinc, as well as beneficial phenolic compounds. De Lara Lopes *et al.* [139] reported that monguba almonds exhibit low moisture content (<15%; 3.2-11.4%), which enhances their storage stability and microbiological safety while reducing susceptibility to biochemical deterioration [140, 141]. Monguba almonds contain crude protein ranging from 11.5% to 15.4%, with lower levels observed in the pericarp and leaves (7.8% and 10.4%, respectively), while total carbohydrate content ranges from 25.8% to 35.0%. They also possess relatively high dietary fibre content (12.0-17.2%), exceeding that of oats, a well-known high-fibre food [142] along with a valuable profile of micronutrients.

In addition, studies by Rezende *et al.* [143], Becker *et al.* [144], and Rodrigues *et al.* [141] have reported significant levels of phenolic compounds in monguba almonds, ranging from 0.207 to 13.28 mg/g (dry weight). Antioxidant activity, as assessed by the TEAC method, indicates that these phenolics are the primary contributors to the seeds' antioxidant potential. Key compounds such as caffeic and ferulic acids have been identified and are known for their free radical scavenging properties. Monguba almonds therefore demonstrate notable antioxidant capacity, with TEAC values reported up to 60.82 μmol TE/g. Owing to their favourable nutritional composition and bioactive properties, monguba almonds have potential applications in the food, pharmaceutical, and cosmetic industries. Additionally, the bark has been suggested as a natural antifungal agent and a potential source of dietary fibre for industrial use or flour production, although further research is required to confirm its practical applications and safety.

5. Conclusion

Non-conventional foods represent a promising and sustainable alternative to conventional food sources in addressing global challenges related to food security, malnutrition, and environmental sustainability. Diverse sources such as fungal biomass, insects, seaweeds, inulin-rich plants, oilseeds, pseudocereals, spent yeast, and emerging systems like plant-based and cultured meat offer a wide range of nutritional and functional benefits. These ingredients are rich in proteins, essential amino acids, dietary fibre, bioactive compounds, vitamins, and minerals, making them valuable for the development of functional and fortified foods. In addition to their nutritional advantages, non-conventional foods also contribute to improved techno-functional properties such as emulsification, gelling, texture enhancement, and flavour development in various food products. Despite their potential, challenges such as consumer acceptance, regulatory approval, safety evaluation, and large-scale production need to be addressed for wider commercialization. However, ongoing research and technological advancements in food processing and biotechnology are steadily improving their applicability and acceptance. Overall, non-conventional food sources are expected to play a significant role in the future food system by providing nutritious, sustainable, and innovative solutions to meet the dietary needs of a growing global population.

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