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Review

The Production of High-Added-Value Bioproducts from Non-Conventional Biomasses: An Overview

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Abstract: In recent decades, biomasses from different industrial segments have created new interesting perspectives, including sustainable development. Moreover, reusing waste, such as biomass, also impacts the economy, i.e., the circular economy. The main biomasses and their applications are evident in the energy, food, chemistry, fine chemical, and pharmaceutical sectors. Several questions should be asked regarding the trending topic of the circular economy, including biomass availability and seasonality, energy demand (processes), and the real environmental impact. Thus, this review focuses on biomass collected from non-conventional (unusual technology at the industrial scale) food-processing residues, particularly from 2016 to 2023, to produce biomaterials and/or bioproducts for the food sector.

Keywords: agro-biomass; conventional; non-conventional; application; food

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1. Introduction

Agricultural biomasses can be used to obtain new products and/or bioactive molecules, mainly for further applications in the food sector. Biomolecules are in high demand by health-food and pharmaceutical production companies. In this sense, a sustainable economy must be able to produce long-term solutions to climate change and environmental degradation, such as limiting overshoots, and unsustainable consumerism, including animal food and synthetic materials, to create a new, sustainable future [1].

A wide range of biomass residues from agriculture and food industries exist. Their applications are presented in Table 1. According to Antar et al. [2], the global biomass produced until 2018 was used by the energy generation sector. Saleem [3] showed several possibilities for converting agricultural biomasses into renewable energy sources, such as bioethanol collected from fruit and vegetable residues. Since the 17th century, biofuel production from agricultural waste has been investigated. In this sense, the first patent was presented in 1834 [4]. Other sectors have also investigated the use of biomasses, for instance, food-packaging, pharmaceutical, chemistry, civil building, and electric field industries [4,5], and produced polymalic acid, a homopolymer of L-malic acid obtained from food-processing waste and renewable biomass, for its application in the biomedical sector. Ranganathan et al. [6] showed several applications of biomass residues to produced biopolymers, mainly to reduce the demand for fossil-based polymers. However, these biomaterials present limitations due to their fragility, such as their barrier to water vapor, and mechanical and thermal elements [6,7]. Figure 1 summarizes the conventional applications of agro-food biomass residues at present.

Thus, during the sustainable development of reducing food waste during the production and transformation stages, as well as when evaluating its residues and biodiversity, agro-food residues, such as fruits, vegetables, tubers, and non-conventional vegetable sources, have shown great potential to impact the economies of different countries, without affecting the socio-environmental aspects. Most agro-food residues are rich in macromolecules, such as carbohydrates, proteins, and lipids, and active compounds, such as pigments, flavonoids, and polyphenols. This review discusses the production of biomaterials or biomolecules from biomass sub-products and their applications, particularly in the food sector.

Table 1. Biomass collected from agri-foods or food-processing waste using the biorefinery concept.

Biomass	Conversion	References
Sunflower seed residue oil extraction	Fuel to produce energy	[8]
Bamboo leaf waste	Dye adsorption (wastewater), hardwood floors, furniture	[9,10]
Eucalyptus leaves	Dye adsorption from contaminated waters	[11]
Rice straw	Delignification for bioethanol production	[12]
Agro-forestry biomass waste	Ethylene glycol production (direct catalytic conversion)	[13]
Sugarcane bagasse waste	Nanocellulose extraction for food-packaging products (biofilms)	[14]
Olive stones	Extrusion pretreatment for sugar production in food sector	[15]
Orange peel waste	Extraction of essential oils, pectin, and bacterial cellulose for the food industry	[16,17]
Grape stems	Extraction of polyphenol and volatile compounds	[18]
Sugarcane straw	Production of bio-butyric acid	[19]
Discarded food-waste residue	Biogas generation	[20]

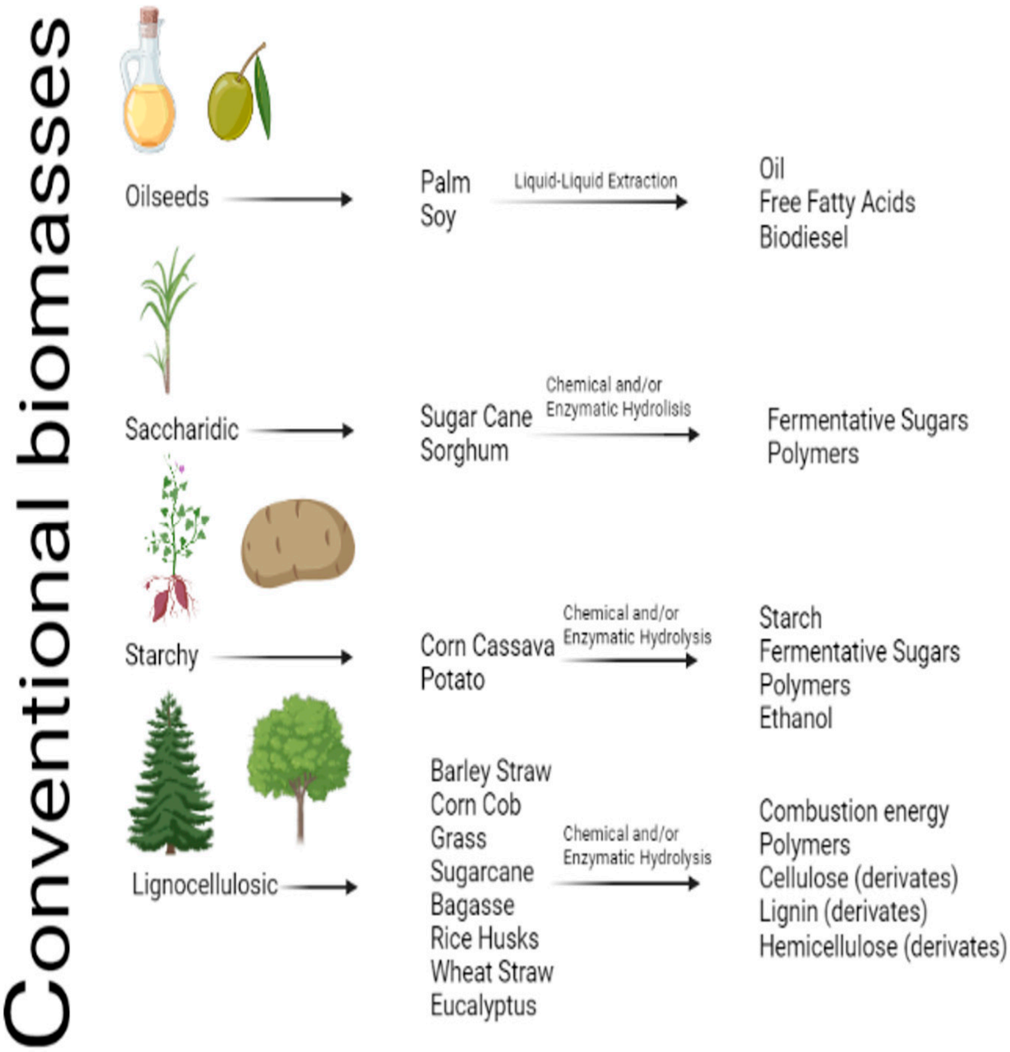

Figure 1. Conversion of conventional biomass residues to biomolecules.

Agricultural biomass has been used to develop sub-products and applications in several sectors. From 2016–2023, approximately 162 thousand reports used the keywords agro-food, food processing, waste, and application. Most of the research focuses on renewable energy and other applications, such as animal food, food ingredients, food-packaging, medicine, chemical, and textile industries. Thus, the keywords of non-conventional biomass, non-conventional fruits and vegetables, food-processing, and agro-food waste, were restricted to 2016–2023 in the Scopus and Google Scholar databases. Then, the words non-conventional seeds and non-conventional fruits and vegetables, including the words biomass or waste, were combined with biomaterials or ingredients. The non-conventional biomass materials of seeds, nuts, and fruits from Brazil (mainly from Cerrado and Amazon) were mostly exhibited during the search.

2. Bioproducts and Materials from Non-Conventional Sub-Products

In the food-supply chain, plenty of waste is produced by industries, in addition to consumers, while transporting and storing food that is damaged or inadequate for the market. This high quantity of residues or waste negatively impacts the environment and increases the lack or unavailability of food, especially for individuals with a low-income. Thus, to reduce food waste, studies are being conducted on various food sources, such as the use of residuals from rhizomes, cereals, and oilseeds, which are considered non-conventional residues (Figure 2).

2.1. Turmeric and Ginger Rhizome Biomass

Turmeric and ginger are mainly used in in Asian cuisines as condiments and flavorings. Moreover, these rhizomes have potent anti-inflammatory activities and health benefits due to their chemical compositions, such as curcumin, which is the main component of turmeric and gingerols and shogaols in ginger extract.

In the food sector, there is an increasing global demand for higher food-production rates. Thus, several strategies and technologies are being developed to increase the availability of ready-to-eat food with an extended shelf life and a reduction in synthetic chemical preservative agents. Among these strategies is the conversion of biomass residues into macro- and nano-molecules for applications in food. Ginger and turmeric rhizome residues have been studied as alternative biomass materials to be as preservatives in food. In this sense, essential oils or oleoresin extraction residues have been used to develop functional coating products, films, and active nano-molecules [21]. Tosati et al. [22] produced and applied starch from turmeric residue containing curcumin as active compounds to extend the food shelf-life using different approaches. For sausages, the effectiveness of the functional coating as an antimicrobial agent against mesophilic, lactic acid, and psychrotrophic bacteria was studied. This active coating extended the shelf-life of sausages for 30 days when compared to the traditional formulation. Similarly, turmeric residue starch was used to develop a hydrogel, and its effectiveness was evaluated by activating the curcumin with UV light against listeria innocua cross-contamination during the sausage-processing stage. It was observed that the curcumin in the coating, when activated by UV light, improved the product's resistance to listeria at several concentrations. In addition to these applications, turmeric biomass can also be used in food formulations as a colorant, added as a powder or extract, as nano- and macro-molecules, simultaneously promoting the antimicrobial and antifungal effects [23,24]. These authors showed the versatility of turmeric biomass applications in the food industry.

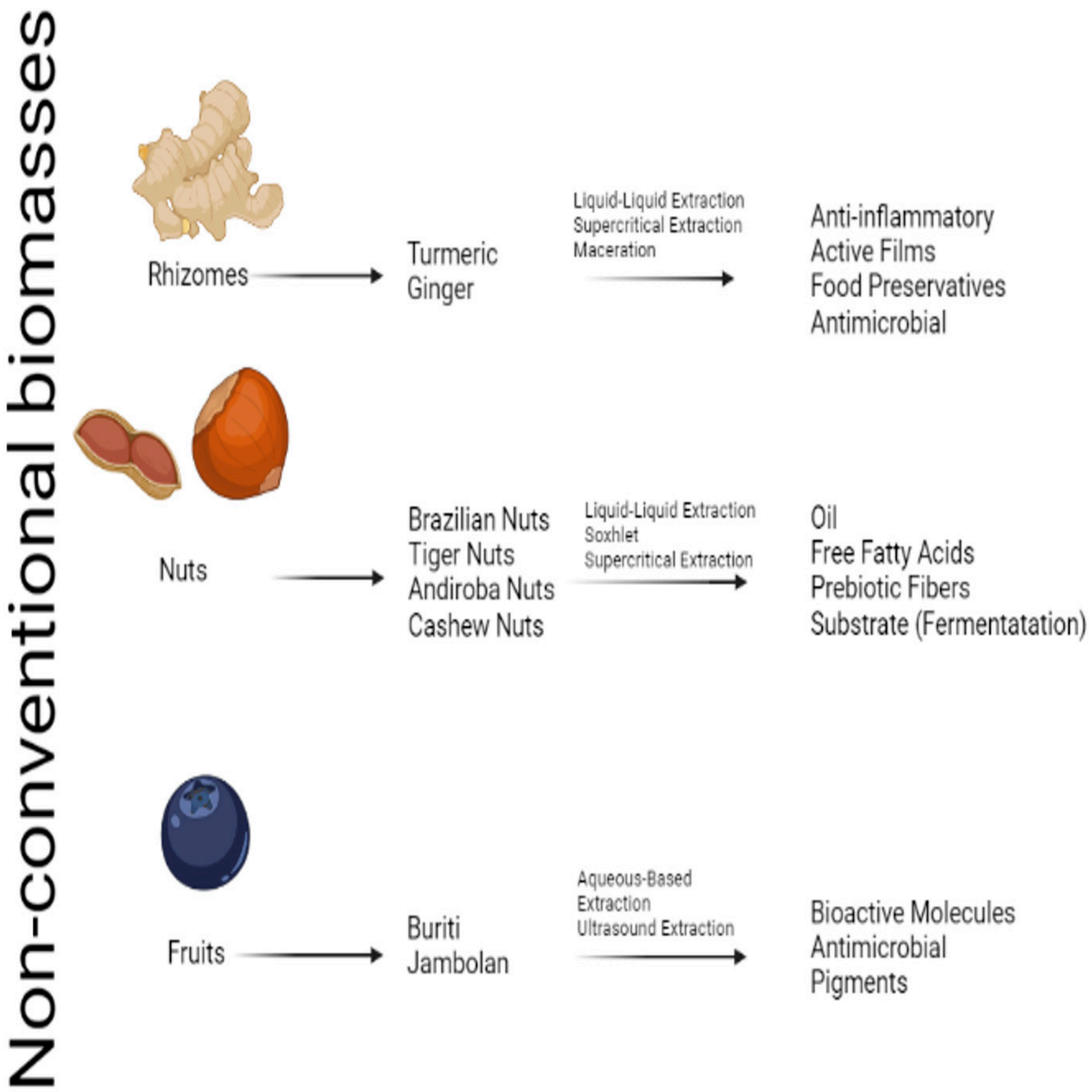

Figure 2. Conversion of non-conventional biomass residues to biomolecules.

Ginger residue also has been researched as an alternative product in the food sector; in one study, ginger residue obtained from processing presented approximately 80% of the dry, raw material and a biomass rich in fiber and starch. These molecules can form cohesive polymeric chains, which allows for their use as food-additive products during the production of films or edible active coatings, since they are a source of fiber and starch. Active films, when used in direct contact with food, stand out for their longevity because they act as a barrier against detrimental environmental conditions, such as low or high humidity levels, the presence of oxygen and light, and the control of their permeability to gas. Furthermore, ginger residue components, such as terpenes and phenolic compounds, exhibit biological activities, such as antimicrobial and pharmacological properties, including antibacterial, antifungal, antiviral, anti-inflammatory, antioxidant, and antitumor potentials. Therefore, the production of food films from the residue of ginger extracts has the potential to add active properties to food, prolonging its shelf-life and safety, and simultaneously enabling the reduction in the use of fossil-based polymers and their consequent environmental damage [25]. In a different field, Liangshuo et al. [26] synthesized biomass-based porous carbon materials with high specific surface areas using ginger slices by the activation and carbonization technique. Gao et al. [27] obtained oil from residual ginger waste, and micro-fibrillated cellulose was used to develop biobased material for applications in food, textiles, and membranes, in addition to sugar and starch recovery. In addition, the authors recovered bio-oils and energy-dense hydrochar.

2.2. Cereals, Nuts, and Seeds

Lignocellulose biomass has been used to obtain green fuels, with sugarcane straw being one of the most used in the industry. The main sources of lignocellulosic biomass are cellulose, hemicellulose, and lignins, generally cleaved by enzymatic hydrolysis. These waste from unconventional biomass is also being studied for its potential as an alternative co-adjuvant of bioproduct-processing, such as rye straw, rye bran, and oat bran waste products used as substrates by Drzymała et al. [28] for the growth of the yeast *Yarrowia lipolytica*, a microorganism known to have great biotechnological potential.

Biomass products from cereals, such as xylitol lactic acid, activated carbon, and phenolic acids, are wasted [29]. Furthermore, straws of spring cereal have been used as animal food due to their high nutritional value [30]. Rocha-Meneses et al. [31] ranked the countries that produced more cereal waste and their potential application in the bio-energy production sector. The data for the production of oat and rye cereals were obtained from 2005–2015, from the FAO bio-energy and food security database. Hassan et al. [32] showed that North America is the largest producer of cereal waste (around 35%). These residues cause environmental problems due to their high content of organic and inorganic harmful compounds, solid waste, and nutrients producing a biological oxygen demand (BOD) and chemical oxygen demand (COD) [32].

Nuts are also raw materials that produce high-biomass sub-products containing high levels of oil that can be used to cook and are included in cosmetic formulations. In addition, they are rich sources of carbohydrates and fibers. The waste from nuts maintains certain nutrients that can be incorporated into food formulations to improve their functional properties or to obtain fractioned nutrients, such as tocopherol, monounsaturated fatty acids, and lignocellulose, among other compounds [33,34].

Brazilian, tiger, andiroba, and cashew nuts are some examples of non-conventional nut residues that can be used as a source of nutrients in several industries and to reduce waste. For tiger nuts, waste can be obtained in a powder form as flour to produce gluten-free products, with high-dietary-fiber levels, and as probiotics in dairy and biobased products [33].

Cashew is a tropical tree indigenous to South America; however, it was spread to different countries by the Portuguese during their colonization of these countries during the 16th century. Brazil nuts are an Amazon nut traded in the international market. Cashew and Brazil nuts are consumed, in general, after the removing the dried shells, as snacks and in cereals, and also made into food items, such as chocolate bars. Both nuts, in recent years, have been used to produce milk for vegan consumers or individuals with allergies or lactose intolerance towards cow milk [35]. Cashew nutshell waste presents a residual oil fraction of around 35%, and chemical compounds, such as cardanol in a liquid extract residue, are a rich, functional agro-waste material. The nutshell liquid waste materials, which produces 1-octene and 3-nonylphenol by catalysis, are substances used in the chemical industry to produce polyethylene resin [36]. Cashew and Brazil nut waste have been studied to produce lignocellulose or fuel from the shell and pericarp, around 85% from total seeds; in addition, biochar and bioplastic materials have also been considered [37,38]. Cashew nuts are considered a source of high nutritional quality, mainly due to their protein, polyunsaturated fatty acid, carbohydrate, and mineral contents, in particular calcium, iron, and phosphorus. Additionally, Brazil nut cake residues from oil production is also a potential source of nutrients to produce bio-products. Gomes et al. [39]

produced encapsulated microparticles from Brazil nut cake waste as a new ingredient for food formulations. The microparticles showed high levels of phenolics compounds, such as quercetin, p-coumaric, gallic, and p-hydroxybenzoic acids. The same compounds were identified in raw residual cake from nut oil extracts, where the tocopherol compounds in the cake and selenium content in the microparticles were high. Leandro et al. [40] showed that Brazil nut waste can be used as flour to produce fibers, oligosaccharides, fertilizers, and energy. Sartori et al. [41] showed that a combination of antioxidant compounds, such as flavonoids, tocopherols, selenium, oleic acid, and linoleic acid, and other compounds that have anti-inflammatory activities in humans are present in the nuts and their residues.

Andiroba (*Carapa guianensis*) is a native Amazon tree; however, it was cultivated in western India and South Africa. Its seeds or nuts are used to obtain oil for the cosmetic and pharmaceutical industries. Native Amazons (Indigenous) use andiroba oil as a therapeutic treatment for physical injuries, such as bruises. A significant application of andiroba oil is in the cosmetic industry in butter formulations as a humectant, soap, gel, and oil for the skin. Due to the presence of oleic, linoleic, palmitic, and stearic acids in andiroba oil, they have been used in skincare and cosmetic formulations. In addition, some limonoids were identified in residual seed oils, a compound class that has health benefits, such as cholesterol reduction, anti-malarial effects, and cancer prevention [42]. Andiroba seed waste has also been studied to produce activated carbon, due to its specific surface area and porosity [43,44]. It is worth noting that phenolic compounds (antioxidant properties) can be extracted from andiroba seed residual cake.

2.3. Non-Conventional Fruit Biomass

Buriti (*Mauritia flexuosa*) is an Amazon and Cerrado palm fruit whose pulp is used to produce oil, and their residues were studied to produce biodiesel on a large scale. Buriti waste biomass can be divided into mesocarps, the residual cake from oil and peels. These residues are rich in lignocellulose, fibers, and residual oil content functional compounds, such as carotenes. Endocarp flour from Buriti is used to produce gluten-free cookies as a potential source of dietary fiber [45]. In Buriti peel extract, it was identified that saturated and unsaturated fatty acids could be used in food formulations. Both pulp and peel extracts presented antimicrobial activities against *Enterococcus fecal*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus*, showing their potential applications in the food sector [46].

Jambolan is a fruit rich in anthocyanin; however, it is considered an ornamental tree and the fruit is not valued in the commercial market or its use as a table fruit. Due the high anthocyanin content in the edible pulp, considered a compound class with health benefits, several studies have been developed using the jambolan as a new alternative for food ingredient, food colorant, or for its application in food-packaging [47–49]. Additionally, a study on the production of jambolan nectar as an alternative functional food was conducted [50].

Brazilian Cerrado (Savannah) can also produces fruits, such as murici (*Byrsonima crassifolia*), pequi (*Caryocar brasiliense Camb*), and sweet passion. These small fruits are processed to produce jelly, juice, and pulp. The seeds from these fruits can be a biomass source rich in oil and bioactive compounds. Pequi is rich in riboflavin, thiamine, provitamin A, and oil, attributing a high nutritional value to these edible fractions. Murici seed presents oil as the main biomass waste fraction, containing palmitic, oleic, and linoleic acids, as well as fibers and carbohydrates. In murici pulp, fatty acids are responsible for 95% of the total fatty acids. Sweet passion fruits are considered sources of oil, due to their high lipid content, and fiber (41.2 g/100 g). From these seeds, several macronutrients can be obtained and incorporated in food formulations [51–53].

Cashew pulp waste juice is also a promising source of bioproducts, once cashew tree cultivation is performed, primarily aiming for cashew nut production, in which cashews are considered as agricultural waste and a by-product of cashew nut production [54–58]. Cashew pulp is rich in bioactive compounds with anti-inflammatory, antimicrobial, and antifungal properties. In addition, cashew apple juice has lipoxygenase activity and is effective against Helicobacter pylori, which causes gastric diseases [59].

2.4. Legumes

Legumes also produce high residue levels, where an increase from 34 to 44% of the legume production rates in Europe was observed [60–63]. Soybeans, peas, chickpeas, and broad beans are the main commodities produced in Europe (FAOSTAT. Food and Agriculture data. 2017. Available online: http://www.fao.org/faostat/en/#home (2 April 2023). These biomass residues can be excellent nutrient sources for food applications, mainly vegetable proteins with a great potential to replace vegetable proteins and to produce vegan meat. Additionally, they can be a source of fiber and natural colorants. Micro- and macro-nutrients are present in the seeds and skin [60–62] showed that bean by-products have a rich composition of minerals (Mg, Fe, Zn, and Mn), proteins, and lipids. [63] evaluated buckwheat fractions in comparison to the functional and nutritional properties. The research showed that this vegetable biomass has high protein, lipid, dietary fiber, and mineral contents, such as K, Mg, Ca, Fe, Zn, and Mn. However, these macro- and micro-nutrients are evident in specific fractions, such as endosperm (fine flour) and semolina with a high amount of endosperm and small amount of bran; bran contains pure-bran and shell-content-bran portions and a pure shell. Thus, these fractions can be used in several health products. Table 2 shows the main cereal, seed, and nut residues' chemical compositions.

Table 2. Non-conventional sustainable biomass conversion using the circular economy.

Biomass	Main Composition	Trends for Applications in the Food Sector	References
(Rhizome) turmeric residue: from volatile and oleoresin extractions	Saturated fat, calcium, phosphorus, sodium potassium, thiamin, iron, riboflavin, dietary fibers, sugars and proteins, curcumin, starch	Macro- and nano-molecules in food: anti-inflammatory, antimicrobial food packaging (active biopolymer): active films and coatings	[64–66]
(Rhizome) ginger from volatile and oleoresin extractions	Total carbohydrates, dietary fibers, sugars, proteins, and starch Vitamins: B (thiamine) and E Essential oils: monoterpenes and sesquiterpénes; oleoresin: shogaols, gingerols	Macro- and nano-molecules in the food sector: anti-inflammatory and antimicrobial Packaging (biopolymer): active films and coatings	[25,27]
Tiger nuts	Minerals (protective nutrients), fibers, fat, proteins (higher than cassava), vitamins	Food formulation; green energy	[59,67]
Brazil nuts: shell and seed residues from oil extraction, milk, husks	Carbohydrates: starch, sugars; dietary fiber; fat: saturated, monounsaturated, polyunsaturated; protein: glutamic acid, arginine, leucine; vitamins: B, C, and E; minerals: calcium, iron, magnesium, manganese, phosphorus, potassium, sodium, zinc	Active food packaging; biomaterials for food applications; biopolymers; effluents treatment; biodiesel; and green energy	[40,41,68–70]

Table 2. *Cont.*

Biomass	Main Composition	Trends for Applications in the Food Sector	References
Cashew shell (nuts) and pulp residue from juice extraction	Protein, ash, sodium (Na), lipids, phenolic compounds, lignin, fibers, starch	Food formulation, active food package (biopolymer), synthesis material production, biodiesel	[54,56,57,71]
Buriti: skin, pulp waste from oil extraction	Lipids, proteins, ashes, dietary fibers, carbohydrates	Food industry: bioactive molecules, antimicrobial pigments	[72–74]
Jambolan: pulp	Monomeric anthocyanins: phenolics and tannins	Food colorant, meat control, food packaging	[47–49,75]
Pequi: skin and seeds	Furanic compounds, organic acids, and derivatives, such as levulinic acid	Biochar, food pigments and ingredients	[53,76]
Bean and pea flours	Protein and lipids	Emulsion stability and foaming	[62]
Buckwheat grain flour milled fractions	Protein, carbohydrates, and minerals	Suplementary food: gluten-free food products	[63]

3. Collection and Application of the Bio-Compounds and Molecules from Biomass Agro-Foods

Biomass waste from non-conventional raw materials (fruits and vegetables), including seeds, fruits, and roots, were discussed in this study. Mostly, biomass was used for biodegradable, smart, or active packaging and sensors in the food sector and as ingredients for food formulations. However, industrial applications at present are related to cosmetics, mainly produced from Amazonian seeds, fruit, and nuts.

The applications or use of natural dyes or colorants, functional foods, and active biomaterials using natural compounds have the following challenges: (1) obtaining and stabilizing the bio-compounds; (2) establishing their functionality when added into or on food, and (3) evaluating their function and behavior in the human body and whether they produce health benefits.

For the extraction of compounds or molecules from biomass, the process that maintains the bioactive molecules or compounds, the research should focus on green technologies and solvents, as well as the energy that is required to obtain the products. Thus, regarding the biomass processing stage, the chain of sustainability in the circular economy will be preserved. Thus, the residual oil collected from ginger waste was recovered by supercritical CO_2 and hydrodistillation. Hydrothermal microwave technology was used to obtain starch, micro-fibrillated cellulose, and sugar. Bio-oil and hydrochar were obtained by conventional microwave pyrolysis [27]. According to Luiza Koop et al. [47], Jambolan extract was obtained using ethanol at room temperature and concentrated by ultra- and nanofiltration membranes to preserve the anthocyanins. Green extraction technologies are essential to the recovery and preservation processes, sustainably, the active compounds or active molecules for future applications in the food sector or cosmetic or pharmaceutical industries. In addition, these technologies do not apply organic solvents or produce residues that can represent potential environmental risks; on the other hand, liquid–liquid extraction based on organic solvents, such as hexane, petroleum ether, among others, must at least be avoidable. In this sense, the mostly used emergent or green extraction technologies are supercritical fluid (SF), ultrasound, microwave, hydrostatic high pressure, ultraviolet light, pulsed electric field, and cold plasma. SF is a technology that can be used to obtain oil or extract to encapsulate or fractionate bioactive compounds or biomolecules using moderate temperatures and high pressure. This technology is based on the enhanced solvating power of gasses above their critical point when a highly compressed fluid combines the thermodynamic properties of gases and liquids [77]. Regarding the bioactive molecules, the most favorable solvent is carbon dioxide, due its lower critical pressure and temperature values. The great advantage of this technology is its ability to produce extracts free of chemical residues; on the other hand, the main disadvantage is the high cost of the equipment (setup). Chai et al. [78] used SF to obtain protein and starch from agri-food residues and to develop biomaterials. Tzima et al. [79] presented recent applications using SF to obtain pigments, lipids, and bio-compounds from algae. Li and Xu [80] showed several studies using SF to obtain phenolic compounds from tropical biomasses, and also correlated the chemical structure of compounds with their solvent polarity values. Ultrasound technology is also defined as a green technology that can be used to obtain biomolecules. This process is based on the cavitation process that accelerates heat and mass transfer processes improving the release of compounds from the matrix, thus reducing the processing time and presenting a higher yield [81–83]. Therefore, the application of friendly technologies to recover bioproducts from biomass residues can contribute to the preservation of biomolecules, coproducts, or compounds, and the reduction in energy consumption levels.

Natural active compounds, such as anthocyanins, curcumin, and carotenoids, are unstable to light, pH range, heat, and oxygen contact; moreover, they present low water solubility levels and, consequently, low bioavailability levels. In this sense, the applications of the natural active compounds from biomass in food formulations, or to produce biomaterials, must be protected or stabilized before their utilization. The most common strategy to preserve bio-compounds is encapsulation to produce nano- or micro-particles. Additionally, the exploration and valorization of the by-products for the food application sector or as co-adjuvants of healthcare is necessary to investigate their mode of action both in food and the human body [47,48,84]. Koop et al. [85] produced an active biohybrid to stabilize jambolan pigments using montmorillonite, and this biohybrid was used to create a cassava starch bio-label to control the freshness of meat during storage. Curcumin microparticles were stabilized into hydroxymethyl propyl cellulose using an antisolvent technique. The stabilized microparticles were incorporated into the biodegradable film formulation. The release of the native and micro-particles of curcumin were also studied. Modified curcumin showed a higher release percentage than native curcumin from the film [86]. A cellulose nanocrystal was also produced to stabilize bio-compounds obtained from several biomasses before their applications [87]. Ahmed et al. [88] stabilized curcumin by nano-emulsion using isolated protein from peas as a partial substitution of sodium caseinate and evaluated the in vitro digestion, digestibility, and bio-accessibility, and concluded that pea protein can be used to protect, carry, and delivery bio-compounds. Abbas et al. [89] showed the influence of modified starch using chitosan and carboxymethyl cellulose (CMC) under a stable environment, including pH and temperature levels, and the in vitro digestibility of curcumin for its application in food and beverages. Several studies have demonstrated that carotenoids have excellent antioxidant, antimicrobial, and anti-inflammatory properties, significantly contributing to the reduction in cancer incidence and depression outcomes [90,91]. The carotenoids present in buriti oil were stabilized by spray-dryer microencapsulation using chickpea protein and high-methoxyl pectin complexes. Chickpea proteins were isolated by isoelectric precipitation, and the polymer combination provided high carotenoid protection [92]. Thus, these nano-encapsulated bioactive products can be used as substitutes for synthetic dyes or in other sectors.

The recovery of biomolecules, such as peptides and polysaccharides, also need to be evaluated for their functionality, before being applied in the food sector. In general, the extractions of these biomolecules were achieved using organic solvents and purifications for further applications. However, in recent decades, green technology, such as water and supercritical CO_2, and ultrasound have been used. [93] obtained three polysaccharides from ginger skin, following the purification protocol. Wang et al. [94] extracted, by enzymatic hydrolysis, and purified polysaccharides from ginger rhizomes and showed that these polysaccharides, such as mannose, glucose, and galactose, have high antioxidant and anti-inflammatory activities.

All the factors described must be considered for the applications, mainly in the food sector. Biodegradable materials, such as coating and films, and the release rate from active compounds from the coating and film into the food is enough to preserve the food or to provide the health benefits. These bio-based materials (biodegradable packaging, film, and coating) are produced using macromolecules, such as starch, proteins, lipids, polysaccharides, and cellulose, obtained from renewable sources. Thus, the biomass from non-conventional agro-foods creates alternatives for active food-packaging materials produced from functional waste. Table 3 shows the main technologies that were used to obtain coproducts or products from agro-food biomasses.

Table 3. Technologies for obtaining molecules and bio-compounds from biomass agro-foods.

Biomass	Technology	Biomolecules or Coproducts Obtained	Main Results	References
Curcuma longa (CL) and *Curcuma (CA) amada*	Supercritical fluid	Oleoresins, curcuminoids, and total volatiles	CL have better bioactivity than CA because of the high concentration of curcuminoids. In vivo anti-inflammatory activity os CA is greater than CL	[95]
Turmeric, ginger residue, and pomegranate peel	Soxhlet extraction with absolute ethanol	Essential oil and oleoresin	Milk incorporated with ginger; turmeric and pomegranate peel extracts with high biological properties	[96]
Ginger leaves and stems	Extraction methods: hot water (HWE), ultrasound-assisted extraction (UAE), alkaline solution extraction (ASE), and enzyme-assisted extraction (EAE)	Active polysaccharides	ASE produces the highest yield and lower hypoglycemic and antioxidant activities	[97]
Tiger nuts	Soxhlet extraction with petroleum ether	Oil: oleic acid, palmitic acid, linoleic acid, stearic acid, tocopherols, tocotrienols, phytosterol Residues: fibers and polyphenols	Short extraction time and high yield with residues in oil	[98]
Tucuman (coproduct of tucuma kernels)	Ultrasonic-assisted extraction and spray dryer	Oily extract and microparticles	Total carotenoids contained in oily extract was higher than microparticles	[99]
Symphytum officinale	Ultraviolet-light-assisted extraction	Flavonoids and allantoin	UV radiation enhances the yields of active ingredients	[100]

4. Biomass from Non-Conventional Agri-Foods and Sustainability: Future Perspectives

Plastic or packaging from synthetic polymers are permanent waste products. The production and use of these fossil-based polymers are still 95% greater than all primary materials; in 2017, this exceeded nine billion meters of tons, in which seven billion tons of waste was generated. For this reason, the use of biomass for several products, such, as biodegradable packaging, is a good alternative to reduce the waste from agricultural residues and the use of fossil-based polymers, in addition to the bio-energy sector promoting a bio-circular economy. Particularly, in the packaging sector, per year, it is estimated that nine million tons of fossil-based polymers (plastic) in rivers, oceans, and lakes generate microplastics that harm marine life and affect the human food chain through seafood production and water; if this growth continues, the prediction is that, in 2050, the production rate will reach approximately 1.1 billion tons. On the other hand, the waste food supply chain will reach approximately 1.3 billion tons, causing a negative impact on the soil, water, and overall environment [101], including large waste effluents in food industry and high levels of water consumption. Thus, due to the importance of reducing the use of fossil-based polymers and their presence in landfill, it is important improve the properties of these bio-plastics, such as the mechanical properties and permeability to humidity and gas. In addition, for new sources of food ingredients, regulations are necessary; thus, in practice, there are implications for the utilization of food waste, in both the pharmaceutical and cosmetic sectors.

5. Conclusions

Conventional biomass waste has been used to extract or produce high-added-value compounds (e.g., palm residue—oils, free fatty acids, biodiesels; sugar cane bagasse—fermentable, xylose-based xylooligosaccharides). However, biomass agro-foods present high potential sources of biomolecules with functional properties for use in the food sector. Many non-conventional residues can be investigated and explored at the industrial scale, such as Jambolan—with a rich biomass of anthocyanins (173.69 mg/100 g) and phenolics. The seeds, skin, and shells are promising sources of fibers, proteins, lipids, and minerals with functional properties. Thus, the food industry sector must pay special attention to biomass waste content in bioactive compounds in order to reduce environment waste and increase the availability of natural ingredients.

Therefore, these residues are promising sources of molecules that can be applied in both the food and pharmaceutical industries.

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