Chapter

Introductory Chapter: From Waste to New Resources

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1. Introduction

Food represents as one of the most basic human needs, providing our physical integrity. The entire planet is facing an alarming issue, regarding the amount of edible food and by-products, which are wasted in an increasingly manner. Moreover, food manufacturing requires resources such as soil and water and involves various processes, which generate huge amounts of food waste. As the production of food is resource-intensive, food losses and wastes are strongly correlated with a broad range of environmental problems, such as water and air pollution, soil erosion, and greenhouse gas emissions; all of these undesirable effects occur in all stages of production, storage, and transportation as well as in the case of adopting a deficient management system [1].

The generation of food waste is inevitable, especially during the pre-consumption stage. It is estimated that up to 42% of food waste is generated from household activities, 39% occur from the food manufacturing industry, and 14% occur from the food service sector (catering and restaurants), while 5% is lost during storage and distribution. This problem is intensified by the global population growth leading consequently to an increasing demand for natural resources like food and energy [2, 3].

Nowadays, the biggest challenge of the scientific world is to provide viable alternative models that combine food production with an efficient valorization strategy of waste and by-product, minimization of energy consumption, and environmental protection. In this context, the exploitation of food waste or by-products for the recovery of valuable functional compounds can be considered as being one of the most feasible approaches [4].

In order to implement a circular economy in any industrial sector, two main strategies are needed: reducing waste levels and finding the most sustainable solution to manage the remaining waste. In particular, the waste management of new strategies focus on the following actions: waste prevention, reuse, recycling, energy recovery, and, lastly, disposal [5].

Until a few decades ago, food waste was considered neither a cost nor a benefit being usually discarded to landfills, sent for composting, or used as animal feed. The negative perception on these by-products and implicitly the application of a deficient management lead to environmental degradation and especially to significant loss of valuable material that could otherwise be exploited as food, fuels, and a great variety of additives [6].

At present, the attitude has changed radically, the researches being intensely oriented toward the identification and extraction of valuable compounds from residues and their reintegration in the food industry but also in other fields such as cosmetics, pharmaceuticals, or agriculture (**Figure 1**).

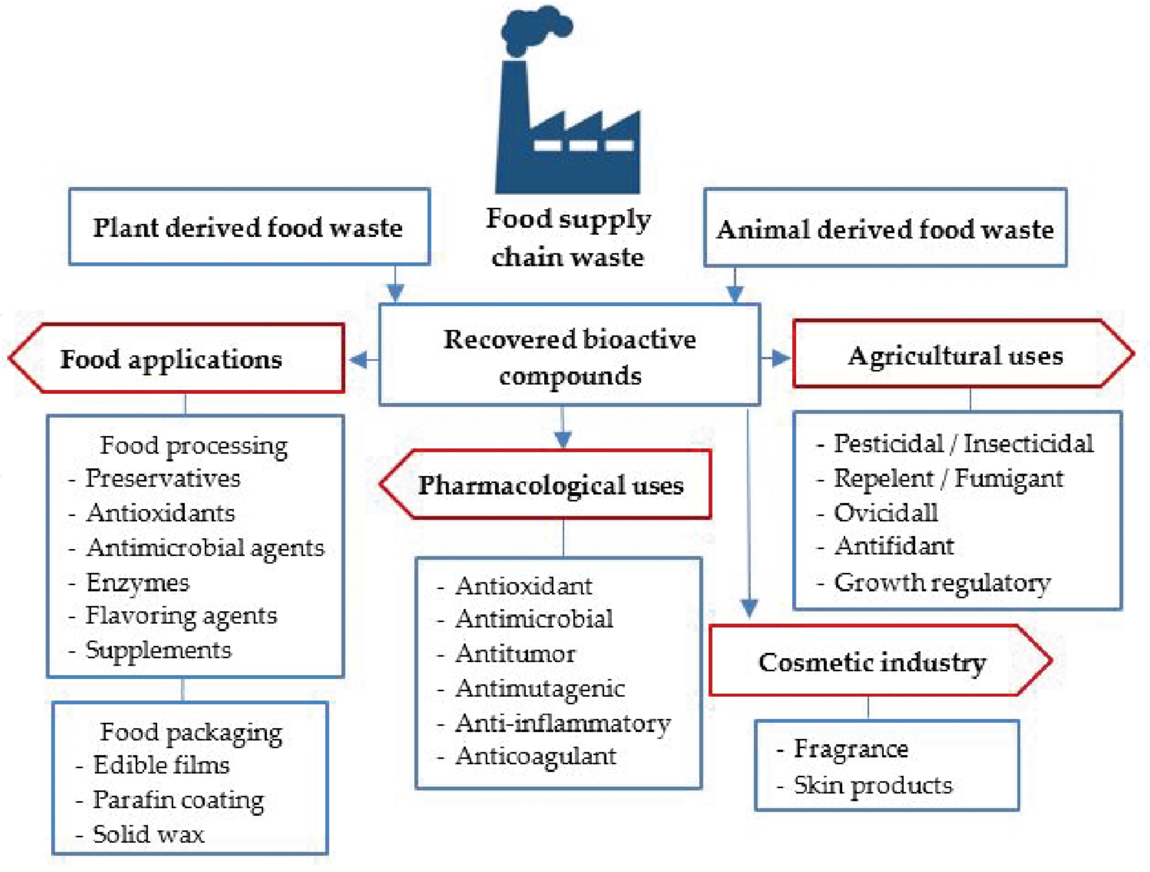

Figure 1.
The main applications of bioactive compounds extracted from agri-food waste.

Using the recovered bioactive molecules as functional ingredients represents a sustainable alternative of food waste exploitation as an inexpensive source of valuable compounds while developing innovative food and nonfood products with health-promoting benefits and at the same time contributing to an efficient waste reduction management.

2. Extraction technologies for bioactive compounds from food waste

Most of the wastes generated by the agri-food industries are difficult to store, transport, and process because of the biological instability, pathogenic potential, high levels of nutrients or enzyme activity, high water content, and the potential for self-oxidation.

The new aspects concerning the use of agri-food wastes as by-products for further exploitation in the production of various functional products must be environmentally friendly and sustainable from the economic point of view [7–9]. Therefore, it is imperative to identify the most feasible and optimized stabilization methods in order to ensure a flow of biomass with a constant composition and reduced storage and transport costs.

For this purpose, technological innovation has favored the development of many effective exploitation methods, with cogeneration of electricity and thermal biogas, also called green energy. In addition, the implementation of a biorefinery concept offers remarkable opportunities to valorize biomass by converting it to a wide range of chemicals with many applications in food, cosmetic, and pharmaceutical industries [10, 11].

The innovative approach of converting food waste in new generation of useful products involves the application of unconventional methods and advanced techniques in order to model the most appropriate and sustainable recovery system (**Figure 2**).

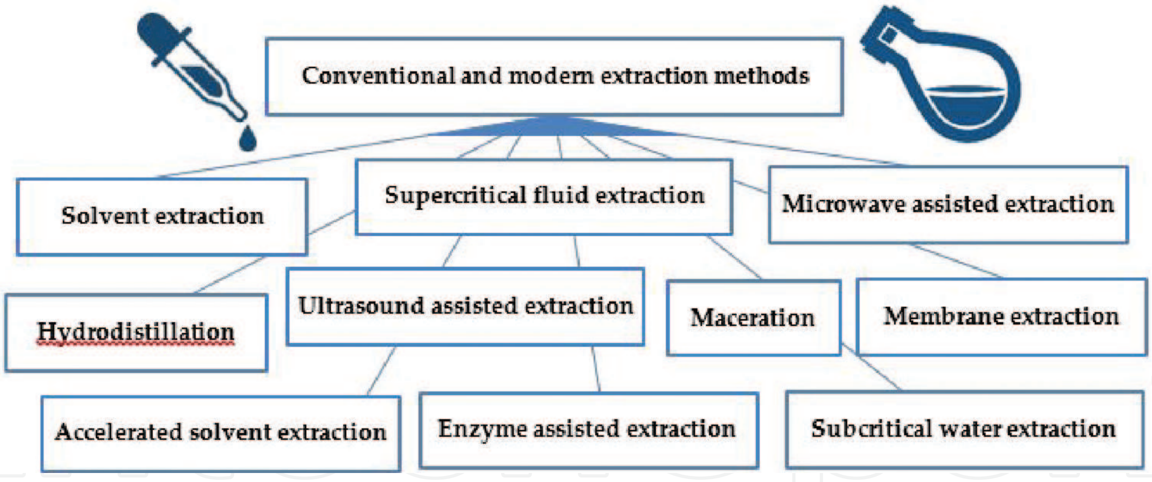

Figure 2.
A schematic representation of the most used conventional and novel techniques suitable for extracting biomolecules.

Nevertheless, the extraction protocols cannot be used indiscriminately, and their choice depends on the type of bioactive compounds and matrix structure, the processing scale (pilot or industrial level), the balance between processing costs and economic income of the recovered component, and their new assigned destinations [6].

In the last years, the researches focused on the development and optimization of the methods for the recovery and purifications of the functional compounds; some of them are based on new emerging techniques, but some are effective by applying and modeling the existing conventional method. In both situations, the extraction of the high-value components must be environmentally friendly and economically feasible to perform.

The applied parameters have a major impact on the release of the bioactive compounds from the matrix but also on their structure and functionality. Therefore, selecting the most suitable extraction protocol is a decisive step for the recovery of the valuable component [6, 9, 12].

Several examples of bioactive compounds recovered from food processing by-products and the selected extraction methods are presented in **Table 1**.

3. Food preservation for minimizing food waste

Beside the possibilities mentioned before for the proper management of food waste and its valorization through the recovery of the bioactive compounds, we also need to consider the role of food preservation to reduce food waste. Following harvest, slaughter, or manufacture, all foods start to lose quality. The rate at which food quality is lost is dependent on food type, composition, the way it was processed, packed and storage conditions. On the other hand, the lost of quality and safety attributes of the foods may occur at any stage in the food chain generating food waste: raw material storage; product formulation; processing; packaging; storage in the factory; distribution to depots and storage; distribution to retail outlets; display in stores; sale to the consumer and further storage; preparation for consumption. Nonetheless, by applying conventional, highly advanced or hurdle preservation techniques (**Figure 3**), one can impede the chemical or microbiological deteriorations, thus preventing outbreaks of foodborne illness and at the same time limiting the food waste. As it is illustrated in **Figure 3**, in the food industry, beside the commonly used preservation techniques, a number of new ones are being developed to

Recovered compounds	Waste source	Extraction method	Ref.
Polysaccharide/dietary fibers	Fruits pomace, sugar beet, sunflower heads	Solid-liquid extraction	[13]
	Citrus peel and apple pomace	Subcritical water extraction	[14]
	Cereal by-products	Enzymatic treatment and sequential extraction	[15]
	Apple pomace	Hot-compressed water	[16]
		Organic acids	[17]
	Olive mill wastewaters	Ultrafiltration and nanofiltration	[18]
	Rice bran	Microwave treatment and microbial fermentation	[19]
Phenolic compounds	Apple pomace	Microwave-assisted extraction	[20]
		Electric field-assisted extraction	[21]
	Tomato pomace and skin	Enzymatic-assisted extraction/solvent extraction	[22]
	Potato peels	Microwave-assisted extraction	[23]
	Olive cake	Ultrasound-assisted extraction	[24]
	Avocado peel and seeds	Solvent extraction	[25]
	Wheat beans	Ultrasound-assisted extraction	[26]
	Tea by-products	Supercritical fluid extraction; microwave-assisted extraction/solvent extraction	[27, 28]
	Bran and germs	Ultrasound-assisted extraction	[29]
	Grape by-products	Ultrafiltration	[30]
		High-voltage electrical discharges and ultrafiltration	[31]
		Supercritical fluid extraction	[32]
		Solvent extraction/microwave-assisted extraction/ultrasound-assisted extraction	[33]
	Blueberry residue	Supercritical fluid extraction and pressurized liquids	[34]
	Flax seeds	Solid-liquid extraction	[35]

Recovered compounds	**Waste source**	**Extraction method**	**Ref.**
Caffeine	Tea waste	Microwave-assisted extraction/solvent extraction	[28]
Oils	Rice bran	Supercritical carbon dioxide extraction and compressed liquefied petroleum gas/solid-liquid extraction	[36, 37]
Essential oils	Citrus peel	Solvent extraction/hydrodistillation	[38]
		Steam explosion at high temperature and pressure	[39]
		Microwave-assisted hydro-diffusion	[40]
Proteins	Brewers' spent grain	Sequential extraction of proteins and arabinoxylans; enzymatic-assisted extraction	[15, 41]
	Rice by-products	Enzymatic hydrolysis and membrane filtration technique	[42]
	Hazelnut meal	Solvent extraction (water, acetone)	[43]
	Rapeseed by-products	Ultrasound-assisted aqueous extraction	[44]
Carotenoids	Tomato pomace and skin	Enzymatic-assisted extraction	[45]
		Supercritical fluid extraction/solvent extraction	[46]
		Supercritical fluid extraction	[47]
	Citrus peel	Ultrasound-assisted extraction	[48]
	Sea buckthorn seeds	Supercritical carbon dioxide fluid extraction	[49]
Proteins and bioactive peptides	Whey wastewater	Membrane separation/ultrafiltration/microfiltration/nanofiltration/reverse osmoses	[50]
		Mild enzymatic hydrolysis	[51]
	Cheese whey	Ultrafiltration/nanofiltration	[52]
	Fish and chicken	Isoelectric solubilization and precipitation	[53]
	Sardine solid waste	Enzymatic hydrolysis and ultrafiltration	[54]
	Shellfish	Enzymatic hydrolysis and micro-, ultra-, and nanofiltration/ion exchange chromatography	[55]
Sugars	Whey wastewater	Membrane separation and spray drying	[50]
	Cheese whey	Ultrafiltration/nanofiltration	[52]

Table 1.
Examples of bioactive compounds from plant- and animal-derived by-products and the applied extraction techniques.

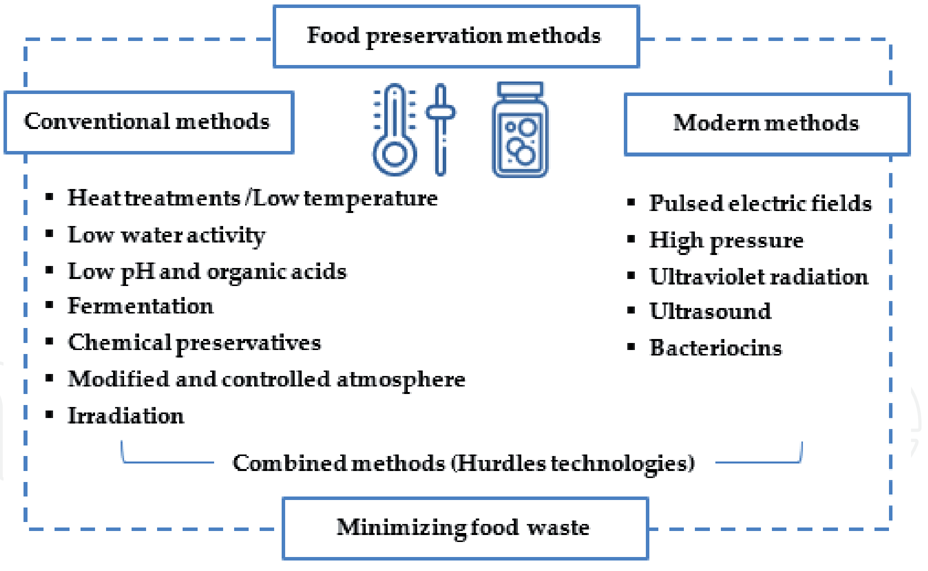

Figure 3.
A schematic representation of the most used conventional and novel techniques for foods preservation.

satisfy the current demands of economic preservation and consumer satisfaction in safety, nutritional and sensory aspects. Also, as the preservation of foods is often a multicomponent issue, the "hurdle" concept was introduced, highlighting the complex interaction between the factors that are significant for food safety and stability [56–58].

4. Concluding remarks and future trends

The idea of converting the agri-food waste into functional ingredients is an area of research with huge potential and opportunities. Many researches in biotechnology have already shown that agri-food by-products are no longer regarded as a waste but rather a valuable substrate for producing a new range of useful compounds. Based on this, it is an undeniable fact that, through compatible biotechnological processes, every food processing by-product possesses a relevant potential for a sustainable reuse.

The recent findings, presented in the chapters of this book, highlighted the potential reuse of food industry by-products and led to the idea that multidisciplinary approaches should be implemented in order to achieve the most effective exploitation protocol or to develop integrated biorefineries

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