CellPress

Review

Exploitation of Food Industry Waste for High-Value Products

Rajeev Ravindran[1] and Amit K. Jaiswal[1,*]

A growing global population leads to an increasing demand for food production and the processing industry associated with it and consequently the generation of large amounts of food waste. This problem is intensified due to slow progress in the development of effective waste management strategies and measures for the proper treatment and disposal of waste. Food waste is a reservoir of complex carbohydrates, proteins, lipids, and nutraceuticals and can form the raw materials for commercially important metabolites. The current legislation on food waste treatment prioritises the prevention of waste generation and least emphasises disposal. Recent valorisation studies for food supply chain waste opens avenues to the production of biofuels, enzymes, bioactive compounds, biodegradable plastics, and nanoparticles among many other molecules.

Food Waste as a Global Concern

The global population is expanding at an exponential rate every year. There is a huge demand for food and energy to meet the needs of society. Rapid urbanisation combined with slow progress in the development of and ineffective waste management strategies leads to the accumulation of food waste. A study published by the EU in 2010 revealed that almost 90 million tonnes of food waste are expelled from the food manufacturing industry every year [1]. Food waste, being high in nutritional content, putrefies on accumulation, providing breeding grounds for disease-causing organisms. This poses serious environmental issues and very few options exist today to deal with them. While preventive measures can be taken to reduce the generation of food waste it is important to deal with the existing accumulated food waste. The idea of converting food waste into energy and other chemicals used in our daily activities is an area of research with huge potential and opportunities. This review deals with the types of food waste and problems associated with them, the legislation pertaining to reducing food waste as well as using it as a renewable **feedstock** (see Glossary), and the various products and the latest valorisation techniques developed in recent years using food waste as a raw material.

Food Industry Waste as a Renewable Resource

Food industry waste is particularly interesting for renewable energy researchers as it is mostly lignocellulosic in nature, with high cellulose and lignin content (except animal-derived food waste). Many studies have reported on various technologies for the conversion of food waste such as apple pomace and brewers' spent grain into biofuel [2,3]. Cellulose and hemicelluloses on enzymatic breakdown release glucose and xylose, which can be converted into ethanol by fermentative microorganisms [4]. Furthermore, lignin on pyrolysis and anaerobic digestion yields H_2 and CH_4 [5]. In the quest for renewable energy resources with the backdrop of rising oil prices, one overlooks the fact that food waste is a reservoir of other value-added chemicals. Recent studies suggest that the production of bulk chemicals from biomass waste is 3.5 times more profitable than converting it into biofuel [6]. Meanwhile, **biorefinery** is an emerging

Trends

Food supply chain waste is an abundant resource with significant potential to be used as raw material for fuel production and other industrially viable compounds.

The latest legislation on waste management places much emphasis on the valorisation of food industry waste and the technologies associated with it.

Biorefinery is a novel concept analogous to the petroleum refinery where all components of the raw material are converted into commercially important products (e.g., biofuel, enzymes, oils, nutraceuticals).

This review discusses the latest developments in the use of food supply chain waste with emphasis on the most innovative products developed from such waste.

[1]School of Food Science and Environmental Health, College of Sciences and Health, Dublin Institute of Technology, Cathal Brugha Street, Dublin 1, Republic of Ireland

*Correspondence: amit.jaiswal@dit.ie, akjaiswal@outlook.com (A.K. Jaiswal).

 http://dx.doi.org/10.1016/j.tibtech.2015.10.008

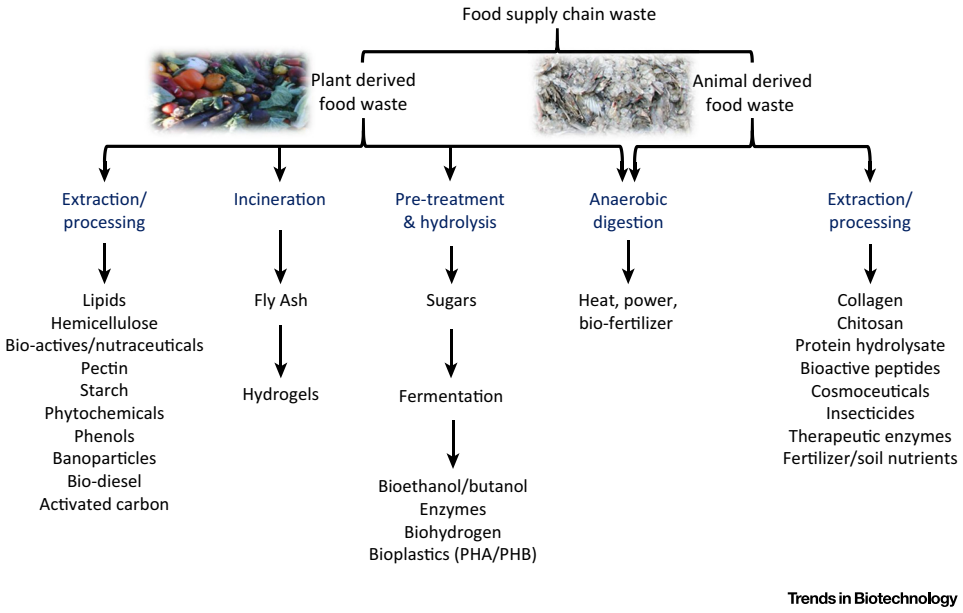

Figure 1. Possible Commercial Products That Can Be Derived from Food Supply Chain Waste.

concept in the field of biomass waste management suggesting that all kinds of biomass-derived material can be converted into different types of biofuels and chemicals through various conversion processes [7]. Figure 1 provides a comprehensive overview of the various functionalised molecules that can be derived from food supply chain waste (Box 1).

Various food industry processes (processing, packaging, transportation. and storage) in their current form are highly inefficient considering the volume of waste they generates during their various stages. These wastes are mainly organic in nature and characterised by high **biological oxygen demand (BOD)** and c**hemical oxygen demand (COD)** and variations in composition and pH owing to seasonal variations and handling processes. Such wastes lead to bacterial contamination due to the high water content and high accumulation rates, not to mention disposal management problems and the cost associated with them [8]. The present logistic strategies practised in the food industry are incapable of dealing with the hurdles of waste management. Incorporating technologies to derive value-added products, chemicals, and fuels is a positive step towards dealing with this problem. However, a steady and incoming flow of raw materials is crucial to keep the industry interested in valorisation studies of food waste. Post-consumer leftover food is the most obvious indicator of the available food waste raw material since is visible on a daily basis. However, waste generated from the last link of the food chain raises several problems since it is a mixture of materials that are heterogeneous in nature and not segregated. By contrast, waste from each stage of the production process is consistent in its chemical composition. Therefore, variations in feedstock can be overcome by novel collection and storage strategies, making it easier for valorisation. There are no exact reports on the amount of waste generated from different food processing industries. Table 1 provides an estimate of the various forms of food waste generated in Europe and the USA.

Current Legislation on Waste Management

Legislation pertaining to waste management in Europe started in the 1970s with the European Economic Community, the precursor to the EU, trying to define 'waste' as a basis to devise laws and regulations with respect to the production, handling, storage, transport, and disposal of waste by minimising the ill-effects related to waste generation on health and the environment [9].

Glossary

Biological oxygen demand (BOD): refers to the amount of dissolved oxygen required by microorganisms to assimilate the organic matter present in a water sample at a specific temperature over a certain period of time.

Biorefinery: sustainable processing of biomass into a wide range of marketable products, including fuels. Initially, the complex polymers that constitute biomass can be broken down into their component building blocks (carbohydrates, proteins, fatty acids) and subsequently converted into value-added products.

Chemical oxygen demand (COD): a test commonly employed to measure the organic compound content in water. It is usually performed to determine the amount of organic pollutants in surface water or waste water, an indirect measure of water purity.

Composting: a biological process where microorganisms grow on waste material in a controlled manner, breaking down the organic fraction; the end product, called compost, is rich in soil nutrients and can be used as fertiliser.

Feedstock: any form of renewable biological material that can directly or indirectly be converted into fuel or other compounds. Biomass feedstock includes plant and algal biomass, which can be converted into fuel sources such as combustible alcohols or commercially important products such as enzymes.