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Chapter 5 – Biorefineries for the valorization of food processing waste

Antonio D. Moreno, Mercedes Ballesteros, María José Negro*

CIEMAT, Department of Energy, Biofuels Unit, 28040 Madrid, Spain

Abstract

The large amount of waste produced by the food industry constitutes a great loss of valuable materials and raises serious management problems from both the economic and environmental point of view. Many of these residues or by-products have, however, the potential to be utilized as raw materials into alternative production systems such as biorefineries. The present chapter deals with the use of the waste resulting from the food manufacturing industry, taking grape-derived waste, brewer's spent grain, olive-derived waste, potato-derived waste and dairy by-products as biorefinery examples. These processes are presented showing the feasibility and constraints of applying industrial symbiosis towards the implementation of a circular bioeconomy. Furthermore, value-added products with especial interest for the nutraceutical and pharmaceutical industry are highlighted, including some antioxidants and phenolic compounds with anticancer activity.

Keywords: Bioeconomy; Biowaste; Waste management; Industrial symbiosis; Nutraceuticals.

7.1. Introduction

The increasing global demand for food production to meet the needs of an exponentially-growing population is claiming for sustain and effective strategies for food waste management, especially in terms of treatment and waste disposal. The Food and Agriculture Organization has estimated the production of food waste in about 1.3 billion tons/year worldwide (FAO, 2011). Only in Europe, 173 kg/person of food (corresponding to ca. 90 million tons in total) are discarded every year as waste, even though much of this food is still suitable for human consumption (Stenmarck et al., 2016). These figures come from households (53%), the food manufacturing industry (19%), the food service sector (12%; including ready-to-eat food, catering and restaurants), primary production (11%), and losses derived from the distribution chain (5%). Today, these waste fractions are usually recovered or disposed for composting, crops ploughed in/not harvested, anaerobic digestion, bioenergy production, cogeneration, incineration, disposal to sewer, landfill, or discarded to sea, having tremendous economic and environmental impacts. For instance, Europe losses about €143 billion annually due to food waste (Stenmarck et al., 2016). Furthermore, these residues promote severe environmental damage since they contribute to the greenhouse gas emissions, may cause groundwater contamination due to landfilling, and represent an excellent nutrient-rich niche for the growth of disease-causing organisms (Ravindran and Jaiswal, 2016).

As an alternative to the traditional methods for food waste management, food waste is nowadays considered a very attractive raw material for the so-called biorefineries. This is due to its high organic content and the presence of several valuable compounds such as oils, sugars, proteins and phenolic compounds. Biorefineries are industries capable of converting biomass feedstocks (including industrial wastes, the organic fraction of municipal solid wastes, lignocellulose, and algal biomass) into a wide range of renewable bioproducts such as biofuels, bioplastics, fertilizers, nutraceuticals, and/or phytochemicals (Ravindran and Jaiswal, 2016). In this context, the use of food waste as biorefinery feedstock will contribute to cut down the amounts of residues discarded, offering huge potentials and opportunities for a better economic and environmental performance of the food sector. This strategy will also aid at developing and implementing a “zero waste” bioeconomy, where the industrial symbiosis –the use of wastes from one process as raw materials in another one– works as the central core.

As a concept, circular economy started back in the 1970s, including contributors such as U.S. professor John Lyle, his student William McDonough, the German chemist, Michael Braungart, and, architect and economist, Walter Stahel (Winans et al., 2017). Now, sustainability criteria, material and energy efficiency, and the needs for reducing waste production and greenhouse gas emissions are the main driving forces for the circular economy to go beyond the research perspective (Kaur et al., 2018). Circular economy aims at preserving product values and to extent the materials and resources lives as long as possible. In this way, efficient production and consumption are prioritized, following continuous and regenerative cycles. This leads to a reduced consumption of raw materials and energy, which in turn, results in less amount of waste and greenhouse gas emissions during the production process. Within the framework of a sustainable economy, biorefineries will integrate different technologies (physical, thermochemical, chemical and biological) for the conversion of the residual biomass, obtaining several energy and chemical products of industrial interest for the development and implementation of a sustainable bioeconomy.

One of the major challenges for the use of food waste as biorefinery feedstock is sample heterogeneity. Food waste includes residues from cereals, root and tubers, oil crops and pulses, fruit and vegetables, meat, fish and dairy products. Households and the food manufacturing sector are the largest contributors to the generation of food waste. However, while households provide complex heterogeneous and not segregated mixtures, the food manufacturing industries offers the possibility of collecting more homogenous materials. This is key for the optimal valorization of these residues, since feedstock variations lead to differences in the chemical composition of wastes. Thus, the implementation of proper collection and storage strategies at each stage of the production chain (food processing, packaging, transportation, and storage) would contribute to the suitable sorting of these materials for their subsequent use.

The present chapter reviews the use of food waste derived from the food manufacturing sector as feedstocks for the production of relevant bioproducts (excluding energy-related products), highlighting the most recent advances for waste conversion from the bioeconomy point of view.

7.2. The food industry: wastes and valuable by-products

Considering its biochemical nature, food waste can be classified into animal-derived waste and plant-derived waste. In addition to these main groups, food waste can also be divided into 7 subcategories according to the waste origin (Galanakis, 2012).

7.2.1. Animal-derived waste

Meat, fish and dairy products are the three main subgroups included in the animal-derived waste. These food products have largely increased their production and consumption worldwide, specifically in developed countries (Uçak, 2007).