Organic kitchen food waste valorization applying the biorefinery concept in the Colombian context

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Keywords: Food residues, Biorefineries, Organic kitchen food waste, Valorization.

Food residues are among the most important issues addressed by different international entities due to the high volume of generation presented in recent years [1]. This high food residue generation issue is attributed to several factors: (i) inefficiency in the food supply chain, (ii) agricultural losses of products, and (iii) high food waste rates in cities. International organizations (e.g., the Food and Agriculture Organization, FAO) have proposed to classify food residue according to the generation stage [2]. Thus, the term Food Losses is applied to described those residues produced in the agronomic stage, while the term Food Waste is used to describe the residues produced in the retail and consumption stage. Several authors studied how to reduce the amount of Food Waste and Food Losses produced in industrialized and developed countries by implementing governmental policies. Nevertheless, these attempts to reduce the Food Loss and Waste production problem have not achieved the expected results. Instead, Food Loss and Waste have produced other problems related to the environment since the decomposition of the organic fraction produces pollution to natural resources such as water, air, and soil. In this way, the valorization of Food Loss and Waste to other products has been profiled as a potential alternative to decrease these issues and promote the sustainable production of added-value products, leaving aside fossil fuels. The use or valorization of Food Loss and Waste has been reported at different scales (i.e., laboratory, pilot, and bench) in the open literature. These valorization opportunities have been proposed considering as main advantages (i) the versatile Food residues composition and (ii) the high production volumes in any location. An increasing trend to obtain platform products, added-value products, and energy vectors has been identified since the chemical composition of Food residues is rich in many important components such as fats, fibers, sugars, starch, and extractives. Moreover, the high production volumes of these residues allow guarantee continuous raw material supply in any productive process (from a theoretical perspective). Regarding the potential of Food residues to produce different added-value products, biotechnological processes have been studied as a potential option to upgrading Food Loss into a series of chemicals such as ethanol, butanol, levulinic acid, succinic acid, among others. Food losses have been studied since these also have been considered as a residue from agronomic practices (e.g., sugarcane bagasse and orange-peel losses). However, first is necessary to carry out a comprehensive study of the fermentable sugars production potential of Food Loss. In 2018, Colombia generated 24.84 million tons of municipal solid waste of which 46.84% were food waste generated in households and the remaining generated in the agricultural and industrial sector [3].

This work was focused on determining the prefeasibility in technical and, economic terms of the most promising alternatives for using food waste generated in Colombia. In this sense, the non-standard food waste was analyzed considering the residues generated in the consumption stage (Organic Kitchen Waste - OKW) in terms of fruits and vegetables. The sustainability analysis of OKW valorization starts from the chemical characterization of the waste. The food waste samples composition was obtained from a model that reflects the Colombian population consumption traditions. The methodology was defined for determining the OKW composition model integrates six steps (see Figure 1). The methodology has involved the use of information provided by international organizations. This information allows establishing the main criteria to develop the steps described in the methodology. The input data cover (i) the seven food groups defined by FAO, (ii) the products that make up the family household food basket in Colombia, and (iii) government consumption statistics. The seven food groups are: (i) Dairy products (DP), (ii) Fish and seafood (FS), (iii) Meat and meat products (MP), (iv) Fruits and vegetables (FV), (v) Oily crops and pulses (OCP), (vi) Roots and tubers (RT) and (vii) Cereals (C). The list of food products that make up the basic family household food basket and government consumption statistics (including food imports) stipulated by the National Administrative Department of Statistics (DANE) [4] was taken. The composition of the OKW was carried out in the laboratory from the mixture of each food product in the seven established groups. The OKW samples were analyzed for raw material accessibility (x-ray diffractometric), chemical composition (extractives, cellulose, hemicellulose, lignin, pectin, protein, fats, starch and ash), total and volatile solids, and proximate analysis (volatile matter, fixed carbon and ash). Then, the production of fermentable sugars from enzymatic hydrolysis with cellulolase, glucoamylases and pectinases enzymes was analyzed. Fermentable sugars were analyzed with a liquid chromatograph (Shimadzu Lachrom elite L-2490 / EZChrom Elite) with refractive index detector and a Hi-Plez Ca column in order to determine the kinetic curve. Hydrolysis was analyzed for 72 hours. The solid remaining from enzymatic hydrolysis was used for the production of biogas by anaerobic digestion.

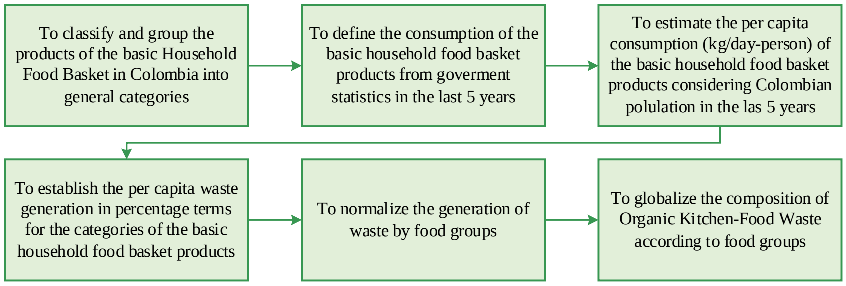

Figure 1. The model for the OKW developed considering the methodology

The experimental results were used as input data in the technical and economic analysis. The analysis started from the simulation of the appreciation of OKW to obtain the mass and energy balances. In this stage, three biorefinery scenarios were analyzed for the valuation of OKW. The first scenario comprised the production of ethanol, biogas, and fertilizer. The second scenario was the production of levunilic acid, biogas, and fertilizer. In the third scenario, lactic acid, biogas, and fertilizer production were analyzed. The scenarios were simulated in Aspen Plus V.9.0 software. The economic pre-feasibility was determined from the net present value and the investment return period. Capital costs were obtained in Aspen Economic Analyzer V.9.0 software.

The results of the chemical composition of the organic kitchen food waste a high moisture content in wet basis, which suggest biotechnological applications instead of thermochemical processes. Moreover, a high starch, fats, and cellulose content was determined. These platforms show the high potential of the organic kitchen food waste to produce fermentable sugars and biochemical products through fermentation, Nevertheless, the presence of toxic compounds must be avoided. The experimental production of fermentable sugars supports the chemical characterization results since higher concentration were obtained compared with other raw assays reported in the open literature. On the other hand, the biogas methane content was higher than 55%. The technical, economic, environmental, and social analyses showed better results when biogas, levulinic, and fertilizer are produced in a biorefinery. As conclusions, the OKW is a potential raw material to be upgraded applying the biorefinery concept since this raw material has the potential to provide a series of different platforms (e.g., sugars, oils). In addition, the compositional model can be applied in any other context.

The authors express their gratitude to the call PROGRAMA NACIONAL PARA LAS MUJERES EN LA CIENCIA UNESCO-L'ORÉAL-MINCIENCIAS-ICETEX and the research program entitled "Reconstrucción del tejido social en zonas posconflicto en Colombia" SIGP code: 57579 with the project entitled "Competencias empresariales y de innovación para el desarrollo económico y la inclusión productiva de las regiones afectadas por el conflicto colombiano" SIGP code 58907. Contract number: FP44842-213-2018

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