Life Cycle Analysis of Food Waste Valorization in Laboratory-Scale

T. Soleymani Angili[1], K. Grzesik[1], E. Salimi[2], M. Loizidou[2]

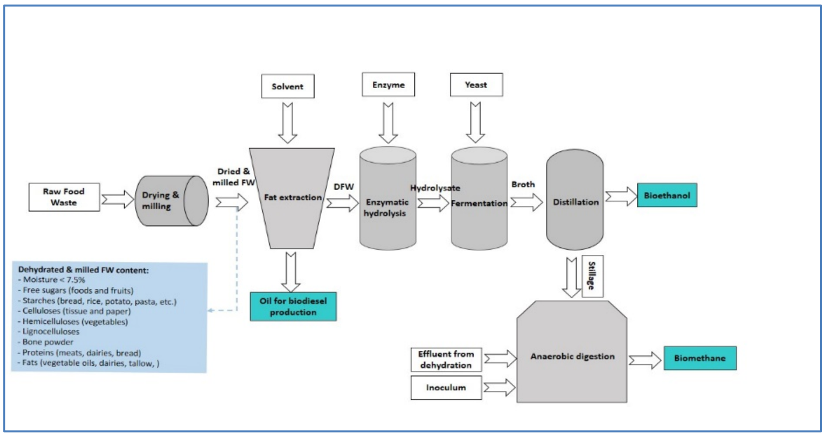
[1]Faculty of Mining Surveying and Environmental Engineering, AGH University of Science and Technology, 30, 30-059 Krakow, Poland
[2]Unit of Environmental Science Technology, School of Chemical Engineering, National Technical University of Athens, GR-15780 Athens, Greece

Keywords: LCA, Bioethanol, Biomethan, Biodiesel, Food waste, Valorization
Presenting author email: angili@agh.edu.pl

The substitution of fossil fuels started with biofuels produced from food crops containing starch or sugar as the first-generation biofuels. The conversion of food crops into bioethanol raised concerns about food security on a global scale Vohra *et al*. (2014). Therefore, second-generation of biofuels based on non-food resources was considered. Over the past few years, more researches have focused on the so-called 2G biofuels that residues or by-products are utilized again, compared to the 1G biofuels that sugars and starch were used Soleymani Angili *et al.* (2021). Among all different alternatives for the production of biofuels, food waste (FW) could be a favorable bioenergy source. Using food waste as a feedstock has a potential to meet the expectation of 2G biofuels in terms of environmental savings and revenue generating that along with other valuable co-products can contribute to biorefinery profits.

The aim of the study was to investigate the early-stage Life Cycle Assessment (LCA) for food waste conversion to bioethanol, biomethane and oil split over different scenarios. The novel aspects of this study consist of laboratory-scale scenarios, to guide the decisions for selecting the most environmental friendly food waste valorization scenario in future scale-up. This study could be an approach to foresee the environmental hotspots in the very early development stage and for highlighting drawbacks connected to implementation of conversion processes at the pilot and industrial scale.

In the scope of this research, as simplified process flow chart, Figure 1, shows the milling- dehydration, solid–liquid fat extraction, enzymatic hydrolysis, fermentation, distillation, and anaerobic digestion were considered. The goal of this study was to assess and compare the LCA result of defatted food waste and non –defatted FW valorizarion scenarios. The scope of the LCA covers two scenarios, A and B, included the processes of production within a "gate-gate" system boundary where a chain of material/energy flow occur to produce the final products of interest. The scenarios differ in terms of fat extraction process. Scenario A presents bioethanol production from defatted FW included fat extraction through a solvent "n-hexane 95%", and scenario B without oil production step, were modeled by SimaPro version 8.5.2.0 LCA software. The functional unit (FU) has defined as the conversion of 1 kg of food waste substrates. The infrastructures of the equipment have excluded from the system boundary and the study has focused on the operation of the system. Collection and transportation of RFW has also excluded in this study.



Dehydrated & milled FW content:
- Moisture < 7.5%
- Free sugars (foods and fruits)
- Starches (bread, rice, potato, pasta, etc.)
- Celluloses (tissue and paper)
- Hemicelluloses (vegetables)
- Lignocelluloses
- Bone powder
- Proteins (meats, dairies, bread)
- Fats (vegetable oils, dairies, tallow,)

Figure 1. Flow chart of the conversion system

In this study, for preparing the life cycle inventories, the details of conversion process of FW to bioethanol were obtained from experimental procedures performed in the laboratory. Input/output data are based on optimized quantity of the materials, chemicals and energy utilized during the experiments. Also, LCA modeling of scenarios involves selection of data from Ecoinvent v3, Wernet *et al.* (2016). For processes not found in Ecoinvent databases input/output data is obtained from literatures. The electricity consumption for the processes was calculated based on the power of devices and the time of using. Also the data on yeast production was adopted from the paper published by B.Dunn *et al.* (2012) and all electrical power used in the laboratory-scale conversion were supplied by the Greece national electricity grid. In the analysis, the "zero burden assumption" was considered of which upstream environmental burdens were not included in the analysis. Furthermore, food waste collection and transportation were excluded from the system boundary. Based on LCI analysis of the inputs and outputs of the FW conversion to bioethanol and co-products, the environmental impacts were estimated by IMPACT 2002+ method Humbert *et al.* (2012). The characterized impacts were then normalized against the average impacts, so that the relative importance of the impacts in different categories considered in the LCA. The normalized results were weighted and aggregated to provide single score LCA results, which are inclusive and convenient indicators to show the final results.

Reference

- Vohra, M. et al. (2014), Bioethanol production: Feedstock and current technologies;Review, Journal of Environmental Chemical Engineering, 2: 573–584, http://dx.doi.org/10.1016/j.jece.2013.10.013
- Soleymani Angili, T. et al. (2021), Life Cycle Assessment of Bioethanol Production: A Review of Feedstock, Technology and Methodology, Energies, 14: 2939, https://doi.org/10.3390/en14102939
- Wernet, G. et al. (2016), The ecoinvent database version 3 (part I): overview and methodology, International Journal of Life Cycle Assessment, 21:1218–1230, https://doi.org/10.1007/s11367-016-1087-8
- B. Dunn, J. et al. (2012), Energy consumption and greenhouse gas emissions from enzyme and yeast manufacture for corn and cellulosicethanol production, Biotechnology Letters,34:2259–2263, https://doi.org/10.1007/s10529-012-1057-6
- Humbert, S. et al. (2012), A user guide for the Life Cycle Impact Assessment Methodology. IMPACT 2002+, https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.454.741&rep=rep1&type=pdf