# Improving sustainability of potato processing industries

V. Felekis, C. Stavraki, D. Malamis, S. Mai, E.M. Barampouti

National Technical University of Athens, School of Chemical Engineering, Unit of Environmental Science Technology, 9 Iroon Polytechniou Str., Zographou Campus, GR-15780 Athens, Greece
Keywords: Potato industry waste, Potato peel waste, Potato tubers, Potato slices, Starch, Chips, Bioethanol
Presenting author email: chrysanthi.stavraki@gmail.com

The ever-increasing population has contributed to a significant increase in food and agricultural production according to the Food and Agriculture Organization (FAO). This has led to rapid industrialization, which is expected to be accompanied by vast volumes of industrial waste causing degradation of environment (Nikolaou and Kourkoutas 2017). The food industry waste is full of organic and nutrient substances. There is, therefore an urgent need to work on producing foods with low carbon footprints, minimize food waste, and utilize the waste generated from food production for other purposes.

Potato is the fourth main crop consumed worldwide. As a result, global potato production has increased by about 18% since 2001 to 2020 (FAO 2020). However, potato industries generate massive amounts of waste, approximately 0.16 tons of solid waste are generated per ton of potato processed (Pathak, et al. 2018). For instance, a potato chips industry includes waste from peeling (potato peel), from sorting (potato tubers), from cutting (potato slices and starch) and from frying (bad quality chips). These substrates consist of carbohydrates, proteins, lipids, and lignocellulosic substances such as cellulose, hemicellulose, and lignin. Due to its composition, this waste can be considered a potential feedstock for advanced techniques in food-processing, pharmaceutical and biosynthesis sectors, which increase the interest of their valorization for producing value-added bioproducts (Wu 2016). Converting these feedstocks to biofuels would be a viable solution for creating alternative energy sources while also reducing polluting gas emissions (Li, et al. 2022). Bioethanol is considered as one of the most promising renewable fuel and it can be produced by microorganisms through fermentation of this waste.

The present study concentrates on the bioethanol production from potato processing waste, aiming to its degradation and its valorization. Four waste streams were supplied by Tsakiris S.A., Coca-Cola 3E, Greece, and delivered to the Unit of Environmental Science and Technology, School of Chemical Engineering at National Technical University of Athens: potato peels, potato tubers and slices, starch and chips.

The conversion of starchy and lignocellulosic matter into bioethanol includes three steps: pretreatment, enzymatic hydrolysis and fermentation. Some of these steps have been applied simultaneously, resulting in high ethanol yields (Simultaneous Saccharification Fermentation, SSF) and this has emerged as a more effective method for bioethanol production compared to the conventional separate hydrolysis and fermentation (SHF). Due to the differences in chemical composition and structural characteristics, the necessity of pretreatment depends on the feedstock. Therefore, every substrate was characterized in order to determine its composition which is summarized in the Table 1.

Table 1. Composition of waste streams of a potato processing industry.

| Parameter (% d.b.) | Potato peels | Potato tubers & slices | Starch | Chips |
|---|---|---|---|---|
| Moisture (%) | 86.90 | 75.94 | 1.24 | 2.83 |
| Total Solids (%) | 14.10 | 24.06 | 98.26 | 97.17 |
| Oils (%) | - | - | - | 36.19 |
| Starch (%) | 17.31 | 52.79 | 83.43 | 39.92 |
| Cellulose (%) | 18.94 | 7.03 | - | 7.37 |
| Hemicellulose (%) | 13.12 | 35.46 | - | 2.56 |
| Lignin (%) | 20.39 | 4.99 | 8.60 | 0.77 |

After several tests, it was found that potato peels, potato tubers and starch require specific pretreatment, in order to improve the hydrolysis of starch and cellulose. Specifically, potato peels were pretreated with alkali to remove lignin. In this study, the best results reached 71% ethanol yield, when dry potato peels were pretreated with 1% w/v NaOH for 6 hours at 50°C, starch hydrolyzed with $50\ \mu L_{NS22109}\ g_{starch}^{-1}$ for 1 hour at 65°C, cellulose hydrolyzed with $300\ \mu L_{NS22177}\ g_{cellulose}^{-1}$ for 24 hours at 50°C and fermented with 1% S. Cerevisiae for 24 h at 30°C. Moreover, autoclave pretreatment has been verified as an effective way to pretreat potato tubers. Therefore, wet potato tubers, with 15% solid loading, were autoclaved at 121°C for 15 min and then they were simultaneously hydrolyzed and fermented, using $40\ \mu L_{SpirizymeXL}\ g_{starch}^{-1}$ and 2% w/w *S. cerevisiae*, resulting in 79% ethanol yield. Similarly, under the same conditions, the starch waste stream achieved 74% ethanol yield. It is worth mentioning that the respective yield without pretreatment was equal to 59%. Lastly, chips proved to be the most efficient substrate in terms of bioethanol production, without the need for pretreatment, while 57.5 $g\,L^{-1}$ of bioethanol are obtained from 20% solid loading by adding 20 $\mu L_{SpirizymeXL}\,g_{starch}^{-1}$ and 2% w/w *S. cerevisiae* at 35 °C, for 27 hours, which corresponds to ethanol yield of almost 100%. The latter could be attributed to the thermal processing of potatoes during frying within the production line.

From the integration of the results presented above and the mass balances of typical potato processing industry, it was calculated that 13.7 L bioethanol can be produced for each tonne of potato processed (Figure 1).

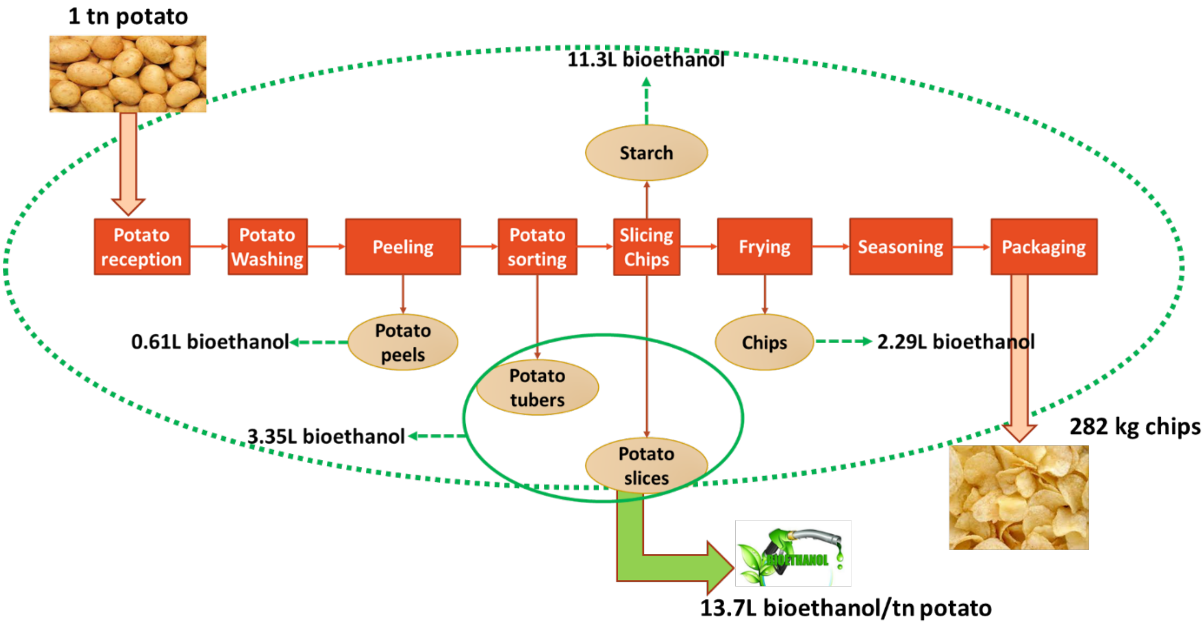


Figure 1. Bioethanol production from the different potato waste streams of a potato processing industry.

It is interesting to note that the oil from waste chips may be recovered and utilized for biodiesel production, and the residues after ethanol distillation can be used as feedstock for anaerobic digestion producing biogas and biofertilizer, aiming to improve the sustainability of the industry. The results obtained from the present study provide an innovative solution for waste management and a great potential from an economic and environmental aspect.

## Acknowledgements

The authors acknowledge funding through LIFE CIRCforBIO (LIFE Ref. No: LIFE18 CCM/GR/001180) project for supporting this work.

## References

FAO. *FAOSTAT.* 2020. https://www.fao.org/faostat/en/#data.

Li, Jun, Renyong Zhao, Youjie Xu, Xiaorong Wu, Scott R. Bean, and Donghai Wang. "Fuel ethanol production from starchy grain and other crops: An overview on feedstocks, affecting factors, and technical advances." *Renewable Energy*, April 2022: 223-239.

Nikolaou, Anastasios , and Yiannis Kourkoutas. "Exploitation of olive oil mill wastewaters and molasses for ethanol production using immobilized cells of Saccharomyces cerevisiae." *Environmental Science and Pollution Research* , 26 December 2017: 7401–7408.

Pathak, Pranav D., Sachin A. Mandavgane, Nikhil Manoj Puranik, Swapnil Jaygopal Jambhulkar, and Bhaskar D. Kulkarni. "Valorization of potato peel: a biorefinery approach." *Critical Reviews in Biotechnology*, 14 June 2018: 0738-8551.

Wu, Di. "Recycle Technology for Potato Peel Waste Processing: A Review." *Procedia Environ Science*, 14 February 2016: 31: 103–107.