**Life Cycle Assessment of the replacement of hexane by ethanol in the soybean oil extraction Process**

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**Highlights**

* Life cycle assessment of the extraction was performed with ethanol as solvent.
* Carbon footprint of bioethanol-extracted soybean oil is smaller than hexane-extracted.
* Bioelectricity may be co-product of the ethanol-soybean oil plant.

**1. Introduction**

The replacement of non-renewable solvents in industrial process will contribute to the consolidation of the low-C economy. In 2015, Brazil signed the Paris agreement and committed to reduce 37% of greenhouse gases emissions, based on 2005, until 2025. Other commitment was to reach 45% of renewable energy sources on the Brazilian energy grid and to promote clean technologies in the industrial sector. Brazil is the second larger producer of soybean, responsible for 35.38% of the worldwide production in 2015. According to [1], the 2020 soybean production forecast is 114.7 million metric tons and 10 million of tons of soybean oil. Although hexane is the conventional solvent used for soybean oil extraction the extraction of oilseeds with ethanol is a sustainable and technically feasible alternative [2,3,4]. Both anhydrous ethanol and hydrous ethanol (1G bioethanol from sugarcane) can be used for seed oil extraction. Besides, in order to contemplate a future biorefinery integration, vapor and electricity demands may be supplied in a cogeneration system using sugarcane bagasse. This work aims to simulate these oil extraction process, and to quantify the environmental impacts of this solvent replacement through LCA.

**2. Methods**

The process was simulated in the equation-oriented Environment for Modelling Simulation and Optimization (EMSO). The process consists of a cracker, conditioner, flaker, expander, extractor, desolventizer, toaster, evaporator, degumming, deacidified and solvent recovery section. Four scenarios assessed, using the solvents hexane, hydrous ethanol, anhydrous ethanol recovered by glycerol extractive distillation, and anhydrous ethanol recovered by mono ethylene glycol (MEG) extractive distillation. The solid fraction from the extraction proceed to the desolventizer-toster in order to remove the solvent from the meal. The liquid fraction is carried to an evaporator and then to a solvent recovery section. Hexane is recovered in a set of evaporators and a stripping column. Hydrous ethanol is recovered through distillation. The anhydrous ethanol is recovered by extractive distillation using either MEG or glycerol. In order to proceed with LCA, an inventory of raw-materials, emissions and products was done. GWP gases emissions for each process were calculated, within a birth to gate scope (including the harvest in the field for soybean and sugarcane) and considering energetic allocation to the multiple products.

**3. Results and discussion**

Ethanol requires a higher solvent-soybean ratio when compared to hexane. So, the energy demands for the first alternative is higher. On the other hand, in a biorefinery concept, more bagasse will have to be burnt, and so more surplus bioelectricity may be sold to the grid. LCA shows that GWP emission in the whole ethanolic process of extraction are slightly higher, due to the higher vapor and cooling water demands. However, since more bioelectricity is produced, the GWP related to soybean oil with ethanol extraction is lower than the one with hexane extraction.

**4. Conclusions**

A life cycle assessment of the extraction of soybean oil with ethanol was performed, and compared to the conventional hexane extraction. The GWP emission related to the soybean oil extracted with ethanol was lower than the one with hexane. Boeletricity and vapor generated play an important role in this process. Further studies could contemplate the integration with ethanolic biodiesel processes.

**References**

1. Abiove – Brazilian Association of Vegetal Oil Industries, 2016. Biodiesel: long term opportunities and challenges (in Portuguese).http://www.abiove.org.br/site/\_FILES/Portugues/07102016-131231-07\_10\_2016\_n-\_cenario\_para\_o\_biodiesel\_em\_2030(2).pdf (accessed 26 March 2019).
2. Ferreira, M. C., Bessa, L. C., Abreu, C. R., Meirelles, A. J., Batista, E. A., 2018. Liquid-liquid equilibrium of systems containing triolein+(fatty acid/partial acylglycerols/ester)+ ethanol: Experimental data and UNIFAC modeling. Phase Equilib.(476), 186-192. <https://doi.org/10.1016/j.fluid.2018.07.030>
3. Sawada, M.M., 2014. Effects of different alcoholic extraction conditions on soybean oil yield, fatty acid composition and protein solubility of defatted meal. Food Res. Int. 62, 662-670. <https://doi.org/10.1016/j.foodres.2014.04.039>.
4. Toda, T.A., Sawada, M.M., Rodrigues, C.E., 2016. Kinetics of soybean oil extraction using ethanol as solvent: Experimental data and modeling. Food Bioprod. Process. 98, 1-10. https://doi.org/10.1016/j.fbp.2015.12.003