Integral valorization of grapevine shoots from the variety Grüner Veltliner: A techno-economic assessment.

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Keywords: Grapevine shoots, biorefineries, simulation, techno-economic assessment, sustainability.
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1. Introduction

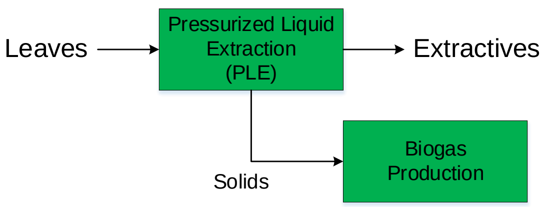
Lignocellulosic biomass keeps getting momentum as an alternative to fossil carbon sources for the production of biobased chemicals, materials, biofuels, and bioenergy (Menon and Rao, 2012). Agroindustry and forestry are some production chains where LB can be produced and it was accounted that the annual production of LB is around 3.7×10^9 tons (Bentsen et al., 2014). Cellulose, hemicellulose, lignin, and extractives are some of the platforms that can be used from these feedstocks and their entire valorization should be considered for the production process to be sustainable (Serna-Loaiza et al., 2019). Among the different agricultural chains, vineyards are one of the most spread crops worldwide with around 8 million hectares (Statista, 2021). The annual waste generated during the cultivation, processing and harvesting in the vineyards has been estimated to be 5 tonnes per hectare (Zacharof, 2017), with the primary residues being grapevine shoots (GVS), lees, and marc (processed grape skins, seeds, and stalks). In Austria, grape production accounted to approximately 330 thousand tons with an area of 48 thousand hectares in the year 2018 (Food and Agriculture Organization of the United Nations (FAO), 2020).

Grapevine shoots and vineyard residues from red and white grape varieties from Spain, Portugal, and Italy, among others, have been studied extensively for the production of bioactive compounds, lignin, biofuels, biogas, and other products (Cebrián et al., 2017; Dávila et al., 2019; Gañán et al., 2006; Luque-Rodríguez et al., 2006; Moreira et al., 2018). In Austria, the most widely cultivated grape variety is *Grüner Veltliner* with around 47% of the total white wine area in Austria (Heidinger, 2021). However, only few studies have been published on the specific characterization of the bioactive compounds and valorization potential of the lignocellulosic components for the grapevine shoots of this specific variety. In a previous study, (Serna-Loaiza et al., 2022) characterized the GVS, quantified the bioactive compounds and evaluated the production of hemicellulosic sugars and lignin. However, evaluating possible integration scenarios and determining the techno-economic feasibility of a biorefinery to valorize the Grüner Veltliner's GVS is still necessary to be performed.

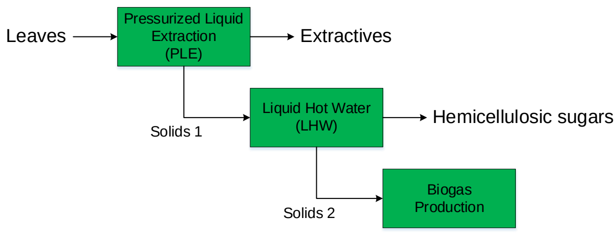
Based on the mentioned elements, this work consisted on performing a techno-economic assessment of different simulated scenarios for the valorization of the GVS from the variety Grüner Veltliner. The proposed scenarios were based on the characterization and evaluation performed by (Serna-Loaiza et al., 2022) for the primary biorefining of the GVS into three main intermediate products: extractives, sugars, and lignin. The final solids after the subsequent extractions were then fed to an anaerobic digestion stage for the production of energy. The scenarios were proposed considering the separation of the leaves and the stems from the GVS, and a scenario considering the use of both fractions together. The mass and energy balance obtained from the simulations were used to calculate the energy requirements and then to carry out a techno-economic assessment.

2. Materials and methods

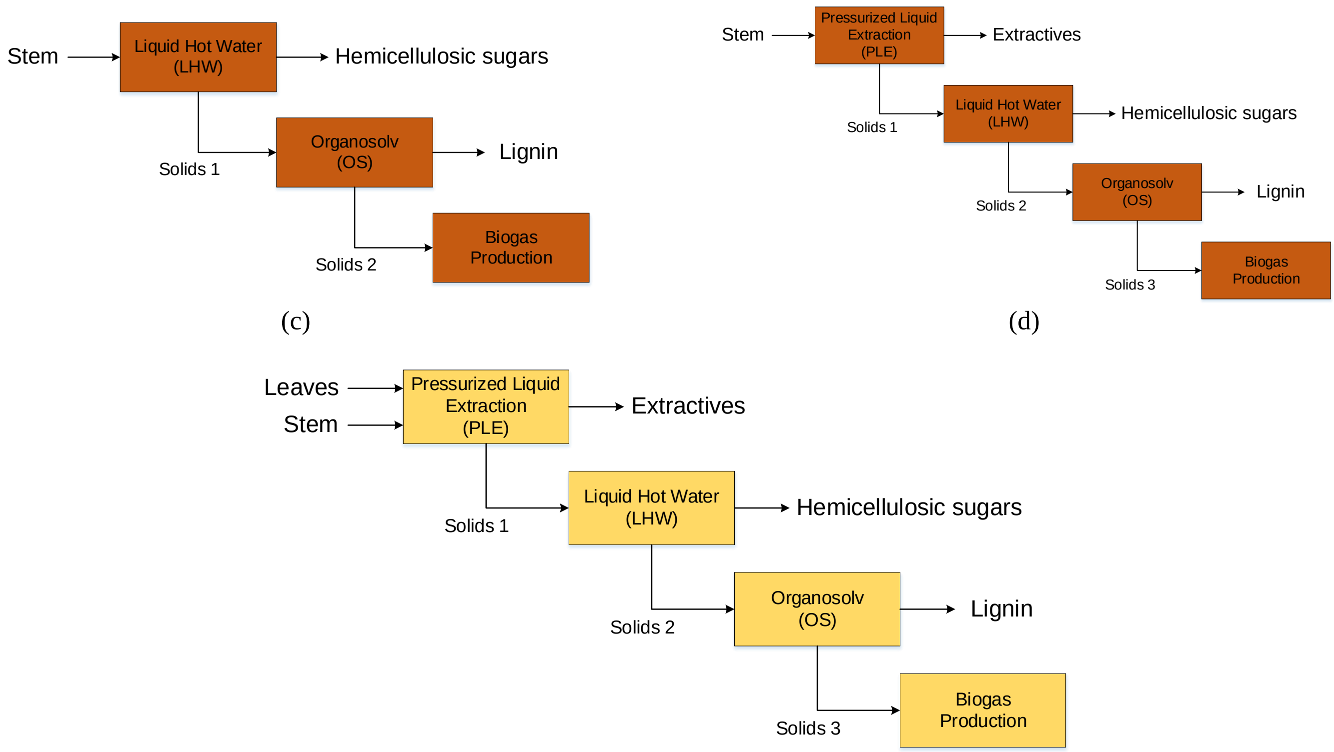
2.1. Simulated scenarios



(a)



(b)



(e)

Figure 1. Simulated scenarios for the valorization of the GVS. (a) and (b) correspond to the valorization of the leaves as separate feedstock. (c) and (d) correspond to the valorization of the stem. (e) corresponds to the integrated valorization of leaves and stems

2.2. Process Simulation and Techno-Economic Assessment

The commercial software Aspen Plus V10.0 was used to simulate the different scenarios. The software does not include biomass and its components (cellulose, hemicellulose, lignin, etc.) on its databases; therefore, the properties required for the simulation were taken from the NREL/MP-425-20685 "Development of an ASPEN PLUS Physical Property Database for Biofuels Components" (Wooley and Putsche, 1996). The package Aspen Energy Analyzer of the software was used for the calculation of the energy requirements of the process as utilities (cooling water, low, mid and high-pressure steam, and electricity) used in heat exchangers, boilers, pumps, compressors, mills, and reactors, among others. The Net Present Value (NPV) was used to determine the economic performance of the process, and it was calculated based on the total cost of the process (capital cost, cost of utilities, raw materials and reactants, and operational costs) and the gross income of the products and by-products. The cost of the equipment was calculated using the software Aspen Process Economic Analyzer V10.0 (Aspen Technologies, Inc., USA). The capital depreciation, maintenance costs, labor costs, fixed charges, general and administrative costs and plant overhead were calculated based on the percentages described for the economic assessment of chemical processes of (Peters et al., 1991).

3. Results and discussion

The integrated valorization of the grapevine shoots improved the mass usage of the residue and increased the yields in the stages focused on the production of hemicellulosic sugars. Lignin production does not increase significantly given the low content of this component in the leaves. However, biogas production improved due to the increased mass to be processed and the previous removal of extractives. Furthermore, the energy consumption does not increase significantly, but the output products increase, which was reflected in the economic performance of the processes (NPV).

References

Bentsen, N.S., Felby, C., Thorsen, B.J., 2014. Agricultural residue production and potentials for energy and materials services. Prog. Energy Combust. Sci. 40, 59–73. https://doi.org/10.1016/j.pecs.2013.09.003

Cebrián, C., Sánchez-Gómez, R., Salinas, M.R., Alonso, G.L., Zalacain, A., 2017. Effect of post-pruning vine-shoots storage on the evolution of high-value compounds. Ind. Crops Prod. 109, 730–736. https://doi.org/10.1016/j.indcrop.2017.09.037

Dávila, I., Gullón, B., Labidi, J., Gullón, P., 2019. Multiproduct biorefinery from vine shoots: Bio-ethanol and lignin production. Renew. Energy 142, 612–623. https://doi.org/https://doi.org/10.1016/j.renene.2019.04.131

Food and Agriculture Organization of the United Nations (FAO), 2020. Grape Production 2018 [WWW Document]. URL http://www.fao.org/faostat/en/#data/QC (accessed 7.7.20).
Gañán, J., Al-Kassir Abdulla, A., Cuerda Correa, E.M., Macías-García, A., 2006. Energetic exploitation of vine shoot by gasification processes: A preliminary study. Fuel Process. Technol. 87, 891–897. https://doi.org/https://doi.org/10.1016/j.fuproc.2006.06.004
Heidinger, S., 2021. Austrian Wine Statistics Report 2020 [WWW Document]. Austria Wine. URL https://www.austrianwine.com/press-multimedia/statistics-1/austrian-wine-statistics-report (accessed 12.30.21).
Luque-Rodríguez, J.M., Pérez-Juan, P., Luque De Castro, M.D., 2006. Extraction of polyphenols from vine shoots of Vitis vinifera by superheated ethanol-water mixtures. J. Agric. Food Chem. 54, 8775–8781. https://doi.org/10.1021/jf061855j
Menon, V., Rao, M., 2012. Trends in bioconversion of lignocellulose: Biofuels, platform chemicals & biorefinery concept. Prog. Energy Combust. Sci. 38, 522–550. https://doi.org/https://doi.org/10.1016/j.pecs.2012.02.002
Moreira, M.M., Barroso, M.F., Porto, J.V., Ramalhosa, M.J., Švarc-Gajić, J., Estevinho, L., Morais, S., Delerue-Matos, C., 2018. Potential of Portuguese vine shoot wastes as natural resources of bioactive compounds. Sci. Total Environ. 634, 831–842. https://doi.org/10.1016/j.scitotenv.2018.04.035
Peters, M.S., Timmerhaus, K.D., West, R.E., 1991. Cost Estimation, in: Plant Design and Economics for Chemical Engineers. McGraw Hill, New York, p. 923.
Serna-Loaiza, S., Kornpointner, C., Pazzaglia, A., Halbwirth, H., Friedl, A., 2022. Biorefinery concept for the valorization of grapevine shoot residues: Study case for the variety Grüner Veltliner. Unpubl. Manuscr.
Serna-Loaiza, S., Miltner, A., Miltner, M., Friedl, A., 2019. A Review on the Feedstocks for the Sustainable Production of Bioactive Compounds in Biorefineries. Sustainability 11, 6765. https://doi.org/10.3390/su11236765
Statista, 2021. Vineyard surface area worldwide from 2000 to 2020 [WWW Document].
Wooley, R.J., Putsche, V., 1996. Development of an ASPEN PLUS physical property database for biofuels components. Citeseer, Colorado.
Zacharof, M.-P., 2017. Grape Winery Waste as Feedstock for Bioconversions: Applying the Biorefinery Concept. Waste and Biomass Valorization 8, 1011–1025. https://doi.org/10.1007/s12649-016-9674-2