Implementing Sustainable Practices in Olive Oil Production Using Life Cycle Assessment (LCA)

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Abstract

The social and business consciousness towards sustainability has led to a growing focus on environmentally friendly business strategies. The present research work aims to achieve sustainable and technical production in the olive oil sector. Nowadays, the incorporation of digital technologies such as sensors, edge computing, big data, machine learning, artificial intelligence, and the Internet of Things in production companies facilitates the collection of data at production level. Later, the evaluation of the generated data allows the implementation of the Life Cycle Assessment (LCA) methodology.

The goal is to quantify environmental impacts and select relevant indicators, considering the variety of production processes and the different types of olive oil produced. This three-dimensional sustainability approach aligns with the United Nations' Sustainable Development Goals of the 2030 Agenda, responding to the need to evaluate the environmental impact throughout the product life cycle. To address the increasing concern about measuring the circularity and sustainability of olive oil, the present research work employs the LCA methodology by integrating it from the early stages of the product. In this case, a "from door to door" approach has been developed. The research study compiles progress in implementing environmental sustainability criteria in the specific case of an olive oil mill sited in Andalusia region (south of Spain), proposing a specific LCA methodology for olive oil production in this olive oil mill.

Introduction

According to various studies, where the results showed that the agricultural phase was the most impactful in the life cycle of olive oil, Espadas-Aldana et al. (2019). Other LCA studies on olive oil and olives based on 10 studies concluded that the process with the greatest environmental impacts was olive cultivation (Joumri et al., 2023). On the other hand, Avraamides et al. (2008) conducted a life cycle inventory analysis to study the resource consumption and emissions to air, water, and soil from olive oil production in Cyprus, where in the olive processing stage, resource consumption originated mainly from energy generation processes, while emissions were mostly related to liquid waste disposal. As a conclusion from the analyzed studies, the agricultural phase is the most impactful in the life cycle of olive oil, primarily due to fertilization, pesticide treatment, and irrigation. Additionally, waste generation and management also played a crucial role in the environmental impacts associated with this phase. Therefore, the agricultural stage has the greatest impact throughout the life cycle of olive oil production. In the mill, on the other hand, in the olive processing stage, the impact derived from resource consumption mainly originated from water usage in the process and energy generation, while emissions were mostly related to liquid waste disposal.

Experimental methodology

The LCA will be applied "From door to door" approach, as we will only consider the oil milling processes within the doors of the oil mill. Another aspect to consider is the identification of system boundaries, including the unit processes in the LCA. The present work includes the following process areas: reception area, under the hoppers area, milling area, settling area, and the pitter area.

Next stage is defining the functional unit as the starting point for the analysis. For the specific production process under consideration, the production of 1 liter of olive oil was adopted as functional unit. This unit will be

used to quantify the indicators and express all impacts generated on the environment: soil, water, energy consumption, generation of liquid or solid waste, etc.

Finally, for the inventory analysis, it is needed to collect the data about the material and energy balance of the system, although it can include other parameters such as land use, radiations, noise, vibrations, affected biodiversity, etc.

The principles and requirements for conducting LCA studies are standardized in ISO 14040:2006 and 14044:2006 and requires the specification of the "environmental impact categories". The key lies precisely in the selection of specific categories, as they represent different environmental aspects of interest, such as the contribution of emissions produced during oil production to climate change, freshwater eutrophication, or depletion of fossil resources. The categories involved in the mill's process for production of olive oil are showed in Table 1:

Table 1. Environmental impact categories applied to the present study in IMPACT 2002+.

Impact categories	Damage category	Midpoint reference substance
Aquatic acidification, AQ	Ecosystem quality	kg SO2 eq
Aquatic eutrophication, EUQ	Ecosystem quality	kg PO4 eq
Global Warming Potential, GWP	Climate change	kg CO2 eq
Land Occupation, LO	Ecosystem quality	m2org
Ozone layer depletion, ODP	Human health	kg CFC-11 eq
Abiotic Depletion - elements	Resources	kg Sb eq
Abiotic Depletion - fossil fuels	Resources	MJ
Respiratory organics, RO	Human health / Ecosystem quality	kg C2H4 eq
Water consumption	Resources	m3 H2O eq.
Marine aquatic ecotoxicity	Ecosystem quality	Kg 1,4-DB eq
Fresh water aquatic ecotoxicity	Ecosystem quality	Kg 1.4-DB eq
Human toxicity	Human health	Kg 1.4-DB eq.

Conclusions

The awareness of the productive sectors regarding compliance with the SGD of the United Nations 2030 Agenda is increasing day by day. And in this field of work, tools such as LCA have become indispensable, since they allow optimization under sustainability criteria.

Particularly, it is important to dedicate time and efforts to define the vision and objectives of an LCA database that responds to the need for reliable data for a proper analysis of the generated impacts.

The present research work based on the analysis of the production processes carried out in an oil mill located in the south of Spain concludes the need for a collection of specific, reliable and real process data at the plant level. This study based on data from the digitalization of the processes in this oil mill concludes that the reliability of the data is maximum, which led to the preparation of a reliable inventory that faithfully reproduced the real production process of the olive oil mill.

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