CEST 2023

*18th International Conference on Environmental Science and Technology*

*Athens, Greece, 30 August to 2 September 2023*

# Circular Economy: Assessment of Circularity in Olive Oil Mills

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**Abstract.**A central issue for academics and politicians regarding the circular economy in the last few years has been the evaluation and monitoring of the circularity level, so that conclusions can be drawn about how the implemented policies have been transitioning toward sustainability. Even though the research community has been working extensively on this subject, there has not been a consensus on what indicators to use to measure circularity in the agri-food industry so far.

The aim of this paper is to highlight the circular economy (CE) indicators used in the agri-food sector, based on scientific literature and practice, so as to identify those that could assess circularity in olive oil mills. Furthermore, the project aims to develop a tool that will be able to assess the success of CE strategies and remove some of the ambiguity surrounding CE in practice. Due to the uncontrolled disposal of waste from olive mills, the Mediterranean countries that produce the majority of olive oil have to cope with major environmental issues, so the transition to a CE in olive oil industry is essential.

**Keywords:**circular economy in olive oil mills, circularity assessment, indicators of circular economy

## 1. Introduction

Due to the rapid degradation and depletion of natural resources of the planet, it has became imperative to alter the existing economic model (Weigend Rodriguez et al. 2020). A revolution occurred in economic development with CE. Developing a CE requires a comprehensive assessment and monitoring of circularity in every aspect of economic activity, as well as in agriculture and food production. Inherently intertwined with agriculture, the agri-food sector is a key player in sustaining the natural resources. While it provides several perspectives by reducing food losses and waste, valorising by-products, reusing resources and using biomass in cascades (Aznar-Sanchez et al. 2020). In addition to causing degradation of natural resources such as water, land, labor, energy and capital, through the emission of greenhouse gases, it intensifies climate change and global warming (Mor et al. 2021). As a means of recovering nutrients, compounds, and materials (Chiaraluce et al. 2021), CE will revolutionize the agri-food industry (Mirabella et al., 2014). It is therefore becoming critical for actors and industry practitioners to acquire appropriate tools, methods and indicators, to assess and quantify the progress concerning circularity, as part of the transitioning process to a more circular system (Nikkhah et al. 2021).

Based on scientific literature and practice, this study aims to highlight the CE indicators used at the agri-food sector in order to identify those that could be used to assess circularity in olive oil mills. Moreover, this project will develop a tool that will enable CE strategies to be assessed and open up some of the ambiguity concerning CE strategies concerning olive oil industry.

## 2. Circularity assessment

Assessing and monitoring circularity has become a crucial part of economic development policy, as circularity gains attention (Chobanova 2020). While circular metrics are appeared to be essential for business and public stakeholders, several circularity indicators have been developed to address the lack of an integrated method for measuring CE effectiveness (Rigamonti and Mancini 2021).

To measure the performance of their projects, stakeholders may use several frameworks that have been developed recently. Some of these frameworks include the Material Circularity Indicator (MCI), which is a measure of the quantity and intensity of circular and restorative flows at the product and/or company level, and compares the performance to the average of the industry. Even though Life Cycle Assessment (LCA) is not devoted to CE, it helps evaluating the environmental or social impacts of a product system at every stage of its life cycle (from raw material extraction to end of service). As well as, using the Circular Economy Toolkit (CET) the potential for improving circularity of products is identified and assessed, and recommendations for improvement are provided at every stage of the product's life cycle. Last but not least, the Circular Economy Indicator Prototype (CEIP) can evaluate the circularity of a product and give it a score (%) and a radar diagram indicating the performance of each life cycle step (EIT 2018).

## 3. Methodology

A review of the global literature was conducted in Scopus, Science Direct, ResearchGate and Google Scholar. The used keywords were ‘‘measuring circular economy in olive oil industry’’, ‘‘circular economy assessment’’, ‘‘circular economy indicators’, ‘‘measuring circular economy in agri-food sector’” “circularity metrics”.

## 4. Circularity assessment in the agri-food sector

Circular economy (CE) modeling in agri-food production can reduce environmental burdens, improve resource efficiency, and ensure socially responsible practices. A key part of this process is the measurement of sustainability indicators. In spite of a wide range of literature describing sustainability and CE indicators, there is a lack of studies that provide a comprehensive framework for measuring sustainability and CE for agri-food systems (Silvestri et al. 2022).Table 1 provides some indicators selected by the literature to measure and monitor the CE in the agri-food sector.

**Table 1**. Indicators assessing CE in agri-food sector

| **Indicators** | **Source** |
|---|---|
| Circular production and resource efficiency | *Atanasovska et al 2022* |
| • Use of renewable energy in production | |
| • Use of LCA approaches to monitor production | |
| • Constant production optimization for resource efficiency | |
| • Circular food labeling | |
| • Optimum location of facilities based on environmental and social considerations | |
| • Creating a transportation system that is sustainable and socially responsible | |
| • Land use and resource management | |
| • Purchasing strategies for local businesses | |
| • Community impact indicators (job creation, inequality reduction, food security) | |
| • Adoption of innovative food processing practices, technology integration, etc., (Bio-innovation) | |
| Recycle, reuse, and redistribute | |
| • Waste selling to other companies | |
| • Recycling stream optimization (manufacturing waste reuse) | |
| • Fertilizer production through recycling and reuse | |
| • Availability of waste separation and/or recycling centers | |
| • Waste used for manufacturing new products | |
| • Circular packaging use | |
| • Existence of an internal plan to cut back on raw material input | |
| • Reuse of equipment cleaning material | |
| Stakeholder (relation and engagement) | |
| • Availability of a sustainable/circular and social stakeholder selection strategy | |
| • Environmental/circular value certification and value auditing of stakeholders | |
| • Collaboration with eco-industrial park stakeholders to support CE | |
| • Environmental, circular, social value deliver training | |
| • A sustainable, circular, and social plan that incorporates resilience-thinking | |
| • Educating consumers about food consumption | |
| • Consumer commitment | |
| Human resource management | |
| • Management support | |
| • Programs for employee training and incentives | |
| • Inner campaigns to raise awareness of social and environmental issues | |
| • Regional employment policy | |
| **Air** | *Poponi et al 2022* |
| • Total emissions | |
| • Ozone layer depletion potential | |
| • Global Warming Potential | |
| • Photochemical oxidant | |
| • Particulate matter formation | |
| **Water** | |
| • Water use | |
| • Water scarcity index | |
| • Integrated water resources management (implementation level) | |
| • Freshwater extraction as a percentage of freshwater resources available | |
| • Eutrophication potential(marine and freshwater eutrophication) | |
| • Freshwater ecotoxicity | |
| **Soil** | |
| • Degraded land over total land area | |
| • Acidification potential | |
| **Energy** | |
| • Energy required | |
| • Bioenergy production as a% of renewable energy | |
| • Use of waste to recover energy | |
| • Energy self-sufficiency indicator | |
| • Total energy consumption | |
| • Nonrenewable energy demand | |
| • Consumption of renewable energy as a share of total energy | |
| • Use of primary renewable energy | |
| • Energy productivity | |
| **Waste** | |
| • Economic FLW indicator | |
| • Recycling rates | |
| • Waste sent to landfill | |
| • Nutrient circularity indicators (C, N and P) | |
| **Cost, value, and productivity** | |
| • Total capital investment for CE | |
| • Profitability (Investing in CE | |

| | |
|---|---|
| innovations at a low cost<br>• Gross Value Added<br>• Cost of manufacture<br>• Amounts paid to workers based on total economic output<br>• Total GVA based on total economic output<br>• Fixed capital investment<br>• Payback period<br>• Value added to the Economy<br>**Equality**<br>• Involvement in the adoption of circular practices and participation in local democracy<br>• Implementation of circular practices with social inclusion<br>• Creating new job opportunities via a circular model, both in terms of staffing and skills<br>**Knowledge and Innovation**<br>• Extent of staff training<br>• Availability of latest technologies<br>• Agri-food sector investment in research and development to total added value<br>• Intensity of local competition | |
| The focus is on primary production:<br>• Indicatorsconcernedthe material cycles of the main inputs required for production(use and loss of inputs from and to the environment)<br>• Indicators related to optimizing the use of food products (the final impact of consumption)<br>• Indicators related to the origin, collection, and valorisation of the residual streams (organic and inorganic) throughout the entire food chain. | *Vermeyen et al 2021* |
| 1. Land use<br>2. Soil as input<br>3. Composition and (re)use of minerals, such as N,P,K and other trace element, and the losses to the environment<br>4. Source and (re)use of energy<br>5. Animal feed: source, composition, and use<br>6. Source and (re)use of water<br>7. Residues (non-edible) and food loss (edible)<br>8. Waste streams associated with food production and processing: origin, use and (cross-cutting) reuse<br>9. Managing logistics and transportation in the food industry<br>10.Innovating the production and processing of food (design, digitalization, etc.) | *Van Schoubroeck et al 2022* |
| • total input (Sum of all inputs into the (sub-)system)<br>• nutrient use efficiency: $\frac{products}{total\ input}$<br>• secondary-to-total input: $\frac{secondary\ input}{total\ input}$<br>• emissions and losses: $\frac{emmissions\ and\ losses}{total\ input}$<br>• recycling rate: $\frac{reused\ flows}{total\ waste\ generated}$<br><br>The assessment is focused on P, as itis not volatile, is always bound to biomass, is a better 'trace indicator' for food flows and is decent to the CE concept (can be both a scarce resource and a pollutant) | *Papangelou and Mathijs 2021* |

Literature (Genovese et al. 2017; Nikkah et al 2021; Ncube et al. 2022) suggests that the most effective methods for assessing the environmental effects of agri-food systems are generally based on lifecycle assessment (LCA) principles. Products, processes, and activities/operations can be assessed with LCA as a way of bringing together the impacts resulting from collaborative supply chain partners (extraction and processing of raw materials, manufacturing, transportation, distribution, re-use and recycling, and final disposal). As a holistic approach, LCA helps supply chain managers incorporate environmental impacts across all stages of the supply chain, wherever and whenever those impacts occur(Genovese et al. 2017). Rocchi et al. (2021) proposed a modification of the Material Circularity Indicator (MCI) (EMF 2015) to measure circularity in agri-food sector. Specifically, in this study, modified MCI findings were integrated with approaches to LCA adapted for poultry. As stated by Rocchi et al., 2021, MCI does not valorize non-edible food by-products (Rocchi et al. 2021). Thus, such a calculation is not suitable for circularity measurement in olive oil industry, nor can it determine how close olive oil mills are to circularizing themselves.

## 5. The case of olive oil industry

Olive oil production is an extremely important economic activity for EU countries, representing 69% of world production (Joumri et al. 2023). As part of the olive oil extraction process, significant amounts of wastes are generated, including olive mill solid waste and olive mill wastewater (OMWW), which are rich in precious compounds but toxic to the environment (Mechnou et al 2021).Despite the fact that OMWW is highly toxic, it is often discarded without being pre-treated (in water bodies, in soil etc), causing serious problems to the natural ecosystems (Donner and Radic 2021).Assessing circularity in the olive oil industry, and in particular in olive oil mills that process the oil, is imperative for implementation of CE in this industry.

As a tool for measuring and monitoring the use of resources, emissions and wastes into the environment, as well as the associated impacts, LCA is widely accepted (Santagata et al. 2020). Taking into account the LCA of olive oil has been applied for more than a decade in order to identify and recommend remedies for environmental hotspots (Espadas-Aldana et al. 2019).Throughout the life cycle of olive oil, Banias et al. (2017) conducted a systematic literature review to assess the usage of environmental tools in farming, manufacturing, packaging, warehousing, transportation, and reverse logistics. As an example of a similar approach, Nikkah et al. 2021 used a LCA methodology to evaluate the circularity of a food waste valorization system (refining oil from olive kernels) (Nikkah et al. 2021).

Consequently, the LCA methodology could be used to assess the circularity of the olive oil mills, compared with assessments made using the indicators that was highlighted in Table 1.

## 6. Conclusions

For the olive oil industry to thrive in the future, it has to use waste streams as feed to get products with high added value.In the CE context, its sustainability characteristics need to be assessed using advanced tools (e.g. LCA) with the main goals of improving economic viability, reducing footprints, and complying with the most stringent environmental policies.

In order to measure the CE implementation in olive oil industry it is proposed the use of LCA methodology compared with some indicators, retrieved from the literature, that assess circularity in agri-food sector in general. The next step is to test these indicators in order to validate their applicability and effectiveness in practice. This could give the opportunity of creating a tool that would provide to olive oil mills' owners the potential to assess their circularity in an easy manner and give them the scenarios of improvement.

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