Technical Article Nº 12

Strategies for adapting food processes to climate change: transforming olive waste into valuable resources

Adapting food processes to climate change through the waste-to-resource concept involves transforming food waste into bioenergy, organic fertilisers and bioplastics, using microbial processing for by-product conversion, and adopting sustainable packaging solutions. Other strategies include composting organic waste to improve soil quality, recovering energy from waste through anaerobic digestion, utilising resilient and underutilised crops and optimising supply chains with digital tools to reduce food loss. These approaches promote a circular economy, enhance food security, reduce environmental impact and foster climate resilience in food systems.

Farmers are adjusting their practices to cope with the challenge, but many of these solutions remain confined to specific regions or agricultural sectors. The EU-funded CLIMED-FRUIT [1] project is working to bridge this gap by collecting and sharing innovative, climate-adaptive practices from various European agricultural groups to enhance resilience and promote effective climate change adaptation and mitigation. This article presents a non-exhaustive list of experimental results from experiences and research carried out across Europe and identified in the framework of the CLIMED-FRUIT project.

Reuse of olive by-products and co-products

Olive oil extraction has increased significantly due to the health benefits of olive oil, leading to the production of large amounts of olive mill wastes (OMWs), which cause serious environmental issues. Depending on the extraction method, these wastes include polluted wastewater and solid residues, such as olive skin, stones and pomace. Olive pomace, consisting of crushed husk, pulp and stones, along with liquid residue, represents a significant by-product, with 35 kg of pomace and 100 litres of liquid produced per 100 kg of olives [2]. The modern two-phase extraction method, considered more eco-friendly than the three-phase process, still produces waste with a high moisture content of around 65–70% [3]. Managing these wastes is an ongoing challenge for olive oil producers, from both economic and environmental standpoints. However, adopting a ‘zero waste’ strategy through the waste-to-resource concept can transform OMWs into valuable products, supporting a circular economy in the olive oil industry [4]. OMWs, rich in organic material and bioactive compounds, are increasingly seen not as waste but as a resource to be reused. This approach promotes sustainable practices and can have significant socioeconomic benefits, especially in low-income regions, contributing to more sustainable and eco-friendly olive oil production processes (Fig. 1).

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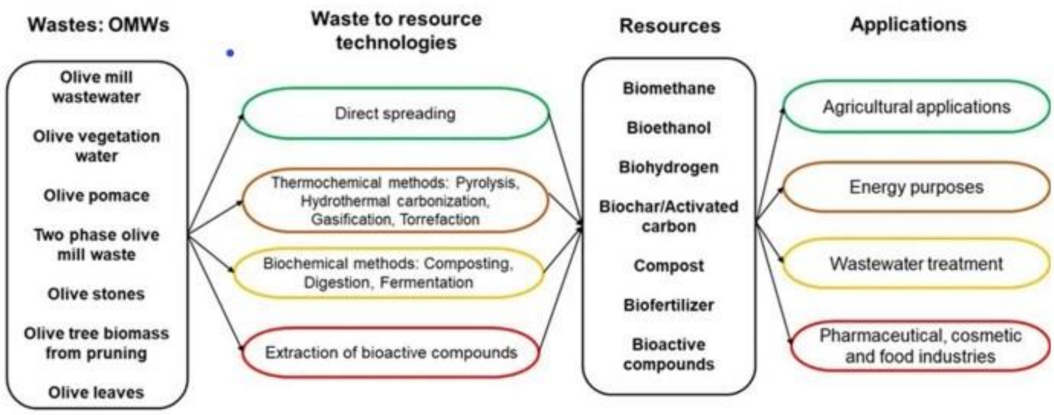

Fig. 1. OMW applications following the waste-to-resource concept [4]

Olive processing waste: biofuel example

The Mediterranean countries produce 95% of the global olive oil supply [5]. The olive oil industry in the Mediterranean area is evolving due to climate change and environmental pressures. Olive oil production generates considerable waste, particularly olive pits and pomace, which pose disposal challenges but also present significant opportunities for energy recovery potential. Olive pits and pomace, with calorific values of 17–20 MJ/kg and 19-24 MJ/kg, can be utilised in biomass boilers or transformed into high-efficiency pellets, offering a renewable alternative to fossil fuels and reducing energy costs in olive mills [6] [7]. Olive pomace can be converted into fuel briquettes and pellets through drying, sieving, grinding, and compression, providing biofuels for olive oil production, such as heating water during grinding, and enhancing circular, energy-resilient processing systems [8]. The impurity content (pulp, skin and small twigs) modifies the properties of olive stones as a fuel. Higher fractions of impurities cause lower bulk densities, as well as higher net calorific values, ash, fines below 1 mm, oil and nitrogen content [9].

The EU BIOmasud® plus project [10] aimed to promote the sustainable market for Mediterranean solid biofuels used in residential heating, with the primary objective of developing integrated solutions to enhance the quality and sustainability of Mediterranean solid biofuels. This included extending BIOmasud® certification to new biofuels and countries. The BIOmasud® plus project has commercialised olive stone and cake as biofuels in Spain, Greece, Italy, and Turkey, with olive cake being the second most used biofuel in Spain's industry in 2015. Unlike solid biofuels like firewood and briquettes, the quality of olive stone is not graded by the ISO 17225:2014 standard. Spain has established a national standard (UNE 164003:2014) for grading olive pit quality for combustion purposes. Additionally, 7 Spanish and 5 Italian olive stone producers are certified by the BIOMASUD quality system for Mediterranean biofuels. Innovative thermochemical (e.g.,

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pyrolysis, gasification) and biochemical (e.g., bioethanol, biogas) conversions of olive by-products are being explored, though largely at the research stage.

In southern Italy, the Bitonto Olive Producers Cooperative [11] is a cooperative mill with a high awareness of the environmental impact of two-phase olive mill waste. The quantity of processed products stands at 150,000 quintals of olives delivered per olive oil campaign. The waste comprises 30–40% pitted pomace, 12–13% olive stones and 50% oil mill wastewater. The cooperative utilises 1–2% of the 12,000 qx/campaign (Fig. 2A) of produced olive stones, which are converted into thermal energy to supply three internal water heaters (Fig. 2B). The remainder of the olive stones is sold to a private party and represents 5% of the turnover. Furthermore, the pitted olive pomace and mill wastewater are provided to a biogas digester company to convert the waste into biogas through anaerobic digestion.

Fig. 2. The olive stones produced by the cooperative (A) and the water heater used to produce hot water onsite(B)

Olive residues to generate bioinsecticides for pest control

The main objective of the EU project LIFEWaste4Green [12] was to mitigate the adverse effects on the environment and human health of chemical origin pesticides, currently used in stone fruit crop protection.

Olive mill wastewater (OMW), a byproduct of olive oil production, poses a serious environmental problem in olive oil-producing countries like Morocco, as it is often discharged into ecosystems without prior treatment. OMW is known for its antimicrobial and biocidal properties, making it effective in controlling plant pests. Due to its high phenolic content, crude OMW has been explored as a natural bio-insecticide against *Potosia opaca* in date palms [13]. Experimental results showed that crude OMW caused weight loss of treated larvae comparable to the commercial insecticide Cordus (50% chlorpyriphos ethyl) in concentrations of 17% and 15%, and mortality rates nearly

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equivalent to those of the commercial insecticide Kemaban (48% chlorpyriphos ethyl). Additionally, OMW extract had a strong insecticidal activity against *Euphyllura olivina* and *Aphis citricola* (Fig. 3) when the applied concentration was 2 g/L [14]. The biocidal activity of OMW is mainly attributed to its high phenolic compound content.

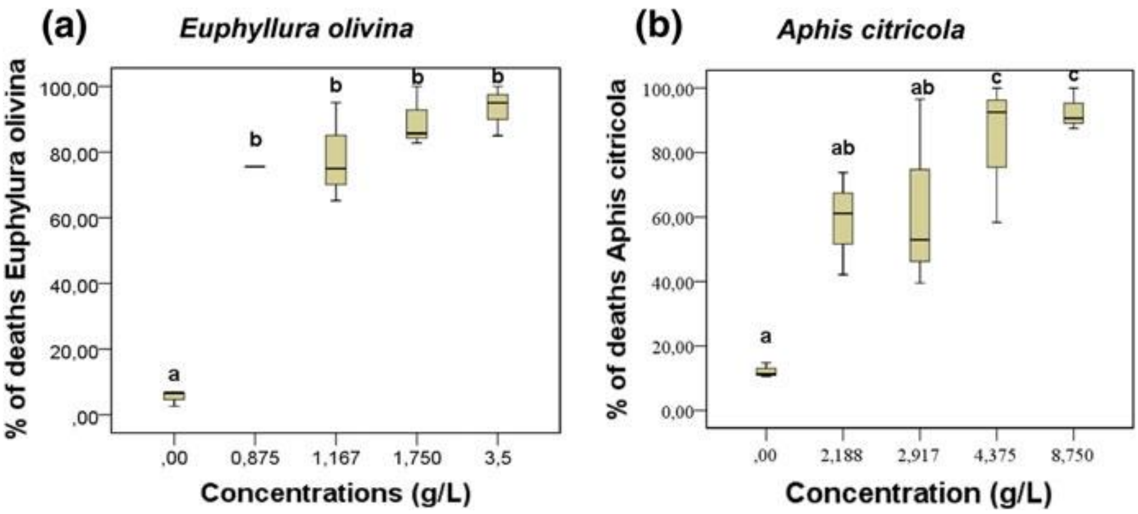

Fig. 3. Assessment of the toxicity of different concentrations of OMW extracts after 24-h exposure [14]

Transforming olive waste into animal feed

Olive by-products represent a valuable and underutilised resource for livestock feeding, particularly in Mediterranean regions where olive oil production generates large amounts of agricultural waste. Recent studies have highlighted how these by-products, such as olive leaves, olive cake (OC), olive pomace and olive mill stone waste (OMSW), can be safely and effectively used in the diets of both ruminants and monogastric animals such as pigs, improving sustainability while maintaining or even enhancing animal performance and product quality.

Olive leaves, for example, can provide up to 50% of the energy and amino acid requirements for sheep and goats at maintenance levels. When adequately supplemented, they can serve as part of the forage component in productive diets. Farmers are advised to feed olive leaves fresh, as drying or ensiling them can reduce their nutritional value. However, caution is needed due to their high copper (Cu) content, which may limit their use, particularly in sensitive species [15].

Olive cake (OC), the solid residue left after oil extraction, is another promising feed ingredient. It can be preserved by ensiling or by incorporating it into multi-nutrient blocks, making it more practical for farm use. A recent study [16] showed that feeding OC to Bísaro pigs did not negatively affect key productive parameters such as growth, average daily feed intake (ADFI), feed conversion ratio (FCR) or digestibility. Two trials tested different OC types and inclusion levels. In the first, pigs were fed diets with 0%, 5%, 10%, 15% and 20%

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exhausted OC (EOC) for 15 days. In the second, over 82 days, pigs received either a control diet or diets containing 10% crude OC, 10% two-phase OC, 10% EOC or 10% EOC with 1% added olive oil. Across both trials, OC was well accepted, and no negative effects were observed. In fact, feed intake increased with higher inclusion levels. These results support OC as a safe, sustainable feed ingredient at moderate levels, helping farmers reduce feed costs and utilise local agro-industrial by-products.

In ruminants, incorporating OC at up to 15–20% of dry matter in diets does not impair digestion or growth. More importantly, OC supplementation improved the quality of milk and meat by increasing monounsaturated fatty acids (MUFAs) and decreasing saturated fatty acids (SFAs). These changes enhance the nutritional value of animal products for consumers by reducing the risk of cholesterol-related diseases [17].

Olive pomace and OMSW are also rich in fibre and energy, but their use is limited by antinutritional compounds such as polyphenols and tannins, especially in raw form [18]. However, novel studies [19] [20] demonstrated that solid-state fermentation (SSF) with beneficial fungi such as *Pleurotus ostreatus* can detoxify OMSW, increase its protein and fat content and improve digestibility, especially for poultry. Mixing OMSW with other by-products, such as oat bran, can further enhance its feed value, offering farmers a low-cost, nutritious alternative that also supports animal health through the presence of bioactive compounds such as β-glucans.

In summary, olive by-products offer a sustainable, cost-effective feeding solution for farmers. With proper processing and inclusion levels, they can maintain animal productivity, improve product quality and contribute to more circular, environmentally friendly farming systems.

Conclusion

Olive oil production creates large amounts of waste, but these by-products, such as olive pomace, pits, leaves and mill wastewater, can be valuable resources when properly managed. Instead of treating them as waste, farmers can use them to produce biofuels, natural pest control products, compost or even livestock feed. These practices not only reduce disposal problems and environmental harm but also offer new ways to save costs or generate income. Feeding animals with olive by-products, for example, can cut feed expenses while maintaining product quality. Using pomace or stones as fuel helps lower energy bills in olive mills. Even wastewater can be used as a natural insecticide. These strategies are already being applied across Mediterranean regions and supported by EU projects. By adopting them, farmers contribute to more sustainable, circular farming, turning waste into opportunity.

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