Safeguarding Halloumi: Reducing Carbon Footprint and Enhancing Anaerobic Digestion Viability through Digestate Co-Composting with green waste

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Introduction

Anaerobic Digestion (AD) is a widely recognized and extensively used technology in waste management, particularly for animal manure, due to its environmental benefits. It aligns with the objectives of the European Green Deal and subsequent policies. Many of these policies support AD as a key circular solution for agricultural waste management, emphasizing its role in reducing livestock methane emissions, producing biogas, and generating renewable energy.

Halloumi holds a prominent position as Cyprus' leading export product, with a recorded value of €186.5 million in the first six months of 2024 (CYSTAT, 2024). However, the value chain of halloumi cheese, is heavily influenced by waste management practices, particularly those involving cow manure. As the EU prioritizes emissions reduction under the Green Deal, the carbon footprint associated with halloumi production poses a potential threat to its future marketability and sustainability and AD emerges as a prominent solution.

Currently, manure management in Cyprus involves either the direct application of raw manure to land - leading to significant environmental problems such as water pollution (nitrification, eutrophication), excessive greenhouse gas emissions, phytotoxicity, and contamination from animal treatment pharmaceuticals, (Sawatdeenarunat *et al.*, 2016) - or treatment at AD facilities. Existing AD facilities in Cyprus are known for their inadequate handling of liquid and solid digestate, which can exacerbate environmental concerns.

Despite the well-documented benefits of AD, many existing facilities across Europe were established primarily through governmental grants and incentive schemes. The number of new AD installations declined significantly following the closure of such schemes (Spackman, 2024). This reliance on financial support reflects the economic challenges of AD plants, which are not typically profitable without external funding. In Cyprus, AD plants are predominantly associated with piggeries and slaughterhouses, operating primarily to manage waste in compliance with legal requirements rather than as economically viable enterprises.

The economic unsustainability of current AD practices presents a threat to the commissioning of new AD plants in Cyprus, jeopardizing AD as a viable solution for safeguarding halloumi. The prospect of co-composting digestate, an emerging topic in Cyprus, presents a unique opportunity to improve the financial stability of AD plants while solving problems associated with poor digestate and manure management. This study aims to review the existing situation in Cyprus, including the regulatory framework governing waste and AD practices, and propose a specific technical solution, that can be supported by the Cypriot government.

Methods

The study combined regulatory and practical analyses to evaluate the current state of AD and digestate management in Cyprus. The regulatory review examined key EU and Cypriot frameworks, to determine legal requirements for AD plants and the feasibility of co-composting within existing practices. To understand how the provisions of the law translate into operational practices and terms imposed on AD facilities and farms, a review of available environmental permits was conducted. Additionally, grants, funding schemes, and the operational status of AD facilities in Cyprus were assessed through a comprehensive analysis of official documents and literature. Dairy market trends were also analyzed to assess the urgency of addressing emissions associated with halloumi production and the potential role of AD in reducing the carbon footprint of this critical export product.

To complement the regulatory review, field research was conducted, including interviews with farmers and site visits to farms and AD plants. The findings from the regulatory review and field research were synthesized to evaluate whether co-composting could serve as a viable solution to current challenges and whether its strategic inclusion in government planning could safeguard halloumi production while improving solid waste management in farming. The integration of legal, technical, practical and financial perspectives allowed for a complete overview of the situation.

Results and discussion

In July 2024 the EU Ecodesign for Sustainable Products Regulation came into force, introducing eco-design requirements for EU market products, including carbon footprint reduction in production processes. Even though food products are excluded, it signals the EU's sustainability trajectory. This shift is reflected in market trends, with companies like Petrou Bros Dairy Products LTD (Alambra) obtaining Environmental Product Declarations for halloumi and Arla incentivizing farmers to lower emissions (Spackman, 2024). With 78–83% of milk supply chain emissions occurring at the farm level, (Sorley *et al.*, 2024), AD emerges as a crucial solution. Recognized under the Renewable Energy Directive for its carbon reduction potential (-45 g CO_{2eq}/MJ for manure treatment), AD also offers savings associated with carbon emissions, through renewable electricity production.

Legal provisions mandate the proper disposal of manure and digestate, including a six-month storage requirement and a maximum BOD limit for the latter of 3,000 mg/l (ABE 12/2022). Inadequate implementation and enforcement result in frequent mismanagement, raising concerns among environmental scientists and authorities. Many AD facilities in Cyprus rely on lagoons for digestate storage - a practice strongly opposed by local authorities due to associated odor and environmental risks, as highlighted during discussions with locals. Adding digestate co-composting with green waste in the process, offers a promising solution by reducing BOD levels, utilizing excess liquid, and decreasing the storage area required, thereby improving environmental outcomes.

Growing soil health concerns across the EU, led to the EU Soil Monitoring Directive. The urgency of the situation has led the Cyprus government to introduce funding under the CAP for farmers who use compost in their fields, offering up to €40/m^3 of compost for specific crops (Ministry of Agriculture, 2024). The compost products currently utilized under this scheme are often of poor quality, with inorganic materials and large uncomposted pieces observed during field visits. Introducing co-composting of digestate with green waste could address multiple issues by improving digestate quality, reducing the costs associated with liquid management - such as those from aerobic digestion - and producing high-quality compost that meets agricultural standards. Furthermore, co-composting can create a revenue stream for AD facilities and encourage farmers' participation by giving back compost to offset the gate fees they pay for manure acceptance. This approach fosters a circular scheme, creating a mutually beneficial cycle that incentivizes ongoing collaboration between farmers and AD facilities.

The proposed technical solution involves the mechanical separation of digestate into liquid and solid components upon exiting the AD reactor. The solid digestate would be utilized in windrow co-composting, mixed with locally available shredded prunings. The liquid digestate would be used to maintain the necessary moisture levels in the windrows, with an anticipated reduction of up to 50% in liquid volume. Any surplus liquid would either be stored in covered tanks or be processed via reverse osmosis filtration for agricultural irrigation. The concentrated brine resulting from reverse osmosis could be left to evaporate in smaller aerated lagoons, used during co-composting, or even recirculated into the anaerobic digester, depending on its quality and specific criteria.

This complete framework for the operation of AD plants and the exploitation of every resulting product and by-product could lead to the economic viability of the AD plants in a circular manner, engaging stakeholders and improving solid waste management.

Conclusion

The transition to sustainability will impact all products in the EU, including halloumi cheese. While not required immediately, by 2030, it is anticipated that the carbon footprint of halloumi will need to be measured, with specific benchmarks set, making CO_2 reduction efforts unavoidable. Given the significant portion of emissions that occur at the farming stage, the responsibility will largely fall on farmers.

AD is a well-recognized solution for waste management, and the Cypriot government has included it in its Integrated National Energy and Climate Plan for 2021–2030, prioritizing AD for animal waste treatment. However, further action is needed to turn this Plan into a reality. The economic viability of AD plants can be significantly enhanced through the production of compost, provided there is a market for the product. As long as the EU continues to push for tangible soil improving actions, the existing governmental funding is expected to continue, securing the market. It is crucial for the Cypriot government to recognize the co-composted product as compost and include it in the funding framework, in line with the EU Fertilising Products Regulation.

Funding the co-composted product of AD digestate under existing funding schemes is considered an important aspect for the financial and environmental sustainability of AD plants. It creates a circular funding mechanism that improves soil health, benefits farmers, and supports the broader community while economically safeguarding AD plants. This approach also establishes a solid foundation for managing emissions associated with halloumi production, ensuring alignment with sustainability goals.

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