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Food Engineering Strategies for Sustainable Food Supply Chains: Interdisciplinarity is the key

Editorial

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Food supply chains are the backbone of our global food systems. Ensuring that these supply chains are robust and can withstand disruptions such as climate change and pandemics is vital for all societies. Just as important is the supply chains' sustainability, given that they are a major emitter of greenhouse gasses (GHG). To meet this dual challenge requires new, interdisciplinary strategies that draw on scientific, technical and social innovations right across the disciplinary spectrum. Addressing this challenge was the main motivation for this special issue.

Our short communication summarises some of these innovations via the keywords in the title. Firstly, *food engineering* embodies the Journal's mantra. It refers to the understanding of issues such as food homeostasis, metabolic exhaustion, stress reactions of microorganisms to inhibit microbial growth, physicochemical reactions and extend shelf-life, all while retaining nutritional value and other quality parameters (Tsironi et al., 2021). Such investigations result in the development of novel food processing methods and packaging solutions. They combine existing new processing technologies such as thermal and minimal non-thermal processes (Asaithambi et al., 2021; Abakarov & Nuñez, 2013) with novel packaging solutions (e.g. biodegradable and active materials for packaging; Luo et al., 2022; Wang et al., 2022; Bahmid et al., 2021).

The term *'Sustainable food supply chains'* provides the system boundaries and points to future research needs. Traditionally food engineering has focused on processing, although about 80% of total energy required to provide food to consumers is expended post production. This part of the chain is also responsible for major losses, waste, costs and GHGs emissions (Heldman, 2022). To meet the objectives of the SDGs and particularly SDG 2 ("*end hunger, achieve food security and improve nutrition*"), will require a more holistic and comprehensive focus on all of the components of our food supply chains, beyond production and processing. Specifically, we must focus on the hard and soft infrastructure components such as facilities, warehousing, transport, distribution networks and labour.

The next keyword is as common as it is underrated; sound, scientifically grounded strategies are essential for the effective governance of our food systems. Functional *strategies* focus on impacts throughout the food distribution system by linking disciplines across food supply chain processes and operations, including processing and packaging (Manzini & Accorsi, 2013). Such effective strategies go beyond specific, localised optimisations by embracing innovations from food science and technology, energy and environmental engineering and industrial engineering. For instance, problems such as how to design a supply chain for organic kiwifruit (*Actinidia deliciosa*) from growers to gross markets must be solved holistically. This includes, for instance, determining which non-thermal process for shelf-life extension to include and when technological interventions are required to manage environmental stresses during transportation in a typical demand season. It also includes decision points on when to use biodegradable active packaging versus traditional package that can be recycled or reused, based on the expected shelf-life of the product. In a globally connected world, it is essential to address such issues holistically rather than being content with partial answers from monodisciplinary research (Lillford & Hermansson, 2021).

Two key barriers to interdisciplinarity are the lack of a common vocabulary between researchers from different fields and the cultural barriers between "science" and "engineering" (Barbosa, 2021). As part of an optimistic vision of future food systems there is no room for such barriers and a new common, shared, open, multicultural vocabulary must include terms such as *waste management*, *shelf-life*, *LCA* and *LCC (i.e. Life Cycle Assessment and Life Cycle Costing)*, *digital twins*, *logistics* and *transportation*, *kinetic models*, *packaging*, *reuse* and *recycling*, *environmental impacts* and *footprint*, *optimization* and *simulation*, *energy*, *processing*, *thermal properties*, *IoT (i.e. Internet-of-Things)*, *Machine learning*, *nutritional values and by-products*. It is also time to recognise and embrace that sound engineering is based on good science, while scientific impact depends on smart engineering. In this vein, Bhat (2021) discusses various technological innovations, current trends, sustainability challenges and transformations that are likely to influence the future of the agri-food sector.

Developing effective, adaptive strategies to meet the ever-increasing food and nutrition demand of diverse populations in a sustainable manner is one of the main challenges of the 21st Century. From an industrial perspective, the sustainability of food supply chains must enable the development of innovative and technologically advanced agriculture and processing technologies, smart packaging, functional, transparent warehousing and transportation systems and optimal operations that enhance synergies across such systems. To address this challenge, we need scientifically sound, quantitative models and methods. Such quantitative tools will be essential to design, prototype, engineer and control novel food processing methods and eco-friendly packaging. They will also play a vital role in improving the sustainability of processing and distribution technologies. Hence, innovative strategies and solutions must be considered in light of their economic, environmental and social impacts on all supply chain participants to ensure that benefits and risks are shared equitably without generating undesirable externalities.

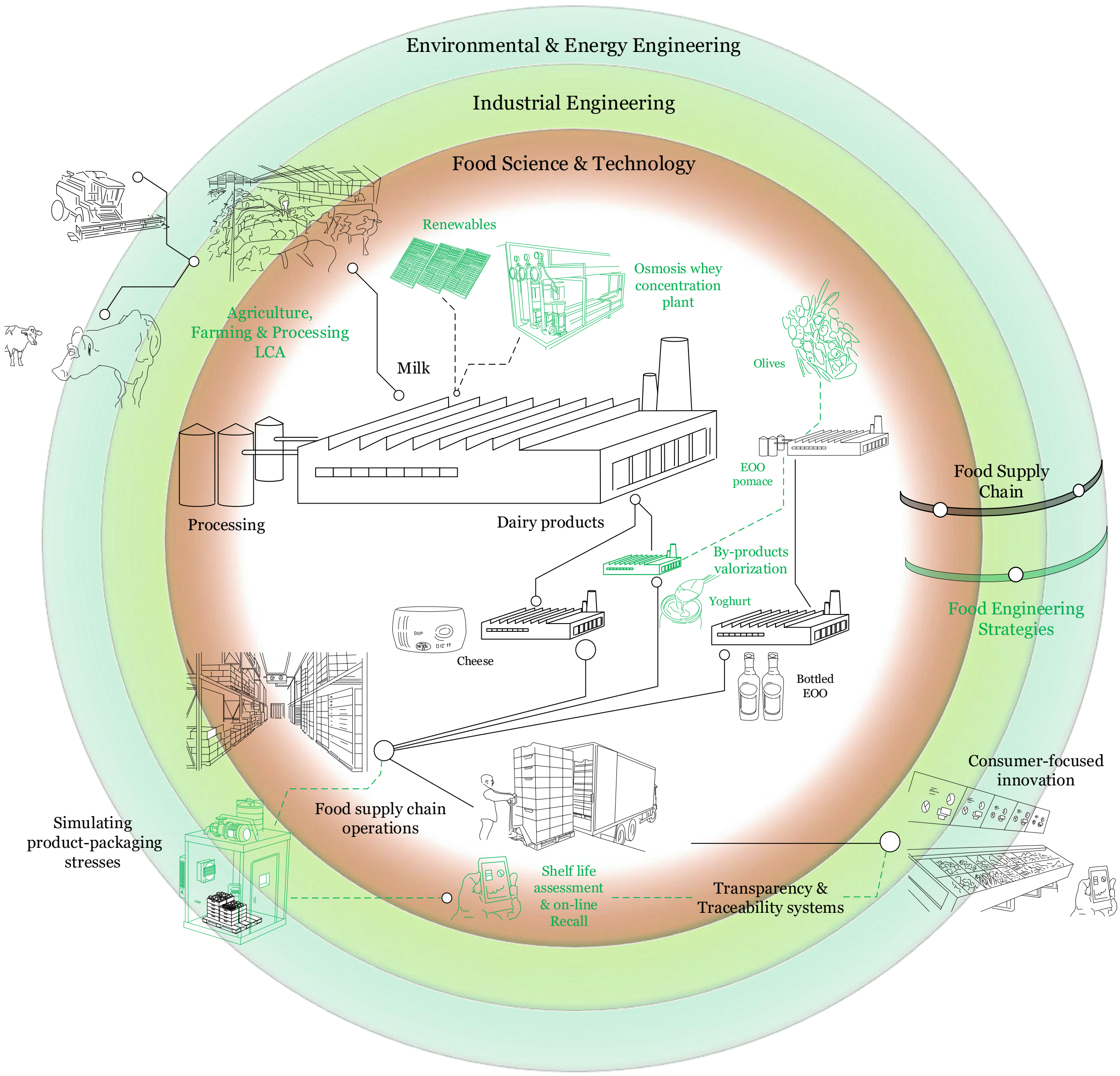

Fig. 1. Examples of food engineering strategies throughout an integrated dairy-EOO supply chain systems.

This Special Issue of the *Journal of Food Engineering* clusters original research papers that describe advances in sustainable food processing and packaging technologies, wastes and by-products valorisation, distribution and recall approaches, methods and strategies that maintain and enhance food safety and food sustainability. For example, Ribeiro et al. (2021) reported that olive pomace powders, a by-product of the Edible Olive Oil (EOO) industry, can be used as valuable, functional ingredients for fortifying some dairy products (e.g., yoghurt). Given the annual amount of olive pomace produced, incorporating this by-product into dairy foods is a win-win strategy that meets environmental and economic sustainability goals of the EOO sector, while providing consumers with additional nutritional benefits through increased dietary fibre, unsaturated fatty acids and phenolics. The environmental impacts of a dairy supply chain, including farming and cheese production, are assessed in the report of Borghesi et al. (2022). Amongst others, the report provides quantitative assessments of the value of renewables and how whey concentration plants, based on reverse osmosis, can reduce the carbon and water footprints of cheese production.

Along the supply chain packaged food is often exposed to environmental stresses that affect shelf-life, packaging conditions, quality and sensorial properties. Accorsi et al. (2022) investigates such issues using a supply chain cyber-physical twin made of a tailored climate-controlled chamber tested on bottled EOO, wine, dry food and dairy products. When spoilage prevention strategies fail, food recalls need to be triggered. Gunawan et al. (2022) used optimization (i.e., dynamic Mixed-Integer Linear Programming) to find the most effective recall timing to prevent major loss and minimize costs, in the case of bulk food supplies. Such a model is validated within a EOO bulk supply chain enabling coherent action toward a sustainable bioeconomy ecosystem as portrayed in Fig. 1.

The contributions to this special issue were selected to demonstrate the value of collaboration across disciplines right along the food value chain. While this is a promising start, much work remains to be done. The development of effective and adaptable strategies for sustainable food supply chain will depend not only on the respectful interactions between scientists and engineers across all disciplines; it will also require the involvement of policymakers and consumers in a solution-oriented, co-design process. Only then will we be able to truly innovate our food supply chain, making them fit-for-purpose in a rapidly changing environment.

References

Abakarov, A., Nuñez, M. (2013). Thermal food processing optimization: Algorithms and software. *Journal of Food Engineering*, 115(4), 428-442.

Accorsi, R., Bortolini, M., Gamberi, M., Guidani, B., Manzini, R., Ronzoni, M. (2022). Simulating product-packaging conditions under environmental stresses in a food supply chain cyber-physical twin. *Journal of Food Engineering*, *320* (2022), 110930.

Asaithambi, N., Singh, K.S., Singha, P. (2021). Current status of non-thermal processing of probiotic foods: A review. *Journal of Food Engineering*, 303 (2021), 110567.

Bahmid, N.A., Dekker, M., Fogliano, V., Heising, J. (2021). Modelling the effect of food composition on antimicrobial compound absorption and degradation in an active packaging. *Journal of Food Engineering*, 300 (2021), 110539.

Barbosa M.W. (2021). Uncovering research streams on agri-food supply chain management: A bibliometric study. *Global Food Security*, 28 (2021), 100517.

Bhat, R. (2021). Future Foods: Global Trends, Opportunities and Sustainability Challenges, (Ed. Bhat, R., Elsevier Sciences, Academic Press, December 2021), Paperback ISBN: 9780323910019, total pages, 786.

Borghesi, G., Stefanini, R., Vignali, G. (2022). Life cycle assessment of packaged organic dairy product: A comparison of different methods for the environmental assessment of alternative scenarios. *Journal of Food Engineering*, 318 (2022), 110902.

Gunawan, I., Vanany, I., Widodo, E. (2022). Bulk food recall decisions: Postponement and preponement to sustain food business. *Journal of Food Engineering*, 317 (2022), 110843.

Heldman, D.R., (2022). Sustainability of the food supply chain; energy, water and waste. *Food Engineering Innovations Across the Food Supply Chain – Chapter 3*, 47-60. Academic Press (2022).

Lillford, P., Hermansson, A. M. (2021). Global missions and the critical needs of food science and technology. *Trends in Food Science & Technology*, 111, 800-811.

Luo, Q., Hossen, Md A., Zeng, Y., Dai, J., Lia, S., Qin, W., Liu, Y. (2022). Gelatin-based composite films and their application in food packaging: A review. *Journal of Food Engineering*, 313 (2022), 110762.

Manzini, R., Accorsi, R. (2013). The new conceptual framework for food supply chain assessment. *Journal of Food Engineering*, 115(2), 251-263.

Ribeiro, T.B., Bonifácio-Lopes, T., Morais, P., Miranda, A., Nunes, J., Vicent, A.A., Pintado, M. (2021). Incorporation of olive pomace ingredients into yoghurts as a source of fibre and hydroxytyrosol:

Antioxidant activity and stability throughout gastrointestinal digestion. *Journal of Food Engineering*, 297 (2021), 110476.

Tsironi, T., Koutinas, A., Mandala, I., Stoforos, N.G. (2021). Current and new Green Deal solutions for sustainable food processing. *Current Opinion in Environmental Science & Health*, 21, 100244.

Wang, C., Gong, C., Qin, Y., Hu, Y., Jiao, A., Jin, Z., Qiu, C., Wang, J. (2022). Bioactive and functional biodegradable packaging films reinforced with nanoparticles. *Journal of Food Engineering*, 312 (2022), 110752.