Exploring Safety-by-Design: Physicochemical Properties and Ecotoxicological Evaluation of Thyme Oil-Based Nanocarriers

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In recent years, the science of nanocarriers (NCs) has rapidly expanded, finding application in many different fields. However, the increased human and environmental exposure to these materials raises important questions about their safety; their small size, large surface area, and high reactivity can lead to novel biological interactions and potential toxic effects [1]. It is essential to assess their impact not only on humans, but also on animals and the environment, in accordance with the One Health concept [2], which highlights the interconnection of these three domains. In this context, nanotoxicology emerges as a key discipline for evaluating and understanding the risks associated with the use of nanomaterials, especially in light of the development of sustainable NCs. In this work, different NCs were prepared (nanoemulsions and liposomes), all based on thyme essential oil, chosen for its strong antimicrobial properties [3]. The samples were characterized from a physicochemical standpoint, evaluating hydrodynamic diameter, PDI, ζ-potential, stability under different experimental conditions, polarity, microviscosity and fluidity. After assessing their stability in the culture media of microalgae *Scenedesmus sp.* And *Daphnia magna*, the toxicological profile of the NCs was investigated by monitoring algal growth and Daphnia viability.
This study allowed us to identify the possible properties of NCs associated with toxicity, define non-toxic concentration ranges, and highlight the importance of adopting a multi-species toxicological approach to gain a more comprehensive understanding of the effects of NCs. Given the emerging interest in the One Health approach, an integrative experimental set up is essential for advancing knowledge and promoting the safe and sustainable development of NCs.

[1] N. Bentrad, et al. Springer Nature Switzerland, Cham, 2025, pp. 171–196.
[2] M. E. Velazquez-Meza, et al. Vet World 15 (2022) 743–749.
[3] A. Kowalczyk, et al. Molecules 25 (2020) 4125.