Integrating environmental and nutritional assessment of fresh seaweeds

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1. Introduction

The global food system is increasingly unable to meet growing demand without intensifying environmental, socioeconomic and health pressure, highlighting the urgent need to transition food production and consumption away from resource-intensive and emission-intensive pathways. To address these challenges, the Farm-to-Fork Strategy, part of the European Green Deal, aims to accelerate the transition to fair, healthy, and environmentally sustainable food systems (European Commission, 2019).

Seaweeds are emerging as a promising alternative food resource, providing high-quality proteins, key micronutrients and bioactive compounds linked to better metabolic, cardiovascular, and immune health. When properly processed and incorporated into diets, seaweeds can help reduce micronutrient deficiencies, enhance overall protein quality, and lower sodium and saturated fat intake compared to many conventional processed foods.

Integrating Life Cycle Assessment with nutritional assessment (e.g., nutrient-density metrics or nutritional footprint) in seaweed-based value chains is crucial for identifying environmental and nutritional hotspots, and informing production-related, dietary, and policy decisions that promote more sustainable and health-supporting food systems.

This study aims to assess the environmental performance and nutritional footprint of fresh *Ulva spp.*, a green seaweed wild-harvested on the Galician coast.

2. Methods

The functional unit (FU) is 1 kg of fresh seaweed. A cradle-to-gate approach was applied, i.e. wild harvesting, cleaning, refrigeration and packaging. Primary data for seaweed cultivation and processing were sourced from a PORTO-MUIÑOS, S.L. company (Spain), complemented by secondary data from Ecoinvent database (Wernet et al., 2016). Environmental impacts were

quantified using the Environmental Footprint method, considering acidification (AC), climate change (CC), marine eutrophication (EM), freshwater eutrophication (EF), resource use – fossil (RUF) and resource use – minerals and metals (RUMM).

The nutritional footprint was quantified by applying the qNRF1.10.2 (quality Nutrient Rich Food 1.10.2) equation proposed by Fernández-Ríos et al. (2024), which integrates selected essential nutrients and a protein quality scoring component. A nutrient-based FU was defined as 1000qNRF1.10.2.

3. Results and discussion

Regarding the environmental performance of fresh *Ulva spp.* production, the refrigeration stage emerged as the main hotspot (Figure 1), contributing from 53% (RUMM) to 73% (EM) of the total environmental impact associated, primarily due to the electricity demand for storing the seaweed under refrigerated conditions. In contrast, for RUMM, harvesting was identified as the predominant contributor, primarily driven by the production and use of nylon 6 nets required in the seaweed harvesting. Regarding the nutritional composition, the wild-harvested *Ulva spp.* is mainly composed of carbohydrates (including dietary fibre), protein, and minerals.

4. Conclusions

This study demonstrates that refrigeration has a significant influence on the environmental impacts of fresh *Ulva spp.*, suggesting that more efficient refrigeration systems and increased electricity supply from renewable sources may help mitigate the environmental impacts of seaweed production. Seaweed emerges as a promising option for more sustainable diets, although further comparisons with conventional foods and a more complete nutritional assessment are still needed.

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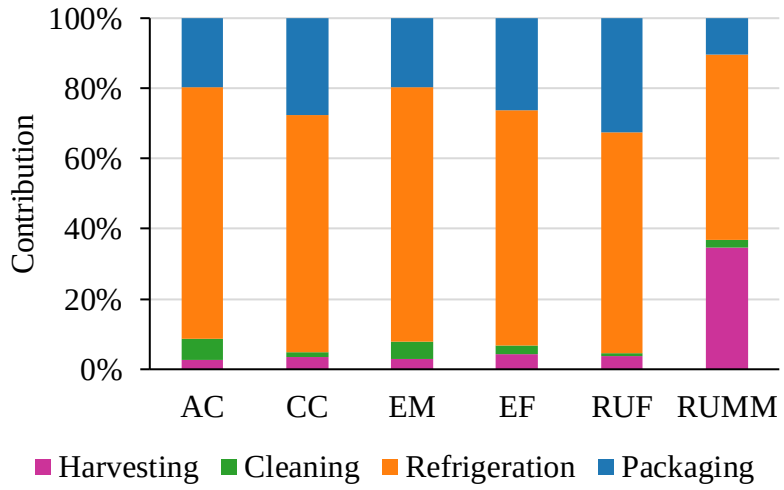


Figure 1. Relative contributions to the environmental impacts of fresh seaweed production (*Ulva* spp.). AC, acidification; CC, climate change; EM, eutrophication – marine; EF, eutrophication – freshwater; RUF, resource use – fossils; RUMM, resource use – minerals and metals.