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The Environmental Impact of 'Superfoods': A Space for Debate and Joint Reflection †

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Abstract: This paper aims to provide an overview of the environmental impacts of superfoods. For this purpose, a bibliographic search was conducted to find articles developing the life cycle assessment of four of the most popular superfoods (quinoa, chia, spirulina, and kale), as well as identify potential future environmental challenges. The main outcomes reveal that, with the limited information currently available, it cannot justifiably be claimed that superfoods present environmental benefits compared to traditional products, and the impacts will increase in a medium to long term due to the change of current agricultural systems into intensive commercially oriented systems caused by the growth of demand.

Keywords: Life cycle assessment (LCA); GHG emissions; agri-food system; food choice; food supply chain (FSC); agricultural products; environmental challenges

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1. Introduction

In recent years, the so-called 'superfoods' have become the influential new trend that has taken over the food industry. Even though there is not an official definition of this term, superfoods are known as foods that provide an important amount of vitamins, minerals, protein, fiber, and other nutrients that play an important role in diets and contribute to the proper operation of the body [1]. According to the *Superfoods Market Report 2020* [2], a growing demand trend on the consumption of superfoods was observed in last years, especially during the COVID-19 outbreak due to the concern of some citizens about maintaining a healthy diet and boosting the immune system. In addition, the global superfood market is projected to increase a compound annual growth rate of 5.1% during the next lustrum [2]. However, despite they can present an opportunity to address food insecurity [3], it is important to not underestimated other target problems, such as combating environmental degradation. Agriculture is a significant contributor to climate change, accounting for one-fifth of total greenhouse gas (GHG) emissions among all economic activities [4]. In fact, the overall food supply chain (FSC) has ecological interactions, not only by means of emissions, but also alongside land use, natural resources depletion or biodiversity loss [5]. For this reason, tools such as life cycle assessment (LCA) are key to support the transition toward increasing sustainability of current patterns of food production and consumption [6]. In this context, the objective of the present paper is twofold. On the one hand, a revision of the state of the question regarding LCA applied to superfoods will be conducted, with the final goal of identifying the 'gaps' addressing this issue and proposing an appropriate methodology. On the other hand, a review of future environmental consequences of superfoods production, both in short and medium-long term, will be carried out.

2. Methods

According to the objective, a bibliographic search was conducted to assess the state of art of superfoods LCA-related studies and review their potential impacts in nature. In a preliminary revision, it was observed that the number of articles is quite limited, so that we proposed four specific superfoods in order to obtain a global and general perspective of the state of the question. Hence, quinoa, chia, spirulina, and kale were considered since they are gaining the most attention from consumers today. The search was carried out using the database of Scopus [7], as it has greater number of references and provides larger reliability than other widely used sources, such as Web of Science or Google Scholar [8]. The terms "life cycle assessment" or "LCA" combined with "chia", "kale", "spirulina" or "quinoa" must appear in the abstract, keywords, or title. The methodology followed as well as the results obtained in the search are illustrated in Figure 1. On the other hand, for assessing the environmental performance of these products in short and medium-long term, the words "environment" and "superfood" were introduced in the database. In this case, Google Scholar [9] was included along with Scopus with the aim of maximize the amount of information and conclusions.

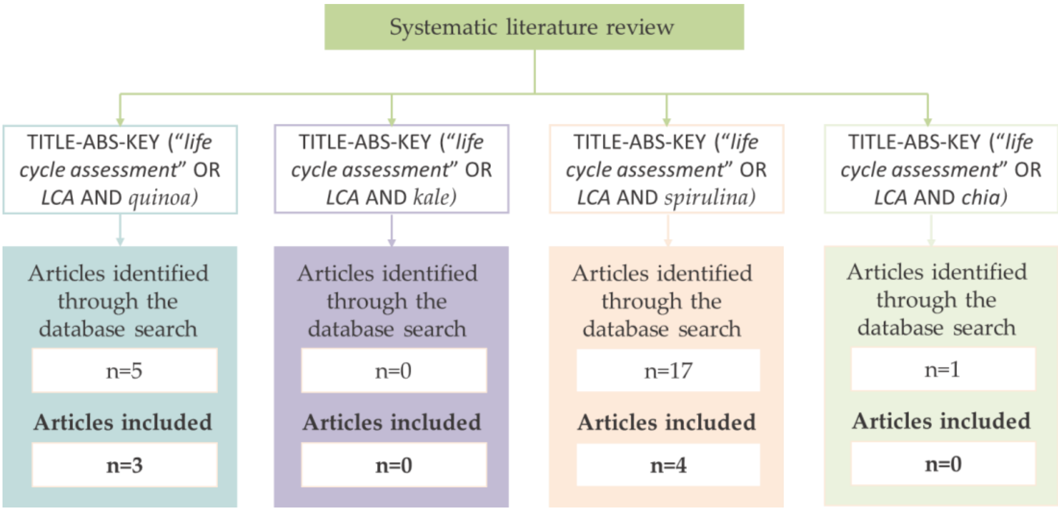

Figure 1. Methodology and results of the bibliographic search conducted in Scopus.

3. Results and Discussion

3.1. Literature Revision and LCA Methodology Applied to Superfoods

A total of 23 documents were found, but only seven were included in the review. Three of these articles addressed the LCA of the production of quinoa, whereas the remaining assessed spirulina. On the contrary, neither kale nor chia were evaluated from an environmental perspective using LCA as operational tool. In the case of spirulina, it is remarkable that most of the documents were excluded since they were focused on non-food purposes, for instance, production of biodiesel or energy by means of algae biomass.

Regarding the characteristics of the systems, we identified and assessed the key elements of LCA methodology: functional unit (FU), scope, impact assessment categories, as well as other aspects such as software and database used. Generally, FU of 1 kg or ton of product were largely considered, i.e., 1 kg [10] or 1 ton [11] of quinoa, or 1 kg of spirulina, both fresh or dried biomass [12,13] and tablets [14]. They present the simplest unit of reference for comparisons and is usually the most suitable for cradle-to-gate analysis, both farm gate [10,11], or processing-plant gate [12–14]. On the contrary, Cancino-Espinoza et al. [15] used a reference given by the weight of a direct-sale product, 500 g of packaged quinoa. This provides a very good reference unit in the case of eco-labeling of the product, since the consumer can know the environmental impacts of the package purchased and consumed. Equally appropriate, although perhaps a bit more confusing, is the case of the FU of 'serving', used by Thomas et al. [16], since it developed the LCA of products containing spirulina, such as milk or jam, and therefore provided the impacts per consumption, not per quantity. In other cases, FU were used in reference to by-products or compounds extracted from the superfood itself, such as pigments [12], proteins [13,14], PUFA (polyunsaturated fatty acids) [12] or oil [13]. In relation to the software, four of seven studies conducted the assessment in SimaPro [11,13,15,16], whereas the remaining used R [10] or did it manually [12]. However, all authors applied the Ecoinvent database for calculations since it is one of the most consistent, coherent and transparent LCA databases [17]. Finally, the environmental impact method and categories assessed varied significantly in each study. The calculation of global warming potential (GWP) was common in all studies, probably due to the great importance of GHG emissions nowadays, and the importance of this indicator since it is one of the most used, representative, and understandable by almost everyone. Other indicators such as ozone depletion potential (OPD), resources depletion (ADP fossil and ADP elements), acidification (AP), eutrophication (EP), or toxicity indicators (HTP, MAETP, FAETP…) played an important role in these types of studies. However, the only recommendation when choosing impact indicators is that the choice should depend on the type of product under study and the possible impacts it may have on the environment.

3.2. Short and Medium-Long Term Challenges of Superfoods

The limited number of articles developing LCA of superfoods or their environmental effects hindering the process of drawing conclusions about the environmental benefits of superfoods. At this point, there is not enough objective and quantitative evidence that these products offer a better environmental performance than other traditional foods. For instance, GHG emissions of the production of organic quinoa accounts 0.88 kg CO_2 eq./kg [15], whereas those of conventional quinoa 1.02 kg CO_2 eq./kg [10], and spirulina tablets 7.7 kg CO_2 eq./kg [14]. As comparative framework, conventional rice production generates 1.65 kg CO_2 eq./kg, organic rice an average of 2.7 kg CO_2 eq./kg [18], beans 0.51 kg CO_2 eq./kg, corn 0.53 kg CO_2 eq./kg, and pork 5.85 kg CO_2 eq./kg [19]. In light of these values, no general conclusion can be reported, and only through the development of LCA of each specific food, accurate and well-justified arguments can be claimed. Fortunately, a growing trend in the publication of these articles is taking place, so that in a short to medium term these 'gaps' in knowledge can be filled.

On the other hand, given that superfoods are mostly agriculture products, some environmental challenges can be identified according to the problematic of this sector. Likewise, based on the progress of the production and consumption patterns of other food products, we can make some projections of the challenges we will have to face in a medium to long term. A summary of this information is illustrated in Figure 2.

Even though the consumption of superfoods is not extremely high today, urbanization, high disposable income, and changing lifestyles of individuals is boosting their attention in the global market [20]. Currently, the main environmental side-effects associated with their production may lie in the hotspots of any agricultural activity, i.e., use of agrochemicals and organic waste generation. It is believed that superfoods are produced in a 'natural' way, with little or no technological intervention and with traditional agricultural practices without chemicals [21]. Nonetheless, the reality differs considerably from the theory. According to the inventory data of the LCA studies previously reviewed, quinoa production requires diesel and energy for transport and agricultural machinery, as well as organic (manure) or chemical fertilizers and pesticides for the organic [15] and conventional [11] production, respectively. Likewise, spirulina tablets production needs a supply of synthetic fertilizers and energy for the algae growth [14]. Although no other studies are available, it is logical to think that to produce other superfoods such as chia or kale, these types of products would also be necessary. On the other hand, food loss, which occurs in the production, harvesting and processing, could represent another important issue, decreasing the yield and generating high amounts of waste to manage [22]. Another common problem in food supply chains (FSC), and particularly in superfoods FSC, is that the production is located far from the consumption. Superfoods are usually produced in 'exotic' locations, for instance, maca and quinoa are originated from Peru and açai from the Brazilian Amazon [21]. This makes products must travel significant distances to supply markets around the world, boosting transformations in processing technologies and packaging, and impacting strongly on the environment. In addition, superfoods originate in most cases within complex and diverse crop agricultural systems. The increase in demand will force these systems to change into intensive and commercially-oriented production systems, causing profound impacts on landscape, diets, carbon footprints, and biodiversity among others [23]. Agriculture intensification is usually accompanied by commercialization and conversion to monocrop agriculture [24], so that sustainable intensification and agroecological practices present an opportunity to deal with this situation [25]. Crop diversification and additional diversification measures, such as crop rotation, mixed cropping, or changing cropping patterns, have the potential to lead to higher and more stable yields, increase profitability, and achieve greater resilience in the agroecosystems in the long term [26]. On the other hand, policy measures are essential to influence decisions of farmers and production methods, by means of, for instance, agri-environmental programs (AEP). AEP are a main possibility to encourage less intensive production, both to reduce market surpluses and to alleviate environmental pressure considering different action fields, e.g., environmentally friendly production methods [27]. In addition, the existence of third-party sustainability certifications represents a great opportunity to ensure that all products consumed have a sustainable origin that has been tracked [23]. Finally, at this point it is imperative to highlight the importance of addressing a life cycle thinking for ensuring a transition towards a more sustainable production and consumption patterns. Main challenges addressing LCA studies reside in the inherent variability of the agricultural system both in the inventory data and in the possible impacts, evidencing the need for specific guidelines for agricultural inventories [28].

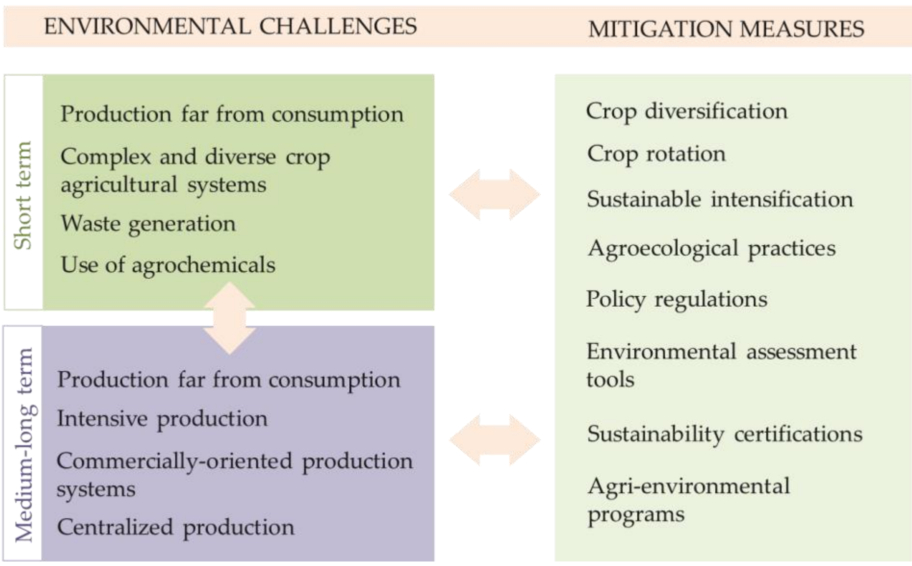

Figure 2. Summary of the environmental challenges and potential solutions addressing the superfoods sector.

4. Conclusions

The evident growth in the demand of superfoods along with the significant environmental impacts of the food sector have led to major concerning about the environmental repercussions of production and consumption patterns of these products. The bibliographic search reveals that, albeit an increase in the number of articles addressing LCA of superfoods is producing, the amount of information is still too limited to draw objective and well-justified conclusions about the environmental benefits of these products. Currently, this market sector is quite small compared to the major commodities, but the challenges it faces now are the same as for the rest of agricultural activities, and they will grow as demand increases. The shift from current agricultural systems to intensive commercial oriented systems will lead to a significant increase in emissions, loss of biodiversity, and other environmental issues. To deal with this trouble, sustainable intensification, agroecological practices, crop diversification and crop rotation, and, especially, a life cycle thinking, are key and provide the opportunity to achieve a sustainable and resilient superfood sector.

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Conflicts of Interest: The authors declare no conflict of interest.

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