Life cycle assessment of Vitamin D_2-based extract from Mushroom waste

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The worldwide food production is accountable for 25% of the total greenhouse gases emissions, and for a significant biodiversity loss (Ramos et al., 2020). Food waste has emerged as global problem, amounting to one-third of all food production, which represents expressive economic losses and unnecessary environmental pressure (FAO, 2011). Particularly, a large amount of mushrooms waste is generated during mushrooms production (about 20 % of total production) (Papoutsis et al., 2020). Mushrooms are a well-known source of several compounds with several health benefits and high economic importance, such as ergosterol. Through ultraviolet (UV) irradiation, mushrooms' ergosterol can be converted in Vitamin D_2, which is a desired additive to enrich the bioactive properties of foods (Corrêa et al., 2018).Vitamin D_2 plays an important role in the prevention of some diseases, namely: bone and muscle health, cancer, liver function, obesity, depression, and diabetes (Taofiq et al., 2017).

The life cycle assessment (LCA) can be used to systematically estimate the potential environmental impacts of a product along its life cycle. Even at an early stage of development, LCA allows to identify critical processes and hot spots, for which improvement suggestions could be proposed and re-assessed (Monteiro et al., 2020). Thus, this study aims to support decision towards the production of Vitamin D_2 bio-additives extracted from mushroom waste, comparing the life cycle environmental impacts of two different extraction routes at an early stage of development, and identifying the main drivers for improvement.

The LCA methodology (ISO, 2006a, 2006b) was applied to evaluate the potential impacts of the production of Vitamin D_2 enriched extracts by two different routes from mushroom bio-residues (depicted in Figure 1): A) Initial UV-irradiation of the mushrooms; B) Final UV-irradiation of the ergosterol extract. Thus, considering a "cradle-to-gate" approach and a functional unit (FU) of 1 g of extract, the environmental impacts were evaluated considering primary data from lab-scale experiments within the scope of the ValorNatural project. This information was completed with secondary data from EcoInvent (v3.7).

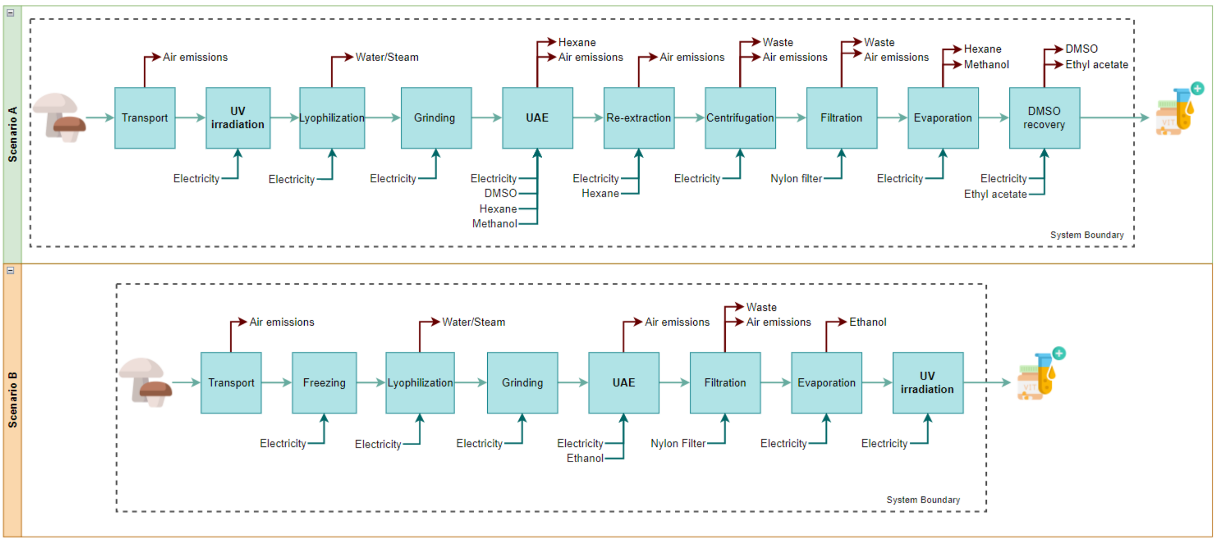

Figure 1. Unit processes and system boundaries under the study

Since the raw material is considered a by-product from the mushroom production industry, different allocation approaches were assumed to estimate the impact of the mushroom production stage, namely (i) a mass allocation (a=1), and an economic allocation where the by-product has no economic value (a=0). The life cycle impacts were calculated using the ReCiPe (v1.03) method for 11 midpoints impact categories, considered the most significant and representative for this study: Global Warming (GW), Stratospheric Ozone Depletion (OD), Ozone Formation (OF), Terrestrial Acidification (TA), Freshwater Eutrophication (FE), Marine Eutrophication (ME), Human Toxicity (HT), Land Use (LU), Mineral Resource Scarcity (MRS), Fossil Resource Scarcity (FRS), and Water Consumption (WC).

Figure 2 depicts the relative contribution of each unit process for the environmental impacts obtained, considering the mass allocation of a=1 for scenario A (Figure 2(A)) and scenario B (Figure 2(B)). In both scenarios, the most significant processes are those with highest energy consumption, namely lyophilization (21 % - scenario A; 35 % - scenario B), and evaporation (22 % - scenario A; 19 % - scenario B). Moreover, mushroom production accounts for 16 % and 21 % of the impacts in scenarios A and B, respectively, being more meaningful in ME and WC categories, representing more than 60 % of the impacts. On the other hand, transport and grinding present minor environmental impacts. Comparing the global impacts of both scenarios (Figure 2(C)), scenario A showed to have a better environmental performance (e.g.: GW – 3,62 kg CO_2-eq) than scenario B (e.g.: GW – 9,31 kg CO_2-eq), presenting, on average, less 61 % of the impacts than the latter.

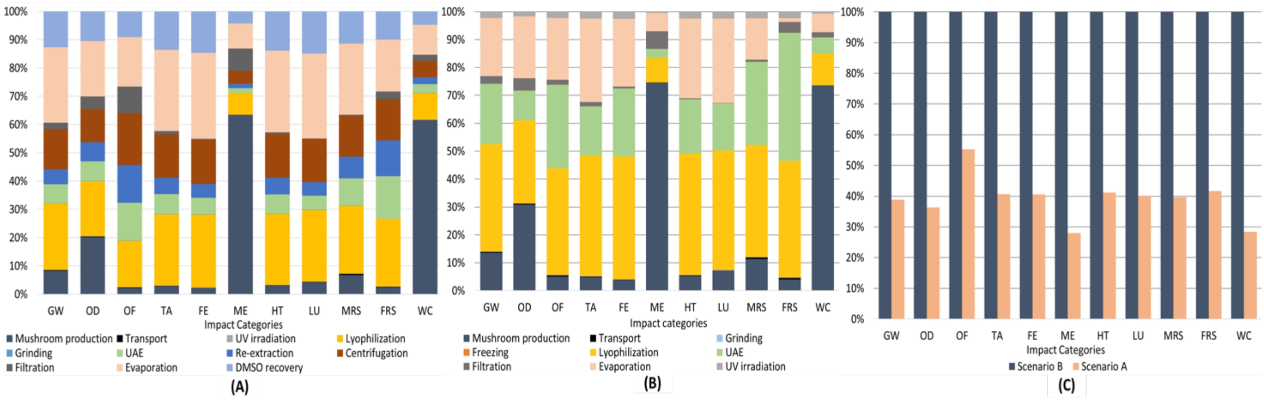

Figure 2. LCA environmental impacts for 1 g of Vitamin D2 enriched extract produced by UV irradiation at the beginning of the process (A) and at the end (B) and relative comparison among A and B (C)

Considering the different allocation scenarios, if the raw material without economic value (a=0) is considered, the total environmental impacts could decrease by 16 % (scenario A), and 21 % (scenario B). Hence, this unit process could have either significant or minimal impacts, depending on the allocation applied.

Summing up, scenario A demonstrated an eco-friendlier route than scenario B. Energy consumption is the factor that contributes to most of the environmental impact in all categories under the study. In addition, the unit processes causing more environmental burdens in both scenarios are lyophilization, evaporation, and mushroom production. Nevertheless, depending on the economic allocation considered, different results could be obtained.

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