Environmental Life Cycle Assessment of Durum Wheat Pasta and Chickpea Pasta

Introduction

The food sector faces a major challenge to deliver sustainable nutrition. Intensive agricultural practices adopted to meet growing global food demand have driven massive anthropogenic pressures on the Earth's ecosystems, notably via land occupation, fertiliser use and animal-related greenhouse gas (GHG) and ammonia emissions (Steffen et al., 2015). Synthetic Nitrogen Fertilizer (SNF) use causes high environmental and economic damage, as its production is resource-intensive, and its over-application causes N leaching and GHG emissions, degrading air, water, and soil qualities (Sutton et al., 2011), and biodiversity loss (Mozumder & Berrens, 2007). Meanwhile, billions of people are directly affected by the paradoxical coexistence of undernutrition and obesity (WHO, 2017; Zelman & Kennedy, 2005). Diet quality is worsening, through a declining consumption of healthy foods and an increasing intake of calories, refined grains, meat, added fats and sugars (Kendall, Esfahani, & Jenkins, 2010; Willett et al., 2019). Legumes provide an affordable and sustainable solution to these issues.

From an environmental perspective, legumes alleviate the damage caused by extensive use of SNF through N fixation in soils by virtue of their symbiosis with N_2-fixing bacteria. Accumulation of this fixed N in plants boosts yields (Peoples et al., 2009). Furthermore, the use of legumes in agriculture increases biodiversity, and reduces weed invasion (Sturludóttir et al., 2014). The loss rate of organic carbon in soils can also be slowed, and carbon sequestration rates enhanced (Peoples et al., 2019).

This paper reports the results of a comparative LCA of chickpea and durum wheat pasta assessed over fourteen impact categories recommended by PEF Guidance (European Commission, 2018c) and a land occupation indicator. It also uses a nutritional functional unit first proposed by Van Dooren (2016), the Nutrient Density Unit (NDU). The use of the NDU in food LCAs allows the comparison of different products, and it is adequate to look at the presence of three macronutrients per kilocalories when investigating nutrient density. We hypothesise that legume pasta has a lower environmental impact than durum wheat pasta, and that these benefits are more pronounced in terms of nutrient density, and not just weight of the product.

Methods

This LCA study is a comparative assessment of the overall environmental impact from cradle to fork arising from the consumption of chickpea pasta or conventional durum wheat pasta. The open source software OpenLCA 1.8.0 was used to calculate the environmental footprint of the two pasta products, using

Agrifootprint 3.0 (Blonk Consultants, 2019) and Ecoinvent 3.5 (Wernet et al., 2016) international databases. Inventory data on chickpea pasta were collected specifically for this study from CLICKS Ltd., the Bulgarian manufacturer of chickpea pasta Variva®. Data on durum wheat pasta production were adapted from Bevilacqua, Braglia, Carmignani, & Zammori (2007) and modelled as though the durum pasta was manufactured in Bulgaria to make the geographical origin of the two products identical.

Results

Impact category	Unit	Impact per 250g (DW) cooked pasta			Pasta NDU FU	
		Wheat pasta	Chickpea _SNF	Chickpea _inoc	Wheat pasta	Chickpea pasta
Abiotic depletion (fossil fuels)	MJ	5.21	5.29	5.08	6.35	2.2
Abiotic depletion	kg Sb eq	5.68E-07	6.71E-07	6.71E-07	6.93E-07	2.79E-07
Acidification	molc H^+ e	0.009	0.003	0.003	0.011	0.0014
Freshwater eutrophication	kg P eq	0.0004	0.0003	0.0003	0.0005	0.0001
Ionizing radiation HH	kBq U235	0.09	0.06	0.06	0.1	0.0232
Global warming potential	kg CO_2 eq	0.48	0.48	0.45	0.58	0.1985
Marine eutrophication	kg N eq	0.0017	0.0016	0.0016	0.002098	0.0007
Ozone depletion	kg CFC-11	3.60E-08	3.93E-08	3.93E-08	4.39E-08	1.64E-08
Photochemical ozone formatio	kg NMVO	0.0017	0.0015	0.0015	0.002	0.0006
Terrestrial eutrophication	molc N eq	0.03	0.01	0.0078	0.038	0.0038
Water use	m^3	0.44	0.33	0.33	0.54	0.1377
Land use	m^2	0.62	1.65	1.65	0.76	0.6875

Table 1 lists the derived environmental impacts for twelve impact categories. Two functional units are shown; per 250g cooked pasta and per NDU. In terms of 250g cooked pasta, chickpea pasta has the highest environmental impact for abiotic depletion (fossil fuels), abiotic depletion, ozone depletion, land use, and the three toxicity-related categories. The carbon footprints of 250g of cooked chickpea and durum wheat pastas are the same, at 0.48 kg CO_2 equivalents. For the same weight of pasta, chickpea pasta requires around twice the amount of arable land than durum wheat pasta, $0.62m^2$.yr-1 versus $1.65m^2$.yr-1 respectively. Where the FU is on a nutritional basis, per NDU, chickpea pasta scored lower than durum wheat pasta over all environmental impact categories.

Discussion and Conclusions

An attributional LCA was performed to compare chickpea (*Cicer arietinum*) pasta versus durum wheat (*Triticum durum*) pasta from cradle to fork, using a weight-based functional unit and a nutrient-accounting

FU, the NDU. Different functional units can yield opposite results. To produce the same amount of wheat and chickpea pasta, this LCA showed that wheat pasta had a similar environmental impact than chickpea pasta, except in land use for which chickpea pasta required 2.5 times more land area. However, considering nutrition as the key function of food, comparing two types of pasta on a weight basis is highly limiting. Using the NDU as a functional unit showed that to provide the same nutrition, chickpea pasta had a minimal environmental impact when compared to durum wheat pasta.

Chickpea cultivation, transport from factory to consumer, and packaging were identified as the main environmental hotspots of the life cycle of chickpea pasta production. This study also highlighted the environmental damage associated with unnecessary use of synthetic nitrogen fertilisers for chickpea cultivation, and how farmers should inoculate their crops to obtain similar yields while having a much lower environmental impact. A change in packaging type, better cultivation practices and research into yield improvement will further decrease the environmental impact of chickpea pasta.

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