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Life cycle assessment of bread from several alternative food networks in Europe

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A B S T R A C T

In this study, we used LCA to test the influence of practicing low-input farming, on-farm processing and direct distribution on the environmental impact of bread consumption. Primary data were collected from four commercially active producers (two in France, one in Italy and one in Portugal) who cultivate cereals under low levels of inputs, process grains on farm and distribute their products directly to end consumers. Environmental impacts of products were compared to equivalents from supermarkets, characterised by higher rates of applied inputs at the agricultural stage, industrial processing and centralised distribution. The scope of LCA was from cradle to the consumer. The study revealed a high variability of results between individual cases. At the agricultural stage, products from a low-input cropping system integrated with livestock production in France and from a small-scale labour intensive production in Portugal showed similar or better performance on most impact categories to those from high-input agriculture, while horse farming in France and a stockless cultivation of ancient wheat cultivars in Italy revealed mostly higher environmental burdens. Decentralised processing and distribution in France had similar or slightly higher impacts to conventional supply chains, while Italian and Portuguese cases revealed clearly higher environmental burdens for most impact categories. Results demonstrate that while there might be a positive relationship between the scale and eco-efficiency of processing and distribution, the level of agricultural inputs, yields and transport distances cannot be used as proxies of environmental performance. Products of low-input systems can have much higher, similar or lower impacts to their high-input counterparts due to the influence of site conditions and the management. More research assessing the effectiveness of context-specific management systems is needed as oppose to the generic comparisons between labelling schemes (i.e. organic and conventional farming).

1. Introduction

Scientists are divided over several contrasting perspectives on how to mitigate negative environmental impacts of agriculture and to achieve sustainable food security (Garnett, 2013; Garnett and Godfray, 2012). One particular vision entails that the current "industrial" model of food system that dominates in high-income countries is based on a too high level of inputs and that this needs to change towards a more self-sufficient structure that resembles of a natural ecosystem in its complexity and diversity (Pretty, 1995). The term agro-ecology is often used to describe the science at the interface of agriculture and ecology (Altieri, 1995), using "ecosystem approach" as a guiding paradigm for the design of agricultural systems (Thrupp, 1998). Although the exact procedures or techniques are not clearly defined, high levels of plant diversity (Ratnadass et al., 2012) and genetic diversity (Altieri, 2004) are seen as important parts of the system. The approach stresses out the importance of conserving landraces, local breeds of domestic animals, indigenous plants and traditional knowledge (Altieri, 2004).

In Italy, recent years have seen a growing demand for products made of ancient varieties, landraces or even wheat ancestors, such as emmer *Triticum dicoccon* or spelt *Triticum spelta* (Guarda et al., 2004; Piergiovanni, 2013). Landraces are plant populations that have distinctive properties but lack formal breeding improvements (Villa et al., 2005), the type of plant material that dominated agricultural production before the XX-th century. Traditional, low-input cropping systems are reintroduced on marginal lands and

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farmers are profiting from price premiums that consumers are willing to pay for such products (Piergiovanni, 2013). Low-input cropping system is a part of a low-input farming system, which is managed with the minimum use of farm-external inputs (Kulak et al., 2013). In France, there are currently 69 active associations of farmers who cultivate landraces under low-input regimes (Réseau Semences Paysannes, 2012). Some of them go as far as to using draft animals for field operations (PROMMATA, 2013). Maintaining genetic heterogeneity in the fields is seen as important element of the cropping system (Réseau Semences Paysannes, 2012). As the modern processing industry requires grains of uniform physiochemical properties, farmers cultivating landraces can be found processing grains and selling products directly to end consumers. The term Alternative Food Network (AFN) describes networks of producers, consumers and other actors that emerge as a result of consumer demand for alternatives to the standardised stock of foods available in modern supermarkets (Renting et al., 2003). In France, a dedicated term "Paysan-boulanger" (fr. "farmer-baker") evolved to describe an entrepreneur that is involved in both farming and bread production (Demeulenaere and Bonneuil, 2010). Consumers can purchase their products either on-farm or through dedicated shops and food cooperatives in cities.

Although the production and supply of bread have already been the subject of several LCA studies (Andersson and Ohlsson, 1999; Bimpeh et al., 2006; Braschkat et al., 2004; Espinoza-Orias et al., 2011; Geerken et al., 2006; Korsaeth et al., 2012; Meisterling et al., 2009; Moudry et al., 2013; Nielsen and Nielsen, 2003b; Prem et al., 2007), it remains unclear whether the introduction of alternative bread supply chains based on traditional, low-input farming systems and decentralised processing causes reductions or increases of environmental impacts from diets, or what aspects of such production can be beneficial from the environmental perspective. Historical developments in bread supply chains were studied with LCA by van Geerken et al. (2006) who showed that photochemical oxidation and Global Warming Potential (GWP) per kg of bread in Belgium decreased in the last 200 years. This result, however, was due to the fact that brushwood and coal were intensively used in XIX century's ovens and wheat was transported with the use of coal-powered ships. Acidification and eutrophication potentials on the other hand were shown to have increased over time due to the increased use of mineral, water soluble fertilisers in modern agriculture (Geerken et al., 2006). Most LCA studies on wheat production reveal that reducing fertilisers below optimum levels leads to increasing the global warming potential and several other impacts (Kulak et al., 2013). Environmental impacts of agricultural mechanisation are also a matter of controversy. Spugnoli and Dainelli (2013) suggested that the switch from mechanical traction to animal draft power in a developed country increases the primary energy consumption and the Global Warming Potential per unit of cultivated area. Cerutti et al. (2013b) arrived at the opposite conclusion, revealing benefits of animal labour. Most studies comparing organic and conventional wheat production confirm the lower global warming potential and energy use of organic wheat as compared to conventional wheat (Nemecek et al., 2011a; Williams et al., 2006). The switch to organic wheat would therefore lower the environmental impacts for bread if other aspects of production and distribution remained the same. However, industrial processing was demonstrated to be preferable over local bakeries and the domestic bread-making (Bimpeh et al., 2006; Braschkat et al., 2004). Andersson and Ohlsson (1999) also revealed that there is a tipping point above which increased distances in bread supply chains outweigh the benefits from increased economies of scale.

The aim of this study was to assess, if the introduction of alternative bread supply chains based on low-input farming and on-farm processing can reduce the negative impacts of bread consumption. To address this goal, four existing, commercially operating cases were studied. The selection of cases covered two different European climatic zones: Temperate Oceanic and Mediterranean as well as two contrasting scales of production: farms below 10 ha and above 70 ha. Selected producers aimed at minimisation of external inputs at the agricultural stage as a strategy for improving environmental performance and all the processing and distribution occurred on-farm or within the distance of 50 km. Environmental impacts of products over the whole value chain were quantified with the use of Life Cycle Assessment and compared to standard references - breads from high-input agriculture, industrial bakeries and distributed through supermarkets. In two cases, wheat production in standard references was modelled based on average practices of farmers in regions of Beauce in France and Castilla y León in Spain. We also collected primary data from a high-input organic producer in Northern Portugal.

2. Methodology

The methodology of Life Cycle Assessment was applied in the study. It follows a procedure consisting of four interrelated stages: i.) Goal and scope definition, ii.) Life Cycle Inventory (LCI), iii.) Life Cycle Impact Assessment (LCIA) and iv.) Interpretation (ISO, 2006a, b).

2.1. Goal and scope definition

Alternative food networks provide consumers with an alternative to the standard stock of products available in the supermarket. Consumer choice to buy the bread from the farmer over its standard equivalent induces a number of changes in the environmental impacts of bread consumption. In order to address the goal of the study, we need to know if the balance of these changes for particular impacts is positive or negative. Fig. 1 shows stages in the life cycle of bread that have negative impacts on the environment. We go from the assumption, that switching to the bread from a low-input farmer does not affect the overall quantity of consumed bread nor does any of the other dietary choices of the consumer. We also assume that emissions related to the digestion and wastewater treatment do not differ between the two alternatives. In this case, consumer decision to choose alternative bread affects environmental impacts across four stages in the product life cycle – cultivation, milling, baking and retail as well as transport between these four stages and during the shopping trip. The functional unit (FU) was chosen as 1 kg of bread ready for the consumption at consumer's home.

2.2. Life Cycle Inventory (LCI)

Fig. 2 shows system boundaries considered in the analysis.

2.2.1. Description of systems under study

Table 1 provides key information about analysed systems. The full list of Life Cycle Inventories can be found in the electronic supplement (Tables S1–S7).

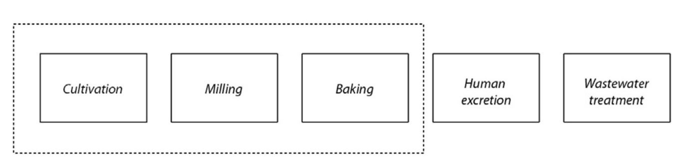

Fig. 1. Stages in the life cycle of bread with negative impacts on the environment.