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Environmental impacts of food losses along the entire Swiss potato supply chain – Current situation and reduction potentials

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ABSTRACT

Food production causes large environmental impacts. In Switzerland, more than half of the initial potato production is not directly consumed by humans but lost. To analyze the environmental impacts caused by these losses, we conducted a Life Cycle Assessment concerning the demand for nonrenewable energy resources, the global warming potential, human toxicity and ecotoxicity (terrestrial and aquatic). We allocated these environmental impacts at each stage of the Swiss potato supply chain to marketable potatoes and potato losses. Furthermore, this study investigated how potential loss reduction scenarios and various loss treatments (animal feed, biogas, incineration) might affect the total ecological performance of the supply chain. The results showed that potato losses were responsible for 39% of the total terrestrial ecotoxicity, 31% of the total potato supply chain's global warming potential, 31% of its human toxicity, 27% of its aquatic ecotoxicity and 23% of its demand for nonrenewable energy resources. The results indicated in general that environmental benefits due to the loss treatments were bigger than benefits achieved by the loss reduction scenarios. Loss treatments, in particular feeding and fermentation, could reduce the examined impacts, but not generating losses represented a better option, especially at the household stage (the impacts here were 8–42 times as high as the impacts of losses at agricultural production). A combination of loss reduction and loss treatment could overcompensate the environmental impacts caused by potato losses because potatoes may be used to substitute for other goods.

1. Introduction

Food losses do not only have economic, social and ethic aspects but also cause considerable environmental impacts (Scholz et al., 2015). In particular for defining food loss reduction goals, not only the quantity of food losses but also their environmental impact needs to be considered (Scholz et al., 2015). Agriculture is very resource intensive and therefore causes high environmental pressure (Moll and Watson, 2009) especially when we consider the resource use and the environmental impacts resulting from the production of inputs like fertilizers, pesticides and energy (Mouron et al., 2006). In addition, post-harvest treatments such as transportation, storage, processing, packaging and refrigeration contribute substantially to the environmental impact (Garnett, 2011; Sonesson et al., 2010). Thus, food losses do not only imply that resources get lost but that various environmentally relevant impacts are caused in vain (Scholz et al., 2015).

Although many recent studies have assessed the total environmental impacts of food production including losses (Andersson et al., 1998; Bystricky et al., 2014; Jungbluth et al., 2000; Manfredi and Vignali, 2014), we do not know to which extent these environmental impacts are caused specifically by the losses, because most of these studies do not distinguish between the sold products for human consumption and their associated losses. The aim of this study was to assess the environmental impacts of the consumed potatoes and their associated losses separately for a current potato supply chain in Switzerland for which losses and the reasons of the

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losses had been analyzed in a previous study (Willersinn et al., 2015). Furthermore, this study examined to which extent a number of identified potato loss reduction strategies can improve the ecological performance of the entire supply chain. Because we knew that not only reducing the quantities of food losses but also loss treatments may improve performance (Takata et al., 2012), we included three loss treatments (animal feed, biogas, incineration) in the analyses. A focus on the entire supply chain (and not just on particular stages) was required as a previous study had shown that a decrease in losses at one stage coincided with an increase in losses at another stage (Eriksson, 2012).

2. Methods

2.1. Goal and scope definition

To assess the environmental impacts and the utilization of resources, we followed the ISO standardized Life Cycle Assessment (LCA) method (ISO 14040, 2006). This method has been used frequently to identify hotspots of environmental impacts throughout the life cycle of a product and to support environmentally related decisions (Notarnicola et al., 2012). Within the scope of this study, we considered all processes of the entire Swiss potato supply chain (including the preparation of potatoes for meals in private households) and particularly the occurrence and the treatment (including possible substitutions for other goods) of potato losses at each stage of the supply chain. We assumed that all fresh potatoes are traded by wholesalers, then sold by retailers and finally consumed in private households. Direct marketing from Swiss farms to private consumers was neglected due to small market shares (Schmid et al., 2010). The goals of this study were:

- To analyze the environmental impacts of the various stages (from farm to final consumption) of the Swiss fresh potato supply chain. Hotspots of environmental impacts are presented.
- To simulate how possible actions and modifications defined by six loss reduction strategies could improve the ecological performance of the whole Swiss potato supply chain.
- To evaluate how loss treatments influence the results of the LCA.

2.2. Mass flow of the current supply chain, system boundary and data sources

Based on the results of a previous study conducted in 2014/2015 by Willersinn et al. (2015), we separated the mass flow of fresh potatoes from field to plate into two paths: The first path represents the mass flow of fresh potatoes finally leading to the consumption of 1 kg fresh potatoes in Swiss private households. The second path represents the mass flow of the associated losses occurring at each stage of the supply chain. From these two paths, we deduced the functional unit: 1 kg of consumed fresh potatoes considering the losses at all stages that were associated with this finally consumed unit. For our study, we divided the whole potato life cycle into four modules (A = agricultural production, W = wholesaler, R = retailer, H = private household), according to the stages of the supply chain (Fig. 1). Transportation to a module was part of the respective module. For the purposes of our study, it was crucial at which processing stage within a module the losses occur. Therefore, we subdivided module W into two phases: (a) the delivery, storage, washing and optical sorting phase and (b) the packaging phase. In addition, as not all fresh potatoes being bought will be boiled, we subdivided module H into two phases: phase (1) included transportation, storage and preparation, whereas phase (2) included the cooking and eating process.

At agricultural production, we considered all used energy and emissions corresponding to cultivation inputs. Impacts that refer to the life cycle of infrastructures were not considered in order to maintain comparability with Manfredi and Vignali (2014), Jones et al. (2012), Abeliotis et al. (2013) or Karakaya and Özilgen (2011). Transports were included at agricultural production except for transportation of potato losses as we assume them to be used straight on the farms. Each following stage contained all inputs and outputs associated with all relevant processes. Fig. 1 shows the investigated system, the system boundary and the mass flow of fresh potatoes and potato losses at each stage of a current Swiss supply chain for fresh potatoes.

For the LCA study, we used data collected for a previous study (Willersinn et al., 2015) through expert interviews with supply chain participants (structured face-to-face interviews) and data provided by literature and publicly available databases. Existing databases were predominately from Switzerland or at least from other European countries.

2.3. Definition of loss reduction scenarios

Based on the mass flow depicted in Fig. 1, we identified six loss reduction scenarios that may reduce potato loss quantities or shift losses to an earlier stage of the chain, thus improving the ecological performance of the entire potato supply chain (Table 1).

2.3.1. Scenario A1: pesticides against wire worms

- Strategy: Goldor Bait (active ingredient: Fipronil) is used at the farm stage to chemically combat wire worms. Currently, Goldor Bait is applied in several areas in Germany but has been prohibited in Switzerland. According to Keiser et al. (2007), approximately 7% of the total potato stock on the field is lost due to wire worms or the transmitted dry core disease. Goldor Bait is declared to have a degree of efficiency of 70% (Heger et al., 2010). Therefore, we estimated that total losses might decrease by five percentage points when Goldor Bait is applied.
- Assumptions: The loss rate at the farm stage stays constant as farmers use the nascent sorting capacity to sort out other damages which could not have been sorted out by farmers in the current situation (C). That means that farmers sort the potatoes as intensively as in the current situation. At wholesalers, where the potatoes are sorted again, the loss rate decreases as fewer defected tubers[1] occur within the deliveries. At all other stages, no differences occur.

2.3.2. Scenario A2: improved quality sorting at farms

- Strategy: Farmers sort their potatoes more intensively than in C before they deliver them to wholesalers.
- Assumptions: Farmers sort out 80% of all defected tubers [in C, they sort out 60% (Willersinn et al., 2015)]. Consequently, losses at the farm stage increase but losses at wholesalers decrease. The total loss rate stays constant, but the ecological performance might improve as losses occur earlier within the potato supply chain.

[1] Defected tubers are potatoes with qualitative scarcities (e.g. green tubers, rotten tubers, damages by slugs and wire worms, scab, deformities, dry core).