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## Quantity and quality of food losses along the Swiss potato supply chain: Stepwise investigation and the influence of quality standards on losses

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## ABSTRACT

This paper presents the results of a stepwise investigation of the quantity and quality of food losses along the Swiss potato supply chain. Quantitative data were collected from field trials, from structured interviews with wholesalers, processors and retailers, and from consumer surveys in combination with a 30-day diary study. The “Swiss trade customs for potatoes” pose the basis for the qualitative evaluation of losses. The influences of technological, institutional (business and economy; legislation and policy), and social drivers on the generation of fresh potato and processed potato products losses were assessed. Losses due to quality standards driven by food safety and consumer preferences for certain aesthetic standards have been evaluated too. Across the entire potato value chain, approximately 53–55% of the initial fresh potato production and 41–46% of the initial processing potato production are finally lost. Losses between organic and non-organic supply chains differ from 2% to 5%. From the total initial fresh potato production, 15–24% gets lost during agricultural production, a further 12–24% at wholesalers, 1–3% at retailers, and 15% at private households. In comparison, 5–11% of the initial production gets lost at wholesalers, a further 14–15% during processing, 0% at retailers, and 2% at private households. Losses during agricultural production do not vary much (13–25%) between fresh and processing potatoes. Approximately half of total potato losses occur because potatoes do not meet quality standards. 25–34% of these quality-driven losses are caused by food safety reasons, and the remainder are caused by consumer preferences or suitability for storage. In total, social drivers (e.g., consumer preferences, behavior, or socio-demographical factors) are responsible for two-thirds to three-fourths of all fresh potato losses and 40–45% of all processing potato losses. Technological drivers cause circa one-third of the total processing potato losses. The majority of the rejected potatoes are used as animal feed (67–90%) in Switzerland. Approximately 30% of all fresh potato losses are disposed while just 4–5% of all processing potato losses are thrown away. The interviewed experts stated that lower quality specifications might cause lower loss rates at the first stages of the supply chain but higher ones at the later stages due to worse storage or processing abilities of potatoes with defects, which also might affect proper tubers.

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**Abbreviations:** WRAP, waste & resources action programme;  $L_F$ , Loss rate at farm stage;  $L_W$ , Loss rate at wholesaler referring to delivered amount;  $L_{W,t}$ , Loss rate at wholesaler referring to total agricultural production;  $L_I$ , Loss rate at processing industry referring to delivered amount;  $L_{I,t}$ , Loss rate at processing industry referring to total agricultural production;  $L_R$ , Loss rate at retailer referring to delivered amount;  $L_{R,t}$ , Loss rate at retailer referring to total agricultural production;  $L_C$ , Loss rate at consumer referring to delivered amount;  $L_{C,t}$ , Loss rate at consumer referring to total agricultural production;  $L_{SC}$ , Loss rate over the whole potato supply chain referring to total agricultural production;  $DT$ , defected tubers;  $MT$ , mechanically damaged potatoes while harvesting;  $QL_W$ , average taxation results of potatoes rated as inadequate at wholesalers;  $QL_I$ , average taxation results of potatoes rated as inadequate at processing industry;  $QL_F$ , losses due to quality standards at farm;  $OL_F$ , losses due to overproduction.

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### 1. Introduction

Food losses and the influence of food quality standards on the losses have become a topic of increasing environmental and social interest, especially in developed societies. [Kranert et al. \(2012\)](#) found out that many studies and publications deal with the causes, quantity, and disposal of food losses in Europe, and with the conditions that allow recovery from losses for human consumption. The conclusion of this meta-study was that the causes of food losses and the conditions for recoverability are well-known, whereas the databases for estimating the quantity and quality of food losses are rather scanty for most of the agricultural products ([Kranert et al., 2012](#)). On the other hand, as far as we know, no

study exists which assesses the influence of quality standards imposed on farmers and other supply chain actors on food losses in Europe, although these standards are often cited as being responsible for high losses (Gustavsson et al., 2011; Hurschler, 2012; Stuart, 2009). To what extent losses due to quality standards are driven by food safety and consumer health legislation and which share is driven by consumer preferences for certain aesthetic standards is also not known so far. Furthermore, the results of the existing food loss studies are not comparable due to different assessment methods (see Table 1). Reviews and updates of available data on food losses are often used to generate “new” estimates on food losses (Gustavsson et al., 2011; Kantor et al., 1997; Parfitt et al., 2010). For Switzerland, Beretta et al. (2012) and the WWF (2014) used this method and thereby estimated potato losses ranging from 66% (WWF, 2014) to 68% (Beretta et al., 2012), based on a former British estimate (WRAP, 2012).

However, to realistically record and particularly to reduce food losses, a detailed database of the quantity, causes and utilization of losses at each segment of the supply chain is necessary. First, this paper aims at creating such a database for the typical fresh potato and processing potato supply chains in Switzerland and presenting a methodological approach to estimating losses of agricultural commodities in a sufficient way. Because organic potatoes are produced on 6% of the total Swiss potato crop area (Bundesamt für Landwirtschaft BLW, 2014) this paper distinguishes between non-organic and organically produced potatoes. Second, this paper aims at quantifying potato losses due to quality standards, to what extent they are driven by food safety and consumer health, and to what extent they are driven by consumer preferences. Data were collected from field trials, from structured interviews with wholesalers, processors and retailers, and from consumer surveys and household diaries. Potatoes were chosen for this study as they seem to be one of the commodities with the highest loss rates (Kranert et al., 2012; WWF, 2014) for which a reduction of losses is of particular environmental and social interest. Thus this study also aims at assessing the potential for reducing potato losses in Switzerland.

A literature review of the assessment of potato losses in developed countries is provided in Section 2. The method of the research conducted is described in detail in Section 3. The reference framework is also defined in that section. Afterwards the results of this study are presented and discussed. In the last section of this paper, a conclusion is provided.

## 2. Assessing potato losses: literature review

Most recently published food waste studies represent comparisons at the level of the European Union or the entire world (Gustavsson et al., 2011; Katajajuuri et al., 2014; Parfitt et al., 2010). The range of methods used to estimate losses is large. Analysis of literature and statistical data in combination with stakeholder interviews (Kantor et al., 1997; Kranert et al., 2012; WRAP, 2011) are used as well as mass flow models (Gustavsson et al., 2011; Hall et al., 2009) to estimate losses. At household stage, waste composition analysis (Fehr and Romão, 2001; Schneider and Obersteiner, 2007; Watanabe, 2009; WRAP, 2008), household diaries (Langley et al., 2010; Selzer et al., 2009; Wenlock et al., 1980; WRAP, 2008), analysis of statistical data on food consumption and nutrition (Hall et al., 2009; Kantor et al., 1997; Watanabe, 2009), quantitative consumer surveys (Pekcan et al., 2005; Schneider and Lebersorger, 2009; WRAP, 2012), and qualitative consumer interviews (Glanz and Schneider, 2009) are the most popular methods for gathering food waste data.

An overview of food loss studies including potatoes in an aggregated product group as well as results of specific potato studies in

the developed world is given in Table 1. The extent of losses varies as a function of the reference framework. Table 1 also provides the particular assessment method of each study.

## 3. Method

### 3.1. Food loss definitions

Food losses occurring at the end of the food chain (retail and final consumption) are often called “food waste,” because they relate to wasteful behavior of retailers and consumers (Gustavsson et al., 2011; Parfitt et al., 2010). Due to the fact that this study investigates potato losses from field to plate, which are caused not only by wasteful behavior but also by technological and other reasons, we use the term food loss for all stages of the supply chain. We apply the definition by Östergren et al. (2014) that defines food loss as “any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea)”.

In many regions of the world potatoes are most often eaten boiled and unpeeled (Camire et al., 2009). Furthermore, Arun et al. (2015) described the potato peel as “nutrient-rich” which is a good source of dietary fiber. Thus we define the potato including the peel as edible for human consumption. For many years now farmers have stopped growing potatoes for animal feed in Switzerland. Hence all potatoes which are used for animal feed nowadays were originally intended for human consumption and therefore represent a food loss according to Östergren et al. (2014). In this study the point of reference is the crop yield at farm stage before harvest, including defected tubers that are separated later in the potato value chain. These boundaries are basically the same that Beretta et al. (2012) defined in their study.

For assessing the potential to reduce potato losses we relate the losses to technological, institutional (business/economy and legislation/policy) and social context categories which were developed by Canali et al. (2014). Within each context category Canali et al. (2014) have distinguished three different groups (Table 2). These groups represent the drivers for the generation of food losses from which we derive the potential of food loss reduction. In the technological context categories, the three groups relate to the possibilities of food loss reduction through application of available technologies. In the business context category, the groups are related to possibilities of business management solutions reducing losses. In the social context category, the three groups are related to the efficacy of actions increasing social awareness and information. In the institutional (legislation and policies) context, the groups of drivers have been formed following the type of legislation and policy to which the identified drivers are referred.

### 3.2. The potato value chain and quality specifications

This study analyzes two different types of potato supply chain intended for human consumption, which cover more than 94% of the total potato production in Switzerland from 2011 to 2013 (Swisspatat, 2014).<sup>1</sup> The first type represents that for fresh potatoes harvested in summer<sup>2</sup> in Switzerland. This supply chain covers the potato flow from Swiss farms via wholesalers and retailers to Swiss households, which represents 32% of the total potato production for human consumption (29% for non-organic and 3% for organic

<sup>1</sup> The remaining 6% of the total potato production are seed potatoes (Swisspatat, 2014).

<sup>2</sup> Potato losses of early potato production are not taken into account because their share in the total Swiss potato production is relatively small (<4%).

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