# Decreasing food loss and waste through supply chain management

## Summary Abstract

Reducing food loss and waste across global supply chains is of utmost importance. Therefore the authors provide an overview of loss and waste causes of developing and developed countries first. Second, to synthesize current literature on waste management measures and to provide a measurement framework for reducing loss and waste through supply chain management, the authors conduct a systematic literature review. Thereby they investigate 215 studies from two different electronic databases. Third, four recommendations for future waste management research are given.

**Keywords:** Food Supply Chain Management, Waste Reduction, Systematic Literature Review

**Introduction**

Feeding a rapidly growing population and simultaneously reducing food loss and waste (in the following "loss/waste") along the supply chain (SC) is one of the crucial challenges of this century (Parfitt et al., 2010). Although the root causes of waste may be diverse, developing as well as developed countries lose and waste an average of one third of food produced annually, translating into about 1.3 billion tons per year (Gustavsson et al., 2011). Despite the consumers' responsibility for a large portion of the total loss/waste produced, there is still a significant amount of food that gets wasted in post-harvest SC processes.

Efficient means of logistics and supply chain management (SCM) can support the reduction of loss/waste across the food supply chain (FSC) (Jedermann et al., 2014). Even though research on loss/waste management practices in FSC exists, most of it only focus on sub-problems and lack an holistic approach (Shukla and Jharkharia, 2013). Nevertheless different countermeasures and practices have been studied already. Rijpkema et al. (2014), for example, examine the impact of sourcing strategies on waste and product quality of perishables, while Grunow and Piramuthu (2013) investigate how RFID technology can support waste reduction across the SC. Others analyze how to facilitate loss/waste reduction through efficient information sharing (IS) practices (Kaipia et al., 2013; Ferguson and Ketzenberg, 2006).

Although various aspects of loss/waste reduction in FSC have been examined, no systematic approach has been undertaken to map a holistic picture of SC measures and concepts to reduce loss/waste. Therefore, it is the aim of this study to provide a FSC loss/waste management framework that synthesizes already stated literature on logistics and SCM practices focusing at loss/waste reduction. It thereby extends current research on loss/waste management by identifying potential gaps and limitations to guide the development of FSC waste management more efficiently. To achieve this, the authors aim at answering the following research questions (RQ):

RQ1: What are the main causes of loss/waste in FSC?
RQ2: Which SCM measures assist in reducing loss/waste in FSC and how can they be classified?
RQ3: What are the limitations of current research and what are the needs of future research?

In the following we focus our research on loss/waste management for perishables including agricultural products as well as animal products.

**Research Design**

Mapping the landscape of loss/waste causes and FSC waste management practices for perishables requires a systematic approach to collect and examine pertinent literature. Therefore systematic literature reviews provide an unbiased approach for collecting relevant literature. Additionally it assists the synthesis of diverse knowledge in order to refine research according to a specified research question (Tranfield et al., 2003). Because of the importance of literature reviews for SCM research, different systematic methodologies have been developed (e.g., Tranfield et al., 2003; Durach, 2016). The authors of this study follow the procedure proposed by (Durach, 2016). The methodology provides a systematic and rigor six step procedure that assists an unbiased and transparent approach.

*Determination of focus of review*

Before starting a systematic literature review it is of utmost importance to state a clear research questions for the focus of the review (Durach, 2016). Because of the practical relevance of food loss/waste reduction the authors wanted to ensure a significant practical contribution. Hence, the authors conducted seven pre-study interviews involving practitioners from the retail, food manufacturing and logistics service provider industry. First, they mutually agreed that there is an increasing need for waste reduction measures. Second, they confirmed that most of the established waste management practices focus on reducing waste at a particular stage of the process or waste of a particular SC actor instead of looking at the whole SC. Third, even if companies nowadays are not always willing to pay unless they significantly benefit from waste reduction efforts, they feel a growing exogenous pressure coming from customers and legislative authorities. Fourth, to prepare for the rising importance of the topic, companies need to better understand current measures and best practices and how they can be integrated in a holistic SCM context. Consequently the authors formulated the above mentioned second research question (RQ2) and solved it applying a systematic literature review approach.

*Preparation for the literature search*

Before starting the literature search the authors defined four inclusion criteria. (1) The article mainly deals with food loss/waste reduction at least at one stage of the SC, (2) The title or abstract shows an indication that food loss/waste reduction measures are discussed, (3) The mitigation measures discussed are rank among the area of SCM, (4) The article is written in English or German. To ensure a comprehensive set of studies the authors didn't limit their search to specific types of publications. Any kinds of ex-ante limitations have been avoided.

*Search for literature*

For the literature search the authors decided to base their review upon an electronic database search. Therefore they chose two distinct databases, Business Source Complete (by EBSCO) and SSCI-Database (by Web of Knowledge). To better craft appropriate search strings the authors first read thematically relevant literature to collect possible keywords as a basis for the literature search. Afterwards two different search strings have been developed that are adjusted to the specifics of the respective database. By using the strings shown in Table 1 the authors compiled 980 articles from Business Source Complete and 618 articles from SSCI-Database. 15 duplicates have been eliminated.

*Table 1 - Overview of search strings*

| | |
|---|---|
| **Business Source Complete (by EBSCO)** | (AB=(supply chain OR logistic*) OR TI=(supply chain OR logistic*) OR KW=(supply chain OR logistic*) OR SU=(supply chain OR logistic*)) AND (AB=(waste OR loss OR reduc* OR minimi* OR prevent* OR avoid*) OR TI=(waste OR loss OR reduc* OR minimi* OR prevent* OR avoid*) OR KW=(waste OR loss OR reduc* OR minimi* OR prevent* OR avoid*) OR SU=(waste OR loss OR reduc* OR minimi* OR prevent* OR avoid*)) AND (AB=(food OR grocery OR perisha*) OR TI=(food OR grocery OR perisha*) OR KW=(food OR grocery OR perisha*) OR SU=(food OR grocery OR perisha*)) |
| **SSCI-Database (by Web of Science)** | (TI=(supply chain OR logistic*) OR TS=(supply chain OR logistic*)) AND (TI=(waste OR loss) OR TS=(waste OR loss)) AND (TI = (reduc* OR minimi* OR avoid* OR prevent*) OR TS=(reduc* OR minimi* OR avoid* OR prevent*)) AND (TI=(food OR grocery OR perisha*) OR TS=(food OR grocery OR perisha*)) |

AB: Abstract Search; TI: Title Search; KW: Keywords; SU: Subject Term; TS: Topic Search

*Selection of pertinent literature*

To collect the relevant studies for solving RQ2 two authors individually read the titles and abstracts of all 1,582 articles by applying the inclusion criteria. Only articles that met all inclusion criteria have been selected for further consideration. Consequently the articles have been condensed to 215 studies.

*Analysis and synthesis*

Subsequent to the selection all 215 articles have been read and analyzed. To solve RQ2 the authors followed a bottom-up approach aiming at summarizing and classifying the measures of food loss/waste reduction in SCM. If an article mentioned relevant measures just briefly by citing other authors, these citations have been tracked back and read as well. According to the last step of the literature review – (6) reporting and using the review results – the next section will depict and discuss the findings of the analysis following the aforementioned research questions.

## Findings

In the following, the above stated research questions will be answered. First, an overview of main causes of loss/waste in FSC in developing as well as developed countries is given, classifying them into them into different areas of occurrence. Second, by systematically identifying and examining a comprehensive set of studies dealing with loss/waste mitigation measures, the authors provide a measurement framework of FSC waste management that synthesizes the current state of literature. Third, four recommendations for future research in this field will be given.

*Causes of loss and loss/waste in FSC*

Causes of loss/waste occur on every stage of food processing and production, including all stakeholders as well as warehousing and transportation processes and food packaging. During the literature review the authors collected these causes and assigned them to different areas of occurrence as shown in Table 2.

*Table 2 - Main causes of loss/waste in FSC*

| Area of causes | Developing countries | Developed countries |
|---|---|---|
| **Harvesting and post-harvesting** | • weather-related loss<br>• suboptimal harvest period<br>• damage of crops<br>• inadequate infrastructure<br>• low level of automation<br>• defective harvesting equipment<br>• lack of qualified personnel | • weather-related loss<br>• over production<br>• damage of crops |
| **Food producing industry** | • transformational processes<br>• contamination | • transformational processes<br>• production failures<br>• technical issues |
| **Retail** | • lack of cooling systems<br>• inappropriately equipped storage and sales areas<br>• unhygienic conditions | • inaccurate sales forecasts<br>• uncertainties according to date indications<br>• inappropriately equipped sales areas<br>• inefficient optimization efforts<br>• promotions and discounts |
| **Trans-portation** | • inadequate infrastructure<br>• inappropriately equipped transport vehicles<br>• low transportation safety of perishable goods<br>• unreliable transport packaging<br>• inappropriate load securing | • long throughput times<br>• long transport distances<br>• delivery delays<br>• overloading of terminals<br>• inadequate temperature measurements<br>• unreliable transport packaging |
| **Ware-housing** | • low storage capacities<br>• inappropriate storage conditions and cooling systems<br>• long distances to warehouses<br>• warehouse usage is not aligned to customer demand | • technical malfunction of cooling systems<br>• manual errors in cooling regulation<br>• inappropriate storage conditions |
| **Packaging** | • lack of packaging knowledge<br>• inappropriate packaging for transportation and storage | • large packaging units<br>• defective packaging<br>• inefficient packaging design |
| **Processes** | • Lack of holistic view of value-adding processes in FSC due to egocentric profit optimization<br>• Lack of communication between FSC actors<br>• Inefficient processing processes | • High complexity of value-adding processes<br>• Lack of holistic view of value-adding processes in FSC<br>• Lack of communication<br>• Lack of transparency along the FSC |

| | |
|---|---|
| **Guidelines and regulations** | • Specification of aesthetic standards of regulating authorities<br>• High requirements of consumer<br>• Guidelines for waste disposal due to non-suitability for processing<br>• (seasonality or weather-related) change of quality/appearance specifications by retailers<br>• Rules to ensure that there is a minimum time left to the expiration date |

*FSC loss/waste management framework*

Current measures for reducing food loss/waste in FSC can be classified into eight different clusters that are shown in Figure 1. Thereby purposeful IS and the efficient use of technologies provide the fundamental pillars of food loss/waste management.

Without sharing information (e.g. quality-, stock- or demand-related information) between SC actors the vast potential of loss/waste reduction in FSC cannot be fully exploited. It enables optimized inventory management (Booth, 2013; Ferguson and Ketzenberg, 2006) and forecasting (Casper, 2008), improved shelf life prediction (Hertog et al., 2014) as well as the alignment of packaging technologies to the needs of the SC (Verghese, 2013). Nevertheless, the current willingness for inter-organizational IS is relatively low and companies more or less rely on self-optimization (Mena et al., 2014). This is exacerbated by the fact that the benefit of inter-organizational IS is unbalanced (Ferguson et al., 2006). To expedite inter-organizational IS companies across the SC first have to jointly recognize its potential and thereby understand the purposeful utilization of technologies. To lower the barriers of an overall SC transparency, companies should establish vertical cooperation. In order to sustainably synchronize SC processes between different actors, initiatives should aim at long-term strategical cooperation instead of short-term contractual agreements. It has been shown that even a partial increase of transparency achieved by IS between some SC members increases the performance of the whole SC (Thron et al., 2007). To cope with the growing complexity of FSC global and industry-wide standards for data exchange have to be established (Manzouri et al., 2014; Ratliff, 2010).

Modern technologies are the main facilitator of IS and enable the efficient implementation of numerous food loss/waste reduction measures that will described in the remaining measurement clusters. Current literature investigates many different technologies as enablers of IS and waste reduction. The use of barcodes is widespread across the industry but the possible amount of information that can be shared is relatively low. In contrast the application of RFID in FSC is not as widespread but can be highly beneficial and has been the focus of many researchers (Kelepouris et al., 2007; Kumar et al., 2009; Kumari et al., 2015). The strategic advantages of RFID in SCM – e.g. waste reduction, automated traceability of goods, improved IS and data accuracy (Tajima, 2007) – hold true for FSC management. Especially in FSC RFID tags can be combined with sensors that are measuring different information such as temperature, humidity, lighting conditions and others (Abad et al., 2009; Hafliðason et al., 2012) to monitor and predict the quality and shelf life of the products. Gathered information can be utilized by dynamic shelf life models to better align SC decisions and waste reduction. These models calculate remaining shelf life dynamically instead of relying on fixed dates of expiration (Grunow and Piramuthu, 2013; Hertog et al., 2014). Sensor-RFID systems can also be linked to decision support systems (DSS). These systems aim at recognizing risks in an early stage and at providing possible solutions to the user (Wang et al., 2010). Whereas traditional DSS base their proposals on predetermined models and algorithms, modern approaches try to implement self-updating knowledge acquisition (Peng et al., 2014). Intelligent containers tend to merge the concepts of sensor-RFID and DSS to counter the lack of IS across global FSC (Dittmer et al., 2012). Sensor-based information is recorded to track the conditions of perishables in different areas of the container. Dynamic shelf life models use the information and transfer them into DSS in order to (Lang et al., 2011).

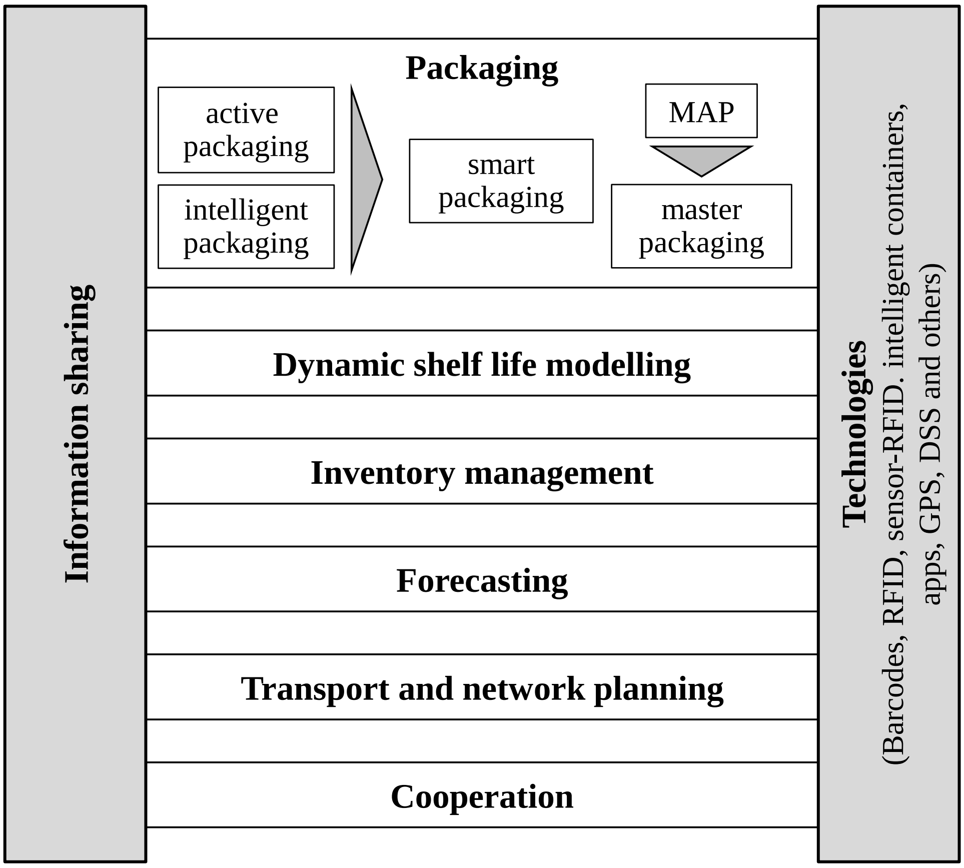


*Figure 1 - measurement framework for FSC loss/waste management*

Reduction of food loss/waste can also be achieved by inventory management concepts. The most conventional first-in-first-out (FEFO) concept only focuses on the arrival date at the warehouse without acknowledging the the shelf life of perishables. Hence, the first-expire-first-out method ensures that perishables with less time left to their determined expiration date will be picked first (Dada and Thiesse, 2008). This concept can be extended by dynamic shelf life models leading to a dynamic FEFO picking sequence (Lang et al., 2011). In addition warehouses can be equipped with controlled atmosphere technologies that measure and control oxygen and carbon content as well as humidity and temperature to increase the shelf life of perishables (Kader, 2004).

Packaging concepts are one of the main contributions to a reduction of food loss/waste and have been extensively investigated. Innovative packaging solutions can increase the shelf life and reduce waste across the SC while protecting the perishables (Price, 2015). Applications in practice demonstrated that companies can reduce up to

50% of their food waste by investing in packaging technologies (Checkout, 2015). By examining the literature on food packaging technologies the authors derived five packaging concepts that have been investigated. (1) Modified atmosphere packaging (MAP) aims actively or passively controlling the packaging conditions in order to lower perishability of goods transported (Caleb et al., 2013; Mahajan et al., 2014). (2) Master packaging concepts are transport containers that provide a protective environment for multiple good that are already packaged. At the point of sale the goods are removed from the master packaging and placed in store shelves (Jeong et al., 2013). (3) Active packaging includes additives to the packaging material to improve the transport conditions or shelf life of perishables (Day, 2008). These additives either release substances or absorb them from the surrounding environment (Dainelli et al., 2008). (4) Intelligent packaging does not influence the packaging conditions. It monitors and communicates the quality of goods transported to identify waste causes and to enhance IS across the FSC (Dainelli et al., 2008; Yam et al., 2005). (5) Smart packaging can be seen as a combination of active and intelligent packaging that monitors, communicates and actively controls the quality of perishables transported (Kuswandi et al., 2011).

A large part of total food loss/waste is generated by inaccurate forecasts of customer demand. Nevertheless literature on appropriate forecasting mechanisms that acknowledge the specifics of FSC is sparse (Shukla and Jharkharia, 2013). To attain more accurate forecasts, companies have to include a variety of data consisting of pricing structures, historical data, seasonality, weather conditions, complementarity of goods and others. It has been shown that the application of automated software-based sales forecasting mechanisms can lead to a loss reduction of up to 50% compared to manually adjusted forecasts (Casper, 2008).

Because of the particular requirements of perishables transport and network planning is very challenging but it can contribute to a reduction of loss/waste. Due to the use of packaging, cooling and monitoring technologies transport mode selection is of importance and alternative modes of transport become relevant (Jedermann et al., 2014; Maras, 2015).

*Future needs for research*

To guide food loss/waste management across SC the authors derive four recommendations for future research.

(1) Integrated inter-organizational cooperation – Current literature mostly focusses on minimizing food loss/waste for one SC actor instead of proposing means of cooperative actions across the SC. The recent level of integration in FSC is less than in other industries, such as automotive. The authors are in complete agreement that SC wide cooperation and IS is one fundamental key of success.

(2) Holistic FSC loss/waste management framework – Most of the investigated literature does not only focus on focal firms instead of SC, it also does not investigate measures in a holistic SCM context. The proposed measurement framework could be the basis for research on a holistic FSC loss/waste management framework that explains mechanisms and interactions of these measures and how to implement multiple measures across the whole SC.

(3) Efficient regulatory measure for loss/waste reduction – Research can assist governments and authorities in setting up appropriate regulatory measures and guidelines in order to achieve loss/waste reduction.

(4) Reverse food logistics – Normally perishables that reach their expiration date or lack a specific outer appearance are thrown away. In the spotlight of emerging

regulatory measures like in France – retailers are forced to return consumable goods to social facilities – reverse food logistics gains importance. Research can provide insights on how to setup cost-efficient logistics systems to return goods to social facilities or secondary utilization (e.g. biogas plants).

**Conclusion**

By systematically examining a set of 215 studies the authors identified eight measurement clusters that are investigated in current literature. Thereof IS as well as an appropriate use of modern technologies are the main contributors of FSC waste management and enable the application of measures from other clusters as well. Four distinct recommendations for future research have been given in order to guide the improvement of loss/waste management in FSC.

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