Measuring food losses in the supply chain through value stream mapping: a case study in the dairy sector

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Chapter Outline

9.1 Introduction

9.1.1 Background

The terms food loss and food waste are often utilized synonymously, but they do in fact differ based on where they occur along the supply chain. Food losses take place during production, harvest, processing, and distribution; unlike food waste, which occurs at the retail and consumer levels of the chain (Parfitt et al., 2010; Richter and Bokelmann, 2016; Willersinn et al., 2015). Nonetheless, both elements point to

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a certain quantity of food, calories, or nutrients that are intentionally or unintentionally disappearing from the food supply chain before consumption. Food loss and waste (FLW) is an endemic and growing global problem, estimated at over 30% of produced food that is not consumed (Gustavsson et al., 2011). Within vulnerable regions, FLW contributes to the dire state of food insecurity at a time when increased food production, as a solution, is costly and exploits scarce productive agricultural land and water (Godfray et al., 2010; Phalan et al., 2011).

There is an increasing interest in promoting efforts leveraging FLW reduction as a means of assuring adequate and equitable food availability, if surplus food could be redistributed appropriately to the hungry (Garrone et al., 2014). Tackling FLW in both developed and developing countries is associated with positive outcomes especially on food prices, thus increasing economic access to food among people likely to experience hunger (Buzby and Hyman, 2012; Rutten, 2013). Thereby, actions that minimize FLW in food systems directly support their sustainability, contributing to food security to offset pressure on increased food production (Munesue et al., 2015; Smith, 2013; West et al., 2014). The fight against FLW is reinforced by Sustainable Development Goal (SDG) target 12.3, which aims at halving food waste at retail and consumer levels, whilst simultaneously reducing food losses along production and supply chains (Hanson, 2017). SDG 12.3 primarily targets quantifiable losses or wastes, equivalent to a quarter of available calories that are missed and never consumed (Pangaribowo et al., 2013). Such a loss would ideally feed close to 10% of the current 821 million undernourished people in developing countries (FAO et al., 2018; Munesue et al., 2015). However, strategies to reduce FLW in developing countries are hindered by an absence of reliable data on FLW that occurs within different food value chains (Affognon et al., 2015). The few studies that do link FLW with macro- or micronutrients lost from the supply chain are also limited to developed countries (Cooper et al., 2018; Love et al., 2015; Spiker et al., 2017). This absence could hinder evidence-based follow-up of SDG 12.3 indicators especially in countries experiencing food and nutrition insecurity (Barrett et al., 2010; Francis et al., 2012; Gil et al., 2006).

There exist additional obstructive factors to FLW data acquisition. FLW definitions and measurements methods are inconsistently used, exacerbating identification and quantification problems that ultimately affect mitigation efforts (Chaboud and Daviron, 2017; Redlingshöfer et al., 2017). The lack of harmonized or integrated FLW assessment is a historical problem limiting acquisition of reliable and comparable FLW data. This is partly the reason for inconsistencies in the approximation of the magnitude of FLW around the world (Xue et al., 2017). To solve this problem, the FLW protocol was developed as a standard for accurate accounting and reporting of FLW (Hanson, 2016). It facilitates comparison across regions, countries, and between other smaller entities like companies and organizations. It also covers the entire food chain, distinguishes food loss from food waste, considers (in-)edible food parts, as well as possible destinations of FLW (Hanson, 2017). The protocol is based on the idea that what gets measured can also be managed and hence crucial to the design and development of appropriate FLW mitigation strategies. Although the FLW protocol proposes 10 FLW quantification methods, it does not address the need for complementary approaches for identification of FLW hotspots. Such identification approaches could form the basis to successfully apply standards, like the FLW protocol, hence strengthening FLW measurements and improving subsequent mitigating efforts along the supply chain, while considering a life cycle perspective of FLW (Corrado et al., 2017). Because the supply chain constitutes various hotspots where FLW occurs, a life cycle assessment (LCA) further lays the foundation and facilitates holistic analysis of products, processes, or activities (Roy et al., 2009). As such, approaches that transverse the entire supply chain should consider stakeholder awareness creation, interest development, and establishment of strategic actor partnerships so as to increase success (Aschemann-Witzel et al., 2017; Muriana, 2017; Parmar et al., 2017; Richter and Bokelmann, 2016).

9.1.2 Stakeholder adoption of lean manufacturing practices for food loss and waste assessment and mitigation

Although comprehensive assessments of FLW are still a challenge in many contexts, efforts to minimize FLW contribute to the realization of nutrition sensitive agriculture, prioritized to sustainably address global hunger by 2030 (Keding et al., 2013). As such, a recent study by Wesana et al. (2018) provides evidence that value chain actors support initiatives to reduce FLW and subsequently promote nutrition sensitive food systems. Findings in this study are based on the theory of organizational readiness to change, modeled to evaluate actor willingness to adopt lean manufacturing practices along the dairy supply chain to reduce FLW. The theory specifically associates change valence to change commitment on one hand and implementation capability to change efficacy on the other hand. Further, the concept of the multiactor approach was linked to both change commitment and efficacy.

Interviews conducted among farmers, processors, retailers, and distributors of milk products provide evidence that unmarketable products are normally discarded and so constitute FLW. The study affirms that FLW occurs at multiple stages of the supply chain and further justifies the need for multiactor collaboration to tackle this problem (De Steur et al., 2016; Göbel et al., 2015). It is thus indicated that actors who value the adoption of lean manufacturing and are also positive about a multiactor approach exhibit an increased commitment for implementing lean practices to reduce FLW. In addition, a positive perception of the resources required to reduce FLW using lean practices is more likely to increase an actor belief of having the ability to successfully implement advocated initiatives. This study contributes to this limited body of evidence related to perceptions of value chain actors towards nutrition sensitive agriculture (Allen and de Brauw, 2017; Jaenicke and Virchow, 2013). Current policy dialogues are also in favor of this approach so as to improve expected impacts of agriculture on nutrition outcomes (Hodge et al., 2015; Van Den Bold et al., 2015). This could potentially increase the success of strategies that are nutrition sensitive if an enabling policy environment is established following recommended frameworks (Gillespie et al., 2013; Pingali and Sunder, 2017).

9.1.3 Value stream mapping as a hot spot identification approach for food loss and waste assessments

Value stream mapping (VSM) has been proposed as a method that can be used to identify and map hotspots of FLW along the agrifood value chains (De Steur et al., 2016). It is part of lean manufacturing, a management philosophy that was developed to eliminate wastes in production systems (Womack et al., 1990). Since its inception in the automobile sector, it has been utilized in other sectors including the agrifood industry (Dora et al., 2014; Zokaei and Simons, 2006). As a lean tool, VSM, a method that facilitates systematic documentation of flow of materials and information in producing a product, is becoming particularly popular in the agrifood sector (Panwar et al., 2015). This approach involves mapping the production configuration to identify lean wastes categorized as defects, overproduction, inappropriate processing, unnecessary inventory, unnecessary motion, transport and waiting (Dal Forno et al., 2014; Womack, 2006).

A study by De Steur et al. (2016) was the first to systematically aggregate evidence on the potential of using VSM to identify FLW along food supply chains. This study compiled evidence from the available literature that applied VSM in an agrifood context to confirm VSM's adaptability to efforts targeting reduction of FLW. Thereby, 24 studies dealing with lean manufacturing aspects or concepts (i.e., VSM, lean management, lean philosophy, lean thinking, lean principles, lean practices, and lean tools) as well as food related aspects (i.e., food, food supply chain, agrifood chain, food industry, food sector, and agriculture) were selected as they tackled loss and waste identification and or minimization. Information that was considered relevant to FLW was obtained including supply chain actors, types of food products, VSM related aspects (state maps, other lean tools, and lean metrics), and types and reasons for waste.

In this study, it was observed that VSM was either used in a single- or multiactor setting in various agrifood contexts including factories, warehouses, hospital kitchens, primary producers, and distributors (i.e., wholesaler and retailers). Different food products were studied including bread, ready to eat foods, peaches, wine, mango juice, yogurt, ketchup, biscuits, snacks, coffee, tea, nougat, soups, vegetables, beef, lamb, pork, and edible oil while some studies targeted restaurants and warehouses with no specific type of food mentioned. This study further illustrated that VSM is used in various ways. Thereby, a graphical mapping technique was commonly applied including both the current and future state maps while the description of these states was less used. From case studies that used VSM, lead time and the number of operators were the commonest indicators used to determine performance improvement. Subsequently, future state maps were characterized by other lean improvement tools including Kaizen, Just-In-Time, Kanban, and Cellular Manufacturing.

Table 9.1 provides an overview of lean related waste occurrences at different stages of the supply chain that were linked to FLW in an agrifood setting. Findings showed that there were two categories of FLW including discarded food and nutrient losses. Discarded food was mainly associated with defects in products,

Table 9.1 Hotspots and wastes and their causes derived from agrifood studies applying value stream mapping, split up according to stage

Hot spot	Form of loss/waste	Lean waste	Cause of waste	References
Primary production	Discard	Unnecessary inventory	Uncertainty in supply of raw material	Seth et al. (2008)
			Use of push production system	Taylor (2005, 2006)
		Defect in product	Nonconformance to specifications[a]	Taylor (2005)
Processing	Discard	Defect in product	Nonconformance to specifications[a]	Folinas et al. (2015), Goriwondo et al. (2011), Jiménez et al. (2012), Noorwali (2013), Sathiyabama and Dasan (2013), Seth et al. (2008), Shobha and Subramanya (2012), Taylor (2005, 2006), Vlachos (2015)
			Short shelf life due to microbial spoilage	Darlington and Rahimifard (2006), Francis et al. (2008), Melvin and Baglee (2008)
		Inappropriate processing	Poor and overtopping, overbaking, variation in size/shape	Sathiyabama and Dasan (2013)
			Poor timing of slicing operation	Goriwondo et al. (2011)
			Food loss due to forming and loss of processing materials	Kennedy et al. (2013)
		Overproduction	Poor demand forecast	Darlington and Rahimifard (2006), Noorwali (2013)
		Unnecessary inventory	Excess stock of either raw materials or finished products	Jiménez et al. (2012), Lehtinen and Torkko (2005), Noorwali (2013), Shobha and Subramanya (2012), Tanco et al. (2013), Taylor (2005)

(*Continued*)

Table 9.1 (Continued)

Hot spot	Form of loss/waste	Lean waste	Cause of waste	References
	Nutrient loss	Defect in product	Nonconformance to specifications[a]	Sathiyabama and Dasan (2013)
		Inappropriate processing	Overbaking	Sathiyabama and Dasan (2013)
			Inappropriate peeling, washing, and pasteurization	Folinas et al. (2015)
Storage	Discard	Defect in product	Short shelf life due to microbial spoilage	Glover et al. (2014)
Foodservice/consumption	Discard	Defect in product	Wrong meal service	Ahmed et al. (2015)
			Mismatch with customized needs of consumers	Rahimnia et al. (2009)
		Overproduction	Poor demand forecast	Engelund et al. (2009)

[a]Including incorrect weight and fat levels, poor/overtopped products, variation in size/shape, breakages, scrap, and/or poor quality.

Source: From De Steur, H., Wesana, J., Dora, M.K., Pearce, D., Gellynck, X. (2016). Applying value stream mapping to reduce food losses and wastes in supply chains: a systematic review. Waste Manage. 58, 359−368.

unnecessary inventory, inappropriate processing, and overproduction wastes in lean manufacturing. Main attributing factors were nonconformance with specifications, short shelf life, rejected meals, uncertain supply of raw materials, push production, poor processing outcomes, and poor demand forecast. Similarly, nutrient loss was associated with defects in products as well as inappropriate processing, where nonconformance to specifications, overbaking, inappropriate peeling, washing, and pasteurization were identified as key causes for this type of loss. The processing stage of production was by far considered the main hot spot for the occurrences of lean related FLW along the food supply chain. This gives an indication of the potential of VSM to systematically identify FLW together with hotspots where they occur, which creates an avenue for quantification of losses and wastes in a holistic manner as well as facilitates information sharing among stakeholders. This opens up opportunities to use other lean manufacturing tools to minimize the occurrence of FLW. As such, this review pointed to the need of a practical application of VSM specifically targeting losses and wastes that occur in a specific food supply chain.

Therefore, the aim of this chapter is to apply VSM analysis at chain level, while integrating the FLW standard. This is expected to lead to a reliable and systematic mapping of hotspots to facilitate FLW measurement and reporting. As a consequence, mitigating approaches could be initiated along food supply chains. Furthermore, these methods are applied within the confines of the product life cycle approach (Corrado et al., 2017). There are few studies conducted following the FLW standard (Tostivint et al., 2017), and none have used a systematic mapping approach in an agrifood chain of a nutrient-rich food product. This study used the dairy value chain in Uganda as a case.

9.2 Methodology

Data were collected in August 2017, using a case study approach at a dairy company (not named because of confidentiality), located in the western region of Uganda. The company operates a dairy farm, a processing plant, and various distribution channels. This set-up formed a value chain that was suitable for the application of the VSM methodology to conduct a holistic assessment of FLW whilst adhering to the FLW protocol (Hanson, 2016; Womack, 2006). With reference to the guidelines of the protocol and having established the purpose of this case study, the scope of this study included the period of data collection, specified target type of material [i.e., only edible (milk) products] as well as setting boundaries for data collection [i.e., three stages of the supply chain, one dairy company, (milk) products]. Destinations of lost or wasted products were observed during data collection and were reported as findings. Interviews were conducted with different personnel that worked at the three supply chain levels of the dairy company. In addition, observations of processes were made so as to confirm key informants' responses. In case of inconsistencies in responses, the observed situation took precedence.

A semistructured questionnaire was used to guide the data collection. Its development was based on the principles of lean manufacturing and comprised three sections (Hines et al., 2004; Womack, 2006). The first included general information about the stage of the supply chain, the process name, and the constituent step. The second sought information on the cycle time (i.e., time a process takes from start to finish), waiting, or nonvalue adding time and the number of operators managing a process. The third section was used to detail losses and wastes observed along the different stages of the supply chain and included types of loss/waste based on the seven lean wastes (i.e., defects, waiting, transport, overprocessing, motion, overproduction, and unnecessary inventory). This information facilitated the creation of a "current state map" depicting the present situation along the dairy supply chain with an emphasis on steps, processes, and occurrence of FLW. Microsoft Visio 2016 was used to design the current state map. Lastly, lead time was also calculated using the cycle time and the waiting/nonvalue adding time observed by following operations along the supply chain. The quantity of FLW was calculated following the load tracking method developed by the Food and Agriculture Organisation (FAO, 2016). Thereby, the quantity of milk or its products was recorded before and after an activity, from which the difference constituted the quantity of FLW.

9.3 Results

9.3.1 Characteristics of the dairy supply chain examined in the case study

Table 9.2 shows findings from observations made along the value chain and the interviews conducted with key personnel operating within the company. Observations made at three levels of the value chain (farm, processor, and distribution) indicate that production follows specified steps, each made up of at least two operations. During data collection, the focal farm had 51 lactating cows that were milked twice a day. This was also reported as the average number in the previous 6 months. The farm is run by a farm manager and an accountant who are employed on a long-term basis, in addition to over 15 personnel on short term employment basis (mostly milk men and other casual laborers). The farm on average produces 200 L of milk a day but also acts as a collection center for farmers in the neighborhood. Therefore, farm records indicated that approximately 1400 L of milk were normally collected every 3 days for delivery to the processing plant during dry seasons. However, the quantity of milk collected was reported to be higher in the wet seasons of the year. The processor mainly operates on orders made from customers (i.e., wholesalers and retailers) and so generally uses a pull system to produce milk products.

During fieldwork for this case study, it was observed that the processor was supplied with 20,000 L of raw milk, based on a past order from farms in the region. Although the processing plant was directly linked to the focal farm and its partner

Table 9.2 Characteristics of the dairy supply chain

Supply chain stage	Steps	Operation	Capacity/units handled/processed	Operators
Farmer	Milking	• Preparation • Hand milking • Measurement • Pouring milk into cans	51 cows	5
	Collection and storage	• Transfer cans to cooling center • Delivery of milk from other farms	2000 L	2
	Distribution	• Milk quality testing • Transfer milk from cooling tanks to trucks • Delivery to the processing plant	1400 L/3 days	4
Processor	Milk reception	• Milk quality testing • CIP of inlet, pasteurizer, and tanks • Milk inlet • Pasteurization • Cooling • CIP of inlet and pasteurizer	50,000 L	2
	Yogurt Mixing	• CIP of mixture • Milk transfer to mixture • Add milk powder and sugar	3000 L	3
	Pasteurization + homogenization	• CIP of tube pasteurizer and homogenizer • Pasteurization and homogenization	3000 L	3
	Fermentation	• CIP of fermentation tank • Milk inlet • Add culture, flavor, and color • Start fermentation • Test pH	3000 L	3

(*Continued*)

Table 9.2 (Continued)

Supply chain stage	Steps	Operation	Capacity/units handled/processed	Operators
	Cooling	• CIP of cooling tank • Milk inlet • Start cooling	3000 L	3
	Packaging	• Prepare packaging machine • Prepare packaging material (cups + seals) • Calibrate machine with real product • Channel yogurt to machine • Pack and seal • Print manufacture and expiry dates • Arrange sealed cups in boxes	72 cups/min	15
	Storage	• Place boxes on pellets • Transfer pellets to store	25 boxes/pellet > 200 m^2	3
	UHT			
	Homogenization + sterilization	• CIP of sterilizer • Pasteurization • Transfer to deaerator • Homogenization • Milk inlet into sterilizer • Sterilization • CIP of sterilizer	6000 /h	2
	Aseptic tank holding	• CIP of aseptic tank • Milk inlet from sterilizer • CIP of aseptic tank	6000 L	2

	Packaging	• Prepare tetra packaging machine + CIP • Prepare packaging material (tetra pack + caps) • Calibrate machine • Channel milk from aseptic tank to tetra packing • Print manufacture and expiry dates • Apply top caps • Arrange sealed tetra packs in boxes • CIP of tetra packing machine	6000 L/h	15
	Storage	• Place boxes on pellets • Transfer pellets to store	15 boxes/pellet > 200 m^2	3
Distributor	Loading and transportation	• Transfer stock from storage to truck	Depends on order	4
		• Truck journey to Kampala		2
	Unloading & storage	• Transfer stock from truck to store		4
		• Distribution to customers		4

farmers, it was also supplied by other farmers in the region to reach its storage capacity of 50,000 L of milk. This made it possible to receive 20,000 L of milk or more whenever there was a need. The processor currently makes yogurt and ultra-high temperature (UHT) milk, and mainly distributes these products for sale to wholesale and retail outlets in Kampala and neighboring towns. The plant has a capacity to process 3000 L of pasteurized milk into yogurt while 6000 L of pasteurized milk can be processed into UHT milk at a time. Line production is used and there are two separate lines for yogurt and UHT processing. A batch system is utilized and all pasteurized milk contained in storage tanks is normally processed so that the next delivery of milk is not mixed up with old stock of milk that would still be kept in the tanks. There is a milk laboratory, stationed between the two production lines, where all quality tests are carried out to ensure that recommended standards are met. In addition, the plant is equipped with two separate types of packaging machinery for yogurt and UHT. Packing material is supplied from Nairobi, Kenya on a monthly basis. The plant has two storage facilities located adjacent to the packaging areas of both lines, with each connected to a loading area. There are close to 30 personnel working at the processing plant including the Chief Executive Officer, process manager, marketing manager, technicians, laboratory analysts, food technologist, and other staff responsible for packing and storage of finished products. Yogurt and UHT milk are periodically transported to an additional and separate storage facility located elsewhere in Kampala to replenish old stock before final distribution to wholesalers and retailers, or for sale to end consumers.

9.3.2 Current state map for production of yogurt and ultra-high temperature milk

Fig. 9.1 outlines the dairy company's production processes for yogurt and UHT milk. Below, the findings are described for each stage of the supply chain.

9.3.2.1 Farmer level

Focal farm and partner farms: The process of production starts at this level with milking of cows. At the focal farm, this takes place in a milking parlor, which accommodates around 10 cows at a time, while the rest are held in a nearby paddock awaiting their turn. Each cow is restrained before being hand milked with buckets by one of four men, each milking one cow at a time. Once the cow's udders are emptied, the milk is measured and then poured into a 50-L milk can. It was noted that this process of milking each of the 51 cows took approximately 3 hours to be completed.

Collection center: Following milking, the cans are transferred to the collection center for cold storage. Other farmers also deliver their milk to this center. At the storage center, there are two employees that receive milk from farmers and store it in a 2000-L tank; this process takes on average 2 hours. The process of transferring the milk is manual and so delivery to the center is done either with the assistance of

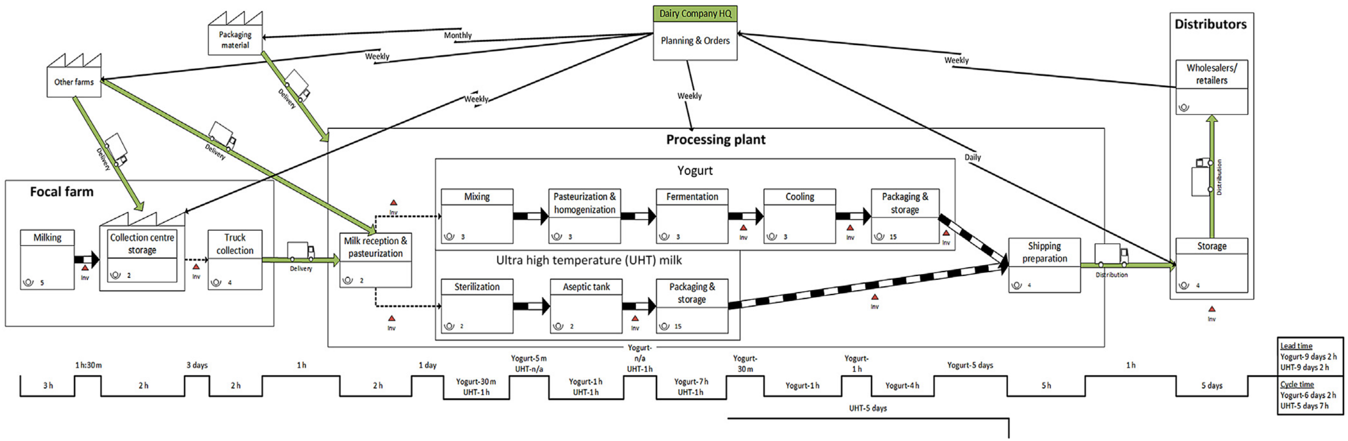

Figure 9.1 Current state map of the dairy supply chain of yogurt and UHT milk.

a wheelbarrow or with a bicycle or motorcycle. At the center, the milk is decanted into small 10 L buckets, allowing the 50-L can to be easily lifted and emptied into the storage tank. The cooling center also uses a generator as a source of power for cooling and this is run for 30 minutes in every 24 hours.

Distribution: Every third day, a truck collects milk from the center for delivery to the processing plant. Collectors first have to test the quality of the milk before it can be loaded into the truck. The process of transferring milk into the truck is manually done by four persons and normally takes 2 hours to complete. A pipe is connected from the cooling tank to the truck. Milk is first measured using a 50-L can, and so 50 L of milk are poured into the truck following each measurement. This process continues until the truck is full or milk in the cooling tank is finished, the former situation occurring more often.

9.3.2.2 Processor level

Orders for milk delivery are placed weekly with these orders initiating milk processing activities at the plant.

Milk reception: This is the first activity conducted at the plant. On the day that milk was delivered, it was observed that a sample of milk was first tested to determine its quality and assess if it would be suitable for processing as yogurt or UHT milk. Thereafter, CIP of the inlet system was conducted, followed by the actual input of milk into the plant. As milk is pumped into the system, pasteurization immediately starts before milk is channeled to the cooling storage tanks. At the start of the milk inlet, there is a milk-milk push through the system but at the end, water is used to push pasteurized milk into storage tanks. When all the milk is received and stored, CIP of the inlet system and the pasteurization tubes is conducted. The whole process of milk reception was done by two personnel and took 2 hours to receive 20,000 L of milk that were delivered by two trucks.

9.3.2.2.1 Yogurt

Mixing: The actual processing of pasteurized milk into yogurt starts when a mixture is made with sugar and milk powder. On the day this process was observed, two batches of yogurt were produced (i.e., plain and mango flavored yogurt). Plain yogurt was produced first, with 2800 L of pasteurized milk being channeled into the mixer from one of the storage tanks. Then 160 kg of skimmed milk powder and 128 kg of sugar were poured into the mixer. This was performed by three workers and the mixer ran for exactly 30 minutes, before the product was channeled to the pasteurizer and homogenizer. The same process was followed for the next batch of mango flavored yogurt, which only started when the first batch was already at the next step of processing.

Pasteurization + homogenization: The product from the mixer is pasteurized again before it is channeled to the next step. The pasteurizer also acts as a temporary storage element and this is facilitated by its structure (i.e., a series of holding tubes). Pasteurization takes place first and homogenization immediately commences but some milk remains in the tubes. Milk sent to the homogenizer pushes out water that would have remained during CIP conducted earlier, into the drainage system. Since the process here is continuous, drainage of water is closely observed, with the outlet valve being manually closed after the output is presumed to be milk and not water. In this case, milk is used to push out water but the opposite occurs at the end when water is instead used to push out the remaining milk that could not be sent to the next step, to the drainage system. Both processes take around 1 hour and are managed by three persons. This process was also repeated for the second batch of mango flavored yogurt.

Fermentation: Once pasteurization and homogenization are complete, milk is then sent to the fermentation tank. There are two tanks, each with a capacity of 3000 L, which makes it possible to handle two batches almost concurrently. At this step, it was however difficult to determine how much of the product was sent to the tank. This could be determined later during packaging. It was also at this step that only culture (thermophilic bacteria) was added in case of plain yogurt. For mango yogurt, flavor and color were also added. There is also a heat treatment that is applied that facilitates the fermentation process. Fermentation took 7 hours to complete and it was monitored to maintain the pH at 4.2−4.5, a lower pH being detrimental to the expected quality of the product. However, it was reported that the duration may be longer than 7 hours if the desired acidity is not yet reached. Two personnel were responsible for this process.

Cooling: At the end of the fermentation process, yogurt is sent to one of two cooling tanks. A valve is opened, and yogurt instantaneously moves to the cooling tank. The main purpose is to inactivate thermophilic bacteria so that fermentation stops. As earlier noted, the start of this process was delayed by 30 minutes for both batches, yet the preceding process had completed. Cooling takes around 1 hour and is managed by two workers. They also had to observe a yellowish-orange change in color of yogurt in the pipes because the mango flavored batch was later channeled to the other cooling tank.

Packaging: Before this commences, the packaging machine has to be prepared with all of the necessary packing material (i.e., cups and seals) and a date printer. Additionally, at least 15 people have to be positioned along the packing conveyer belt to arrange finished products in boxes, ready for storage. Therefore, cooled plain yogurt was channeled directly to the packaging machine and it was packed in 450 g cups, which was later, followed by mango flavored yogurt. In the end, there were 5659 cups with plain yogurt and 6055 cups with mango flavored yogurt that were appropriately packaged, with the whole process lasting 4 hours.

Storage: This is done concurrently with packaging. Boxes each with 12 cups are arranged on a pallet and then a plastic wrap is applied around it. Each pallet could accommodate 24 boxes, which were subsequently transferred to the storage area using a hand pallet jack. Products were arranged according to the date of production; hence new stock was not mixed with old stock.

9.3.2.2.2 Ultra-high temperature milk

Sterilization + homogenization: Before this process, 9900 L of milk in storage tanks were first repasteurized using the pasteurizer of the yogurt line. The double pasteurized milk was then directly sent to the UHT production line, pushing out water to the drainage area in the process. The temperature of milk was then raised and maintained between 70°C and 75°C and then it was channeled to the deaerator, also kept at the same temperature. Before sterilization at 132°C–140°C, milk was first homogenized so that fats could be broken down. Milk was held at sterilization temperature for 3–5 seconds and it took around 90 minutes to process the 9900 L of milk.

Aseptic tank holding: Prior to sterilization, the aseptic tank was first prepared to receive milk in a condition that significantly reduces the risk of microbial growth. This was done using steam at a temperature of 147°C and cooled down using sterile air. Milk that is sterilized was then sent to the aseptic tank for temporary storage before it was packed. This process lasted for 1 hour.

Packaging: Preparation of the tetra brik aseptic packing machine was done at the same time sterilization was initiated. This involved CIP and placing the packing materials into the machine. As already noted, milk in the aseptic tank was not immediately packed. This was because the packing machine was still being prepped even though this had been started earlier. Once ready, milk was then sent from the aseptic tank for packing. The first tetra packs were used to calibrate the machine so as to reduce errors on packages. Good packs were labeled with dates and as they moved on the conveyer belt, top covers were applied using a precise cap applicator. UHT milk was then packed in boxes, each containing 10 one-liter tetra packs. There were 15 personnel who were engaged in the whole process of packaging, and this lasted for 1 hour.

Storage: UHT milk in 1-L packs were arranged in a box with a capacity of 12 packs. Sealed boxes were then placed on pallets, wrapped with a plastic, and transferred to storage with a hand pallet jack. Care was taken that newly produced UHT milk was not mixed with old stock, hence pallets were arranged according to the date of production.

9.3.2.3 Distribution

Finished products (yogurt and UHT milk) are periodically transported to the storage facility in Kampala. Products on pallets were loaded into a truck using a hand pallet jack. The truck travels a distance of 300 km to deliver products to the storage facility in Kampala. Once there, products are offloaded and stored according to the dates of arrival. Thereafter, the same process of loading, transportation, and off-loading is followed when products are distributed to customers.

9.3.3 Identification of food loss and waste and their destinations along the dairy value chain, with a link to lean manufacturing

Findings in Table 9.3 illustrate losses and wastes identified and are also explained later according to the stage of the supply chain.

Table 9.3 Food losses, lean waste linkage, and their destinations along the dairy value chain

Supply chain stage	Steps	Food losses	Lean waste linkage	Destination
Farmer	Milking	Spillage of milk	Defect	Discard
		Milk kept in open cans for long periods	Inventory Defect	Discard
	Collection and storage	Spillage of milk	Defect	Discard
		Milk in cooling tank before distribution	Inventory	
	Distribution	Spillage of milk	Defect	Discard, given to employees, ghee and milk powder production
		Poor quality milk rejected		
		Uncollected milk in tank	Overproduction Inventory	
Processor	Milk reception	Spillages of milk	Defect	Discard, ghee and milk powder production
		Unpasteurized milk sent to the drain		
		Milk in trucks not pumped		
		Poor quality milk rejected		
	Yogurt			
	Mixing (2 × 2800 L)	Spillage of milk powder and sugar	Defect	Discard
	Pasteurization + homogenization	Milk mixed with water	Defect	Discard
		Heat labile micronutrient degradation	Overprocessing	Packaged
	Fermentation(Plain and mango)	Yogurt with very low pH (sour taste) rejected	Defect Overprocessing	Discard
		Yogurt unnecessarily kept longer in tank	Inventory	
	Cooling(Plain and mango)	Yogurt drained out during batch change-over	Defect	Discard
		Yogurt kept unnecessarily longer in tank	Inventory	Packaged

(*Continued*)

Table 9.3 (Continued)

Supply chain stage	Steps	Food losses	Lean waste linkage	Destination
	PackagingPlain: 5659 cupsMango: 6055 cups	Yogurt with incorrect weight rejected Yogurt in damaged cups rejected Yogurt with seal leakage rejected Yogurt with error/unclear dates rejected Yogurt with mixed flavor rejected	Defect	Discard, given to employees
	Storage	Old stock used as buffer	Inventory Overproduction	Distributed, discard
	UHT			
	Sterilization(with pasteurization + homogenization)9900 L	Milk drained out during removal of water Heat labile micronutrient degradation	Defect Overprocessing	Discard Packaged
	Aseptic tank holding	Sterilized milk awaiting packaging	Inventory	Packaged
	Packaging8532 tetra packs	Tetra pack with weak seal rejected Tetra pack with design error rejected Tetra pack with pin hole rejected Tetra pack with no applied cap rejected Tetra pack with wrong/unclear dates rejected	Defect	Discard
	Storage	Old stock used as buffer	Inventory Overproduction	Distributed, discard
Distributor	Loading, transportation, unloading, and storage	Damage on packaging Delivered products not distributed immediately	Defect Inventory	Discard Distributed

9.3.3.1 Farmer level

Focal farm and partner farms: During milking, it was observed that a portion of the milk was normally spilled on the floor. This takes place during hand milking and when milk is poured from a bucket into cans. The main causes of spillages that were identified are inattentiveness of milk men when performing a task and also the restlessness of the cows. For the latter, there was also an increased risk that the cow would kick the bucket, causing a bigger loss of milk. Spilled milk becomes a product defect that cannot be recovered and hence can be categorized as discarded milk. There is also a practice of keeping milk in open cans located in the milking parlor for prolonged periods of time. Flies were observed hovering over the cans and coming into contact with the milk. This exposed the milk to microbial contamination and hence increased the likelihood of deterioration. The loss attributed to this can occur in subsequent stages of processing when milk goes bad due to poor handling practices at a preceding task, hence being rejected and or discarded. As far as lean manufacturing is concerned, this practice constitutes a defect that additionally results in an accumulation of inventory, limiting the start of the next step in the production system.

Collection center: The system of transportation used exposes milk to spillages if cans are not properly covered and its occurrence is exacerbated by bumpy roads en route to the center. As milk was poured into the cooling tank, it was also easily spilled on the floor and on top of the tank. Spilled milk is considered a defect since it cannot be used anymore. During storage, it is also presumed that the tank is capable of maintaining cold temperatures, built up during the first 30 minutes of cooling. This is problematic since there was no control that was observed on the tank to monitor changes in temperature. Hence, there is also a high chance of milk deterioration due to microbial growth especially if there was some form of microbial contamination at an earlier stage. Moreover, milk that is stored in the cooling tank for days without being distributed results in an accumulation of inventory.

Distribution: If milk in the cooling tank is of low quality, it may be rejected by distribution trucks. Sometimes the collection center receives a lower price for low quality milk. Alternatively, such milk ends up with processors who produce dairy products that do not depend a lot on the quality of the milk. An example that was reported was the production of ghee and milk powder from such milk, where it could be used as a raw material. Another possible destination reported was that rejected milk is sometimes given to farm employees or thrown away since it cannot further be used for any purpose. While milk is loaded into the truck using 50-L cans, a lot of spillages normally occur. This results in a considerable loss of product, for example, on the day 1400 L of milk were collected, it was observed that 28 cans were loaded into the truck. Each can spilled around 100 mL of milk, which was approximately 3 L of milk lost at that stage. Further, the truck was unable to load all of the milk contained in the cooling tank. This was the case because it had already made rounds from other centers arriving at the focal collection center last. This was reported to be the usual routine followed by the truck. Therefore, almost 500 L of milk remained in the tank, and this balance can be considered an overproduction waste. This also leads to a situation where the remaining milk is easily mixed with fresh milk that is received from farmers on subsequent days. Hence, increasing the chances of cross-contamination and possible rejection of milk during the next truck pick-up.

9.3.3.2 Processor level

Milk reception: During milk inlet, spillages were observed around the truck. However, the connection to the plant inlet valve was tight enough and no spillages were observed. It was reported that milk of poor quality was always rejected and was not used at the plant. Such milk was distributed to other processors for the production of ghee and milk powder. An observation was made that a proportion of unpasteurized milk remained in the whole system after pasteurization and storage. This milk was pushed out of the reception unit into the drainage system using a force provided by water that is automatically pumped into the system once pasteurized milk is stored. There was also milk that remaining in the trucks that could not be pumped into the processing plant. This milk is disposed of while trucks are cleaned for the next delivery.

9.3.3.2.1 Yogurt

Mixing: Because the whole mixture is sent to the next step, losses at mixing were minimal. It was only the ingredients added (i.e., skimmed powder milk and sugar) that were spilled on the working surfaces and floor. Spilled ingredients could not be reused and were discarded into drainage as scrap.

Pasteurization + homogenization: During pasteurization and homogenization, milk is lost twice into the drainage. First is when incoming milk is used to push out water from the system. The outlet valve is only closed once the personnel think that it is only milk in the system. This is done manually; it is very hard to tell and a subjective decision is always made. Therefore, a certain quantity of milk is allowed to drain out together with water. The second time is when a new batch has to be processed and the system has to be cleared of any milk. All the remaining milk is pushed out by water into drainage. It was estimated that between 20 and 50 L of milk are lost at this step. It should be noted that losses at this level continue to occur even with the next batch because the same principle applies. Milk is also pasteurized the second time since it was delivered to the plant. This increases the likelihood that thermal labile micronutrients are affected in terms of quality.

Fermentation: During the fermentation phase, the main threat as far as losses are concerned is increased acidity of yogurt (i.e., pH below 4.2). Once this occurs, yogurt develops a sour taste that is irreversible, and the product is discarded; hence the whole batch is lost. Another possible loss was with the ingredients added that were seen spilled on top of the tanks. When fermentation was complete, there was an observed 30-minute lag before yogurt was channeled to the next process, hence product held at this step became inventory. This also provided an opportunity for thermophilic bacteria to continue the breakdown of yogurt, which could further lower the pH.

Cooling: By the time the first batch was sent through pipes to one of the cooling tanks, another batch was almost completing its fermentation. At this point, no CIP was performed, the cooling tank was sealed, and it was noted that plain yogurt that remained in the pipes was pushed out into drainage by incoming mango flavored yogurt. The operator reported that approximately 12 L of yogurt are drained out of the system per minute. As such, it took around 5 minutes for almost 60 L of plain yogurt to drain out of the system. As earlier mentioned, a yellowish-orange color change in the pipes was the signal operators used to initiate closure of the drainage valve. It may also be suggested that inventory accumulates at this stage, especially when the next process was not prepared in time.

Packaging: During packaging, there were 68 plain, 17 mango, and 132 mixed flavored yogurt cups that had defects. These defects included incorrect weight, damaged cups, seal leakages, errors in dates printed, and unclear dates. Many of the defects occurred at the very start of packing when the machine was being calibrated. Such products were separated and not packed for distribution to customers. Additionally, before mango flavored yogurt was packed, the product that first came out of the system was not purely mango (i.e., mixed flavor). It was clearly observed that the first product had a very light yellowish color, which indicated a mix with plain yogurt. The operator in charge also highlighted that it is even worse if another flavor such as pineapple is also produced. Therefore, cups with this mix were also separated from those with a consistent yellowish-orange color typical of mango flavored yogurt. It was also observed that the surfaces of working tables were slippery and without end-stops, in that three sealed cups were knocked over by workers who were arranging them in boxes. Most products damaged during packing were thrown away and a few were given to employees. When the number of cups packed are converted into liters, 2472.4 and 2645.4 L of plain and mango flavored yogurt, respectively, were eventually packed and suitable for distribution to customers. Compared with 2800 L of pasteurized milk that were used as raw material for each batch, overall, there was a 327.8 L (11.7%) and 154.6 L (5.5%) loss of marketable milk product from mixing to packaging stage for plain and mango flavored yogurt, respectively.

Storage: There was no sign of packed yogurt loss observed during storage. However, old stock was observed in storage that was reported to act as buffer whenever an urgent order was made at times when production was not planned. This constitutes both accumulating inventory and overproduction and issues may arise if the old stock is not distributed in good time before specified expiry dates.

9.3.3.2.2 Ultra-high temperature

Sterilization + homogenization: At this step, the process of pushing out water from the system using incoming milk was the source of loss. The operator had to wait and ensure that all water had been drained. This required that some amount of milk be concurrently disposed of in the process. It was observed that almost 400 L of milk were lost to drainage at this point. In addition, exposing milk to a second pasteurization process increases the likelihood that heat labile micronutrients are compromised, hence affecting the nutritional value of the final product.

Aseptic tank holding: There was no sign of physical loss observed at this step. However, since the next process did not start promptly, there was an accumulation of inventory.

Packaging: Losses of milk were immediately observed when the tetra brik machine was being calibrated. The first packs that came out had a lot of errors and it took many attempts to come up with an acceptably packaged product. Observed errors included weak package seals, design errors, pin holes, wrong application of the cap, and wrong/unclear dates. It was both reported and observed that such milk would not be reused and all of it was discarded. Midway through packing, the same errors happened and still more milk was discarded. There were 8532 tetra packs that were appropriately packed. This was equivalent to 8532 L of milk since each pack contained 1 L. When compared with 9900 L channeled from the storage tanks, a loss of 1368 L of milk or 13.8% was identified.

Storage: No loss was observed during storage. But the delay to distribute finished products was associated with an accumulation of inventory. It was also highlighted that the old stock present was used as buffer in case an urgent order is made at times of no production. This gave an indication that although the processing plant mainly operates on orders, it also produces more products than ordered. This in a way may be rational, but the plant also runs a risk of loss if such a buffer is not distributed on time before its expiry date.

9.3.3.3 Distribution

No losses were observed at the time of data collection. However, workers reported having experienced losses during loading, off-loading, and transportation. This gave an indication of additional hotspots where losses, in terms of physical damage to packages, could occur if enough care is not taken. There is also accumulation of inventory at the second storage facility since distribution to customers is normally not done immediately.

9.4 Discussion

This case study applied VSM, following guidelines of the FLW protocol to map hotspots for food related losses and wastes along three stages of a dairy value chain in Uganda, thereby confirming that VSM is applicable in an agrifood context to make a comprehensive overview of the nature of losses and wastes that occur along the supply chain (De Steur et al., 2016), while following specific lean manufacturing practices adapted to the dairy sector (Malmbrandt and Åhlström, 2013). As a foundation for value chain analysis, the current state map of the dairy value chain indicates that the production of milk products constitutes a series of dependent steps and operations that are potential hotspots for losses and wastes. Although the majority of losses and wastes were noted to occur at the processing stage, unsatisfactory handling practices at the farmer level increased the likelihood of milk rejection and subsequent disposal upstream. The issue of losses and wastes instigated at earlier stages of the chain has also been reported in a study about food losses and reduction strategies in Switzerland (Beretta et al., 2013). Unfortunately, awareness among actors of what happens down or upstream is limited and is hardly observed because of barriers that hinder integration along the supply chain (Taylor and Fearne, 2009), thereby reinforcing the need for targeted awareness creation to promote implementation of collective strategies at all chain levels with input from various actors (Göbel et al., 2015; Halloran et al., 2014).

With respect to loss or waste types, results indicated that milk products were oftentimes discarded, while some supply chain operations were linked to nutrient losses. Product defects were by far the main reason for discarding milk products, a finding that supports previous literature (Halloran et al., 2014; Muriana, 2017). Selectively discarding products that fail to match quality standards expected by consumers is common practice among producers as a way of increasing or sustaining market share of their products (Willersinn et al., 2015). There were also instances of accumulated inventory along the chain, and subsequent poor handling could in a way render milk unacceptable for further processing, hence being discarded. The same was true for overproduction of milk products that were not transferred upstream at the same rate as they were produced. Although production of food is increasingly affected by uncertain demand forecasts, producers continue to use push strategies that result in either accumulation of inventory or stock (Buzby and Hyman, 2012; Silvennoinen et al., 2015). Perishability of dairy products such as UHT milk and yogurt hence underlines the need to adopt lean production based pull strategies such as just-in-time production (Lyonnet and Toscano, 2014; Mackelprang and Nair, 2010). This has the potential to reduce losses due to unnecessary inventory and overproduction. Overprocessing was also identified as a factor affecting the integrity of milk products as far as nutrient quality of final products is concerned. Although the practice of double pasteurization at high temperatures has merits linked to the microbial safety assurance of food products, it potentially results in nutritional losses (Qi et al., 2015; Shewfelt, 2017). This also applies to other nonheat operations such as washing and other physical treatments applied to food, with vitamins being most susceptible (Atungulu and Pan, 2014; Francis et al., 2012), thereby confirming that the processing stage is an important hot spot for nutrient losses.

Limited standardization of operations especially at the farmer level could have been the underlying casual factor for the losses that were observed at this stage (Papargyropoulou et al., 2014; Parfitt et al., 2010). At the processing plant, there were some established process controls, but these were insufficient to prevent almost 14% or 5%−12% of observed losses along the UHT and yogurt production lines, respectively. Nonetheless, it remains important to establish and continuously improve controls, traversing the entire value chain, as a way of promoting collaborative efforts against losses and wastes (Mena et al., 2014). This practice could facilitate continuous improvement, a principle in lean manufacturing that promotes efficiency and lowers production costs (Rivera and Chen, 2007).

Lean metrics such as lead time play a key role to justify processes that need improvement. Our results indicate that the production process of a given batch of milk products take approximately 10 days from the farmer level to the point of distribution. Given the perishability of most milk products (Kaipia et al., 2013), improvements in production efficiency are needed so that consumption is not limited by the shortened shelf life of edible products (De Treville et al., 2004). Future research should therefore consider investigating and confirming the causal association between process standardization and control with the occurrence of FLW at different stages of the food chain. In addition, food producers should strive to improve production efficiency to lower the time it takes to have a finished product ready for consumer use.

Although discarding of unmarketable milk products was a popular destination, there are times when such products are given to employees. This supports findings from a study on the adoption of lean manufacturing to reduce FLW among dairy chain actors (Wesana et al., 2018). While this is a good practice, it can only be implemented to a limited extent because not all rejected products can be absorbed by available employees. In developing country contexts like Uganda, with a considerable part of the population facing hunger especially due to compromised economic access to milk or other nutrient-rich food products, there is a need to develop effective mechanisms by which unmarketable but edible products can be effectively redistributed beyond employees to the needy. This can be in the form of organized charity distributions, like those that have been implemented in other countries (Richter and Bokelmann, 2016; Schneider, 2013). Governments can take initial steps to foster an enabling environment for actors in the food industry and charity organizations to interact and promote effective collaboration as far as FLW is concerned (Garrone et al., 2016). This also could provide a suitable platform to create critical awareness and promote collective problem diagnosis to design alternative uses and destinations of products that would otherwise be discarded from the supply chain.

Even though identification of FLW hot spots along the three supply chain levels was possible while following the principles of VSM and the FLW protocol, quantifying the magnitude was not straightforward, as also reported in previous studies (Affognon et al., 2015; Chaboud and Daviron, 2017; Elimelech et al., 2018). There were observable efficiency differences in operations and equipment used at different stages of the supply chain, a limitation also identified by Corrado et al. (2017). Findings from the case study point to the absence of automation at the farmer and distribution/storage levels relative to the processor level. The organization of operations during processing of yogurt and UHT milk to a given extent facilitated FLW quantification. By comparing the amount of raw material used at the start of processing with the final product at the end, the magnitude of loss during the processing level was determined. However, there are some process components (i.e., drainage outlets) that ideally would require future investment in innovative technologies with quantification capabilities. This would be complementary to advocated improvement of production efficiency as a way of mitigating FLW (Parfitt et al., 2010; Shafiee-Jood and Cai, 2016).

9.5 Conclusion

This study has implications for the agrifood industry with regard to the systematic identification of hotspots along the value chain where FLW occurs. Applying VSM could help value chain actors to holistically establish the magnitude of FLW, by comparing the amount of material used at the start of a production process to the final quantity of product emerging at the end of the processes. Wherever possible, this should be done for every activity along the value chain. Efforts to minimize FLW should emphasize adoption of this practice more at the processor level of the chain, as this has shown to be a key stage where most losses occur, while also promoting actor integration and collaboration along the supply chain. Given the complexity of food production systems, establishing suitable controls to monitor FLW may be hindered by associated costs if new equipment needs to be installed, especially in resource constrained country settings. However, recent evidence shows that actors in the dairy value chain are more likely to adopt lean manufacturing strategies to reduce food losses if they are aware of associated benefits and are able to collaborate with other actors for a common purpose. Therefore, food producers should continuously be engaged and informed about the potential of lowering production costs following the adoption of lean waste reduction strategies along supply chains. As a consequence, the availability of nutrient-rich foods like dairy products is enhanced in a sustainable way without necessarily investing more in increased food production that has proven to be a costly venture. Future studies should extend this work and apply VSM to other agrifood value chains and further justify the potential of lean manufacturing strategies, integrated with other established accounting and reporting guidelines or approaches for FLW assessments and subsequent minimization.

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