Measuring food and nutritional losses through value stream mapping along the dairy value chain in Uganda

Joshua Wesana[a,b,*], Xavier Gellynck[a] , Manoj K Dora[c], Darian Pearce[a], Hans De Steur[a]

[a] Department of Agricultural Economics, Faculty of Biosciences Engineering, Ghent University, Ghent, Belgium.
[b] School of Agricultural and Environmental Sciences, Mountains of the Moon University, Fort Portal, Uganda.
[c] College of Business, Arts & Social Sciences, Brunel Business School, Brunel University, London, United Kingdom.

* Corresponding author: Department of Agricultural Economics, Ghent University, Coupure Links 653, 9000 Ghent, Belgium. Email: Joshua.Wesana@UGent.be, wesanaj@yahoo.com. Tel: +32 9 264 59 45.

Abstract

The growing burden of food losses has intensified the need for reliable and comparable data. This study extends the application of lean manufacturing practices and uses Value Stream Mapping (VSM) analysis with the Food Loss and Waste (FLW) Accounting and Reporting Standard to identify hotspots and analyze the magnitude of both food and nutritional losses in the food value chain. A case study on the dairy value chain in Uganda is utilized to understand the production configuration (primary production, processing and distribution). Through linking hotspots where food loss in milk production takes place to specific salient reasons, this case provides an estimation of the magnitude of losses occurring in yogurt and UHT milk production lines. Findings reaffirm the processing stage as a principle hotspot for discarding yogurt as well as UHT milk products. Throughout processing, from start to finish, food losses at chain level are estimated to be in the magnitude of up to 14%. This also translates to a substantial nutritional value disappearing from the food system, which compromises the ability of people to meet their nutrient recommendations. The case study represents a pragmatic assessment that combines the mapping advantages of VSM with accounting and reporting guidelines of FLW Accounting and Reporting Standard to contribute to a detailed assessment of food and nutritional losses. Thereby, reinforcing initiation of evidence-based and targeted reduction strategies along food supply chains.

Keywords:
Food loss and waste; Nutritional loss; Value Stream Mapping; FLW Standard; Milk products; Uganda

1.0 Introduction

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). The widely accepted distinction between food loss and food waste, that is based on the point of occurrence along the supply chain, is derived from the Food and Agricultural Organization (Gustavsson et al., 2011). Thereby, food loss involves a decrease in the quantity of edible food observed at production, harvest, processing and distribution while food waste involves the removal of food that is fit for human consumption at the retail and consumer levels of the chain (Parfitt et al., 2010; Richter & Bokelmann, 2016; Willersinn et al., 2015). Nonetheless, both elements point to a certain quantity of food, calories or nutrients that are disappearing from the food supply chain before consumption.

There is an increasing interest in promoting efforts leveraging FLW reduction as a means of assuring adequate and equitable food availability, especially 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, particularly on food prices, thereby increasing economic access to food among people likely to experience hunger (Buzby & Hyman, 2012; Rutten, 2013). 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 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). This target primarily looks at quantifiable losses or wastes, equivalent to a quarter of available calories that are missed and never consumed (Pangaribowo et al., 2013). Such a loss is the equivalent of feeding close to 10% of the current 821 million undernourished people in developing countries (FAO et al., 2018; Munesue et al., 2015). The food insecurity situation is also worsened by considerable loss in nutritional value embedded within lost or wasted food that is never consumed (Sawaya, 2017). Yet the few studies that do link FLW with macro- or micro- nutrients lost from the supply chain are limited to developed countries (Cooper et al., 2018; Love et al., 2015; Spiker et al., 2017). Therefore, strategies to reduce FLW in developing countries are hindered by an absence of reliable data on FLW as well as nutritional losses that occurs within different food value chains (Affognon et al., 2015). This absence could impede 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 exists additional obstructive factors to FLW data acquisition. FLW definitions and measurement methods are inconsistently used, exacerbating identification and quantification problems which ultimately affect mitigation efforts (Chaboud & 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 Food Loss and Waste Accounting and Reporting Standard was developed for consistent and transparent accounting and reporting on the definitions and amount of FLW (Hanson et al., 2016). It facilitates comparison across regions, countries and between other smaller entities like companies and organizations. While the FLW Standard provides a firm set of requirements and common language, users determine what is within the scope of their FLW inventory. For example, a user is required to state and decide whether inedible parts (i.e. the part of a product not intended for human consumption, such as bones or pits) are included or excluded. Similarly, there are 10 possible destinations where food may go when it leaves the human food supply chain. Which destinations are included in an inventory is up to the user of the FLW Standard and its particular goals. If seeking to meet the target of SDG 12.3, the best practices is to reduce by 50% the amount of food and/or associated inedible parts to all destinations except that which goes to the higher value destinations of animal feed and bio-based materials/biochemical processing (e.g. industrial products) (Hanson, 2017). The FLW accounting and reporting standard is based on the idea that what gets measured can also be managed, making quantification crucial to the design and development of appropriate FLW mitigation strategies. Although the standard proposes ten FLW quantification methods, it does not provide guidance on how to identify FLW hotspots. Such complementary identification approaches could form the basis to successfully guide decisions about where and why FLW is being generated and reductions may be most relevant. This could strengthen FLW measurements and improve 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 occur, a Life Cycle Assessment (LCA) further lays the foundation and facilitates holistic analysis of products, processes, or activities (Roy et al., 2009). Approaches that transverse the entire supply chain should also improve stakeholder awareness and establish strategic actor partnerships so as to increase success (Aschemann-Witzel et al., 2017; Muriana, 2017; Parmar et al., 2017; Richter & Bokelmann, 2016).

In a previous study, the potential of Value Stream Mapping (VSM) as a method that can be used to identify and map hotspots of FLW along the agri-food value chains has been established (De Steur et al., 2016). VSM is part of *lean manufacturing*, an operations business strategy 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 agri-food industry (Dora et al., 2014; Panwar et al., 2015; Zokaei & Simons, 2006). The VSM approach involves mapping the production configuration in order to identify lean wastes (i.e. defects, overproduction, inappropriate processing, unnecessary inventory, unnecessary motion, transport and waiting), which De Steur et al. (2016) have linked to the occurrences of food related losses and wastes, in particular discarded food and nutrient losses. As VSM holds the potential to systematically identify FLW and hotspots where they occur, there is need to translate this theoretical understanding into practice, specifically in the context of nutrition sensitive value chains, i.e. by assessing food and nutritional losses along a nutrient-rich food supply chain (Morgan et al., 2018).

Therefore, the aim of this study is to apply VSM analysis at chain level, based on the FLW Accounting and Reporting standard. This is expected to lead to a reliable and systematic mapping of hotspots to facilitate subsequent food and nutritional loss measurement and reporting. As a consequence, mitigation approaches could be initiated along food supply chains. Currently there are few peer-reviewed studies that use the FLW Accounting and Reporting standard (Chaboud, 2017; Tostivint et al., 2017), while none of them has used a systematic mapping approach in an agri-food chain of a nutrient-rich food product.

This study used the dairy value chain in Uganda as a case. The dairy sector was selected mainly because milk is an important source of essential nutrients needed for improved nutrition, hence fits within the concept of nutrition sensitive value chains. In 2011, the per capita consumption of milk was approximated at 35 liters, but it has since increased to 54 liters (Balikowa, 2011; Ekou, 2014). This can be attributed to a number of interventions that have been implemented by government and other organizations to increase milk production in the country. Many farmers have crossbred local breeds with the Holstein Friesian breed to enhance productivity and milk is mainly supplied through informal and formal market channels. While the informal channel is the largest, it is not well organized and unprocessed milk is directly sold to consumers. The formal channel is more structured and is made up of milk processors, wholesalers and retailers (Ekou, 2014). As a consequence, the formal supply chain allows each actor to obtain an economic value that is generally higher than in the informal channel. There are over 40 milk processing plants, producing UHT milk, yogurt, pasteurized milk, powdered milk, cheese, butter, ice cream and ghee. These products are largely consumed locally but a proportion is exported to neighboring countries, even though the local demand for milk is higher than available supply (Kabwanga & Atila, 2015). Although milk production has been increasing over the years, processors still lack enough raw milk to operate at full capacity. The failure to satisfy local demand is further worsened by losses at various stages of the supply chain, that are estimated at around 25% of the total production, translating to an economic loss of 23 million dollars per year (Kabwanga & Atila, 2015; TechnoServe, 2008). This situation therefore necessitates loss reduction measures implemented along the whole chain to complement strategies used to increase production of milk in the country.

2.0 Methodology

Data were collected in August 2017, using a case study approach at a vertically integrated dairy chain *(not named because of confidentiality)*, located in the western region of Uganda. It operates a dairy farm, a processing plant and various distribution channels, and therefore was suitable to apply VSM methodology for a holistic assessment of food and nutritional losses whilst adhering to the FLW standard (Hanson et al., 2016; Womack, 2006). With reference to the guidelines of this standard, the "scope" of this study, in figure 1, included the period of data collection (i.e. one day in August 2017), specified "type of material" targeted (i.e. only edible (milk) products), "destinations" (i.e. landfill, refuse/discard and sewer) 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.

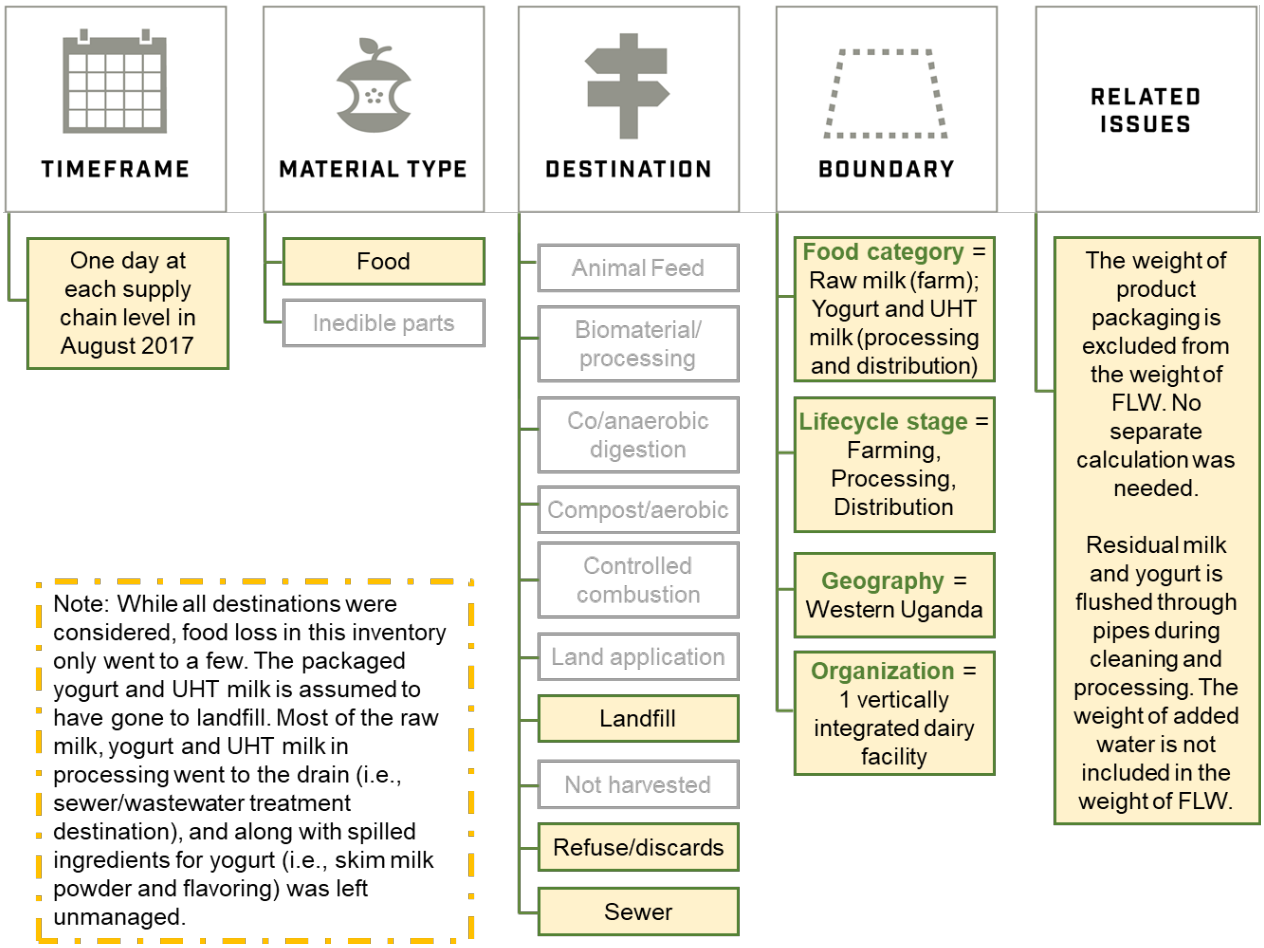


Figure 1: The scope of dairy loss inventory in Uganda, based on the FLW standard

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 semi-structured questionnaire was used to guide data collection. It's development was based on the VSM practice 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, process name and constituent step. The second sought information on cycle time (i.e. time a process takes from start to finish), waiting or non-value adding time and the number of operators managing a process. The third section was used to detail losses and wastes observed along different stages of the supply chain and included types of loss and waste based on the seven lean wastes (i.e. defects, waiting, transport, over processing, motion, over production and unnecessary inventory) (Hines & Rich, 1997; Womack, 2006). This information was used to create 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 cycle time and waiting/non-value adding time observed by following operations along the supply chain.

Furthermore, the magnitude of FLW was calculated following the load tracking method developed by the Food and Agriculture Organization (FAO, 2016). Thereby, the quantity of milk or its products was recorded before and after an activity, from which the difference constituted the magnitude of FLW. Additionally, the nutritional value embedded in FLW was evaluated based on the Tanzania food composition table, which is closer to the diet in Uganda (Lukmanji et al., 2008), for which no tables exist (yet). Macronutrients assessed included; energy (kcal), protein (g), fat (g) and carbohydrate (g). Micronutrients (mg or µg) investigated included; Calcium, Phosphorus, Magnesium, Potassium, Sodium, Iron, Zinc, Vitamin A, Vitamin E, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12 and Vitamin B5. The quantity of each nutrient was determined by multiplying the total observed FLW magnitude, either in grams (g), milligrams (mg) or micrograms (µg) with the amount of that nutrient found in 100g of both UHT milk and yogurt as indicated in the food composition table. Total loss from all products was then summed up and divided with Recommended Daily Allowance (RDA) of adult males and females. The RDA, which represents the daily level of intake that is adequate to meet the nutrient requirements of nearly all healthy people was preferred to other reference values, in line with previous studies (Cooper et al., 2018; Spiker et al., 2017). RDA values were based on the Dietary Reference Intakes guidelines developed by the Food and Nutrition Board and Institute of Medicine (Otten et al., 2006). The outcome of this calculation was the number of people, whose recommended intakes, could be met if FLW observed along the dairy chain did not occur.

In line with the FLW standard, *Box 1* further illustrates how the conducted food and nutritional loss inventory meets the eight reporting and accounting requirements of the FLW standard.

Box 1: FLW STANDARD **REQUIREMENTS – Summary of how the reported food loss inventory meets the eight reporting and accounting requirements of the FLW Standard**
1. **Base FLW accounting and reporting on the principles of relevance, completeness, consistency, transparency, and accuracy** • **Relevance:** Three stages of the dairy value chain were evaluated to conduct a systematic assessment of hotspots where losses in dairy products occur, as a foundation of implementing measures for their reduction • **Completeness:** All possible losses along the three stages were considered. Those that were not accurately measured were estimated based on information that was available. • **Consistency:** The same tool (i.e. semi-structured questionnaire) was used to collect data from all stages. Interviews and observations were also used at all stages. • **Transparency:** The entire inventory is reported and represented in a transperant way aligned to interviews and observations made along the three stages of the value chain. However, the name of the vertically intergrated dairy facility is withheld to adhere to the confidentiality that was required prior to the fieldwork. All observed processes and associated food loss hotspots of the chain are reported in good detail to allow third party assessment of the inventory. Instances when accurate estimates of observed losses were not possible to obtain are reported accordingly. • **Accuracy:** There is a reasonable degree of accuracy of the magnitude food losses assessed objectively especially at the processing stage. At the farm and distribution, the magintude of losses are based on reported and or subjectively observed losses. Therefore, accurency varries at different stages of the dairy chain.
2. **Account for and report the physical amount of FLW expressed as weight** Losses of milk are mainly observed and reported as liters. After processing, yogurt losses are reported in grams. The translation of lost quantities of dairy products into nutrient losses is reported as grams, miligrams and or micrograms.
3. **Define and report on the scope of the FLW inventory** • **Timeframe:** Data is reported for periods in August 2017. Each stage of the chain required one day of data collection • **Material type:** Food including dairy products (i.e. raw milk, UHT milk and yogurt). The inventory does not include inedible parts since dairy products do not have such parts. • **Destination:** While all destinations were considered, food loss in this inventory only went to a few. Packaged yogurt is assumed to have gone to landfill. Most of the raw and UHT milk and spilled ingredients for yogurt (i.e. skim milk powder and flavoring) went to the drain (i.e. sewer/wastewater treatment destination). • **Boundary:** o ***Food category:*** Dairy products - GSFA 01.0 [Fluid milk and milk products – 01.1] o ***Lifecycle stage*****:** Three stages of the food supply chain 1. ISIC 0141—raising of cattle 2. ISIC 1050—manufacture of dairy products 3. ISIC 4923—freight transport by road

- *(continued)*
    - ***Geography*:** Uganda, UN country code 800
    - ***Organization*:** One vertically integrated dairy facility, including a focal farm, a processing plant and distribution channel.
- **Related issues:** The weight of product packaging is excluded from the weight of FLW. No separate calculation was needed. Residual milk and yogurt is flushed through pipes during cleaning and processing. The weight of added water is not included in the weight of FLW.

4. **Describe the quantification method(s) used. If existing studies or data are used, identfy the source and scope**

A survey with interviews and visits was used to gather data on food losses from personnel working at the three stages of the supply chain. In addition, mass balance method was applied by comparing quantities of inputs and outputs in the processing of yougut and UHT milk.

5. **If sampling and scaling of data are undertaken, describe the approach and calculation used, as well as the period of time over which sample data are collected (including starting and ending dates)**

Sampling of the data was not undertaken. One vertically integrated dairy chain was targeted. So all parts of the entity were included in this inventory. Data is taken at one point in time or in one production cycle. Therefore, no consideration was taken for possible differences in losses overtime.

6. **Provide a qualitative description and/or quantitative assessment of the uncertainty around FLW inventory results**

It is possible that the quantification method used might either underestimate or overestimate the quantities of food losses at different processses of milk production. Reports from personnel may be biased since they depended on their ability to recall and or also estimate the loss at a certain point in the production process. This could introduce a systematic error in the data. To reduce this uncertainty, reports were triangulated with observations made by the researcher in the field. Further, food losses were initially measured in liters and then transfromed into kilograms for subsequent analysis of data. This could introduce a certain degree of conversion errors. Data was also collected at one time and so there is no assessment of the temporal variation of observed magnitude of losses in dairy products.

7. **If assurance of the FLW inventory is undertaken (which may include peer review, verification, validation, quality assurance, quality control, and audit), create an assurance statement**

Assurance of the inventory was undertaken by the surpervisor of the researcher that collected the data. This was done at two levels. First, the suitability of tools to be used for data collection was assessed. The second level was after field work whereby data was checked before analysis and there after reported results were validated and considered to be acceptable. This was a first-party assurance.

8. **If tracking the amount of FLW and/or setting an FLW reduction target, select a base year, identify the scope of the target, and recalculate the base year FLW inventory when necessary**

Not conducted because it was out of the scope of the study.

3.0 Results

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

Table 1 provides an overview of the key characteristics of our case, based on observations made along the dairy value chain and interviews conducted with key personnel operating within the chain. Observations made at three levels of the value chain (farm, processor and distribution) indicate specific steps in production, 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 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 employees on short-term contracts (i.e. mainly milk men and other casual laborers). The production of the farm averages 200 liters of milk a day, while the farm also acts as a collection center for farmers in the neighborhood. Therefore, farm records indicated that approximately 1400 liters of milk were normally collected every 3 days for delivery to the processing plant during dry seasons. However, during wet seasons of the year, the quantity of milk collected was reported to be higher. The processor stated to mainly operate based on orders from customers (i.e. wholesalers and retailers), which means that the farm generally applies a pull system to produce milk products.

During fieldwork observations, the processor was supplied with 20000 liters 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 farmers, also other farmers were suppliers, enabling the processor to successfully reach its storage capacity of 50000 liters of milk. As a consequence, it was possible to receive at least 20000 liters of milk whenever there was a need. The processor currently focuses on yogurt and UHT milk production, with wholesale and retail outlets in Kampala and neighboring towns as main distribution channels. Line production is used and there are two separate lines for yogurt and UHT processing. The plant has a maximum capacity to process 3000 liters of pasteurized milk into yogurt while 6000 liters of pasteurized milk can be processed into UHT milk at a time. A batch system is utilized and all pasteurized milk contained in storage tanks is normally processed. As a consequence, the next milk delivery is not mixed up with old stocks of milk that would still remain in the tanks. There is a milk laboratory, stationed between the two production lines, where all quality tests are carried out to ensure recommended standards are met. Moreover, the plant is equipped with two separate types of packaging machinery for yogurt and UHT. The 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, which are both connected to a loading area. There were about 30 employees 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. Before final distribution to wholesalers and retailers, or for sale to end consumers, yogurt and UHT milk are periodically transported to an additional and separate storage facility located elsewhere in Kampala to replenish old stock.

Table 1: 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 & Storage	-Transfer cans to cooling center -Delivery of milk from other farms	2000 liters**	2
	Milk transfer to processor	- Milk quality testing -Transfer milk from cooling tanks to truck -Delivery to the processing plant	1400 liters/3 days	4
Processor	Milk reception	-Milk quality testing -CIP of inlet, pasteurizer & tanks -Milk inlet -Pasteurization -Cooling -CIP of inlet & pasteurizer	50000 liters**	2
	<u>Yogurt</u>			
	Mixing	-CIP of mixture -Milk transfer to mixture -Add milk power & sugar	3000 liters*	3
	Pasteurization + homogenization	-CIP of tube pasteurizer & homogenizer -Pasteurization & homogenization	3000 liters*	3
	Fermentation	-CIP of fermentation tank -Milk inlet -Add culture, flavor & color -Start fermentation -Test pH	3000 liters*	3
	Cooling	-CIP of cooling tank -Milk inlet -Start cooling	3000 liters*	3
	Packaging	-Prepare packaging machine -Prepare packaging material (cups + seals) -Calibrate machine with real product -Channel yogurt to machine -Pack and seal -Print manufacture & expiry dates -Arrange sealed cups in boxes	72 cups/min	15
	Storage	-Place boxes on pellets -Transfer pellets to store	25 boxes/pellet >200 sq. m	3
	<u>UHT milk</u>			
	Homogenization + Sterilization	-CIP of sterilizer -Pasteurization -Transfer to de-aerator -Homogenization -Milk inlet into sterilizer -Sterilization -CIP of sterilizer	6000 liters*	2
	Aseptic tank holding	-CIP of aseptic tank -Milk inlet from sterilizer -CIP of aseptic tank	6000 liters*	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 & expiry dates -Apply top caps -Arrange sealed tetra packs in boxes -CIP of tetra packing machine	6000 liters/h	15
	Storage	-Place boxes on pellets -Transfer pellets to store	15 boxes/pellet >200 sq. m	3
Distributor	Loading & 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

CIP stands for Cleaning In Place
* stands for liters per batch
** stands for maximum holding capacity of cooling tanks

3.2 Current state map for production of yogurt and UHT milk

Figure 2 outlines the production processes for yogurt and UHT milk in the selected dairy chain Below, the findings are described for each stage of the supply chain (farmer, processor, distributor).

3.2.1 Farmer level

Focal farm and partner farms: The process of production starts with milking the cows. At the level of the focal farm, this takes place in a milking parlor that accommodates around 10 cows at a time, while the rest are held in a nearby paddock awaiting their turn. Each cow is restrained before manual milking 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-liter milk can. Repeating this process for each of the 51 cows took approximately 3 hours in total.

Collection center: Following cow milking, the milk 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 2 employees that receive milk from farmers and store it in a 2000-liter tank; this process takes on average 2 hours. The process of transferring milk is manual, by which delivery to the cold storage center is done either with the assistance of a wheel barrow or with a bicycle or motor cycle. At the center, milk is decanted into smaller, 10 liter buckets, by which the 50-liter can be easily lifted and emptied into the storage tank. The cooling center uses a generator as a source of power for cooling, which is switched on once a day and runs for only 30 minutes.

Milk transfer to processor: Every third day, a truck, with a capacity of 10000 liters, collects milk from the cold storage center for delivery to the processing plant. Collectors first need to test milk quality before it can be loaded into the truck. This process of transferring milk into the truck is manually done by 4 persons and normally takes 2 hours to complete. A pipe is connected from the cooling tank to the truck. Milk levels are first measured using a 50-liter can, which is then used to pour the milk into the truck. This process continues until the truck is full or milk in the cooling tank is finished, the former situation occurring more often.

3.2.2. Processor level

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

Milk reception: This is the first activity that takes place at the dairy plant. On the day of delivery, a sample of milk was first tested to determine its quality and assess whether it can be processed into yogurt or UHT milk. Next, Cleaning In Place (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 while at the end, water is used to push pasteurized milk into storage tanks. When all the milk is received and stored, CIP of inlet system and pasteurization tubes follows. The whole process of milk reception was done by 2 personnel and took approximately 2 hours to receive 20000 liters of milk that were delivered by 2 trucks.

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, 2 batches of yogurt were produced (i.e. plain and mango flavored yogurt). Plain yogurt was produced first, with 2800 liters of pasteurized milk being channeled into the mixer from one of the storage tanks. Then 160kg of skimmed milk powder and 128kg of sugar were poured into the mixer. This was performed by 3 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 already reached the next step of processing.

Pasteurization + homogenization: The product from the mixer is pasteurized again before it moves to the next step. The pasteurizer also acts as a temporary storage element, which 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, which would have remained during CIP conducted earlier, into the drainage system. Since this process 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. The opposite occurs at the end when water is used to push out the remaining milk to the drainage system. Both processes are managed by 3 persons and take on average 1 hour. A similar operation was performed for the second batch of mango flavored yogurt.

Fermentation: Once pasteurization and homogenization are complete, milk is sent to the fermentation tank. As there are two tanks, each with a capacity of 3000 liters, the processor could handle two batches almost concurrently. At this step, it was however difficult to determine how much of the product was sent to the tank, though this could be determined at the stage of packaging. It is also at this step that only the culture (thermophilic bacteria) was added in case of plain yogurt. For mango yogurt, also flavor and color were added. Moreover, the fermentation process is facilitated through a heat treatment. Fermentation, handled by two employees, took about 7 hours to complete. 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, according to the employees, the duration may be much longer when the desired acidity is not yet reached.

Cooling: At the end of the fermentation process, yogurt is sent to one of two cooling tanks. After the valve is opened, yogurt instantaneously moves to a cooling tank. The main purpose is to inactivate thermophilic bacteria so that fermentation stops. As mentioned before, the start of this process was delayed by 30 minutes for both batches, until the preceding process had completed. The cooling activities took about 1 hour and is managed by 2 employees. The yellowish-orange change in color of yogurt in the pipes that they observed, was due to the fact that mango flavored batch was later channeled to the other cooling tank.

Packaging: Before this activity commences, the packaging machine has to be prepared with all 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 all finished products in specific boxes, ready for storage. In practice, cooled plain yogurt was channeled directly to the packaging machine and was packed in 450g 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. The duration of this process took 4 hours.

Storage: This is done concurrently with packaging. Boxes, each with 12 cups, are arranged on a pallet followed by plastic wrapping. 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 in order to avoid mixing up old and new stock of dairy products.

UHT milk

Sterilization + homogenization: Before this process, 9900 liters of milk in storage tanks were first re-pasteurized using the pasteurizer of the yogurt line. The double pasteurized milk was then directly sent to the UHT production line, pushing out water into drainage in the process. The temperature of milk was then raised and maintained between 70-75˚C. Next, milk was channeled to the de-aerator, while remaining the same temperature. Before sterilization at 132-140°C, milk was first homogenized in order to break down fats. Milk was held at sterilization temperature for 3-5 seconds. The whole batch of 9900 liters of milk took around 90 minutes to process.

Aseptic tank holding: Prior to sterilization, the aseptic tank was prepared to receive milk in a condition that significantly reduces the risk of microbial growth. Therefore, steam was used at a temperature of 147^{0}C and cooled down using sterile air. Sterilized milk was then sent to the aseptic tank for temporary storage before it moves to packaging. This process lasted for 1 hour.

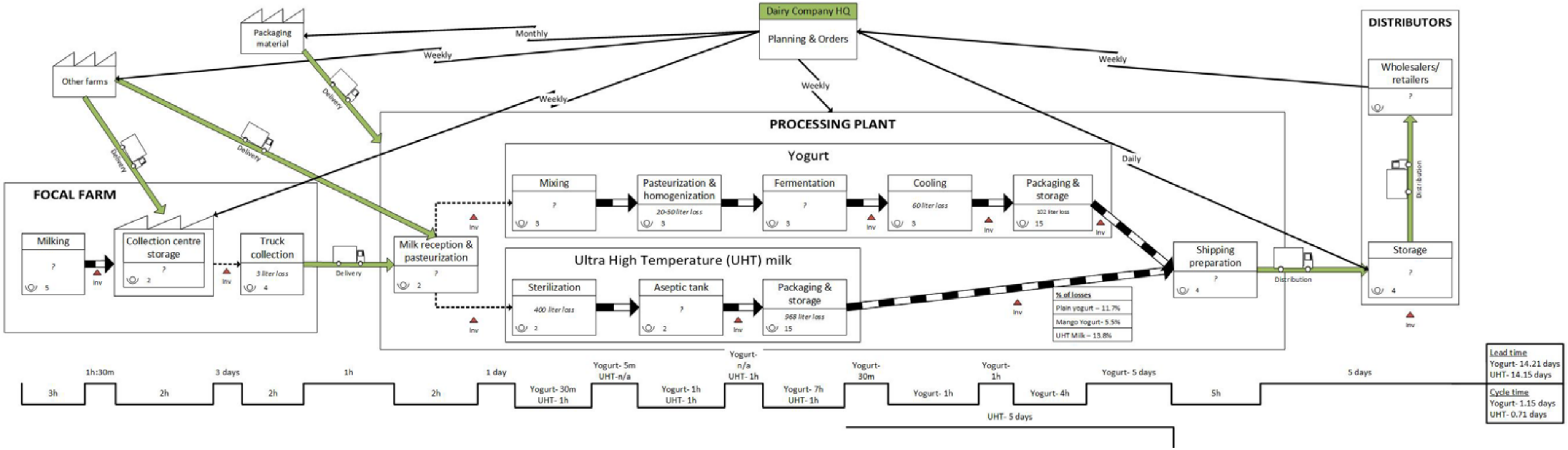
Packaging: Preparation of the tetra brik aseptic packing machine was done at the same time sterilization was initiated. This involved CIP and placing the packing materials into the machine. As already noted, milk in the aseptic tank was not immediately packed because the packing machine was still being prepared, despite the fact that the latter was initiated 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 labelled with dates as they moved on the conveyer belt, and 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, which lasted for about 1 hour.

Storage: UHT milk in one-liter 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. The employees carefully checked whether the newly produced UHT milk was not mixed with old stock. Therefore, pallets were arranged according to the date of production.

3.2.3 Distribution

Finished products (yogurt and UHT milk) are periodically transported to the storage facility in Kampala. Products on pallets are loaded into a truck using a hand pallet jack. The truck travels a distance of 300km 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 offloading is followed when products are distributed to customers.



? Means that losses were observed but it was impossible to obtain estimates

Figure 2: Current state map of the Dairy supply chain of yogurt and UHT milk

3.3 Identification of food and nutritional losses and their destinations along the dairy value chain, with a link to lean manufacturing

Findings in table 2 illustrate losses and wastes identified and are also described below for each subsequent stage of the supply chain.

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 occurs during hand milking and when milk is poured from a bucket into cans. The main causes of spillages relate to the inattentiveness of milk men when performing a task as well as 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 which 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. As flies were observed hovering over the cans and coming into contact with the milk, milk was exposed to microbial contamination which 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 which additionally results in an accumulation of inventory, hampering the start of the next activity in the production system.

Collection center: The system of transportation exposes milk to spillages if cans are not properly covered and its occurrence is exacerbated by bumpy roads on 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 as it cannot be used for consumption. 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 observed on the tank to monitor changes in temperature. Hence, there is also a high risk of milk deterioration due to microbial growth. This is especially the case when there was some form of microbial contamination beyond what is naturally expected at an earlier stage. Moreover, milk that is stored in the cooling tank for days without being distributed results in an accumulation of inventory.

Milk transfer to processor: 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 where less emphasis is put on milk quality. An example that was reported was 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. While milk is loaded into the truck using 50-liter cans, a lot of spillages normally occur. This led to a considerable loss of product e.g. on the day 1400 liters of milk were collected, it was observed that 28 cans were loaded into the truck. Each can spilled around 100ml of milk. In total, approximately 3 liters of milk was lost at that stage. Further, the truck was unable to load all of the milk contained in the cooling tank 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 liters of milk remained in the tank, and this balance can be considered an overproduction waste as well as inventory. This also results in a situation where the remaining milk is easily mixed with fresh milk that is received from farmers on subsequent days. This increases the risk of cross-contamination and, hence, possible rejection of milk during the next truck pick-up.

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 production of ghee and milk powder. A proportion of unpasteurized milk remained in the 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. But there was also milk that remained in the trucks as it could not be pumped into the processing plant. This type of milk is disposed-off while trucks are cleaned for the next delivery.

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 working surfaces and floor. Spilled ingredients could not be reused and were discarded into drainage.

Pasteurization + homogenization: During pasteurization and homogenization, milk is lost twice into drainage. The first time is when incoming milk is used to push out water from the system. The outlet valve is only closed once the personnel presume only milk is still in the system. This is done manually and, as it is very hard to tell, 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 20-50 liters of milk are lost at this step. Losses at this level continue to occur in the next batch, as 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 which is irreversible, and the product has to be discarded, which means the whole batch is lost. Another potential loss was with the ingredients added which 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. In this case, the product became inventory. Moreover, this also offers thermophilic bacteria the opportunity 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 which remained in the pipes was pushed out into drainage by incoming mango flavored yogurt. The operator reported that each minute, approximately 12 liters of yogurt are drained out of the system. Altogether, it took around 5 minutes for almost 60 liters of plain yogurt to drain out of the system. As mentioned before, a yellowish-orange color change in the pipes was used as a signal by operators to initiate closure of the drainage valve. Thereby, 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 printed dates and unclear dates. Many of the defects occurred at the very start of packing, i.e. 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 up with plain yogurt. The operator in charge also highlighted that it is even worse if another flavor such as pineapple is produced. Therefore, cups derived from 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 3 sealed cups were knocked over by workers who were arranging them in boxes. Most products damaged during packing were thrown away while a few were given to employees. When the number of cups packed are converted into liters, 2472.4 and 2645.4 liters of plain and mango flavored yogurt, respectively, were eventually packed and suitable for distribution to customers. When compared with 2800 liters of pasteurized milk that were used as raw material for each batch, overall, there was a 327.8 (11.7%) and 154.6 (5.5%) liter loss of marketable milk product from mixing to packaging stage for plain and mango flavored yogurt, respectively.

Storage: There were no indications of packed yogurt loss during storage. However, old stock was observed in storage in order to provide a buffer whenever an urgent, unplanned order was made. This constitutes both accumulating inventory and over production and issues may arise if the old stock is not distributed in good time before specified expiry dates.

UHT milk

Sterilization + homogenization: At this step, the process of pushing out water from the system using incoming milk was the key 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 liters 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: Observations did not reveal any physical product loss 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 during calibration of the tetra brik machine. 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. Halfway through packing, the same errors occurred leading to more milk being discarded. There were 8532 tetra packs that were appropriately packed. This was equivalent to 8532 liters of milk since each pack contained 1 liter. When compared to 9900 liters channeled from the storage tanks, a loss of 1368 liters of milk or 13.8% was identified.

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

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 provides an indication of additional hotspots where losses, in terms of physical damage to packages, could occur if not enough care is taken. There is also accumulation of inventory at the second storage facility since distribution to customers is normally not done immediately.

Table 2: 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[K]
		Milk kept in open cans for long periods	Inventory Defect	Discard[K]
	Collection & Storage	Spillage of milk	Defect	Discard[K]
		Milk in cooling tank before distribution	Inventory	
	Milk transfer to processor *(3 liters lost)**	Spillage of milk Poor quality milk rejected	Defect	Discard, Given to employees, Ghee & milk powder production[K]
		Uncollected milk in tank	Over production Inventory	
Processor	Milk reception	Spillages of milk Unpasteurized milk sent to the drain Milk in trucks not pumped Poor quality milk rejected	Defect	Discard, Ghee & milk powder production[K&UK]
	Yogurt			
	Mixing *(2X 2800 liters)*	Spillage of milk powder and sugar	Defect	Discard[K]
	Pasteurization + homogenization *(20-50 liters lost)**	Milk mixed with water	Defect	Discard[K]
		Heat labile micronutrient degradation	Over processing	Packaged[K]
	Fermentation (Plain & Mango)	Yogurt with very low pH (sour taste) rejected	Defect Over processing	Discard[K]
		Yogurt unnecessarily kept longer in tank	Inventory	
	Cooling -Plain & Mango *(60 liters lost)**	Yogurt drained out during batch change-over	Defect	Discard[K]
		Yogurt kept unnecessarily longer in tank	Inventory	Packaged[K]
	Packaging Plain-*5659* cups = *2472.4 liters (327.8 liters lost)** Mango-*6055 cups = 2645.4 liters (154.6 liters lost)**	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 [K&UK]
	Storage	Old stock used as buffer	Inventory Over production	Distributed, Discard[K&UK]
	UHT			
	Sterilization (*9900 liters)* (with pasteurization + homogenization) *(400 liters lost)*	Milk drained out during removal of water	Defect	Discard[K]
		Heat labile micronutrient degradation	Over processing	Packaged[K]
	Aseptic tank holding	Sterilized milk awaiting packaging	Inventory	Packaged[K]
	Packaging 8532 tetra packs = *8532 liters (1368 liters lost)**	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[K]
	Storage	Old stock used as buffer	Inventory Over production	Distributed, Discard[K&UK]
Distributor	Loading, transportation, unloading & storage	Damage on packaging	Defect	Discard[UK]
		Delivered products not distributed immediately	Inventory	Distributed[UK]

* Estimated loss along steps of the supply chain
[K] Known destination
[UK] Unknown destination

3.4 Nutritional losses embedded in FLW along the dairy value chain

An evaluation of nutrients lost together with FLW is shown in table 3. Finding indicate 17 nutrients, together with energy, were lost with discarded milk products. UHT milk had the highest quantities of lost nutrients compared to plain and mango yogurt. The magnitude of loss depended on the quantity of product lost as well as the nutrient content per 100g of milk product. So, high values for micronutrients do not necessarily mean that their loss is higher than macronutrients. The difference is due to the units used while computing nutrient values from food composition tables (i.e. g, mg and μg). Furthermore, it can be observed that losses in macronutrients (i.e. protein, carbohydrate and fat) were relatively similar. Conversely, there were wide variations among micronutrients, with calcium, phosphorus, potassium, vitamin A, folate and vitamin B12 having high losses. Based on gender disaggregated RDAs, results show high number of people, whose recommended intakes could have been met by lost nutrients. There are similarities between the two gender groups whenever RDAs were equivalent. The lowest number of people whose energy intakes could be met if dairy products were not discarded is 574 for energy. The numbers for macronutrients are higher, with lost protein equated to 1116 male and 1358 female adults. The potential for micronutrients is even greater, showing possible coverage in tens of thousands, millions and billions of people.

Table 3: Physical and Nutritional losses embedded in discarded UHT milk and yogurt

	Nutrient	UHT milk	Plain yogurt	Mango Yogurt	Total	RDA		Missed potential *(Total/RDA)*	
						Male	Female	#Male	#Female
Quantity of product	At the start *(liters)*	9 900	2 800	2800					
	At the end *(liters)*	8 532	2 472.4	2 645.4					
	FLW *(liters)*	1 368	327.6	154.6					
	FLW (%)	13.8	11.7	5.5					
	FLW *(kg)*	1 409	337.4	159.2	1 905.6				
Nutrients in FLW	Energy *(Kcal)*	845 400	205 814	9 7112	1 148 326	2 000	2 000	574	574
	Protein *(g)*	45 088	11 809	5 572	62 469	56	46	1 116	1 358
	Carbohydrate *(g)*	63 405	15 857.8	7 482.4	86 745.2	130	130	667	667
	Fat *(g)*	46 497	11 134.2	5 253.6	62 884.8	/	/	/	/
	Calcium *(mg)*	1 620 350 000	408 254 000	192 632 000	2 221 236 000	1 000	1 000	2 221 236	2 221 236
	Magnesium *(mg)*	154 990 000	40 488 000	19 104 000	214 582 000	400	310	536 455	692 200
	Phosphorus *(mg)*	1 296 280 000	320 530 000	151 240 000	1 768 050 000	700	700	2 525 786	2 525 786
	Potassium *(mg)*	1 972 600 000	522 970 000	246 760 000	2 742 330 000	4 700	4 700	583 474	583 474
	Sodium *(mg)*	774 950 000	0	0	774 950 000	1.5	1.5	516 633 333	516 633 333
	Iron *(mg)*	1 409 000	0	0	1 409 000	8	18	176 125	78 278
	Zinc *(mg)*	5 636 000	0	0	5 636 000	11	8	512 364	704 500
	Vitamin A *(µg)*	3.9452E +11	91 098 000 000	42 984 000 000	5.28602E +11	900	700	587 335 556	755 145 714
	Vitamin E *(µg)*	1 409 000 000	337 400 000	159 200 000	1 905 600 000	15	15	127 040 000	127 040 000
	Riboflavin *(mg)*	2 818 000	337 400	159 200	3 314 600	1.3	1.1	2 549 692	3 013 273
	Niacin *(mg)*	1 409 000	337 400	159 200	1 905 600	16	14	119 100	136 114
	Folate *(µg)*	70 450 000 000	23618 000 000	11 144 000 000	1.05212E+11	400	400	263 030 000	263 030 000
	Vitamin B12 *(µg)*	5 636 000 000	1349 600 000	636 800 000	7 622 400 000	2.4	2.4	3 176 000 000	3 176 000 000
	Vitamin B5 *(mg)*	5 636 000	1349 600	636 800	7 622 400	5	5	1 524 480	1 524 480

RDA- Recommended Dietary Allowance
Missed potential- The number of people whose RDA can be meet if a specific nutrient was not lost

4.0 Discussion

This case study applied VSM, following guidelines of the FLW accounting and reporting standard to map hotspots for food related losses along three stages of a dairy value chain in Uganda. Thereby, it follows specific lean manufacturing practices adapted to the dairy sector (Malmbrandt & Åhlström, 2013). As a foundation for value chain analysis, the current state map of the dairy value chain indicates that production of milk products constitutes a series of dependent steps and operations which are potential hotspots for losses. Although the majority of FLW 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 FLW instigated at earlier stages of the chain has also been reported in a study on food loss reduction strategies in Switzerland (Beretta et al., 2013). Unfortunately, awareness among actors of what happens down or upstream is limited and is hardly observed due to barriers that hinder integration along the supply chain (Taylor & Fearne, 2009). Thereby, reinforcing the need for targeted awareness creation to promote the 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 types, results indicated that milk products were often times 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 over production 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 which result into either accumulation of inventory or stock (Buzby & Hyman, 2012; Silvennoinen et al., 2015). Thereby, perishability of dairy products such as UHT milk and yogurt underlines the need to adopt lean production based pull strategies such as Just-In-Time production (Lyonnet & Toscano, 2014; Mackelprang & Nair, 2010). This has the potential to reduce losses due to unnecessary inventory and overproduction. Over processing 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 is also true for other non-heat operations in other food groups such as washing and physical treatments, with vitamins being most susceptible (Atungulu & Pan, 2014; Francis et al., 2012). Thereby, our study demonstrates that the processing stage is also an important hotspot 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 losses observed along the UHT and yogurt production lines, respectively. The nutritional value loss attributed to this was also significant, with both marco- and micro- nutrients disappearing from the food system, in line with previous studies (Cooper et al., 2018; Spiker et al., 2017). As a consequence, the amount of essential nutrients needed for people to meet their Recommended Daily Allowances is lowered, which potentially increases undernutrition. Nonetheless, it remains important to establish and continuously improve controls, traversing the entire value chain, as a way of promoting collaborative efforts against these losses (Mena et al., 2014). This practice could facilitate continuous improvement, a principle in lean manufacturing that promotes efficiency and lowers production costs (Rivera & 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 product takes approximately 14 days from the farmer level to the point of distribution. Given the perishability of most milk products (Kaipia et al., 2013), improvement in production efficiency is 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. This results from the optimal use of resources coupled with minimal wasteful processes and is also linked to better in-line flow and product value for the customer (Engelund et al., 2009; Simons & Zokaei, 2005).

Although discarding of unmarketable milk products to the drain and land fill were popular destinations, there are times when such products were given to employees. This supports previous findings 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 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 & 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 have been discarded from the supply chain.

Even though identification of FLW hotspots along the three supply chain levels was possible while following the principles of VSM and the FLW standard, quantifying the magnitude was not straightforward, as also reported in previous studies (Affognon et al., 2015; Chaboud & 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 processing 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 & Cai, 2016). In addition, the enclosed system of production used by the processor limits the possibility of taking product samples for nutrient analysis to assess changes along different production steps. This made direct nutrient analysis impractical and was further hindered by limited time and data collection resources. To tackle this limitation, the assessment of the nutritional value lost as a result of milk loss was performed using food composition tables. Nonetheless, nutrient values from food composition should be viewed as an approximation of the actual nutrient content of assessed food products. In addition, the nutrient evaluation in this study is based on the Tanzania food composition table to represent the food context of Uganda. Although foods in both countries can be equated based on proximity, there might be noticeable differences. The table used is also limited with regards to milk products produced by different processing technologies (i.e. UHT vs pasteurized milk). Hence, food composition tables need to be revised to cater for various forms of food products including the methods used during processing and preparation.

Although this case study was limited to the current state map, there are important Kaizen aspects that could be taken into consideration while improving the production configuration and flow of products through the stages of the dairy value chain (i.e. future state map). This will most likely reduce the lead time for producing and supplying yogurt and UHT milk that is illustrated in the current state map. At the farm level, milking time and observed losses due to milk spillage could be reduced by using milking machines which are more efficient (Castro et al., 2012; Rodenburg, 2017). If this is implemented with a direct link to cooling tanks at the collection center, losses due to poor handling practices and microbial contamination could also be minimized (Boor et al., 2017). During collection of milk, it is recommended that milk is pumped into trucks instead of using handheld buckets to minimize additional spillage losses that were observed. This subsequently could reduce the time it takes for milk to be loaded into collection trucks. The capacity or number of collection trucks should also be increased to ensure that all stored milk is loaded and no balance is left due to inadequate truck capacity (Paredes-Belmar et al., 2017). This could help reduce milk inventory from accumulating at farm level. At the processing plant, although production based on orders was reported, observations indicated situations of over production of yogurt and UHT milk to act as buffer stock. Given that these products are perishable and could easily spoil, it is recommended that the processor considers adopting the pull strategy of production fully as way of minimizing both inventory and over production wastes (Lyonnet & Toscano, 2014; Mackelprang & Nair, 2010). Raw milk received at the plant should be pasteurized once and this means that further processing into yogurt and UHT milk should be done immediately to limit the need of the second pasteurization process as currently done. This would reduce thermal sensitive nutrient loss as well as accumulation of milk in tanks as inventory (Bogahawaththa et al., 2018; Qi et al., 2015; Shewfelt, 2017). The processor should also consider installing detection and quantification systems at drainage points along production lines so that the product that is discarded can be accurately assessed (Bibi et al., 2017). Automatic detection capabilities would additionally prevent avoidable milk losses especially at times when a subjective decision is made to determine whether the product being drained out is a mixture of milk and water or only milk. During yogurt processing, efforts should be made to ensure that recommended fermentation time is not exceeded to prevent loss of an entire batch due to high acidity (De Brabandere & De Baerdemaeker, 1999; Soukoulis et al., 2007). To further reduce lead time, cooling should be initiated immediately after the specified 7 hours of fermentation and thereafter packaging should commence without delays as observed in the current state of production. UHT milk production line has similar idle time before packaging and this non-value adding wait should be reconsidered by the processor. After packaging, the current state map indicates a delay of 5 days before shipping takes place. Although products are kept in ideal storage facilities, it might add value to reduce this wasted time and avoid accumulation of stock in storage before delivery to the customer. Thereby, the time it takes to deliver of products should be shortened during the distribution stage (Chen et al., 2013; Manzini & Accorsi, 2013). One option could be to invest in additional trucks or to have customers collect products from the storage facility. As a whole, these improvement measures are likely to reduce identified milk losses as well as the lead time observed from the current state of yogurt and UHT milk production. Hence could increase customer satisfaction and in the nutrition sensitive value chain perspective, increase availability and access to nutrient-rich milk products to positively influence food and nutrition security.

5.0 Conclusion

This case study has implications for the agri-food industry with regard to the systematic identification of hotspots of food and nutritional losses along the value chain. 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, while also estimating embedded nutritional losses. Wherever possible, this should be done for every operation along the value chain. Efforts to minimize food and nutritional losses 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 adoption of lean waste reduction strategies along supply chains. As a consequence, 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 agri-food value chains and further justify the potential of lean manufacturing strategies, integrated with established accounting and reporting guidelines or approaches for food and nutritional loss assessments and subsequent minimization.

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