Low cost innovations and technologies for controlling milk loss

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Introduction

The concern for achieving global food security has increased attention on food waste and losses by policy makers (at global and national levels), the private sector and civil society. In 2015 the UN published 17 new global goals for sustainable development, one of which specifically targets the issue of food waste and losses.[1] Every year, 1.3 billion tonnes of food, about a third of all that is produced worldwide, is wasted (Gustavsson et al. 2011). If global food waste and losses were reduced by just 25%, there would be enough food to feed the more than 800 million people who currently suffer from hunger and malnutrition.[2] Furthermore, wasted food is also associated with an array of negative environmental impacts, including unnecessary greenhouse gas emissions and inefficient use of water and land. If food waste was a country, it would rank as the third highest national emitter of greenhouse gasses after USA and China.[3] In response, in recent years there has been a growing amount of literature which documents the significant economic, social and environmental costs of global food waste and losses. These studies provide details on the cost of food waste and loss to various stakeholders in the food supply chain, including individual households, retailers, food manufacturers and agricultural producers (see, for example, Buzby et al. 2014; Chapagain & James, 2011; Foster et al., 2006; Gustavsson et al., 2011; Lee et al., 2015; Monier et al., 2010; Okawa, 2015; Quested et al., 2013; Rutten, 2013; Rutten & Verma, 2015; Vanham et al. 2015).

In one of the major attempts to quantify the size and causes of food waste and losses, FAO (2014) conducted a study in Kenya: "Food Loss Assessments: Causes and Solutions: Case Studies in Small-scale Agriculture and Fisheries Subsectors". The study pointed to four sector-specific commodities which account for the largest share of food waste in the country. The commodities were banana, maize, milk and fish (Global Initiative on Food Loss and Waste Reduction, 2014).

The annual milk production in Kenya is approximately 4.9 million tonnes per year, of which about 360 thousand tonnes of milk products go to waste (Global Initiative on Food Loss and Waste Reduction, 2014). Most of the milk is wasted through spillage and spoilage occasioned by poor access to markets, rejection at markets, poor milk handling practices and irregular power supply in milk processing plants. Not only does this cause a significant loss from an economic and nutritional perspective, it is also an environmental loss (Clune, Crossin, & Verghese, 2016).

[1] UN Sustainable Development Goal #12 "Halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses"
[2] Global Food Waste: The Numbers Behind the Problem. http://insinkerator.co.uk/uk/page/global-food-waste-stats

The leading causes of milk loss have been identified as:

- Poor marketing infrastructure, for example, roads
- Inadequate/unhygienic handling equipment
- Poor product quality due to lack of technical know-how, and lack of price incentives for efforts to improve quality
- Lack of appropriately trained personnel along the milk value chain
- Inappropriate transport equipment and poor handling practices
- Pest and diseases, especially mastitis
- Long distance from the farm to market
- Inadequate/ineffective milk cooling facilities along the milk value chain

The knowledge of existing innovations and technologies of reducing the causes of milk losses is limited among the value chain actors. Against this backdrop, this brief explores existing low-cost innovations and techniques of reducing milk losses to better understand the breadth of solutions available and identify potential opportunities for scaling those solutions, especially for smallholder farmers.

Low cost innovations and technologies to reduce milk loss

1. Milk preservation innovations and technologies

Milk contains a combination of water, sugars, protein and minerals. These contents provide an ideal medium for bacterial growth at ambient temperature. Although some bacteria are harmless, raw milk can be a vector for infectious diseases, and studies have shown that it often contains pathogens such as Brucellosis and Escherichia coli (Swai & Schoonman, 2011). Cooling milk slows down bacterial growth, reducing spoilage, and ensuring the milk is safe for consumers. In Kenya, the poor cold chain is a recognized problem for the dairy sector. The next section highlights some of the low-cost innovations for preserving milk.

a. Cold water bath

Because milk spoils easily if it is left at high temperatures for long periods, it must be stored in a cool place soon after milking. For farmers without refrigerators or coolers, the milk can be wrapped in a wet sack or blanket (Figure 1) or stored in a cold-water bath or in a hole in the shade (Figure 2). This can preserve the milk, especially if the milk container is well covered to prevent dirt from entering the milk (Lore, Kurwijila, & Omore, 2006).

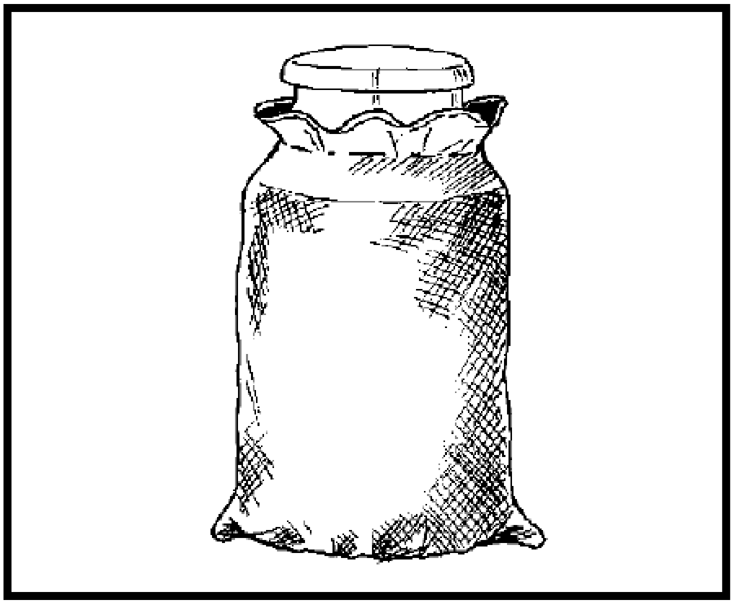


Figure 1: *Milk wrapped in wet sack*

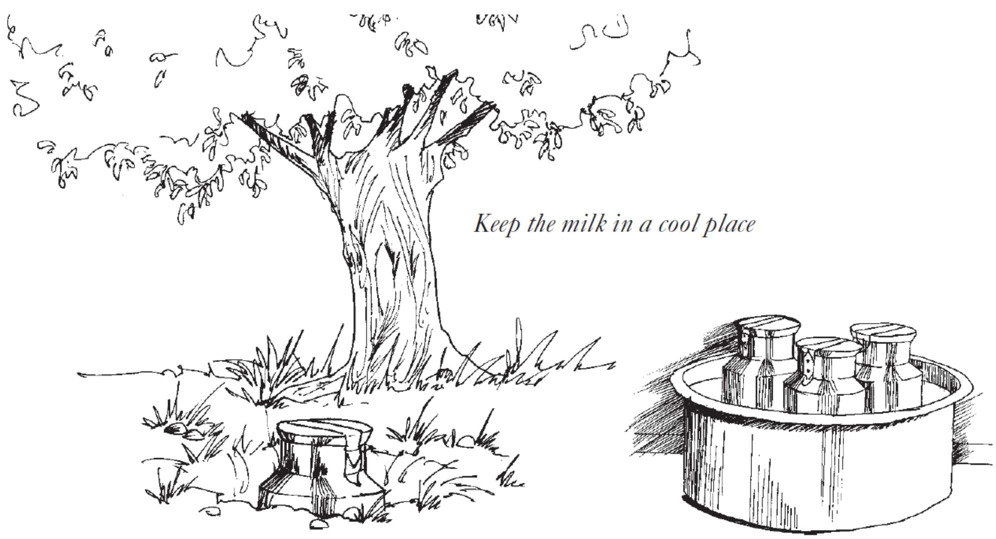


Figure 2: *Milk stored in a hole under shade or in cold water*

These technologies are relatively cheap and accessible to most smallholder dairy farmers but can only preserve the milk for a relatively short period (a maximum of one day). Therefore, they are appropriate for storing milk for short periods before it is delivered for further processing such as pasteurization or boiling.

b. Solar powered milk coolers

The solar powered milk cooler targets small-scale dairy farmers who produce
between 5 and 30 litres a day. The innovation was borne out of the need to reduce losses incurred by small-scale dairy farmers due to poor storage. It is an assembly of a refrigerator equipped with an adaptive controller that converts it into a smart ice-maker when powered on solar energy. The smart ice-maker has a capacity of 160 litres and can produce up to 13 kg of ice a day. The systems are supplied with 25 reusable plastic containers (2 kg capacity) and two, 30 litre insulated milk cans with removable ice compartments. The system is powered by 600 watt peak (Wp) solar PV modules and 2 batteries with a total capacity of around 1.5k Wh (Figure 3). With the solar powered milk cooling system, the collector can collect the evening milk with the next day's morning milk and be assured that the milk will be acceptable.

Figure 3: Solar powered milk cooler

Photo courtesy of *Standard* Newspaper, 26 May 2018

Source: https://www.standardmedia.co.ke/business/article/2001281737/milk-coolers-to-cut-post-harvest-losses.

The United Nations Agency for International Development (USAID) started piloting this innovation in 2015 in Baringo and Nyandarua counties, and at Egerton University. The innovation is currently being tested at Sam Malanga Co-operative Society in Siaya County in western Kenya and the Sidi Bouzid region in central Tunisia. Initial results from USAID indicate improved milk quantity and incremental gross earnings gain at current milk prices. The initial surveys show that users sell between 2 and 45 litres of extra evening milk each day, indicating gross incremental income gains ranging from US$23 to 650 per month. The innovation can be scaled by investment groups who can purchase the system and develop a business model where they offer small-scale farmers the milk cooling service or sell ice. This will create revenue streams for the investors, employment to the masses and increased milk production hence higher household income.

c. Use of ice to cool milk

If small amounts of milk must be collected and transported over long distances, and it is not technically or economically feasible to cool the milk in advance, ice may be used (Figure 4).

Figure 4: Using ice to cool milk

Source: *https://www.fao.org/AG/againfo/temes/documents/dairyman/DAIRYPIC/PG.*

d. Cooling with natural water systems—mains, wells or ground water

Immersion cooling methods: Immersion cooling involves placing the milk cans in a stream, river, lake or tank (Figure 5). This method is most effective when the water temperature is 10°C or below. Cooling milk to below 10°C slows bacterial growth. Diverting the water source to a cooling tank in which milk cans are placed is another common method. When available, ice can be added to the water tank to

facilitate the cooling, but ice should never be added directly to warm fresh milk
for cooling. To avoid any heating effect from the surrounding air, cooling tanks should be insulated. (Moffat *et al.,* 2016).

Figure 5: Cooling using natural water systems

Source: Moffat *et al.,* 2016

Surface milk coolers (open cooling systems): An open cooling system is based on surface coolers that use pressurized water from the mains or pumped from a natural source. Surface coolers can be constructed from horizontal stainless-steel pipes attached to a vertical metal plate; the cooling water is passed through the pipes. Warm milk is fed on to the vertical plate from a small tank mounted at the top of the unit. The milk cools as it passes over the plate and is collected in milk cans (Figure 6). As they are open to the air, surface coolers are subject to contamination from dust and insects, and considerable care must be exercised to ensure correct cleaning and sanitation (Lore, Kurwijila, & Omore, 2006).

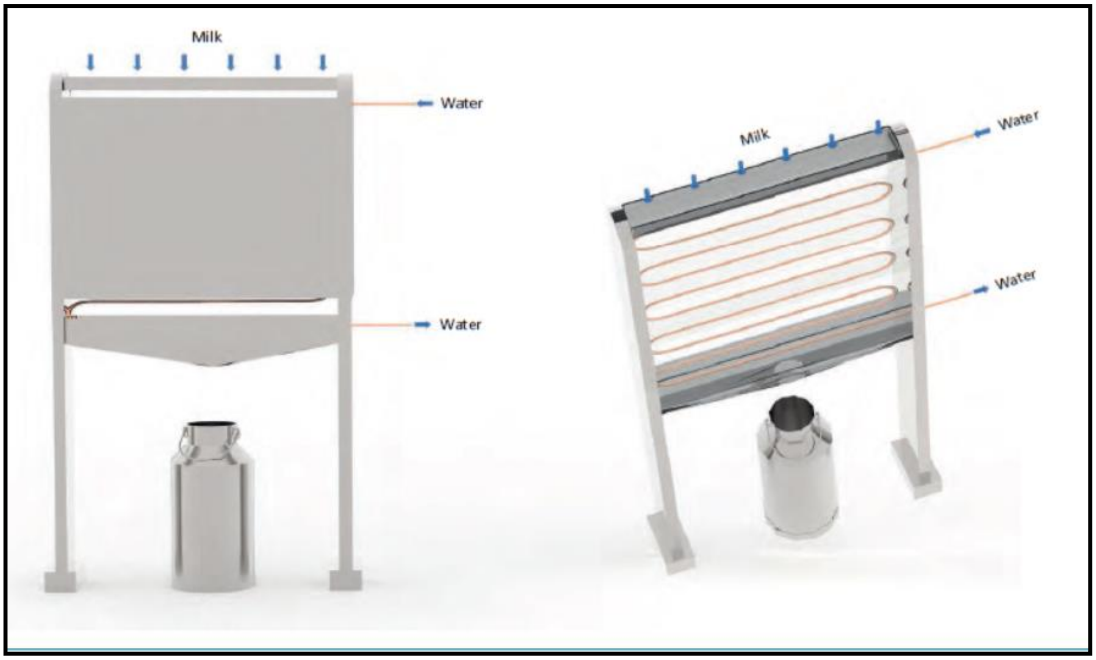


Figure 6: Surface milk cooler

Source: Moffat *et al.,* 2016

e. *Refrigerated immersion cooler or cooling rings*

Immersion cooling rings (Figure 7) also use pressurized water from the mains or pumped from a natural source and can be used to cool milk in cans. In this system, a perforated tubular ring is placed over the neck of the milk can and cold (or iced) water is passed through the ring to run down the outside of the can and cool its contents. A small-scale refrigeration system can be used for immersion cooling where a single-phase power supply is available. The refrigeration system is attached to a cooling head, which is inserted into a can of warm milk or a specially designed insulated stainless-steel container with capacity of 25–125 litres (Figure 8). A refrigerant is passed through the immersion coil to reduce the milk temperature. The system often includes a trolley to allow easy transportation of the milk tank. Such systems may be of use in very small milk collection centres or privately-owned milk cooling stations or milk shops (Lore, Kurwijila, & Omore, 2006).

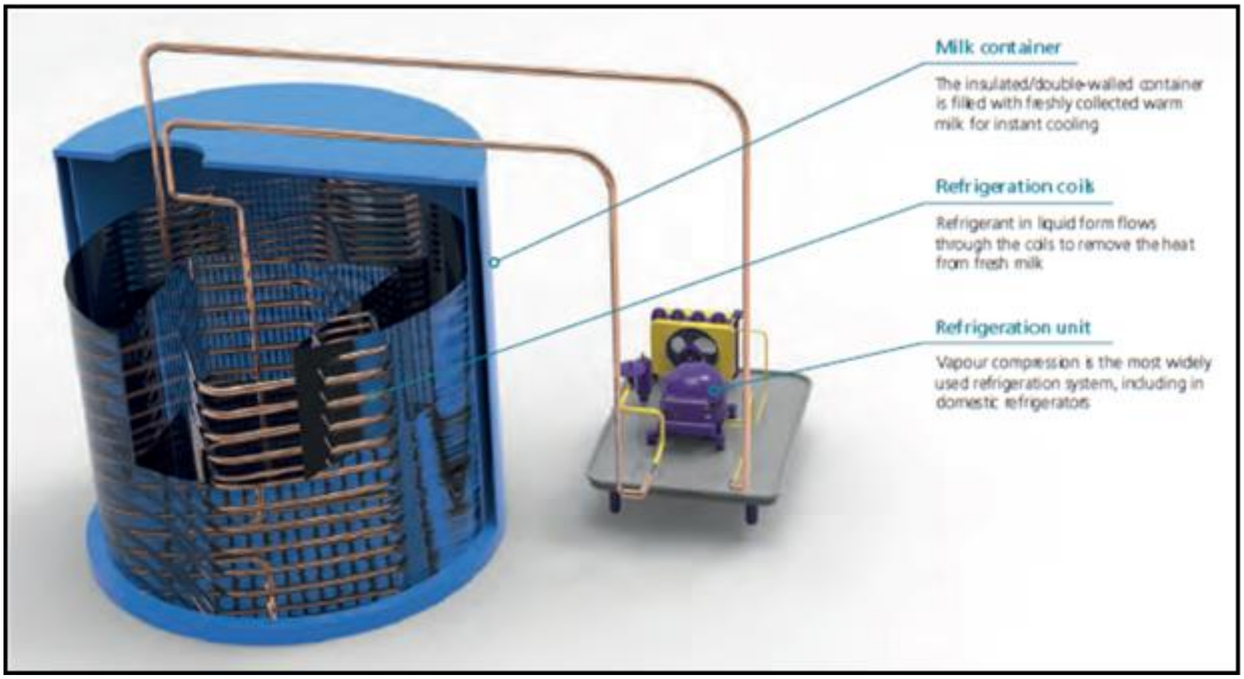


Figure 7: Immersion cooler with refrigeration unit and insulated cooling and storage container

Source: Moffat *et al.,* 2016

Hygienic milk handling technologies and innovations

A major cause of milk loss is use of unhygienic containers to store and transport the milk. The number of spoilage bacteria in raw milk depends on the level of hygiene during milking and the cleanliness of the vessels used to store and transport the milk. Raw milk is also associated with pathogenic bacteria which cause milk-borne diseases, such as tuberculosis, brucellosis or typhoid fever. Hygienic milk production, proper handling and storage of milk, and appropriate heat treatment can reduce or eliminate pathogens in milk (Kurwijila, 2006). A Food and Agriculture Organization of the United Nations (FAO) study on post-harvest milk losses (food losses) in Kenya noted that they are highest at the farm level (Muriuki, 2003). Losses at farm level result from spillage, lack of market and rejection at market. Rejection at market is a result of poor hygienic conditions and the time taken to reach markets (long distances and bad roads). The study estimated the total quantitative losses in the dairy cattle milk supply chain at 7.3%. Good hygiene practices at all stages of milk collection are important in reducing milk losses and improving the quality and shelf life of dairy products. In the next section, some of the innovations for handling milk hygienically are highlighted.

a. Mazzi Container

This is a durable 10-litre container which was invented specifically to streamline the collection, storage and transport of milk in developing countries (Figure 8). The unique design helps smallholder farmers and other low-income stakeholders in the dairy value chain maximize their yield and reduce costly spillage and spoilage. The Mazzi container is made of durable, food-grade plastic that can be dropped or kicked without breaking. It can be easily cleaned by hand because of a large opening and a unique design that leaves no inaccessible areas where micro-organisms can hide. The can's black funnel secures to the top of the container to help farmers capture milk, sieves physical contaminants, and clearly shows symptoms of clinical mastitis during milking. The sieve-like opening on the funnel also limits spills if the container is kicked over or dropped.[4] Mazzi containers are being used in Kenya, Tanzania, Uganda, Rwanda, Ethiopia, Sudan, South Sudan and Somalia, however, expansion into India, Peru, Morocco, Pakistan and Sri Lanka is also expected.

Figure 8: Mazzi can container

2. Milk quality testing innovations and technologies

Farmers and operators of milk collection points and centres need systems of quality control for the milk they receive from individual farmers. This enables segregation of poor quality milk at collection centres, avoiding avoid milk losses. Several simple tests, if carried out judiciously and consistently, will enable farmers and milk collection centres avoid milk losses resulting from mixing poor and good quality milk. The tests outlined in the following sections can be carried out at the farm or collection centres or in a dairy processing factory.

[4] http://www.mazzican.com/

a. *Sight-and-smell (organoleptic) tests*

These involve the preliminary quality tests conducted at farm level, at the processing plant's reception platform or at the collection centre. The sight-and-smell test is performed by assessing the milk with regard to its smell, appearance and colour. This test is quick and cheap to carry out, allowing for segregation of poor quality milk. No equipment is required, but the tester should have a good sense of sight and smell. Milk that cannot be adequately judged in this way is subjected to tests that are more objective (Lore, Kurwijila, & Omore, 2006). The procedure for testing involves shaking the can a little then opening the lid and immediately smelling the milk. You then examine the milk for factors such as colour and any other foreign objects on the surface of the milk, and the sanitary condition of the milk can. The condition of the can indicates whether the milk can has been cleaned and how milk has been handled. The tester feels the milk can with an open palm/hand to determine the temperature. This roughly indicates whether the milk has just been milked (if warm) or is from the previous evening's milking (if cold).

b. *Clot-on-boiling test*

This test is quick and simple. It allows for detection of milk that has been kept for too long without cooling and has developed high acidity, or colostral milk that has a very high percentage of proteins. Such milk does not withstand heat treatment hence this test could be positive at a much lower acidity (see Figure 9).

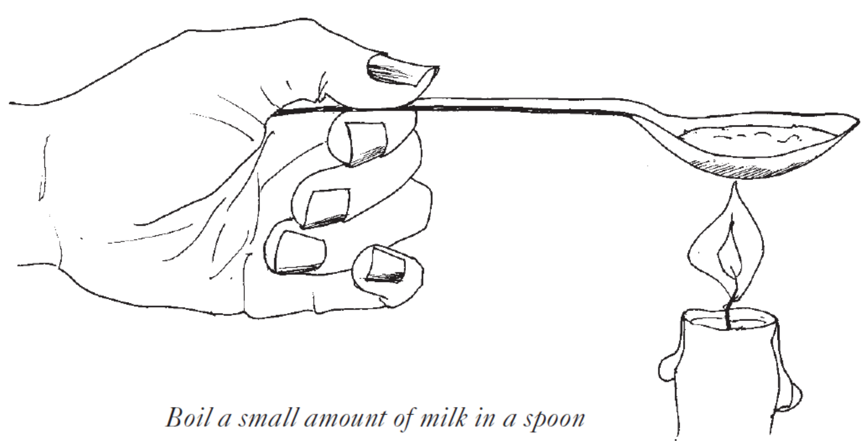
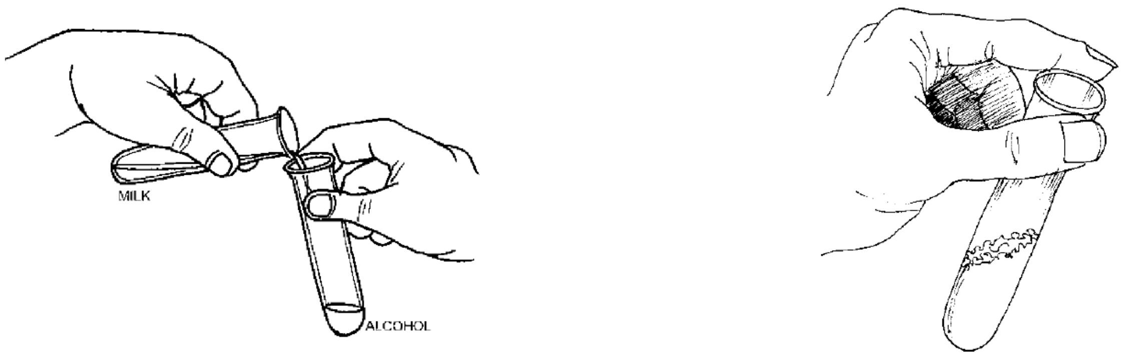


Figure 9: Clot-on-boiling milk test

c. *Alcohol Test*

The alcohol test is quick and simple. The specific type of alcohol used is 'ethanol'. It enables detection of bad milk that may have passed the previous two tests because it is more sensitive to lower levels of acidity (see Figure 10). It also detects milk that has been kept a long time without cooling, colostrum or milk from a cow with mastitis (Kurwijila, 2006).

The alcohol test



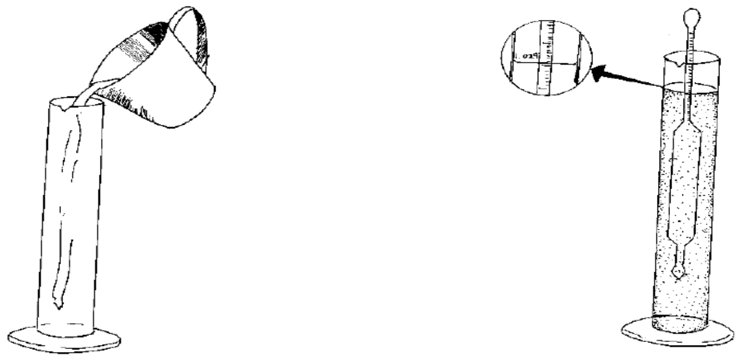
Mix 2 ml of milk with 2 ml of 70% alcohol

If the milk coagulates, it fails the test

Figure 10: Illustration of alcohol test for milk quality

d. Lactometer test

The lactometer test (Figure 11) is used to determine if the milk has been adulterated with water or solids. Adding anything to milk can introduce bacteria that will make it spoil quickly. Adulterating milk is illegal. The lactometer test is based on the fact that milk has a heavier weight or density (1.028–1.036 g/ml) than water (1.000 g/ml). When milk is adulterated with water or other solids are added, the density either decreases (if water is added) or increases (if solids are added). Farmers also remove cream, especially from the evening milk, for domestic use. If cream is removed from milk, the density of milk goes up and its butterfat goes down. This is an economic loss to the processing plant and unacceptable as per the Kenyan standards. If milk fat (cream) is added to milk, the density decreases. The equipment used to measure milk density is called a lactometer. Most lactometers are marked from “0” (representing density of 1.000 g/ml) to “40” (representing density of 1.040 g/ml) (Kurwijila, 2006).



Equipment used for determining the milk density

Figure 11: Lactometer test

Milk collection/ marketing innovations

Bulk milk coolers

A bulk milk cooler (BMC) is a two-shelled container consisting of an inner and outer stainless-steel shell with injected polyurethane foam insulation between the two shells. Each BMC is equipped with an in-built light weight, low rpm (25–32) agitator, a refrigeration system and an additional milk reception unit, a pumping device and a generator set. The refrigeration system consists of a hermetically sealed compressor, controls and safety features that make the BMC extremely reliable and energy efficient. The milk from suppliers is poured into the reception unit and stored in a BMC where it is cooled to 4°C within 2–3 hours of its collection. The milk in the cooler is maintained at this temperature until it is pumped into specifically designed milk transportation tankers through which it reaches the milk processing plant.

3. Quality-based milk payment system

Milk quality is an important aspect of dairy production. It affects milk processing, its technological properties, and thus economic efficiency. Dairy industries worldwide have instituted penalty and premium programmes to provide incentives for dairy producers to improve milk quality. Most of these programmes focus on bulk tank milk quality, such as total bacterial count, somatic cell count and milk composition (percentage of fat, protein and solids non-fat) (Draaiyer et al., 2009; Dekkers et al., 1996). Premium payments motivate farmers to produce high quality milk without disrupting the milk supply chain of the market they operate in. Farmers are paid not only for the quantity of raw milk they deliver, but mainly for its quality. A quality-based milk payment system is a very effective system not only to enhance the attention for milk quality and food safety, but also to improve the quality of the raw milk. The use of quality-based milk payment (QBMP) systems to improve milk quality is widespread throughout the world.

In the Netherlands, the milk price is based on the fat and protein content of the milk. In India some private dairies pay the middlemen according to a QBMP system. The payment is based on fat and solid non-fat content. In China several central laboratories were established to implement a QGMP system. The standards are being applied by both Parmalat and ZamMilk, which account for 100% of the commercial farmers and 85% of smallholder farmers who deliver milk to milk collection centres in Zambia. In Kenya, a QBMP system is being implemented by Bio Foods. The system rewards dairy farmers for high milk components and low bacteria counts, both of which are needed to market quality dairy products under the Bio name. Farmers in the QBMP system receive training in animal husbandry and feeding and in other good farming practices. These good practices contribute to reduced milk losses.

4. Training Manuals on Hygienic Milk Handling

The International Livestock Research Institute (ILRI) in collaboration with several institutions has also developed training modules for milk collection centre operators, transporters, small-scale traders and milk processors that cover the minimum competencies for hygienic milk handling and processing. These trainings can be scaled up through continuous training and capacity building programmes.

(a) Training guide for farm-level workers and milk handlers

ILRI in collaboration with other institutions has designed training manuals to provide basic knowledge on how to produce and handle milk hygienically at farm level. The aim of the training manuals is not only to help reduce losses of milk due to spoilage, but also to help produce and market safe milk at the farm for human consumption. The aim of this guide, therefore, is to help trainees acquire basic knowledge and skills in:

- How to produce clean milk that is fit for human consumption
- How to handle milk in accordance with good hygienic practice
- Procedures for carrying out basic milk quality tests

The guide is designed to be used during on-site training (2–3 hours per day) at the farm or for outreach training (1–3 days) by a business development service provider at a suitable location near the farm. After the training, the participants undergo a theory and practical test to evaluate their level of competence in hygienic milk production and handling. If they pass the test, they are awarded a certificate in basic hygienic milking and milk handling. The manual can be found at the following link:

https://cgspace.cgiar.org/handle/10568/1763

https://cgspace.cgiar.org/handle/10568/1696

(b) Training guide for small-scale milk traders

The training guide for milk traders was developed through collaboration between dairy regulatory authorities in Kenya, Rwanda, Tanzania and Uganda; the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) through its Programme for Agricultural Policy Analysis (ECAPAPA); and ILRI. This document will help you become competent in basic hygienic milk trading and transportation. The training manual is meant to help the milk traders become competent in basic hygienic milk trading and transportation. The aim of the guide is therefore to help trainees acquire basic knowledge and skills in the following areas:

- Hygienic milk production
- Hygienic milk handling
- Milk quality control and testing
- Hygienic milk storage, preservation and trading

The guide is designed to be used for on-site training (2–3 hours per day) at a suitable location. The manual can be found in the link below:

https://cgspace.cgiar.org/handle/10568/1760

(c) Training guide for small-scale milk processors

The training guide for milk processors was developed through collaboration between dairy regulatory authorities in Kenya, Rwanda, Tanzania and Uganda; ASARECA through ECAPAPA; and ILRI. The document is meant to help the small-scale milk processors acquire basic knowledge and skills in the following areas:

- Hygienic milk production and handling
- Milk quality control and testing
- Milk quality grading and payment systems
- Hygienic milk storage, preservation, transportation and processing/packaging
- Maintenance of milk handling and cooling equipment
- Dairy effluent management systems
- Code of hygienic practice

This is not a detailed manual on processing of specific milk products, rather it aims to help the trainees to satisfy the basic requirements for hygienic milk processing. The guide is designed to be used for residential training at a suitable institution, on-site training at the processing plant or outreach training by business development service providers. The manual can be found at the following link:

https://cgspace.cgiar.org/handle/10568/3493

Conclusions

In Kenya, most of the identified viable innovations and technologies for reducing milk loss exist, but lack of farmer knowledge on available solutions and lack of robust milk supply chains hampers access to and adoption of these solutions. Generally, the innovations and technologies identified could be scaled up through:

i) Campaigns and promotion
ii) Training and capacity building
iii) Further research to generate affordable and appropriate technologies to cater for emerging needs of farmers

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