Frequent Load Shedding: its Effects on the Cold Chain and Milk Quality in the Large Scale Dairy Value Chain in Mashonaland East Province, Zimbabwe

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Dedication

To all family members, love you lots.

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Abbreviations

BRC	British Retail Consortium
CCP	Critical Control Point
CFU	Commercial Farmers Union
Cwt	Hundredweight unit- equivalent to 100 pounds (45kg)
DSU	Dairy Services Unit
DHI	Dairy Herd Improvement
DZPL	Dairiboard Zimbabwe Private Limited
EMA	Environmental Management Authority
GAP	Good Agricultural Practices
GMP	Good Manufacturing Practices
HACCP	Hazard Analysis and Critical Control Points
ICT	Information and Communication Technology
IFS	International Food Standard
ISO	International Organisation for Standardisation
kVA	Kilovolt-ampere
kWh	Kilowatt hour
LSD	Large Scale Dairy
NDC	National Dairy Co-operative (NDC)
MW	Megawatts
PRP	Prerequisite Programs
QMS	Quality Management System
SPC	Standard Plate Count
TBC	Total Bacteria Count
UHT	Ultra-high temperature processing
WTO	World Trade Organisation
ZESA	Zimbabwe Electricity Supply Authority
ZADF	Zimbabwe Association of Dairy Farmers
ZDIT	Zimbabwe Dairy Industry Trust

Abstract

Zimbabwe has been experiencing frequent load shedding (power cuts) in recent years. This load shedding is a result of shortage of generating capacity from the national power utility to match the high national energy requirements. The study sought to analyse the effect of this load shedding on the dairy cold chain and milk quality in the dairy value chain in Mashonaland East province and come up with intervention strategies for improvement. Thirty large scale dairy farmers in Mashonaland East were randomly selected for the survey. The farmers were grouped into two clusters according to their method of milk delivery (can and bulk milk collection). Key informants and experts who are actors and supporters in the chain were interviewed in case studies to get in depth knowledge about the research subject. The study revealed that the province was experiencing massive unscheduled load shedding. The frequency of load shedding was on average three times per week and ranging between 4-8 hours and 9-15 hours per day in duration. The results showed that load shedding was causing damage to the cold chain equipment due to fluctuations in voltage (power surges and single phasing). A few producers had installed voltage meters and surge protectors to protect the equipment. There was no correlation ($p > 0.05$) between load shedding and Total Bacteria Counts (TBC) in this study. This result showed that load shedding was not affecting milk quality, and a reasonable explanation could be that the use of generators had helped in maintaining milk storage temperature and hygiene. However, the use of generators was raising the production costs in this dairy value chain and making it uncompetitive. There were also growing concern for environmental pollution. The recommendations in this study included encouraging producers to install voltage and surge protectors to prevent damage to cold chain equipment, to invest in energy saving technologies such as plate heat exchangers (PHT) and modern bulk tanks that are energy efficient. Actors in the chain particularly producers are encouraged to consider other alternative renewable energy sources such as solar and biogas energy and reduce dependency on electricity from the grid or generators.

Keywords: cold chain, load shedding, total bacterial counts

Chapter 1 : Introduction

1.1 Background

Zimbabwe is a landlocked country, centrally situated in Southern Africa and sharing borders with Mozambique (to the East), South Africa (to the South), Botswana (to the West) and Zambia (to the North) (Figure 1.1). Harare is the capital city and is situated in the northern part of the country. The country covers an area of 399 757 km^2 with a population of about 12 million people and has a sub-tropical climate which supports a wide range of agricultural activities (Ministry of Industry and Commerce, 2012). Agriculture contributes 20.3% to Gross Domestic Product (World Factbook, 2013). About 70% of the population is dependent on farming for livelihood with livestockand crop production being the important enterprises (FAO, 2005). The major ruminant species kept are cattle, goats and sheep. Natural grazing is the most important source of livestock feed. Major farming sectors in Zimbabwe are the large-scale commercial, small-scale commercial, communal and resettlement. Large-scale commercial farms, which have been previously owned mainly by white farmers, have an average size of 2 200 ha, with about 55% being located in high potential rainfall areas (FAO, 2005).These farms are characterised by relatively high levels of investment. In contrast, small-scale commercial farms occupy the smallest land area with an average farm size of about 12.5 ha. The farms are leased from the government. The communal farming sector has the highest human population density (FAO, 2005). However, since year 2000 the government embarked on a land reform exercise to redress the historical land imbalances which sought to ease pressure on communal lands through resettlement into more productive lands.

Figure 1.1. Map of Zimbabwe. Source:(Google maps, 2012)

The dairy sector in Zimbabwe has a dualistic marketing and production system comprising of a fairly sophisticated large scale dairy sector and a small holder sector which mainly produces milk for the informal market (Mupeta, 1996). The dairy value chain in Zimbabwe is dominated by large scale dairy farmers contributing 98% of the marketed milk and only 2% comes from the smallholder sector. The large-scale commercial dairy (LSCD) sector has large farms with high producing (> 5000 kg/lactation) pure exotic cows and their crosses (Ngongoni, Mapiye, Mwale, & Mupeta, 2006). Most dairy farms are located in Mashonaland East province because of its close proximity to Harare where about 46% of the national milk intake is processed. Further, the province has a climate and topography better suited for dairy as compared to other regions in the country. The dairy value chain in Zimbabwe has undergone a lot of reforms in the past decade characterised by a decrease in the number of producers and a decline in the national milk production which has affected the supply chain.

Maintaining the cold chain in the dairy value chain starts at the farm level and continues through transportation, processing, retailing and finally to consumer (Joshi, Banwet, & Shankar, 2010). Milk is a perishable commodity which can easily get spoiled when exposed to high temperatures which favours rapid multiplication of bacteria and loss in milk quality. Joshi *et al*. (2010) described the "cold chain" as the supply chain of perishables and involves the equipment and processes used to keep perishable products in a conditioned environment. Refrigeration stops or reduces the risk of food poisoning, spoilage and maintains the quality, safety and shelf life of dairy products in the cold chain (James & James, 2010). Maintaining the cold chain is important in guaranteeing the safety and quality of food to consumers.

The electricity supply in Zimbabwe has been characterised by frequent load shedding (interrupted electricity supply/ power cuts) in recent years. The national power supplier company is still unable to adequately source and supply the national energy requirements despite the steady improvements in the economy. In order to manage the available resources the power authority carries out load shedding across the country (Waniwa, 2010). Actors in the dairy value chain need electricity for running milking machines, processing and for cooling raw milk and its processed products. Hence the frequent power cuts which in most cases are unscheduled have a high risk of breaking the dairy cold chain which has to be maintained from the farm to the consumer table.

1.2 Problem statement

The frequent load shedding experienced countrywide is a high risk to the maintenance of the dairy cold chain amongst actors in the large scale dairy value chain in Mashonaland East province. Unlike processors who are located in the city with minimal load shedding, the situation is different with producer farmers whose farms are located away from cities and experience frequent unscheduled power cuts. As a result, producer farmers are particularly vulnerable as they form an integral part of the start of this cold chain with knock-on effect amongst actors downstream. Milk must be cooled as soon as possible after milking to a temperature below 4^{O}C in order to minimise bacterial growth which doubles every 20 minutes at high temperature (Harding, 1995). Power interruptions affect the cooling of milk and this in turn affects the keeping quality of raw milk and dairy products (Gwezuva, 2011).

1.3 Justification of the study

The Zimbabwean dairy regulations require milk to be supplied to processing plants within 72 hours after milking and a milk storage temperature of 4°C at the farm and during transportation (RGN, 1977). Gwezuva (2011) revealed that a majority of dairy producers in Zimbabwe are having milk rejected by processing plants and 78% of the cases is attributed to sour milk.

Temperature is a critical control point (CCP) at farm storage, transportation, processing and retailing to guarantee the safety and quality milk products to consumers. Although previous research has hinted at the risks posed by power cuts on the cold chain, little research has been conducted in Zimbabwe to assess how frequent power cuts are affecting the dairy cold chain. Therefore, the study seeks to analyse and evaluate the extent to which power cuts have affected the cold chain and milk quality in this value chain.

1.4 Objective of the research

To analyse the effect of load shedding on the dairy cold chain and milk quality in the dairy value chain in Mashonaland East province and propose intervention strategies.

1.5 Research Questions

Main Research question 1:

1. What is the current status of load shedding in Mashonaland East Province?

Sub questions

1.1. What is the frequency and duration of loading shedding in the province?
1.2. What are the actors in the chain currently doing to deal with load shedding?
1.3. What support services are available from stakeholders in the chain on load shedding?
1.4. What is the effect of load shedding on production costs?
1.5. What are the milk rejection rates at the farm reception and the processing plant linked to load shedding?

Main Research question 2:

2. What are the factors to be considered to maintain the cold chain and milk quality from farms to processing plants?

Sub questions

2.1. What infrastructure is available to maintain the cold chain by actors in the chain?
2.2. What are the critical control points (CCP) in the dairy cold chain to ensure safe and quality milk production?
2.3. What are the milk quality testing procedures available at collection at the farm level and reception at the processing plant?

Chapter 2 : Literature Review and Conceptual Framework

2.1 Definition of terms

i. **Cold Chain:** The supply chain of perishables termed "cold chain" is described as the equipment and processes used to keep perishable products in a conditioned environment (Joshi *et al*., 2010).

ii. **Load shedding:** Interrupted electricity supply or power cuts.

iii. **Private standards**: is a term used to describe food and farm assurances that have been developed by interested parties (e.g. producers, food industry sectors, manufacturers, retailers, non-governmental organisations) to provide specific sets of rules for production, processing, manufacturing and distribution that can be independently checked so that the next stages in supply chains can be assured to meet set standards (Baines, 2010).

iv. **Food Quality**: Quality as defined by Luning and Marcelis (2009) is meeting or exceeding customer and consumer expectations. Customers are those who receive a product (ranging from raw materials to finished products) e.g. the milk factory is the customer of farmers who supply the milk. Quality management refers to all activities that organisations use to direct, control and co-ordinate quality, including formulating a quality policy, setting quality objectives, quality planning, control, assurance and improvement.

v. **Organoleptic tests**: are simple, initial and important tests based on smell, taste and appearance which enables rapid segregation of poor milk if a skilled person with good senses carries them out.

vi. **Food safety**: Refers to the absence of hazards or existence of hazard levels within acceptable risk. Hazard is a potential source of danger that may contaminate a food product. A risk refers to the probability during any step of food production of a hazard contaminating food which if consumed can cause a health disorder. It is a measure of the probability and severity of harm to human health. Hazards can be classified into three classes i.e. biological, chemical and physical. Biological hazards mainly involve living organisms which are able to colonise foods and in some cases grow or survive in the food matrix. The organisms produce toxic metabolites e.g. bacteria, moulds, parasites, viruses and prions. On the other hand chemical hazards include mycotoxins, aflotoxins and residual chemicals. Physical hazards include foreign objects normally not present in food e.g. soil, stones, dust, metals, insects (Luning & Marcelis, 2009).

2.2 Conceptual Framework

2.2.1 Value Chain Concept

The conceptual framework of the study takes a value chain concept which is an analytical and operational tool. A value chain is a specific type of a supply chain which takes up the fact that a product is rarely directly consumed at the place of its production but undergoes transformation by adding value before it reaches the consumer. Actors incur costs which they recoup by charging for the service. In a value chain actors know each other well and form stable, long-term relationships. Actors work together to increase their efficiency and competitiveness. Actors invest time, effort, and money to reach a common goal of satisfying consumer needs (KIT &

IIRR, 2008). Chain actors are those involved in producing, processing, trading or consuming a particular agricultural product, they own the product at one point in the chain. Chain supporters on the other hand do not own the product but provide financial and non-financial support services and include bankers, credit agencies, business service providers, government, research and extensionists (KIT & IIRR, 2008).

The value chain concept analyses both quantitative and qualitative aspects of the chain which includes information, money flows, value shares and gender issues. The dairy value chain can be divided into four different stages being: feed production, dairy farm, milk processing and retail sector (Valeeva, Meuwissen, Oude Lansink, & Huirne, 2005). In this study, the supply chain of perishables termed the cold chain will be used to assess the Large scale dairy value chain in Mashonaland Province in Zimbabwe. The cold chain starts at the farm level (e.g. pre-cooling) and covers up to the consumer level (cooling practices and behavior) (Joshi, Banwet, & Shankar, 2009). A typical cold chain infrastructure as described by Montanari (2008) generally consists of pre-cooling facilities, cold storages, refrigerated carriers, packaging, warehouse, traceability, retailer, consumers and information management systems. A typical cold chain is shown in Figure 2.1.

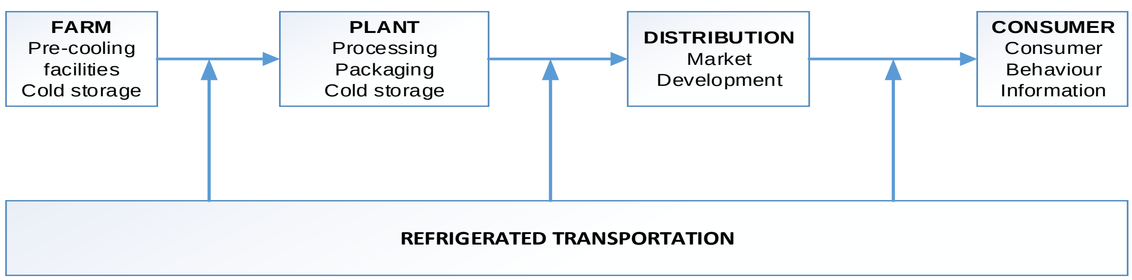


Figure 2.1. Dairy Cold chain. *Source* **:** *Montanari (2008) in Joshi et al. (2009)*

2.2.2 Cold Chain Management Concept

Global cold chains management (CCM) is described as the process of planning, implementing and controlling efficient, effective flow and storage of perishable goods, related services and information from one or more points of origin to the points of production, distribution and consumptions in order to meet customers' requirements on a worldwide scale (Bogataj, Bogataj, & Vodopivec, 2005). Cold Chain Management (CCM) is also described by Shabani, Saen, and Torabipour (2012) as a system of managing activities related to perishable products like medicine, blood, dairy, meat, food, vegetables, mushrooms, flowers and fruit products, which must be distributed in a special time and kept in the particular environment condition. The cold chain is described from different perspectives (producer–processor–distributor–retailer) and its been found that the cold chain is frequently broken at various stages, which drastically reduces its performance (Joshi, Banwet, Shankar, & Gandhi, 2012).The temperature and other types of preservation control at each stage of the supply chain are essential to maintain the prescribed quality of the product until it reaches final consumer. Salin and Nayga (2003) states that the integrity of the cold chain must be preserved from the point of production, processing, through each of the transport stages – handling, loading, unloading, and storage – and extends to storage at the consuming household. Once products are in the cold chain, each activity is supposed to be carried out a fixed temperature and in a certain time frame (Aiello, La Scalia, & Micale, 2012).The cold chain consists of two distinct types of operation. In primary and secondary chilling the aim is to change the average temperature of the food. In others such as chilled storage, transport and retail display the prime aim is to maintain the temperature of the food (James & James, 2010a). Removing the required amount of heat from food is difficult, time and energy consuming operation, but critical to the operation of the cold chain. As food moves along the cold chain it becomes increasingly difficult to maintain its temperature. Failure to understand the needs of each process results in loss in weight, higher energy use, wastes of resources, economic losses, reduced shelf of life or deterioration in product quality (James & James, 2010a; Shabani *et al*., 2012).

Temperature abuse in the cold chain can cause microbial hazard and losses of product quality, temperature control is essential to keep the final consumer safe (Bogataj *et al.,* 2005). Recently, the concept of 'cold traceability' was introduced which requires some tools and equipment such as thermometers, temperature recorders, temperature indicators and time-temperature integrators mostly for static approach to the quality control of perishable goods (Bogataj *et al*., 2005). This concept helps to trace different groups of perishable goods like poultry and other meat, fish, fruits and vegetable, confectionery, ice cream and other dairy products which are transported under different cooling requirements. The cold chain management requires very careful temperature control and quick reactions when deviations appear in temperature or time delays occur. It therefore implies that maintaining perishable goods requires efficient equipment with special features, proper operating modes, and appropriate information system.

2.3. Dairy sector in Zimbabwe

Zimbabwe dairy sector has a dualistic dairy marketing and production system, with a fairly sophisticated commercial dairy farming sector and a small holder dairy which mainly produces milk for the informal market (Mupeta, 1996). Zimbabwe is the second country after South Africa with an organised dairy sector in southern Africa. The commercial sector is highly mechanized and is equipped with modern dairy equipment and high yielding dairy cows >5000 litres per lactation. These standards made Zimbabwe's commercial dairy farms compare very favourably with dairy farms in Europe and North America (Mupunga & Dube, 1997).

2.3.1. Large scale commercial producers

Commercial dairy production in Zimbabwe started as far back as 1912. However, due to pre-independence policies of separate development which catered mainly for the commercial farming sector, dairying was exclusively for Large Scale Commercial dairy (LSCD) farmers who produced milk on commercial lines in order to satisfy the national needs of the country (Mupeta, 1996). The infrastructure was so designed to supply milk and milk by-products to the urban population which account for 30% of the country population. As a result dairies handling liquid milk, production of butter, cheese other dairy products were located around major towns for easy transportation of milk. Until 1980, large commercial farms, the former European farming sector, occupied close to 80% of the specialised and diversified farming area in the intensive farming regions of Zimbabwe with top herds averaging over 9000 kg milk per 306 day lactation (Mupeta, 1996). Over 50% of all large-scale commercial land is located in natural ecological regions 1 to 3, the high (1000mm) - to medium (650mm) potential rainfall regions. Production systems are influenced by the five agro-ecological regions found in Zimbabwe (Table 2.1).

The large-scale commercial dairy sector has been shrinking from the period the Government decided to embark on a programme to redress the land imbalances that had existed in the country. This program has seen some of the farms subdivided into small units and others no longer used for dairy production. The number of registered dairy producers in the country is 188 down from 514 in 1990 (DSU, 2013). The head size on a farm ranges from 50-300 cows composed mainly of European breeds refer to chain map in Figure 2.2. The predominant dairy cattle breeds are the Holstein-Friesian breeds (66%), Red Dane (24%), Jersey (6%), Guernsey (3%) and 1% crosses (Mandiwanza, 2007). Artificial Insemination (A.I) is used for breeding purposes. Productivity per cow has dropped in the past decade from an average of 25 litres a day to the current 14 litres a day (DSU, 2013). The reasons are due to the genotypes being used, reduced land sizes to grow enough feed and a decline in research. This has resulted in the drop in annual milk production from 256 million litres a year in 1990 to about 90 million litres a year in 2006 (Mandiwanza, 2007). Feeding on large scale commercial dairy farms is a combination of home grown feeds (home mixing) with bought–in concentrate feeds, maize silage and where irrigation is available planted pastures (midmar rye and lucerne) are grown (Warambwa, 2007).

Table 2.1. Dairy Production Areas and Systems in Zimbabwe

Area	**Description: Region** I: >1000mm rainfall; **Region II**: 750-1000mm; **Region III:** 650-800mm; **Region IV**: 450-650mm; **Region V**: <450mm
Harare	The production systems found in this area (Regions II and III) varies from intensive zero grazing, through irrigation pastures to dairy ranching with low feed inputs. Being a cropping area, a great deal of home-grown feed is used for a home-mixing based on maize silage, oil cakes and purchased concentrates. About 46% of the national milk intake is processed in Harare.
Gweru	Production for this area is about 25 % of total production and being Region III most feeding is out of the bag, with some home mixing where irrigation is available.
Bulawayo	About 7 % of total production is found here in Region IV. Certain areas are well supplied with irrigation providing for pastures and crops for home mixing and the balance of feed is bought in.
Kadoma	This is a marginal cropping area between Region I and III with a mixture of feeding systems and contributing about 5 % of production.
Mutare	This area is marginal, Region II with a mixture of feeding and contributing 6% of the total production.
Chipinge	This area (Region I) is normally well watered so dairy production is based on home grown forage and grain. The region has however been badly affected by drought in recent years. Natural disasters like drought, tends to have a very noticeable effect on production in this area

Adopted: Borland and Moyo (1996)

2.3.2. Small holder producers

The development of smallholder sector which accounts for 70% of the country's population (communal, resettlement and small scale commercial) was started in 1980, while maintaining production in the large scale sector. This saw the formation of the Dairy Development Programme (DDP) to spearhead milk production from smallholder areas. The smallholder sector consists of small herds on small land sizes and communal grazing lands. These farmers mainly use indigenous breeds and their crosses which are adaptable to the harsh conditions. Milk production is characterised by low volumes, 4-6 litres per cow a day (Munangi, 2007). Milk is produced for home consumption with surplus sold locally through milk collection centers and informal markets. This sector contributes only 1-2% of marketed national milk production (Figure 2.2).

2.3.3. Processors

The dairy processing industry has grown from two major companies namely Dairiboard Zimbabwe Private Limited (DZPL) and Nestle Zimbabwe, to 34 small to medium processors across the country. About 39% of the national milk intake is processed by Harare DZPL with 7% going to Nestle (Figure 2.2). DZPL previously enjoyed monopoly in the marketing of milk and dairy products before deregulatory measures were introduced in 1994. Although DZPL has no regulatory powers or responsibilities, it still processes 90% of the milk sold into the national pool and continues to operate seven factories spread throughout the country as a result of its historical monopolistic role (Borland & Moyo, 1996). Nestle, a leading multi-national company involved in dairy, operates a processing factory in Harare, and it purchases raw milk directly from its contracted producers. Several smaller processors started operating but are finding difficulties in meeting quality standards. Raw milk is processed into various milk products. The national processing capacity is 400 million litres but less than 30% of this capacity is utilised due to lower milk production (Mandiwanza, 2007). As a result distribution of milk products is characterised by low volumes and huge overheads which results in high unit costs. Table 2.2 gives an overview of registered dairy operators in Zimbabwe.

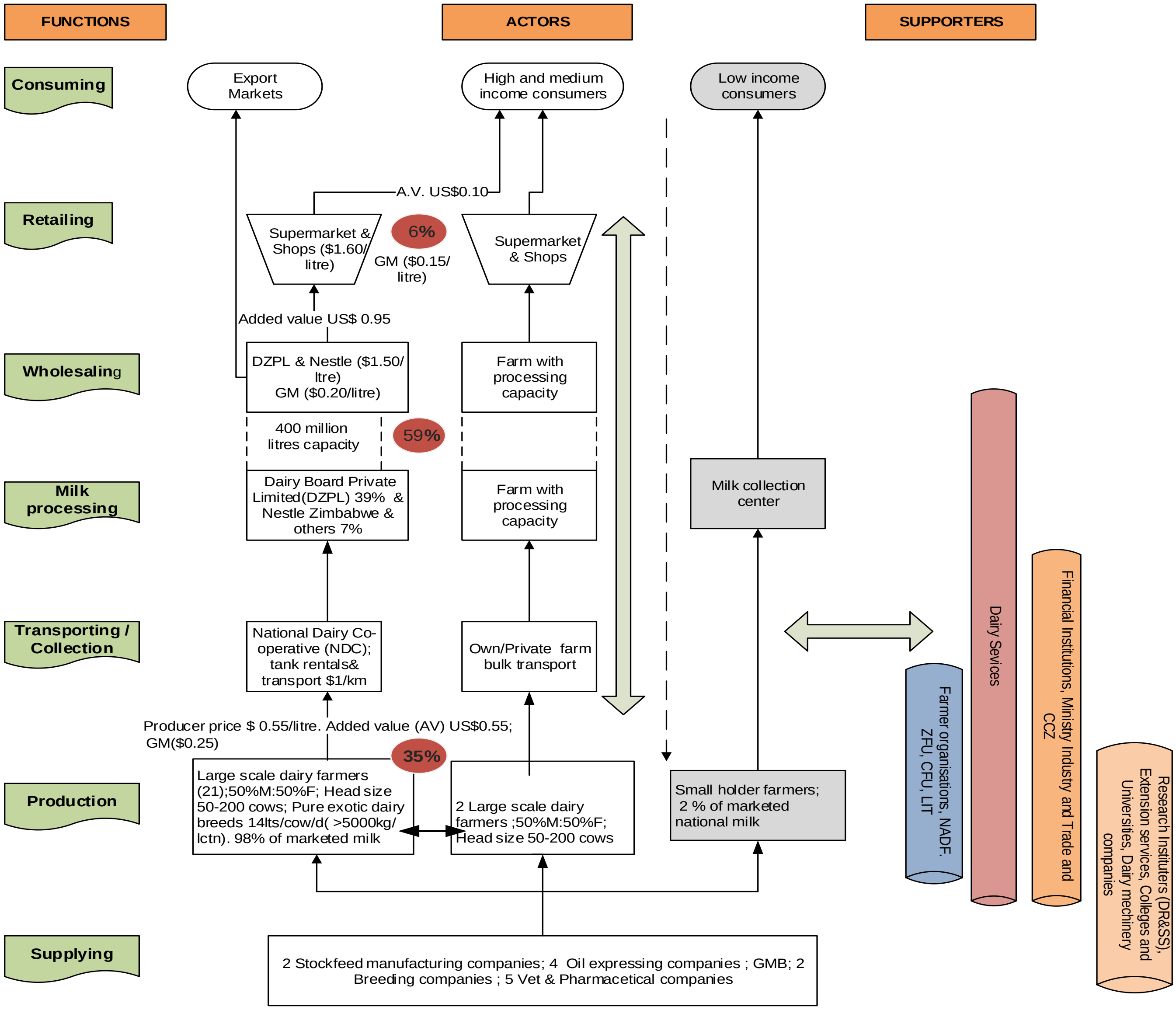
Table 2.2. Registered Dairy Operators

	Mashonaland	Gweru	Kadoma	Bulawayo	Chipinge	Mutare	Total
No. of registered producer wholesalers	41	33	1	31	12	14	132
No. of registered producer retailers	13	2	2	3	0	2	22
No. of producer retailer processors	22	1	3	4	0	4	34
No. of producers on cans	47	22	4	27	0	11	111
No. of producers on bulk	29	14	2	11	12	9	77
Total number of registered producers	**76**	**36**	**6**	**38**	**12**	**20**	**188**
No. of processors	10	2	0	2	1	1	16

Source: DSU (2013)

2.3.4 Value Chain map: Dairy sector in Zimbabwe

A summary of the value chain map of the dairy sector in Zimbabwe is shown in Figure 2.2. The chain map shows the interactions between actors and supporters including the quantitative and qualitative aspects.



Key

% Male: % Female: % M: % F

Information flow

GM: Gross Margin in US$

Value share:

Money flow:

Product Flow:

Figure 2.2. Value chain map of the Dairy sector in Zimbabwe

2.3.5. Chain supporters

Chain supporters are those stakeholders in this dairy value chain who do not own the product but provide support for the actors and ensure that safe milk products reach the consumer. Figure 2.2 shows the chain supporters in the dairy value chain in Zimbabwe which are described as follows:

- **Dairy Services**- a government regulatory department that regulates the functioning of dairy farms. This department offers operating licenses to dairy farms after inspecting the premises and compliance with the Dairy Act [Chapter 18:08] of Zimbabwe.

- **The Department of Veterinary services**- provides the legal control of animal diseases and is responsible for scheduled disease control through field services and diagnosis through the laboratory. However, all individual treatments of dairy animals and herds excluding scheduled diseases are carried out by private veterinarians.

- **Henderson Research Institute**- a livestock research station in the Department of Research and Specialists Services (DR&SS) located in Mashonaland East province conducts research in dairy as well as offering advisory services to both large and small holder dairy farmers. The role of research in the chain has been grossly affected with inadequate funding.

- **Extension services**- are offered mainly by government institutions and non-governmental organisations. Dairy farmers receive technical expertise in breeding, feeding, milking machinery and dairy hygiene. Extension services have declined due to high staff turnover and inadequate resources to reach out to the farmers.

- **Farmer unions**- include the Commercial Farmers Union (CFU), Zimbabwe Farmers Union (ZFU) and the Zimbabwe Association of Dairy Farmers (ZADF) which is made up of dairy farmers who deliver milk to processors. These farmer organisations interact with other stakeholders in the dairy value chain and have a role in influencing policy on research, pricing, extension, marketing and financing.

- **Financial institutions**- several financing options for dairy farming exist. Working capital and funds for capital expenditure are available through the Agriculture Sector Productivity Enhancement Facility (ASPEF) and various commercial bank facilities.

2.3.6. Information flow

A good information flow exists in this dairy chain as seen by the interaction and information exchange among actors and supporters, see chain map in Figure 2.2. The Zimbabwe Association of Dairy Farmers (ZADF), a farmers' organisation regularly holds quarterly meetings for all stakeholders in the value chain to discuss the challenges, strides, farmers' experiences and market information. The organisation has a role in influencing policy on research, pricing, extension, marketing and financing. Annual ZADF general meetings are held to reward the best performing dairy farmer and famers regularly interact to share information. New technologies from research findings are disseminated by extension workers to farmers. However, the role of research and extension services in providing critical information to the farmers including marketing has declined due to limited institutional capacity. There is little use of information and communication technology (ICT) in extension yet this is now being used in various countries, for example South Africa and Kenya (Makodza, 2007). Nevertheless, dairy farmers' herds registered with the Dairy Herd Improvement scheme (DHI) still receive on a regular basis, dairy reports with information regarding their herd health status and milk production. Information on price reviews is also provided to the farmers by the processor and ZADF. Money flows from the consumer, retailer and processor before finally reaching the farmer. Pricing is from top to down, government sets the final retail price of milk products and the producer price is worked down from this retail price by applying a prescribed percentage. The competiveness of the industry is affected by the price controls which in many cases lag behind variable costs incurred. This leads to low gross margins and failure by farmers to recapitalise.

2.4. Load shedding

In many developing countries even where grid electricity is available, supply is often erratic and of poor quality (Chaurey, Ranganathan, & Mohanty, 2004). Among rural states in India, while certain have achieved relatively lower transmission and distribution losses, others are plagued by long power cuts (load shedding) and voltage fluctuations (Chaurey *et al*., 2004). Reliable and quality electricity can in many ways bolster economic development as highlighted by Chaurey *et al*. (2004) in the India dairy production case where the use of an Electronic Milk Testing machine which correctly estimates the fat content of the milk, made the sector more competitive on the market.

Scheduled load shedding experienced in South Africa has led to several organisations indicating to sue the power utility- Eskom over income loss with legal claims amounting to R3-million (€220 000)[1] from individual businesses (Thakali, 2008). Load shedding affects the dairy industry throughout the value chain (National Agricultural Marketing Council, 2008). At farm level, for example, losses are brought about by lower milk production due to cows suffering from heat stress, as well as damage to electric motors and computer systems and stoppages during the milking process. In addition, power outages also impact on the cold chain's capacity to maintain acceptable temperature regimes, resulting in product losses and wastage. The Milk Producer Organisation of the South African dairy industry estimates that losses within the cold chain could cost R100 million (€7,3 million) a month with continued load shedding (National Agricultural Marketing Council, 2008; Thakali, 2008). This figure excludes losses incurred by retailers due to interruptions to the cold chain brought on by power failures. In modern farming,

[1] 1 EUR =13.61 ZAR

power loss would mean immediate problems for milking robots, feeding systems, water pumps, cleaning systems, light, indoor climate control and heating, waste treatment, cooling of products, computers and communication (Lassen, 2013). The ability of a food supplier to control the temperature of his product is imperative in order to comply with food safety regulations, bulk milk must be cooled immediately and the cold chain remain unbroken until it is delivered to the manufacture. These temperature limits have been established to limit bacterial growth that might potentially harm consumers (Lassen, 2013).

There are possible solutions to supplement the demand-supply gap for grid based electricity or in inaccessible areas. These include distributed generation DG which is the application of small modular power generating technologies (such as wind turbines and micro-turbines, renewables such as solar systems, biomass gasfiers minigrids, hybrids, typically in the range of 1 kW to 50MW). These can be combined with energy management and storage systems, and used to improve the operations of the electricity delivery systems at or near the end user. These technologies may or may not be connected to the electric grid. In India, the DG programme is favoured in view of the need to tackle the problems of peak load shortage which has been characterised by frequent power cuts occurring up to 20 hour a day and for 20 days in the month (Chaurey *et al*., 2004).

Some of the DG technologies such as wind turbines and biomass cogeneration systems feed electricity to high-voltage transmission systems. However, a small DG unit, typically of less than 10MW capacity can instead be connected to the low-voltage local distribution network or installed on buildings. Distributed generation is yet to be tried on a large scale in rural electrification projects in India because there are still many barriers‒technical, financial, regulatory, and institutional‒that need to be addressed adequately. Nonetheless there are many technologies available for off-grid schemes that are mature and field-proven, notably Chile, have been successful in expanding electricity access in rural using alternative electrification technologies (Chaurey *et al*., 2004). The U.S. African Development Foundation (USADF) is teaming up with General Electric Africa to launch the Power Africa Off-Grid Energy Challenge. The Power Africa Challenge is a three-year, US$2 million challenge that will award 20 or more grants of up to US$100,000 each to African organizations providing off-grid solutions that deploy renewable resources and power economic activities to rural or urban regions currently lacking energy access (U.S. Department of State, 2013). The program aims to support Africa's efforts to solve the challenge of insufficient and inconsistent power supply (U.S. Department of State, 2013).

2.4.1 Electricity Supply in Zimbabwe

The Zimbabwe Electricity Supply Authority (ZESA) provides the bulk of electricity generated, transmitted, distributed and supplied in Zimbabwe (Kayo, 2002; Mangwengwende, 2002). ZESA's installed capacity currently stands at 1961MW and the generation is composed of hdro and thermal power (Kayo, 2002). Mbohwa (2003) reports that of this power generated 633 MW is from hydroelectric power at Kariba Dam and 1295 MW of coal thermal power mostly from the Hwange Power Station. Private generation accounts for some 68MW but this is on a seasonal basis and is consumed internally (Kayo, 2002). Electricity generation capacity in the country has stagnated at around 2000 Megawatts (MW) since 1985, even though demand has been growing steadily (Mbohwa, 2003).

Zimbabwe has been faced with serious electrical power shortages which has resulted in electrical energy imports rising to between 40% and 50% of total energy needs (Kayo, 2002; Mbohwa, 2003). The power sector has been starved of investments and an inadequate revenue flow to finance new investment. Additionally, Government approved tariff levels have been insufficient to finance investment requirements as well as other costs at generation, transmission and distribution levels (Kayo, 2002). To augment its own supplies, ZESA imports up to 40% of its demand from South Africa (150 MW), Mozambique (upto 500 MW), Democratic Republic of Congo (100 MW) and Zambia (50 MW) through an interconnected grid line (Mbohwa, 2003).

According to ZESA (2013) report, the country has experienced load shedding since 2007 as a result of low generation capacity. Load shedding as defined by the power utility, is a controlled temporary way of cutting power to parts of the country when there is not enough electricity to meet the needs of customers. Further, customers being load shed should not experience a power failure for more than 5 hours (ZESA, 2013).

2.5 Milk quality

Milk quality refers to milk that meets minimal compositional standards (i.e. butterfat%, protein%, lactose and total solids %) and hygienic standards (total bacterial counts and somatic cell counts). Milk should be of high microbiological quality, free of antibiotics and have a composition within acceptable limits. High protein, fat and total solids concentrations in the milk are associated with high yields in the resulting dairy products (Bencini *et al*., 2010). The quality of dairy products is to a large extent dependent on the quality of raw milk used in their production. Non-pathogenic bacterial species (psychrotrophic bacteria) determine the milk quality and limit the shelf-life by the production of off flavours, unwanted acidification, and structure defects, hence high-quality milk should contain less than 10^5 bacterial cells mL^{-1} (Marco & Wells-Bennik, 2008). As such countries have different legal standards and payment schemes. Legal standards are the minimum acceptable for milk offered for sale and human consumption. Supplies that do not meet these criteria may be rejected by the processor or purchased subject to specified penalties. Premiums are offered to milk that exceeds minimum quality standards. Zimbabwe legal milk standards and Total Bacterial Count (TBC) premiums are shown in Table 2.3.

Table 2.3. Legal milk standards and TBC premiums

Factor	**Legal Standard**	**Bacterial Band**	**Bacterial Range**	**Premium**
Butterfat	3.0%	AA	<20 000	14%
Solids-Non-Fat	8.0%	A	<50 000	7%
Acidity	0.19% *	B	50 001-150 000	3.5%
Harmful Organisms	Nil	C	150 001-250 000	0%
Preservatives to foreign substances	Nil	D	250 001-375 000	-3.5%
Total Bacterial Count	<500,000 cfu/ml	E	375 001-500 000	-7%
Somatic Cell Count	<1,000,000 c/ml	F	>500 000	-14%

Source: Dairiboard Zimbabwe (Private) Limited (2009)

2.5.1 Microbiological quality

Bacteria with an optimum growth at low temperatures of (0-15^{O}C) are psychrophiles, whilst mesophiles grow at medium temperatures (20-40^{O}C) and thermophiles grow at high temperatures (45-55^{O}C) (Harding, 1995). Psychrotrophic bacteria can grow at refrigeration temperatures and are of interest to those storing milk at low temperatures. Psychrophiles bacteria grow slowly and mostly feed by breaking down proteins (proteolysis) and fats (lipolysis). These bacteria can develop in raw milk during cold storage and high numbers can produce enough enzymes to cause flavour defects. Hence, measurement of bacterial numbers in milk is of interest because of their direct role in milk spoilage and as indicators of poor hygienic production. On the other hand mesophilic bacteria grow at 'normal' temperatures ranging from about 20 to 40 ^{O}C and are typified by lactobacilli which can attack the milk sugar lactose and convert it to lactic acid causing souring and even curdling of milk stored at ambient temperature (Harding, 1995).

2.6. Process flow of milk in the cold chain

2.6.1 Cooling and storage of milk on the farm

When milk leaves the cow it is virtually free from bacteria and its temperature is about 37^{O}C. Bacterial contamination from milking equipment can introduce bacteria into the milk (Harding, 1995). Bacterial contamination of milk can occur in the farm environment, during milking, storage, treatment, and transport of milk, and as a result of mastitis in the cattle herd (Marco & Wells-Bennik, 2008). Milk is an ideal balanced food for man and also provides an ideal medium for growth of bacteria. These bacteria feed by breaking down proteins (proteolysis), fats (lipolysis) and sugar lactose into lactic acid causing souring. Bacteria multiply by binary fission and in favourable conditions at high temperatures, fission can occur every 20-30 min, so in as little as 12 hour one cell can become well over 10 million viable counts (Harding, 1995). Milk must therefore be cooled as soon as possible after milking to a temperature below 4^{O}C in order to minimise bacterial growth. Cold water, chilled water or preferably refrigerated units can be used for cooling milk at the farm. Where milking machines and refrigerated bulk farm tanks are used, an ice bank in the bulk vat very rapidly cools milk to below 4^{O}C (Harding, 1995).

2.6.2. Collection, delivery and reception of milk

The frequency at which milk should be collected depends on the on-farm storage capacity and the refrigeration temperatures which can be achieved. Potential transport cost savings can be made by less frequent collection of milk with a possibility of storing milk for 7 days at 1.5-2^{O}C provided the initial quality is excellent (Harding, 1995). Milk is commonly stored on the farm at cooling conditions for up to 2 day before transport to the dairy for processing (Forsbäck, Lindmark-Månsson, Svennersten-Sjaunja, Bach Larsen, & Andrén, 2011).

2.6.3. Can collection

Cooled milk in cans is usually taken to a convenient collection point just before the collection vehicle arrives in many systems. Cans should be protected from sunshine and are usually taken to collection centres where milk in each individual can is inspected. If the milk is acceptable, the volume is measured and recorded, samples are taken and the cans are emptied into a bulk vessel for cooling and storage (Harding, 1995). The can delivery is common amongst smallholder dairy farmers in Zimbabwe. However, the system has been adopted by some large scale dairy farmers whom because of low milk production find it uneconomical to send milk to the processor using the bulk milk collection but rather send the milk directly to the processor by cans.

2.6.4. Bulk collection

Milk stored in refrigerated bulk tanks is collected by being pumped into a tanker, after the tanker driver has checked the temperature assured himself by sight and smell that the milk is satisfactory. The milk volume will have been measured by a calibrated dipstick or normally by use of an automatic flow meter on the collection vehicle. In modern dairy, automatic recording of milk volume together with other data such as temperature is becoming more common using micro-computers on the collection vehicles. In this system automatic data capture provides a collection ticket, a copy of which is left with the producer and data on magnetic tape which can be automatically transmitted to the collection centre computer (Harding, 1995). Since the individual farm supply will be blended in the tanker together with supplies from other farms, it is desirable to take samples of each consignment at point of collection for traceability should there be any problems with the quality of milk in the tanker (Harding, 1995). It is particularly important that the milk is at the correct temperature before loading since the refrigeration systems used in most transport containers are not designed to extract heat from the load but to maintain the temperature of the load. Irrespective of the type of refrigeration equipment used, the product will not be maintained at its desired temperature during transportation. In large containers used for long distance transportation food temperatures can be kept within ± 0.5^{o}C of set point (James & James, 2010a).

Bulk Milk Collection in Zimbabwe is commercially carried out by the National Dairy Co-operative (NDC). NDC also owns and rents out bulk storage tanks to producers. The cooperative is run commercially and is owned by large scale commercial dairy producers in the chain. Recently, processors own bulk milk trucks to augment the National Dairy Cooperative fleet. Gwezuva (2011) pointed out that the frequent power cuts and reduction in milk volumes has seen quite a number producers opting to deliver milk in cans to processing plants as a cost saving strategy. This has affected milk quality with large volumes of milk being rejected at milk processing plants.

2.6.5. Delivery and storage prior to processing

The bulk tanker, having collected milk from its allocated farms, will then deliver it to the processor. The bulk tanker contents will normally be sampled on receipt, the milk is inspected by smell and taste and tested by rapid techniques to ensure the milk is of acceptable quality (Harding, 1995).

2.6.6. Storage of milk prior to processing

Where milk is to be stored before being pasteurised, bacteriological spoilage can best be minimised by keeping milk cool, preferably at temperature below 4^{O}C. If milk is to be stored for long periods, deep cooling to 2^{O}C is applied (Harding, 1995).

2.6.7. Tests for cooled milk

For milk cooled to below 5^{O}C, the psychrophilic and psychrotrophic organisms grow and different test methods are required. The most widely used test as a general indication of good hygienic production is the total bacterial colony count (TBC) commonly called standard plate count (SPC) (Harding, 1995).

2.6.8. Milk quality control at reception in Zimbabwe Dairy sector

Before taking milk at the farm in the bulk transport system, milk is examined by a trained bulk driver who either accepts or rejects the milk at the farm if it does not meet set quality standards. The examination includes rapid platform/organoleptic tests that examines the colour of the milk, smell or flavours and measuring the temperature. The driver also measures the volume of milk using a dip stick or flow meter mounted on the truck. A sample is also collected by the driver and put in a cooler box with ice for further laboratory tests at DSU laboratories. The basis for the laboratory tests is to check on milk keeping quality, milk cleanliness, milk composition and milk safety which will be used as a basis for payment by the processor to the producer. At the processing plant reception, milk will undergo further platform tests before being offloaded into plant silos. Volume of milk is measured. Milk from producers can be accepted or rejected depending on platform tests results.

2.6.9. Dairy Herd Improvement (DHI) and quality payment laboratories

The Dairy Herd Improvement (DHI) is a good management practice for farmers to have a measure of the yield and quality (fat and protein) of individual cows within the herd in order to provide them with information to better feed individual cows and to judge the value of the cow for breeding and sale. Such service is often provided by an independent DHI Authority and these often operate mass testing laboratories, using automatic instrumental methods of analysis (Harding, 1995). Samples of bulked herd milk are also taken regularly for quality payment purposes (Harding, 1995). All commercial dairy herds in Zimbabwe fall under the Zimbabwe Dairy Herd Recording scheme (ZDHI). Individual lactating cow milk samples are taken once in two months for lab analysis on milk quality and composition. Factors that are analysed are herd health parameters, bacterial counts and somatic cell counts (SCC), milk composition (fat, protein, and lactose levels). This herd information is sent to the farmer for their dairy herd management and is coordinated by Dairy Services Unit.

2.7. Quality and safety standards in the food supply chains

A number of food scares in recent years have left consumers confused about what is and not safe and uncertain of the government's role in supporting their interests (Martinez, 2010). This has resulted in increasing public distrust and reduced consumer confidence in the safety of food, the food industry and government's ability to regulate, manage and communicate food risks (Martinez, 2010). Microbiological hazards in food are judged by scientists to be one of the main risks to health. As a result major buyers such as multiple food retailers frequently require their suppliers to implement food safety controls based on hazard analysis and critical control points (HACCP) principles. Although private standards have been developed in many countries, some standards have progressed beyond national status to become global standards and have become the domain of private sector with governments mainly providing a regulatory and hygienic oversight (Baines, 2010). These standards include pre-farm gate standards (Global GAP and ISO 22000) and food industry standards; [British Retail Consortium (BRC) Global, International Food Standard (IFS), and International Organisation for Standardisation (ISO 22000)]. However with some of the standards (ISO 9001:2000 and BRC) a company can be certified against the specific standards, but HACCP only provide guidelines or principles to support a company in setting up its own Quality Management System (QMS) (Luning & Marcelis, 2009).

The Codex Alimentarius standards (a collection of internationally recognized standards, codes of practise guidelines relating to food, food production and food safety) although not compulsory, they are increasingly being embraced in national rules and guidelines especially the adoption of HACCP. However, private standards are not subject to World Trade Organisation (WTO) trade rules as they are classified as voluntary standards even although they may dominate supply chains and effectively be used as conditions for market access (Baines, 2010). Reviews of various supply chains have shown that the adoption of HACCP to address food safety risks generally does not include primary production level where codes of good agricultural practice (GAP) are in practice. The main arguments for relying on GAPs is that HACCP is considered to be too difficult to implement. Baines (2010) pointed out that HACCP can be strategically placed further along vertically integrated chains. Indeed adopting HACCP at strategic stages has been particularly important for safer supply of livestock products (e.g. meat at slaughter stage and milk from first buyers onwards). When GAPs are considered within HACCP system they should be accurately described as HACCP prerequisite programmes (Martinez, 2010).

2.8. Critical Control Points (CCP)

A critical control point (CCP) is a step (i.e. point, procedure, operation, or stage in the food production system) at which control can be applied and where control is essential to prevent or eliminate a food safety hazard or to reduce to an acceptable level (Luning & Marcelis, 2009). There is no standard CCP in food production process they are unique at each stage. Moreover there is no limit on the number of CCP's that may be identified in the flow diagram, however it is important to strive for a lean system, and prevent an excessive number of CCP's (Luning & Marcelis, 2009).

2.9. Quality control in Zimbabwe Dairy sector

The Dairy sector in Zimbabwe is guided by the national Dairy Act [Chapter 18:08] and dairy regulations RGN No. 886 of 1977. The Dairy Act gives basic principles whilst the regulations are narrow and specific for each aspect of dairy activity to fulfill the principles of the Dairy Act (DSU, 2013). These regulations are enforced by Dairy Services, a government regulatory body. Milk and milk products for sale can only be produced on dairy farms and processing plants specifically registered for this purpose. To be registered, the premises must meet the requirements for clean milk production and the sale of milk should be regularly tested to ensure that it meets the minimum legal standards (Gwezuva, 2011). Milk processors encourage production of good quality milk by paying premiums for good quality milk and implementing penalties or rejections for poor quality milk.

Chapter 3 : Methodology

3.1 Study Area

The study was conducted in Mashonaland East province in Zimbabwe (Figure 3.1). This province is located in natural ecological region II and III with an average annual rainfall of 650-1000mm.The dairy production systems found in this area varies from intensive zero grazing, through irrigation pastures to dairy ranching with low feed inputs. Being a cropping area, a great deal of home-grown feed is used for a home-mixing based on maize silage, oil cakes and purchased concentrates. Most dairy farms are located in Mashonaland East province because of its close proximity to Harare where about 46% of the national milk intake is processed, the climate and topography is better suited for dairy as compared to other regions. Hence the province forms a representative sample to draw conclusions on the overall status of the dairy sector. The dairy farms are connected to the national electricity grid, and fall within a distance of 15 to 130 kilometers to the processor linked through a good road network of tarred roads (DSU, 2013).

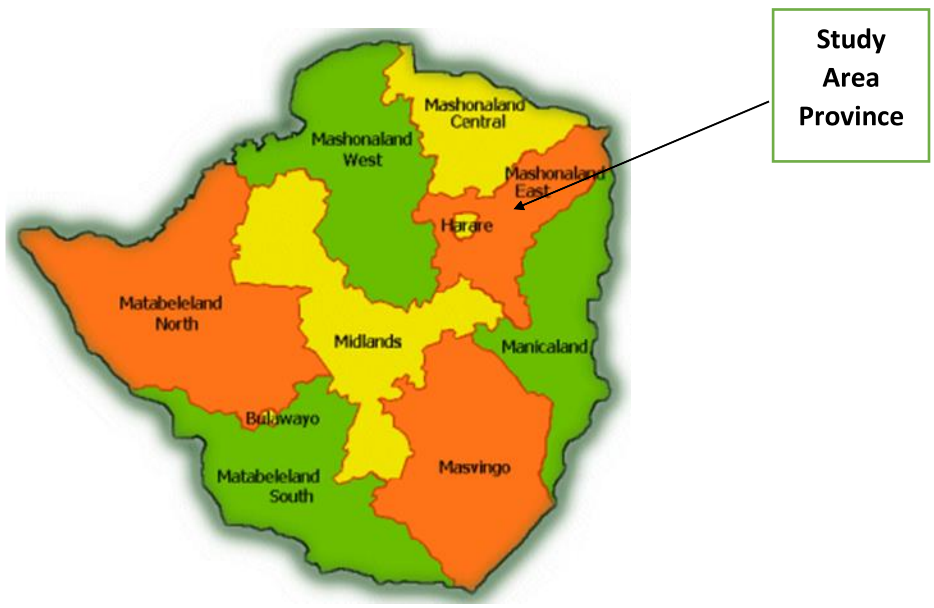


Figure 3.1. Location of Mashonaland East province in Zimbabwe. Source: (Google maps, 2012)

3.2. Overview of research strategy

The research collected both quantitative and qualitative data based on empirical data through desk study, surveys and case studies. Sources of information included individual people (respondents, informants and experts), literature and real observations. Thirty large scale commercial dairy (LSCD) famers in Mashonaland East were randomly selected for the survey using national data from Dairy Services Unit (DSU). The farmers were grouped into two clusters according to their method of milk delivery (can and bulk milk collection). Key informants and experts were interviewed in the case studies to get in-depth knowledge about the research subject. Retailer shops were visited to get a snippet view of the responses. The contact details for individuals for surveys and case studies was sought from DSU. This was followed by contacting the people through e-mail and telephone to make appointments for data collection and briefing them on the aim of the study. The period for data collection was four weeks from July to August 2013. Surveys were conducted first before case studies of key informants and experts. This sequence of data collection was influenced by matters of logistics and time management given the short duration for data collection and the need for key informants to respond to concerns arising from the farmer's surveys.

3.3. Secondary data

3.3.1. Desk research

Literature review to contextualise and summarise current literature on the research subject was sought mainly from the digital library of Wageningen University. Various books and journals, internet sites, annual and monthly reports from DSU and other stakeholders in the dairy sector in Zimbabwe were used as sources of information. Value chain mapping as a tool was used to show the actors relationships in the dairy value chain in Mashonaland East using information from literature and the researcher's insight knowledge of the chain. A desk study on TBC was conducted using secondary data from test results obtained from the database of DSU. The rolling six months records for Total Bacteria Count (TBC) from the interviewed farmers were further compared with DSU records for statistical analysis.

3.4. Primary data

3.4.1 Survey

A survey was carried out with assistance of dairy officers from Dairy Services unit (DSU) in Harare. The target group was large scale dairy farmers in Mashonaland East province. The choice for the target group was justified by the fact that most dairy farms are located in this province because of its close proximity to Harare where about 46% of the national milk intake is processed. Hence the province formed a representative sample to draw conclusions on the overall status of the dairy sector. Thirty large scale dairy farmers in Mashonaland East were randomly selected from DSU database and interviewed using structured questionnaires with open and close ended questions (Annex 1). All farmers interviewed were experiencing load shedding. Two clusters of farmers were established according to method of milk delivery. The farmers were divided into those using the bulk milk collection and farmers using the can milk collection system (15 for each group). This clustering made it possible to evaluate the effect of load shedding on the cold chain as these farmers have different delivery intervals to the processor and farm storage time.

Closed questions were pre-corded for easy data entry. Inclusion of open questions gave a deeper understanding of the respondents' views. Pre-testing of the questionnaires was conducted on a colleague at DSU to make certain that all the questions were understandable to all the interviewees and make adjustments were necessary. Basic protocols for carrying out interviews were followed and the objectives of the study was clearly explained to respondents. Face-to-face structured interviews were conducted with respondents. The interviewer read the questions and recorded the answers of each respondent. Although the use of face-to-face interviews as a means of data collection had the advantage of avoiding any possible misunderstandings of questions and answers among respondents, its major drawback was the amount of time associated with the method which limited the size and geographical coverage of the survey. Farms indicated on the itinerary were visited each day (at least 4 farms per day) and one hour was spent at each farm.

3.4.2 Case study

Open interviews using a checklist or an unstructured questionnaire (Annexes 2-4) were conducted on key informants to get in depth information (qualitative data) about the effects of load shedding on the dairy cold chain. In this method a question guide was provided for the interviewer to direct the interview. However, the specific questions and the sequence in which they were asked was not precisely determined in advance. The questioning was characterised by probing and follow up depending on the type of the answer from the respondent. The case studies were conducted with the following experts and informants:

3.4.3 Chairperson, Zimbabwe Association of Dairy Farmers (ZADF)

The informant represents the views of all dairy farmers in the country. Decisions made in the sector on issues related to farmers can only be successful with the full backing of the association thus the need to involve them. Interviews focused on load shedding, cold chain infrastructure in the value chain and operational costs due to load shedding.

3.4.4 Chief Executive Officer, National Dairy Cooperative (NDC)

Milk transportation is an integral part of the cold chain. The Chief Executive Officer is the head of the transportation cooperative NDC which is involved in transporting 95% of the milk delivered to processors. The bulk milk truck drivers from this co-operative are trained to carry out platform tests at the farm which includes checking the temperature of the milk before accepting the milk. If there is non-conformity with set standards the milk will be rejected. Interviews focused on collection intervals and milk rejections associated with load shedding.

3.4.5 Chief Dairy Officer (CDO), Dairy Services Unit

Dairy Services Unit has the responsibility of regulating the dairy sector by administering the Dairy Act and offering advisory services. Therefore the contribution of the Chief Dairy Officer was important in giving an overview of the status of the dairy value chain.

3.4.6 Quality Control Manager- (Dairiboard Zimbabwe and Nestle Zimbabwe)

Milk produced in Mashonaland East province contributes to 46% of the national milk intake processed in Harare by the two major processing companies Dairiboard Zimbabwe Private Limited (DZPL) and Nestle Zimbabwe. The Quality controller managers of these processing companies are directly in charge of all product quality aspects at the processing plant. Raw milk rejection at plant intake or reception area is a decision directly under the Quality Controller.
Interviews focused on milk rejections, milk quality standards, load shedding and cold chain.

3.5 Observations

Observations were used to validate the information given by farmers during survey interviews by checking with that on the ground. A brief extract on the retailers to assess how load shedding was impacting the cold chain was conducted on random supermarkets in Harare. Table 3.1 shows a summary of data sources.

Table 3.1. Summary of Data Sources

Sub question	Information	Source
1.1.	Frequency and duration of loading shedding in the province.	Case study/ open interview with key informant, Survey, Desk study (secondary literature and data)
1.2.	Interventions of actors in the chain to deal with load shedding.	Survey, Case study with all key informants and experts
1.3.	Support from stakeholders.	Survey, Case study
1.4.	Effect of load shedding on production cost.	Survey, Case study
1.5.	Milk rejection rates at the farm reception and the processing plant arising from load shedding.	Survey, Test results (from Dairy services data base)
2.1.	Infrastructure available to maintain the cold chain by actors in the chain.	Survey , Case study interviews
2.2.	Critical control points in the dairy cold chain to ensure safe and quality milk production.	Case study with experts
2.3.	Milk quality testing procedures available at collection at the farm level and reception at the processing plant.	Case study with key informants and experts

3.6 Data analysis

The Statistical Package of Social Sciences (SPSS) version 21, was used for data entry and analysis to generate descriptive analysis and inferential statistics (Chi-square test, Mann Whitney test, t-test and correlations). Quantitative data from surveys was coded to enable SPSS analysis and easy data entry. For qualitative data, the input of the interviews from the case studies was processed by grouping, organizing and structuring the responses. Correlation between microbiological counts and load shedding was analysed with Spearman tests of SPSS.

3.7 Limitations of the study

The study did not interview the power utility (ZESA) to get the organisation views on load shedding. The information was derived mainly from secondary data through literature. Although retailers and consumers form an integral part of the cold chain, the study did conduct in-depth surveys with these actors. The research only did snippet surveys and observations on these actors, this leaves a scope for further research. In addition, the research was conducted during the period the country was holding general elections as such the study was interrupted for a week to pave way for elections.

Chapter 4 : Results

This section represents the findings of the interviews from survey and case studies in the dairy cold chain. The results start with producers as the first actors in this chain and ends with retailers. Responses from case studies of key informants are also presented.

4.1 Demography of the sample

The demography of interviewed producers revealed a gender proportion of 83% males and 17% females. The sample size for the survey (n=30) was clustered into can and bulk delivery method each representing 50% in proportion. The producers interviewed were of varied ethnicity and comprised of 50% black farmers, 47% white and 3% Indian or Asian farmers. The majority (70%) of the farmers interviewed had a dairy farming experience of 11 years or more. Figure 4.1 shows a collage of pictures from some of the producers interviewed.

Figure 4.1. Sample of producers interviewed. Source: (Author, 2013)

4.2 Frequency and duration of load shedding in the province

The study showed that the majority (47%) of respondents in the province were experiencing load shedding at a frequency of 3 times a week (Figure 4.2). The mean value for frequency of load shedding was also 3 times per week (Annex 5). The load shedding was ranging between 4-8 hours and 9-15 hours per day in duration each response representing 33% (Table 4.1). The majority (93%) of respondents stated that the load shedding was not scheduled and only a few (7%) mentioned that it was.

Figure 4.2. Frequency of load shedding per week in Mashonaland Province Zimbabwe

Table 4.1. Duration of load shedding/day

Hours	No. of respondents	Percent (n=30)
1-3 hrs	6	20
4-8 hrs	10	33
9-15 hrs	10	33
Other	4	13
Total	30	100

4.2.1 Milk production challenges due to load shedding at producer level

The producers revealed that due to load shedding they were experiencing a plethora of problems *inter-alia:*

- Milking is affected due to disruptions in milking times. Farmers resorting to hand milking which leads to high cost of labour (Figure 4.3).
- Milk yield is affected because of lack of water for animals to drink (water pumping from electric boreholes affected by load shedding).
- High cost of diesel to power generators to cool milk, run milking machines, lighting and general errands on the farm.
- Damage to machinery due to voltage fluctuations from the power utility.
- Hygiene on the farms is affected because of lack of heating and water for cleaning milk equipment.
- Cold chain is broken which affects the cooling of milk.
- There has been a rise in the use of imported milk powders by processors.

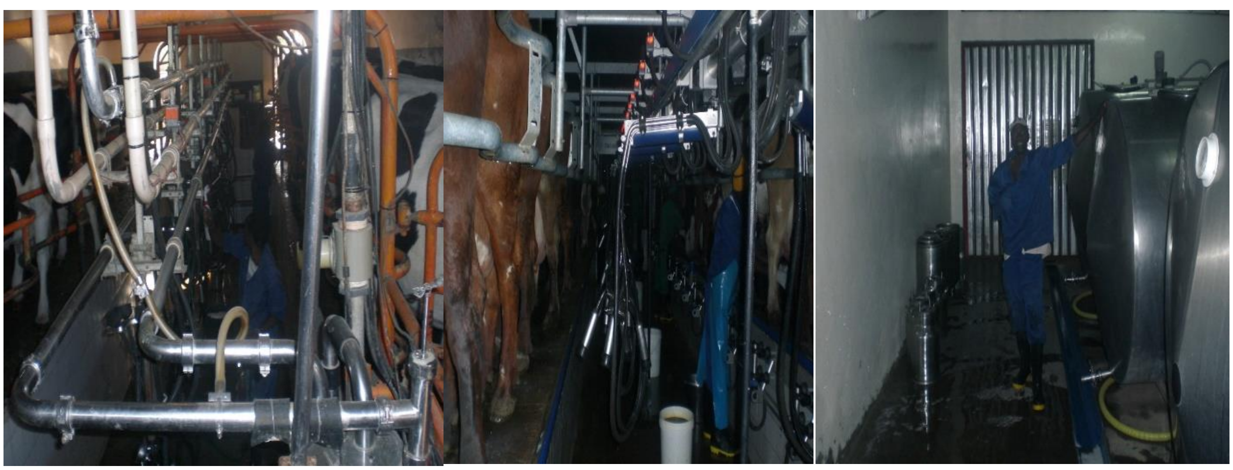


Figure 4.3. Some of the operations affected at the farm, milking (left) and bulk chilling (right) Source: (Author, 2013).

4.2.2 Interventions to deal with load shedding and temperature maintenance

The majority of producers (50%) stored milk at 3^{o}C, followed by 27% who kept milk at 4^{o}C, 13% kept milk at 2^{O}C and the remainder (10%) at 5 ^{O}C. The opinion of producers regarding the relationship between temperature maintenance and load shedding showed that 97% (n=29) of the respondents thought that load shedding affected milk storage temperature and 3% declined this view (Figure 4.4). Those in agreement added that storage tanks required a continuous supply of electricity for effective chilling while those who declined stated that it depended on the availability of generator and duration of load shedding otherwise they might not be no effect. To maintain recommended milk storage temperatures in the wake of load shedding most producers had resorted to using big generators (50kVA or more) to maintain the cold chain and sustain other operations. However, this resulted in high investment and running costs. Some farmers were sending the milk directly to the processor or calling the bulk transporter to immediately deliver milk to processor, which again came with huge costs.

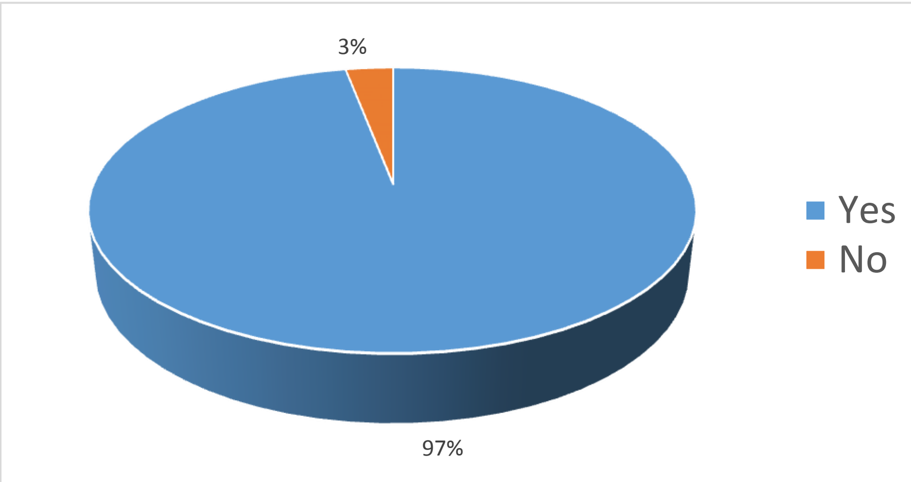


Figure 4.4. Storage temperature affected by load shedding

4.2.3 Milk rejections linked to load shedding

About 60% of the producers reported that they did not encounter milk rejections by the processor because of unacceptable temperatures and only 40% experienced these rejections in the past. The frequency of rejections were on average 2 times per year with an estimated loss in revenue per individual producer of US$ 1 500/year (€1 138)[2] (Annex 6). No rejections were reported at the time of the study (year 2013). There were no significant ($p>0.05$) differences in milk rejections between bulk and can delivery producers (Annex 7).

4.3 Effect of load shedding on production costs

The majority of farmers were using heavy duty generators as a backup to load shedding. These generators have an output of 80-100 kVA and can power three-phase appliances such as bulk chilling tanks, milking machines and borehole motor pumps (Figure 4.5). However, they come at a high cost of US$18000 - $ 24000 per unit (€13661- €18214) depending on the size and brand name. These generators consume on average 14 litres of diesel/hour and normally the producers operate these generators for 3 hours and switch them off when the milk is chilled to the correct temperature to minimise generator running hours and costs.

[2] 1USD=0.76 EUR

Figure 4.5. Generators being used by producers. Source: (Author, 2013)

Given that producers have a milking frequency of 2 times per day, the generator hours can be 6 hours on average depending on the duration of load shedding. Most producers interviewed complained that the cost of running generators was high. Table 4.2 shows a comparison of the cost of using a generator and electricity from the grid to cool milk and Table 4.3 shows the cost of a running a generator during periods of load shedding for major dairy activities (milking machine, running boreholes and milk chilling). Annexes 8-9 show the figures for average unit energy use in kWh/cwt for various cooling systems and the ZESA tariffs used for calculating the milking cooling cost. The results from the tables shows that it is expensive to run generators as compared with the electrical grid**.** These calculations concur with the calculations of some of the farmers interviewed who said, "*On a bad month they could spend US$ 2 000 on generator (diesel) use compared to the US$ 700 they would normally pay from the electrical grid*."

Table 4.2. Comparison of electricity and generator for chilling milk

Cooling Method	**Time (hrs)**	**Power Consumed (kWh)**	**Price /kWh (US$)**	**Cost per cwt (US$)**
Electricity	1	1	0.14	0.14
Generator	1	0.53	1.35	0.71

Adopted: Upton, Murphy, French, and Dillon (2010)
*Electrical energy (kWh) = Power consumed (kW) * time (hrs)* price per kWh
**Price of diesel is US$ 1.35 per litre
***Cwt is Hundredweight unit- equivalent to 100 pounds (45kg)

***Table 4.3*. Cost of running a generator per week (Incl. other farm operations)**

Duration of load shedding per day	**Average frequency of load shedding per week**	**Average fuel consumption ltrs/hr**	**Cost of diesel (US $)/ltr**	**Total cost/week (US $)**	**Total cost/month (4wks) (US $)**
8	3	14	1.35	454	1 814

4.4 Effect of load shedding on Milk quality

Milk delivery interval for the majority of producers to processors was every 2nd day (77%) followed by daily delivery (20%) and 3% delivered after 3 days. A high proportion of producers

(90%) agreed that there was a relationship between load shedding and milk quality with only a few (10%) disagreeing (Figure 4.6). This relation was attributed to the disturbance in milk chilling as a result of power cuts which can lead to an increase in bacterial count and milk spoilage. Other factors highlighted by producers related to the fact that dairy cows are used to milking routine and any disturbance in the cycle will cause mastitis (inflammation of the udder) which negatively affects milk quality. Producers use borehole water for their dairy activities which is pumped by electricity. A lack of water for cleaning milking machinery and other general purposes due to load shedding compromise on hygiene and milk quality (TBC). The proportion of producers who disagreed stated that it depended with the availability of a backup generator and duration of load shedding. However with the generators, producers could only afford to cool milk intermittently for 3 hours soon after milking and not continuously to minimise on generator hours. This could compromise milk quality, because the bulk tank agitator should continuously run for effective cooling of the milk and prevent milk fat accumulation. There were no significant ($p>0.05$) differences in the opinion regarding relationship between load shedding and milk quality between bulk and can delivery farmers (Annex 10).

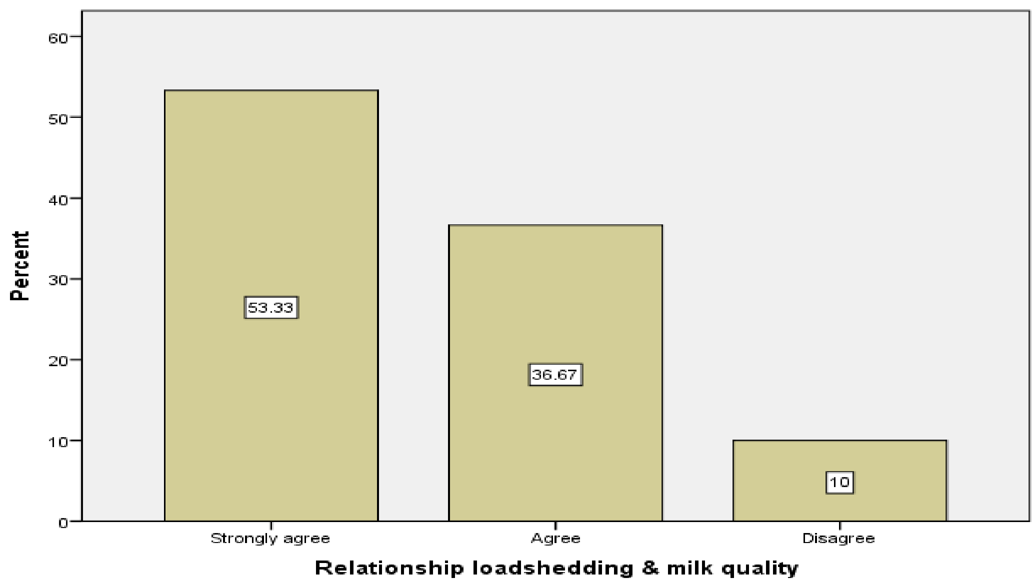


Figure 4.6. Relationship between load shedding and milk quality

4.4.1 Total Bacteria counts

Table 4.4 shows the average Total Bacteria Count (TBC) for a rolling 6 months period of raw milk from the producers. Most farmers were in band C (30%) followed by 23% in band B, with each having a TBC range of 150 0001-250 000 and 50 0001-150 000 respectively. A considerable number 20% and 17% were in premium band AA and A respectively. Most respondents (87%) affirmed that there was a relationship between TBC and load shedding and the remainder (13%) said there was no relationship. There were significant difference ($p<0.05$) in TBC between can and bulk delivery farmers (Annex 11). Can delivery farmers had a higher TBC count of 150 001-250 000 (Band C) than bulk delivery farmers who were in Band B.

However, there was no correlation ($p > 0.05$) between load shedding and Total Bacterial Count (Annex 12).

Table 4.4. Average TBC for producers

TBC count per ml	No. of producers	Percent (n=30)
AA <20 000	6	20
A <50, 000	5	17
B 50,001-150,000	7	23
C 150, 001-250,000	9	30
D 250,001-375,000	2	7
E 375,001-500,000	1	3
Total	30	100

Source: DSU (2013)

4.4.2 Opinion on current legal standards

The majority (83%) of farmers felt that the current legal standards on milk quality were appropriate. A few (17%) of the producers felt that the standards were strict as some farmers explained that, "*The regulatory body was putting first world standards on a developing country without providing the supporting stuctures."* Nonetheless, there were no significant ($p>0.05$) difference in the evaluation of current legal standards between can and bulk delivery farmers which proves that the legal standards were generally viewed as appropriate by both parties (Annex 13).

4.4.3 Infrastructure to maintain the cold chain

The study revealed that nearly half (47%) of the farmers had bulk tanks, cans, thermometers and generators as their cold chain equipment (Figure 4.7). Other farmers had an assortment of other equipment on their farms which included cold rooms, immersion tanks and a few had plate heat exchangers (PHT). Figure 4.8 shows some of the cold chain equipment owned by the producers.

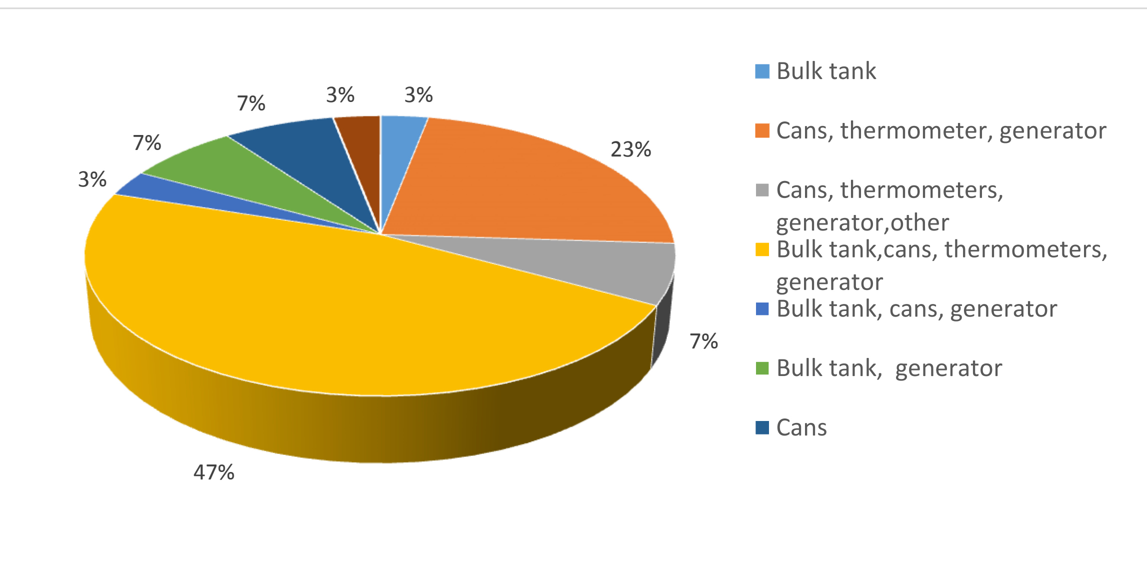


Figure 4.7. Equipment to maintain cold chain

Figure 4.8. ***Various cold chain equipment from left to right, milk cans, open bulk cooler, closed bulk cooler and plate heat exchanger. Source: (Author, 2013)***

4.4.4 Support services available to maintain the cold chain

The producers stated that they were not getting any financial assistance from chain supporters to address load shedding and maintain the cold chain. It has been the producers' own initiative to purchase generators as a mitigating measure but this situation needed to improve. The producers further compared their situation with seasonal tobacco farmers who normally get preferential treatment by being exempted from load shedding during peak periods of production, a situation dairy producers have been unsuccessfully lobbying from the power utility.

4.5 Bulk Transporters

4.5.1 Response from Chief Executive Officer, National Dairy Cooperative (NDC)

The Chief Executive Officer (CEO) of the bulk milk transporter pointed out that milk is susceptible to lack of chilling and when there is no power people run generators but it is expensive because of the number of generator hours needed to maintain milk temperature. The CEO highlighted that, "*Producers are not cooling the milk continuously, and the tendency is for producers to immediately cool milk before collection so that milk can be collected at the correct temperature of 4 ^{o}C and avoid milk being rejected. However, this has a serious impact on milk quality*." The bulk collector confirmed that they conduct platform tests and checks for correct temperature before accepting milk at the farm. The bulk transporter highlighted that when load shedding is prolonged the producer can call the transporter to collect the milk outside the normal scheduled collection interval of every second day. However, this becomes expensive for the farmer as they have to pay more for the route which is normally shared amongst producers falling under the same route under normal scheduled collection intervals. A break in the cold chain could occur if there is no electricity when the bulk tanker reaches the processor. It will be difficult to pump milk out of the bulk tankers and this delay can lead to deterioration in milk quality. As an intervention to address the effect of load shedding to producers, the bulk transporter has been advising farmers on where to acquire generators, otherwise the issue of load shedding had been viewed as a national problem which is beyond them. Comparing the cost of milk production with other regional countries such as South Africa, the production cost in Zimbabwe was high due to various factors which included power cuts despite the basic producer price of US$ 0.50/litre (€0.38)[3] being the highest in the region. The bulk transporter highlighted that biogass ingesters could be an intervention strategy to address the effects of

[3] 1USD=0.76 EUR

load shedding but stressed that solar as an alternative has the limitation of needing many panels to generate the required kilowatts to run the equipment. Figure 4.9 shows the fleet of vehicles used by the bulk transporter to maintain the cold chain.

Figure 4.9. Bulk transport system. Source: (Author, 2013)

4.6 Response from Milk processors

4.6.1 Milk quality testing procedures

The informants from the two major milk processing companies (Dairiboard Zimbabwe Private Limited (DZPL) and Nestle Zimbabwe) indicated that they conduct tests for antibiotics, temperature, organoleptic tests, alcohol test and adulteration using the freezing method at milk reception. They pointed out that milk is received at 4-6^{o}C and had not rejected milk because of unacceptable temperature in recent past but for other reasons such as antibiotic residues. The informants indicated that load shedding was precarious to the maintenance of the cold chain. Nonetheless, this problem was being circumvented by use of generators. Producers were reported to have a tendency to overcool milk in anticipation of load shedding. The informant from Nestle Zimbabwe indicated that his company was supporting farmers contracted to them with generators under a loan scheme. All their producers had two generators with one standby generator in case the other fails. This proved how serious load shedding was to the cold chain. The company had gone further to negotiate with ZESA for uninterrupted electricity supply although it was slightly more expensive by 2% from the normal tariffs.

4.6.2 The Critical Control Points (CCP)

The Critical Control Points in this dairy cold chain were identified as temperature control at milk storage at the farm level, transportation, processing and storage of dairy products at retailer level. The processors expressed that the current legal standards on milk quality were comparable to any in the world. Milk quality testing was done by an independent body Dairy Services, which is involved in testing and grading of raw and processed dairy products, see Figure 4.10.

Figure 4.10. Technicians at Dairy services doing lab tests on milk products and a milk recorder taking milk samples for Dairy Herd Improvement (DHI) tests. Source: (Author, 2013)

The processors had in place international food safety standards and certification such as HACCP, ISO 22000, ISO 14000 (environmental) and Nestle had its own Quality Management System (NQMS). Although load shedding was also affecting processors in maintaining the cold chain, the effect was minimised by investment in massive generators and big water tanks. From the processors point of view these generators were seen as an investment. The processors indicated that one has to come up with this calculation that, *"If the generator is not there what are the losses, the investment has to match the down-time or losses that may occur*." As the lead firms in this chain, the processors extension wing, work closely with producers to improve milk quality. The processors offer premium prices for good quality milk which can go up to US$ 0.72c /litre up from the basic price of US$ 0.50c/litre.

The processors highlighted that in order to address load shedding and maintain the cold chain, interventions should include improving the country's electricity generation capacity through its thermal and hydro power stations and use of alternative energy sources such as biogas, generators and solar power. They hinted that a pilot solar project at one of the dairy farms was in the pipeline which would see the construction of over-head solar panels lined up in paddocks performing a dual purpose of generating electricity and providing shed to the dairy cows. This concept is derived from solar farms in South Africa. The informants also mentioned that there has to be a change in the mindset of people to reduce carbon footprints and more holistically there is need to strengthen the manufacturing sector to drive the economy. Figure 4.11 shows one of the processing plants visited DZPL.

Figure 4.11. Key informant from Nestle from left (middle gentleman) and DZPL processing plant. Source: (Author, 2013)

4.7 Retailers

A visual assessment in retailer shops showed a distinct presence of long life or UHT milk products and powdered milk (Figure 4.12). Snippet interviews of retailers revealed that as a result of load shedding, they had resorted to run expensive generators to keep perishable products such as milk products on the shelves. There was an inconspicuous presence of fresh milk on the supermarket shelves. There was an indication that processors had shifted from producing fresh milk for retailing largely because of its short shelf life which was negatively affected by load shedding. Retailers indicated that fresh milk was quickly getting sour and they received many complaints from consumers.

Figure 4.12. Milk products found on retailer supermarkets. Source: (Author, 2013)

4.8 Chain supporters

4.8.1 Chairperson: Zimbabwe Association of Dairy Farmers (ZADF)

The Chairperson of the Dairy Farmers Association mentioned that the effects of load shedding was felt on the whole chain from input suppliers, producers, processors, retailers and consumers. Producers and processors were affected in the sense that they were not able to chill the milk and maintain the temperature of milk products. The Chairperson indicated that at retailer level, distributers and consumers' had shifted from fresh milk to long life (UHT) milk because of the short shelf life of fresh milk. Further, actors in the chain had resorted to the use of generators in response to load shedding.

Although the association was still working on the actual figures, the Chairperson hinted that the costs of production at producer level were high. The costs of running generators was estimated to be three times more than using electricity from the grid. These high production costs were said to affect the competiveness of the dairy chain when compared to regional imports. Even though the basic producer price of US$ 0.50/litre of milk being offered by the sector was said to be high in the region, the chain actors needed to cut on production costs especially generator costs to remain viable. The producers also needed to improve on milk quality which was threatened with load shedding to get premium prices. Stock feed companies were reported to transfer the costs of running generators to the next actors in the chain by increasing stock feed prices despite the fact that milk prices remained fixed. The association was working on benchmark figures to lobby for an increase in milk prices to the Government.

In response to alternative energy sources, the Chairperson (Figure 4.13) expressed that solar technology was not really developed in Zimbabwe and was currently used on a small scale. Solar energy was currently used for just heating water and lighting. Hence, the Government needed to come with policies to promote use of solar energy and change the mindset of actors. "*Use of these alternative energy sources, including Biogas could half consumers' bills*," said the Chairperson.

Figure 4.13. Chairperson of ZADF (right) on a water heating solar system. Source: (Author, 2013)

4.8.2 Livestock and Meat Advisory Council

This organisation together with ZADF had a mandate to come up with the actual cost of the effect of load shedding on the dairy chain. At the time of the interview there were no figures on the costs, however the economists indicated that calculations for the cost would be derived from primary data from farmers on direct costs such as fuel use, indirect costs like rejections/losses. Other costs would include shift from milk machines to hand milking, labour costs, costs of buying and servicing generators, transport to buy fuel, depreciation of generators and damage to machinery.

4.8.3 Chief Dairy Officer-Dairy Services Unit

The Chief Dairy Officer (CDO) expressed that the effect of load shedding was more severe at production level as most farmers had challenges during milking and have in turn resorted to hand milking especially those without generators (Figure 4.14). Chilling of milk was affected because milk has to be cooled immediately within 2 hours from 37^{o}C to 4^{o}C and this implies more generator hours.

Figure 4.14. Interview with Chief Dairy Officer (lady behind the computer) Source: (Author, 2013)

The CDO confirmed earlier findings that no cases of milk rejections had been reported at processor reception because of unacceptable temperature. However there were reported cases where the bulk tanker driver fails to pump milk into the bulk truck on arrival at farms without electricity. The CDO expressed that although actors in the chain had been circumventing effect load shedding on the cold chain by using generators this was costly when compared to use of electricity from the grid. As such, the production costs were high and uncompetitive despite the fact that the basic producer price of US$0.50 /litre of milk was the highest regionally. There have been growing concern from the Environmental Management Authority (EMA) on the implications of generators in environmental pollution. Resultantly, EMA has been considering options of levying producers for the pollution. The effect of load shedding at retail level was felt in the decrease in shelf life of milk products. The consumption pattern of fresh milk had decreased from 27% to 7% per capita. The current legal milk standards of RGN 1977, were being reviewed to match international standards. The institution has been lobbying the power utility ZESA to address the plight of actors in the dairy cold chain regarding load shedding. The government had been approached to provide generators under various schemes, although most producers were buying on their own accord.

Chapter 5 : Discussion

This chapter will discuss the findings from analysing the effect load shedding on the dairy cold chain and milk quality in the dairy value chain of Mashonaland East province of Zimbabwe. The findings from this study will be compared with literature and results from other similar studies.

5.1 Demography of the sample

From a value chain perspective it was evident that gender aspects were incorporated in this chain as represented by a fairly reasonable 17% of females in the study. This showed that women have a role in this chain as some of the farms visited were owned by women. Reflecting on the historical background of large scale dairy in Zimbabwe which was dominated by white producers, it was interesting to see how the situation had changed in recent years with an almost equal proportion of both black and white producers involved in large scale dairying. This demography is a result of the land reform programs the Government adopted. Having the majority of producers with dairy farming experience of more than 11 years meant that the producers knew well the chain and could give credible contribution to this study. The clustering of producers into can and bulk delivery system made it possible to compare how these two groups of farmers were being affected by load shedding as they had different storage and delivery intervals.

5.2 Frequency of load shedding

The high frequency and long duration of load shedding experienced in the province showed how serious load shedding was affecting actors in the cold chain particularly producers. Although the power utility, ZESA (2013) had indicated on their website that load shedding should not exceed 5 hours in affected areas and makes efforts to inform its customers on impending power cuts, the situation on the ground was contrary. The producers were experiencing longer periods of unscheduled load shedding which made it difficult to plan ahead and caused a break in the cold chain. These results are similar to the Indian situation were frequent power cuts can occur up to 20 hours a day for 20 days in the month (Chaurey *et al*., 2004). However, this is in contrast with the South African situation, where the power utility Eskom makes efforts to inform its customers, and load shedding is scheduled (Thakali, 2008). According to a ZESA (2013) report, the Zimbabwean power system will remain vulnerable for the next five to eight years given the shortage of capacity to generate more electricity. This is viewed as a national challenge that requires all stakeholders to contribute towards a solution.

5.3 Effect of load shedding on the cold chain

The observation that a majority of producers managed to store milk at a temperature of between 3-4^{O}C despite experiencing long hours and frequencies of load shedding was surprising. Load shedding could have been expected to influence the efficiency and integrity of the cold chain since it requires keeping the refrigeration system in a running state (Joshi *et al.*, 2009). The damage to cold chain equipment as a result of load shedding was expected as only a few producers had installed surge protectors and voltage meters to protect their equipment from voltage fluctuations (Fig 5.1). Similar findings have been obtained in South Africa where load shedding was causing damage to electric motors, computer systems, milking machines and cooling facilities (Lassen, 2013).

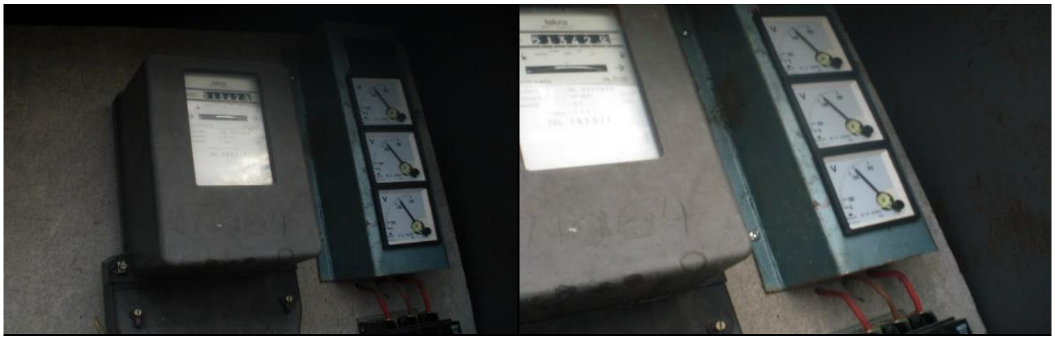


Figure 5.1. Equipment to monitor voltage from the grid. Source: (Author, 2013)

5.4 Critical Control Points (CCP) in the cold chain

The identification of Critical Control Points (CCP) as temperature control at farm storage, transportation, processing and at retailer level concurs with the cold chain model of Montanari (2008).This suggests the importance placed by actors within the cold chain on food quality and safety. The adoption and certification in global food safety standards at processor level made this chain competitive. The National dairy standards of 1977 operating at producer level were old. Although these standards were still relevant, it would be prudent to have them reviewed to match international standards and regulations such as GAP.

5.5 Milk rejections at farm and processing plant

The lack of milk rejections in the current study in relation to temperature control could be explained by the fact that producers could call the transporter immediately to collect the milk outside normal collection intervals if load shedding took longer time, although the transport cost would be high. Use of generators had also helped to maintain the cold chain as a quick reaction to deviations. Although can delivery producers in this study did not send their milk through a bulk delivery system they had immersion tanks where they stored their milk before transportation to the processor as shown by the illustration in Fig 5.2 which maintained the cold chain. Can delivery producers had the flexibility to deliver the milk to the processor at any time to prevent milk rejections. This explains the observation that showed no differences in milk rejections between bulk and can delivery producers.

Figure 5.2. Can delivery producer with milk in cans being chilled in immersion tanks. Source: (Author, 2013)

5.6 Load shedding and milk quality

In this study no correlation was found between load shedding and microbial milk quality (TBC). It would have been expected that since power cuts affect the cold chain, a high temperature in milk was expected to increase the TBC. This observation although ironic, is similar with the findings of Gran, Mutukumira, Wetlesen, and Narvhus (2002) who found no correlation between temperature of milk and the number of microorganisms. It may be argued that various factors affect TBC as stated by Marco and Wells-Bennik (2008) who indicated that bacterial contamination of milk can occur in the farm environment , during collection, storage, treatment of milk and as a result of mastitis in the cattle herd. The fact that producers were using generators as a corrective or preventive action against the effects of load shedding in maintaining the cold chain and slow down bacterial growth could explain this lack of correlation. Harding (1995) mentioned that Total bacterial colony count (TBC) is a widely used test which gives a general indication of good hygienic production. Hence in this case TBC could not be limited to the cold chain alone, but also to hygienic practices such as cleaning and milking practices. It would have been expected that loading shedding could have directly affected milk quality as a result of the disturbance in the water pumping system for cleaning purposes, heating of geysers and prevalence of mastitis from interrupted milking routine. Again the use of generators could have averted this problem. The difference in TBC between can and bulk delivery farmers which showed can delivery farmers having a higher TBC count than bulk delivery farmers could be explained by the difference in milk storage and delivery intervals between the two systems. Most producers in the can delivery system stored milk in cans in chilled water immersion tanks whose temperature control efficiency might not be comparable to bulk tanks. During transportation of milk in cans the milk is exposed to ambient temperature and sunshine which could raise the temperature and increase TBC. This is substantiated by James and James (2010a) who said even where refrigeration equipment is used temperature fluctuations occur. The temperature fluctuations could be more in can delivery system.

5.7 Cold chain infrastructure

The cold chain infrastructure in this dairy chain was well developed (Figure 5.3). These findings are in line with Montanari (2008) who described a typical cold chain infrastructure as generally consisting of pre-cooling facilities, cold storages, refrigerated carriers, packaging, warehouse, traceability, retailer, and consumers, supported by information management systems. In addition Joshi *et al.* (2012) asserted that cold chain management is easier when there is a robust infrastructure in comparison to a weaker infrastructure. However, the technology of most of the chilling equipment was outdated, consisting of three phase systems which consume a lot of energy. A few producers were using plate heat exchanges (PHT) to pre-cool the milk before entering the bulk tanks. This exerts a lot of demand on the already strained energy situation in the province. Several studies have indicated that milk cooling is the largest consumer of electricity constituting 30% of total energy costs of operating a dairy (Pressman, 2010; Upton *et al*., 2010). Hence a consideration for more efficient cooling systems could lower the energy demands.

Figure 5.3. A producer showing two generators available at the farm with one standby generator to the left. Source: (Author, 2013)

5.8 Effect of Load shedding on production costs

It was evident that load shedding had impacted negatively on production costs for actors in the chain. The high cost of purchasing and running generators in comparison to using electricity from the grid was making the chain uncompetitive. In a bid to remain viable and avoid financial losses many processors had switched to using imported milk powders as the main ingredients in their processed dairy products instead of fresh milk. These powders do not have a high nutritional value as compared to fresh milk and have a questionable traceability. Nonetheless, processors could make huge profits by using powders as they can be stored and used when needed because they are not perishable. The raise in the cost of stockfeed in the dairy industry was a result of the disturbance in winter wheat irrigation which was being hampered by load shedding.

5.9 Actors intervention strategy for load shedding

The use of generators had been viewed as an investment by actors which had ameliorated the negative effects of load shedding to the cold chain. However, the large scale use of generators is under scrutiny from the Environmental Management Authority (EMA) body which raised concern on pollution issues related to noise and exhaust fumes emissions. The environmental body is concerned with environmental issues focusing on clean energy sources. As such a certain amount of fuel should be kept at the farm otherwise the producers will be levied for environmental issues which would increase their production costs. By considering the three components of sustainability which are equity, environmental and economic aspects (3E's), it may be argued that the use of generators is not sustainable when environmental aspects such as pollution and economic aspects dealing with viability are considered. Other alternative clean and environmentally friendly energy sources such as solar and biogas could be worthy pursuing in this chain. However, these technologies require high capital investments to set up but become cheaper and sustainable in the long run.

5.10 Available support services

There were indications from one processing company that there were supporting producers contracted to them to secure generators under a loan scheme. However, most producers had on their own initiative bought generators to maintain the cold chain and run other dairy operations that required electricity. The government, the power utility and other chain supporters had not done much to support the actors in the chain to address the issue of load shedding. Processors as the lead firm in this value chain, needed to do more in terms of giving support to producers to have a guaranteed supply of quality and safe raw milk. Bencini *et al*. (2010) stated that the quality of dairy products is to a large extent dependent on the quality of raw milk used. Offering advisory advice on quality aspects alone as is the current case by processors, was not enough.

5.11 Milk Quality testing procedures

The milk testing procedures at farm and processor level reception conformed to international practices. However recent practices which had seen processors taking a role in milk quality testing for payment was stirring payment disputes. The producers have been accusing processors of short changing them as these two actors have conflicts of interests. Milk testing for payment scheme is normally a responsibility of an independent laboratory, in this case Dairy Services Unit. However, in recent times processors had taken this role because of the incapacity of DSU. Although this issue is still not fully addressed, DSU needs to be capacitated and take full charge of its responsibilities. The quality milk payment system in place is encouraging producers to improve their milk quality. This has an effect of improving the quality and safety of milk products in the chain to satisfy the final consumer.

Chapter 6 : Conclusions and Recommendations

6.1 Conclusions

The frequency and duration of load shedding experienced in this study was high and affecting all actors in the chain particularly producers. The cold chain infrastructure in this chain, although adequate was operating on old technology with high energy demands. Load shedding was causing damage to cold chain equipment due to fluctuations in voltage as a few producers had installed voltage meters and surge protectors to protect their equipment. Load shedding did not affect milk storage temperature in the chain as a result of interventions of generators. Although the use of generators ameliorated the effect of load shedding on the cold chain, their use was raising the production costs in this dairy value chain and making it uncompetitive. Additionally, use of generators was raising environmental concerns of pollution. Milk quality was not affected by load shedding possibly as a result of interventions of generators which had helped in maintaining milk storage temperature and other hygienic practices. There was inadequate support services from chain supporters to help actors address load shedding despite the serious impact this was having on the chain. It can therefore be concluded that in this study, load shedding was affecting components of the cold chain which included cold chain equipment and raising production costs but was not necessarily affecting storage temperature and milk quality. The findings from this study can be used for further research to improve the dairy cold chain in Zimbabwe in light of load shedding.

6.2 Recommendations

Basing on the findings and conclusions from this study, the following recommendations are made to producers who are mostly affected by load shedding in this cold chain. The intervention strategies will mainly focus on infrastructural development to reduce dependency on the national electricity grid. These interventions supports assertions made by Mbohwa & Fukuda (2003) who suggested that small to medium scale power generation units have a role to bridge the power deficit in Zimbabwe through consideration that it is very expensive to invest in large-scale unit. The interventions proposed will require huge initial capital investments to set up. Nonetheless, the concept of value chain financing should be considered to provide access to finance chain actors particularly producers for the value chain to work well. Financial services can be sourced from commercial banks and through government support. The triangle of value chain finance which incorporates processors as guarantors for producers to access loans from commercial banks can help to finance some of the interventions highlighted below.

Cold chain equipment

- **Voltage meters and Surge protectors**

Most producers had their three phase cold chain equipment (bulk tanks, electric motors) damaged from the effect of load shedding due to power surges and single phasing/low voltage. Producers are encouraged to invest in Class 2 surge arrestors for 3-phase appliances (Figure 6.1) and install voltage meters to check voltage fluctuations and prevent damage to equipment. The approximate market price for surge arrestors is US$249 per unit.

Figure 6.1. Class 2 surge arrester for 3-phase appliances. Source: (Sinetech, 2013)

- **Plate Heat Exchangers (PHT)**

Milk cooling consumes 30% of dairy's daily energy use. It means that much of the electricity energy generated from using generators is devoted towards bulk chilling of milk. There is need to become more efficient in energy use and lower production costs. Pre- cooling of milk using Plate Heat Exchangers (PHT) shown in Figure 6.2, reduces the temperature of the milk from around 35°C to 18 – 20°C before entering bulk tanks. This further reduces the time required to bring down the temperature of milk to 4^{O}C which significantly reduces the load on the refrigeration by 60%. As such Plate Heat Exchangers are an efficient way of taking heat out of milk and play an important part in ensuring milk is cooled quickly for storage and reducing the demand for electrical energy. Producers are therefore encouraged to invest in these PHT, as currently a few producers have them. The market price is around US$4753/unit (€3612)[4] (Mechinox South Africa, 2013).

Figure 6.2. M6 Plate Heat Exchanger. Source : (Mechinox South Africa, 2013)

[4] 1USD=0.76 EUR

❖ **Modern Technology in bulk tanks**

The technology of the direct expansion (DX) bulk chilling tanks used by the producers is outdated and not energy efficient. Modern cooling systems have energy saving features such as high rigidity and excellent insulation for efficient cooling. They also use the latest plate technology which allow milk to be cooled efficiently even at low milk volumes enabling blending of milk at all times and maintaining milk quality. There is need to invest in energy efficient milk cooling systems that can significantly reduce operating costs and can also be powered by alternative energy sources such as solar or biogas. The National Dairy Cooperative (NDC) which owns and rents out most of these bulk tanks to producers could upgrade this infrastructure.

Alternative energy sources

Although many producers had invested in one or more generators that would momentarily keep the problems of load shedding on the cold chain at bay, the use of generators is not economically and environmentally sustainable. Other alternative energy sources which are sustainable should be pursued.

❖ **Solar System**

Zimbabwe experiences long hours of sunshine throughout the year. Solar system is a renewable energy source and is an option to consider to address the crisis of load shedding. Although the initial cost to set up the solar system is high depending on the scale of energy requirements for the producer, this investment is cheaper in the long run. A producer can be totally independent from the power grid. The Zimbabwean solar system industry is not well developed, but the country can take a cue from its neighbouring country South Africa where solar energy systems have been well developed and backed by reputable companies who offer back up services. Three types of solar systems options are available to producers for adoption, depending on their individual needs.

Stand-alone System

This type of system is fully independent of the power grid and there is no interaction with the power grid (Figure 6.3). The size of the solar array, system components and the battery reserve capacity is dictated by the electrical usage of the property, the amount of reserve for periods of little or no sun and the climatology of the area. This type of system has no restriction and can be installed practically anywhere (Sinetech, 2013).

Figure 6.3.Commercial solar farms in South Africa. Source: (Sinetech, 2013)

Grid –Tie System

This system is most popular in Europe (Figure 6.4). This system does not have a battery or related battery equipment. It feeds all electric power generated by the solar panels through a mains synchronized high quality inverter and offsets the power that would normally be consumed from the electricity grid. It slows, the electricity meter depending on the time of day, the loads present and the size of the solar system installed. This system is simple and popular because there are no batteries to replace and the system costs less than the "grid-interactive" system however, its ideal in areas where there are few electricity power failures (Sinetech, 2013).

Figure 6.4. A dairy farm in The Netherlands using a Grid -Tie system with solar panels on the roof. Source: (Author, 2013)

Grid-Interactive system

This system has a battery and additional slow controls. It can either feed into the electricity meter to or in some cases reverse it (depending on the meter) when excess power is present and it can provide backup power during electricity failures. The system size depends on the appliances or devices requiring power or it can selectively support appliances considered to be most necessary during power failures. These systems are more expensive because of the battery reserve capacity and additional controls required in the system. However there are useful in areas with frequent power failures (Sinetech, 2013).

A rough estimate, of the cost of setting up the three different solar systems can range from US$ 5000- US$ 20 000 on a small scale; medium size US$20 000- US$59 000 and on a large scale US$59 000-US$118 000 depending on the size of the set up required (Sinetech, 2013).

- **Biogass ingesters**

Manure and plant material available at farms can be harnessed into biogas that can generate electricity for chilling, milking and heating water. Simple and inexpensive small scale biogas digesters consisting of a tank and a system to collect and store the biogas can be constructed at the farms (Figure 6.5). Use of biomass power is widely used in developed countries like the United States and this technology can be adopted by the producers to address their energy requirements and cushion them from load shedding.

Figure 6.5. A simple biogas digester construction at Tamera experimental site (Southern Portugal). Source: (Culhane, n.d.).

- **Generators**

Generators have proved useful to actors in the chain, their continued use is encouraged whilst other options are considered.

- **Time scheduling of load shedding**

Load shedding was not scheduled and this made it difficult for actors in the chain to plan ahead. Actors in this cold chain should continue to engage the power utility to have load shedding scheduled and given fixed times so that they can synchronise their activities.

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Annex 1: Survey Questionnaire-Producers

Section A –Background information

1. Gender

Male	1
Female	2

2. Milk delivery method

Bulk	1
Can	2

3. Dairy farming experience

Less than or equal to 5 yrs	1
6 -10 years	2
11 years and more	3

4. Ethnicity

Black	1
White	2
Coloured	3
Indian or Asian	4
Other (specify)	5

Section B. Load shedding in the province

5. Are you experiencing load shedding at your farm?

Yes	1
No	2

If you answered Yes to question 5 please proceed to question 6. If your answer is No, please specify the reasons, otherwise some of the proceeding questions will not be relevant in your case.

6. How many times do you experience load shedding per week (7 working days)?

7 times (i.e. daily)	1
2 times	2
3 times	3
Other (specify)	4

7. What is the duration of load shedding per day?

1-3hrs	1
4-8 hrs	2
9-15 hrs	3
Other (specify)	4

8. Is the load shedding scheduled?

Yes	1
No	2

9. What milk production challenges are you encountering due to load shedding?

…………………………………………………………………………………………………...

…………………………………………………………………………………………………

10. At what temperature do you keep the milk at the farm?...

11. Is this temperature affected by load shedding?

Yes	1
No	2

Please explain………………………………………………………………………………………

…………………………………………………………………………………………………….

…………………………………………………………………………………………………….

12. What have you been doing to manage this load shedding in relation to maintaining specified milk storage temperature of 4^{o}C?..

…………………………………………………………………………………………………….

…………………………………………………………………………………………………….

13. What effect has loadshedding had on production cost?...

…………………………………………………………………………………………………….

14. What effect has load shedding had on milk price?...

…………………………………………………………………………………………………….

14. Have you encountered milk rejections by the processor due to milk not meeting specified temperatures?

Yes	1
No	2

15. If Yes .How many times in the current year?...

16. What is the estimated loss in revenue from milk rejected? (*Calculated as:* ***volume*** *X* ***frequency*** *X* ***producer price***)……………………………………………………………………….

……..

Section C- Milk Quality

17. What is the milk collection or delivery interval?

Daily	1
Every 2nd day	2
3rd day	3
4th day	4

18. In your opinion is there a relationship between load shedding and milk quality?

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1	2	3	4	5

Explain……………………………………………………………………………………………….

……..

19. What is your weighted average Total Bacteria Count (TBC) for the last 6 months?

Band and Range	Code
AA <20 000	1
A <50, 000	2
B 50,001-150,000	3
C 150, 001-250,000	4
D 250,001-375,000	5
E 375,001-500,000	6
F >500,000	7

20. Is there a relationship between your TBC and load shedding? Please explain……………….

……….

21. What is your opinion on current legal standards on milk quality?

Appropriate	1
Outdated	2
Strict	3

22. What technical service do you get from other stakeholders in addressing load shedding in relation to the cold chain?...

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

23. What equipment and processes do you have to maintain the cold chain? (*Mark more than one option)*

Bulk tank	1
Cans	2
Thermometers	3
Generator	4
Other (specify)	5

24. What is your opinion regarding load shedding in your cold chain? ……………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

25. Any other comments?..

……………………………………………………………………………………………………

Thank you for your co-operation in completing this questionnaire.

Annex 2: Checklist for Processors

1. What platform tests are done at milk reception?

2. What is the frequency of milk rejections at processor reception attributable to milk not meeting the correct temperature?

3. Is there a relation between load shedding and the cold chain? Yes/No. Please explain.

4. What infrastructure and processes are available across the actors to maintain the cold chain?

5. What are the critical control points (CCP) in dairy cold chain?

6. How are the actors controlling the CCP?

7. What is your opinion on the current legal standards of milk quality?

9. Which international food safety standards have been implemented? (*More than one option applicable*)

HACCP	1
ISO 22000	2
GAP	3
Other (specify)	4

10. What is being done by your company to assist producers improve milk quality?

11. What is the frequency of load shedding per month at processor level?

12. How are you dealing with load shedding in maintaining the cold chain?

13. Are there production costs associated with load shedding?

14. What role can you play in ensuring quality milk products?

15. What needs to be done by the sector to address load shedding and maintain the cold chain?

Annex 3: Checklist Regulatory Institute - Dairy Services Unit

Subject	Comments
1. What is the effect of load shedding among actors in the dairy cold chain?	
2. Is there a relation between frequency of load shedding and milk rejections related to unacceptable milk temperatures?	
3. What milk quality standards and regulations are in place?	
4. How are quality management practices being implemented?	
5. Is there need to change the current standards?	
6. What is the general level of TBC of dairy farms in Mashonaland East?	
7. What effect has load shedding had on the production costs of milk and milk price?	
8. What role is the institution playing to help actors maintain the cold chain in the wake of load shedding?	
9. What is the level of participation of actors and stakeholders from the sector in formulating possible solutions to load shedding in relation to maintaining the cold chain and milk quality?	

Annex 4: Checklist Bulk transporter

Subject	**Comments**
1. How has load shedding affected bulk transportation of milk at farm level?	
2. What is your collection interval at the farms?	
3. What is the frequency of milk rejections at farm level due to unacceptable temperatures?	
4. What interventions should be in place to address effects of load shedding on the cold chain?	
5. Are there economic costs encountered in bulk milk transport associated with load shedding?	

Annex 5: Frequency of load shedding

		Frequency of load shedding /week
N	Valid	30
	Missing	0
Mean		2.73
Std. Error of Mean		.191
Median		3.00
Std. Deviation		1.048

Annex 6: Loss in revenue from milk rejected

VOLUME (Ltrs)	**FREQUENCY**	**PRODUCER PRICE (US $)**	**TOTAL LOSS (US$)**
1500	2	0.50	1 500

Annex 7: Chi-Square test

Milk rejections from load shedding * milk delivery method

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.556[a]	1	.456		
Continuity Correction[b]	.139	1	.709		
Likelihood Ratio	.558	1	.455		
Fisher's Exact Test				.710	.355
Linear-by-Linear Association	.537	1	.464		
N of Valid Cases	30				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.00.

b. Computed only for a 2x2 table

Annex 8: Energy uses for various cooling systems

Type of Cooling System	Average Daily Energy Use	Avg. Unit Energy Use
Tube cooler and DX (original system)	99 kWh	11.66 kWh/tonne 0.53 kWh/cwt
Plate cooler and variable speed milk pump, DX only	57.1 kWh	6.82 kWh/tonne (0.31 kWh/cwt)
Chiller mode: Plate cooler, chiller, and variable speed milk pump. Ambient temperature > 0°C	83 kWh	9.9 kWh/tonne (0.45 kWh/cwt)
Ambient cooling mode: Plate cooler, chiller, and variable speed milk pump. Ambient temperature = 0°C	51 kWh	6.2 kWh/tonne (0.28 kWh/cwt)
Ambient cooling mode: Plate cooler, chiller, and variable speed milk pump. Ambient temperature < -7°C	40 kWh	4.84 kWh/tonne (0.22 kWh/cwt)

Source: Legett, Peebles, Patoch, and Reinemann (1997)

Annex 9: Tariffs used for calculating milk cooling cost

Unit Type	Cost per unit (US$)	Tariff
Energy charge per kWh	0.14	Agricultural Customers

Source: ZESA (2013)

Annex 10: Mann-Whitney Test

Test Statistics

	Relationship load shedding & milk quality
Mann-Whitney U	95.500
Wilcoxon W	215.500
Z	-.789
Asymp. Sig. (2-tailed)	.430
Exact Sig. [2*(1-tailed Sig.)]	.486[b]

a. Grouping Variable: Milk delivery method

b. Not corrected for ties.

Annex 11: Independent sample t-test

	Levene's Test for Equality of Variances		t-test for Equality of Means			
	F	Sig.	t	df	Sig. (2-tailed)	Std. Error Difference
Average TBC Equal variances assumed	1.815	.189	-3.197	28	.003	.438
Equal variances not assumed			-3.197	26.494	.004	.438

Annex 12: Spearman correlation test

Correlations

			Frequency of load shedding /week	Average TBC
Spearman's rho	Frequency of load shedding /wk	Correlation Coefficient	1.000	.185
		Sig. (2-tailed)	.	.327
		N	30	30
	Average TBC	Correlation Coefficient	.185	1.000
		Sig. (2-tailed)	.327	.
		N	30	30

Annex 13: Mann Whitney test for legal standards

Test Statistics

	Legal milk standards
Mann-Whitney U	90.000
Wilcoxon W	210.000
Z	-1.445
Asymp. Sig. (2-tailed)	.148
Exact Sig. [2*(1-tailed Sig.)]	.367[b]

a. Grouping Variable: Milk delivery method

b. Not corrected for ties.