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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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ABSTRACT

The study sought to analyse the effect of load shedding on the dairy cold chain and milk quality in the dairy value chain. Thirty large scale dairy farmers in Mashonaland East were randomly selected for the survey. 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 case studies to get in depth knowledge. The study revealed that the province was experiencing massive unscheduled load shedding, averaging three times per week and ranging between 4-15 hours per day in duration. The results showed that load shedding was causing damage to the cold chain equipment due to fluctuations in voltage. There was no correlation ($p > 0.05$) between load shedding and Total Bacteria Counts (TBC) in this study mainly to generator use. However, the use of generators was raising the production costs in this dairy value chain and causing environmental pollution. The recommendations in this study encouraged producers to install surge protectors to prevent damage to cold chain equipment, investment in energy efficient technologies and renewable energy sources such as solar and biogas energy to reduce dependency on electricity from the grid and generators.

INTRODUCTION

Zimbabwe has been experiencing frequent load shedding. This load shedding is a result of shortage of generating capacity from the national power utility to match the high national energy requirements. 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. 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.

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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). 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. Therefore, the study sought to analyse and evaluate the extent to which power cuts have affected the cold chain and milk quality in this dairy value chain.

MATERIALS AND METHODS

Experimental site: The study was conducted in Mashonaland East province in Zimbabwe. This province is located in natural ecological region II and III with an average annual rainfall of 650-1000mm which is better suited for dairy as compared to other regions. Most dairy farms are located in Mashonaland East province because of its close proximity to the capital city 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

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.

Desk research: Literature review to contextualise and summarise current literature on the research subject was sought mainly from the digital library, various books, journals, internet sites, annual and monthly reports from Dairy Services Unit (DSU) and other stakeholders in the dairy sector in Zimbabwe. Value chain mapping was used as a tool 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 for Total Bacteria Count (TBC) was conducted using secondary data from the six months rolling test results obtained from the database of DSU.

Survey: 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. 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 had 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 to make certain that all the questions were understandable to all the interviewees and adjustments made were necessary. Face-to-face structured interviews were conducted with respondents. Farms indicated on the itinerary were visited each day (at least four farms per day) and one hour was spent at each farm.

Case study: Open interviews using a checklist or an unstructured questionnaire were conducted on key informants to get in depth information (qualitative data) about the effects of load shedding on the dairy cold chain. The informants and experts included the Zimbabwe Association of Dairy Farmers (ZADF), National Dairy Cooperative (NDC), Dairy Services Unit, Quality control managers for processors (Dairiboard Zimbabwe and Nestle Zimbabwe). The questioning was characterised by probing and follow up depending on the type of the answer from the respondent.

Observations: Observations were used to validate the information given by farmers during survey interviews by checking with events 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.

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. 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.

RESULTS AND DISCUSSION

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 three times a week. Load shedding was ranging between 4-15 hours per day in duration. The majority (93%) of respondents stated that the load shedding was not scheduled. 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. 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 could 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).

Interventions to deal with load shedding and temperature maintenance: To maintain recommended milk storage temperatures of 3-4^{o}C, 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 requested the bulk transporter to immediately deliver milk to processor, which came with huge costs. 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).

Milk rejections linked to load shedding: About 60% of the producers reported that they did not encounter milk rejections by the processor due to unacceptable temperatures and 40% had experienced these rejections at some point but not at the time of the study. There were no significant ($p>0.05$) differences in milk rejections between bulk and can delivery producers. The lack of milk rejections in the current study in relation to temperature control could be explained by the fact that producers could request the transporter to immediately 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. 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.

Effect of load shedding on production costs: The majority of farmers were using heavy duty generators as a backup to load shedding. These generators had an output of 80-100 kVA and can power three-phase appliances such as bulk chilling tanks, milking machines and borehole motor pumps.

However, they came at a high cost of US$18000 - $ 24000 per unit depending on the size and brand name. These generators consumed on average 14 litres of diesel/hour and normally the producers operated these generators for three hours and switched them off when the milk is chilled to the correct temperature to minimise generator running hours and costs. Given that producers had a milking frequency of two times per day, the generator hours could average six hours per day. Most producers interviewed complained that the cost of running generators was high.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. 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 was 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 was concerned with environmental issues focusing on clean energy sources. 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 was not sustainable when environmental aspects such as pollution and economic aspects dealing with viability were 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.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 bought generators on their own initiative to maintain the cold chain and run other dairy operations that required electricity.

Effect of load shedding on Milk quality: A high proportion of producers (90%) agreed that there was a relationship between load shedding and milk quality with only a few (10%) disagreeing. This relation was attributed to a possible increase in bacterial count and subsequent milk spoilage when the cold chain is broken. Other factors highlighted by producers related to the fact that dairy cows are used to a milking routine and any disturbance in the cycle will cause mastitis (inflammation of the udder) which negatively affects milk quality. Producers used pumped water for cleaning machinery and basic hygiene hence load shedding could compromise on hygiene and milk quality. The proportion of producers who disagreed stated that it depended with the availability of a backup generator and duration of load shedding. Most respondents (87%) affirmed that there was a relationship between total bacterial count (TBC) and load shedding. There were significant difference ($p<0.05$) in TBC between can and bulk delivery farmers. Can delivery farmers had a higher TBC count of 150 001-250 000 (Band C) than bulk delivery farmers who were in Band B (50,001-150,000). However, there was no correlation ($p> 0.05$) between load shedding and Total Bacterial Count. In this study no correlation was found between load shedding and microbial milk quality (TBC). It was expected that 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, & 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 & 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 preventive action against the effects of load shedding in maintaining the cold chain and slowing 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.

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 &James (2010a) who said even where refrigeration equipment is used temperature fluctuations occur. The temperature fluctuations could be more in can delivery system.

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. 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).The cold chain infrastructure in this dairy chain was well developed. 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 cold chain 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 exerted 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. Reports of damage to machinery due to voltage fluctuations from the power utility were highlighted. 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. 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).

The Critical Control Points (CCP): 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 and 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.

Bulk Transporters: The bulk transporter highlighted that when load shedding is prolonged the producer can request 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 unscheduled collection. 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.

Milk Quality Testing: Milk quality testing was done by an independent body, Dairy Services Unit (DSU), which is involved in testing and grading of raw and processed dairy products. 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 were accusing processors of short changing them as these two actors had 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.

Milk Processors: The processors had in place international food safety standards and certification such as HACCP, ISO 22000, ISO 14000 (environmental) and Nestle Zimbabwe had its own Quality Management System (NQMS).The adoption and certification in global food safety standards at processor level made this chain competitive. Although load shedding was also affecting processors in maintaining the cold chain, the effect was minimised by investment in massive generators. From the processors point of view generators were seen as an investment. The milk quality payment system in place was encouraging producers to improve their milk quality. This had an effect of improving the quality and safety of milk products in the chain to satisfy the final consumer. 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 as the lead firm in this value chain, was not enough. 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. 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 high nutritional value as compared to fresh milk and have a questionable traceability. Nonetheless, processors could make huge profits by using powders as they could be stored and used when needed because they are not perishable.

Retailers: A visual assessment in retailer shops showed a distinct presence of long life or UHT milk products and powdered milk. 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 a conspicuous absence of fresh milk on the supermarket shelves.

Chain supporters: The Dairy Farmers Association mentioned that the effects of load shedding were felt on the whole dairy value chain from input suppliers, producers, processors, retailers and consumers. The effect of load shedding was more severe at production level as most farmers had challenges during milking and had in turn resorted to hand milking especially those without generators. 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.

Conclusion

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, it was raising the production costs in this dairy value chain and making it uncompetitive. Additionally, use of generators was raising concerns on environmental 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 were 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 light of load shedding.

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