RESEARCH REPORT

TRANSPORT OF MILK – FROM FARM PRODUCTION TO PROCESSING

Linda van den Broek

4/10/23

Business Management in Agriculture and Food

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TRANSPORT OF MILK – FROM FARM PRODUCTION TO PROCESSING

CLIENT

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Githunguri, 2022

PREFACE

My name is Linda van den Broek, and I am a fourth-year student of the HAS Green Academy – University of Applied Sciences in Venlo. I study Business Management in Agriculture and Food. In September 2022, I started the minor Agricultural Development in Emerging Countries at AERES University of Applied Sciences in Dronten. As part of the minor offered by AERES Dronten, and the internship abroad offered by HAS green academy, I did an internship at Githunguri Dairy Farmers Co-Operative Society in Githunguri, Kenya. During my internship at Fresha, I was assigned to develop a research report on a topic of interest for the company.

I conducted this research report for Githunguri Dairy Farmers Co-Operative Society. This report has been developed as a result of the research conducted on the transportation of raw milk from farm production to processing.

I would like to thank Githunguri Dairy Farmers Co-Operative Society for the assignment, Francis Muhande and Lynda McDonald for their feedback and guidance throughout the project. Lastly, I would like to thank Andrew Kariuki, Daan Westrik and Marjolein de Bruin for their assistance during the project.

All others who have not been mentioned above and who have also contributed to this research, thank you very much.

GLOSSARY

CFU – Colony Forming Units

DEO – Dairy Extension Officer

FMD – Foot and Mouth Disease

GDFCS – Githunguri Dairy Farmers Co-Operative Society / Fresha Dairy Brands

GDP – Gross Domestic Product

KES – Kenyan Shilling

L.R – Lateral Root

UoAS – University of Applied Sciences

TABLE OF CONTENT

SUMMARY

Githunguri Dairy Farmers Co-Operative Society (GDFCS), also known as Fresha Dairy Brands, was founded by thirty-one dairy farmers to increase opportunities in the market for small-scale dairy farmers. In 2004, GDFCS started operating its own milk plant which increased the profitability and size of the organization. Today, the cooperative has a total of 27,500 members, of which 11,700 are active. Eighty percent of Fresha's members are small-scale dairy farmers with an average of one to five cows. Many of these farmers struggle with low milk yields per cow of on average eleven liters per cow per day, reduced milk quality and low profitability. Due to insufficient knowledge and inadequate infrastructure, many small farmers depend strongly on Fresha to supply their milk to this dairy cooperative.

The quality and quantity of milk of Githunguri Dairy Farmers Co-Operative Society is poor due to the collection process of raw milk, quality losses and high transportation costs within the supply chain from farm production to processing. Which negatively affects the profitability of the members of Fresha, and Fresha itself. This study searched for an answer to the question: 'How can Githunguri Dairy Farmers Co-Operative Society increase the efficiency and decrease the costs of transport within the supply chain, from farm production to processing, to increase profitability in 2023?'

The research has shown that the milk supply chain of Fresha can be divided into a short and long chain. Fresha's short milk supply chain is as follows: dairy farmers bring the milk to a collection center, or a mobile collection point, where the milk is collected and then directly transported to the processing plant. The short supply chain is present in the areas close to the milk processing plant. Unlike the short chain, Fresha's long milk supply chain has an additional stop and is as follows: dairy farmers bring the milk to a collection center or a mobile collection point, and then it is taken to a cooling center. Another option is bringing the milk directly to a cooling center which includes a collection center. At the cooling center, the milk is cooled for several hours before being transported to the processing plant. The long supply chain is present in the areas further away from the milk processing plant.

Research showed that the cost of transporting raw milk in 2022 was KES 2.64 per kilogram of milk per month. Of which KES 2.03 per kilogram of milk per month originated from own transportation and KES 0.61 per kilogram of milk per month from hired transportation.

The main opportunities for improvement to increase quality and to ensure efficiency are: improving the infrastructure (roads), the overall time between milking and entry to the factory at which the milk is above 6°C, the temperature of milk before, during and after transport and the position of milk cans when stored to drain and dry. Furthermore, a way to reduce transport costs are: outsourcing transport of milk cans to hired transporters and encouraging a transition from transporting milk in milk cans to milk tankers. The improvements can be implemented in the following ways: engaging the government to improve the infrastructure (roads), building multiple cooling centers, and investing in insulated tankers, for which an investment plan should be investigated. In addition, implementing policies and training can ensure that milk is cooled to less than 6°C, temperature is measured, recorded, and analyzed, and milk cans are stored upside down to drain and dry. Finally, transportation of milk cans can be outsourced to hired transporters by maintaining control over the supply chain with the implementation of policies, training, and monitoring systems.

This research has shown that Githunguri Dairy Farmers Co-Operative Society can increase the efficiency and decrease the costs of transport within the supply chain, from farm production to processing, by improving the infrastructure, the duration of time between milking and entry to the processing plant at which the milk is above 6°C, the temperature of milk before, during and after transport, the position of milk cans when drained and dried and outsourcing partly or all transport to hired transporters to increase profitability in 2023.

It is recommended to Githunguri Dairy Farmer Co-Operative Society to outsource part or all transportation of raw milk to hired transporters. To control the supply chain as well as the hired transporters, it is important to use policies, training, and monitoring systems. Furthermore, incentives could be made to encourage a transition over time from transporting milk in milk cans to milk tankers or to look at how to efficiently and cost-effectively transition to more own milk tankers. In addition, it is advisable to investigate the possibilities of developing an investment plan for the construction of additional cooling centers and insulating milk tankers. Furthermore, the transport schedule should be changed to increase the cooling time of milk at the cooling center. With the help of both investments and changes in the transport schedule, the time during which raw milk - from milking to receipt at the milk processing plant - exceeds a temperature above 6°C, can be minimized. Lastly, it is recommended that policies and training on the importance of the temperature before, during and after transport should be drawn up and given, covering the measurement, recording and analysis of milk temperature and emphasizing the maximum acceptable temperature of 6°C. Policies and training should also be established for the draining and drying of milk cans to ensure milk quality.

1. INTRODUCTION

1.1 CONTEXT & BACKGROUND

In 1961, Githunguri Dairy Farmers Co-Operative Society (GDFCS), also known as Fresha Dairy Brands, was founded by thirty-one dairy farmers to increase opportunities in the market for small-scale dairy farmers. In 2004, GDFCS started operating its own milk plant which increased the profitability and size of the organization. Today, the cooperative has a total of 27,500 members, of which 11,700 are active. Eighty percent of Fresha's members are small-scale dairy farmers, producing 270,000 liters of milk per day, which is collected at 213 collection points. The company's mission is to "consistently provide affordable high-quality brands to the market through application of the best business practices for the maximization of stakeholder's values" (Fresha, 2020).

The dairy farmers who are members of Githunguri Dairy Farmers Co-Operative Society are small farmers with an average of one to five cows. Many of these farmers struggle with low milk yields per cow of on average eleven liters per cow per day, reduced milk quality and low profitability. Due to insufficient knowledge and inadequate infrastructure, many small farmers depend strongly on Fresha to supply their milk to this dairy cooperative. Unexpected weather conditions and severe droughts have greatly reduced farmer incomes, as they need to purchase additional feed and water. In September 2022, Githunguri Dairy Farmers Co-Operative Society together with Tetra Laval started a project called Dairy Hub, which aims to increase farmers' dairy productivity, milk quality and profitability by 10%. Indirectly, this will also increase the profitability of GDFCS by allowing them to process and market more milk and of better quality (McDonald, personal communication, 16-11-2022).

Agriculture is the largest sector of the economy, and contributes to half of Kenya's GDP, a quarter directly and a quarter indirectly (Kenya Kwanza, 2022). Kenya's dairy sector is estimated at 14% of Kenya's agricultural GDP. Milk is produced by small dairy farmers, who account for 56% of total milk production. Larger commercial farmers produce the remaining milk. There are an estimated 1.8 million smallholders in the sector (about 80% of producers) (Njeru, 2022).

Milk is produced by both native and exotic breeds, and often a cross between the two. There are about five million dairy cows in Kenya producing an estimated four billion liters of milk annually (Njeru, 2022). The highest milk production is achieved in Kiambu district. Figure 1 shows this district. In 2021, this county produced 1.13 billion liters of milk (Egerton University & Kenya Dairy Board, 2021). Githunguri Dairy Farmers Co-Operative Society is located in this region and this area has been declared the highest in milk production countrywide over the last five years.

Figure 1: Kiambu district. Source: (Google Maps, 2022).

Tegemeo Institute of Agricultural Policy and Development examined the cost of milk production in Kenya 2021. This report showed that the average milk production was 10.1 liters per cow per day, and Kiambu district had the highest production of 12.6 liters per cow per day and 4,520 liters per cow per year (Egerton University & Kenya Dairy Board, 2021).

In sub-Saharan Africa, Kenya achieves the highest per capita milk consumption, in part due to the culture of drinking milk tea. In 2019, they drank about 82.7 liters of milk per year (Our World in Data, n.d.). There is a huge demand for dairy, currently it is eight billion liters per year. Kenya is unable to meet this demand and therefore imports milk from neighboring countries such as Uganda. It is expected that the demand for milk will continue to increase due to population growth. The government has therefore prioritized in national strategy and plans, for the development of the dairy sector (Njeru, 2022).

Kenya faces a number of challenges in meeting the high demand for dairy products. These include:

- Urbanization, which alters eating habits and aggregates the rising food demand, is changing food systems in West and East Africa, including Kenya. Depending on how affordable food markets are, more people will buy food as urban populations rise. To meet rising demand, food production may rise across the continent, but this necessary rise is unlikely without expanding agricultural land use (De Bruin & Dengerink, 2020). One of the consequences of urbanization is that cities are increasingly expanding, and more and more highways and houses are being built, which is taking up significant amounts of land previously used for agriculture or nature (National Geographic, n.d.). This leaves less land available to produce food for the growing Kenyan population.
- Drought and other severe climatic conditions have affected Kenyan farmers badly. Many of them have lost their livestock due to diseases and malnutrition (Caritas, 2022).
- In 2019-2020, outbreaks of Foot-and-Mouth Disease (FMD) occurred in Kenya. Foot-and-Mouth Disease is highly infectious and spreads very rapidly, especially on farms of small-scale livestock farmers in the absence of effective biosecurity measures. Livestock productivity in the impacted regions was severely affected, and restrictions on livestock transportation had an impact on both domestic and regional trade. Resulting in the destruction of many livestock farms (Ouma, 2021). Continuing consequences of FMD are that future production is impacted also, as young stock is not reaching puberty, and being bred as expected (McDonald, personal communication 27-3-2023).

1.2 PROBLEM STATEMENT

The quality and quantity of milk of Githunguri Dairy Farmers Co-Operative Society is poor due to the collection process of raw milk, quality losses and high transportation costs within the supply chain from farm production to processing. Which negatively affects the profitability of the members of Fresha, and Fresha itself.

During the last three years, milk collection volumes of Githunguri Dairy Farmers Co-Operative Society have been substantially impacted by droughts and Foot-and-Mouth Disease. Furthermore, due to urbanization, more and more people start living and working in cities. One of the consequences of this process is that cities are increasingly expanding and taking up significant amounts of land previously used for agriculture. Which causes people to leave the farming business due to difficult conditions to get access to enough land to grow crops and poor profitability. In order to increase farmers' profitability, the dairy industry must further develop and increase dairy productivity and milk quality. Currently the milk quantity and quality of Fresha is poor due to a lack of knowledge, poor infrastructure (roads), and uncooled transport. The organization wants to improve raw milk collection. Due to high transport costs and quality losses, GDFCS wants to make this process more efficient. In 2022, the average transportation cost for raw milk was 2.63 KES per kg of milk. By gaining insight into the supply chain, from farm production to processing, it should become clear how costs can be reduced and how the collection process can be made more efficient by for example shortening the transport movements by building more cooling centers, replacing the current milk tankers with insulated tankers to ensure the quality of the milk, etc. By lowering the costs and improving the quality, the organization hopes to also increase its profits and grow its market share to fulfill customer demand.

1.3 RESEARCH QUESTIONS

1.3.1 MAIN-QUESTION

How can Githunguri Dairy Farmers Co-Operative Society increase the efficiency and decrease the costs of transport within the supply chain, from farm production to processing, to increase profitability in 2023?

1.3.2 SUB-QUESTIONS

1. What does the milk supply chain, from farm production to processing, look like?
2. What are the costs of transporting milk within the supply chain, from farm production to processing?
3. Where lie opportunities for improvement to increase the efficiency of the supply chain, from farm production to processing?
4. How to implement the improvements in the supply chain, from farm production to processing?

2. METHODOLOGY

This research was a six-week exploratory study, and by using a combination of methods, the research questions have been answered:

- Desk research has been used to gather information about the milk supply chain and ways to increase efficiency and decrease costs of transport within the supply chain.
- Eight dairy farms, fifteen collection centers, six cooling centers and the processing plant have been visited together with people from Fresha's Dairy Extension Office and Quality Control to get an understanding of the milk supply chain of Githunguri Dairy Farmers Co-Operative Society. Furthermore, this helped to see where opportunities for improvement lie.
- The financial and logistic department have been contacted and interviewed about the transportation costs within the supply chain, from production to processing, in order to find out how to reduce these costs.
- Thirteen people from the Dairy Extension Office and Quality Control have filled out a questionnaire to find out how the improvements found can be implemented within the supply chain to make the process more efficient and to decrease costs.

1. Sub question 1: 'What does the milk supply chain, from farm production to processing, look like?' has been answered through desk research, using literature published by Agriculture & Food Security. Finding out about what the milk supply chain, from production to processing, looks like is important for this research as it gave insight into how milk is transported from dairy farms to the processing plant. This information has been gathered by desk research, using an article called 'Food safety and the informal milk supply chain in Kenya,' published by Agriculture & Food security. This publication was chosen because it has information on the food safety and milk supply chain in Kenya. Besides desk research, information has been gathered by visiting eight dairy farms, fifteen collection centers, six cooling centers and the processing plant together with people of the Dairy Extension Office and Quality Control departments to get an understanding of what the milk supply chain of Githunguri Dairy Farmers Co-Operative Society looks like. After these visits the different areas in which Githunguri Dairy Farmers Co-Operative Society is active have been visualized, by a digital map, shown in Chapter 3.1.2.

2. Sub question 2: 'What are the costs of transporting milk within the supply chain, from farm production to processing?' has been answered by contacting, interviewing, discussing, and reviewing data with the financial and logistic department about the transportation costs. Finding out about the costs of transporting milk between the links within the supply chain is important for this research as it gave more insight into how to increase efficiency within the supply chain and decrease the transport costs.

3. Sub question 3: 'Where lie opportunities for improvement to increase the efficiency of the supply chain, from farm production to processing?' has been answered by means of the information found in sub question 1 and 2. Furthermore, people from the Dairy Extension Office and Quality Control have filled out a questionnaire. In total thirteen employees shared their opinion and experiences, which helped to find ways to improve efficiency within the supply chain. These people were chosen because they have experience of how the supply chain works and gave insights into how they think it could be improved. Furthermore, these employees are also part of the Dairy Hub project and were willing to help. The opportunities

for improvement within the supply chain are significant for this research as it gave insight into how to increase the efficiency of the supply chain.

4. Sub question 4: 'How to implement the improvements in the supply chain, from farm production to processing?' has been answered through using the information found in sub question 3 and 13 people from the Dairy Extension Office and Quality Control have completed a questionnaire about how they would implement the improvements in the supply chain. The ways to implement the improvements in the supply chain are important for this research to allow Githunguri Dairy Farmers Co-Operative Society to increase the efficiency of the supply chain and to decrease the costs.

3. RESULTS

3.1 MILK SUPPLY CHAIN, FROM PRODUCTION TO PROCESSING

3.1.1 KENYAN MILK SUPPLY CHAIN

The milk supply chain in Kenya consists of various activities and procedures, such as: production, transportation, processing, handling, and consumption of milk. The Kenyan dairy sector can be divided into two groups: the formal and informal sector. Milk supplied to processing plants is part of the formal sector, also known as the 'cold chain.' Members of this section are milk processors, cooperatives, supermarkets, retail outlets, milk bars and other organizations that trade processed milk products. These actors have a license which allows them to operate, they have fixed facilities and are inspected on a regular basis. Dairy farmers deliver raw milk to collection points of a dairy cooperative after which it is transported to the dairy factory. The processing plant turns the raw milk into dairy products, such as pasteurized milk, yoghurt, butter, and ghee which are then sold to retailers, or directly to consumers in urban areas and non-dairy processing areas (Birachi, 2006). Milk sold and used in unprocessed form is part of the informal sector / 'warm chain' and represents 86% of the milk market (Nacul & Revoredo-Giha, 2022). Organizations that comprise this sector include mobile traders, milk bars, brokers, and self-help groups. Dairy farmers sell the raw milk directly to consumers in dairy processing areas, or it is sold at local markets where small traders sell the unprocessed milk to retailers or to consumers in urban and non-dairy processing areas (Birachi, 2006). The actors participating in this sector are either not registered or do not have a license to operate (Nacul & Revoredo-Giha, 2022).

The supply chains differ in terms of size, geographic distribution, degree of licensing, relative remuneration, perception of quality and long-term prospects for the development of the dairy industry (Birachi, 2006). As a result of population growth, urbanization and growing demand for dairy products, the industry is constantly evolving and the various institutions and supply chains continue to develop (Nacul & Revoredo-Giha, 2022). Figure 2 shows the Kenyan dairy chain schematically.

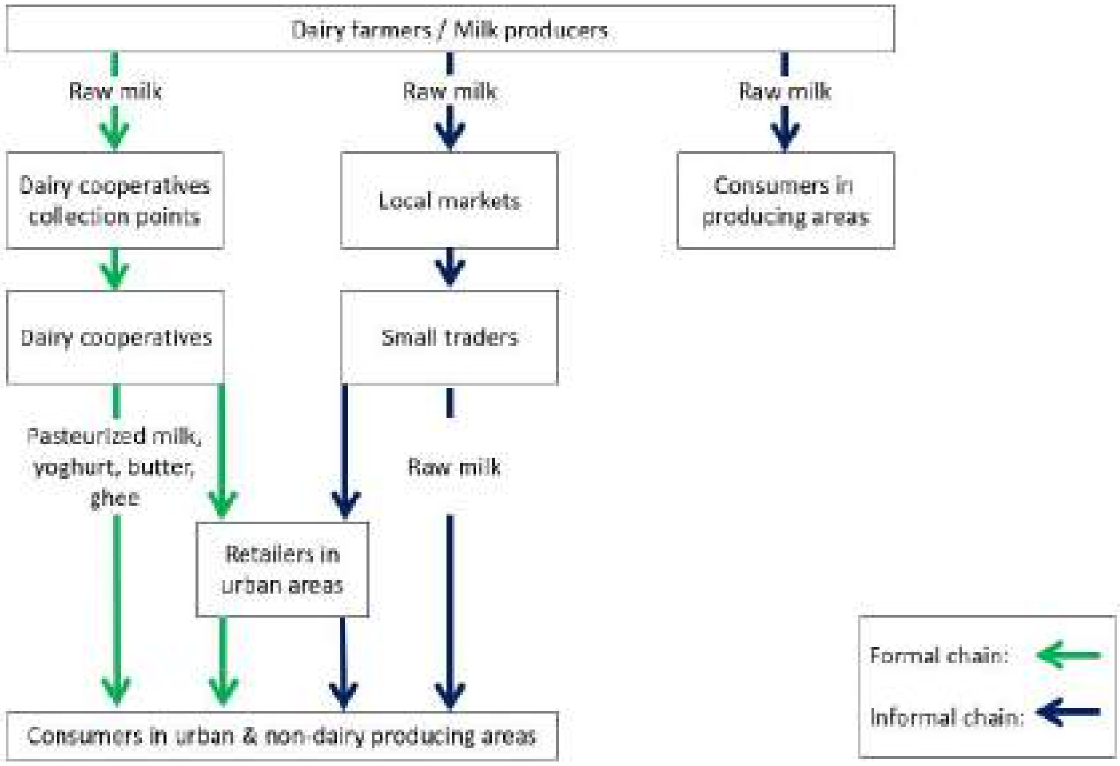

Figure 2: Kenyan dairy chain. Source: (Nacul & Revoredo-Giha, 2022).

3.1.2 FRESHA'S MILK SUPPLY CHAIN

In Githunguri, the region where Fresha is located, 95% of the milk produced is part of the formal chain and delivered to Githunguri Dairy Farmers Co-Operative Society. Only 5% of the milk market is part of the informal sector (McDonald, personal communication, 27-3-2023).

Fresha's milk supply chain consists of: dairy farms, milk collection centers, milk cooling centers and the milk processing plant. A total of 11,700 dairy farmers are active members of Githunguri Dairy Farmers Co-Operative Society, which delivers the produced milk to collection centers. In total, Fresha has 49 collection centers and 151 mobile collection points distributed along 10 different routes. A collection center is a building made of brick where milk is collected in aluminum cans that are cleaned and/or stored at this location. The grader and attendant come by themselves to this location. After collection, the grader waits with the attendant for the truck to ensure that all milk that has been collected, has been picked up, which then will be transported to the processing plant. A mobile collection point is a building made of wood to which dairy farmers bring their milk, wait for a truck with the grader, assistant, and milk cans. Depending on where the mobile collection points or the collection centers are located, and the milk volume, the raw milk is taken to one of the 13 cooling centers. Only the raw milk of route 1 is taken directly to the milk processing plant. The milk of the other routes is transported to the milk processing plant after being cooled in one of the cooling centers. Figure 3 shows the locations of the (mobile) collection centers, cooling centers and the milk processing plant. The collection centers are marked in green; the mobile collection points are blue; the cooling centers are yellow, and the milk processing plant is marked purple. A distinction is also made between the different routes. The legend shows the pictogram for each route. Appendix A.3. includes a link to the digital map, as well as the numbering and names of all locations.

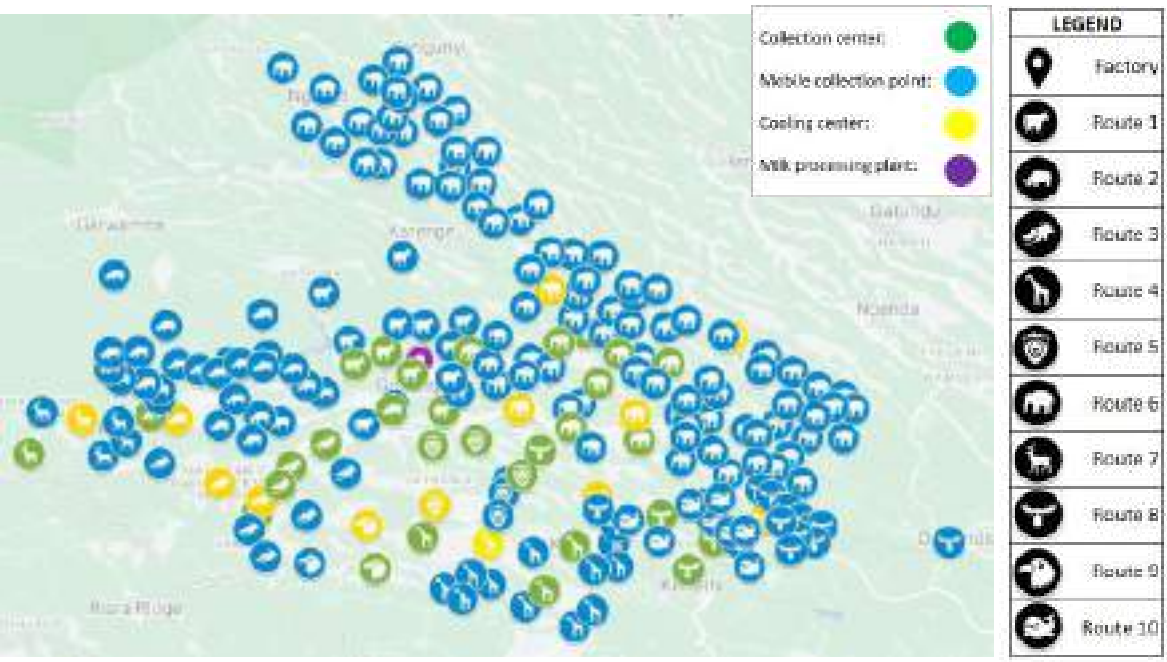

Figure 3: Digital map of locations of (mobile) collection centers, cooling centers and the processing plant. (L. van den Broek, 2022).

The milk supply chain of Fresha can be divided into a short chain and long chain. To get a better idea of what the chains look like, they are explained in more detail in section 3.1.2.1 and 3.1.2.2.

3.1.2.1 FRESHA'S SHORT MILK SUPPLY CHAIN

Fresha's short milk supply chain is as follows: dairy farmers bring the milk to a collection center, or a mobile collection point, where the milk is collected by a grader and his attendant and put in aluminum milk cans. The milk cans are then directly transported by a truck to the processing plant. Furthermore, throughout the supply chain, milk tests are performed at various points in the process to assess milk quality. The short supply chain is present in the areas close to the milk processing plant. In figure 4 the short milk supply chain is schematically visualized and below each step is explained in more detail.

Figure 4: Fresha's short milk supply chain. Source: (L. van den Broek, 2022).

The dairy farmers who are members of Githunguri Dairy Farmers Co-Operative Society deliver their cow milk twice a day. The size of the dairy farms determines, among other things, how and by whom the cows are milked. It also affects the amount of milk produced. Figure 5 shows the different farm sizes. The left picture shows a small farm with two cows where the owner milks the cows manually. The picture in the middle was taken on a farm with fifteen cows and the employees milk the cows by hand. The cows in the right image are kept on a farm with thirty-five cows where the employees milk the cows with a milking machine.

Figure 5: Fresha's members dairy farms. Source: (L. van den Broek, 2022).

After the cows have been milked, the farmer brings the unrefrigerated milk in aluminum milk cans to the nearest collection center. The milk collection points can be divided into two types, namely a collection center and a mobile collection point. A collection center is a building made of brick where milk is collected in aluminum cans that are cleaned and/or stored at this location. The grader and attendant come by themselves to this location. After collection, the grader waits with the attendant for the truck to ensure that all milk that has been collected, has been picked up, which then will be transported to the processing plant. A mobile collection point is a building made of wood to which dairy farmers bring their milk, wait for a truck with the grader, assistant, and milk cans. At this location, the cans are not washed nor stored. In figures 6 and 7 the difference between the two milk collection centers is visualized.

Figure 7: Fresha's collection center. Source: (L. van den Broek, 2022).

Figure 6: Fresha's mobile collection point. Source: (L. van den Broek, 2022).

The farmers transport the milk to a collection center or mobile collection point using one of the following methods: by foot, wheelbarrow, bicycle or motorbike, donkey carts or their own transportation such as a car, in figure 8 these methods are visualized. When building the collection points, GDFCS took the location into account so that it is central to the farmers. On average, farmers are located within 1.5 to 2 kilometers from the nearest collection point to which they deliver their raw milk.

Figure 8: Fresha's members transporting raw milk. Source: (L. van den Broek, 2022).

Upon receiving at a collection point, milk from the dairy farmers is tested by the grader to assess the quality of the milk. At this stage of the process, the following tests are performed:

- <u>Lactometer test:</u> Check the density of the milk; every milk can individually.
- <u>Alcohol test:</u> Check the stability of milk proteins; every milk can individually.

If the milk has a density between 27 L.R to 32 L.R and no flakes or skim appear while doing the alcohol test, the milk is allowed to continue in the process. If the milk fails the tests, the dairy farmer is sent home with the milk. In case of continuing failed results, a Dairy Extension Officer (DEO) is sent to the farm in question to investigate the cause. Figure 9 shows how both tests are performed and in Appendix A.4. the procedures of the tests are described.

After approval of the milk, the farmer then pours the milk through a filter, into an aluminum milk can owned by the cooperative, with an identical number. This milk can is connected to a weighing scale, which is linked to an app, called PIMPAPP that uses the identical farm number to register how many kilograms of milk the farmer has brought in. The identical milk can number is also recorded in order to trace which milk belongs to which farmer. In this way, in case of rejection in the follow-up process, it is possible to find out from which farmers milk is in a specific can. Figure 10 shows the farmers pouring the milk in the milk can and the app linked to the weighing system on which the farm number, milk can number, and amount of milk can be seen.

Figure 9: Performance lactometer and alcohol test. Source: (L. van den Broek, 2022).

Figure 10: Farmer pouring raw milk in Fresha's milk can and PIMPAPP linked to the weighing scale. Source: (L. van den Broek, 2022).

After all the milk has been collected, in case of a collection center, the full milk cans are put together and the grader notes the number of cans collected and records the number of kilograms for the administration. In this way, it can be checked how much milk was taken in and if it corresponds with the amount of milk processed at the plant. The grader then waits with the attendant for the truck to ensure that all milk that has been collected, has been picked up, which then will be transported to the processing plant. Depending on the route, the truck collects milk cans at several collection centers before unloading at the processing plant. In case of a mobile collection point, the full milk cans are loaded directly in the truck and go to the next mobile collection point. After completing the mobile route, the truck transports the milk to the processing plant. Figure 11 shows what loading the truck with milk cans looks like.

Figure 11: Loading the truck with milk cans to transport them to the processing plant. Source: (L. van den Broek, 2022).

Upon arrival at the plant, the milk cans are tested again to assess the quality of the milk. At this stage of the process, the following tests are performed:

- Lactometer test: Check the density of the milk; every milk can individually.
- Alcohol test: Check the stability of milk proteins; every milk can individually.

If the milk has a density between 27 L.R to 32 L.R and no flakes or skim appear while doing the alcohol test, the milk is allowed to continue in the process. If approved, the milk cans are manually emptied, and the processing starts. This is shown in figure 12. In case of rejection on arrival, the milk is not processed and sold as pig feed. Reasons for rejection after collection are souring of milk due to long transportation / problems along the way, hygiene of Fresha's milk cans and incomplete execution of tests during milk collection. The rejection of milk is explained in more detail in chapter 3.3.2.

Figure 12: Unloading milk cans at the processing plant. Source: (L. van den Broek, 2022).

The milk cans are cleaned after being emptied. This is accomplished by rinsing the milk can with cold water after it has been emptied to remove any remaining milk. After that, warm water and chlorine-based sanitizer is used to wash the can's inside. The can is then given a second cold water rinse to get rid of any remaining soap. The milk jugs are then drained and air dried inverted on a rack at the collection center after being disinfected with sodium bicarbonate.

3.1.2.2 FRESHA'S LONG MILK SUPPLY CHAIN

Unlike the short chain, Fresha's long milk supply chain has an additional stop and is as follows: dairy farmers bring the milk to a collection center or a mobile collection point, and then it is taken to a cooling center. Another option is bringing the milk directly to a cooling center which includes a collection center. At the cooling center, the milk is cooled for several hours before being transported to the processing plant. Furthermore, throughout the supply chain, milk tests are performed at various points in the process to assess milk quality. The long supply chain is present in the areas further away from the milk processing plant. In figure 13 the long milk supply chain is schematically visualized and below each step is explained in more detail.

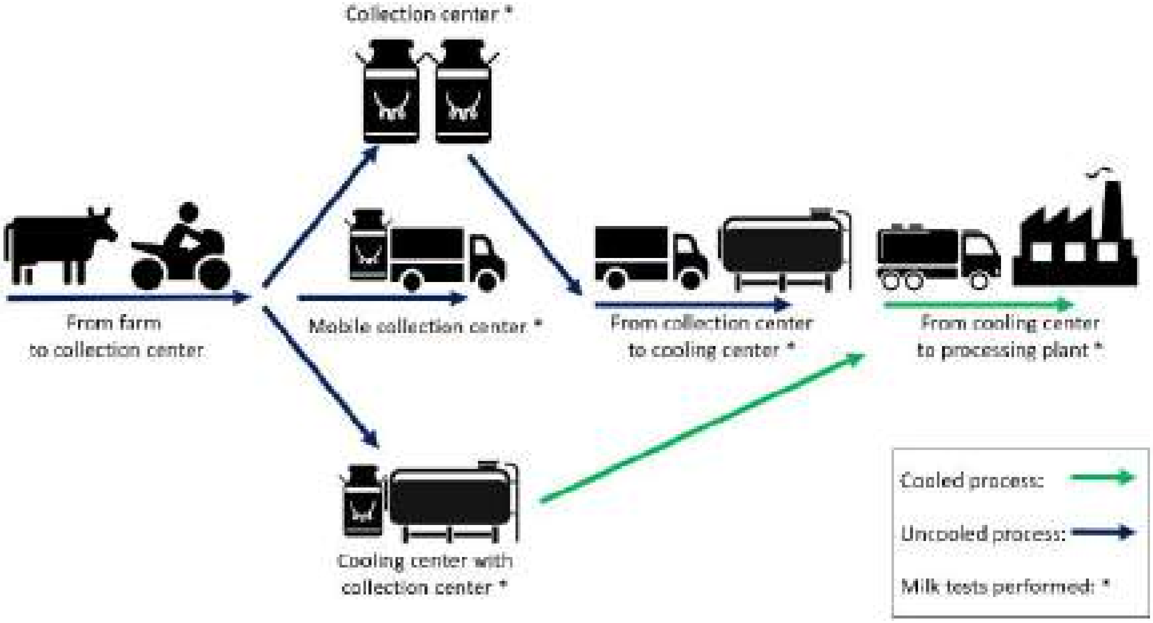

Figure 13: Fresha's short milk supply chain. Source: (L. van den Broek, 2022).

Two times every day, the dairy farmers who are members of Githunguri Dairy Farmers Co-Operative Society deliver milk from their cows. The scale of the dairy farms affects a variety of factors, including how and who milks the cows. Figure 14 displays the various farm sizes. A little farm with two cows can be seen on the left, and the owner milks them by hand. The image in the center was taken on a farm with fifteen cows, and the workers manually milked the cows. The cows in the right image are kept on a farm with thirty-five cows, and the workers use a milking machine to milk the cows there.

Figure 14: Fresha's members dairy farms. Source: (L. van den Broek, 2022).

The farmer transports the unrefrigerated milk in aluminum milk cans to the closest collection facility after milking the cows. In case of the long milk supply chain, milk collecting centers can be classified into three categories: collection centers, mobile collection points, and cooling centers with collection center. At a collection center, the milk is gathered in aluminum cans and kept or sanitized. This collection facility is made of brick and both the grader and the assistant travel to this location on their own. They wait for a truck to come and pick up the aluminum milk cans after collecting so that they can be taken to the processing facility. A mobile collecting point is a wooden building where dairy farmers can bring their milk and wait for a truck to arrive with the grader, attendant, and milk cans. Cans are not cleaned or kept in storage at this site. Furthermore, dairy farmers who live close to a cooling center have the option of going directly to such a center with a collecting point. The milk is collected at this location, which also includes a milk cooling tank that allows the milk to be rapidly cooled after being received. Figures 15 and 16 show the differences between the three milk collection centers. The picture on the left picture of figure 15 showing the collection center, and the right image visualizing the cooling center with collection center. Figure 16 shows mobile collection points.

Figure 16: Fresha's collection center and cooling center with collection center. Source: (L. van den Broek, 2022).

Figure 15: Fresha's mobile collection point. Source: (L. van den Broek, 2022).

The farmers use one of the following methods to transport the milk to a collection facility: walking, riding a (motor)bike, using donkey carts, or driving their own vehicle, as shown in figure 17. Githunguri Dairy Farmers Co-Operative Society considered the area's accessibility to the farmers when constructing the collection facilities. The distance between farmers' homes and the nearest collection point to which they deliver their raw milk is typically 1.5 to 2 kilometers.

Figure 17: Fresha's members transporting raw milk. Source: (L. van den Broek, 2022).

The grader and the assistant test the milk from dairy farmers upon receiving it at the collection center to assess the quality of the milk. At this stage, the following tests are performed:

- Lactometer test: Check the density of the milk; every milk can individually.
- Alcohol test: Check the stability of milk proteins; every milk can individually.

The milk is permitted to proceed with the process if it has a density between 27 L.R to 32 L.R and no flakes or skim show up while performing the alcohol test. The dairy farmer is sent home with the milk if the milk fails the test. A DEO is assigned to the farm in question to look into the problem if the results keep failing. Figure 19 demonstrates the execution of both tests and in Appendix A.4. the procedures of the test are described. Figure 18 illustrates the farmers filling the milk cans while the PIMAPP, connected to the weighing system is also visible, showing the farm number, milk can number, and amount of milk.

Figure 19: Performance lactometer and alcohol test. Source: (L. van den Broek, 2022).

Figure 18: Farmer pouring raw milk in Fresha's milk can and PIMPAPP linked to the weighing scale. Source: (L. van den Broek, 2022).

When all the milk has been collected, the full milk cans are collected at a collection center, and the grader records the number of cans collected and the number of kilograms for recordkeeping purposes. In this way, the amount of milk brought in can be determined and can be compared with the amount of milk received at the cooling center, and ultimately the amount processed at the processing plant. To ensure that all the collected milk is delivered to the cooling center, the grader, along with the attendant, waits for the truck to pick up the milk. Depending on the route, the truck unloads at the cooling center after collecting the milk cans at various collection centers. In the event of a mobile collection point, the full milk cans are loaded directly into the truck and driven to the following collection point. After completing the mobile route, the truck delivers the milk to the cooling center. Figure 20 demonstrates what it looks like to load the truck with milk cans.

Figure 20: Loading the truck with milk cans to transport them to the cooling center. Source: (L. van den Broek, 2022).

In case of the milk collected at a cooling center with collection facility, the milk is cooled directly after being received. Upon arrival at the cooling center, the milk is tested. In this stage of the process, the following tests are executed:

- <u>Lactometer test:</u> Check the density of the milk; every milk can individually.
- <u>Alcohol test:</u> Check the stability of milk proteins; every milk can individually.
- <u>Antibiotics test:</u> Check if antibiotics are present in the milk; bulk milk cooling tank.
- <u>Aflatoxins test:</u> Check if aflatoxins are present in the milk; bulk milk cooling tank.
- <u>Neutralizers test:</u> Check if neutralizers are present in the milk; bulk milk cooling tank.

The above-mentioned tests are performed to check if the milk is free of antibiotics, aflatoxins, and neutralizers, such as sodium bicarbonate, which can alter the composition and modify the quality of the milk. In Appendix A.4. the procedures of the test are described. If approved, the milk cans are manually emptied and pumped into the cooling tank, see figure 21. At the cooling center the milk is stored for several hours and cooled to an average of 7°C.

Figure 21: Emptying milk cans and pumping the milk into the cooling tank. Source: (L. van den Broek, 2022).

After the milk cans have been emptied, they are cleaned. This is done as follows: after emptying the milk can, milk residue is removed by rinsing the can with chilly water. Then the inside of the can is washed with warm water and a chlorine-based sanitizer. After that, the can is rinsed again with chilly water to remove soap residue. Finally, the milk jugs are disinfected with sodium bicarbonate and drained and air-dried in an inverted position in a rack either at the cooling center, or a collection center.

Since the dairy farmers deliver milk twice a day, the milk tank is also emptied twice a day and pumped into a tanker truck with a capacity of 10 or 11 tons of milk, see figure 23. Loading the tanker takes about 45 minutes after which the truck drives to the processing plant. Upon arrival at the processing plant, the raw milk in the tanker is tested again. In this way Fresha monitors the milk after every transport movement and they can ensure the quality of the milk. A number of milk tests are performed in this step of the process, including the following:

- Lactometer test: Check the density of the milk; bulk milk tanker truck.
- Alcohol test: Check the stability of milk proteins; bulk milk tanker truck.
- Antibiotics test: Check if antibiotics are present in the milk; bulk milk tanker truck.
- Aflatoxins test: Check if aflatoxins are present in the milk; bulk milk tanker truck.
- Neutralizers test: Check if neutralizers are present in the milk; bulk milk tanker truck.

After approval, the milk is unloaded into two large storage silos after which the processing begins, as shown in figure 22. In case of rejection on arrival, the milk is not processed and sold as pig feed. Reasons for rejection after collection are souring of milk due to long transportation / problems along the way, hygiene of milk cans and incomplete execution of tests during milk collection. The rejection of milk is explained in more detail in chapter 3.3.2.

Figure 23: Loading the tanker truck with cooled milk to transport it to the processing plant. Source: (L. van den Broek, 2022).

Figure 22: Figure 12: Unloading the tanker truck at the processing plant. Source: (L. van den Broek, 2022).

3.2 COSTS OF TRANSPORTING MILK

The milk used by Githunguri Dairy Farmers Co-Operative Society is transported through several stages from farm production to processing. First, the dairy farmer brings the milk to a collection center. The cost of transportation from farm to collection point is the responsibility of the dairy farmer. Then, in the case of the short supply chain, the milk is taken directly to the milk processing plant. This is done by three hired transporters. In case of the long supply chain, the milk is collected from the collection center and transported to a cooling center. This is done by 6 Fresha-owned trucks, and twenty-seven contracted external transporters with a capacity varying between 3 and 7 tons of milk. Lastly, the raw milk is transferred from the cooling center to the milk processing plant by one of GDFCS' 6 tanker trucks, each with a capacity of 10 to 11 tons of milk. The transportation of raw milk, at the expense of Fresha, starts from the collection center (Chepkwony, personal communication). In figure 24 one of Fresha's trucks, one of their tanker trucks and a picture of a hired transporter is visualized.

Figure 24: Fresha's transport and hired transport. Source: (L. van den Broek, 2022).

In figure 25 is shown in red and green who is responsible for transporting the raw milk. In the figure the short supply chain is shown schematically, for the long supply chain the same division of responsibility for transporting the milk applies.

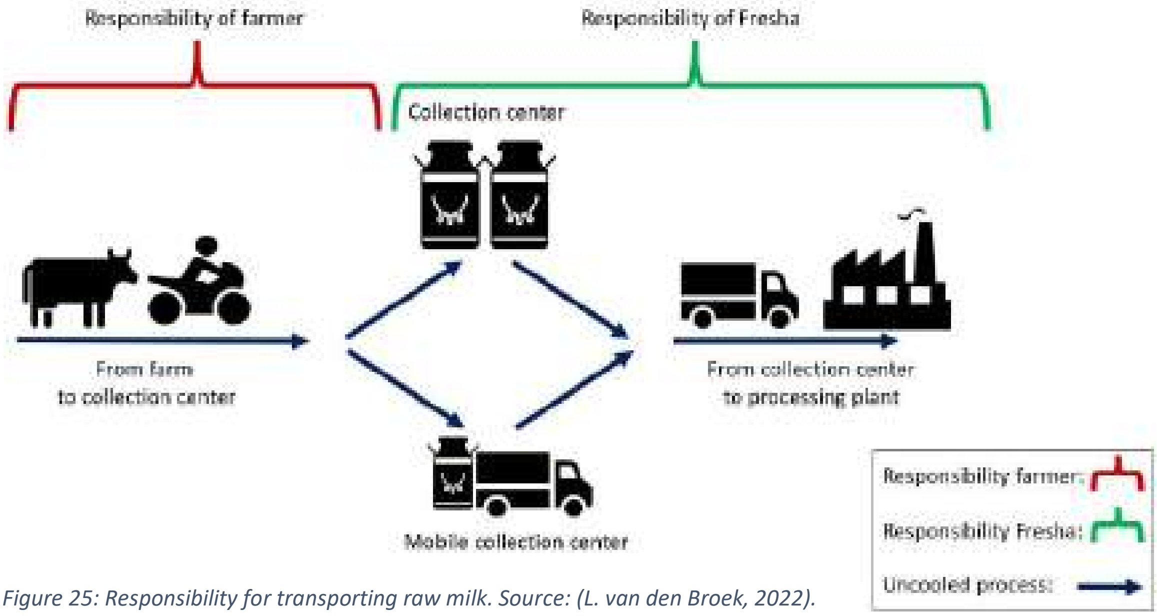

Figure 25: Responsibility for transporting raw milk. Source: (L. van den Broek, 2022).

After conducting a cost-benefit analysis, in which Fresha compared its own transport with hired transport, it was found that using hired transporters is more cost-effective. This is because for their own transportation, Fresha must invest in trucks and pay for maintenance and fuel. In addition, the vehicles and personnel must be insured and personnel costs must be paid. Regarding the hired transport, these are given the annual opportunity to participate in a tender, where a standard maximum monthly payment is agreed upon. This amount is based on the distance the transporter will travel, the condition of the roads (tarmac or poor roads), fuel consumption and the loading capacity of the vehicle. Although hiring transport is economically cheaper, it also comes with risks. For example, these transporters are more difficult to control and monitor when a delay occurs, causing them to be late, affecting the quality of the milk. To mitigate this risk, Fresha has established a policy that ensures that the carrier will be held responsible if the milk goes bad. It is also possible that breakdowns occur, requiring the hired transporter to arrange for alternative transportation to ensure the milk is collected or delivered on time (Chepkwony, personal communication).

3.2.1 TOTAL TRANSPORTATION COSTS

The total transportation costs, including costs of own transport, and hired transporters, of raw milk from Githunguri Dairy Farmers Co-Operative Society in 2021 and 2022 is shown in table 1. In Appendix A.5. it can be seen how the total transportation costs are broken down.

TOTAL TRANSPORT	2021	2022	DIFFERENCE
January	KES 17,318,304	KES 18,216,019	KES +897,715
February	KES 17,502,133	KES 17,983,075	KES +480,942
March	KES 17,596,208	KES 18,768,669	KES +1,172,461
April	KES 18,096,106	KES 18,339,024	KES +242,919
May	KES 17,910,276	KES 21,061,814	KES +3,151,538
June	KES 17,438,888	KES 19,071,860	KES +1,632,972
July	KES 18,180,786	KES 19,107,167	KES +926,382
August	KES 18,186,122	KES 19,737,391	KES +1,551,270
September	KES 18,121,979	KES 19,556,344	KES +1,434,365
October	KES 18,554,884	KES 19,458,923	KES +904,038
November	KES 18,565,431	KES 20,292,864	KES +1,727,433
December	KES 18,540,953	KES 19,603,603	KES +1,062,651
TOTAL	**KES 216,012,068**	**KES 231,196,753**	**KES +15,184,685**

Table 1: Total transportation costs Fresha in 2021 and 2022. Source: (Fresha, 2022).

For 2021 and 2022, table 1 shows the transportation costs for raw milk of Githunguri Dairy Farmers Co-Operative Society on a monthly basis. The difference between the two years is shown in the last column of the table. This difference was calculated based on how much higher or lower the costs were in 2022 compared to 2021.

3.2.2 TRANSPORTATION COSTS OWN TRANSPORT

In total, Githunguri Dairy Farmers Co-Operative Society owns twelve trucks that transport raw milk. The cost of own transportation can be divided into labor costs and material costs. Labor costs include salaries, house allowance, national social security fund, pension fund and medical insurance for the staff. Depreciation, repairs and fuel for the vehicles, insurance and permits comprise the material costs. Table 2 shows the total cost of transporting raw milk with the twelve vehicles owned by Githunguri Dairy Farmers Co-Operative Society.

OWN TRANSPORT	2021	2022	DIFFERENCE
January	KES 13,197,043	KES 14,251,075	KES +1,054,032
February	KES 13,501,213	KES 13,788,936	KES +287,723
March	KES 13,516,696	KES 14,265,967	KES +749,271
April	KES 13,911,992	KES 14,009,480	KES +97,489
May	KES 13,511,079	KES 16,608,129	KES +3,097,051
June	KES 13,472,074	KES 14,704,851	KES +1,232,777
July	KES 14,015,056	KES 14,738,148	KES +723,092
August	KES 14,136,234	KES 15,142,238	KES +1,006,004
September	KES 14,059,585	KES 15,098,336	KES +1,038,751
October	KES 14,263,537	KES 15,152,211	KES +888,674
November	KES 14,481,788	KES 15,607,500	KES +1,125,712
December	KES 14,079,687	KES 14,757,311	KES +677,624
TOTAL	**KES 166,145,982**	**KES 178,124,181**	**KES +11,978,199**

Table 2: Transportation costs of Fresha's own transport in 2021 and 2022. Source: (Fresha, 2022).

For 2021 and 2022, table 2 shows per month the cost of own transportation by the Githunguri Dairy Farmers Co-Operative Society. The difference between the two years is shown in the last column of the table. This difference was calculated based on how much higher or lower the costs were in 2022 compared to 2021.

3.2.3 TRANSPORTATION COSTS HIRED TRANSPORTERS

In addition to internal transportation, Fresha hires thirty external carriers which transport raw milk from collection centers to cooling centers and/or the milk processing plant. The hired transporters can apply for a contract through a tender. A standard maximum price is agreed based on the distance covered, the condition of the roads, the fuel consumption, and the loading capacity of the vehicle. Table 3 shows the total cost of transporting raw milk by the hired carriers.

HIRED TRANSPORT	2021	2022	DIFFERENCE
January	KES 4,121,261	KES 3,964,944	KES –156,317
February	KES 4,000,920	KES 4,194,139	KES +193,219
March	KES 4,079,512	KES 4,502,702	KES +423,190
April	KES 4,184,114	KES 4,329,544	KES +145,430
May	KES 4,399,197	KES 4,453,685	KES +54,487
June	KES 3,966,814	KES 4,367,009	KES +400,195
July	KES 4,165,729	KES 4,369,019	KES +203,290
August	KES 4,049,888	KES 4,595,154	KES +545,266
September	KES 4,062,394	KES 4,458,008	KES +395,614
October	KES 4,291,347	KES 4,306,712	KES +15,365
November	KES 4,083,644	KES 4,685,365	KES +601,721
December	KES 4,461,266	KES 4,846,293	KES +385,027
TOTAL	**KES 49,866,086**	**KES 53,072,572**	**KES +3,206,486**

Table 3: Transportation costs of Fresha's hired transporters in 2021 and 2022. Source: (Fresha, 2022).

Table 3 demonstrates, for 2021 and 2022, the transportation costs of hired transportation by Githunguri Dairy Farmers Co-Operative Society on a monthly basis. The difference between the two years is shown in the last column of the table. This difference was calculated based on how much higher or lower the costs were in 2022 compared to 2021.

3.2.4 TRANSPORT COSTS OWN TRUCKS VERSUS HIRED TRUCKS

In 2022, Fresha used both own and hired transport to transport the raw milk throughout the milk supply chain. In order to understand which way of transport is most cost-effective, the difference between the two has been calculated based on table 2 and 3. The difference between the transport costs of own transport and hired carries in 2022 is shown in table 4.

2022	OWN TRANSPORT	HIRED TRANSPORT	DIFFERENCE
January	KES 14,251,075	KES 3,964,944	KES +10,286,131
February	KES 13,788,936	KES 4,194,139	KES +9,594,797
March	KES 14,265,967	KES 4,502,702	KES +9,763,265
April	KES 14,009,480	KES 4,329,544	KES +9,679,936
May	KES 16,608,129	KES 4,453,685	KES +12,154,445
June	KES 14,704,851	KES 4,367,009	KES +10,337,842
July	KES 14,738,148	KES 4,369,019	KES +10,369,129
August	KES 15,142,238	KES 4,595,154	KES +10,547,084
September	KES 15,098,336	KES 4,458,008	KES +10,640,328
October	KES 15,152,211	KES 4,306,712	KES +10,845,500
November	KES 15,607,500	KES 4,685,365	KES +10,922,135
December	KES 14,757,311	KES 4,846,293	KES +9,911,018
TOTAL	**KES 178,124,181**	**KES 53,072,572**	**KES +125,051,610**

Table 4: Transportation costs of Fresha's own trucks versus hired trucks in 2022. Source: (Fresha, 2022).

Table 4 demonstrates, for 2022, the transportation costs of Fresha's own transport and hired transport by Githunguri Dairy Farmers Co-Operative Society on a monthly basis. The difference between the two ways of transport is shown in the last column of the table. This difference was calculated by how much higher the costs of own transport were compared to hired transport.

3.2.5 MILK INTAKE

In 2021, Fresha collected 85.1 million kilograms of milk from dairy farmers who are members of the cooperative. In 2022, the number of kilograms of milk collected was 87.6 million. Table 5 shows the amount of milk collected in 2021 and 2022 on a monthly basis.

MILK INTAKE	2021	2022	DIFFERENCE
January	6,845,430 kg	7,370,355 kg	+524,924 kg
February	6,167,490 kg	6,679,980 kg	+512,490 kg
March	7,024,114 kg	7,385,147 kg	+361,033 kg
April	6,860,524 kg	7,303,140 kg	+442,616 kg
May	7,304,631 kg	7,732,380 kg	+427,749 kg
June	7,232,163 kg	7,587,552 kg	+355,390 kg
July	7,390,009 kg	7,428,146 kg	+38,137 kg
August	7,349,900 kg	7,239,247 kg	-110,653 kg
September	7,056,782 kg	7,099,347 kg	+42,565 kg
October	7,245,641 kg	7,401,058 kg	+155,417 kg
November	7,154,037 kg	7,048,655 kg	-105,383 kg
December	7,473,716 kg	7,280,952 kg	-192,764 kg
TOTAL	**85,104,437 kg**	**87,555,958 kg**	**+2,451,521 kg**

Table 5: Fresha's milk intake in 2021 and 2022. Source: (Fresha, 2022).

For 2021 and 2022, table 5 shows the raw milk intake per month of Githunguri Dairy Farmers Co-Operative Society. The difference between the two years is shown in the last column of the table. This difference is calculated based on how much higher or lower the milk intake was in 2022 compared to 2021.

3.2.6 TRANSPORTATION COSTS PER KG MILK FRESHA

The cost of transporting raw milk is one of the costs incurred by Githunguri Dairy Farmers Co-Operative Society which is part of the milk processing process. In order to understand the amount of transportation cost per kilogram of milk, it has been calculated based on table 1 and 5. The total costs, including both own and hired transport, of transporting raw milk per kilogram of milk of Fresha is shown in table 6.

COSTS PER KG MILK	2021	2022	DIFFERENCE
January	KES 2.53	KES 2.47	KES -0.06
February	KES 2.84	KES 2.69	KES -0.15
March	KES 2.51	KES 2.54	KES +0.04
April	KES 2.64	KES 2.51	KES -0.13
May	KES 2.45	KES 2.72	KES +0.27
June	KES 2.41	KES 2.51	KES +0.10
July	KES 2.46	KES 2.57	KES +0.11
August	KES 2.47	KES 2.73	KES +0.25
September	KES 2.57	KES 2.75	KES +0.19
October	KES 2.56	KES 2.63	KES +0.07
November	KES 2.60	KES 2.88	KES +0.28
December	KES 2.48	KES 2.69	KES +0.21
AVERAGE	**KES 2.54**	**KES 2.64**	**KES +0.10**

Table 6: Transportation costs of Fresha per kilogram of milk in 2021 and 2022. Source: (Fresha, 2022).

Table 6 shows per month for 2021 and 2022 what the transportation cost per kilogram of milk was for Githunguri Dairy Farmers Co-Operative Society. The difference between the two years is shown in the last column of the table. This difference was calculated based on how much higher or lower the transportation cost per kilogram of milk was in 2022 compared to 2021.

3.2.7 TRANSPORT COSTS PER KG MILK OWN TRUCKS VERSUS HIRED TRUCKS

In 2022, Fresha used both own and hired transport to transport the raw milk throughout the milk supply chain. In order to understand which way of transport is most cost-effective per kilogram of milk, the difference between the two has been calculated based on table 2, 3 and 5. The difference between the transport costs per kilogram of milk of own transport and hired carries in 2022 is shown in table 7.

2022	OWN TRANSPORT	HIRED TRANSPORT	DIFFERENCE
January	KES 1.93	KES 0.54	KES +1.40
February	KES 2.06	KES 0.63	KES +1.44
March	KES 1.93	KES 0.61	KES +1.32
April	KES 1.92	KES 0.59	KES +1.33
May	KES 2.15	KES 0.58	KES +1.57
June	KES 1.94	KES 0.58	KES +1.36
July	KES 1.98	KES 0.59	KES +1.40
August	KES 2.09	KES 0.63	KES +1.46
September	KES 2.13	KES 0.63	KES +1.50
October	KES 2.05	KES 0.58	KES +1.47
November	KES 2.21	KES 0.66	KES +1.55
December	KES 2.03	KES 0.67	KES +1.36
AVERAGE	**KES 2.03**	**KES 0.61**	**KES +1.42**

Table 7: Transportation costs per kilogram of milk of Fresha's own trucks versus hired trucks in 2022. Source: (Fresha, 2022).

Table 7 demonstrates, for 2022, the transportation costs per kilogram of milk of Fresha’s own transport and hired transport on a monthly basis. The difference between the two ways of transport is shown in the last column of the table. This difference was calculated on how much higher the costs per kilogram of milk of own transport were compared to hired transport.

3.2.8 TRANSPORTATION COSTS PER KG MILK THE NETHERLANDS

An interview with FrieslandCampina's Manager of Milk Logistics took place on December 22, 2022. FrieslandCampina is a Dutch dairy organization founded in 1871 by farmers who joined forces and started a co-operative. Today, FrieslandCampina is one of the largest dairy organizations in the world, with branches in thirty-two countries and 22,961 employees (FrieslandCampina, 2023). The Milk Logistics Manager indicated during the interview that the average transport cost of raw milk in the Netherlands is €0.01 per kilogram of milk, this corresponds to KES 1.36. In these costs, the transport of milk from the dairy farm directly to the factory is included, as well as the transport between the factories. The transport costs include labor costs, material costs and overhead costs. It must be taken into account that FrieslandCampina uses the most modern techniques and trucks and applies different labor costs compared to Kenya. Furthermore, the state of the roads and the size of the livestock farmers are not comparable to the situation in Githunguri (Wieleman, personal communication, 22-12-2022). Table 8 shows for 2022 the average costs of transporting raw milk per kilogram of milk of Fresha and FrieslandCampina. The difference between the two dairy cooperatives is shown in the last two columns of the table. This difference is calculated based on how much higher the transportation costs per kilogram of milk was for Fresha compared to FrieslandCampina in KES and percentage.

COSTS PER KG MILK	FRESHA	FRIESLAND CAMPINA	DIFFERENCE IN KES	DIFFERENCE IN PERCENTAGE
2022	KES 2.64	KES 1.36	KES +1.28	+51.5%

Table 8: Transportation costs per kilogram of milk of Fresha versus FrieslandCampina in 2022. Source: (L. van den Broek, 2022).

3.3 OPPORTUNITIES FOR IMPROVEMENT TO INCREASE EFFICIENCY

To gain insight into how to increase the efficiency of collecting and transporting raw milk from the farm to the processing plant, twelve people from the Dairy Extension Office and Quality Control and one person from Tetra Pak completed a questionnaire. This survey asked them about their experiences and opinions on the supply chain and transport of milk as well as how they would increase efficiency. This chapter provides details of the survey results and identifies potential new opportunities for improvement based on insight gained from the information gathered in Chapter 3.1 and 3.2.

3.3.1 QUESTIONNAIRE

By completing a questionnaire, employees from the Dairy Extension Office, Quality Control and Tetra Pak shared their experiences and ideas on how to improve the collection and transportation of milk. The results of this questionnaire are detailed below in table 9. In this table, in white, the questions are stated. The numbers on the left visualize the number of people giving a certain answer. The answers to the question are shown on the right side of the table. Appendix A.6. shows the questions and answers for each person.

What department do you work for?	
12	Dairy Extension and Quality Assurance
1	Tetra Pak
What do you think is done well in the collection process of raw milk?	
7	Checking parameters of milk by means of quality tests
6	Duration and number of times of milk collection
2	Distance between farmer and collection centers
What would you change in the collection process of milk to make it more efficient?	
2	Nothing
3	Infrastructure (roads)
4	Additional cooling and/or collection centers
5	Reducing time between milking and collection
2	Milk quality tests at farm level, before collection
What do you think is done well in the transport of raw milk from farm to processing plant?	
7	Duration of transport to cooling center/processing plant
4	Use of aluminum milk cans and tanker trucks to transport milk
1	Right number of vehicles to transport milk
What would you change in the transportation of raw milk from farm to processor to make it more efficient?	
2	Nothing
4	Infrastructure (roads)
2	Status of vehicles (cooled/cleaned/well maintained)
2	Additional cooling and/or collection centers

Table 9: Results questionnaire. Source: (L. van den Broek, 2022).

Possible areas for improvement are reducing the duration of time between milking and cooling, building more collection, and cooling centers, improving the infrastructure (roads), and improving the status of the vehicles.

3.3.2 MILK REJECTION

During both the short and long supply chain, raw milk is inspected repeatedly for density, milk protein balance, antibiotics, aflatoxins, and neutralizers. At several stages in this process, rejection occurs based on the aforementioned tests. The main reasons for milk rejection are shown in table 10. The reason and possible cause for rejection depend on the stage in the process: during milk collection or after transport at the milk entry to the cooling center or processing plant.

MILK REJECTS	REASON OF REJECTION	POSSIBLE CAUSE OF REJECTION
During milk collection	Alcohol positive	Hygiene (cows/stable/milk can farmer) Mastitis Late or extended lactation
	Off smell / Acidity	Hygiene, storage temperature, duration of transport to collection center
	Density <27 L.R or >32 L.R	Treated milk: water or neutralizers added
After transport at the milk entry to the cooling center or processing plant.	Alcohol positive	Test not executed properly during milk collection
	Off smell / Acidity	Cleaning, draining, and drying of Fresha's milk cans, duration of time that milk is not cooled to 4°C, milk temperature at collection that exceeds the maximum acceptable of 6°C

Table 10: Main reasons of rejection Fresha. Source: (L. van den Broek, 2022).

To gain insight into the amount of milk being rejected, table 11 has been developed. This table shows the total milk rejection per month for both 2021 and 2022. Total milk rejection includes the rejection during collection of the milk as well as after transport at the milk entry to the cooling center or processing plant. The difference between the two years is shown in the last column of the table. This difference was calculated based on how much more or less kilograms of milk was rejected in 2022 compared to 2021.

MILK REJECTS	2021	2022	DIFFERENCE
January	2,927 kg	1,224 kg	-1,703 kg
February	2,142 kg	886 kg	-1,256 kg
March	2,040 kg	1,684 kg	-356 kg
April	3,620 kg	2,263 kg	-1,357 kg
May	7,383 kg	3,467 kg	-3,916 kg
June	1,557 kg	953 kg	-604 kg
July	1,632 kg	448 kg	-1,184 kg
August	1,379 kg	1,515 kg	+136 kg
September	867 kg	1,045 kg	+178 kg
October	1,632 kg	1,807 kg	+175 kg
November	2,284 kg	2,117 kg	-167 kg
December	1,799 kg	1,299 kg	-500 kg
TOTAL	**29,262 kg**	**18,708 kg**	**-10,554 kg**

Table 11: Fresha's milk rejection in 2021 and 2022. Source: (Fresha, 2022).

Githunguri Dairy Farmers Co-Operative Society, with regard to the transportation of raw milk, has no direct influence on milk rejection during milk collection due to farm related causes. However, the organization has an influence from collection onwards. From table 10 it can be seen that the causes of rejection during this stage come from duration of time at which the milk is not cooled to 4°C, the temperature of milk before transport which exceeded the maximum of 6°C and the cleaning, draining and drying process of Fresha's own milk cans. Sections 3.3.2.1, and 3.3.2.2 explain the above causes in more detail.

3.3.2.1 TRANSPORT TIME AND COOLING TEMPERATURE

The duration of time in which milk is transported before it is cooled or processed at the processing plant is essential for the quality of the milk, as well as the temperature of cooling. Warm fresh milk should preferably be cooled immediately after milking to preserve quality and prevent spoilage. Cooling to <6°C within two hours of milking (Fonterra, 2020) and to 4°C within a maximum of three to four hours of milking is essential, but faster cooling is preferable (FAO, 2016).

The duration of time in which the raw milk of Githunguri Dairy Farmers Co-Operative Society is transported can be divided into the following stages:

- Dairy farm to (mobile) collection center or processing plant
  The time from milking the first cow, to transporting the raw milk to the collection center or processing plant takes, is estimated, a maximum of 1 hour. The time required depends on the number of cows being milked, the number of personnel, the distance from the dairy farm to the processing plant or nearest collection point, and the means of transportation. Exact data is not available on transportation time from dairy farm to collection center or processing plant (Kamau, personal communication).
- (Mobile) collection center to cooling center
  Transporting the milk from the collection center, or in case of a route with mobile collection points, to a cooling center takes, by approximation, a maximum of 3 hours. The time required depends on, in the case of a mobile route, the number of mobile collection points and the timely arrival of dairy farmers. In addition, the state of the roads, weather conditions, the distance between collection center and cooling center and the condition of the vehicle (chance of breakdown) affect the duration. Exact data is not available on the transportation time from collection center to cooling center (Kamau, personal communication).
- Cooling center to processing plant
  The raw milk which is stored in a milk cooling tank for several hours before it is transported to the milk processing plant by tanker truck. Loading this truck takes on average 45 minutes. The milk is then transported to the plant in on average 30 minutes. The transport time depends on the distance between the cooling center and the milk processing plant, the state of the roads, weather conditions and the condition of the vehicle (risk of breakdowns) (Kamau, personal communication). To understand the exact time transport takes, data on the transport time of milk from the cooling center to the processing plant was analyzed from December 2022. Fresha had a total of twelve cooling centers in operation during this period. Data was collected daily on the time it took for the trucks to transport the milk from the cooling centers to the milk processing plant. As explained in chapter 3.1.2.1 and 3.1.2.2 the dairy farmers deliver the milk twice a day to the collection centers. This means that the milk is also transported from the collection centers to the cooling centers and then to the milk processing plant twice a day. Figure 26 shows for one day the time it took for the milk to be transported during the morning and evening collection. In Appendix A.7.2 transport times are shown for a period of several days.

		9/12/2022		
	Tanker (morning)	Departure cooling center	Arrival processing plant	Time needed
COOLING CENTER	MERANO	12:45	13:16	0:31:00
	GATHAITHI	10:55	11:20	0:25:00
	IKINU	10:14	10:40	0:26:00
	GITHIGA	9:05	9:20	0:15:00
	KAMBAA	9:20	9:42	0:22:00
	GITHIA	11:10	11:36	0:26:00
	KWA MAIKO	9:44	10:40	0:56:00
	KARUAI	10:13	10:36	0:23:00
	GATHANGA	8:20	9:06	0:46:00
	GATHIRUINI	11:24	11:56	0:32:00
	GAKOE	9:30	10:02	0:32:00
	KAMACHARI	12:30	12:46	0:16:00
	AVERAGE			0:29:10
	Tanker (evening)	Departure cooling center	Arrival processing plant	Time needed
COOLING CENTER	MERANO	20:25	20:54	0:29:00
	GATHAITHI	17:50	18:55	1:05:00
	IKINU	18:00	18:13	0:13:00
	GITHIGA	18:02	18:15	0:13:00
	KAMBAA	17:00	18:10	1:10:00
	GITHIA	20:24	20:56	0:32:00
	KWA MAIKO	17:17	18:13	0:56:00
	KARUAI	18:30	19:30	1:00:00
	GATHANGA	18:41	18:55	0:14:00
	GATHIRUINI	21:10	21:30	0:20:00
	GAKOE	19:00	19:19	0:19:00
	KAMACHARI	19:08	19:30	0:22:00
	AVERAGE			0:36:55

Figure 26: Transport time from cooling center to processing plant. Source: (Fresha, 2022).

In addition to the duration of time in which milk is transported between the different links in the supply chain, the temperature of cooling also plays a key role in the quality of the milk.

Milk is very nutritious but also vulnerable to contamination. On the farm, milk can be contaminated with various microorganisms, mainly bacteria. The degree of contamination and the composition of the bacterial population depend on the cleanliness of the cow's environment and the cleanliness of the surfaces with which the milk comes in contact, e.g., the bucket, sieve, milk can, etc. When cows are milked by hand, bacteria can enter the milk via the milker, cow, bedding, and air. The extent of bacterial entry depends largely on the skill and hygiene awareness of the milker and how the cow is managed. If the milk comes from a clean farm, it may only have a few thousand bacteria per milliliter, but if cleaning, disinfection, and refrigeration standards are subpar, it may have several million. In optimum conditions, a bacterial count of less than 20,000 Colony Forming Units (CFU) per ml should be achievable (TetraPak, n.d.).

The quality and bacteria growth of milk produced on the farm is greatly influenced by quick cooling to below 4°C. By slowing the growth of bacteria, this treatment maintains the quality significantly and extends the shelf life of milk (TetraPak, n.d.). Moreover, bacteria multiply quite rapidly as the storage temperature increases. Rapid cooling stops the development of microorganisms at an early stage. If development is stopped at a later stage, the milk may seemingly be of acceptable quality, but its shelf life will decrease, especially if the temperature rises again (Agrawal & Sinha, 2018). The graph in figure 27 illustrates how temperature affects the growth of bacteria in raw milk.

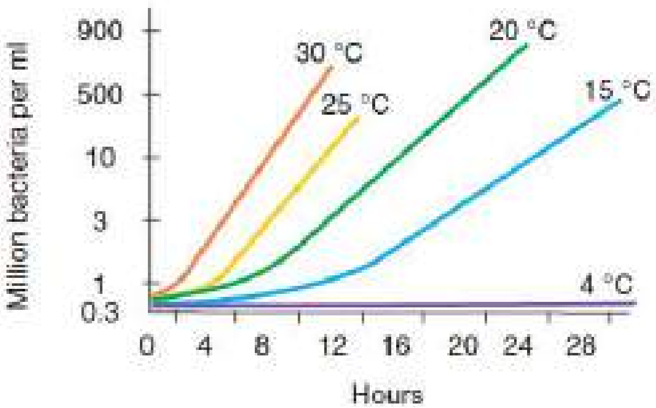

Figure 27: Bacteria growth in raw milk affected by temperature. (TetraPak, n.d.).

Data of the milk temperature of Fresha's milk cooling tanks was collected from December 2022. A limited amount of data was used due to unreliable and inconsistent data. The organization had a total of twelve cooling centers in operation during this period. Data on the temperature of milk is collected daily when it is picked up by a milk tanker. Also, upon arrival at the milk processing plant, the temperature of the milk is again recorded. The milk is transported from the cooling centers to the milk processing plant twice a day. Table 12 shows the average temperature of the milk during the morning and evening collection. The difference between the temperature at departure and arrival is shown in the last column of the table. This difference was calculated based on how much the temperature had increased during transport to the processing plant. In Appendix A.7.3 the milk temperature is shown for a period of several days.

TEMPERATURE	DEPARTURE COOLING CENTER	ARRIVAL PROCESSING PLANT	DIFFERENCE
Morning collection	6.6°C	9.3°C	+2.7°C
Evening collection	7.4°C	9.4°C	+2.0°C

Table 12: Average temperature of milk during morning and evening collection. Source: (Fresha, 2022).

Because milk is very susceptible to contamination by microorganisms, such as bacteria, it is important that milk is cooled to 4°C[1] in an early stage to minimize bacterial growth in the milk. Bacteria multiply rapidly at high storage temperatures. For this reason, both the duration of transport, and the temperature of the milk have an effect on milk quality, and thus the probability of milk rejection. To understand the relationship between transport time, and temperature fluctuations of milk during transport, data was collected on the aforementioned factors of transport from cooling center to milk processing plant in December 2022. Table 13 and 14 show the differences between transport time (longer or shorter than 30 minutes), as well as the temperature of the milk as it leaves the cooling center (higher or lower than 6°C[1]). In Appendix A.7.4 the data which is used to develop table 13 and 14 is shown.

Table 13 shows the correlation between transport duration, in this case less than 30 minutes, and the milk temperature. Data was collected and divided into milk temperature higher or lower than 6°C when it leaves the cooling center. Using this data, the importance of the maximum cooling temperature of 6°C can be determined. In addition, the average temperature of milk when it leaves the cooling center and when it arrives at the milk processing plant can be read from this table. Moreover, the last column shows the temperature difference which takes place during transport from the cooling center to the factory.

TRANSPORT TIME < 30 MINUTES	DEPARTURE COOLING CENTER	ARRIVAL PROCESSING PLANT	DIFFERENCE
DEPARTURE TEMPERATURE < 6°C	3.9°C	5.0°C	+1.1°C
DEPARTURE TEMPERATURE > 6°C	7.7°C	11.0°C	+3.3°C

Table 13: Temperature of milk before and after transport <30 minutes. Source: (Fresha, 2022).

Table 14 displays the relationship between the milk's temperature and the duration of transport, which in this case was greater than 30 minutes. Data was gathered and classified into milk leaving the cooling center with a temperature higher or lower than 6°C. This information can be used to assess the significance of using the maximum cooling temperature of 6°C. This table also shows the typical temperature of milk as it exits Fresha's cooling facility and as it enters the milk processing facility. Additionally, the final column displays the temperature variation that occurs during transportation from the cooling center to the factory.

TRANSPORT TIME > 30 MINUTES	DEPARTURE COOLING CENTER	ARRIVAL PROCESSING PLANT	DIFFERENCE
DEPARTURE TEMPERATURE < 6°C	4.0°C	6.0°C	+2.0°C
DEPARTURE TEMPERATURE > 6°C	7.3°C	11.0°C	+3.7°C

Table 14: Temperature of milk before and after transport >30 minutes. Source: (Fresha, 2022).

[1] The milk cooling system must be capable of cooling the milk to ≤6˚C within two hours of the completion of milking, or 4˚C within three to four hours of milking and maintain the milk at ≤6˚C until collected after which the milk is transported to the processing plant. Desired temperature: 4˚C. Maximum acceptable temperature: 6˚C.

To gain insight into the proportion of milk that meets the milk temperature guideline of a maximum of 6°C, table 15 has been prepared. In percentages it is shown how much milk leaves the cooling center which complies with the maximum temperature of 6°C or which exceeded the 6°C. This is subdivided into transport times from the cooling center to the milk processing plant (longer or shorter than 30 minutes).

PROPORTION OF MILK AT DEPERATURE TEMPERATURE	DEPARTURE TEMPERATURE < 6°C	DEPARTURE TEMPERATURE > 6°C
TRANSPORT TIME < 30 MINUTES	23%	77%
TRANSPORT TIME > 30 MINUTES	22%	78%

Table 15: Proportion of Fresha milk that meets the maximum acceptable temperature of 6°C. Source: (Fresha, 2022).

A possible area for improvement is to reduce milk rejection by ensuring a temperature below 6°C before milk is transported. This may be done by chilling the milk for a longer period and changing the transport schedules to ensure that the milk is below 6°C at collection. Milk rejection can occur due to insufficient cooling of the milk, bacterial growth persists and even increases during transport of milk due to rising temperatures. This can lead to higher bacteria counts which has a negative impact on the shelf life and quality of the final dairy products. This may lead to higher food waste / losses.

3.3.2.2 CLEANING AND STORING OF MILK CANS

All the raw milk produced by the members of Githunguri Dairy Farmers Co-Operative Society is transported in aluminum milk cans. At collection, the farmers deliver their milk and empty their milk cans in the Fresha owned milk cans, after which the farmers go home and clean their milk cans themselves. After the Fresha owned milk cans are emptied, either at the milk processing plant or at a cooling center, the milk cans are cleaned. This is done as follows: after emptying the milk can, milk residue is removed by rinsing the can with chilly water. Then the inside of the can is washed with warm water and a chlorine-based sanitizer. After that, the can is rinsed again with chilly water to remove soap residue. Finally, the milk cans are disinfected with sodium bicarbonate, and drained and air-dried in an inverted position in a rack. This is shown in figure 28.

Figure 28: Washing and drying Fresha's milk cans. Source: (L. van den Broek, 2022).

Cleaning and drying of the milk cans is done at collection centers and cooling centers but not at mobile collection points. In addition to cleaning with soap and disinfecting the milk cans, drying is also essential for the maintenance of milk quality. As mentioned earlier, the milk cans are air-dried in an inverted position. The position in which the cans are dried is important for removing residual water after cleaning. Figure 29 shows a milk can with residual water and a collection center in which the milk cans are not dried in an inverted position, while a rack is available for that purpose. When this is not applied, the remaining water mixes with milk at the next collection moment. This can negatively affect the quality of the milk after collection.

Figure 29: Milk cans with residual water and not dried in an inverted position. Source: (L. van den Broek, 2022).

A potential opportunity for improvement is reducing milk rejection by cleaning and storing milk cans. Milk rejection can occur due to milk cans not being thoroughly cleaned, or improperly dried. At the next collection moment, milk may become contaminated, or mixed with residual water. In both cases, milk quality can be impacted in a negative way. Milk of poor quality is rejected and cannot be processed at the plant.

3.3.3 TRANSPORT COSTS

In chapter 3.2.7 the transportation costs of Fresha's own transportation and hired transportation were compared. In total, Githunguri Dairy Farmers Co-Operative Society owns six trucks carrying milk cans and six milk tankers. Also, 30 transporters are hired which transport the raw milk carrying the milk cans. Table 7 shows the transport costs per kilogram of milk, comparing the transport costs of own and hired transport. From this table it can be seen that in 2022, the transport cost for own transport was KES 2.03 per kilogram of milk. In this same year, the cost for hired transportation was KES 0.61 per kilogram of milk. This results in a difference of KES 1.42 per kilogram of milk. To understand the transportation cost per kilogram of milk for a truck, for both Fresha's own trucks and hired transportation, table 16 has been compiled. This is calculated by dividing the cost per kilogram of milk for each mode of transportation by the number of trucks used. The difference between the two ways of transportation is shown in the last column. This difference was calculated on how much higher the cost per truck for own transportation was compared to hired transportation.

COSTS PER KG MILK PER TRUCK	OWN TRANSPORT	HIRED TRANSPORT	DIFFERENCE IN KES	DIFFERENCE IN PERCENTAGE
2022	KES 0.17	KES 0.02	KES 0.15	89.5%

Table 16: Transportation costs per kilogram of milk per truck of Fresha's own trucks versus hired trucks in 2022. Source: (Fresha, 2022).

A potential opportunity for improvement to reduce the transport costs of Githunguri Dairy Farmers Co-Operative Society is by the way of transport: Outsourcing Fresha's own transport of milk cans by hired transporters. In addition, incentives could possibly be made to encourage a transition over time from transporting milk in milk cans to milk tankers or to look at how to efficiently and cost-effectively transition to more own milk tankers.

3.4 IMPLEMENTING THE IMPROVEMENTS

To gain insight into how the potential new opportunities for improvement could be implemented twelve people from the Dairy Extension Office and Quality Control and one person from Tetra Pak completed a questionnaire. This survey asked them about their experiences and opinions on the supply chain and transport of milk as well as ways to implement the suggested improvements to increase efficiency. This chapter provides details of the survey results and identifies how the potential new opportunities for improvement as mentioned in chapter 3.3.1 could be implemented.

3.4.1 QUESTIONNAIRE

Staff members from Fresha's Quality Control, the Dairy Extension Office and Tetra Pak completed a questionnaire to share their knowledge and suggestions on how to enhance milk collection and delivery. Table 17 below provides a detailed summary of the survey's findings. The questions are written in white. The numbers on the left show how many people responded in a particular way. On the right side of the table are the answers to the question. The questions and responses for each person are displayed in Appendix A.6.

How to implement the change(s) you suggested?	
1	Nothing
4	Involve government to improve infrastructure (roads)
3	Report issues and implement policies/training
4	Draw up investment plan and present it to Fresha's board for financial support

Table 17: Results questionnaire. Source: (L. van den Broek, 2022).

3.4.2 MILK REJECTION

At several stages in the milk supply chain of Fresha rejection occurs based on the outcome of the milk quality tests. The reason and possible cause for rejection depend on the stage in the process: during milk collection at the collection center or after transport at the milk entry to the cooling center or processing plant. The main causes of milk being rejected are hygiene of cows, the milk can hygiene of farmers and Fresha's milk cans. Furthermore, duration of transport and the temperature of milk at collection can impact the milk quality which may lead to rejection. Githunguri Dairy Farmers Co-Operative Society has no direct influence on the milk quality at farm level since it is dependent on farm related issues. However, they have an influence from collection onwards. The causes of rejection during this stage come from the duration of transport, the temperature of milk at collection and temperature fluctuations during transport and the hygiene of Fresha's own milk cans.

Implementing policies and training on the necessity of the temperature to which the milk is chilled, measuring the temperature correctly and recording the data will help to improve the milk rejection process. Due to unreliable and inconsistent data, a limited amount of data could be used for this research. By improving this, milk rejection and food waste can be reduced. In addition, an investment plan for the construction of new cooling centers and potential upgrades of existing cooling centers could be investigated and approved by the Fresha board for financial support. These cooling centers will have to be strategically located to ensure that the transport time of milk from the collection center to the cooling center is shortened, so that milk is cooled to <6°C within two hours and 4°C within three to four hours from milking. Furthermore, an investment plan for insulating the tanker trucks could be investigated. With the help of insulated tankers, the risk of a temperature rise that could cause acidification of milk is reduced. In this way, the quality of the milk is guaranteed during transport from the cooling center to the milk processing plant. Lastly, policies and training must be implemented on the importance of draining and drying Fresha's milk cans upside down to ensure milk quality from milk collection onwards.

3.4.3 TRANSPORT COSTS

The total transport cost for raw milk of Githunguri Dairy Farmers Co-Operative Society can be broken down into costs for own transport and hired transport. In 2022, the transport cost for own transport was KES 0.17 per kilogram of milk per truck. In the same year, the cost for hired transportation was KES 0.02 per kilogram of milk per truck. This results in a difference of KES 0.15 per kilogram of milk per truck.

The transportation costs of raw milk can be reduced by outsourcing more, or all, transport to hired carriers. Using contracted transporters lowers transport costs, because in case of breakdowns they have to arrange new transport at their own expense. Incidentally, it also brings risks. As Fresha outsources more transport, they have less control over the milk supply chain, and thus quality. To ensure this, policies, training, and monitoring systems must be implemented for the hired transporters. In addition, incentives could possibly be made to encourage a transition over time from transporting milk in milk cans to milk tankers or to look at how to efficiently and cost-effectively transition to more own milk tankers.

4. ANALYSIS

4.1 MILK SUPPLY CHAIN, FROM PRODUCTION TO PROCESSING

4.1.1 KENYAN MILK SUPPLY CHAIN

The Kenyan milk supply chain consists of two groups: the formal and informal sector. The formal sector consists of parties active in supplementing milk to processing plants. Members of the 'cold chain' have a license which allows them to operate and process milk. Dairy farmers deliver their raw milk to collection centers, which are part of a dairy cooperative. After the collection, the milk is transported to the processing plant where the milk is processed and turned into dairy products. These products are then sold to retailers or directly to consumers in urban areas and non-dairy processing areas (Birachi, 2006). 86% of the milk market is part of the informal sector, also known as the 'warm chain'. Dairy farmers sell raw, unprocessed milk directly to consumers in dairy processing areas or at local markets where small traders sell the unprocessed dairy to retailers and consumers in urban and non-dairy processing areas. The actors operating in this sector are not registered and do not have an operating license. As a result of population growth, urbanization and growing demand for dairy products, the industry is constantly evolving and the various institutions and the above-mentioned supply chains continue to develop (Nacul & Revoredo-Giha, 2022).

4.1.2 FRESHA'S MILK SUPPLY CHAIN

Over the years, Fresha has been successful at formalizing the milk supply chain, as 95% of the produced milk is sold to the formal sector in Githunguri (McDonald, personal communication, 27-3-2023). Fresha's milk supply chain can be divided into a short and long chain. The short chain is as follows: dairy farmers who are members of Githunguri Dairy Farmers Co-Operative Society bring the raw milk in aluminum cans to the nearest collection center, or mobile collection point. When the milk is collected, a grader and attendant are present to inspect it for density and protein balance. When the milk is graded and approved, the farmers pour the milk into a milk can of the cooperative. Should the milk fail the tests, the dairy farmer is sent back home with the milk. After all the milk has been collected, the grader waits for the truck to pick up the milk to ensure that all milk is collected. The truck then transports the milk to the processing plant. Upon arrival at the plant, the milk is tested again. If the milk passes the lactometer and alcohol tests, then processing starts. In case of rejection, the milk is not processed and sold as pig feed. Possible reasons for rejection after collection are souring of milk due to long duration of time between milking and cooling, the temperature of milk at collection at the cooling center temperature fluctuations during transport to the processing plant and the hygiene of Fresha's own milk cans.

Unlike the short chain, Fresha's long milk supply chain has an additional stop and is as follows: dairy farmers bring the milk to the nearest collection center or mobile collection point, and then it is taken to a cooling center. Another option is bringing the milk directly to a cooling center which includes a collection center. When the milk is graded and approved, the farmers pour the milk into a milk can of the cooperative. Should the milk fail the lactometer and alcohol tests, the dairy farmer is sent back home with the milk. After all the milk has been collected, the grader waits for the truck to pick up the milk. The vehicle delivers the milk cans to a cooling center. Upon arrival at the cooling center, the following milk tests are performed: lactometer, alcohol, antibiotics, aflatoxins, and neutralizers tests. If approved, the milk cans are emptied by hand and pumped into a cooling tank. Here the milk is stored for several hours and cooled to an average of 7°C. The milk tank is emptied by pumping it into a tanker truck. Loading the tanker takes about 45 minutes after which the truck drives to the processing plant. The milk is tested again on the aforementioned indicators and if approved, unloaded into two large storage silos after which the processing begins.

4.2 COSTS OF TRANSPORTING MILK

In this section, based on the data collected in chapter 3.2 it is further analyzed what the costs of transporting raw milk were in 2021 and 2022. Furthermore, the total transportation costs can be split up into the costs of Fresha's own transport and hired transported. By means of graphs, the differences between the two years and two transport methods are shown schematically.

4.2.1 TOTAL TRANSPORTATION COSTS

Figure 30 shows the total transportation costs of raw milk from Githunguri Dairy Farmers Co-Operative Society in 2021 and 2022. This graph shows that transportation costs were lower in 2021 compared to 2022. In 2021, the average cost of transporting raw milk was KES 18,001,006 per month. This had increased by an average of KES 1.3 million per month in 2022, to KES 19,266,396. In 2022, May and November incurred costs significantly above the annual average. In May, labor costs increased and in November, vehicle maintenance costs doubled. Overall, transportation costs increased by KES 15,184,685 in 2022 compared to 2021. The main reasons for the cost increase are higher labor costs, increased fuel costs and repairs of own trucks and fuel compensation for the hired transporters, additional to the agreed standard price.

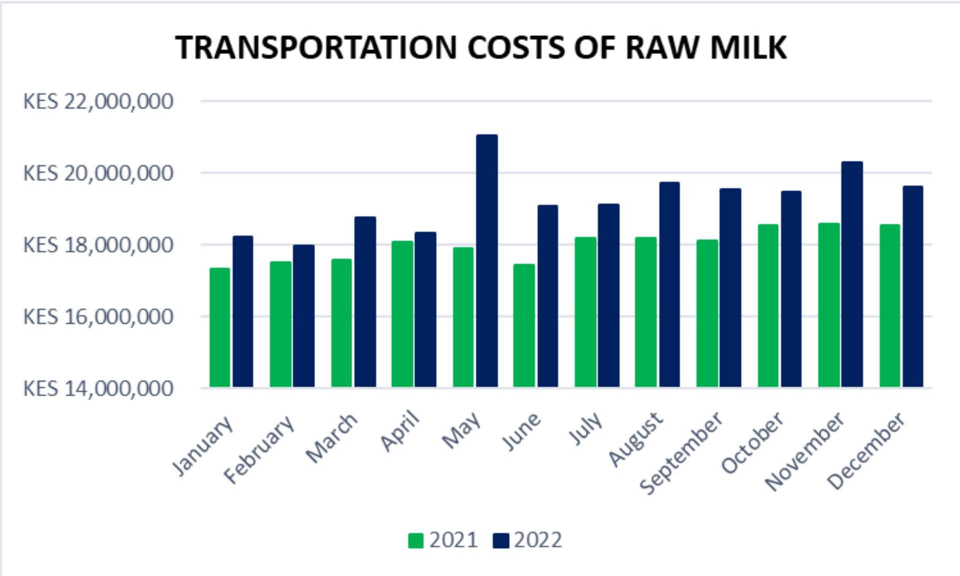

Figure 30: Total transportation costs Fresha in 2021 and 2022. Source: (Fresha, 2022).

To understand how these transportation costs are comprised, figure 31 is attached which illustrates this. From this figure it can be seen that in 2022 23% of the total transportation costs come from the 30 hired transporters. The remaining 77% comes from the costs incurred with Fresha's 12 own trucks. Of the costs of own transportation, labor costs represent the greatest cost, amounting to 68%. These labor costs include salaries, housing allowance, national social security fund, pension fund and health insurance for staff. In addition, maintenance and fuel costs of the trucks account for 17% of the total cost of own transport. The remaining 15% is constituted by the depreciation of the trucks and the necessary insurances and licenses.

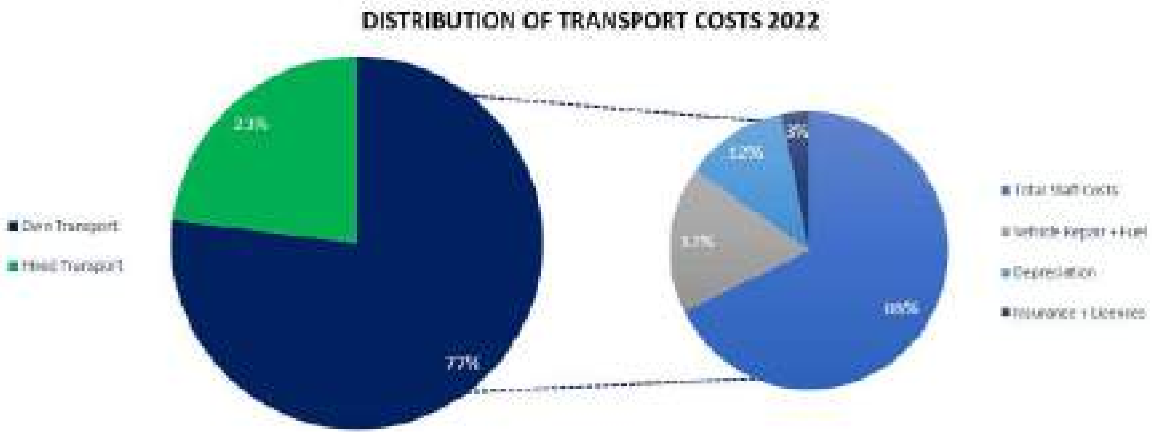

Figure 31: Distribution of transportation costs Fresha in 2022. Source: (Fresha, 2022).

4.2.2 TRANSPORTATION COSTS OWN TRANSPORT

The costs of transporting raw milk with the twelve vehicles owned by Githunguri Dairy Farmers Co-Operative Society is shown in figure 32. From this graph it can be seen that transport costs were generally lower in 2021 compared to 2022. In 2021, the average cost of transportation, using Fresha's own trucks, was KES 13,845,499. The cost had increased by an average of KES 998 thousand in 2022, to KES 14,843,682. The graph shows that there was a major increase during May. This is due to an increase in labor costs. In total, the transportation costs of own transportation in 2022 increased by KES 11,978,199. Besides an increase in labor costs, the increased price of fuel was also a key factor that caused the increase in expenses.

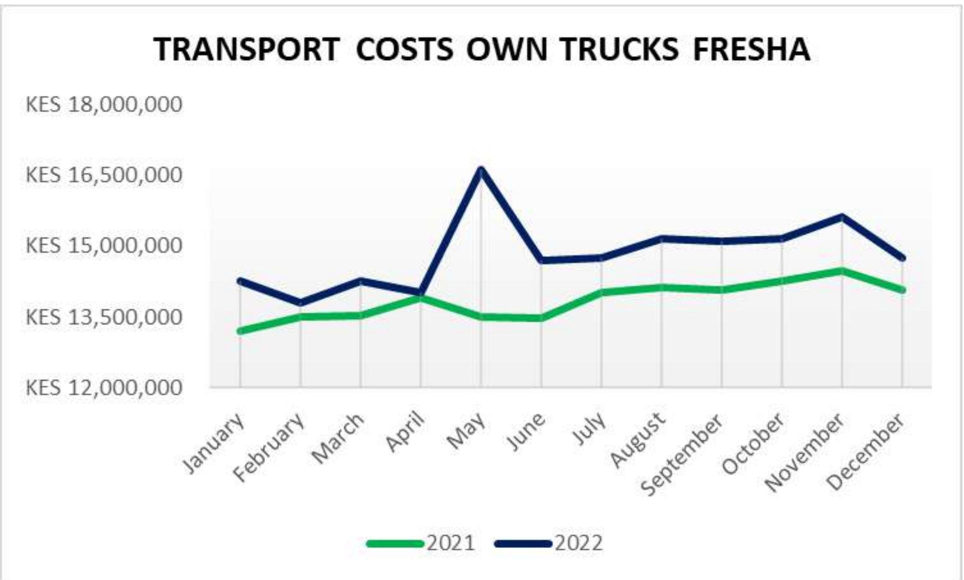

Figure 32: Transportation costs of Fresha's own trucks in 2021 and 2022. Source: (Fresha, 2022).

4.2.3 TRANSPORTATION COSTS HIRED TRANSPORTERS

The costs of transporting raw milk from collection centers to cooling centers and/or the milk processing plant, by means of 30 external carriers is shown in figure 33. This graph shows that transportation costs were generally lower in 2021 compared to 2022. In 2021, the average cost of transportation, using external carriers, was KES 4,155.508. In 2022, the cost had increased by an average of KES 267 thousand, to KES 4,422,715. It can be seen from the graph that in January the cost of hired transportation was higher in 2021 compared to 2022. Incidentally, thereafter the costs increased. Overall, transportation costs of external carriage increased by KES 3,206,486 in 2022. This increase is due to the increased fuel price, for which Fresha provided fuel compensation to the hired transporters, on top of the standard price.

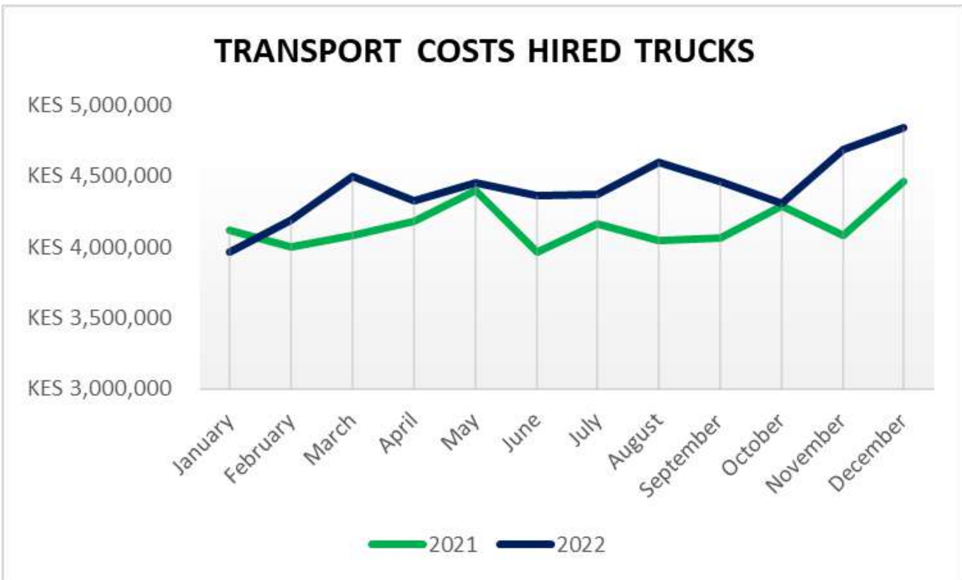

Figure 33: Transportation costs of Fresha's hired transporters in 2021 and 2022. Source: (Fresha, 2022).

4.2.4 TRANSPORT COSTS OWN TRUCKS VERSUS HIRED TRUCKS

The cost of transporting raw milk using the twelve vehicles of the Githunguri Dairy Farmers Co-Operative Society and with the help of thirty external transporters is shown in figure 34. This graph shows that the transportation cost of own transport was substantially higher compared to the hired transport. On average, Fresha's own transportation cost was KES 14,843,682 per month in 2022. In this same year, Fresha paid an average of KES 4,155,508 per month for hired transport. This resulted in a difference of KES 10,688,174 per month. In addition, the chart shows an increase for company-owned transport in May. This is due to an increase in labor costs. Furthermore, the increased fuel price also plays a role in the rise in transportation costs, for both owned and hired transport.

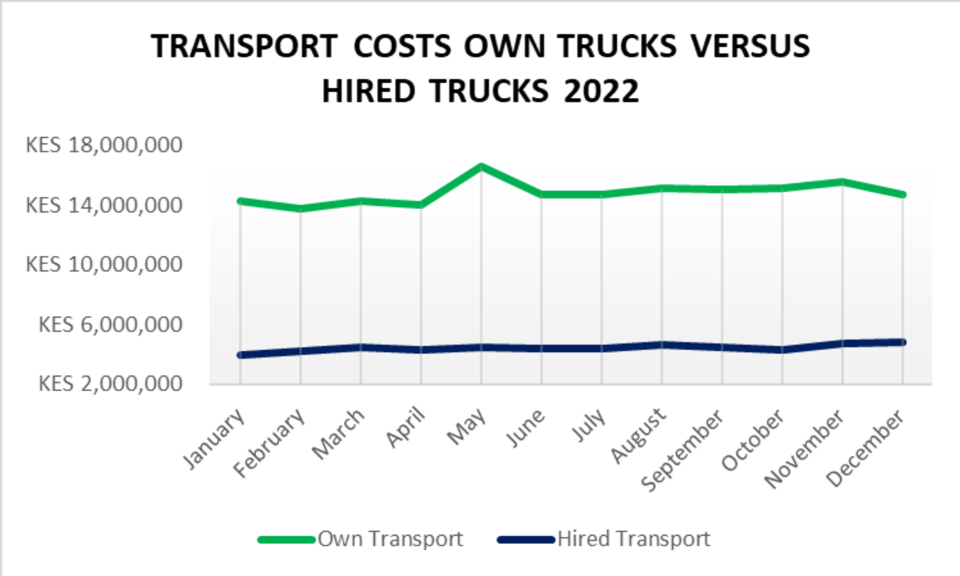

Figure 34: Transportation costs of Fresha's own trucks versus hired trucks in 2022. Source: (Fresha, 2022).

4.2.5 MILK INTAKE

Figure 35 shows the total amount of milk collected in 2021 and 2022 on a monthly basis. From this graph it can be seen that milk intake in 2022 was generally higher compared to 2021. An average of 7,092,036 kilograms per month was collected in 2021. Milk intake in 2022 had increased by 204,294 kilograms to 7,296,330 kilograms per month. The graph shows that more milk was collected in August, November, and December in 2021 compared to 2022. A possible reason for the reduced milk intake in 2022 is the drought period, reducing the availability of good quality feed, which could lead to lower milk production per cow per day. Also, the seasonality of milk production due to calving intervals could be a possible reason.

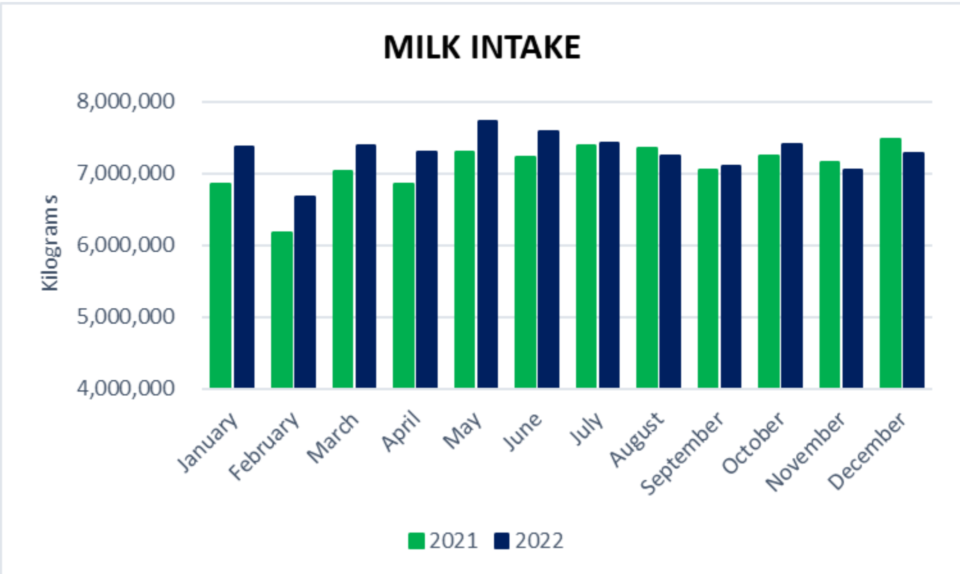

Figure 35: Fresha's milk intake in 2021 and 2022. Source: (Fresha, 2022).

4.2.6 TOTAL TRANSPORT COSTS AND MILK INTAKE

The relationship between the total transportation cost, including the costs for Fresha's own transportation and hired carriers, and milk intake in 2022 is shown in figure 36. From this graph it can be seen that as the milk quantity collected decreases, so does the transportation cost. Also, the costs increase in case of an increase in milk intake. This can be clearly seen in the months of February and May. During these months there is a substantial increase or decrease in milk intake, resulting in a clear increase or decrease in transportation costs.

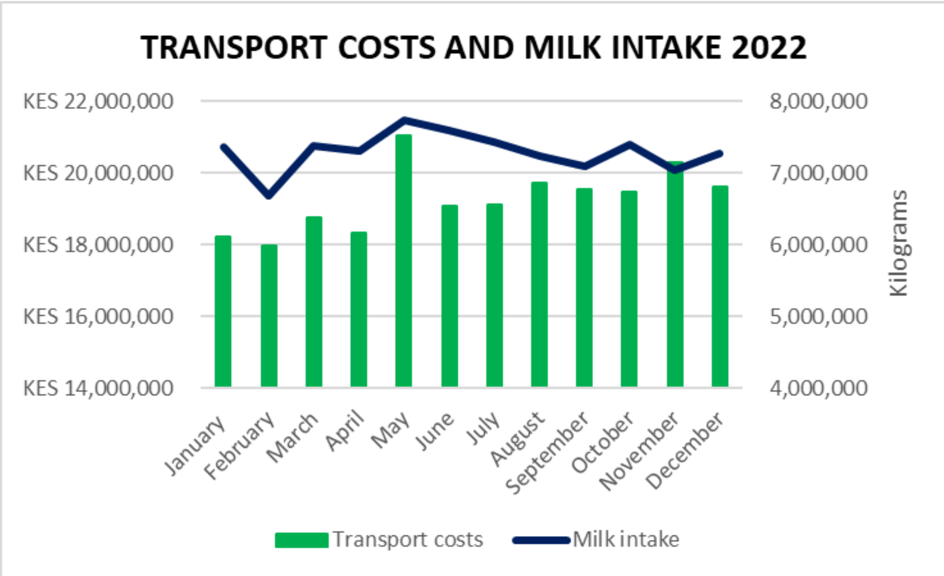

Figure 36: Total transportation costs Fresha and milk intake in 2022. Source: (Fresha, 2022).

4.2.7 TRANSPORTATION COSTS PER KG MILK FRESHA

The total costs of transporting raw milk per kilogram of milk of Fresha is shown in figure 37. The chart shows that transport costs per kilogram of milk were generally lower in 2021 compared to 2022. In 2021, the average cost per kilogram of milk was KES 2.54. In 2022, the cost had increased by an average of KES 0.10, to KES 2.64. The graph shows that in January, February and April, the cost of transportation per kilogram of milk was higher in 2021 compared to 2022. Incidentally, thereafter, costs increased in 2022, with a sharp rise in August and November. Overall, transport costs per kilogram of milk increased by KES 1.18 in 2022. This rise is due to increased labor costs, higher fuel costs and repairs of own trucks, and fuel compensation for hired carriers. In addition, the months of August, November and December saw a decrease in milk intake and increased transportation costs. The high expenses and reduced milk intake in these months resulted in higher costs per kilogram of milk. The same applies to the months of January, February, and April in 2021.

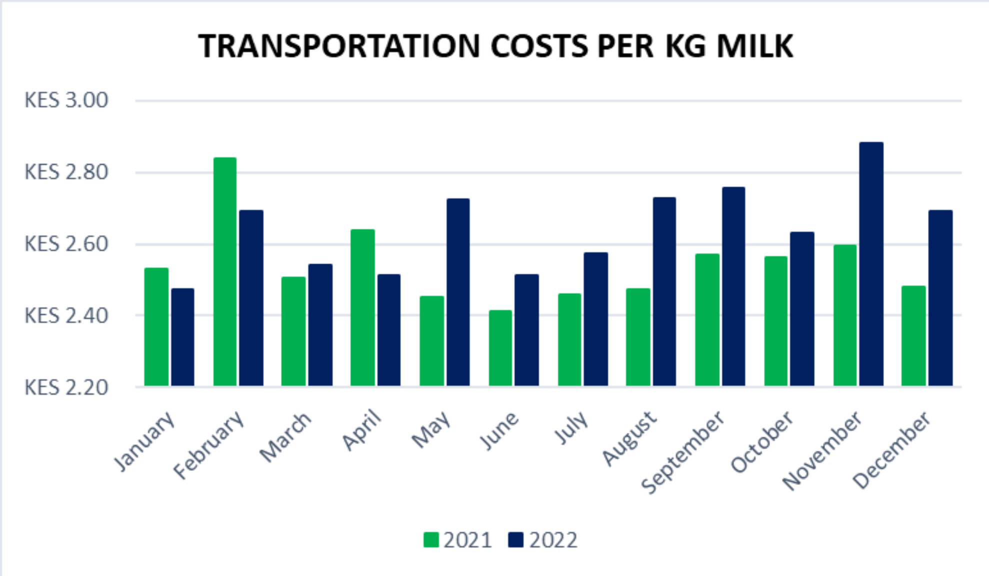

Figure 37: Transportation costs of Fresha per kilogram of milk in 2021 and 2022. Source: (Fresha, 2022).

4.2.8 TRANSPORT COSTS PER KG MILK OWN TRUCKS VERSUS HIRED TRUCKS

The transport costs per kilogram of milk of Fresha's own and hired transport is shown in figure 38. This graph shows that the transportation cost of own transport was substantially higher compared to the hired transport. On average, the transportation cost per kilogram of milk from Fresha's own transportation was KES 2.03 per month in 2022. In this same year, the average cost per kilogram of milk, by hired transportation, was KES 0.61. This resulted in a difference of KES 1.42 per kilogram milk per month, with the cost of own transportation being higher. The same figure shows that the cost of transporting raw milk was much higher in May and November for Fresha's own transportation. This rise is due to increased labor costs, higher fuel costs and repairs of own trucks. Furthermore, the costs per kilogram of milk for the hired carriers rose as well, due to fuel compensation.

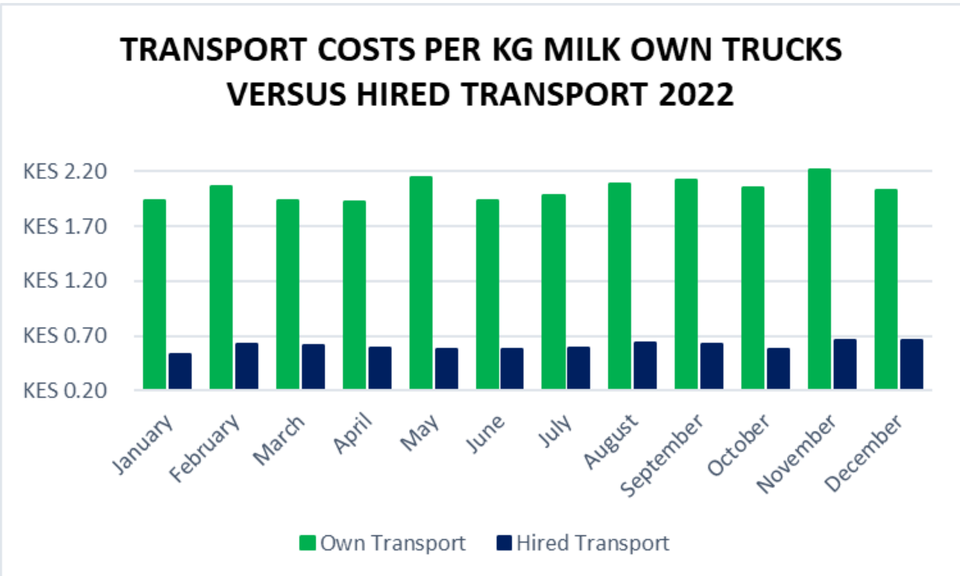

Figure 38: Transportation costs per kilogram of milk of Fresha's own trucks versus hired trucks in 2022. Source: (Fresha, 2022).

4.2.9 TRANSPORTATION COSTS PER KG MILK THE NETHERLANDS

FrieslandCampina's Milk Logistics Manager indicated that the average transport cost of raw milk in the Netherlands is €0.01 per kilogram of milk, equivalent to KES 1.36. This cost includes transportation of milk from the dairy farm directly to the factory, as well as transportation between factories. Transportation costs include labor, material, and overhead costs. In 2022, Fresha's average transportation cost per kilogram of milk was KES 2.64. With that, the organization paid KES 1.28 more transport costs per kilogram of milk than the Dutch dairy cooperative. When comparing the costs of FrieslandCampina and Githunguri Dairy Farmers Co-Operative Society, it must be taken into account that FrieslandCampina uses the most modern techniques and trucks and applies different labor costs compared to Fresha. Furthermore, the state of the roads and the size of the livestock farmers are not comparable. The transportation costs for both organizations are shown in figure 39.

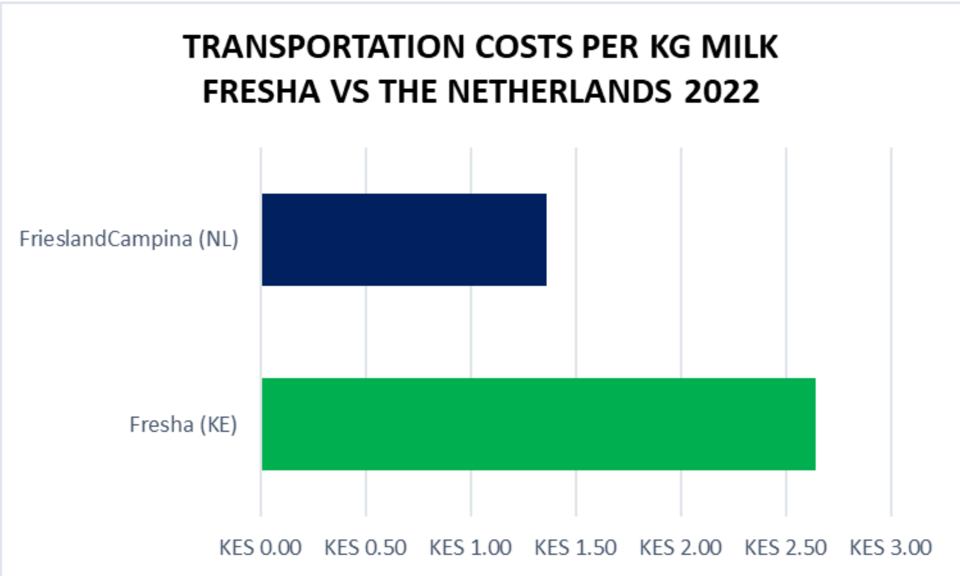

Figure 39: Transportation costs per kilogram of milk of Fresha versus FrieslandCampina in 2022. Source: (L. van den Broek, 2022).

4.3 OPPORTUNITIES FOR IMPROVEMENT TO INCREASE EFFICIENCY

In this section, based on the data collected in chapter 3.3 it is further analyzed what potential new opportunities for improvement are to increase the efficiency within the milk supply chain, from farm production to processing.

4.3.1 QUESTIONNAIRE

A questionnaire was completed by employees of Fresha's Dairy Extension Office, Quality Control and Tetra Pak. By means of the questionnaire, the employees shared their experiences and opinions on Fresha's milk supply chain and transport of raw milk as well as how they would increase efficiency.

Figure 40 indicates the elements that go well in the collection process of raw milk based on the questionnaire answers. According to the employees, a majority of 47% find that performing quality tests, such as the lactometer test, alcohol test, bacterial test, etc. is well carried out during the collection process of milk. In addition, 40% are satisfied with the frequency of milk collection, i.e., twice a day. Regarding the transport distance between the dairy farmers and collection points, 13% indicated that this is carried out well.

The respondents were also asked what they would change in the collection process of raw milk in order to improve the efficiency in the chain, see figure 41. Thirty-one percent of the employees are not satisfied with the duration of time between milking and cooling. In addition, it is suggested to invest in more collection and cooling centers to reduce the duration of time milk is uncooled. Furthermore, 19% are dissatisfied with the infrastructure, including the condition of the roads, which can negatively affect transport time. Moreover, 13% would like to see quality tests conducted at the farm level so that potential problems can be identified at an early stage. Finally, 12% of employees are satisfied with the way milk is collected, and according to them, nothing needs to be changed.

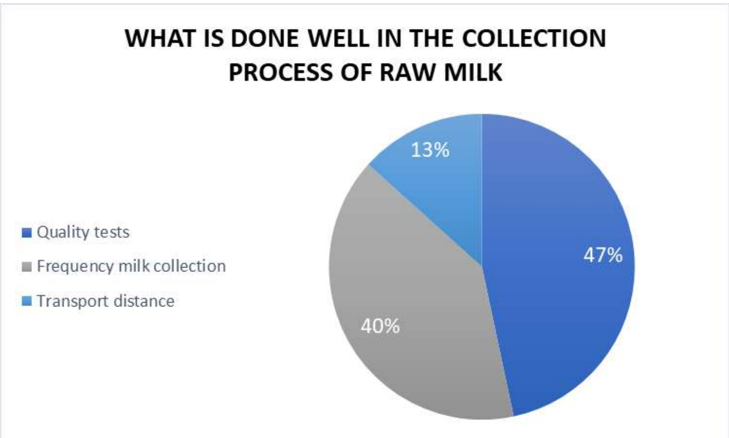

Figure 40: Result questionnaire: What is done well in the collection process of raw milk. Source: (L. van den Broek, 2022).

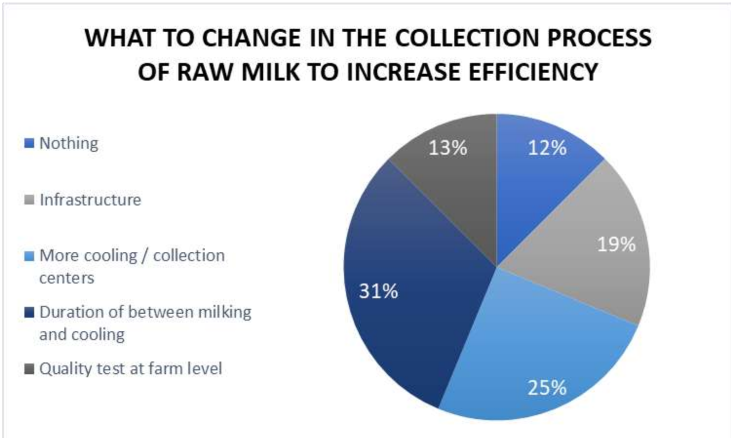

Figure 41: Results questionnaire: What to change in the collection process of raw milk to increase efficiency. Source: (L. van den Broek, 2022).

Besides the collection process of raw milk, the survey also looked at what goes well, or could be improved in the transportation of raw milk. Figure 42 shows what, according to the employees, goes well during transport. From this figure it can be seen that even though it was indicated earlier that the employees are not satisfied with the time in which milk is transported, 59% indicated that they are satisfied with this. This is partly because the previous question was about transport from dairy farmer to collection center, while the question in figure 42 is about transport from the collection center, to cooling centers or the milk processing plant. Also, one-third of respondents are satisfied with the use of aluminum milk cans and tank trucks in which milk is transported. Finally, 8% believe that enough vehicles are used to transport the milk.

Furthermore, the survey asked what employees would like to change to make the transport of raw milk more efficient, see figure 43. Two-thirds of those surveyed would like to change the infrastructure, including the condition of the roads, which also affects the condition of the vehicles. In addition, 17% would place more cooling and collection centers and another 17% are satisfied and do not think anything needs to be changed.

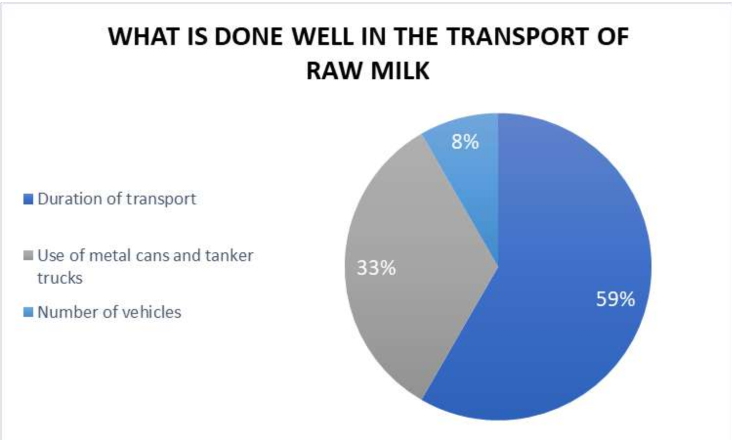

Figure 42: Result questionnaire: What is done well in the transport of raw milk. Source: (L. van den Broek, 2022).

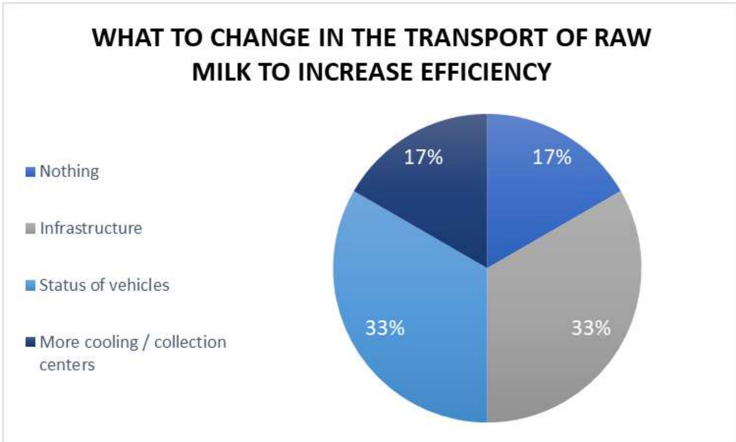

Figure 43: Result questionnaire: What to change in the transport of raw milk to increase efficiency. Source: (L. van den Broek, 2022).

The main opportunities for improvement following this questionnaire, are:

- Duration of time between milking and cooling.
- Building more collection and cooling centers.
- Improve infrastructure (roads).
- Improve the status of the vehicles.

4.3.2 MILK REJECTION

Raw milk is inspected frequently during Fresha's milk supply chain. The milk is tested for the following properties: density, milk protein balance, antibiotics, aflatoxins, and neutralizers. When milk does not pass these tests, it is rejected. The reason and cause of rejection depends on the stage in the process. During the collection of milk, it can be rejected because of the following reasons: positive alcohol test, off smell (acidity) and density below 27 L.R. or above 32 L.R. The rejection of milk during the milk collection stage is caused by farm-related issues, such as hygiene, udder infections, storage temperature, time of transport to the nearest collection center and additives, such as water or neutralizers. Githunguri Dairy Farmers Co-Operative Society does not have a direct control on rejection at this stage, however, they do from the collection time onwards, during storage and transportation of the milk to a cooling center, or directly to the milk processing plant. The most common reasons for milk rejection from this stage in the process are: positive alcohol test and off smell (acidity). The rejection of milk during this stage is caused by insufficiencies within the organization such as, the hygiene of Fresha's milk cans, the duration of transport, the temperature of milk at collection and the subsequent temperature rises during transport to the processing plant.

Figure 44 shows the total amount of milk rejected in 2021 and 2022 on a monthly basis. Total milk rejection includes the rejection during collection of the milk as well as after transport to the cooling center or processing plant. From this graph it can be seen that milk rejection in 2022 was generally lower than in 2021. An average of 2,439 kilograms per month were rejected in 2021. Milk rejection in 2022 had decreased by 880 kilograms to 1,559 kilograms per month. The graph shows that a substantial amount of milk was rejected in January, February, April, May, and July in 2021 compared to 2022. Reasons for the high amount of milk being rejected are the drought period and fodder insecurity, which has an effect on the milk quality. Furthermore, the hygiene of Fresha's milk cans, the duration of transport, the temperature of milk at collection and the subsequent temperature rise during transport to the processing plant could be possible causes.

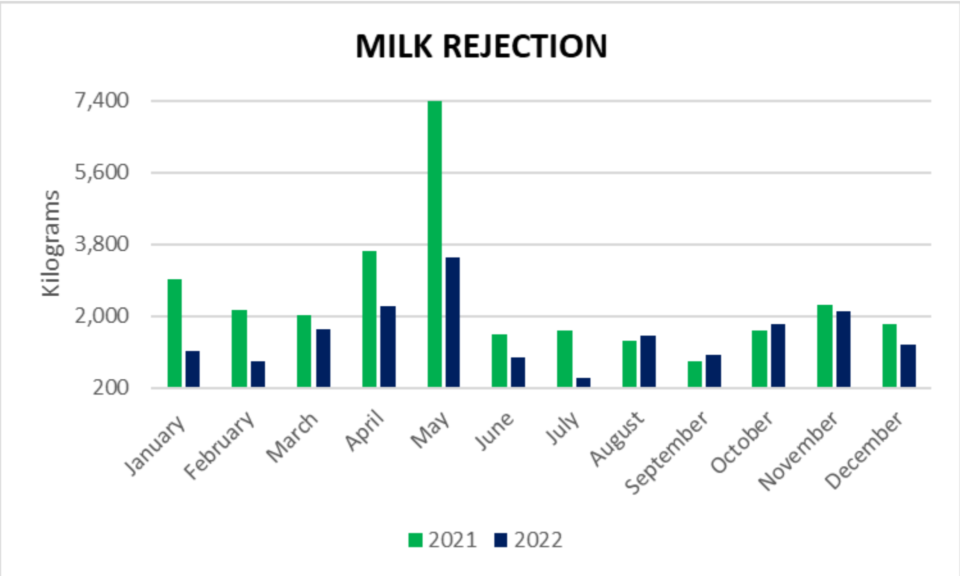

Figure 44: Fresha's milk rejection in 2021 and 2022. Source: (Fresha, 2022).

The Githunguri Dairy Farmers Co-Operative Society has a direct influence on the rejection of milk from collection. The main causes of rejection from this stage are: the duration of transport, the temperature to which the milk is cooled at collection and temperature fluctuations during transport, as well as in the hygiene of Fresha's milk cans. In paragraphs 4.3.2.1 and 4.3.2.2 the above causes are analyzed.

4.3.2.1 TRANSPORT TIME AND COOLING TEMPERATURE

The quality of milk is affected by the time it is transported and the temperature to which it is cooled. To avoid quality losses, it is important to cool fresh milk to <6°C within two hours of milking and to 4°C within a maximum of three to four hours, preferably sooner.

The time in which the raw milk of Githunguri Dairy Farmers Co-Operative Society is transported can be divided into the following stages:

- From dairy farms to (mobile) collection center or processing plant.
- From (mobile) collection center to cooling center.
- From cooling center to processing plant.

Figure 45 shows the maximum time in which milk is transported per stage. It can be seen that in the case of the short supply chain, transport of uncooled milk from the farm to a collection center and then to the milk processing plant takes a maximum of 1 hour. As for Fresha's long milk supply chain, transporting raw milk in this case takes a maximum of 4 hours before it is cooled. Finally, the milk is transported from the cooling center to the milk processing plant in half an hour on average.

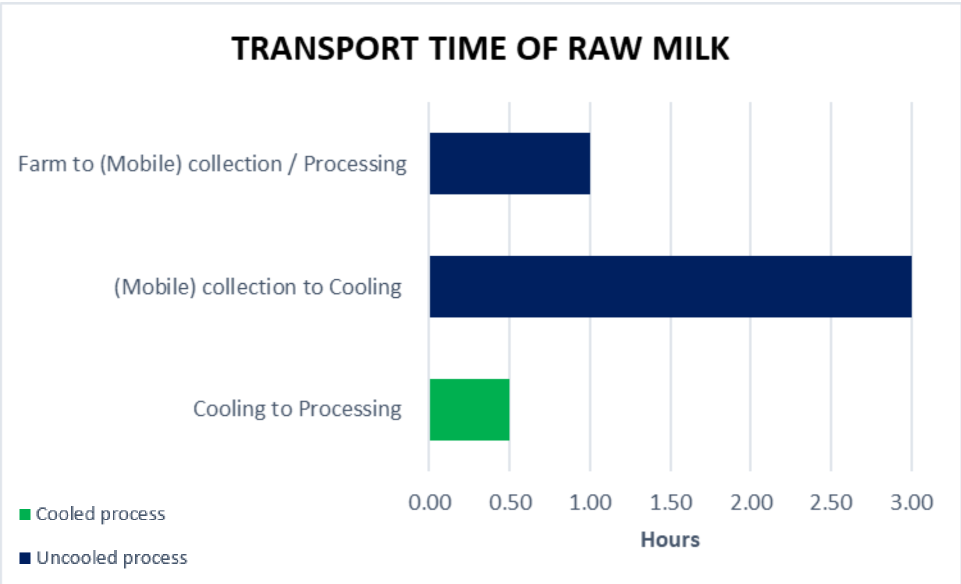

Figure 45: Transport time of Fresha's raw milk per stage in the supply chain, from farm to processing plant. Source: (Fresha, 2022).

Along the long supply chain, the transport of raw milk takes up to four hours before it is cooled at a cooling center. This milk cannot be cooled to 4°C within the maximum time of four hours, since after transportation, the cooling process is just starting. Before the milk reaches the desired 4°C, several more hours will have passed, and quality deterioration will be highly likely to occur.

Next to the duration of transportation, the temperature of cooling plays also an important role in maintaining the quality of milk. Because milk is very susceptible to contamination by microorganisms, such as bacteria, it is important that milk is cooled to 4°C in an early stage to minimize bacterial growth in the milk. Bacteria multiply rapidly at high storage temperatures. If bacterial growth is stopped at a later stage, when bacteria damage has already happened, it can have negative consequences for the quality and shelf life of the milk, especially if the temperature rises again, for example during transport.

Figure 46 shows the average temperature of milk from December 2022 when it leaves the cooling center, as well as when it arrives at the milk processing plant. This graph is based on table 12 and shows that when the milk leaves the cooling center, it does not reach the desired temperature of 4°C nor the maximum acceptable temperature of 6°C. In addition, it can be seen that during both the morning and evening collection, the temperature of the milk rises during transport to the milk processing plant. This gives microorganisms such as bacteria which are present in the milk a chance to multiply. In addition, as indicated above, this has negative effects on the quality and shelf life of the milk, especially in case when the temperature of the milk rises again, which happens in the case of Fresha.

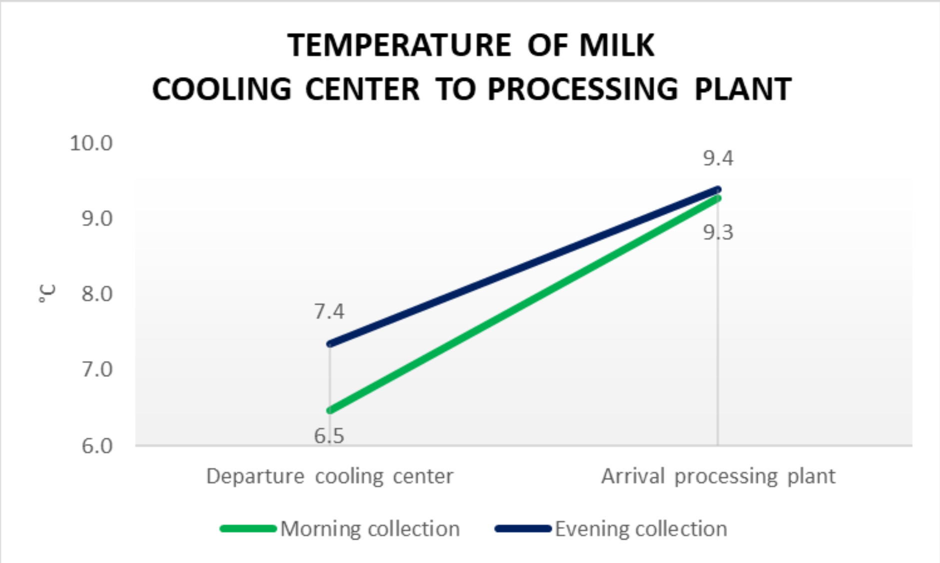

Figure 46: Average temperature of milk during morning and evening collection. Source: (Fresha, 2022).

To understand the link between transport duration and the temperature fluctuations of milk during transport, figures 47 and 48 were developed, based on data from tables 13 and 14. It is important to understand the relation between these two factors as they affect milk quality and thus the likelihood of milk being rejected. Figure 47 shows that, in case of milk, which at departure from the cooling center was below 6°C, in this event 3.9°C, has a temperature rise of 1.1°C when transported for less than 30 minutes. Whereas in case of milk leaving with a temperature above 6°C, in this situation 7.7°C, the milk temperature rises 3.3°C during the same transport time.

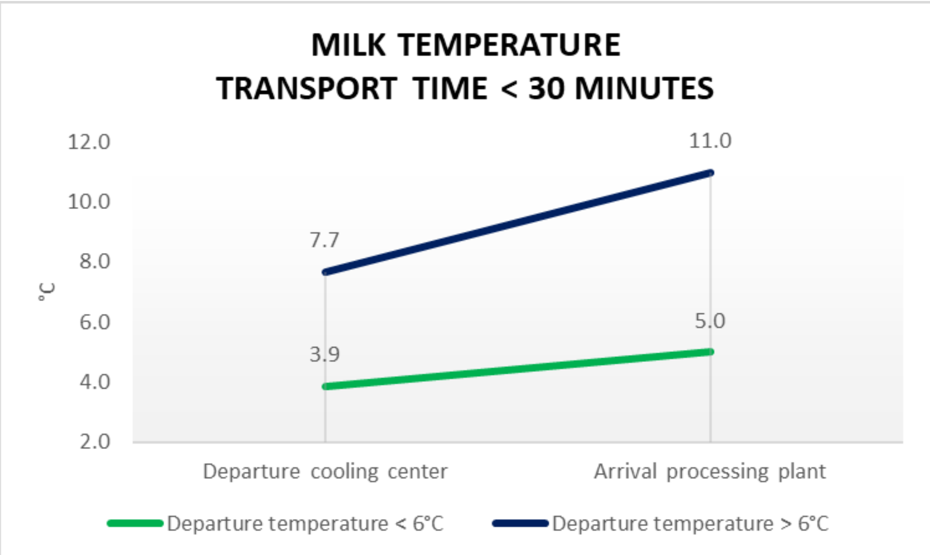

Figure 47: Temperature of milk before and after transport <30 minutes. Source: (Fresha, 2022).

The impact of a longer transportation time was also examined. From figure 48 it can be seen that in case of milk which was below 6°C at departure from the cooling center, shows a temperature increase of 2.0°C, from 4.0°C to 6.0°C, when the milk is transported for more than 30 minutes. For milk that is above 6°C at departure, the milk temperature increases by 2.7°C, from 7.3°C to 11.0°C, during the same transport time.

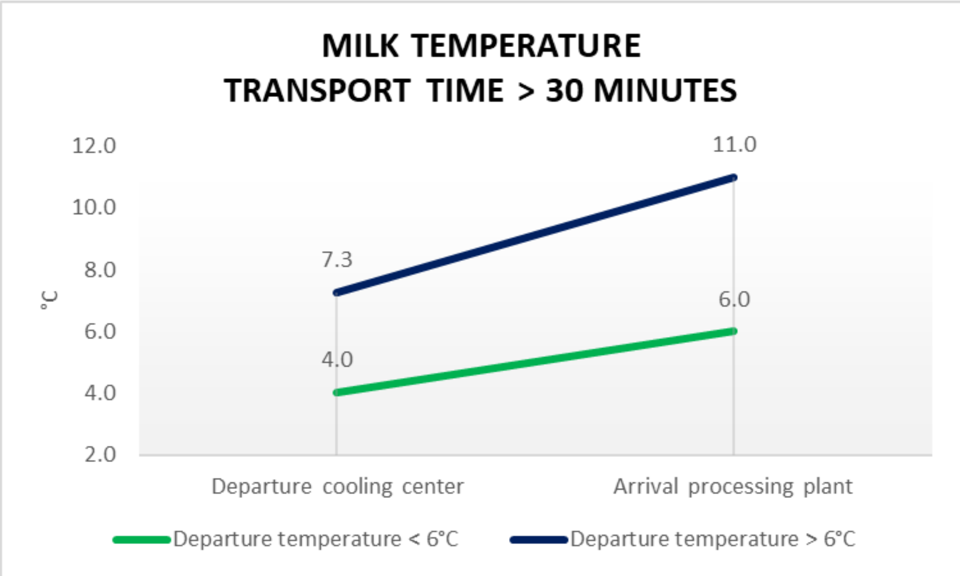

Figure 48: Temperature of milk before and after transport >30 minutes. Source: (Fresha, 2022).

To gain insight into the proportion of milk that meets the milk temperature guideline of a maximum of 6°C, figure 49 has been developed. From this graph it can be seen that only a quarter meets the maximum acceptable milk temperature of 6°C in both the transport longer and shorter than 30 minutes. The remaining three-quarters exceed the maximum acceptable temperature of 6°C.

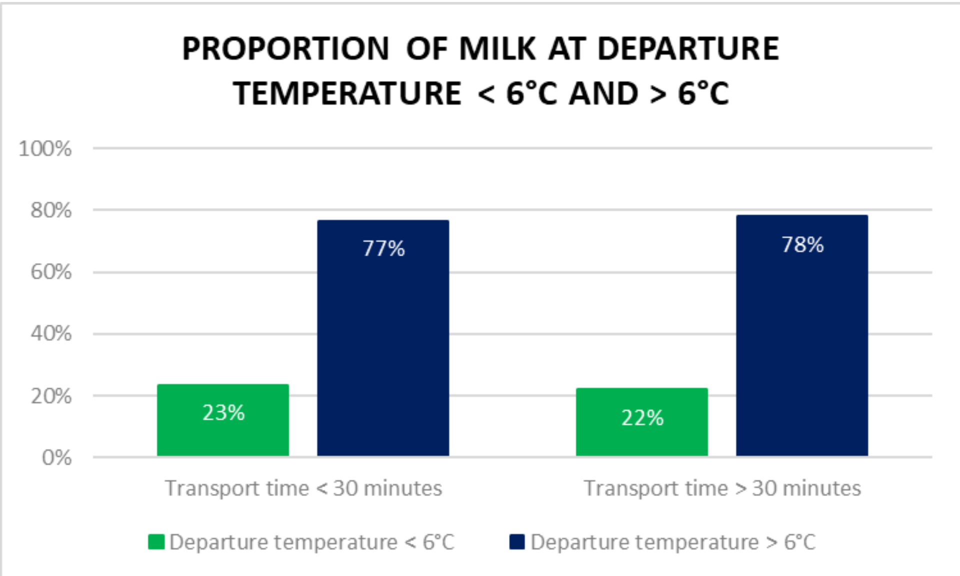

Figure 49: Proportion of Fresha milk that meets the maximum acceptable temperature of 6°C. Source: (Fresha, 2022).

From figure 46, 47 and 48 it becomes clear that for both short and long transport times, it is essential that the milk is sufficiently cooled to a maximum of 6°C before transportation. This prevents a sharp rise in milk temperature during transport, which can also increase the number of bacteria in the milk, which deteriorates milk quality. Furthermore, only a quarter of all the raw milk leaving the cooling center meets the maximum acceptable temperature of 6°C.

The main opportunities for improvement for the transport time and milk temperature, are:

- The overall time between milking and entry to the factory at which the milk is above the maximum acceptable temperature of 6°C.
- Temperature of cooled milk before, during and after transport.

4.3.2.2 CLEANING AND STORING OF MILK CANS

Aluminum milk cans are used to transport raw milk from the dairy farmers of Githunguri Dairy Farmers Co-Operative Society. After the milk is gathered from a collection center, the milk cans are emptied at the milk processing plant or cooling center, where they are then washed, disinfected, and dried. In addition to cleaning the milk cans, drying is also essential to preserving milk quality. The most important part of drying is the position of the milk can during this process. After cleaning, residual water remains in the cans. To remove this water and ensure that the milk cans are dry at the next collection time, they must be kept upside down to drain and dry. If this is not performed, the residual water will stay in the can and may mix with the milk during the next milk collection. This causes altered milk quality and may be rejected in the next milk test, resulting in food waste.

The main opportunity for improvement for cleaning and storing milk cans, is:

- Milk cans must be upside down to drain and dry.

4.3.3 TRANSPORT COSTS

In this section, based on the data collected in chapter 3.3.3 it is further analyzed how transportation costs of Fresha's own transport and hired transport are distributed. Currently the raw milk is transported using twelve of Githunguri Dairy Farmers Co-Operative Society's own trucks and thirty hired trucks. The average transport costs in 2022 of Fresha's own transport was KES 0.17 per kilogram of milk per truck. The costs for hired transport were KES 0.02 per kilogram of milk per truck, in the same year. With that, the organization paid KES 0.15 more transport costs per kilogram of milk per truck for their own transport, which is equivalent to 89.5% of the total costs per kilogram of milk per truck. The transportation costs per kilogram of milk per truck for both modes of transport are shown in figure 50.

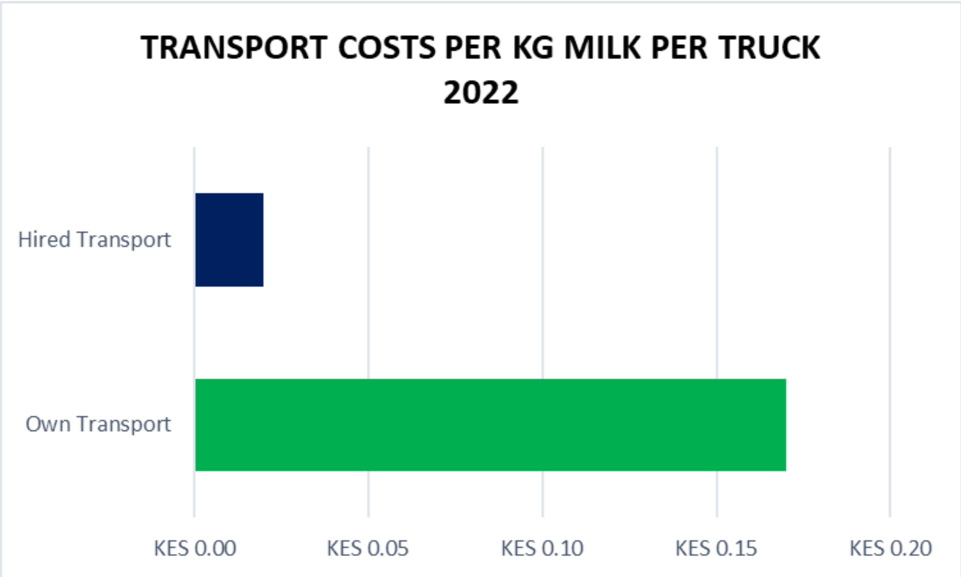

Figure 50: Transportation costs per kilogram of milk per truck of Fresha's own trucks versus hired trucks in 2022. Source: (Fresha, 2022).

The main opportunities for improvement for reducing the transport costs, are:

- Changing the mode of transport, from own transport to hired transport.
- Encouraging a transition from transporting milk in milk cans to milk tankers.

4.4 IMPLEMENTING THE IMPROVEMENTS

In this section, based on the data collected in chapter 3.4. It is further analyzed how the potential new opportunities for improvement as mentioned in chapter 3.3 and 4.3 could be implemented to increase the efficiency within the milk supply chain, from farm production to processing.

4.4.1 QUESTIONNAIRE

Staff members from Fresha's Quality Control, the Dairy Extension Office and Tetra Pak completed a questionnaire in which they shared their knowledge and suggestions on how to enhance milk collection and delivery. The interviewees were asked to indicate what they would change in the milk collection process and the transport of raw milk. They were then asked how these changes could be implemented, see figure 51. Thirty-four percent indicate that by involving the government, through addressing the problems of transporting the milk, the infrastructure (roads) can be improved. In addition, 33% suggest making an investment plan to build more collection and cooling centers and invest in improving the status of the tank trucks and present it to Fresha's board for approval and financial support. Twenty-five percent of those surveyed indicated that reporting problems and providing/implementing policies and training for this would help with solving problems such as transport duration. Finally, according to 8%, no changes need to be implemented.

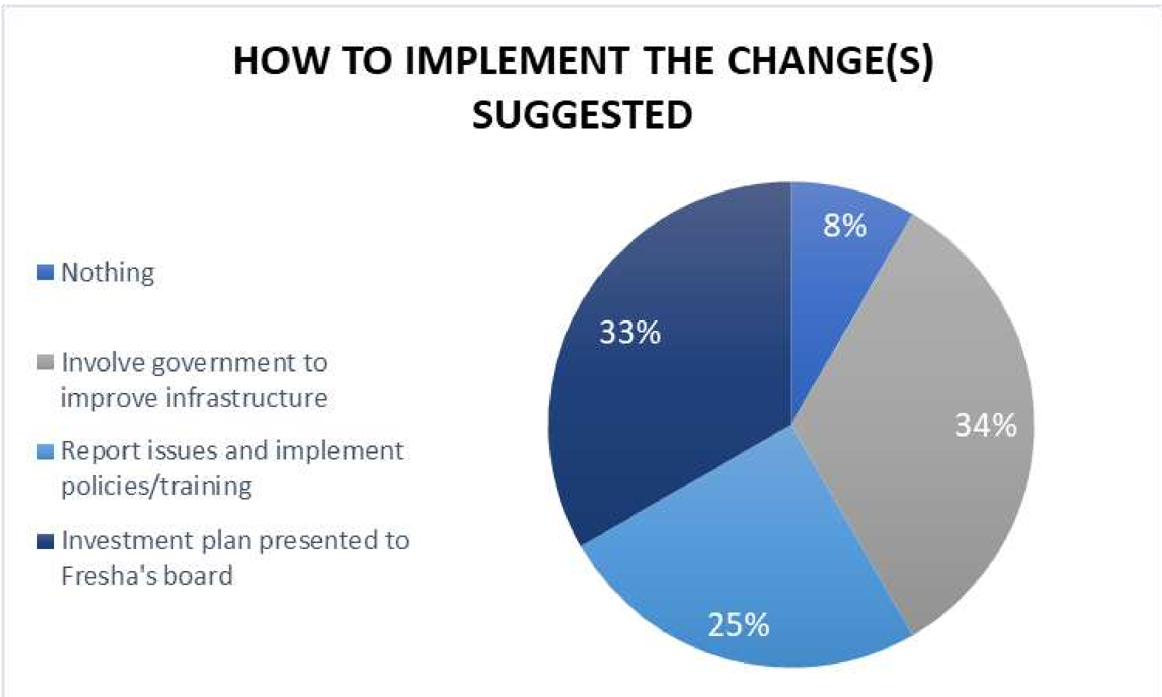

Figure 51: Result questionnaire: How to implement the change(s) suggested. Source: (L. van den Broek, 2022).

4.4.2 MILK REJECTION

The place where milk rejection occurs can be divided into: during milk collection, due to farmer related problems and after transport to the cooling center or processing plant, due to Fresha related problems. Figure 52 shows the different causes of milk rejection from milk collection onwards. Also shown are the improvements and how to implement them.

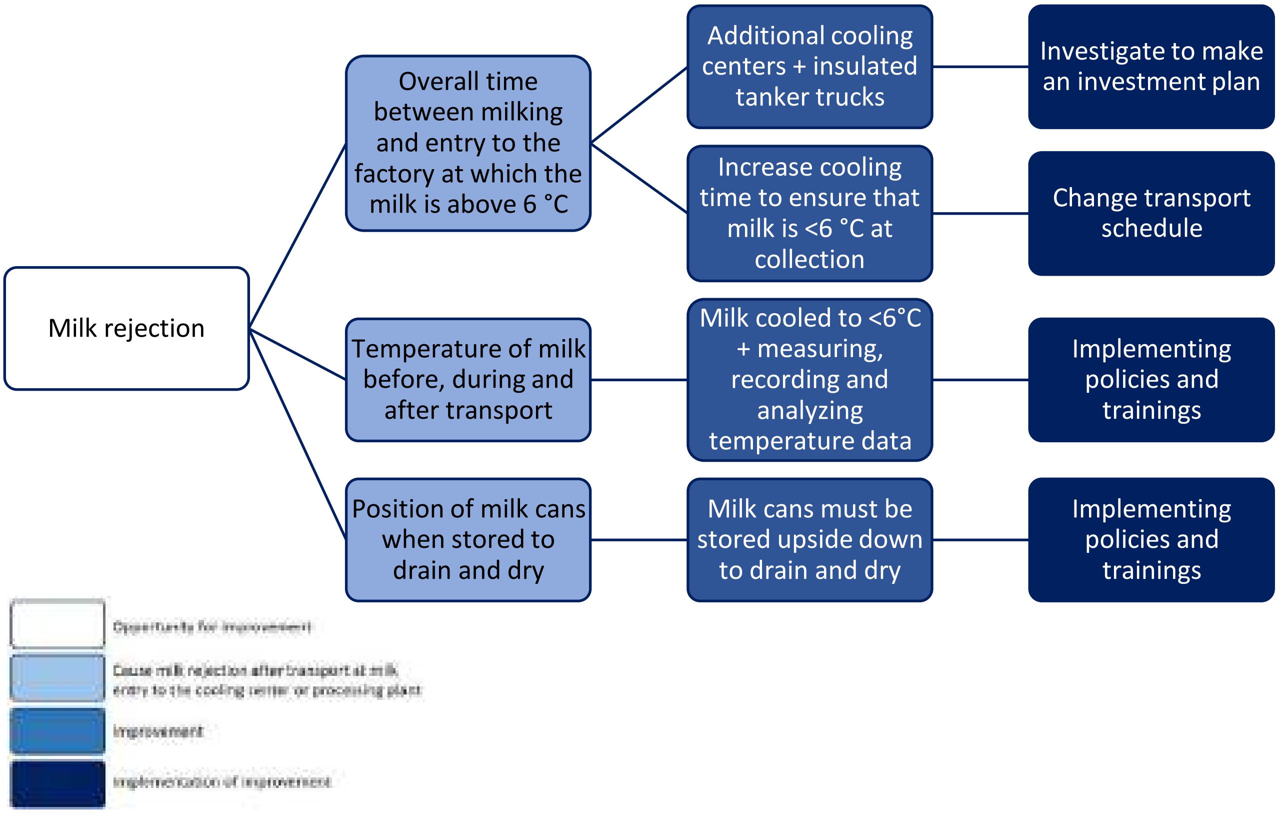

Figure 52: Fresha's opportunities for improvement and ways to implement regarding milk rejection. Source: (L. van den Broek, 2022).

4.4.3 TRANSPORT COSTS

The total transportation cost of raw milk of Githunguri Dairy Farmers Co-Operative Society can be divided into: own transportation and hired transportation. By outsourcing partially, or all transport to hired transporters, raw milk transport costs can be reduced. Figure 53 shows what can be improved and how this can be implemented.

Figure 53: Fresha's opportunities for improvement and ways to implement regarding transportation costs. Source: (L. van den Broek, 2022).

5. CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This study searched for an answer to the question: 'How can Githunguri Dairy Farmers Co-Operative Society increase the efficiency and decrease the costs of transport within the supply chain, from farm production to processing, to increase profitability in 2023?'. For this purpose, research on the transport of raw milk, from farm production to processing, was carried out.

5.1.1 SUB-QUESTIONS

MILK SUPPLY CHAIN, FROM PRODUCTION TO PROCESSING

The milk supply chain of Fresha can be divided into a short and long chain. Fresha's short milk supply chain is as follows: dairy farmers bring the milk to a collection center, or a mobile collection point, where the milk is collected and then directly transported to the processing plant. Unlike the short chain, Fresha's long milk supply chain has an additional stop and is as follows: dairy farmers bring the milk to a collection center or a mobile collection point, and then it is taken to a cooling center. Another option is bringing the milk directly to a cooling center which includes a collection center. At the cooling center, the milk is cooled for several hours before being transported to the processing plant.

COSTS OF TRANSPORTING MILK

Research showed that the cost of transporting raw milk in 2022 was KES 2.64 per kilogram of milk per month. Of these costs, KES 2.03 per kilogram of milk per month originated from own transportation and KES 0.61 per kilogram of milk per month from hired transportation.

OPPORTUNITIES FOR IMPROVEMENT TO INCREASE EFFICIENCY

The main opportunities for improvement to increase quality and to ensure efficiency are: improving the infrastructure (roads), the overall time between milking and entry to the factory at which the milk is above 6°C, the temperature of milk before, during and after transport and the position of milk cans when stored to drain and dry. Furthermore, a way to reduce transport costs are: outsourcing transport of milk cans to hired transporters and encouraging a transition from transporting milk in milk cans to milk tankers.

IMPLEMENTING THE IMPROVEMENTS

The recommended improvements can be implemented in the following ways: engaging the government to improve the infrastructure (roads), building multiple cooling centers, and investing in insulated tankers, for which an investment plan should be investigated. In addition, changing the transport schedule and implementing policies and training can ensure that milk is cooled to less than 6°C. Furthermore, temperature is measured, recorded, and analyzed, and milk cans are stored upside down to drain and dry. Finally, transportation of milk cans can be outsourced to hired transporters by maintaining control over the supply chain with the implementation of policies, training, and monitoring systems.

5.1.2 MAIN QUESTION

This qualitative and quantitative research has shown that Githunguri Dairy Farmers Co-Operative Society can increase the efficiency and decrease the costs of transport within the supply chain, from farm production to processing, by improving the infrastructure, the duration of time between milking and entry to the processing plant at which the milk is above the maximum acceptable temperature of 6°C, the temperature of milk before, during and after transport, the position of milk cans when drained and dried and outsourcing partly or all transport to hired transporters to increase profitability in 2023.

5.2 RECOMMENDATIONS

It is recommended to Githunguri Dairy Farmer Co-Operative Society to outsource part or all transportation of raw milk in milk cans to hired transporters. To control the supply chain as well as the hired transporters, it is important to use policies, training, and monitoring systems. Furthermore, incentives could possibly be made to encourage a transition over time from transporting milk in milk cans to milk tankers or to look at how to efficiently and cost-effectively transition to more own milk tankers. In addition, it is advisable to investigate the possibilities of developing an investment plan for the construction of additional cooling centers and insulating milk tankers.

Moreover, it is advisable to investigate the possibilities of developing an investment plan for the construction of additional cooling centers and insulating milk tankers. Furthermore, the transport schedule should be changed to increase the cooling time of milk at the cooling center. With the help of both investments and changes in the transport schedule, the time during which raw milk - from milking to receipt at the milk processing plant - exceeds a temperature above 6°C, can be minimized.

Furthermore, it is recommended that policies and training on the importance of the temperature before, during and after transport should be drawn up and given, covering the measurement, recording and analysis of milk temperature and emphasizing the maximum acceptable temperature of 6°C. Policies and training should also be established for the draining and drying of milk cans to ensure milk quality.

6. DISCUSSION

During the research, a number of issues occurred that made it impossible to meet the expected submission date. These matters involved taking longer to collect and import the locations of the collection and cooling centers into the digital map than calculated. Also, miscommunication took place, which also meant that receiving the correct information on transportation costs took longer than anticipated. Finally, making the report as detailed as possible also took more time than the 6 weeks planned.

The data gathered showed that Githunguri Dairy Farmer Co-Operative Society is already collecting a lot of data, which is a very good step in the right direction. But an analysis of this data is still missing, which could help the organization with being able to intervene earlier when potential issues arise.

Since transport costs were not specifically broken down between the different links in the supply chain, the question "What are the costs of transporting milk between the links within the supply chain, from farm production to processing?" was adjusted. Instead, total transport costs, costs per kilogram of milk and the differences between the transport costs of own transport and contracted transport have been investigated.

As for the data of transportation duration and milk temperature from the cooling center to the milk processing plant, this involved studying 22 days in the month of December 2022. Due to unreliable and inconsistent data at times, only 6 days were used in the results and analysis. Also, to show the relationship between transport duration and milk temperature, only data from twelve transport moments were used.

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APPENDIX

A.1. STAKEHOLDER ANALYSIS

Stakeholder (SH)	Contact person	Impact	Influence	What is important to the SH?	How could the SH contribute?	How could the SH block?	How to engage the SH?
Fresha Dairy Brands	Francis Muhande	High	High	Good quality and quantity of milk for processing	Give feedback on the structure of the research, findings, and report	Not giving feedback	Increasing efficiency of the supply chain and decreasing costs
Tetra Laval	Lynda McDonald	Medium	Medium	Increase knowledge among farmers worldwide	Give feedback on the findings and report, share experiences of farming worldwide	Not giving feedback	Improve efficiency of the supply chain and increase knowledge
Dairy farmers	-	Medium	Medium	Good milk production, health animals and profitability	Explain / show how they run the farm	Not showing the farm	Increase productivity and profitability of the farm
Extension Officer	-	Medium	Medium	Increase knowledge to assist farmers	Show the farms and how milk is transported from farm to collection centers	Not showing the farms and how the milk is transported	Increase knowledge about the supply chain
Quality control	-	Medium	Medium	Good quality of milk	Show how the quality of milk is tested and how milk is transported from collection center to factory	Not showing how the milk is tested and transported	Increase knowledge about the supply chain
Financial department	-	Medium	Medium	Insight into costs and revenue of the company	Share information about transportation costs within the supply chain	Not giving information about transportation costs	Decrease costs within the supply chain

Table 18: Stakeholder analysis. Source: (L. van den Broek, 2022).

A.2. CONCEPTUAL MODEL + DEMARCATION

A.2.1 CONCEPTUAL MODEL

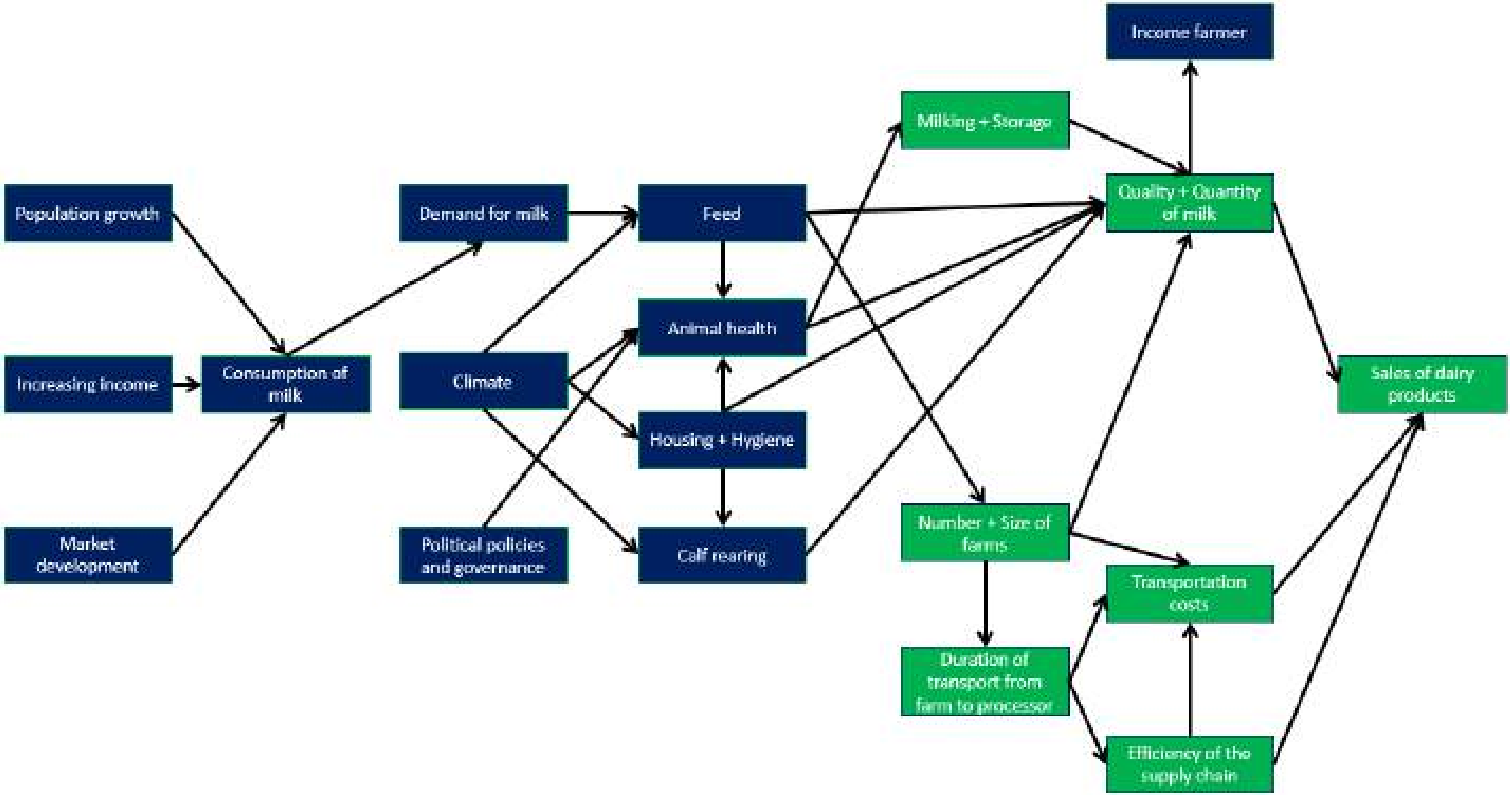

Figure 54: Conceptual model. Source: (L. van den Broek, 2022).

A.2.2 DEMARCATION

Green: Included in the research
Blue: Not included in the research

'Milking + Storage' has an effect on **'Quality + Quantity of milk,'** since the way of milking and storage affects the quality and quantity of milk. Besides that, **'Milking + Storage'** gives insight into the supply chain, from production to processing. Therefore, this variable will be included in the research.

'Number + Size of farms' affects **'Quantity + Quality of milk,' 'Duration of transport from farm to processor'** and **'Transportation costs,'** this is in the scope of the research and will be included.

'Duration of transport from farm to processor' has an effect on **'Transportation costs'** and **'Efficiency of the supply chain.'** The relation between these variables will be studied during the research.

'Quality + Quantity of milk,' 'Transportation costs' and **'Efficiency of the supply chain'** have an effect on **'Sales of dairy products**. This is in the scope of the research and will be included.

'Population growth,' 'Increasing income' and **'Market development'** have a direct effect on **'Consumption of milk.'** Since these variables are out of the scope because they do not directly affect efficiency and costs within the supply chain, it is not included in the research.

'Consumption of milk' affects **'Demand for milk,'** due to lack of time, these variables are not included in the research.

'Climate' has a direct effect on **'Feed,' 'Animal health,' 'Housing + Hygiene'** and **'Calf rearing.'** Furthermore, **'Political policies and governance'** has a direct effect on **'Animal health.'** Since it does not have a direct effect on the efficiency and costs within the supply chain. It is not included in the research. Furthermore, the variables **'Feed,' 'Animal health,' 'Housing + Hygiene'** and **'Calf rearing,'** will be covered in the Dairy Hub project of Tetra Laval and are therefore not included.

'Quality + Quantity of milk' affects **'Income Farmer'** and is not included in this research since it is part of the Dairy Hub project of Tetra Laval.

A.3. DIGITAL LOCATION MAP

A.3.1 LINK DIGITAL LOCATION MAP

https://www.google.com/maps/d/edit?mid=1cp1oRU-K2pLP--R9Z04Gi_TEkwWstVQ&usp=sharing

A.3.2. NAMES AND NUMBERING LOCATIONS

	Route		Centers	
1	1A	Githunguri		CC
2	1Bd	Kamburu		MCC
3	1Bb	Rurudam	3	MCC
4	1Bc	Kahunira		CC
5	1C	Ngochi		CC
6	1Ca	Ngochi Kaboria	3	MCC
7	1Cb	Hosana Childrens Home		MCC
8	1D	Thuthuriki		MCC
9	1E	Magomano	2	CC
10	1Ea	Kiriko		MCC
11	1Fa	Kahunaini		MCC
12	1Fb	Rwe Ruiru	3	MCC
13	1Fc	St. Josephs		MCC
14	1F2	Kiriko		MCC
15	1G	Maisomo		MCC
16	2Ab	Kambaa (New Cooler)		
17	2B	Gitwe		CC
18	2C	Gathangari		CC
19	2Da	Ha Pello		MCC
20	2Db	Mutari		MCC
21	2Dc	Kwa Muthunga		MCC
22	2Dd	Mahura Mbande-ini		MCC
23	2De	Ha Ngigi	9	MCC
24	2Df	Ha Kiri		MCC
25	2Dg	Mathanja Mbande-ini		MCC
26	2Dh	Muguma-ini		MCC
27	2Di	Iruko		MCC
28	2Ea	Ngoboti		MCC
29	2Eb	Ok Jagi		MCC
30	2Ec	Junction	6	MCC
31	2Ed	Ruiru		MCC
32	2Ee	Rung'iri		MCC
33	2Ef	Miti-mingi		
34	2Fa	Ha Mathu		MCC
35	2Fb	Ha Mwarini	4	MCC
36	2Fc	Sara		MCC
37	2Fd	Ha Mathore		MCC
38	2Ga	Ha Kerethi	2	MCC
39	2Gb	Irori		MCC
40	2Ha	Waing'ere		MCC
41	2Hb	Ha Wa Thuo		MCC
42	2Hc	Kanyore	6	MCC
43	2Hd	Ha Wamagu		MCC
44	2He	Munada ini		
45	2Hf	Waing'ere Itanda		MCC
46	2I	Ha King'ara		CC
47	3A	Githiga (Cooler)		
48	3B	Matagata		CC
49	3C	Mungu		CC
50	3D	Kinunga		MCC
51	3E	Kiamachani (Cooler)		
52	3F	Gituamba		MCC
53	3Ga	Gacumako	2	MCC
54	3Gb	Githiga Bay		MCC
55	3H	Githiga 'B'		MCC
56	3I	Munanga		CC
57	4A	Ikinu (Cooler)		
58	4B	Kaoia		CC
59	4B2a	Gitu		MCC
60	4B2b	Gacamako	3	MCC
61	4B2c	Githarakio		MCC
62	4Ca	Waraitho Town		MCC
63	4Cb	Ha Nda Sisters	3	MCC
64	4Cc	Munandaini		MCC
65	4D	Mutaya		CC
66	4E	Mithiya		CC
67	4F	Ha Ngaregira		MCC
68	4G	Magato		MCC
69	4H	Kahangu		MCC
70	4I	Nyangoti		MCC
71	4K	Gacuo		MCC
72	5A	Gathang'i (Cooler)		
73	5B	Kiaria		MCC
74	5C	Ha Kihara		CC
75	5D	Jamaica		CC
76	5E	Gathigi		MCC
77	5F	Thuno		MCC
78	5G	Kamakora		CC
79	6A	Kanjai (Cooler)		
80	6Ba	Kigio		MCC
81	6Bb	Mutomoko		MCC
82	6Bc	Ikomute	5	MCC
83	6Bd	Magume		MCC
84	6Be	Gathanga		MCC
85	6Ca	Manandaini	2	CC
86	6Cb	Junction		MCC
87	6Da	Manande-ini		CC
88	6Db	Junction		MCC
89	6Dc	Gitombo 'B'		MCC
90	6Dd	Kabao-ini		MCC
91	6De	Gitumbo	9	MCC
92	6Df	Kamochai girls		MCC
93	6Dg	Kingu		MCC
94	6Dh	Mihuko 1		MCC
95	6Di	Mihuko 2		MCC
96	6D2	Kirichie		CC
97	6E	Magura		CC
98	6F	Ha-Ndenga		CC
99	6G	Kambanuru		CC
100	6H	Mirasa (Cooler)		
101	6I	Nyaga		MCC
102	6J	Gathiruini (Cooler)		
103	6Ka	Kanjuku store	2	CC
104	6Kb	Kanjuku second		MCC
105	6La	Kiruro		MCC
106	6Lb	Kwa mama		MCC
107	6Lc	Wanjanga	7	MCC
108	6Ld	Githino		MCC
109	6Le	Gatone		MCC
110	6Lf	Mugus Ngecimbe		MCC
111	6Lg	Ka ndenge		MCC
112	6L2a	Muchenga		MCC
113	6L2b	Kanaugu		MCC
114	6L2c	Karatina primary		MCC
115	6L2d	Karatina shopping center		MCC
116	6L2e	Kwa wajoe	9	MCC
117	6L2f	Mung'eni		MCC
118	6L2g	Gwa Kabathe		MCC
119	6L2h	Ngenya		MCC
120	6L2i	Ka Ngiglu		MCC
121	6Ma	Kwambari		MCC
122	6Mb	Thuita shopping center		MCC
123	6Mc	Kengah		MCC
124	6Md	Munandaini		MCC
125	6Me	Thuita primary	10	MCC
126	6Mf	Ngindori primary		MCC
127	6Mg	Hamwengi		MCC
128	6Mh	Ngindori Munandaini		MCC
129	6Mi	Gitangiri		MCC
130	6Mj	Marige shopping center		MCC
131	6N	Kindiga		MCC
132	6Oa	Gatiro		MCC
133	6Ob	Kigumo coffee mill	4 of 18	MCC
134	6Oc	Hamingah		MCC
135	6Od	Kigumo police station		MCC
136	6Oe	Smartcard		MCC
137	6Of	Dallas		MCC
138	6Og	Kibichoi (Cooler)		
139	6Oh	Kibichoi shopping center		MCC
140	6Oi	Ap post		MCC
141	6Oj	Complex		MCC
142	6Ok	Huriangu	14 of 18	MCC
143	6Ol	Gatigumu shopping center		MCC
144	6Om	Kiangari		MCC
145	6On	Machakos		MCC
146	6Oo	Korokoro		MCC
147	6Op	Kiberethi		MCC
148	6Oq	Gecagini		MCC
149	6Or	Mutitithi		MCC
150	6Pa	Gitaambo		CC
151	6Pb	Gitaambo shopping center		MCC
152	6Pc	Gituamba		MCC
153	6Pd	Junction	8	MCC
154	6Pe	Makondu		MCC
155	6Pf	Kiaguyosa church		MCC
156	6Pg	Kiharu		MCC
157	6Ph	Rakahare		MCC
158	6Q	Kairi		MCC
159	6Ra	Gitiku		MCC
160	6Rb	Gachika		MCC
161	6Rc	Gichagocho Kiande-ini		MCC
162	6Rd	Gichagocho	8	MCC
163	6Re	Gathagu PCEA		MCC
164	6Rf	Mucaritei		MCC
165	6Rg	Ha Kanzib		MCC
166	6Rh	Gathiruini shopping center		MCC
167	6R2	Gathugu		MCC
168	6Sa	Kanaku	3 of 5	MCC
169	6Sb	Mugumo-ini		MCC
170	6Sc	Kameru Center	2 of 5	MCC
171	6Sd	Kameru		MCC
172	6Se	Kwa gacheru		MCC
173	6T	Githioro		MCC
174	6U	Matherai		MCC
175	6V	Kamakoro		MCC
176	7A	Githo (Cooler)		
177	7B	Gatine		MCC
178	7C	Ha-Karai		MCC
179	7Da	First center	2	MCC
180	7Db	Second center		MCC
181	7E	Gatiatu		CC
182	8A	Gakoe (Cooler)		
183	8B	Kanjogu		CC
184	8C	Lioki		CC
185	8D	Kwamaiko (Cooler)		
186	8E	Mitahato		CC
187	8Fa	1st		MCC
188	8Fb	2nd		MCC
189	8Fc	3th		MCC
190	8Fd	4th		MCC
191	8Fe	5th		MCC
192	8Ff	6th	10	MCC
193	8Fg	7th		MCC
194	8Fh	8th		MCC
195	8Fi	9th		MCC
196	8Fj	Dagret		MCC
197	8G	Ruguthu		CC
198	8H	Maruru		MCC
199	8Ia	Gatuyu	2	MCC
200	8Ib	Ndimi		MCC
201	9A	Gathaithi (Cooler)		
202	9B	Kamondo		CC
203	9C	Gatiuu		MCC
204	10a	Kwa Wajeheme		MCC
205	10b	Mabucci		MCC
206	10c	Kamili		MCC
207	10d	Kambui	7	MCC
208	10e	Mbaura		MCC
209	10f	Ha Harry		MCC
210	10g	Sine		MCC
211	10Aa	Ha Murengei	2	MCC
212	10Ab	Ndathini		MCC
213	10B	Ngonia		MCC

MCC	Mobile Collection Center
CC	Collection Center
Cooler	Cooling Center

Figure 55: Names and numbering locations digital map of collection and cooling centers. Source: (L. van den Broek, 2022).

A.4. MILK TEST PROCEDURES

A.4.1 LACTOMETER TEST (DENSITY)

1. Mix the milk to obtain a uniform sample.
2. Cool the sample up to 20°C and confirm by use of a thermometer.
3. Fill the measuring cylinder / pint with the cooled milk sample and gently insert the lactometer into the milk.
4. Wait for at least 2 minutes and do not disturb the apparatus.
5. Read the density at the level of lower meniscus formed between the milk and the lactometer stem.
6. If reading is not done at the recommended temperature for that particular lactometer, add or subtract the appropriate correction factor i.e., **C.L.R. = 1 + [0.2(T-20)+LR/1000]**.
7. Remove the lactometer gently and drain off the milk back to the members can.
8. If the milk reading is in the ranges of between 27 L.R to 32 L.R accept the milk.
9. If the reading is less than 27 L.R or greater than 32 L.R reject the milk and advise farmer to deliver during the next shirt for confirmation.
10. During the next delivery, repeat the lactometer test using the same procedure above. For all non-confirming milk, invite the member to observe the results and where possible call an additional witness.
11. If the milk does not confirm during the next shift, you are to refer this case to quality inspectors for a farm visit immediately or within 4 hours. Collect contacts and directions from the members and inform quality inspectors.
12. If milk conforms during the next shift, inform members to visit the office immediately. You should also prepare a milk non-conformance report with details of the member and the test and forward it to the office immediately.
13. Record the details of the test in the occurrence book i.e., member number, route, and lactometer reading.
14. Inform the quality office immediately of reference to the work instruction.

ADDITIONAL INFORMATION

- For non-conforming milk, advise members not to seek a vet service or change their diet (including mineral salts) as you he awaits to conduct second test during the next shift.
- Address all farmers with respect and good rapour.

A.4.2 ALCOHOL TEST (PROTEIN BALANCE)

1. Prepare the milk for testing by agitating to obtain a uniform sample.
2. Dip the alcohol gun in a milk sample at an angle of 90°.
3. Dispense equal amount of milk and ethanol in a beaker.
4. Shake/swirl the beaker by gentle movement and observe for clots/coagulation.
5. If the milk does not coagulate/clot it is alcohol negative and therefore it is accepted.
6. If the milk coagulates its alcohol positive and therefore should be rejected, invite the member to observe the results.
7. Clean the apparatus and repeat the test procedure until the member is satisfied.
8. Record the details of the test i.e., member number, can number, quantity, and the date in the occurrence book.
9. Inform the office of reference to the work instruction.

A.4.3 AFLATOXIN TEST

1. Absorb 200 µL milk sample into micro-well, sucking 5-10 times until the sample mixes evenly with the reagent in micro-well.
2. Observe for no presence of deposition or agglomeration. The color of the mixture should be pink.
3. Insert the strip/dipstick into micro-well and wait for six minutes.
4. Take out the strip from the micro-well and interpret the result in accordance with 7.5 7.6 and 7.7.
5. Negative: line T (result line/the second line) and line C (control line/the first line) are both red or similar.
6. Positive: line C is red and darker than line T.
7. Invalid: line C has no color, which indicates the strip is invalid, in this case, repeat the test again and use a new test strip.
8. Record the positive cans numbers, route center, the quantity of the milk and other relevant details in the occurrence book.
9. Quality graders should notify graders for follow up to identify which member had positive milk.
10. Farmers with positive milk should be assisted by liaising with DEO to control aflatoxin.

A.4.4 ANTIBIOTIC TEST

1. Absorb 200 µL milk sample into micro-well, pipette 3-5 times until sample has been mixed evenly with reagent.
2. Observe for absence of deposition or agglomeration and the color of the mixture should be pink.
3. Insert the strip/dipstick into the micro-well, (with the **sample pad** end fully dipped in the mixture) wait for six minutes.
4. Remove the strip from the micro-well and interpret the result in accordance with steps number 7.6, 7.7.
5. **NEGATIVE:** If line T1 (beta-lactams line/fourth line), T2 (sulfonamides line/third line), T3 (tetracycline line/second line) are all red, darker, or similar to line C (control line/first line).
   POSITIVE: If line C is darker than lines T1, T2, T3.
   INVALID: If line C is absent or not visible.
6. Invite the members to see the results and if possible, elaborate the result.
7. For positive results, reject milk and record the details of the test i.e., member number, can number, quantity, and the date in the occurrence book.
8. Inform the office of reference to the work instruction.

A.4.5 NEUTRALIZER TEST

1. Take one strip from the bottle.
2. Mix milk sample well to be homogeneous before testing.
3. Dip the indicated zone of the test strip in the milk sample for 3 seconds.
4. Remove the test strip from the milk and remove all milk drops from it by tapping the test strip.
5. **NEGATIVE:** Strip remains with color green yellow, white yellow and yellow color after test.
   POSITIVE: Strip changes color from green yellow to green blue, white yellow to yellow brown and from yellow to pinkish red test.
6. For positive results, reject milk and record the details of the test i.e., member number, can number, quantity, and the date in the occurrence book.

A.5. TRANSPORT COSTS

	COST ANALYSIS FOR MILK COLLECTION PER KGS												
PARTICULARS	**Jan-21**	**Feb-21**	**Mar-21**	**Apr-21**	**May-21**	**Jun-21**	**Jul-21**	**Aug-21**	**Sep-21**	**Oct-21**	**Nov-21**	**Dec-21**	**JAN 2021/DEC 2021**
	KSHS.	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**
Salaries and wages	KES 5,748,213	KES 5,833,539	KES 5,791,676	KES 5,749,676	KES 5,818,941	KES 5,868,128	KES 5,850,928	KES 5,817,452	KES 5,749,643	KES 5,704,323	KES 5,694,250	KES 5,735,166	**KES 69,361,935**
Casual labour & Overtime	KES 1,759,534	KES 1,557,897	KES 1,612,791	KES 1,811,631	KES 1,766,835	KES 1,806,358	KES 1,779,588	KES 1,953,299	KES 1,970,954	KES 1,955,699	KES 1,997,877	KES 1,807,284	**KES 21,779,746**
House allowance	KES 1,146,580	KES 1,163,724	KES 1,154,586	KES 1,146,186	KES 1,160,161	KES 1,166,559	KES 1,166,559	KES 1,159,863	KES 1,146,302	KES 1,137,238	KES 1,135,223	KES 1,143,406	**KES 13,826,387**
N.s.s.f.	KES 52,160	KES 52,560	KES 52,160	KES 51,560	KES 52,160	KES 52,360	KES 52,360	KES 52,160	KES 51,560	KES 50,760	KES 50,560	KES 50,760	**KES 621,120**
Staff Provident Fund	KES 437,041	KES 437,041	KES 433,614	KES 421,164	KES 421,164	KES 421,636	KES 421,636	KES 418,983	KES 417,320	KES 412,178	KES 410,442	KES 397,257	**KES 5,049,475**
Staff medical insurance cover	KES 536,850	KES 536,850	KES 536,850	KES 536,850	KES 536,850	KES 536,850	KES 640,112	KES 640,112	KES 640,112	KES 640,112	KES 640,112	KES 640,112	**KES 7,061,772**
Less Management Staff	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	**KES (240,000)**
TOTAL STAFF COST	**KES 9,660,378**	**KES 9,561,611**	**KES 9,561,677**	**KES 9,697,067**	**KES 9,736,111**	**KES 9,831,891**	**KES 9,891,183**	**KES 10,021,869**	**KES 9,955,890**	**KES 9,880,309**	**KES 9,908,463**	**KES 9,753,985**	**KES 117,460,435**
Depreciation	KES 1,694,911	KES 1,694,911	KES 1,694,911	KES 1,694,911	KES 1,694,911	KES 1,694,911	KES 1,793,589	KES 1,793,589	KES 1,793,589	KES 1,793,589	KES 1,793,589	KES 1,793,589	KES 20,931,000
Motor Vehicle Repair	KES 351,739	KES 694,182	KES 587,208	KES 799,689	KES 337,178	KES 197,309	KES 357,314	KES 362,153	KES 393,975	KES 611,194	KES 856,371	KES 583,604	KES 6,131,917
Motor vehicle fuel	KES 1,115,915	KES 1,176,409	KES 1,298,800	KES 1,346,224	KES 1,368,778	KES 1,373,863	KES 1,465,610	KES 1,451,261	KES 1,408,770	KES 1,471,084	KES 1,416,003	KES 1,441,147	KES 16,333,865
External Transport	KES 4,121,261	KES 4,000,920	KES 4,079,512	KES 4,184,114	KES 4,399,197	KES 3,966,814	KES 4,165,729	KES 4,049,888	KES 4,062,394	KES 4,291,347	KES 4,083,644	KES 4,461,266	KES 49,866,086
Insurance	KES 305,250	KES 305,250	KES 305,250	KES 305,250	KES 305,250	KES 305,250	KES 440,858	KES 440,858	KES 440,858	KES 440,858	KES 440,858	KES 440,858	KES 4,476,648
Licences	KES 68,850	KES 68,850	KES 68,850	KES 68,850	KES 68,850	KES 68,850	KES 66,503	KES 66,503	KES 66,503	KES 66,503	KES 66,503	KES 66,503	KES 812,118
TRANSPORTATION COST	**KES 7,657,926**	**KES 7,940,522**	**KES 8,034,531**	**KES 8,399,038**	**KES 8,174,165**	**KES 7,606,997**	**KES 8,289,603**	**KES 8,164,252**	**KES 8,166,089**	**KES 8,674,575**	**KES 8,656,968**	**KES 8,786,968**	**KES 98,551,633**
TOTAL TRANSPORTATION COST	**KES 17,318,304**	**KES 17,502,133**	**KES 17,596,208**	**KES 18,096,106**	**KES 17,910,276**	**KES 17,438,888**	**KES 18,180,786**	**KES 18,186,122**	**KES 18,121,979**	**KES 18,554,884**	**KES 18,565,431**	**KES 18,540,953**	**KES 216,012,068**
MILK INTAKE IN KG	**6,845,430**	**6,167,490**	**7,024,114**	**6,860,524**	**7,304,631**	**7,232,163**	**7,390,009**	**7,349,900**	**7,056,782**	**7,245,641**	**7,154,037**	**7,473,716**	**85,104,437**
COST PER KG	**KES 2.53**	**KES 2.84**	**KES 2.51**	**KES 2.64**	**KES 2.45**	**KES 2.41**	**KES 2.46**	**KES 2.47**	**KES 2.57**	**KES 2.56**	**KES 2.60**	**KES 2.48**	**KES 2.54**
COST PER KG (OWN)	**KES 1.93**	**KES 2.19**	**KES 1.92**	**KES 2.03**	**KES 1.85**	**KES 1.86**	**KES 1.90**	**KES 1.92**	**KES 1.99**	**KES 1.97**	**KES 2.02**	**KES 1.88**	**KES 1.95**
COST PER KG (HIRED)	**KES 0.60**	**KES 0.65**	**KES 0.58**	**KES 0.61**	**KES 0.60**	**KES 0.55**	**KES 0.56**	**KES 0.55**	**KES 0.58**	**KES 0.59**	**KES 0.57**	**KES 0.60**	**KES 0.59**

Figure 56: Transport costs Fresha in 2021. Source: (Fresha, 2022).

	COST ANALYSIS FOR MILK COLLECTION PER KGS												
PARTICULARS	**Jan-22**	**Feb-22**	**Mar-22**	**Apr-22**	**May-22**	**Jun-22**	**Jul-22**	**Aug-22**	**Sep-22**	**Oct-22**	**Nov-22**	**Dec-22**	**JAN 2022/ DEC 2022**
	KSHS.	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**	**KSHS.**
Salaries and wages	KES 5,650,430	KES 5,615,019	KES 5,630,925	KES 5,595,147	KES 7,447,744	KES 5,886,522	KES 5,994,710	KES 5,956,842	KES 5,907,947	KES 5,923,217	KES 5,899,750	KES 5,902,886	**KES 71,411,141**
Casual labour & Overtime	KES 1,935,127	KES 1,756,287	KES 1,846,446	KES 1,762,018	KES 1,918,359	KES 1,857,797	KES 1,821,621	KES 1,964,692	KES 1,892,653	KES 1,878,155	KES 1,993,439	KES 1,792,948	**KES 22,419,540**
House allowance	KES 1,126,467	KES 1,119,477	KES 1,122,558	KES 1,114,263	KES 1,484,790	KES 1,176,007	KES 1,198,069	KES 1,190,511	KES 1,180,733	KES 1,183,787	KES 1,179,093	KES 1,179,721	**KES 14,255,476**
N.s.s.f.	KES 49,960	KES 49,200	KES 49,000	KES 49,000	KES 49,000	KES 48,600	KES 49,200	KES 48,800	KES 48,600	KES 48,600	KES 48,600	KES 48,800	**KES 587,360**
Staff Provident Fund	KES 390,118	KES 391,685	KES 390,532	KES 390,532	KES 410,433	KES 414,807	KES 428,630	KES 422,746	KES 421,120	KES 421,322	KES 418,106	KES 418,786	**KES 4,918,817**
Staff medical insurance cover	KES 640,112	KES 640,112	KES 640,112	KES 640,112	KES 640,112	KES 640,112	KES 598,322	KES 598,322	KES 598,322	KES 598,322	KES 598,322	KES 598,322	**KES 7,430,604**
Less Management Staff	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	KES (20,000)	**KES (240,000)**
TOTAL STAFF COST	**KES 9,772,215**	**KES 9,551,781**	**KES 9,659,574**	**KES 9,531,072**	**KES 11,930,437**	**KES 10,003,844**	**KES 10,070,552**	**KES 10,161,913**	**KES 10,029,375**	**KES 10,033,403**	**KES 10,117,310**	**KES 9,921,463**	**KES 120,782,939**
Depreciation	KES 1,793,589	KES 1,793,589	KES 1,793,589	KES 1,793,589	KES 1,793,589	KES 1,793,589	KES 1,780,020	KES 1,780,020	KES 1,780,020	KES 1,780,020	KES 1,780,020	KES 1,780,020	KES 21,441,654
Motor Vehicle Repair	KES 646,323	KES 702,425	KES 665,143	KES 477,323	KES 598,164	KES 516,906	KES 366,894	KES 453,100	KES 669,088	KES 455,050	KES 1,125,946	KES 450,942	KES 7,127,304
Motor vehicle fuel	KES 1,531,587	KES 1,233,780	KES 1,640,300	KES 1,700,136	KES 1,778,578	KES 1,883,151	KES 2,061,739	KES 2,288,262	KES 2,160,911	KES 2,424,796	KES 2,125,282	KES 2,145,944	KES 22,974,466
External Transport	KES 3,964,944	KES 4,194,139	KES 4,502,702	KES 4,329,544	KES 4,453,685	KES 4,367,009	KES 4,369,019	KES 4,595,154	KES 4,458,008	KES 4,306,712	KES 4,685,365	KES 4,846,293	KES 53,072,572
Insurance	KES 440,858	KES 440,858	KES 440,858	KES 440,858	KES 440,858	KES 440,858	KES 380,079	KES 380,079	KES 380,079	KES 380,079	KES 380,079	KES 380,079	KES 4,925,622
Licences	KES 66,503	KES 66,503	KES 66,503	KES 66,503	KES 66,503	KES 66,503	KES 78,863	KES 78,863	KES 78,863	KES 78,863	KES 78,863	KES 78,863	KES 872,196
TRANSPORTATION COST	**KES 8,443,804**	**KES 8,431,294**	**KES 9,109,095**	**KES 8,807,952**	**KES 9,131,376**	**KES 9,068,016**	**KES 9,036,615**	**KES 9,575,478**	**KES 9,526,969**	**KES 9,425,520**	**KES 10,175,554**	**KES 9,682,140**	**KES 110,413,814**
TOTAL TRANSPORTATION COST	**KES 18,216,019**	**KES 17,983,075**	**KES 18,768,669**	**KES 18,339,024**	**KES 21,061,814**	**KES 19,071,860**	**KES 19,107,167**	**KES 19,737,391**	**KES 19,556,344**	**KES 19,458,923**	**KES 20,292,864**	**KES 19,603,603**	**KES 231,196,753**
MILK INTAKE IN KG	**7,370,355**	**6,679,980**	**7,385,147**	**7,303,140**	**7,732,380**	**7,587,552**	**7,428,146**	**7,239,247**	**7,099,347**	**7,401,058**	**7,048,655**	**7,280,952**	**87,555,958**
COST PER KG (TOTAL)	**KES 2.47**	**KES 2.69**	**KES 2.54**	**KES 2.51**	**KES 2.72**	**KES 2.51**	**KES 2.57**	**KES 2.73**	**KES 2.75**	**KES 2.63**	**KES 2.88**	**KES 2.69**	**KES 2.64**
COST PER KG (OWN)	**KES 1.93**	**KES 2.06**	**KES 1.93**	**KES 1.92**	**KES 2.15**	**KES 1.94**	**KES 1.98**	**KES 2.09**	**KES 2.13**	**KES 2.05**	**KES 2.21**	**KES 2.03**	**KES 2.04**
COST PER KG (HIRED)	**KES 0.54**	**KES 0.63**	**KES 0.61**	**KES 0.59**	**KES 0.58**	**KES 0.58**	**KES 0.59**	**KES 0.63**	**KES 0.63**	**KES 0.58**	**KES 0.66**	**KES 0.67**	**KES 0.61**

Figure 57: Transport costs Fresha in 2022. Source: (Fresha, 2022).

A.6. QUESTIONNAIRE

A.6.1. ANSWERS QUESTIONNAIRE

A.6.1.1 RESPONSE 1

1. What is your name?
   Dorcas.
2. What department do you work for?
   Quality assurance and extension.
3. Please describe your job.
   Give advice to farmers to increase quantity and improve the quality of milk.
4. What do you think is done well in the collection process of raw milk?
   Grading of milk.
5. What would you change in the collection process of milk to make it more efficient?
   Improve on infrastructure and more cooling centers.
6. What do you think is done well in the transport of raw milk from farm to processing plant?
   Taking the shortest time possible to deliver milk to the cooling centers.
7. What would you change in the transportation of raw milk from farm to processor to make it more efficient?
   Working more on infrastructure.
8. How to implement the change(s) you suggested?
   Involving the government to play part in improving infrastructure.

A.6.1.2 RESPONSE 2

1. What is your name?
   Joyce Kamindu.
2. What department do you work for?
   Quality assurance and extension.
3. Please describe your job.
   Providing extension services to farmers on dairy farming.
4. What do you think is done well in the collection process of raw milk?
   Quality test.
5. What would you change in the collection process of milk to make it more efficient?
   It is okay.
6. What do you think is done well in the transport of raw milk from farm to processing plant?
   Use of milk tankers.
7. What would you change in the transportation of raw milk from farm to processor to make it more efficient?
   It is okay.
8. How to implement the change(s) you suggested?
   In my route 1 everything is okay due to the nearness to the processing plant, no milk rejects.

A.6.1.3 RESPONSE 3

1. What is your name?
   Nelson Ndiritu.
2. What department do you work for?
   Quality assurance and extension.
3. Please describe your job.
   Milk grader.
4. What do you think is done well in the collection process of raw milk?
   Quality grading.
5. What would you change in the collection process of milk to make it more efficient?
   Ensure effectiveness of allocated time for milk collection.
6. What do you think is done well in the transport of raw milk from farm to processing plant?
   Timely collection and transportation of milk at the allocated time.
7. What would you change in the transportation of raw milk from farm to processor to make it more efficient?
   Ensure transport vehicles are always clean and well aerated.
8. How to implement the change(s) you suggested?
   Create and implement policies that are friendly and favorable to all parties involved.

A.6.1.4 RESPONSE 4

1. What is your name?
   Jeremiah Maina.
2. What department do you work for?
   Quality assurance and extension.
3. Please describe your job.
   Dairy extension officer.
4. What do you think is done well in the collection process of raw milk?
   Grading of milk and weighing of milk with digital machines.
5. What would you change in the collection process of milk to make it more efficient?
   The clerk should not be the grader, so as to make work easy.
6. What do you think is done well in the transport of raw milk from farm to processing plant?
   We have enough transporting vehicles from different routes.
7. What would you change in the transportation of raw milk from farm to processor to make it more efficient?
   Some routes have old transporting vehicles which delays the process they need to be changed.
8. How to implement the change(s) you suggested?
   By reporting the issues to the department and trying to implement them.

A.6.1.5 RESPONSE 5

1. What is your name?
   Moses.
2. What department do you work for?
   Quality assurance and extension.
3. Please describe your job.
   Train farmers on all aspects of fair farming.
4. What do you think is done well in the collection process of raw milk?
   Timely collection.
5. What would you change in the collection process of milk to make it more efficient?
   Add more collection centers on bigger routes.
6. What do you think is done well in the transport of raw milk from farm to processing plant?
   Milk being transported with aluminum cans and clean lorries and tankers.
7. What would you change in the transportation of raw milk from farm to processor to make it more efficient?
   Have many coolers so that milk is transported with tankers.
8. How to implement the change(s) you suggested?
   All milk from farms goes to cooler first.

A.6.1.6 RESPONSE 6

1. What is your name?
   Joel Kilonzo
2. What department do you work for?
   Tetra Pak
3. Please describe your job.
   Customer management
4. What do you think is done well in the collection process of raw milk?
   Double collection per day (morning and evening).
5. What would you change in the collection process of milk to make it more efficient?
   Add chilling centers closer to farmers to reduce time from milking to chilling.
6. What do you think is done well in the transport of raw milk from farm to processing plant?
   Use of aluminum/stainless steel cans and use of tankers to plant.
7. What would you change in the transportation of raw milk from farm to processor to make it more efficient?
   Ensure all tankers are cooled.
8. How to implement the change(s) you suggested?
   Give specifications of tankers including temperature of milk during offload.

A.6.1.7 RESPONSE 7

1. What is your name?
   Peter Mburu.
2. What department do you work for?
   Quality assurance and extension.
3. Please describe your job.
   My job is ensuring farmers improve the quality and increase quantity of milk through door-to-door training and consistent follow ups.
4. What do you think is done well in the collection process of raw milk?
   Regular testing of milk and construction of collection centers close to farmers less than 2 km distance.
5. What would you change in the collection process of milk to make it more efficient?
   Some routes are too long so I would split them for faster collection.
6. What do you think is done well in the transport of raw milk from farm to processing plant?
   Cooling and short time taken during the process.
7. What would you change in the transportation of raw milk from farm to processor to make it more efficient?
   Lobby the government to improve rural roads to ease transportation of raw milk during rainy season.
8. How to implement the change(s) you suggested?
   Attend public participation forums.

A.6.1.8 RESPONSE 8

1. What is your name?
   Dr. Oyugi Humphrey.
2. What department do you work for?
   Quality assurance and extension.
3. Please describe your job.
   My job is to ensure the wellbeing of the animals so as to produce quality milk, work closely with other staff to ensure the quality of milk is not compromised up to the point it gets to the factory.
4. What do you think is done well in the collection process of raw milk?
   The collection center is positioned close to the farmers and shortly after collection the milk is transported to the cooling centers. This aids in maintaining the original quality of the milk.
5. What would you change in the collection process of milk to make it more efficient?
   Reduce the time between milking and the milk getting to the collection center.
6. What do you think is done well in the transport of raw milk from farm to processing plant?
   Having multiple cooling plants across the catchment area. This ensures milk is collected and chilled as soon as possible to preserve its original quality.
7. What would you change in the transportation of raw milk from farm to processor to make it more efficient?
   Have more coolers to relieve the holding capacity at the processor.
8. How to implement the change(s) you suggested?
   Draw up a plan and present it to the board for financial support.

A.6.1.9 RESPONSE 9

1. What is your name?
   Susan.
2. What department do you work for?
   Quality assurance and extension.
3. Please describe your job.
   Offering extension services to farmers.
4. What do you think is done well in the collection process of raw milk?
   Short duration between milk collection and processing.
5. What would you change in the collection process of milk to make it more efficient?
   Enhance milk testing for each and every farmer before collection.
6. What do you think is done well in the transport of raw milk from farm to processing plant?
   It takes the shortest time possible.
7. What would you change in the transportation of raw milk from farm to processor to make it more efficient?
   Transport using tankers not cans.
8. How to implement the change(s) you suggested?
   Add more time during collection. Invest in tankers.

A.6.1.10 RESPONSE 10

1. What is your name?
   Tabitha.
2. What department do you work for?
   Quality assurance and extension.
3. Please describe your job.
   Advising farmers on dairy farming.
4. What do you think is done well in the collection process of raw milk?
   Milk procedure.
5. What would you change in the collection process of milk to make it more efficient?
   Keeping time.
6. What do you think is done well in the transport of raw milk from farm to processing plant?
   Good handling of milk.
7. What would you change in the transportation of raw milk from farm to processor to make it more efficient?
   Good hygiene.
8. How to implement the change(s) you suggested?
   Training.

A.6.1.11 RESPONSE 11

1. What is your name?
   Carol Muchai.
2. What department do you work for?
   Quality assurance and extension.
3. Please describe your job.
   Assisting and training farmers on milk production at a lower cost.
4. What do you think is done well in the collection process of raw milk?
   Mil collection is done faster and delivered to coolers at the shortest time possible.
5. What would you change in the collection process of milk to make it more efficient?
   Do quality tests every day.
6. What do you think is done well in the transport of raw milk from farm to processing plant?
   Delivered in the shortest time.
7. What would you change in the transportation of raw milk from farm to processor to make it more efficient?
   Infrastructure which is a threat.
8. How to implement the change(s) you suggested?
   Doing tests and working closely with government for improvement on infrastructure.

A.6.1.12 RESPONSE 12

1. What is your name?
   F. Giteru.
2. What department do you work for?
   Quality assurance and extension.
3. Please describe your job.
   Training at farm level.
4. What do you think is done well in the collection process of raw milk?
   Quick delivery.
5. What would you change in the collection process of milk to make it more efficient?
   Nothing.
6. What do you think is done well in the transport of raw milk from farm to processing plant?
   Quick delivery.
7. What would you change in the transportation of raw milk from farm to processor to make it more efficient?
   Nothing.
8. How to implement the change(s) you suggested?
   Not applicable.

A.6.1.13 RESPONSE 13

1. What is your name?
   Gabriel.
2. What department do you work for?
   Quality assurance and extension.
3. Please describe your job.
   Training farmers and checking quality of milk at farm level.
4. What do you think is done well in the collection process of raw milk?
   Checking the parameters of milk (quality check is done well).
5. What would you change in the collection process of milk to make it more efficient?
   Addition of more collection centers to reduce the distance of farmers delivering.
6. What do you think is done well in the transport of raw milk from farm to processing plant?
   Using a cooler tanker.
7. What would you change in the transportation of raw milk from farm to processor to make it more efficient?
   Putting tarmac roads to ease the transport and faster transportation to plant.
8. How to implement the change(s) you suggested?
   Liasing with county government to construct tarmac road.

A.7. TRANSPORT TIME AND MILK TEMPERATURE

A limited amount of data is used due to unreliable and inconsistent data. Therefore, a collection was made, and the other data has not been used in the research.

A.7.1. TRANSPORT TIME AND MILK TEMPERATURE

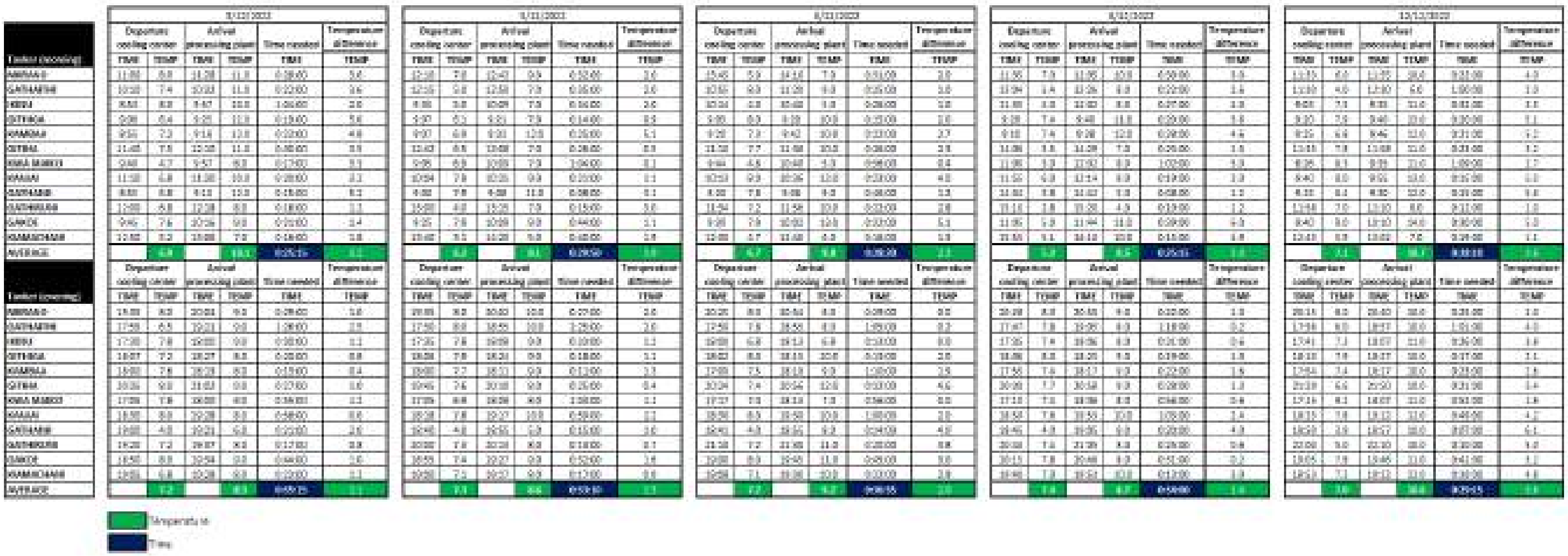

Figure 58: Transport time and milk temperature Fresha. Source: (Fresha, 2022).

A.7.2 TRANSPORT TIME

Tanker (morning)	3/11/2022 Departure cooling center	3/11/2022 Arrival processing plant	3/11/2022 Time needed	3/11/2022 Departure cooling center	3/11/2022 Arrival processing plant	3/11/2022 Time needed	4/11/2022 Departure cooling center	4/11/2022 Arrival processing plant	4/11/2022 Time needed	8/11/2022 Departure cooling center	8/11/2022 Arrival processing plant	8/11/2022 Time needed	10/11/2022 Departure cooling center	10/11/2022 Arrival processing plant	10/11/2022 Time needed	17/11/2022 Departure cooling center	17/11/2022 Arrival processing plant	17/11/2022 Time needed
MBIRAYO	11:00	11:28	0:28:00	12:10	12:42	0:32:00	13:45	14:16	0:31:00	11:38	12:08	0:30:00	11:35	12:58	0:22:00	10:03	13:28	0:35:00
GATHAITHI	10:10	10:32	0:22:00	12:15	12:50	0:35:00	10:55	11:20	0:25:00	13:04	13:26	0:22:00	11:30	12:30	1:00:00	10:43	10:58	0:15:00
KIRIU	8:53	9:57	1:04:00	9:35	10:09	0:34:00	10:14	10:40	0:26:00	11:05	12:02	0:27:00	9:03	9:35	0:32:00	12:47	13:11	0:24:00
GITHIGA	9:00	9:25	0:15:00	9:07	9:21	0:14:00	9:05	9:20	0:15:00	9:20	9:40	0:20:00	9:20	9:40	0:20:00	9:35	9:52	0:17:00
KAMBAA	8:55	9:18	0:23:00	9:07	9:32	0:25:00	9:10	9:42	0:32:00	9:15	9:38	0:28:00	9:25	9:48	0:23:00	9:00	9:25	0:25:00
GITHIA	11:40	12:10	0:30:00	12:42	13:08	0:26:00	11:10	11:36	0:26:00	14:08	14:29	0:21:00	11:35	12:58	0:23:00	11:05	12:30	0:25:00
KWA MAIKO	9:20	9:37	0:17:00	9:05	10:05	1:00:00	9:11	10:00	0:36:00	11:00	12:03	1:02:00	8:36	9:36	1:00:00	12:16	12:34	0:18:00
KAMAU	11:10	11:40	0:30:00	10:00	10:16	0:21:00	10:18	10:38	0:20:00	11:56	12:11	0:15:00	9:43	9:56	0:13:00	9:58	10:23	0:25:00
GATHANGI	8:56	9:10	0:14:00	9:00	9:09	0:09:00	8:33	9:06	0:36:00	11:10	11:13	0:08:00	9:15	9:30	0:15:00	8:41	8:53	0:12:00
GATHIRUINI	12:00	12:18	0:18:00	10:00	10:15	0:15:00	11:30	11:56	0:22:00	15:10	15:20	0:10:00	11:58	12:10	0:12:00	11:06	13:21	0:16:00
GAKOE	9:46	10:16	0:30:00	9:25	10:09	0:44:00	9:33	10:03	0:30:00	11:05	11:44	0:39:00	9:40	10:10	0:30:00	10:15	10:08	0:53:00
KIAMBACHAWA	12:50	12:06	0:16:00	12:40	13:20	0:40:00	12:30	12:46	0:16:00	15:55	16:10	0:15:00	12:43	13:02	0:18:00	11:33	13:50	0:30:00
AVERAGE			0:25:15			0:29:50			0:28:20			0:25:11			0:28:18			0:32:55

Tanker (evening)	Departure cooling center	Arrival processing plant	Time needed	Departure cooling center	Arrival processing plant	Time needed	Departure cooling center	Arrival processing plant	Time needed	Departure cooling center	Arrival processing plant	Time needed	Departure cooling center	Arrival processing plant	Time needed	Departure cooling center	Arrival processing plant	Time needed
MBIRAYO	19:35	20:04	0:29:00	19:35	20:02	0:27:00	19:25	20:54	0:29:00	20:28	20:50	0:22:00	20:15	20:40	0:25:00	19:15	18:57	0:32:00
GATHAITHI	17:55	18:31	1:28:00	17:30	18:55	1:25:00	17:50	18:55	1:05:00	17:47	19:05	1:18:00	17:56	18:57	1:01:00	18:28	18:43	1:15:00
KIRIU	17:30	18:00	0:30:00	17:35	18:08	0:33:00	18:00	18:13	0:13:00	17:55	18:06	0:11:00	17:41	18:07	0:26:00	17:38	17:54	0:16:00
GITHIGA	18:07	18:27	0:20:00	18:06	18:34	0:28:00	18:02	18:15	0:13:00	18:06	18:25	0:19:00	18:10	18:27	0:17:00	18:48	18:43	0:55:00
KAMBAA	18:00	18:13	0:13:00	18:00	18:31	0:31:00	17:00	18:10	1:10:00	17:55	18:17	0:22:00	17:54	18:17	0:23:00	18:40	19:03	0:23:00
GITHIA	20:35	21:02	0:27:00	19:45	20:10	0:25:00	19:24	20:56	0:52:00	20:30	20:58	0:28:00	21:28	22:50	0:22:00	21:05	22:35	0:18:00
KWA MAIKO	17:05	18:00	0:55:00	17:05	18:08	1:03:00	17:17	18:13	0:56:00	17:10	18:06	0:56:00	17:15	18:07	0:52:00	18:55	17:54	0:59:00
KAMAU	18:30	19:28	0:58:00	18:18	19:17	0:59:00	18:50	19:50	1:00:00	18:50	19:53	1:03:00	18:25	19:13	0:48:00	19:26	20:58	1:32:00
GATHANGI	19:00	19:21	0:21:00	18:40	18:55	0:15:00	18:41	18:55	0:14:00	18:45	19:05	0:20:00	18:30	18:37	0:07:00	19:30	19:43	0:13:00
GATHIRUINI	19:30	19:37	0:17:00	19:00	20:13	0:13:00	21:10	21:30	0:20:00	19:40	21:05	0:25:00	22:00	22:10	0:10:00	19:25	19:38	0:13:00
GAKOE	18:50	19:34	0:44:00	18:55	19:27	0:32:00	19:00	19:45	0:45:00	20:15	20:48	0:33:00	19:05	19:48	0:43:00	19:32	19:58	0:34:00
KIAMBACHAWA	19:05	19:28	0:23:00	19:00	19:17	0:17:00	19:08	19:30	0:22:00	19:40	19:53	0:13:00	18:53	19:12	0:19:00	18:05	20:38	0:35:00
AVERAGE			0:55:15			0:53:10			0:50:55			0:54:00			0:29:15			0:38:55

Figure 59: Transport time of milk Fresha. Source: (Fresha, 2022).

A.7.3 MILK TEMPERATURE FLUCTUATIONS DUE TO TRANSPORT

		5/12/2021			5/12/2021			6/12/2021			8/12/2022			12/12/2021			17/12/2012		
	Tanker (morning)	Departure cooling center	Arrival processing plant	Temperature difference	Departure cooling center	Arrival processing plant	Temperature difference	Departure cooling center	Arrival processing plant	Temperature difference	Departure cooling center	Arrival processing plant	Temperature difference	Departure cooling center	Arrival processing plant	Temperature difference	Departure cooling center	Arrival processing plant	Temperature difference
COOLING CENTER	MIRANGO	8.0	11.0	3.0	7.0	9.0	2.0	5.0	7.0	2.0	7.0	10.0	3.0	6.0	10.0	4.0	8.0	9.0	1.0
	GATHAITHI	7.4	11.0	3.6	5.0	7.0	2.0	6.0	9.0	3.0	5.4	8.0	2.6	4.0	6.0	2.0	7.6	11.0	3.4
	IKINU	8.0	10.0	2.0	5.0	7.0	2.0	4.0	5.0	1.0	8.0	8.0	0.0	7.6	11.0	3.4	6.6	7.0	0.4
	GITHIGA	6.4	12.0	5.6	6.1	7.0	0.9	8.0	10.0	2.0	7.4	10.0	2.6	7.9	13.0	5.1	7.9	11.0	3.1
	KAMBAA	7.2	12.0	4.8	6.9	12.0	5.1	7.3	10.0	2.7	7.4	12.0	4.6	6.8	12.0	5.2	7.0	11.0	4.0
	GITIHA	7.5	11.0	3.5	6.5	7.0	0.5	7.7	10.0	2.3	5.5	7.0	1.5	7.8	11.0	3.2	8.0	10.0	2.0
	KWA MAIKO	4.7	8.0	3.3	6.9	7.0	0.1	4.6	5.0	0.4	3.0	8.0	5.0	8.3	11.0	2.7	2.9	4.0	1.1
	KASAMI	6.8	10.0	3.2	7.9	9.0	1.1	8.0	12.0	4.0	8.0	8.0	0.0	8.0	13.0	5.0	8.0	10.0	2.0
	GATHANJI	6.8	12.0	5.2	7.9	11.0	3.1	7.8	9.0	1.2	7.8	9.0	1.2	6.4	12.0	5.6	7.6	12.0	4.4
	GATHIRURU	6.8	8.0	1.2	4.0	7.0	3.0	7.2	10.0	2.8	2.9	4.0	1.1	7.0	8.0	1.0	7.7	10.0	2.3
	GAKOE	7.6	9.0	1.4	7.9	9.0	1.1	7.9	13.0	5.1	5.0	11.0	6.0	9.0	14.0	5.0	6.0	10.0	4.0
	KIAMADHANI	5.2	7.0	1.8	5.1	7.0	1.9	4.7	6.0	1.3	5.1	10.0	4.9	5.9	7.0	1.1	7.8	8.0	0.2
	AVERAGE	6.9	10.1	3.2	6.2	8.2	1.9	6.7	8.8	2.2	5.8	8.5	3.3	7.1	10.2	3.6	6.9	9.4	2.5

	Tanker (evening)	Departure cooling center	Arrival processing plant	Temperature difference	Departure cooling center	Arrival processing plant	Temperature difference	Departure cooling center	Arrival processing plant	Temperature difference	Departure cooling center	Arrival processing plant	Temperature difference	Departure cooling center	Arrival processing plant	Temperature difference	Departure cooling center	Arrival processing plant	Temperature difference
COOLING CENTER	MIRANGO	8.0	9.0	1.0	8.0	10.0	2.0	8.0	8.0	0.0	8.0	9.6	1.6	8.0	10.0	2.0	8.0	9.0	1.0
	GATHAITHI	5.5	9.0	3.5	8.0	10.0	2.0	7.8	8.0	0.2	7.8	8.0	0.2	6.0	10.0	4.0	7.0	17.0	10.0
	IKINU	7.8	9.0	1.2	7.8	9.0	1.2	6.8	6.8	0.0	7.4	8.0	0.6	7.2	11.0	3.8	8.0	10.0	2.0
	GITHIGA	7.2	8.0	0.8	7.9	9.0	1.1	8.5	10.0	1.5	8.0	9.6	1.6	7.9	10.0	2.1	15.0	17.0	2.0
	KAMBAA	7.6	8.0	0.4	7.7	9.0	1.3	7.9	9.0	1.1	7.4	9.0	1.6	7.4	10.0	2.6	8.8	10.0	1.2
	GITIHA	8.0	9.0	1.0	7.6	8.0	0.4	7.4	12.0	4.6	7.7	9.0	1.3	6.6	10.0	3.4	6.8	7.0	0.2
	KWA MAIKO	7.8	9.0	1.2	6.9	8.0	1.1	7.1	7.0	-0.1	7.4	8.0	0.6	9.2	11.0	1.8	8.7	10.0	1.3
	KASAMI	8.0	8.0	0.0	7.8	10.0	2.2	8.0	10.0	2.0	7.6	10.0	2.4	7.8	12.0	4.2	6.0	9.0	3.0
	GATHANJI	4.0	6.0	2.0	4.0	5.6	1.6	4.0	8.0	4.0	4.0	8.0	4.0	3.9	10.0	6.1	6.7	17.0	10.3
	GATHIRURU	7.2	8.0	0.8	7.3	8.0	0.7	7.2	11.0	3.8	7.4	8.0	0.6	5.0	10.0	5.0	7.8	9.0	1.2
	GAKOE	8.0	9.0	1.0	7.4	9.0	1.6	8.0	11.0	3.0	7.8	8.0	0.2	7.8	11.0	3.2	8.0	9.0	1.0
	KIAMADHANI	6.8	8.0	1.2	7.1	8.0	0.9	7.1	10.0	2.9	7.0	10.0	3.0	7.1	11.0	3.9	6.5	9.0	2.5
	AVERAGE	7.2	8.3	1.1	7.3	8.6	1.3	7.2	9.2	2.0	7.3	8.7	1.4	7.0	10.6	3.6	8.0	10.9	2.8

Figure 60: Milk temperature fluctuations due to transport Fresha. Source: (Fresha, 2022).

A.7.4 RELATION TRANSPORT TIME AND MILK TEMPERATURE

Transport time < 30 minutes

Departure temperature < 6°C					
Departure cooling center		Arrival processing plant		Time needed	Temperature difference
TIME	TEMP	TIME	TEMP	TIME	TEMP
12:25	2.9	12:53	4.0	0:28:00	1.1
10:14	4.0	10:40	5.0	0:26:00	1.0
12:30	4.7	12:46	6.0	0:16:00	1.3
Average	3.9		5.0	0:23:20	1.1

Departure temperature > 6°C					
Departure cooling center		Arrival processing plant		Time needed	Temperature difference
TIME	TEMP	TIME	TEMP	TIME	TEMP
10:10	7.4	10:32	11.0	0:22:00	3.6
10:43	7.6	10:58	11.0	0:15:00	3.4
11:00	8.0	11:28	11.0	0:28:00	3.0
Average	7.7		11.0	0:21:40	3.3

Transport time > 30 minutes

Departure temperature < 6°C					
Departure cooling center		Arrival processing plant		Time needed	Temperature difference
TIME	TEMP	TIME	TEMP	TIME	TEMP
13:40	3.1	14:20	5.0	0:40:00	1.9
11:30	4.0	12:30	6.0	1:00:00	2.0
12:15	5.0	12:50	7.0	0:35:00	2.0
Average	4.0		6.0	0:45:00	2.0

Departure temperature > 6°C					
Departure cooling center		Arrival processing plant		Time needed	Temperature difference
TIME	TEMP	TIME	TEMP	TIME	TEMP
17:56	6.0	18:57	10.0	1:01:00	4.0
18:23	7.8	19:12	12.0	0:49:00	4.2
19:00	8.0	19:45	11.0	0:45:00	3.0
Average	7.3		11.0	0:51:40	3.7

Temperature

Time

Figure 61: Relation between transport time and milk temperature Fresha. Source: (Fresha, 2022).