Integrated Assessment of the Presence and Levels of Contaminants (Aflatoxins, Antibiotics, Acaricides, and Pesticides) in Raw Milk in the North Rift Region-Kenya.

SUBMITTED BY

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DEDICATION

I dedicate this thesis to my parents, Victor and Lilian Odera, for their unconditional love and support. Their belief in me, even when I doubted myself, has constantly pushed me to achieve greater heights. I am forever grateful for their encouragement and faith in my abilities.

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LIST OF ABBREVIATIONS AND ACRONYMS

KDB-Kenya Dairy Board

KBS- Kenya Bureau of Standards

PPB- Parts per billion

PPT- Parts per trillion

LTD-Limited

APCM- Agricultural Production Chain management

M1- Molecule 1

ABSTRACT

Kenya is a leading milk producer in Sub-Saharan Africa, with a high per capita milk consumption of 115 liters per year, reflecting the importance of milk as a staple food and a key source of animal protein in the country. However, the quality of milk is compromised by contaminants such as antibiotics, aflatoxins, and acaricides. Bio Foods, a well-known dairy processor producing high-quality dairy products, faces challenges in sourcing high-quality milk free from these contaminants to meet consumer demand.

This study was conducted to identify effective strategies Bio Foods could implement to keep aflatoxin levels within acceptable limits and reduce the presence of residues of antibiotics and acaricides in raw milk. The study examined the levels of these contaminants in both the formal market where Bio Foods is currently sourcing its milk and informal markets, accounting for 80% of total milk sold in Kenya and a potential source of milk for Bio Foods in the North Rift region. It investigated the sources of contamination, farming practices related to these contaminants, and the role of dairy cooperatives and processors as key stakeholders in maintaining low contaminant levels.

A comparative analysis was conducted between farmers supplying Bio foods, cooperative supplying milk to Bio Foods, and those not supplying them. The report highlighted the higher levels of contaminants in the informal channel, which are majorly made of those not supplying Bio Foods. Aflatoxin was found to be low among Bio Foods suppliers and was attributed to the strict measures set by Bio Foods for farmers to adhere to. These practices were not practised by Non-Bio Foods suppliers, and it was noted that the levels were high, with one sample exceeding the 500ppt threshold set by Bio Foods. Aflatoxin was traced back to feeds as the source and other farm practices predisposed the feeds to aflatoxins. Antibiotics were also detected in milk from Non-Bio food suppliers, and their occurrence was linked to treatments at the farm. All the samples tested positive for Acaricides. Farms that used organophosphates tested positive for the chemical, while all the samples tested positive for cypermethrin, indicating multiple entries of this chemical into the milk value chain.

Strategies were proposed for Bio Foods to assist farmers in reducing contaminants in their milk. These strategies included offering training to farmers in the informal channel, linking farmers to reputable suppliers with high-quality products, offering incentives and collaborating with more cooperatives. These strategies would enable Bio Foods to attract more farmers from the informal market and enable Bio Foods to increase their milk intake to meet the rising demand for high-quality dairy products.

CHAPTER ONE

CHAPTER ONE: INTRODUCTION

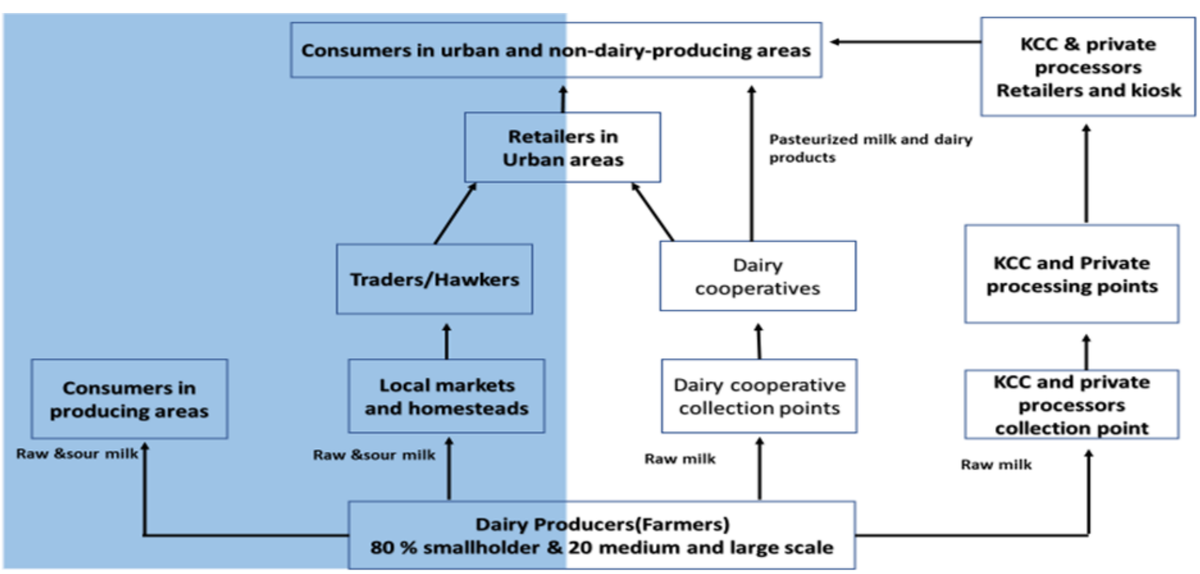
1.1 Dairy Sector in Kenya

Kenya is one of the prominent milk producers in Sub-Saharan Africa (Creemers and Aranguiz, 2019). The country boasts a dairy sub-sector that contributes a substantial 4% - 8% of the Gross Domestic Product (GDP) (Creemers and Aranguiz, 2019). This sector, the largest in Kenya, is an economic driver, providing income and employment to over 1.0 million households across the dairy value chain (Creemers and Aranguiz, 2019). The average per capita milk consumption is high, equivalent to 115 liters. This is due to the fact that the average Kenyan consumes milk daily, and milk is a staple food in people's diets, a significant source of animal protein (International Livestock Research Institute, 2023).

Currently, 80% of the milk in Kenya is produced by smallholder farmers (Creemers and Aranguiz, 2019) and sold in the informal market, which makes up about 80% of all milk sales in the country. The informal dairy market typically lacks infrastructure and reliable access to clean water, electricity, sanitation, and refrigeration facilities, and it does not follow safety regulations. Additionally, it operates without a license, receives little support from the government, and is excluded from the formal market. Most milk in this market is sold raw (unpasteurized) and unpackaged. This sector depends on the spot market, lacking formal contracts and contractual engagement (Zavala Nacul and Revoredo-Giha, 2022).

In contrast, the formal market is managed by licensed dairy enterprises that operate within a clear legal framework, have established facilities, and undergo regular inspections. Key participants in this market include processing companies and cooperatives such as Brookside Dairy Limited, Kenya Co-operative Creameries LTD, Githunguri Dairy Farmers Cooperative Society, and Bio Foods Products Ltd, among other processors (Ministry of Livestock Department, 2010). The contrast between the formal and informal milk marketing channels in Kenya is illustrated in Figure 1 below.

Figure 1: Figure 1 shows the formal and informal milk marketing channels.



Source: APCM student (2024)

The high share of milk commercialized through informal channels poses a challenge to quality control and minimizing losses in the Kenyan dairy sector (Blackmore et al., 2021). Milk's safety and quality are seriously threatened by various contaminants like microbial contamination, antibiotic residues, and chemical contaminants like pesticide and acaricide residues. These compounds enter milk through various direct and indirect routes, making their occurrence challenging to avoid and control. Some contaminants result from agricultural, veterinary, and hygienic practices, which aim to improve milk yield and quality but also leave trace residues in raw milk and finished products (Fischer et al., 2011). This research will investigate the presence and levels of milk contaminants with a focus on antibiotics, aflatoxin, and acaricides in raw milk in the North Rift Region.

1.2 Problem Context

Bio Foods Products Ltd. (Bio Foods) is a privately-owned milk processing company located in Nairobi, Kenya; the company is recognized for producing high-quality dairy products. Bio Foods stands out in the Kenyan dairy market because it maintains strict quality control throughout production, from the farm to the final product. The company's premium products are in high demand among Kenyans who appreciate and can afford quality. However, Bio Foods is currently dealing with the problem of inconsistent supply of high milk volumes with acceptable levels of contaminants. To maintain a consistent supply of high-quality milk, the company sources it directly from the formal sector farmers and one cooperative. It has a strict onboarding process for farmers who must produce at least 300 litres of milk daily, use milking machines, and have access to chilling facilities. Additionally, they must adhere to the company's strict quality standards, including zero tolerance for antibiotic residues, low aflatoxin levels, and low bacterial counts. To meet the demand for milk, there is an opportunity to source milk from the informal market, which accounts for 80% of milk sales. However, the company must ensure that this milk meets its quality requirements. The company needs strategies to keep the three contaminants within acceptable limits before it can source milk from the informal sector.

1.3 Problem Statement

The challenge at hand is the lack of effective strategies to keep the three contaminants (aflatoxin, antibiotics, and acaricides) in milk within acceptable levels. These contaminants make their way into milk through various direct and indirect pathways, including agricultural, veterinary, and hygiene practices aimed at improving milk quality and yield. However, these practices can also leave behind residues in both raw milk and finished products (Fischer et al., 2011). Each of the three contaminants gets into the milk in different ways. Aflatoxin enters early during feed production, harvesting, and storage, making it hard for farmers to control because it comes from outside sources. Once cows eat contaminated feed, removing aflatoxin from the milk is impossible. Acaricides get into the milk at the farm when farmers use these chemicals on cows to control parasites. Antibiotics enter the milk because of veterinary treatments and not withdrawing milk from treated cows. High levels of these contaminants are a food safety risk and a health hazard to consumers. As the main player in this issue, Bio Foods needed practical strategies to manage these contaminants.

1.4 Rationale

The research on the three contaminants in raw milk was important for Bio Foods because these contaminants have been a problem in milk sourcing. The contaminants threaten the safety and quality of the company's dairy products, which could harm consumer trust and affect the business. By studying the levels of these contaminants and finding ways to reduce them, the research would help Bio Foods keep its high standards and protect consumer health. The research would also help Bio Foods with its milk sourcing. By addressing contaminants issues, the company would be able to increase its milk intake from more farmers and suppliers in the informal sector. The research also showed new farmers' challenges in meeting Bio Foods' strict standards. The findings helped Bio Foods create strategies to support these farmers, making it easier for them to meet the company's requirements and increase the supply of safe milk. Additionally, this research contributed to the larger goal of Sustainable Development Goal (SDG) 3: Good Health and Well-being. By improving the safety of Kenya's milk supply chain, the study helped improve public health and supported the economic standards of dairy farmers.

1.5 Research Objective

To find effective strategies that can be implemented by Bio Foods to maintain the levels of aflatoxins within acceptable limits and mitigate antibiotics and acaricide residues in raw milk.

1.6 Research Questions

1. **What is the current state of milk in relation to aflatoxin, antibiotics, and acaricides?**

1.1. What are the three contaminants' levels in raw milk?
1.2. What are the primary sources of the three contaminants in raw milk?

2. **What are the practices employed by stakeholders to contain the levels of these contaminants within acceptable standards?**

2.1. What are the daily practices among dairy farmers in relation to the three contaminants?

2.2. What is the role of dairy processors and cooperatives in relation to the three contaminants?

3. **What strategies can be implemented by key stakeholders to mitigate aflatoxins, antibiotic, and acaricide, contamination in raw milk in the North Rift region in Kenya?**

3.1. What factors affect farmers' capacity to adopt new approaches to address milk contamination with the three contaminants at the farm level?
3.2. What are Bio Foods' capabilities in implementing interventions to address milk contamination with the Three contaminants?
3.3. What is the effectiveness of the current regulatory mechanisms and enforcement practices in addressing contamination issues in the dairy sector in the North Rift region of Kenya?

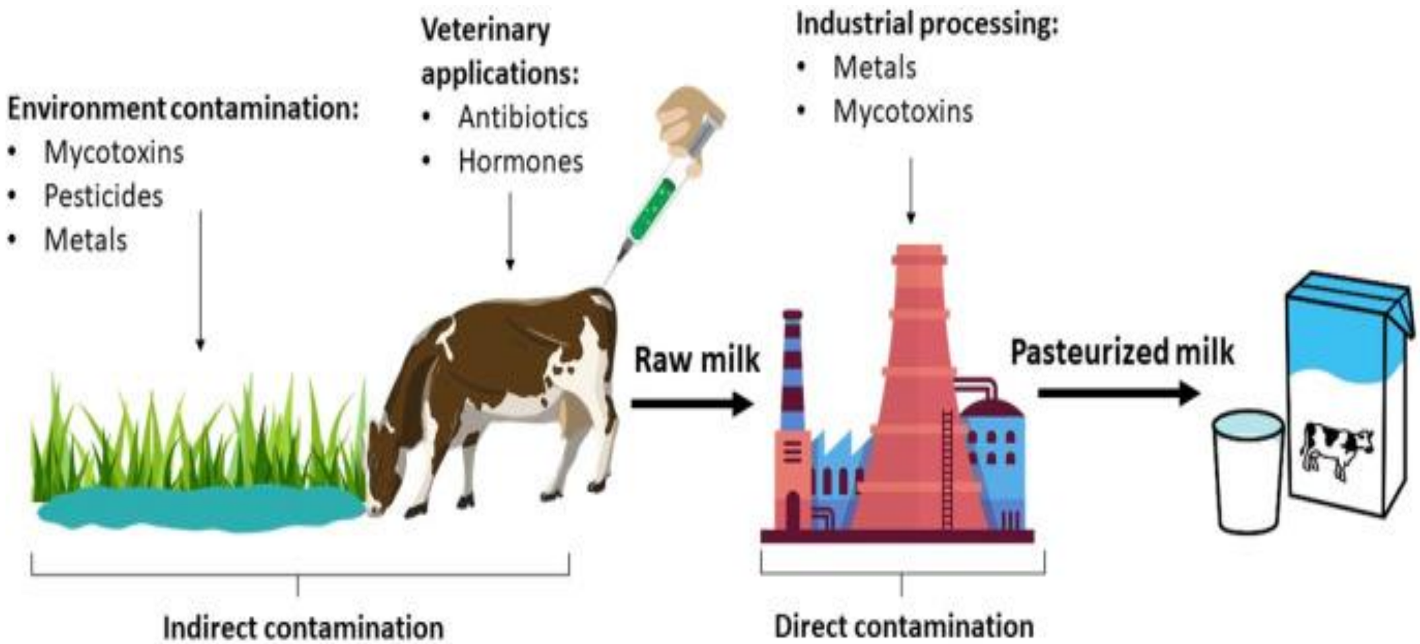
CHAPTER TWO

CHAPTER TWO: LITERATURE REVIEW

2.1 Milk Contaminants

Improved analytical methods that detect very low concentrations of chemicals have shown that milk and dairy products may be contaminated with various potentially harmful chemicals. These compounds can enter milk through different direct or indirect routes. Their presence in milk is difficult to avoid and control for several reasons, such as persistent environmental pollutants. Other contaminants from agricultural, veterinary, and hygiene practices enhance milk yield and quality but may also leave trace residues in the final products (Fischer et al., 2011). Figure 2 below shows different pathways of entry of contaminants into the milk and milk products.

Figure 2: Sources of contamination of cow milk



Source: Calahorrano-Moreno et al., 2022

This research focused on three contaminants: Antibiotics, Aflatoxins, and acaricides. This is because Bio Foods is currently struggling to source milk with zero antibiotics and low levels of aflatoxin. Bio Foods is also committed to quality and would like to know the status of milk in relation to acaricides.

2.2 Acaricides

In Kenya, ticks are a significant pest that severely impacts livestock farming. Ticks and the diseases they carry reduce livestock productivity, which in turn adversely affects farmers' livelihoods (Mutavi et al., 2021). Acaricides are used as dips, sprays, and pour-on to manage and prevent tick infestations. Table 1 below shows the active ingredients in the acaricide products approved for cattle use in Kenya.

Table 1:Table showing acaricide products approved for cattle use in Kenya

Chemical Group	Active Ingredient	Maximum Residue Limit {ug/kg} in milk
Carbamate	Carbaryl	50
Pyrethroid	Cypermethrin, Deltamethrin and Alphacypermethrin.	50
Pyrethroid	Cyhalothrin.	200
Organophosphate	Chlorpyriphos	20
	Chlorphenvinphos	10
Amidine	Amitraz	10

Source: (Ouma, 2023)

Acaricides are classified according to their chemical composition as organophosphates, carbamates, pyrethroids, and amidines. For this study, Chlorophyll (organophosphates) and cypermethrin (Pyrethroid) were chosen due to the high number of farmers using the chemicals in the study area.

2.2.1 Organophosphates

Organophosphates (OPs) are chemical compounds that are organic esters of phosphoric acid. They work by inhibiting acetylcholinesterase (AchE), an enzyme crucial for nerve signal transmission. When AchE is inhibited, nerve signals cannot terminate properly, causing paralysis and eventually leading to the death of the targeted pests (Adeyinka and Pierre, 2019). However, organophosphates are also toxic to non-target organisms' humans. Acute exposure to OPs can result in symptoms such as dizziness, vomiting, respiratory depression, muscle twitching, and excessive secretions. Long-term exposure can lead to more severe health issues, including neuropathy, memory loss, anxiety, and personality changes (Adeyinka and Pierre, 2019)

2.2.2 Pyrethroid

Pyrethroids are synthetic chemicals that include compounds such as cypermethrin; these compounds are generally less toxic and pose lower risks to humans than other acaricides (Adeyinka and Pierre, 2019). Natural pyrethrin, derived from the flowers of Chrysanthemum (pyrethrum), has insecticidal and repellent properties but degrades quickly when exposed to sunlight. In contrast, synthetic pyrethroids have enhanced insecticidal activity and greater stability in the environment compared to natural pyrethrin (Adeyinka and Pierre, 2019).

2.2.3 Entry Pathways of acaricide into the milk

According to the research (Calahorrano-Moreno et al., 2022), we can determine that the entry pathways for acaricides are:

Direct Application:

Acaricides can be absorbed through the skin and transferred into the milk. Residues can be detected in milk within 24 hours of application.

Ingestion via Feed and Forage:

Chlorpyrifos, a pesticide widely used in crop protection, can be present in cattle feed and forage. The pesticide residues in these materials can be ingested by the animals and subsequently appear in their milk.

Environmental Contamination:

Like other organophosphates, chlorpyrifos can persist in the environment, especially in areas where animals are sprayed or dipped. This can lead to contamination of water and soil, which can result in indirect ingestion by livestock.

The presence of organophosphates and chlorpyrifos in milk, even at levels below the maximum residue limits, poses potential health risks to consumers. These compounds are associated with various health issues, including neurological disorders, endocrine disruption, and increased risk of certain cancers. The persistence of these chemicals in the environment and their ability to bioaccumulate in animal products emphasizes the need for stringent regulation and monitoring to protect consumers from potential harm.

2.3 Antibiotics

Antibiotics in dairy are used in three ways: for therapeutic purposes, Prophylactic purposes, and growth promoters. These drugs are commonly used as growth promoters for young ones and in the treatment of various diseases like mastitis, foot rot, and other bacterial infections. Antibiotics in the bodies of cows are eliminated through milk depending on the dose given and the route of drug administration. It also depends on the milk production level and the time difference between injection and milking (Calahorrano-Moreno et al., 2022).

Mastitis is one of the common diseases affecting milking cows. The common treatment for this disease involved a wide use of different classes of antibiotics like tetracyclines, beta-lactams, and oxytetracycline. According to other research, there is widespread use of penicillin and tetracycline in the treatment of mastitis, whose residues have been found in milk (Casseri et al., 2022).

Consuming antibiotic-contaminated milk is both a food safety issue and an emerging public health issue. To control antibiotic resistance in humans, it is important to avoid contamination in milk. (Casseri et al., 2022). The residues are also problematic in processing in the production of fermented dairy products, as antibiotics can hinder the growth of starter cultures, causing fermentation failure and product loss. Additionally, this failure can create conditions for the growth of pathogens like Staphylococcus and Salmonella, increasing the risk of disease outbreaks related to dairy products. (Casseri et al., 2022b)

Given that the use of antibiotics in cows causes residues in the milk, excessive use of these drugs should be avoided, and the withdrawal period should be respected (Calahorrano-Moreno et al., 2022).

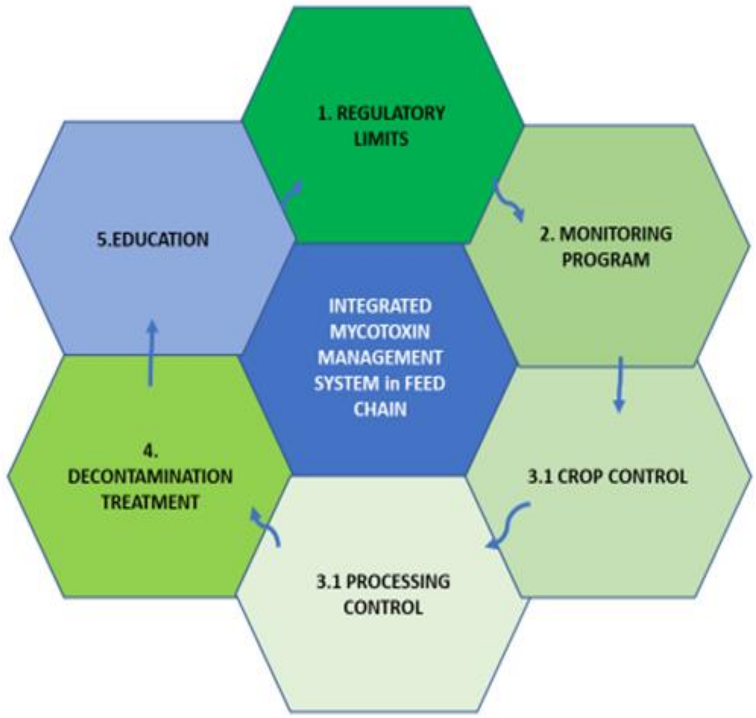
2.4 Aflatoxins

Aflatoxins are natural contaminants produced by species of the mold of genus *aspergillus,* the most common being Aflatoxin Molecule 1 (AFM1) in milk that comes as results of metabolism of aflatoxin B1 in the liver of animals. Aflatoxin was first reported in the 1960s, beginning the concern for this type of contaminant. Over the years, contamination of feeds with toxins has been reported, and this has cause contamination of milk consumed by humans. The main pathway of aflatoxin into the milk chain is through contaminated feeds. ingested by cows (Calahorrano-Moreno et al., 2022). The feeds are affected in all stages of the chain, either in the field during growth, post-harvest during storage, or during transportation.

Aflatoxin M1 in milk is stable and cannot be removed by industrial processes. Once the toxin is in the milk, it cannot be removed. This represents a wicked problem to deal with at the industrial level due to its stability to heat, physical and chemical treatments. Humans are exposed to these contaminants when they consume aflatoxin-contaminated milk, and as classified by the International Agency for Research on Cancer, the aflatoxin has been classified as a human carcinogen (Fumagalli et al., 2021).

To prevent the occurrence of aflatoxin, there exists an innovative integrated system for handling Aflatoxin in the feed chain, which is based on the synchronized use of prevention and control elements such as good agricultural practices, good manufacturing practices, good hygienic practices, quality control and hazard analysis and critical control point at all stages of production in the field to the consumer (Fumagalli et al., 2021). A report by Fumagalli et al. (2021) highlights the chain and on-farm practices that lead to animal contamination and, eventually, milk contamination with aflatoxin and the innovative strategies to prevent mycotoxin contamination. The integrated system is illustrated in figure 4 below.

Figure 3: Integrated system for management and control of aflatoxin in animal feeds



Source: Fumagalli et al (2021)

This integrated system involves setting regulatory limits, closely monitoring cultivation and production phases, and addressing any issues that may arise. It also emphasizes training all individuals involved in the feed chain to prevent and respond to anomalies effectively. This system aims to be proactive, planning how to handle potential contamination rather than reacting after the fact. A Hazard Analysis and Critical Control Points (HACCP) plan is in place to manage aflatoxin hazards in the feed chain. This plan outlines critical control points, hazards, control limits, preventive actions, monitoring strategies, corrective actions, records, and verifications for each step of the feed chain. These parameters are tailored to each operation and depend on the specific risks involved.

In Kenya, the regulations regarding aflatoxin limits in feed and milk are typically set by the Kenya Bureau of Standards (KEBS). KEBS establishes and enforces food safety standards in the country, including maximum allowable levels for aflatoxins in both feed and milk. For aflatoxin levels in feed, the maximum allowable limits are often expressed in parts per billion (ppb). The maximum allowable limit for aflatoxin B1 in complete feed for dairy cattle might be around 10 ppb. Similarly, for milk, the maximum allowable limits for aflatoxin M1, which is the metabolite of aflatoxin B1 excreted in milk by animals, are typically set in parts per trillion (ppt). The Codex Alimentarius Commission has set a maximum limit of 500 ppt for aflatoxin M1 in milk for human consumption.

2.5 Daily practices among dairy farmers in relation to the three contaminants

Antibiotics

Animal husbandry accounts for approximately two-thirds of the global consumption of antibiotics, and this is projected to increase. The use of antibiotics is common in dairy systems in Kenya. These systems are plagued with Mastitis, respiratory infections, and enteric diseases, and dry cow therapy is a predominant reason for antibiotic use (Muloi et al., 2023).

Most smallholder farmers cannot afford veterinary services, so they self-diagnose or rely on veterinary stores for consultation, diagnosis, and drug prescriptions (Muloi et al., 2023).

Adherence to the withdrawal period to ensure that milk from cows receiving antibiotics is safe for consumption is not commonly respected, potentially leading to the inclusion of milk with high antibiotic residues into the uncontaminated milk (Iraguha et al., 2024).

Aflatoxins

Farmers routinely use concentrate feed, typically mixing energy sources and oil by-products. Most feed is stored indoors (94%) in plastic bags, with quality checks largely relying on visual inspection. The duration of feed storage varies widely, sometimes up to six months. Preventive practices, like keeping feed on raised platforms to avoid contamination, are being adopted by farmers to keep aflatoxin in check (ILRI 2014).

According to research done by Blonk et al., 2017, Farmers experience moldy feeds. Farmers reported that they sun-dried these moldy feed ingredients and then fed them to animals. A few of the farmers reported that they picked and sorted the feeds to remove moldy ingredients. Others mixed spoiled grains with good grains to dilute and minimise the potential adverse health impact. This is a possible pathway of aflatoxin into the milk value chain as the moldy feeds contain aflatoxin.

Acaricides

Application of pesticides and acaricides is a common practice among dairy farmers. The chemicals are used according to the manufacturer's instructions and veterinary guidelines. (ILRI, 2014). According to farmers, they use individual acaricides or mix them for effectiveness against ticks.

2.6 The role of dairy processors and cooperatives in relation to contaminants

Dairy cooperatives enable farmers to produce high-quality milk and dairy products, which independent farmers often struggle to achieve due to poor milk handling techniques and outdated technology. Smallholders usually lack chilling or processing facilities due to extreme poverty, low assets, and lack of access to finance. Cooperatives provide these facilities, ensuring good product quality and safety by testing milk daily and training farmers in proper milk handling techniques.

Moreover, cooperatives conduct farmer-oriented research, expand dairy education and extension services, and enhance government involvement in integrated dairy development. They play a crucial role in providing a foundation for farmer service delivery and maintaining stable agricultural knowledge systems. In essence, cooperatives serve as a vital source of market information for dairy farmers. (Koyi, 2020)

2.7 Factors affecting farmers' capacity to adopt new approaches to addressing milk contamination.

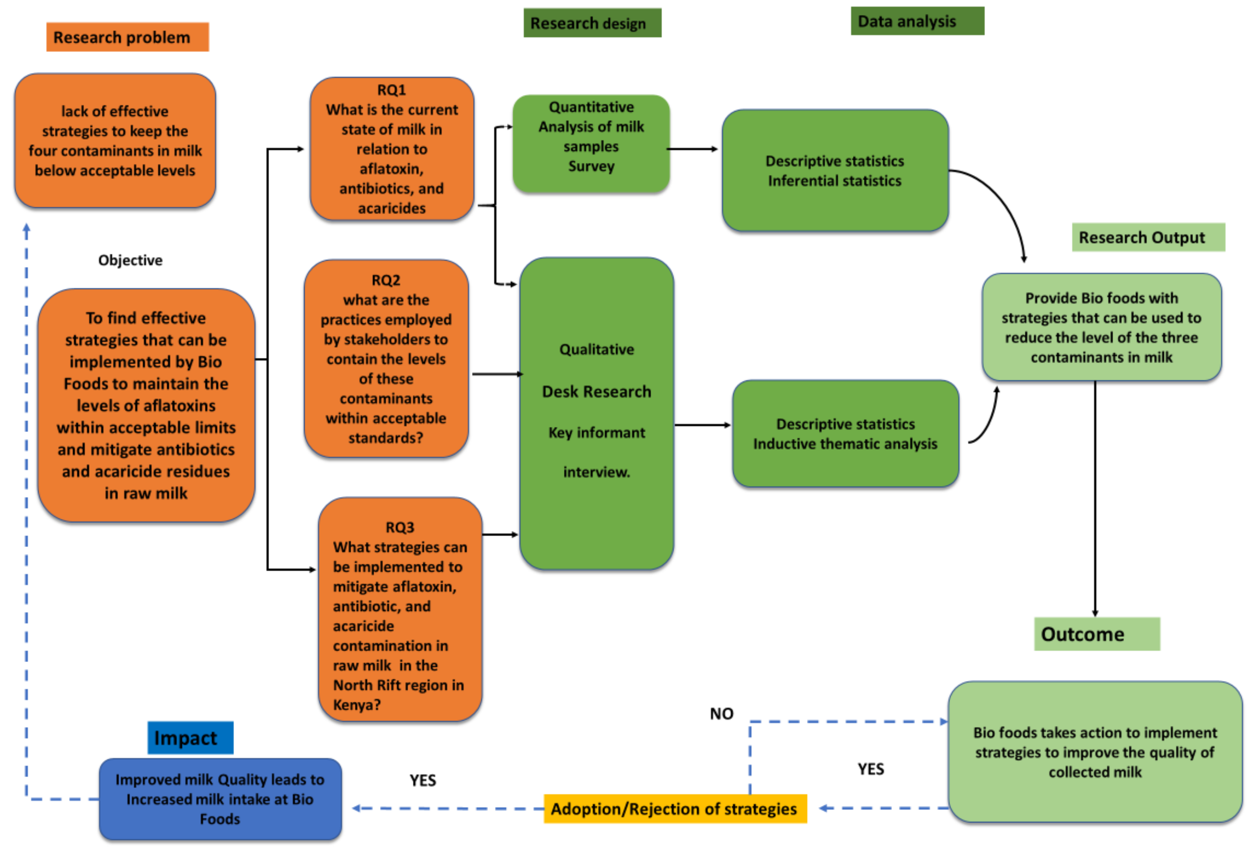
Several factors influence the adoption of new strategies to address milk contamination. Financial constraints are significant, as many farmers struggle to afford new technologies and practices. Market dynamics, such as inconsistent access and fluctuating prices, further complicate these financial challenges. Education and awareness are also critical; many farmers rely on traditional practices and lack information about modern methods. Initiatives by local cooperatives and NGOs improve these situations by offering training and affordable testing kits, which enhance farmers' capacity to manage milk quality. Government policies play a crucial role by providing subsidies and enforcing stricter quality standards, encouraging farmers to comply with better practices. Continuous technical support and training from extension services help farmers implement and sustain these new approaches. Improvements in infrastructure, such as better storage facilities and reliable transportation, are also vital (Zavala Nacul and Revoredo-Giha, 2022)

2.8 Bio Foods' capabilities in implementing interventions to address milk contamination

For Bio Foods to implement strategies effectively that target keeping milk contaminants within acceptable levels, it must carefully evaluate its capabilities across several critical dimensions, often summarized as the 5Cs (Ipat, 2015). First, Bio Foods needs to assess whether its staff possesses the necessary skills and expertise to monitor and control milk contaminants, ensuring that adequate training programs are in place and leveraging past experiences in food safety. Next, the availability of resources, including financial, human, and material, along with the sufficiency of its infrastructure and the time allocated for planning and execution, must be evaluated to determine the overall capacity for stringent quality control measures. Understanding the context in which the strategy will be implemented is crucial, as external environmental factors, legal and regulatory frameworks, and alignment with consumer safety needs can significantly impact success. Collaboration is another vital area, requiring robust stakeholder engagement with suppliers, regulatory bodies, and industry partners, along with strong partnerships and effective communication channels to foster cooperation among all parties involved. By thoroughly assessing these factors, Bio Foods can better position itself to implement strategies that effectively maintain milk contaminant levels within acceptable standards.

2.9 Conceptual Framework

Figure 4: Diagram showing a conceptual framework



Source: APCM student (2024)

To understand the concept of milk contamination in the study area, this research investigated the problem from different dimensions, as indicated in Figure 4 above. The research aimed at understanding the occurrence and level of different contaminants in milk. In addition, this study sought to investigate policies and enforcement mechanisms already in place to address the issue of milk contamination within the study area. As a holistic approach to designing effective strategies to maintain contaminant levels within acceptable limits, the study reviewed farmers' capacity to adopt new approaches to mitigating milk contamination. It also reviewed Bio Foods' capability to implement interventions toward ensuring high-quality milk with reduced contaminants. The research employed a mixed study design approach, combining both qualitative and quantitative aspects. The quantitative aspects, mainly based on a survey and chemical analysis of milk and feed samples, were analysed using descriptive and inferential statistics. The qualitative was analysed through inductive thematic analysis and descriptive statistics. The results from this research helped in formulating practical strategies that could be used to lower the levels of contaminants to within acceptable standards. It is believed that should Bio Foods implement these strategies, the quality of milk will be improved, and this will enable them to increase their milk intake.

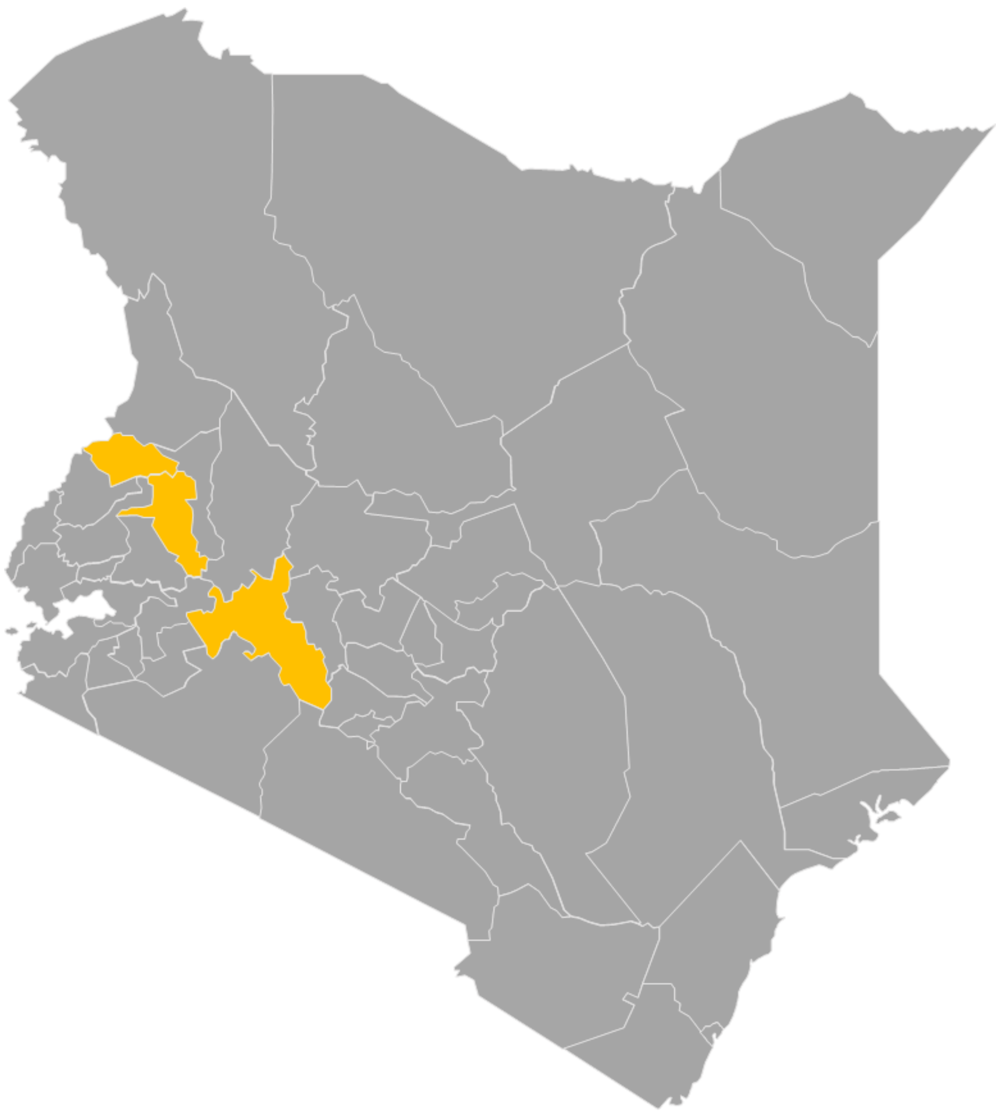
CHAPTER THREE

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Geographical Location

This study was conducted in the North Rift region of Kenya, focusing on three counties: Uasin-Gishu (3,327 km2), Trans Nzoia (2,496 km2), and Nakuru (2,884 km2). These counties were selected because they have the highest potential and presence of dairy (Blonk et al., 2017). They are also the main region where Bio Foods farmers are concentrated, which is also considered a great milk catchment area where Bio Foods will explore to expand its milk intake. Figure 5 below shows the three counties where this study will be conducted.

Figure 5: Map of Kenya showing the study area.



Source: mapaction.org

3.2 Research Strategy

The research used a mixed-method approach, using qualitative and quantitative techniques. Survey was carried out for the quantitative aspect. Additionally, chemical analysis was done to analyse milk samples for contaminants. Animal feed samples were also collected for analysis of aflatoxin. The results from the two groups, Bio Foods suppliers and non- Bio Foods suppliers, were compared to determine the difference in quality. This method was chosen because it provided a comprehensive understanding of the milk contamination, combining numerical data with real on-farm practice data. Key informants from cooperatives, Bio Foods, and Kenya Dairy Board were interviewed for the qualitative part. This method was chosen because it helps gather detailed insights into the informants' views regarding contaminants and their impact. The research compared the quality of milk between Bio food suppliers in the formal marketing channel and Non-Bio food suppliers in the informal channel in relation to the contaminants and developed working strategies for the non- Bio Foods suppliers to enable them to conform to the quality requirement of Bio Foods products, hence cross over from the informal to the formal channel.

3.3 Data Collection and Sampling.

Desk Research.

The research involved a literature review using resources available on Google Scholar and Greeni and reports specifically focusing on milk contamination with the three identified contaminants.

3.3.1 Survey and Key Informant Interviews

Survey

The study included a survey of Bio Foods milk suppliers, non- Bio Foods suppliers, cooperatives supplying Bio Foods, and non-supplying cooperatives. As a selection criterion, the farms were expected to produce 300 litres of milk per day and have cooling facilities. Table 2 below provides a detailed breakdown of the number of farms in the survey. The survey used a semi-structured questionnaire to explore farm-level practices contributing to contamination and the routes through which contaminants enter the milk.

Table 2: A table showing a breakdown of Survey respondents

Groups surveyed	Number of farms
Bio Foods Suppliers	8
No- Bio Foods suppliers	8
Dairy Cooperatives Supplying Bio Foods	1
Cooperatives Not supplying Bio Foods	2

Source: APCM student (2024)

Key Informant Interviews

Various key informants were interviewed for the study. Representatives from cooperatives were interviewed to explore the cooperatives' involvement and role in dealing with the contaminants. Bio Foods representatives were also interviewed regarding their roles and capabilities in implementing strategies to reduce contaminants in milk. After the interviews, Bio Foods team participated in evaluating the company by filling up a 5cs framework. Representatives from the Kenya Dairy Board were also interviewed to assess the effectiveness of current policies concerning milk contaminants. These interviews aimed at gathering diverse perspectives and insights relevant to this research topic. Table 3 below shows a breakdown of the number of respondents.

Table 3: A table showing the respondents for key informant interview

Respondents	Number of respondents
Dairy Cooperatives Supplying Bio Foods	2
Cooperatives Not supplying Bio Foods	2
Kenya Dairy Board	1
Kenya Bureau of Standards	1
Bio Foods	3

Source: APCM student (2024)

3.3.2 collection of feed and milk samples

Feed samples.

Representative samples of feeds (dairy meal) fed to the cows during the survey were collected to analyse aflatoxin B1. The feed samples were kept dry in containers to ensure they were not exposed to moisture. This ensured that the feed quality was maintained from collection to the point of testing.

Table 4: A table showing number of samples for aflatoxin B1 analysis

Milk Supplier	Total number of Suppliers	Total number of samples per farm	Total Samples
Bio Foods suppliers	8	1	8
Non- Bio Foods suppliers	8	1	8
Coop supplying Bio Foods	1	1	1
Coops not supplying Bio Foods	2	1	2
	19		19

Source: APCM student (2024)

Milk Samples

Milk samples were collected from milk tanks after agitation to ensure they accurately represent the entire batch of milk. The milk was collected and transported using sterile sampling bottles in an iced cooler box to maintain the cold chain. Following this, each sample was divided into half; the first half s underwent testing for the two contaminants (antibiotics and aflatoxins) at the Bio Foods laboratory in Eldoret. The remaining part of the samples was frozen for acaricide analysis. At least four samples were collected per farm, each sample in a week. This was to accommodate changes that might have happened at the farm due to changes in feeds or management practices. Acaricides were tested at Egerton University Animal Science Laboratory. Testing for acaricides was done at Egerton because the Bio Foods laboratory in Eldoret did not have the capacity to test for acaricides. The approximate collection time to delivery time at Bio Foods was 6 hours. Samples taken to Egerton Laboratory for chemical analysis were frozen and transported in an iced cooler Box. The table below shows the milk sample size.

Table 5: Table showing the milk sample sizes.

Milk Supplier	Total number of suppliers	Total number of samples per farm	Total samples
Bio Foods Suppliers	8	4	32
Non- Bio Foods suppliers	8	4	32
Bio Foods supplying cooperative	1	4	4
Non- Bio Foods supplying cooperative	2	4	8
	19	4	76

Source: APCM student (2024)

3.4 Data Analysis.

3.4.1 Survey and Key Informant Analyses

Inductive thematic analysis was used to study the qualitative data from the surveys and key informant interviews. This process involved familiarising with the data by reading transcripts and survey responses and coding relevant data related to the research questions and contamination issues. Codes were then grouped into broader themes that captured essential patterns and insights regarding farm-level practices, the role of cooperatives, Bio Foods' strategies, and the effectiveness of current policies by the Kenya Dairy Board. These themes were reviewed to ensure they accurately reflected the data, were distinct from one another, and were then clearly defined and named. The last involved making a summary of the findings.

3.4.2 Chemical analysis of milk and feed samples

Milk and feed samples analysis

Table 6: A table showing the breakdown of the chemical analysis of the milk samples.

ANALYSIS	Samples from Bio Foods suppliers (n=8)	Samples from Non - Bio Foods suppliers (n=8)	Samples from Bio Foods cooperative (n=1)	Samples from Non-Bio Foods Cooperative (n=2)	Total Tests
Antibiotics	32	32	4	8	76
Aflatoxin m1	32	32	4	8	76
Acaricides(organophosphates)	8	8	1	2	19
Acaricide (cypermethrin)	8	8	1	2	19
Aflatoxin B1 in feeds	8	8	1	2	19

Source: APCM student (2024)

Each milk sample was subjected to four chemical analyses, Antibiotics, aflatoxin and acaricides, which were of two classes: Organophosphate and cypermethrin, to determine the individual contaminants. The feed samples were analysed for Aflatoxin B1. Table 6 above summarises all the analyses of the milk samples.

Antibiotics tests

Antibiotics were tested with the Delvo test kits. This was done as an initial test to determine the presence of antibiotics in milk. Milk that tested positive was further tested for specific antibiotics (B-Lactams & Sulfonamides & Tetracyclines Triple Dipsticks) using rapid test strips. The test procedures for both delvo test and specific antibiotics are illustrated in Annex 1a.

Aflatoxin test in milk

Aflatoxin M1 was tested in milk. This is the aflatoxin resulting from the metabolism of aflatoxin B1 in feeds. Aflatoxin M1 in milk was tested using the ELISA Machine. Conditions and procedures for the tests are illustrated in Annex 1b.

Acaricides

Both organophosphates and cypermethrin acaricides in the milk samples were tested using the spectrophotometry method. The procedures are illustrated in Annex 1c.

Aflatoxin test in feeds

Aflatoxin B1 was tested in the feed samples. Aflatoxin B1 is the most common mycotoxin in animal feeds. This is the toxin that is metabolised into aflatoxin M1 in milk. This was tested using the Elisa method. The procedure for the analysis is elaborated in Annex 1d.

Statistics of samples

After the analyses, descriptive statistics, including mean, and standard deviation, were computed for the presence and levels of the three contaminants: antibiotics, aflatoxin, and acaricides. Mean was also computed for the scores on the 5cs framework. The main focus of the analysis was a comparative study between two groups, Bio food suppliers and non-Bio food suppliers, including data from both farmers and cooperatives. This was statistically computed using the independent sample t-test.

3.5: Ethical consideration

Informed consent was obtained from all the respondents and key informants before data collection, ensuring voluntary participation. This involved informing the respondents of the purpose of the research and the findings being used for the study. Research activities adhered to ethical guidelines and protocols established by the Kenyan National Commission for Science, Technology and Innovation, which issued a research permit for this specific research.

CHAPTER FOUR

CHAPTER FOUR: RESULTS

4.1 The levels of three contaminants in raw milk

Table 7: A table showing the levels of the three contaminants in milk

Contaminants	Bio Food suppliers (N=8 farmers)	Non-Bio Food suppliers (N=8 farmers)	Average	Bio Food supplying coop(n=1)	Non- Bio Foods Supplying coop (=2)	average
Aflatoxins in milk (ppt)	116.49 [a] ± 102.37	326 [b] ± 224	221±163.19	360	164 ± 92.9	262 ±46.5
Acaricide (Cypermethrin ug/kg)	85.75 ±5 0.39	104.73 ± 43.12	95.24±43.51	34.75	83.01 ±46.4	58.88±23.2
Acaricide (Organophosphate ug/kg)	14.68[a] ± 27.2	0.0[b]	7.34 ±13.6	42.15	62.14 ± 36	52.15±18
Antibiotics	0.0[a] ±0	1.25[b] ± 0.7	0.675±0.35	0	0	

[a b] different superscript indicates a significant difference at $P<0.05$

Source: APCM student (2024)

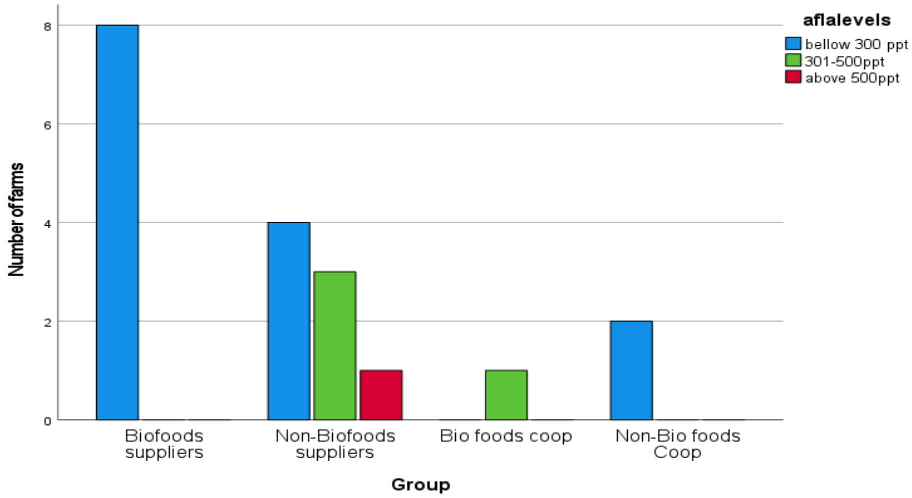
4.1.1) Aflatoxin.

At-test analysis revealed a significant difference in the average aflatoxin levels between milk samples from Bio Foods and Non- Bio Foods farmers, with a significance level of $p < 0.05$. This indicates that Bio Foods farmers had distinct aflatoxin levels with a mean average of 116ppt compared to Non- Bio Foods farmers with a higher mean of 326ppt. However, the aflatoxin level in Bio Foods supplying cooperatives was high at 360ppt compared to the Non- Bio Foods supplying cooperatives, averaging at 164ppt. The information is summarized in table 7 above.

Further analysis of aflatoxin concentrations revealed that 8 Bio Foods farms and 3 Non- Bio Foods farms recorded levels below 300 ppt, considered safe. In contrast, 5 farms not supplying Bio Foods showed aflatoxin concentrations between 301-500 ppt, a range considered critical and warranting corrective measures. This is because the cumulative effects can easily increase the levels. Notably, one Non- Bio Foods farm had aflatoxin levels of 632, which is above the acceptable threshold of 500 ppt in milk, leading to the rejection of the sample.

All the non- Bio Foods-supplying cooperatives recorded low aflatoxin levels, and all were below 300 ppt. In comparison, the Bio Foods-supplying cooperative had aflatoxin levels within the critical range of 300-500 ppt, necessitating further attention and potential corrective action. Figure 6 below provides a visual representation of these findings.

Figure 6: A figure showing aflatoxin concentration of Bi Foods and Non - Bio Foods suppliers.



Source: APCM student (2024)

A comparison was made between Bio Foods suppliers, non- Bio Foods suppliers, and cooperatives regarding aflatoxin levels.

The results showed that Bio Foods suppliers had low aflatoxin levels, ranging from zero to 250 ppt. In contrast, non- Bio Foods suppliers had higher aflatoxin levels, ranging from 0 to 632 ppt. Samples from Bio Foods supplying cooperative had higher aflatoxin levels at 360 ppt, while the non-supplying cooperatives had average levels of 98 ppt and 229 ppt, respectively. These results are shown in table 8 below.

Table 8: A table showing comparison in aflatoxin levels between Bio Foods and Non- Bio Foods suppliers

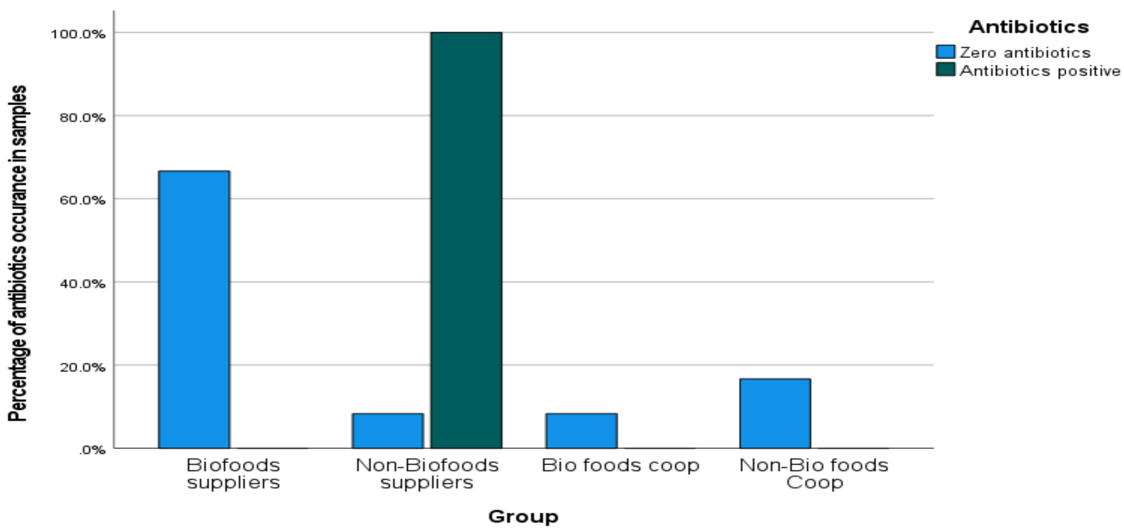
Aflatoxin levels in ppt	Bio Foods farms (n=8)	Non- Bio Foods farms(n=8)	Bio Foods Coop(n=1)	Non- Bio Food Coop(n=2)
Below 300ppt	0 3.3 11 96 160 206 238 218	0 54 176		98 229
300-500		378 416 478 486	360	
Above 500		632		

Source: APCM Student (2024)

4.1.2 Antibiotics.

The t-test results showed a significant difference in antibiotic residues between milk samples from Bio Foods and Non- Bio Foods farmers, with a significance level of $p<0.05$. This means there was a noticeable difference in antibiotic levels between these two groups, with all the antibiotic-positive samples being from the non- Bio Foods supplying farms. No milk from both cooperatives tested positive for antibiotics. Figure 7 below visually represents the presence of antibiotics in the samples collected.

Figure 7: A figure showing the presence of antibiotic residues in samples from Bio Foods suppliers and Non- Bio Foods suppliers



Source : APCM Student (2024).

Further testing of specific antibiotics revealed that these contaminated samples contained specific antibiotics : Betalactams, sulfonamides and tetracycline. Table 9 below shows the antibiotics detected.

Table 9: A table showing the specific antibiotics in milk samples

Sample	Type of antibiotics detected.
1	Sulfonamide& Tetracycline
2	Betalactams
3	Sulfonamide & Tetracycline
4	Tetracycline &Betalactams
5	Betalactams& tetracycline
6	Betalactams
7	Betalactams
8	Betalactams & tetracycline
9	Betalactams and tetracycline
10	Tetracycline

Source : APCM Student 2024

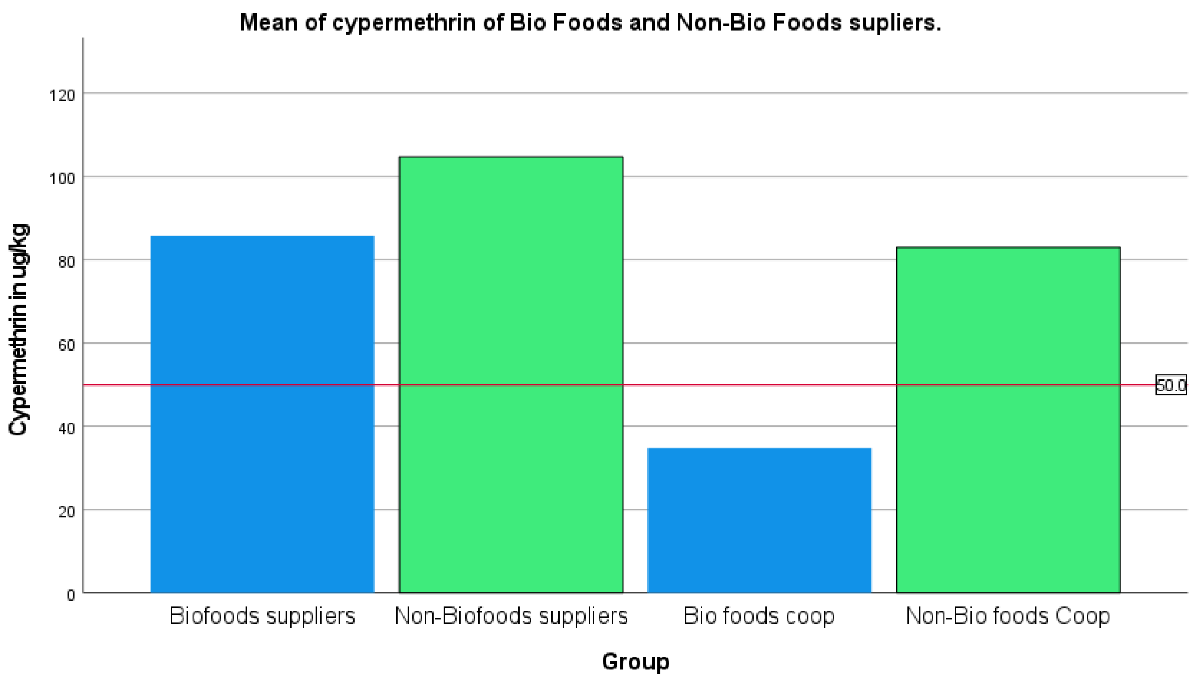
4.1.3 Acaricides

a) Cypermethrin

All the samples collected and tested for cypermethrin were found to be positive. The t-test results showed a significance value of p>0.05, indicating no significant difference in cypermethrin levels between samples from Bio Foods-supplying farms, Non- Bio Foods-supplying farms, and both types of cooperatives. Figure 8 below shows the summary of this information

The maximum cypermethrin residue limit (MRL) is 50 µg/kg. The results revealed that 84% of the samples had cypermethrin levels exceeding this limit, highlighting a widespread use across the tested farms.

Figure 8: A bar showing the mean of cypermethrin of Bio Foods and Non- Bio foods suppliers

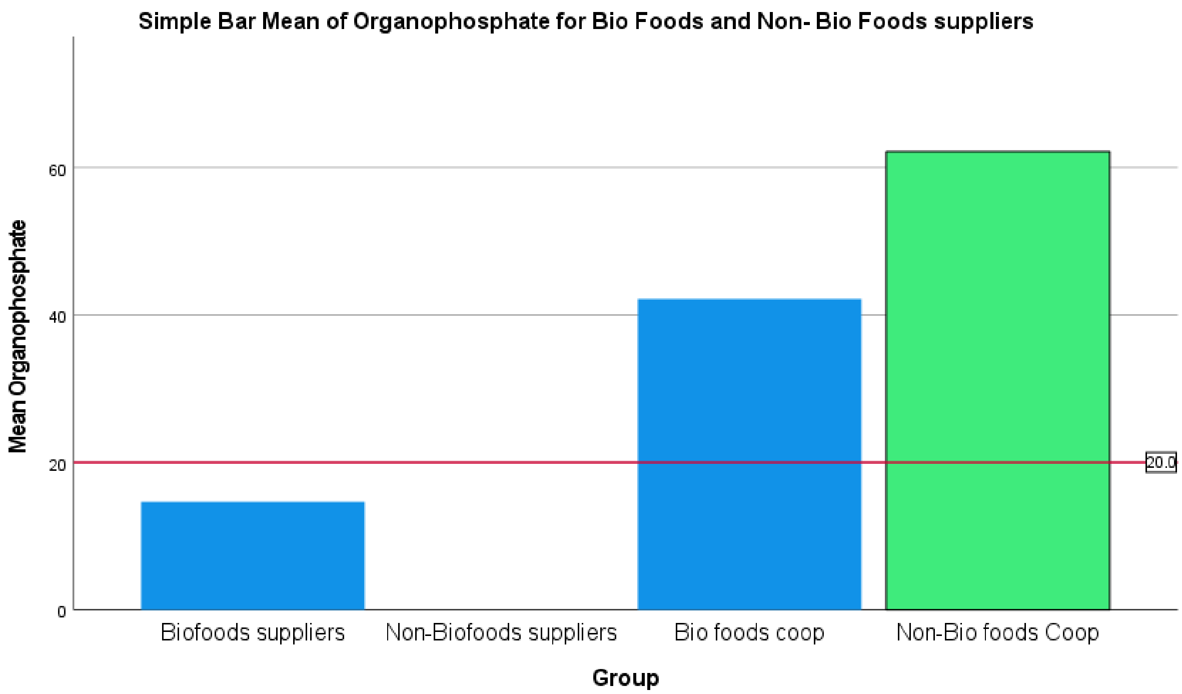


Source: APCM Student (2024)

b) Organophosphates (Chlorpyriphos).

Nineteen samples were tested for organophosphates, with 26% of them testing positive for this acaricide. Notably, all the positive samples exceeded the maximum residue limit of 20 µg/kg. The t-test results showed a significance level of $p<0.5$,indicating a significant difference in organophosphate levels between Bio Foods supplying farms and Non- Bio Foods supplying farms. The mean average for the Bio Foods supplying farms was high at 14.68 ug/kg compared to 0.0 ug/kg for non- Bio Foods supplying farms. However, there was no significant difference in organophosphate levels between Bio Foods supplying cooperative and Non- Bio Foods supplying cooperatives. The bar chart below illustrates the organophosphate levels across the different groups.

Figure 9: Presence and Levels of Organophosphates (Chlorpyriphos) in milk from different groups



Source: APCM Student (2024)

4.2 Primary sources of contaminants.

4.2.1 Primary sources of aflatoxins.

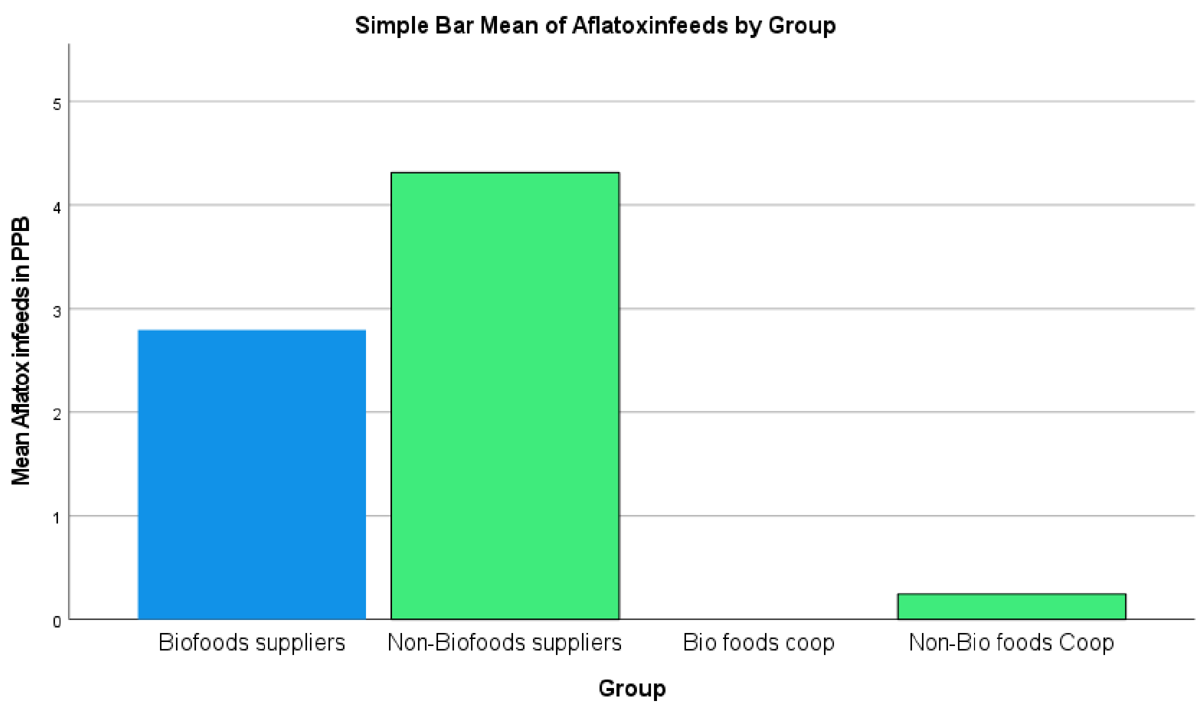
The results revealed that 13 out of 19 samples had aflatoxin B1. A t-test with a p-value of $P>0.05$ indicated that there was no significant difference between the levels of aflatoxin B1 in the samples from the Bio Foods-supplying farms and samples from Non- Bio Foods-supplying farms. The information is summarised in Table 9 below.

Table 10: A table showing a comparison of afltoxinB1 levels between Bio Foods suppliers on Non-Bio Foods suppliers

Contaminants	Bio Food suppliers (N=8 farmers)	Non-Bio Food suppliers (N=8 farmers)	Average	Bio Food supplying coop(n=1)	Non- Bio Foods Supplying coop (=2)	average
Aflatoxins in Feeds (ppb)	2.8 ±2.8	4.32 ± 3.36		0.0	0.25	0

Sixty-eight per cent of feed samples had aflatoxins, and 32% were considered aflatoxin-free, including feed samples from Bio Foods supplying cooperative. This is because aflatoxins in these feed samples were below the detection limits. Figure 9 below visually represents the means of aflatoxin B1 for farmers supplying Bio Foods and Non-supliers.

Figure 10: A figure showing the mean of aflatoxin B1 per group of suppliers



Source: APCM student (2024)

Eighty-eight per cent of the farmers were aware of potential aflatoxin sources, recognising that it could come from grains in ready-mixed concentrates, feed ingredients like maize germ, and by-products of oil seeds. They were also aware that it could result from poor storage in maize silage and, generally, improper feed storage, which could expose feeds to moisture.

Eight one percent of the farmers interviewed used 80% of homegrown feeds, which include fodder such as maize silage, Rhodes grass made into hay, and fresh grass. They purchased 20% of their feed, consisting of concentrates or ingredients for making concentrates. 6% of farmers buy 80% of their feeds, usually due to limited land. 13 % of farmers grow all their own feed.

Eighty-eight per cent of the farmers buy concentrates from reputable suppliers with branded feeds, while another 38% purchase raw materials and mix their own feed. Twenty-five per cent of farmers buy readily available feed from the market, considering proximity and distance from the market to their farms. 12% of farmers receive a certificate of analysis with their feed purchases.

Once the feed arrived at the farms, 88% stored it in well-ventilated, leak-proof storage areas, while 12% mixed the dairy meal and kept it nearby in the barn for feeding. 81% stored feed on pallets, 10% kept it on the floor, and 2% stored it in silos. Half of the farmers had experienced moldy feed, 38% had rarely encountered it, and 13% never had mold issues.

Thirteen per cent of the farmers test every batch of feed for aflatoxins, 6% test each ingredient when mixing dairy meal, and 63% never test their feed for aflatoxins—16% tested their feeds monthly, and 13% test annually.

4.2.2 Primary Sources of Antibiotics

Results showed that all the farmers used antibiotics to treat dairy cows. Tests conducted for specific antibiotics showed that some samples had more than one antibiotic, indicating an off-label use of antibiotics. It was noted that farmers used antibiotics from the penicillin, beta-lactam, and tetracycline classes, with withdrawal periods ranging between 72 to 96 hours for a single injection. 59% of the farm treatments were administered by outsourced veterinary personnel, farm managers did 16%, and 31% were done by resident veterinary staff. Farmers implemented various practices to prevent milk containing antibiotics from mixing with antibiotic-free milk. For instance, 31% of the farmers ensured that cows treated with antibiotics were milked last.21 % of farmers used different portable milking buckets for the antibiotic-treated animals. In contrast, other farmers used distinctive colors on the animals for easy identification and had the names written on the board at the milking parlor.

4.2.3 Primary sources of Acaricides

The findings revealed that 94% of the farmers used acaricides to control ticks, they applied them either by spraying or dipping weekly or biweekly. Among them, 44% used amitraz-based acaricides, 31% used organophosphates, and 19% used cypermethrin-based products. Farmers applied the treatments early in the morning after milking to prevent milk contamination with acaricides. This ensured at least an 8-hour gap between dipping and milking. They also cleaned the udder thoroughly before milking and tested the dip solution to confirm the concentration.

4.3 Daily practices among dairy farmers in relation to the three contaminants.

Table 10 below shows practices by farmers to keep the levels of contaminants in milk within acceptable limits.

Table 11: Table showing Bio Foods farmers' practices in relation to contaminants

Practices by Bio Foods farmers		
Practices about aflatoxin	**Practices about antibiotics**	**Practices about acaricides**
Farmers fed animals on concentrates that were outsourced. Farmers sourced the concentrate from reputable suppliers. Farmers observed aflatoxin trends from the milk analysis report and made informed decisions when purchasing new consignment of feeds. Framers practice Proper storage of feeds in leak-proof, well-ventilated stores. Farmers keep the feed off the ground on pallets. Farmers follow first in, first out to allow feeds to stay for a short time in stores. Farmers harvest maize at the right stage and properly compact and cover well during the ensiling process.	Farmers treated animals using antibiotics. Treatments were done by either the resident Vet or the outsourced vet. Farmers kept records of the treated cows and used them for withdrawal periods and tracking treatment. Treated cows were milked in a different portable bucket milking machine, and animals were separated from the milking herd. Farmers used distinctive colours on the treated cows for easy identification. These included coloured tapes on the tail and coloured sprays. Farmers had a board at the parlor with the identification of treated cows.	Farmers sprayed the animals with acaricides to control ticks. Farmers sprayed/dipped the animals weekly or biweekly using the acaricides. Spraying/ Dipping was done early to have a difference of 8 hrs. before milking. Farmers made the spraying area far from the milking area. Farmers ensured proper cleaning of the udder before milking. Farmers ensured accurate dosing of the acaricides as instructed by the manufacturer. Farmers sampled the deep solution for concentration analysis to avoid overdosing.

Source: APCM Student(2024)

Figure 11: Pictures showing feeds kept on pallets in a feed store

Table 12: A table showing Non- Bio Foods farmers' practices in relation to contaminants

Practices by Non-Bio Foods farmers		
Practices about aflatoxin	**Practices about Antibiotics**	**Practices about acaricides**
Farmers fed animals concentrates that were outsourced, either readily mixed or ingredients for mixing the concentrates. Farmers sourced the concentrate depending on the availability and proximity of the farms to the source of these concentrates. Farmers did not get a certificate of analysis along with the feeds during procurement. Farmers harvest maize at the right stage and properly compact and cover well during the ensiling process. Some farmers kept feed off the ground on pallets, while others stored it on the ground.	Farmers treated animals using antibiotics. Treatments were done by the resident Vet, Outsourced vet, or farm manager. Farmers kept treatment records but for culling purposes. Treated cows were milked last.	Farmers sprayed the animals with acaricides to control ticks. Farmers sprayed/dipped the animals weekly or Biweekly using the acaricides. Spraying/ Dipping was done early to have a difference of 5 hours before milking. Farmers ensured Accurate dosing of the acaricides as instructed by the manufacturer. Farmers made the spraying area far from the milking area.

Source: APCM Student (2024)

Figure 12: Pictures showing feeds on the floor

Source: APCM student (2024)

The findings showed that 75% of the farmers had received training on milk contaminants, primarily through Bio Foods' annual "Farming the Bio Way" program. Farmers who had attended these trainings reported that they were highly effective and informative, helping them maintain high-quality standards, as reflected in the milk summary reports provided by Bio Foods. All farmers expressed interest in participating in more training sessions in the future to improve milk quality further.

4.4 Role of dairy processors and cooperatives in relation to the Three contaminants.

The findings revealed that 81% of the farmers supply milk directly to processors, including Bio Foods, Brookside Dairies, and KCC. Bio Foods is the only processor that closely monitors contaminants, while other processors mainly focus on the volume of milk received.

Roles of Cooperatives and Processors

Setting Quality Standards:

Cooperatives and processors established quality standards for farmers based on Kenya Dairy Board and KEBS regulations. These standards emphasized zero antibiotic tolerance and acceptable aflatoxin levels of up to 500 parts per trillion (ppt).

Creating Communication Channels:

Cooperatives used multiple communication methods, such as SMS, WhatsApp, farmer meetings, AGMs, and zone representatives, to inform farmers about quality standards and expectations. Farmers were also well-informed during their onboarding process. Extension and veterinary officers visited farms to ensure compliance further.

Offering Support and Training:
Cooperatives provided training, capacity building, and sensitization programs to help farmers meet quality standards. They also tested milk for contaminants like antibiotics and offered financial assistance. To motivate farmers, cooperatives gave bonuses for meeting specific quality criteria.

Collaboration with Processors:
Cooperatives facilitated clear communication between farmers and processors to ensure both quality and quantity requirements were met according to their agreements.

Creating Feedback Mechanisms:
Farmers and cooperatives received daily feedback from processors regarding milk deliveries, covering both the volume and quality of milk. Any quality concerns were directly communicated and addressed by the cooperative.

Issue Resolution and Traceability:
When contamination occurred, cooperatives and processors conducted root cause analyses to trace the problem to either the cooperative, the processor, or individual farmers. Farmers found responsible for contamination faced penalties, and extension officers followed up to address the issue.

4.5 Factors affecting farmers' capacity to adopt new approaches to address milk contamination.

The research identified that farmers' capacity to adopt new strategies was significantly influenced by their access to necessary resources. While farmers generally had access to financial resources, they expressed a need for additional support in the form of training and coaching for their farm workers. The willingness of farmers to adopt new strategies depended on several key factors listed below:

Affordability: Farmers were ready to implement strategies that were financially feasible for them.

Applicability: Strategies that could be easily integrated into their existing farm operations without requiring substantial new investments were more appealing to the farmers.

Reliability: Farmers preferred strategies that had a proven track record of effectiveness.

Training and Support: If adequate training was provided during the introduction phase, farmers were interested in adopting the new strategies.

Workforce Capability: The ability of the current workforce to effectively implement the new strategies was crucial for farmers

Freedom: Farmers showed that they valued the freedom to choose strategies that align with their personal preferences and farm management practices.

4.6 Bio Foods' capabilities in implementing interventions to address milk contamination with the Three contaminants.

An analysis of Organizational Capabilities was carried out. The table below shows Bio Foods' 5 Core Capabilities based on three observations.

Table 13: A table showing the core capabilities of Bio Foods

5 Core Capabilities	Score 1-4	Interpretation
Capability to act and commit	3.7	Strong capacity
Capability to build on development objectives	3.4	Strong capacity
Capability to adapt and self renew	3.3	Strong capacity
Capability to relate to external Stakeholders	3.6	Strong capacity
Capability to Achieve coherence	3.6	Strong capacity
Scale 1-4:1=very weak capacity,2=weak capacity,3=strong capacity,4=Very strong Capacity		

Capability to act and commit

The company demonstrated the commendable ability to act and commit through effective strategic planning aligned with its mission, inclusive staff engagement, and a proficient leadership team. Employee retention efforts were robust, fostering a positive work culture.

Capability to build on development objectives

The company had the capability to achieve and advance its objectives, driven by a highly skilled workforce emphasizing gender balance. Providing sufficient infrastructure aligned with the mission, facilitating the realization of the company's goals, and a well-established information system supported effective decision-making. Although some employees were on contract terms, the company's strength lied in its good workforce, adequate infrastructure, and reliable information systems, which provided a solid foundation to build upon and further enhance its ability to meet objectives efficiently.

Capability to adapt and renew

The company demonstrated a strong capability to adapt and renew itself in response to market changes, facilitated by regular monitoring and evaluation processes that inform strategic actions. Staff involvement in decision-making contributed to a sense of belonging, fostering a culture of adaptability. The significant investment in new technologies for both processing and sales positioned the company at the forefront of innovation and helped build a distinctive brand. Moreover, the company's proactive approach to seizing opportunities in a dynamic context underscored its ability to navigate change effectively, showcasing a robust capability to adapt, renew, and stay competitive.

Capability to relate to external stakeholders

The company exhibited a strong capability in relating to external stakeholders, concentrating its engagement primarily on farmers and consumers and having a comprehensive connection with various actors along the value chain. The company had established contacts with the government and works hand in hand in project implementation. Strong horizontal linkages enabled it to build extensive external connections.

Capability to achieve coherence

The company demonstrated a robust capability to achieve coherence, supported by a well-defined strategic plan and clear operational work plan. The strength of the leadership team lied in their dedicated focus on strategic plans and goals, providing a solid foundation for organizational alignment. This clarity extended to the well-informed staff members about their roles and responsibilities, contributing to a cohesive and goal-oriented work environment.

Organization analysis on a sustainability lens

Bio Foods' sustainability efforts extended across environmental stewardship, ethical sourcing, employee welfare, and energy efficiency, showcasing a comprehensive commitment to responsible business practices. On 31 May 2023, the company was B-cop certified. This means the company had met verified social and environmental performance standards, public transparency, and legal accountability.

Listed below are different dimensions of sustainability at Bio food products:

Environmental Initiatives:

- Reduced plastic usage in milk bottles by 25%, making them semitransparent for increased recyclability.
- Manufactured 100% of yoghurt cups from repurposed plastic.
- Introduced biodegradable and compostable cheese packaging.
- Created a two-litre milk bottle, reducing the need for multiple one-litre bottles.

Support for Suppliers:

The company actively engaged with supplier farms to improve environmental impact and welfare standards.

The company actively employed a full-time Dairy Management team to support farmers regarding feed composition and animal welfare, promoting high yields and well-being.

The company audited the supplying farmers annually to ensure they complied with the set standards.

Milk Safety Measures:

- Adhered to a zero-tolerance policy for antibiotic traces.
- Enforced stringent rules on aflatoxin levels in milk to ensure compliance with WHO standards.
- Offered incentives to farmers based on milk quality, promoting cleaner and healthier farming practices

Role of Bio Foods in Dairy Development-Capabilities to implement strategies

The findings indicated that Bio Foods had rigorous testing protocols to detect contaminants such as aflatoxins and antibiotics in raw milk. All milk received by Bio Foods underwent testing. When milk was delivered, only milk that met the required quality standards was approved for processing. Suppose a milk delivery failed to meet the standards, the farmer was immediately informed through a WhatsApp group, followed by a phone call, and a dairy development personnel visited the farm to address the issue.

To prevent contamination, dairy farmers in Bio Foods' supply chain followed strict daily practices. For antibiotics, any treated animal was separated from the milking herd, and its milk was tested after the withdrawal period. The animal was only reintegrated into the herd once its milk tested negative for antibiotics. Regarding aflatoxins, farmers were advised to purchase feeds exclusively from reputable suppliers and got a certificate of analysis indicating the acceptable level of aflatoxins. The dairy development team monitored aflatoxin levels, and when there was a spike, the farmer was promptly notified, and immediate action was taken to mitigate the contamination risk.

Bio Foods had also implemented specific interventions to address contamination from aflatoxins, antibiotics, and acaricides. Farmers were penalised when contaminant levels exceeded acceptable limits, while they were motivated through bonuses when they met quality standards. To support these interventions, Bio Foods provided regular training to farmers. The company's dairy development team conducted farm visits, follow-ups, and audits to ensure that farmers comply with quality standards and that contamination control measures were effectively implemented.

Bio Foods collaborated with dairy cooperatives, processors, and other stakeholders, including the Ministry of Agriculture, to enhance contamination control measures. This collaboration focused on offering farmers training on maintaining milk quality, particularly in relation to contaminants. However, the company faced challenges in ensuring consistent contamination control. This was because competitor processors do not test for these contaminants. Milk rejected by Bio Foods, farmers request the milk to be returned to the farm, and they sold it to other processors.

4.6 Effectiveness of the current regulatory mechanisms and enforcement practices in addressing contamination issues in the dairy sector in the North Rift region of Kenya.

The findings showed that the Kenya Dairy Board's (KDB) current regulatory mechanisms and enforcement practices were centered on ensuring the quality and safety of milk and dairy products in the country, including the North Rift region. Some of the regulatory mechanisms discussed are listed below;

Quality Control and Standardization:
KDB established and enforced quality standards for milk production, processing, and distribution. These standards included setting maximum required limits for aflatoxins, antibiotics, pesticides, and acaricides in dairy products. The standards were aligned with KEBS regulations.

Licensing and Certification:
KDB mandated that all dairy farmers, processors, distributors, and retailers be licensed. Licenses were issued after verifying that the operations comply with hygiene, safety, and quality standards. Regular inspections and audits were conducted to ensure ongoing compliance.

Milk Testing and Monitoring:
The KDB enforced routine milk testing for contaminants like aflatoxins and antibiotics at various points in the supply chain. Dairy processors had to test their products regularly, and the board conducted random sampling to monitor compliance.

Figure 13: A picture showing random testing of milk at KDB

Source: APCM student (2024)

Training and Capacity Building:

KDB conducted regular training sessions for farmers, cooperatives, and processors on best practices for milk production and handling. This included guidance on feed management to prevent aflatoxin contamination and proper antibiotic use to avoid residues in milk.

Collaboration with Stakeholders:

KDB worked closely with other regulatory bodies such as KEBS, the Ministry of Agriculture, and public health authorities to maintain safety standards. They also collaborate with dairy cooperatives and processors to ensured that regulatory requirements are met at every level of the supply chain.

Enforcement of Penalties:

Non-compliance with KDB regulations resulted in penalties, including fines, suspension, or revocation of licenses. The board also had the authority to seize and destroy contaminated dairy products that pose a public health risk.

Traceability and Reporting:

KDB promoted traceability in the dairy supply chain by requiring accurate record-keeping of milk sources, processing batches, and distribution channels. This system helped quickly identify and resolve contamination issues when they arose. However, KDB does not enforce record keeping of drugs purchased and used at the farm level.

However, findings showed that implementing Kenya Dairy Board (KDB) regulations in the North Rift region was challenging due to several factors. A significant portion of milk was sold to the informal sector because many farms were close to towns and estates, providing farmers with a convenient and ready market. This bypassed the formal regulatory framework.

Politics also played a major role in hindering regulation. Farmers blamed the government when inspections led to suspensions, and many farms owned by politicians were difficult for KDB to access, making regulatory enforcement less effective.

A large amount of milk was hawked directly to estates, bypassing essential testing and pasteurization processes. This milk was cheaper and had a quick market, making it profitable for consumers and small-scale farmers.

Additionally, rejected milk from certain processors sometimes re-entered the market because of a lack of direct collaboration between processors and KDB, which prevented proper tracking of rejected milk.

Finally, changing farmers' behaviors and encouraging them to adopt proper farming practices takes time, further complicated KDB's efforts to enforce regulations effectively in the region.

CHAPTER FIVE:

CHAPTER FIVE: DISCUSSION

5.1 current state of milk in relation to aflatoxin, antibiotics, and acaricides

The study revealed the presence of contaminants in milk, including aflatoxins, antibiotics, and acaricides, with varying levels detected among different groups. Specifically, the levels of these contaminants were found to be lower and within acceptable standards in milk supplied by Bio Foods suppliers compared to those from Non-Bio Foods suppliers. Bio Foods does these tests on milk of their suppliers, and they have measures in place for their suppliers to comply. Non-Bio Foods suppliers are unaware of these measures; hence, they do not follow any protocol apart from the ones set by the Kenya Dairy Board.

AFLATOXINS

Aflatoxin in milk was found to be low among farmers supplying Bio Foods. This was due to strict quality standards set by Bio Foods that farmers had to adhere to. The measures started from feed sourcing, where farmers purchased feeds from reputable suppliers and requested a certificate of analysis to ascertain the levels of aflatoxin in feeds. These measures were not employed by Non-Bio Foods suppliers, and it was noted that the levels in the samples from Non-BioFoods suppliers were high.
Aflatoxins were primarily traced back to feeds, especially dairy meals, the main feed tested. All the results showed levels below 5ppb, a threshold considered safe by Bio Foods; however, with cumulative effects and aflatoxin from other sources, these levels could shoot above the 5ppb threshold. The feeds were mainly made of grains, which were highly susceptible to aflatoxins. However, other potential sources, such as silage and various forages consumed by the cattle, could be considered possible contributors to the aflatoxin contamination (Tadele et al., 2023).

Feed storage and feed handling were directly related to the aflatoxin in feeds, which eventually goes into milk. Poor storage of feeds on the floor was identified as a factor that could increase feed exposure to aflatoxins. This was confirmed when samples from the Bio Foods supplying Cooperative showed undetectable levels of aflatoxins in feeds, yet the levels in milk were very high. There were chances farmers picked the feeds from the cooperative in good condition, but due to poor storage, the feeds developed aflatoxins. This is in line with a report by Fumagalli et al. (2021) indicating that aflatoxin management is systemic and includes all stages of the feed supply chain, in this case, feeding on the farm. When clean feed is poorly stored, they get exposed to moisture, leading to the development of molds, causing aflatoxin contamination.

Aflatoxin control in milk requires an integrated system. Closely monitoring the production phase of the feeds to ensure they are not affected before or at the farms. Close monitoring post-harvesting during storage and sensitisation of all the individuals involved in the feed chain is needed to prevent and respond to abnormalities effectively (Fumagalli et al., 2021). Bio Foods as the problem owner in this situation need to raise awareness to the informal channel and initiate corrective actions as some of the strategies that are working for the supplying farms. Through this initiative, they will comply and open a new intake channel from the informal sector.

Antibiotics

Antibiotics were detected in milk from Non-Bio Foods suppliers, and their presence was linked to treatments administered on farms. Bio Foods and Non-Bio Foods suppliers adhered to proper drug use by ensuring only qualified veterinary personnel administered medications. However, poor post-treatment milk handling from treated cows contaminated the entire milk batch. According to analysis done on the antibiotic positive milk for specific antibiotics, it was found out that some of the samples had two classes of antibiotics with antagonistic reaction. This indicated an off-label administration of these drugs.
Same to aflatoxin, antibiotics management also requires prevention methods. There are preventive methods already practiced by Bio Foods suppliers, which are in line with the recommendations by McEwen, Black and Meek (1991). Some of these prevention methods include:

Marking of treated cows and having the names on the board at the parlour:
Small-scale farmers may use part-time labour in milking cows. The part-time labour may not be aware of the necessity of withholding milk from the antibiotic-treated cows, or there may be a failure in communication in identifying the treated cows. Moreover, these are not the same people who do treatments at the farm, in this case there might be a failure of communication on withholding milk hence increasing the risk of contamination. Therefor having a visual colour on the animals that are antibiotic treated is crucial.

Milking treated cows using different equipment:
When all the animals are milked with the same machine, there are higher chances of mixing the milk from antibiotics treated cows with the whole batch. Therefore, to avoid such confusion, use a different equipment or completely hand milk these cows.

Keep records of antibiotic treatment:
Keeping records allows farmers to monitor milk and ensure that it is not collected for bulking from an antibiotic-treated cow.

Increasing withdrawal time:
Should the animals receive a double dose of antibiotics, there should also be an increase in withdrawal time.

There is a need to create awareness of how to implement these practices at the farm level. There is also a need for sensitization in the informal channel about the effects of antibiotics in milk. It is, therefore, a recommendation to Bio Foods to reach out to these farmers and offer training. With training, there are possibilities of farmers changing their farm management practices in regards to antibiotics and ensuring their milk conforms to the required quality parameters, therefore, creating a source of milk for Bio Foods.

To address the antibiotics issue from the routes, there needs to be a collaboration between KDB and the Kenya Veterinary Board. These bodies should formulate policies that regulate the use and access to antibiotics.

Acaricides

All tested samples were positive. Organophosphates were present in samples from farms that used these chemicals for tick control. The average concentration detected was 27.2ug/kg for farms and 52.15 ug/kg for the samples collected from the cooperatives. These exceeded the minimum requirement limits of 20ug/kg. Cypermethrin was detected in all samples, averaging 95.24 for the farms and 58.9 for the cooperatives. These also exceeded the minimum requirement limit of 50ug/kg. There are three possible entry routes of acaricides into milk: drinking water, spraying /dipping, and through contaminated feeds (Calahorrano-Moreno et al., 2022)

The fact that organophosphates were only present in samples where the animals were sprayed using the acaricide indicates that its entry route was through spraying. However, cypermethrin was present in all the samples, suggesting that its pathway was drinking water, spraying or through contaminated feeds.

To manage the occurrence of acaricide residues, it is recommended that the government regulate the accessibility and use of acaricides. Farmers are advised to purchase feeds from reputable suppliers who follow strict quality and compliance regulations. Farmers are also advised to use acaricides correctly according to the recommended guidelines. Farm workers should also be trained on the correct dosage, withdrawal periods and the risk of contamination. Bio Foods should create awareness on the residues of contaminants to both the formal and informal channels, helping them reduce the levels of contaminants, hence making the milk available for uptake.

5.2 Practices employed by stakeholders to contain the levels of contaminants within acceptable standards.

Bio Foods farmers implemented several practices to ensure contaminant levels in their milk remained within required standards. These practices included sourcing animal feeds from reputable suppliers and maintaining proper feed handling at the farm, such as storing feeds raised off the ground and in moisture-free environments. Farmers also obtained certificates of analysis with their feed purchases, verifying that aflatoxin levels were within acceptable limits. Additionally, they adhered to a "first in, first out" policy to prevent feed backlogs in storage. For maize silage, farmers harvested at the appropriate stage to minimize excess moisture, thereby reducing the risk of aflatoxin contamination.

The Bio Foods supplying cooperative and Bio Foods as a processor also played crucial roles in ensuring compliance with these standards. They set targets for farmers, such as achieving zero antibiotic levels, and provided training and sensitization programs to keep farmers informed of expectations. Effective communication channels were established between the cooperative, processor, and farmers to facilitate this process. To further motivate farmers, Bio Foods offered bonuses for meeting set standards and imposed penalties when standards were not met.

However, stakeholders not associated with Bio Foods had very few interventions. Although the Kenya Dairy Board (KDB) has collaborated with other state departments, such as the livestock and veterinary departments, the strategies recommended to farmers are not always effective. There should be a joint effort between Bio Foods and KDB to provide training so that Non-Bio Foods suppliers can also adopt successful strategies used by Bio Foods to ensure their milk meets the required standards.

Bio Foods and cooperatives should also extend their efforts to reach individual farmers in the informal sector. However, it would be challenging to engage with specific farmers individually. Therefore, it is recommended that farmers in the informal sector organise themselves into a union. In this context, a union is a body that advocates and lobbies for the interests of farmers. This would allow them to collaborate with stakeholders in the formal sector and gain access to resources like training.

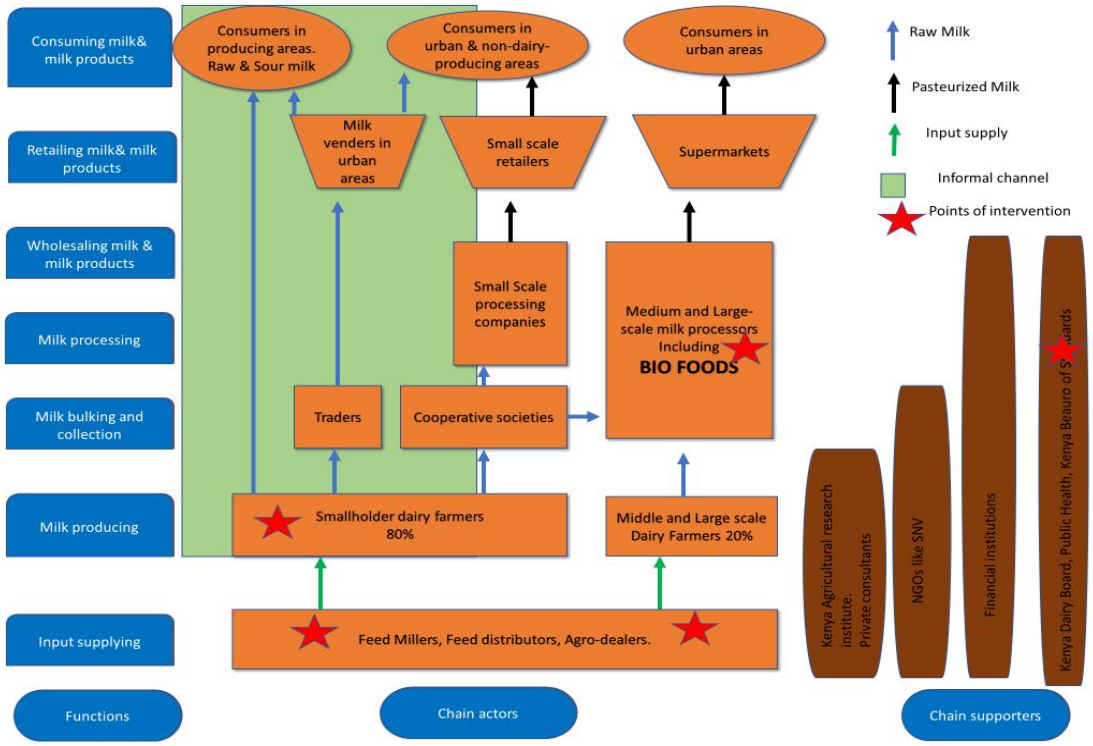
5.3 Strategies that can be implemented to mitigate aflatoxins, antibiotics and acaricides in raw milk in North Rift region

Implementing strategies to maintain low levels of contaminants requires readiness from all involved parties. However, farmers in the informal sector are not yet prepared to adopt these new strategies. While these farmers have access to financial resources, they still require coaching in governance and incentives to motivate them to effectively manage and implement changes. Farm staff also need to understand the fundamental practices that help reduce contaminant levels to implement these strategies successfully.

In contrast, Bio Foods is well-prepared to implement these strategies. The organization possesses the necessary capacity, supported by its strong dairy development department. However, the current regulatory mechanisms enforced by the Kenya Dairy Board (KDB) are less effective for smallholder farmers. To enhance the effectiveness of these regulations, there is a need for stronger collaboration between the KDB, county governments, and the Kenya Bureau of Standards (KEBS).

Strategies that can be implemented to maintain the levels of contaminants within acceptable limits are chain-wide strategies. These strategies involve different actors, like feed and input providers, interventions by chain supporters like KDB, actions by farmers and farm managers, and Bio Foods as the leader. The figure below shows the chain map with the critical control points for controlling the level of contaminants.

Figure 14: A chain map showing chain-wide points of interventions to reduce contaminants



Source: APCM student 2024

Input suppliers

To effectively manage contaminants like aflatoxin, which originate externally and are beyond the direct control of farmers, it is essential to begin control measures from the source. This includes feed dealers, feed manufacturers, and feed ingredient suppliers responsible for sourcing and supplying these materials. It is recommended that these suppliers ensure they provide high-quality feed free from aflatoxin. They should confirm that aflatoxin levels comply with the standards set by the Kenya Dairy Board and the Kenya Bureau of Standards. This requires initial testing of feeds from the source before they are imported and only import feeds that conform to the requirement. Government body, Kenya bureau of standards needs to strictly regulate feed importers to ensure they strictly follow the standards when importing feeds. Additionally, suppliers to provide farmers with a certificate of analysis indicating the feed's aflatoxin levels. When these are implemented, this will enable farmers access to high quality feeds with low aflatoxin levels. Enabling farmers to produce milk low in aflatoxin available for Bio Foods.

Smallholder Dairy Farmers

Smallholder dairy farmers are advised to follow good agricultural practices to maintain low levels of contaminants. In this context, good farming practices refer to methods that help ensure minimal contamination. To motivate farmers to adopt these good practices that will enable their milk to conform, they need to be motivated by being given incentives and a short payment period to ensure they have consistent cash flow. The table below outlines some of the recommended practices that, when applied, will assist farmers produce milk with low contaminants, hence available for intake by Bio Foods.

Table 14: A table showing recommended good farming practices to reduce the levels of contaminants

Practices relating to aflatoxins	Practices relating to antibiotics	Practices relating to acaricides
Source feeds from reputable suppliers. Request a certificate of analysis and only source feeds from suppliers whose feeds have aflatoxins within acceptable levels. Store feeds properly in stores off the ground to ensure feeds are not exposed to moisture and aflatoxin. In cases where farmers realise the feeds have toxins, they use toxin binders.	Ensure that treatments are recorded and only done by qualified vets. Separate the treated animals from the milking herd in a nursing area and milk them separately from the herd. Ensure proper communication with the milking staff on which animals are on treatment. Ensure the treated cows have visual marks to show that they should not be milked together with the milking herd.	Practice good soil management to help avoid the use of chemicals on the soil. Source feeds from reputable suppliers. Regularly test the dip solution to ensure the concentration is within acceptable levels. When using acaricides, strictly dilute according to manufacturer instructions.

Source: APCM Student 2024.

Bio Foods

Bio Foods, as a company with strong collaborative capabilities, as confirmed in this research, could use this to the advantage of its farmers. The company could establish partnerships with private companies, particularly feed suppliers. Many of these companies are international and adhere to global standards for product quality, such as maintaining low aflatoxin levels in feeds and adherence to the international use of acaricides. By forming these partnerships, Bio Foods can work collaboratively to provide farmers with high-quality products. This will allow the farmers to use high-quality products hence low levels of contaminants in milk, which will be available for uptake by Bio Foods.

To help farmers from the informal market meet Bio Foods standards, it is recommended that the Bio Foods team visit the farms and conduct a pre-onboarding evaluation. If non-conformities are identified, a root cause analysis be performed, followed by tailored advice to the farmers. After this analysis, Bio Foods to organize training sessions on good farming practices, including farm management (governance, effective communication channels) and Bio Foods' specific quality requirements. Following the training, farmers should be given time to implement the recommended interventions. Bio Foods should then carry out monitoring and evaluation to assess the effectiveness of these interventions. This evaluation includes tracking trends by collecting milk samples for analysis and conducting on-farm audits to ensure farmers adhere to the recommended practices. This will enable a smooth transition from contaminated milk from the informal sector to the formal into Bio Foods supply chain.

Bio Foods currently collaborates with one cooperative society. However, findings from this study indicate that milk from other cooperatives is less contaminated than milk from individual farmers. Specifically, milk from cooperatives not supplying to Bio Foods had lower aflatoxin levels and tested negative for antibiotics, in contrast to the milk from the Bio Foods supplying cooperative. It is recommended that Bio Foods establish partnerships with these other cooperatives. The first step should involve training their members on Bio Foods' quality requirements, followed by a pre-onboarding training program. After completing these steps, these cooperatives can be integrated into Bio Foods' supply chain, thereby increasing the company's milk intake.

To encourage farmers to transition from informal markets to formal supply chains and meet the quality standards of Bio Foods, it is essential to motivate them with appropriate incentives. One effective approach is to provide training as an incentive. However, to reach a larger number of farmers, it is recommended that Bio Foods encourage the formation of farmer unions. While a cooperative is a farmer-owned and democratically controlled organisation that allows for the bulking of milk, the union is an advocacy and lobbying body that represents the interests of farmers. These unions can serve as platforms where Bio Foods and farmers collaborate to organise training sessions to meet Bio Foods' quality requirements. Additionally, Bio Foods should consider offering competitive payment terms with those in the spot market to further motivate farmers. Farmers can also connect with reputable suppliers through these unions, ensuring they have access to high-quality inputs. If farmers adopt these strategies, their milk is more likely to meet Bio Foods' standards, making them reliable suppliers for the company

These interventions have been developed following the framework outlined below:

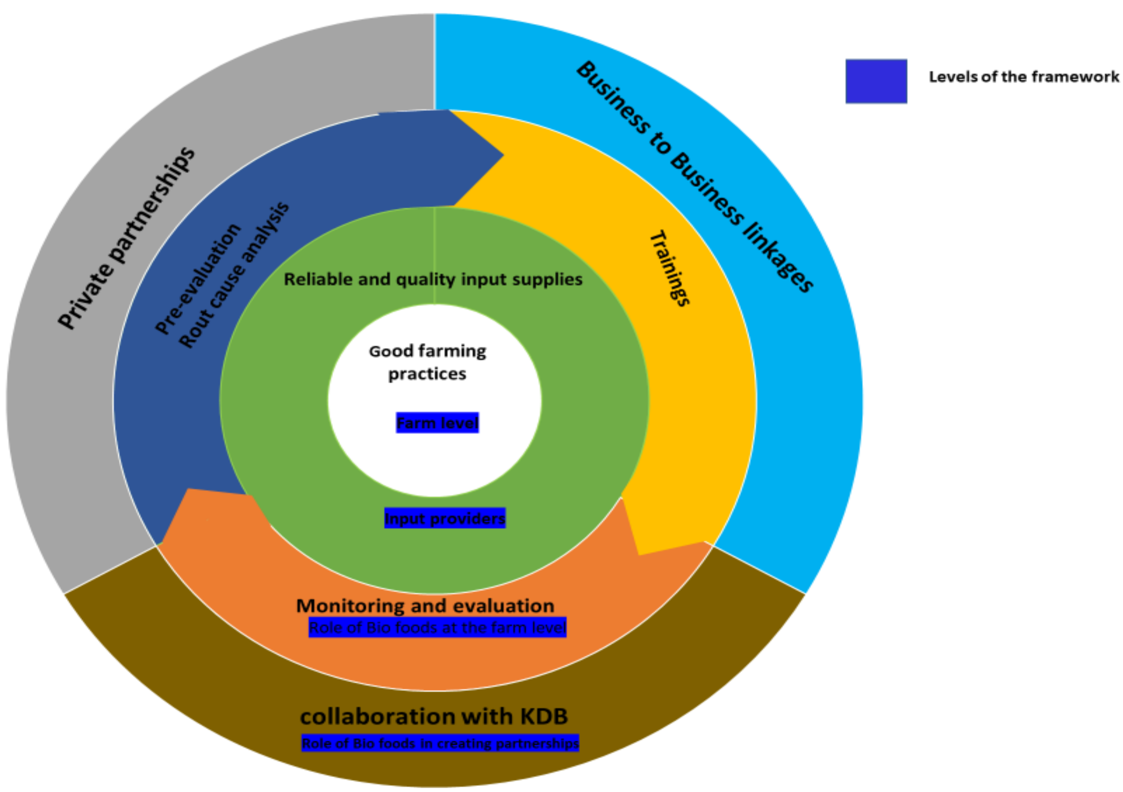
Farm level
Interventions on the implementation of good farming practices at the farm level are at the centre of the framework. These foundational practices are crucial for controlling contaminants that originate at the farm.

Input providers
Interventions in sourcing high-quality farm inputs from reputable suppliers

Role of Bio Foods at the farm level
Interventions by Bio Foods at the farm level to ensure milk conforms to the required standards
This includes providing training, conducting evaluations, and offering ongoing support to ensure farmers can implement and sustain the necessary interventions.

Role of Bio Foods in creating Partnerships and Collaborations that are beneficial to farmers
The final step in the framework involves establishing partnerships and collaborations with private companies and chain supporters. By working together, Bio Foods can help farmers access high-quality inputs and maintain low levels of contaminants.

Figure 16: Figure showing a framework for developing interventions



Source: APCM student (2024)

5.4 Limitations of the research

The major challenge of carrying out the research was the chemical analysis done outside Bio Foods Laboratory. Egerton University had only one Laboratory technician who was retired, and his position was vacant at the time of this research. It took time and patience to call him back to assist with the analysis. However, this did not affect the research findings, though the timelines were affected.

This research was also carried out during a period when there was political unrest in Kenya. Due to protests, transport was sometimes paralysed, and I had to reschedule some appointments with the interviewees and key informants.

5.6 Reflection

5.6.2 Reflection on Research Process

When I joined APCM, my goal was to work on a project related to milk intake, specifically to help Bio Foods increase its milk intake. Initially, I thought about the feasibility of building model farms to supply milk to Bio Foods. The idea of focusing on contaminants was interesting because it seemed like a practical and quick way to get more milk from the informal sector by controlling these contaminants. My background knowledge from ODIS and Spotlight papers were helpful for this topic. As I started writing my research proposal, I found the topic quite broad. It involved studying three different contaminants, including their occurrence, levels, contributing practices, and management strategies. With my supervisor's help, I could narrow down the research problem and questions. After reviewing various sources, I developed a conceptual framework which guided my research.

After presenting my proposal, I had a clearer idea of the work ahead. The data collection process was overwhelming because I had to deal with three different contaminants, each with its challenges. Despite the difficulties, this process was essential for achieving the research goals.

I had very interactive sessions with my respondents and key informants. Listening to how they had different views on milk and milk contaminants. This was a source of rich information that I needed. This process helped me improve my listening skills and be patient. I learnt how to see things from different perspectives. Specifically, this happened when I had farm visits to the Bio Foods suppliers and non- -Bio Foods suppliers. The practices at the farm were quite different. I had to listen and get clear pictures of what was happening in both scenarios.

5.6.3 Research Methodology

I used a mixed-methods approach, combining both quantitative and qualitative techniques as described in the research methodology. The qualitative aspect allowed me to gather detailed information from key informants and review literature during the desk study. The quantitative aspect involved measuring the levels of contaminants in milk and conducting surveys.
I learned a lot during the chemical analyses of the feed and milk samples. I had the opportunity to be in a laboratory set-up. This experience was highly educational for me. Working in a laboratory and

participating in hands-on analysis provided valuable insights. I learned a lot from the laboratory technician. For example, when I went to the laboratory for acaricide analysis, I told the technician that I wanted to test for organophosphate. He asked, “Which organophosphate? There are so many types of organophosphates” I went blank for a moment and then told him I wanted to test for steladon. “That is not organophosphate; that is a trade name”, he said. I had to go back to the literature review and select the right organophosphate I wanted, chlorpyrifos. This was a new learning to me and very helpful because it helped me interpret my data. Still, on the acaricides, we run all the milk tests for cypermethrin analysis. I was surprised when everything was positive. I started to wonder how that could happen, and all these farms were not using cypermethrin for dipping cows! This was against my expectations. So, I went back to my literature review, and indeed, there are different pathways of these chemicals into the milk, not dipping alone. This reminded me that I need to be conscious of confirmation bias as a researcher. Additionally, chemical analysis in milk allowed me to link contaminant levels to specific suppliers and non-suppliers, clarifying the differences and their causes.

5.6.4 Researcher influence

I suspect that my role as a researcher, particularly my association with Bio Foods and my visits to non-Bio Foods farms, may have influenced the results. To address this, I included a disclaimer stating that my visits were conducted in my capacity as a student, not as a representative of Bio Foods. Some farmers who did not supply milk to Bio Foods were hesitant to provide accurate information about their farm practices, fearing that their practices might not align with Bio Foods' recommendations. Additionally, some key informants were reluctant to share complete information because they did not want to be quoted. I respected their decision and took it into account in my analysis.

CHAPTER SIX

CHAPTER SIX: CONCLUSION AND RECOMMENDATION

6.1: Conclusion

6.1.1 current state of milk in relation to aflatoxin, antibiotics, and acaricides

The study indicates that milk from both Bio Foods suppliers and Non-Bio Foods suppliers is contaminated with aflatoxins, antibiotics, and acaricides. However, the contamination levels were significantly lower in milk from Bio Foods suppliers compared to non-suppliers. This reduction in contamination can be attributed to the effective measures implemented by Bio Foods suppliers to control these contaminants. The presence and levels of contaminants were found to be directly related to farming practices. To further reduce contamination levels and facilitate the transition of farmers to the formal sector through Bio Foods, Bio Foods could offer training to farmers in informal channel, provide incentives, and connect farmers with reputable suppliers. These measures will help improve milk quality and encourage more farmers to join the Bio Foods supply chain.

6.1.2: Practices employed by stakeholders to contain the levels of contaminants within acceptable standards

The study revealed that cooperatives and processors, such as Bio Foods, provide significant support to farmers, like training and farmers and implementing practices that ensure that milk meets required standards. However, these practices were not implemented by stakeholders not involved with Bio Foods. To integrate stakeholders outside the Bio Foods supply chain, collaboration between Bio Foods and the Kenya Dairy Board is essential. Additionally, Bio Foods should actively reach out to farmers in the informal channel by extending the practices currently employed with Bio Foods farmers through training forums. This outreach will help disseminate best practices and facilitate the integration of more farmers into the formal supply chain.

6.1.3: Strategies that can be implemented to mitigate aflatoxins, antibiotics and acaricides in raw milk in the North Rift region

The study identified that a comprehensive range of strategies is necessary to improve milk quality and lower contaminants, enabling farmers to integrate into the formal channel. This includes implementing broad interventions across the value chain. Effective strategies involve:

Farmers: Adopting good farming practices to ensure milk quality.

Feed Suppliers and Service Providers: Providing high-quality products and services to farmers.

Bio Foods: Taking an active role in training farmers to meet required standards and ensuring their milk conforms to these standards, collaborating with other chain actors like KDB and other cooperatives and linking farmers to reputable suppliers

By addressing the suggested strategies Bio Foods can enhance milk quality and support the integration of farmers into their milk supply chain hence increasing the intake.

6.2: Recommendations

The following recommendations have been chosen for Bio Foods to assist in shifting farms from the informal to the formal market and increase their milk intake.

Table 15: A table showing the reconditions to Bio Foods

Description of intervention	Accountable stakeholder	output	Outcome
Create Partnerships with more cooperative societies like the ones involved in this study.	Bio Foods and Cooperative Societies	Onboard the cooperatives as new milk suppliers	Intake of more milk from the informal market
Organise pre-onboarding farm assessment to initiate corrective actions and enable farmers from the informal sector to shift to Bio Foods	Bio Foods	Training on good farming practices and Bio Foods quality standards	Onboard more individual farms to Bio Foods supply chain
Create collaborations with private companies in Kenya, especially those in the feeds industry working with international standards and link farmers to these companies.	Bio Foods Private feed companies	Farmers get access to quality products with low contaminant levels. When farmers use these products, their milk conforms to Bio Foods' required standards, and they can be onboard with Bio Foods.	Increased intake of milk at Bio Foods.
Bio Foods to provide farmers with incentives that will encourage them to shift from the spot market	Bio Foods	Effective training Access to quality feeds	Production of high-quality milk with low aflatoxin available for Bio Foods.

Source: APCM student (2024)

Recommendation for further research

This research focused on the three contaminants. However, to create an understanding of the occurrence of acaricide, one of the contaminants, it is recommended that further studies be done on feeds as one of the pathways of this contaminant into the value milk chain.

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Annex 1: Chemical analyses procedures

a) Antibiotics Delvotest Procedure

i. An incubation device was preheated at 64 degrees centigrade.
ii. Ampules were detached from the rest, and the aluminum foil cover was perforated carefully
iii. O.1 ml of milk sample was pipetted into the ampule using a clean pipette.
iv. The ampule was covered with aluminum foil and incubated in the dry incubator for three hours.

Test Readings

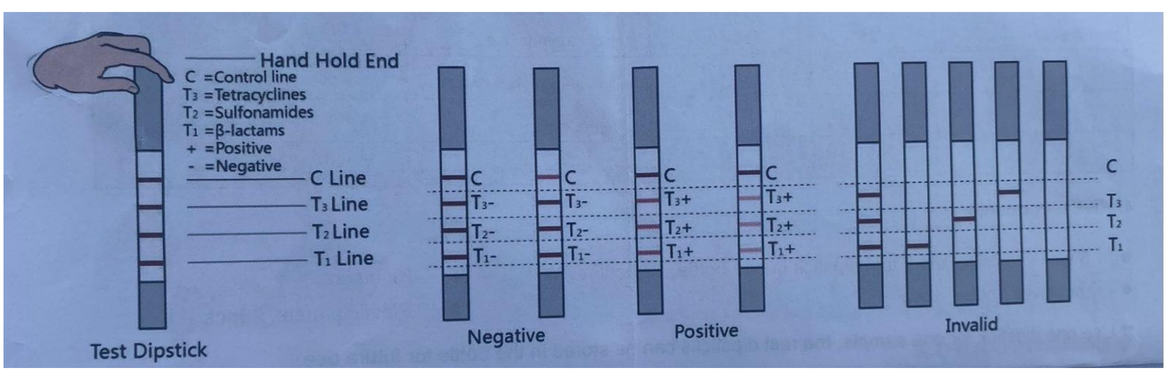
The colors were red from underneath the test plate

a. Partially yellow color—Negative Test. The milk analysed does not contain antibiotics, or the antibiotic concentration is below the detection sensitivity of the test.

b. The milk sample is predominantly purple, which means the test is positive. The sample has antibiotics or is above the detection sensitivity of the test.

Antibiotics-specific test procedure (B-Lactams & Sulfonamides & Tetracyclines Triple test Dipstics)

1. Test kits and samples were brought to room temperature
2. The wells were marked with the farm code
3. The microwells were placed in a metal incubator
4. 200ul of the test samples were dispensed into the wells, then repeatedly absorbed and dropped five times to mix the samples and the reagent completely in the wells.
5. This was incubated for 3 minutes at an ambient temperature (20-25 degrees)
6. The dipstick was inserted into the sample with the sample pad fully dipped into the mixture
7. This was then incubated for 6 minutes at an ambient temperature (20-25degrees)
8. Readings were taken according to the chart below.



b) Aflatoxin M1 test in milk

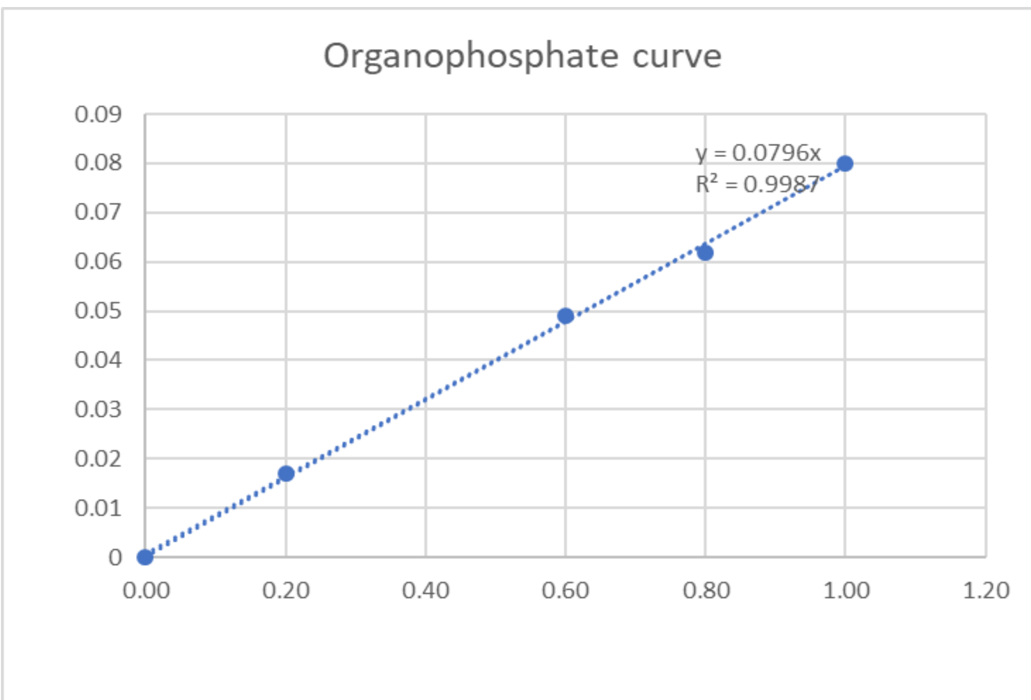
- ✓ The reagents and milk samples were allowed to reach room temperature before use.
- ✓ Mixing wells were set up in a microwell holder for each sample to be analysed, and a set of antibody-coated microtiter wells was placed in a separate microwell holder.
- ✓ Each reagent and sample was prepared by swirling the container before use.
- ✓ 1.2 mL of the sample was pipetted into microtubes.
- ✓ In duplicate, 200 µL of the samples were transferred from the microtubes to the clear microwells and incubated for 20 minutes to enable aflatoxin binding to the microwell surfaces.
- ✓ The contents of the clear microwells were discarded into a disposal basin, and the microwells were tapped and air-dried (face down) on absorbent towels to remove any remaining samples.
- ✓ In the antibody-coated microwells, 75 µL of conjugate and 75 µL of milk samples were combined by priming the pipettor at least three times and incubated for 5 minutes.
- ✓ 100 µL of the solution from the antibody-coated microwells was transferred into the dried clear microwells and incubated for 10 minutes. The clear microwells were then washed by filling them with PBS-T wash buffer and discarding the wash into a disposal basin. This washing procedure was repeated six times, after which the wells were tapped dry.
- ✓ 100 µL of enzyme-substrate (TMB) was added to each well and incubated for 10 minutes, with the wells covered to prevent exposure to direct light.
- ✓ The reaction was terminated by adding 100 µL of stop solution, which caused the blue color to turn yellow.
- ✓ The absorbance of each microwell was measured using an ELISA reader.

c) **Test for acaricides in milk**

Spectrophotometry for (Organophosphates) chlorpyriphos procedure.

- ✓ Two grams of magnesium chloride solution was added to 1 gram of ammonium chloride to make a magnesia mixture. Approximately thirty drops of ammonium hydroxide were added to this solution.
- ✓ After boiling the mixture and allowing it to cool until a strong ammonia smell was detected, the solution was mixed with the sample to form magnesium phosphate, which was then measured using a UV-visible spectrophotometer.
- ✓ 1 ml of the sample was diluted to 10 ml in a volumetric flask with 2 ml of the magnesia mixture and 7 ml of water. The resulting mixture was analysed with a UV-visible spectrophotometer, and the absorbance was recorded.
- ✓ Finally, the concentration of organophosphate in each sample was determined and documented.

Calibration curve for organophosphate experiment

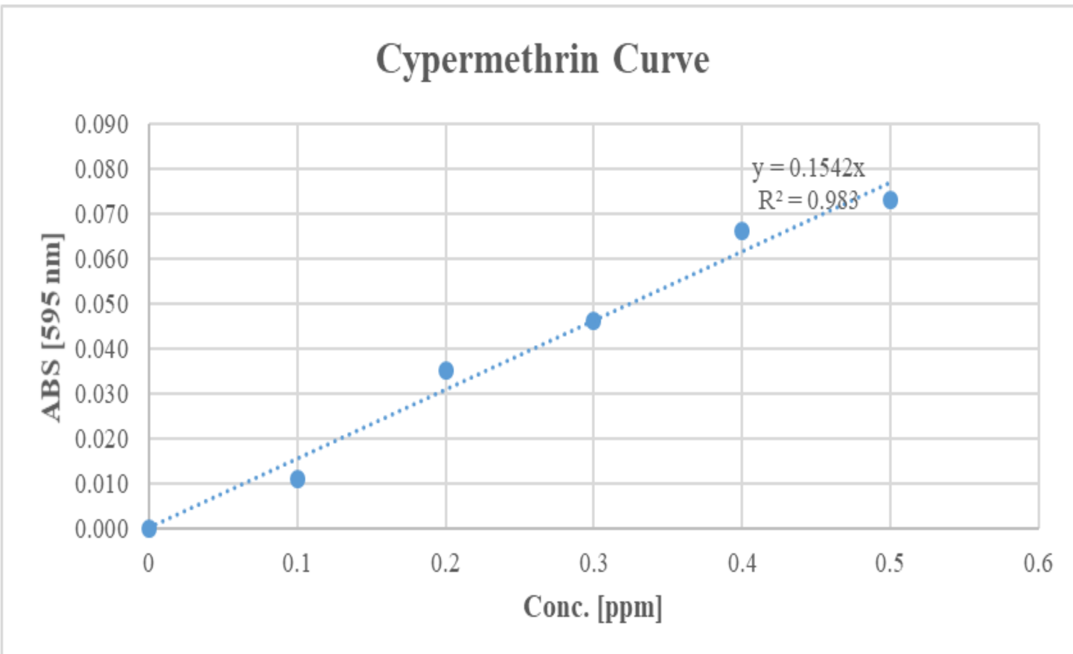


Spectrophotometric procedure for determining Cypermethrin.

- ✓ Reagents were brought to room temperature.
- ✓ 25 ml of milk samples were transferred to a 50 ml volumetric flask.
- ✓ ml of 20% sodium hydroxide was added and left for 10 minutes at room temperature for full hydrolysis.
- ✓ To create complete color, 1 ml of potassium iodide and leuco crystal violet were introduced to an acidic solution, agitated firmly, and left for 15 minutes. The solution was then diluted with 25 ml of water, and the absorbance was measured at 595 nm against a reagent blank.

� The concentration was calculated and reported.

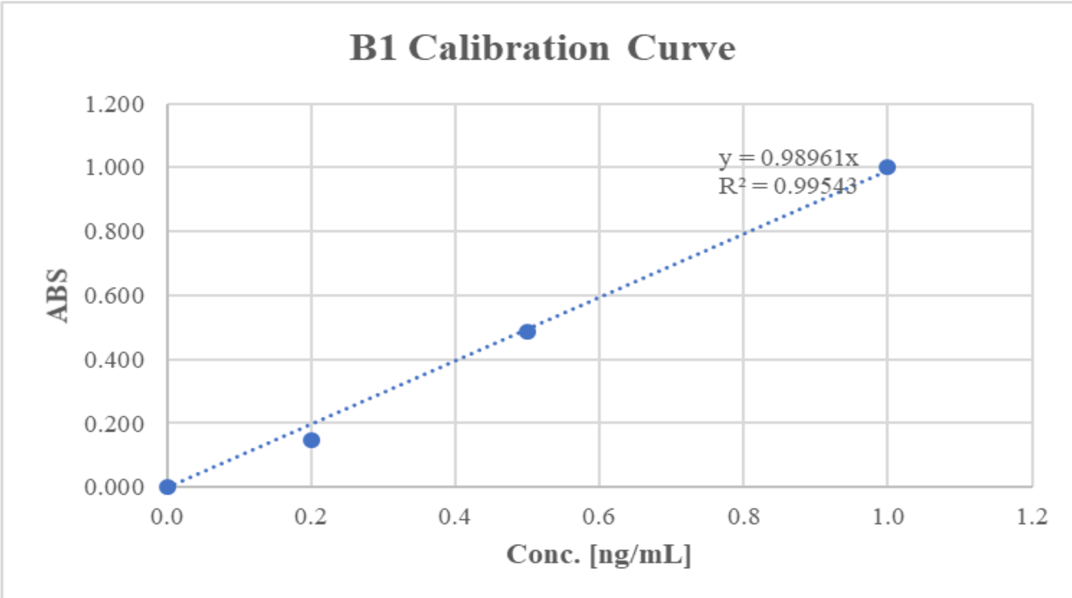
Calibration curve for Cypermethrin experiment



d) **Aflatoxin BI Test procedure**

1. Methanol solution was prepared by combining 70% methanol and 30% water. A 500 ml solution was created and 25 ml was added to each dry feed tube. This was blended for 5 minutes with a vortex mixer.
2. To separate the aflatoxin liquid from the solid feed, the mixer was centrifuged at 4000 rpm for 10 minutes.
3. Samples were tagged and were ready for analysis.
4. To make the wash buffer, the PBS-T powder packet was gently rinsed with deionized water in a 1-liter container.
5. One mixing well was used for testing each standard and sample.
6. Before using each reagent, the vial was swirled to combine it thoroughly.
7. Each Dilution Well received 200 µl of conjugate.
8. Using a new pipette tip, 100 µl aliquots of each standard and sample were added to the appropriate dilution well containing conjugate. This was mixed by priming a pipette at least three times.
9. 100 µl from each dilution well was transferred to the corresponding antibody-coated microtiter well with a new pipette tip. This was incubated at room temperature for 15 minutes.
10. The microwell contents were decanted into a trash basin. The microwells were washed by filling them with PBS-T wash buffer and draining the wash into a trash basin. The washing was repeated.
11. Each microwell received 100 µl of substrate reagent and was incubated for 5 minutes at room temperature. This was covered to avoid direct sunlight.
12. 100 µl of stop solution was added in the same order and pace as the substrate was applied.
13. The optical density (OD) of each microwell was measured using a microtiter plate reader and an ELISA reader.
14. The zero standard was set to 100% binding (Bo), and each standard's percentage binding (%B) was computed. The sample was then expressed as a percentage of the zero binding.
15. A standard dose-response curve was created.

Calibration curve for B1 experiment



Annex 2: The 5 core capabilities of Bio Foods

	5 CORE CAPABILITIES FRAMEWORK						
Capability	**Indicator**	**Pointers**	**1**	**2**	**3**	**4**	
Capability to act and commit	Bio Foods Formulates strategic plans, makes informed decisions, and acts on these plans.	The strategic and operational plan align with company vision mission	**4**	**4**	**3**	**3**	**3.5**
		Staff Actively engage in policy-making and decision-making	**4**	**4**	**4**	**3**	**3.75**
	Bio Foods has motivated a workforce motivated by its mission and vision.	Staff partiipate in regualar discusion on mission and strategy	**3**	**4**	**4**	**3**	**3.5**
		Retention of staff is assured to achieve the goal set	**4**	**4**	**3**	**4**	**3.75**
	Bio Foods employs effective financial resource mobilisation strategies to actualiize its plans.	The company has enough financial resources to implement the strategic plan	**3**	**4**	**3**	**4**	**3.5**
		Bio Foods dairy cooperative has a cost effective approach in emplementing its activites	**4**	**4**	**3**	**4**	**3.75**
	Bio Foods has effective and action-oriented leadership team	Bio Foods has a well-functioning management team	**4**	**4**	**4**	**4**	**4**
		leadership is forcusiong on strategic plan and actively guiding the organisation to achieve its goals	**4**	**4**	**4**	**4**	**4**
	AVERAGE SCORE						**3.71875**
Capability to build on development objectives	The company has adequate systems In place	The systems enhances productivity and ensure the smooth running of processes	4	3	2	3	**3**
		the systems provide adequate information for decision making	4	3	3	3	**3.25**
	Infrastructure is sufficient and relevant for the core tasks	There is good access to internet with hard and software of sufficient qouality	4	4	4	3	**3.75**
		The buldings are sufficient to run regular organisational activies	4	4	3	4	**3.75**
		staff have adequate employment contract	4	4	4	3	**3.75**
	The company possesses adequate	Gender equality is strived for in employment	4	4	2	2	**3**
	AVERAGE SCORE						**3.416667**
Capability to adapt and self renew	Stimulates and facilitates learning and exchange with other organisations	Staff feel comfortable in expressing their views	3	4	3	3	**3.25**
		critical inputs from staff and stakeholders are out into consideration.	4	4	2	3	**3.25**
	Makes systemic use of the result information from M& E to verify strategy and adjust	Learning is an important part of Bio Foods dairy cooperative	4	4	3	3	**3.5**
		M&E done and information jointly analysed and used for decision making.	4	4	3	3	**3.5**
	Bio Foods anticipates dynamics and ready to shift trends.	Bio Foods able to apply new technologies	4	3	2	3	**3**
		Opportunities based in changing context are identified.	4	4	2	3	**3.25**
	AVERAGE SCORE						**3.291667**
Capability to relate to external Stakeholders	Bio Foods dairy form partnerships with relevant stakeholders and maintain them	Seek and identify stakeholders within the industry	3	4	4	4	**3.75**
		Formulate strategic partnerships with the identified stakeholders	3	4	4	4	**3.75**
	Bio Foods dairy have political and social legitimacy in the eyes of NGOs	Has established contacts with the government and its agencies	4	3	3	4	**3.5**
		Participates in subjects related to its mission and contributes to local develoment	4	4	4	3	**3.75**
	Bio Foods is able to mobilize external capacity to achieve organisational goals	Encourages transfer of knowledge from external partners to internal team	4	4	2	3	**3.25**
		Bio Foods maintains its immediate network in order to call upon when needed	4	4	3	3	**3.5**
	AVERAGE SCORE						**3.583333**
Capability to Achieve coherence	Bio Foods shows consistency between mission, strategy and operations	Strategic plan is made operational in a clear work plan	4	4	3	3	**3.5**
		leadership is focusing on the strategic plan and actively guiding the organisation to achieve its goals	4	4	3	4	**3.75**
	Activities of Bio Foods are linked in order to reach the output and objectives	The activites are logoically sequencial from input to output.	3	4	3	3	**3.25**
		Staff know the order of activities and work towords a common objective	4	4	3	4	**3.75**
	AVERAGE SCORE						3.5625

Annex 3: questionnaire & key informant checklist

Questionnaire

I am a Master's student in Agricultural Production Chain Management at Van Hall University of Applied Sciences, the Netherlands. I am conducting a survey on integrated assessment of milk contaminants: aflatoxin, Antibiotics, Pesticides, and acaricides in raw milk in the North Rift Region. I would appreciate your participation in this survey by responding to the questions below. The responses to these questions will be used for the sole purpose of research and treated confidentially.

Thank you for your willingness to participate.

General Information

Name of the farm	
Name of the farm owner	
Name of farm manager	
Location of the farm	
Farming system	

a) Primary sources of the contaminants in milk

1. What is the size of your dairy farm (number of cows)?

How many cows are in milk?	
How many are dry cows?	
How many are pregnant heifers?	
How many are bulling heifers? (Over 13 months)?	
How many calves are there between the ages of 6 and 13 months?	
How many calves are between the age of 0-5 months?	
How many are bulls?	

2. How long have you been in the dairy farming business?

3. What is your knowledge of milk the following milk contaminants?

a) Antibiotics

b) Aflatoxins

c)Acaricides

Section 1: Sources of Contaminants

Sources of Aflatoxins

4. What is the main source and other sources of feeds for your dairy cows?

5. Who is your main concentrate supplier?

6. Where else do you get the concentrate?

7. Do you get a Certificate of analysis along with the feed?

- Yes
- No

8. How do you store feed to prevent contamination with aflatoxin?

9. Do you put your feed on:

- Floor
- Pallet
- Both

10. How frequently do you have issues with the moldy feed?

11. How often do you test your feed for aflatoxins?

- Every batch
- Weekly
- Monthly
- Never
- Other

Sources of Antibiotics

12. Do you use antibiotics to treat your dairy cows?

- Yes
- No

13. If yes, which types of antibiotics?

14. Who administers these antibiotics?

- Resident vet
- Outsourced vet
- Farm manager
- Farm owner
- Other

15. How long is the withdrawal period of these antibiotics?

16. How do you manage the withdrawal period for cows treated with antibiotics?

17. How do you ensure antibiotics are administered properly and responsibly?

18. Do you have management practices you follow to avoid antibiotic residues in milk?

- Yes
- No

19. Which ones?

20. Do you have treatment records?

- Yes
- No

21. If yes, in which form are the records kept?

22. How do you use these records to track antibiotic treatments?

Sources of Acaricides

27. Do you use acaricides to control ticks on your dairy cows?

- Yes
- No

28. Which acaricides do you use?

29. How frequently are acaricides applied?

- Weekly
- Biweekly
- Monthly
- Other

30. How do you apply the acaricides on your dairy cows?

- Dipping the cows
- Spraying
- Applying pour on the cows
- Injecting
- Other

31. How do you ensure the safe application of acaricides to minimize residues in milk?

Section 3: Levels of Contaminants

Aflatoxins

32. Do you know the potential sources of aflatoxins in raw milk?

- Yes
- No

33. If yes, which ones are you aware of?

Antibiotics

34. Do you know any regulations regarding antibiotic residues in raw milk?

- Yes
- No

35. If yes, Which ones?

Acaricides

36. Are you aware of the potential residues of acaricide in raw milk?

- Yes
- No

37. If yes, how do you ensure your milk is free from acaricide residues?

Section 4: Daily Practices Related to Contaminants

Practices Related to Aflatoxins

38. What types of feed do you use for your cows?

39. How do you store your fodder to prevent mold growth?

40. How often do you inspect your feed for mould or contamination?

- Everyday
- Weekly
- Biweekly
- Monthly
- Never
- Other

41. What steps do you take if you find that your feed is moldy?

42. Do you test your feed for aflatoxins?

- Yes
- No

43. If yes, how frequently do you conduct these tests?

- Weekly
- Monthly
- Test for every batch
- Other

Practices Related to Acaricides

47. Do you use acaricides to control ticks and mites on your cows?

- Yes
- No

48. How frequently are acaricides applied?

- Weekly
- Bi-weekly
- Monthly
- Never
- Other

49. What precautions do you take when applying acaricides?

Training and Education

50. Have you received training on how to manage and prevent contaminants in raw milk?

- Yes
- No

51.If so, could you please specify which one?

52. How often do you participate in such training programs?

53. Do you find these trainings useful?

54. How useful are they?

55. Are you interested in attending more educational sessions on milk contaminant control?

- Yes
- No

56. Why?

6: Role of Cooperatives and Dairy Processors

57. Are you a member of a dairy cooperative?

- Yes
- No

58. Does your cooperative support you in managing contaminants in raw milk?

- Yes
- No

59. What kind of support do they offer?

60. To which dairy processors do you supply your raw milk?

- Brookside
- KCC
- Bio Foods
- Other

61. Does the processor have standards regarding contaminant levels in raw milk?

- Yes
- No

62. If yes, Which standards?

63. How does the dairy processors monitor and enforce these standards?

64. Do you receive feedback from processors when you deliver the milk?

65. Which kind of feedback do you receive?

Section 7: Capacity to Adopt New Strategies

Openness to New Practices

66. Are you willing to adopt new practices to reduce contaminants in raw milk?

- Yes
- No

67. What would you consider before adopting new practices?

Access to Resources

68. Do you have access to the necessary resources (financial, technical, educational) to implement new strategies?

- Yes
- No

69. If yes, which ones do you have access to?

70. What types of resources would be most helpful to you in adopting new practices?

Bio Foods checklist

1. What testing protocols and procedures does Bio Foods have in place for detecting aflatoxins, antibiotics, pesticides, and acaricides in raw milk, and how does the company respond when contaminants exceed acceptable levels?

2. What daily practices do dairy farmers in Bio Foods' supply chain follow to prevent contamination, and what support and training does Bio Foods provide to ensure these practices are effective?

3. What specific interventions has Bio Foods implemented to address contamination from aflatoxins, antibiotics, pesticides, and acaricides, and how does the company ensure their successful implementation?

4. How does Bio Foods collaborate with dairy cooperatives, processors, and other stakeholders to enhance contamination control measures, and what challenges does the company face in maintaining effective contamination control?

THE 5CS-BIO FOODS

Kenya Dairy Board Checklist

1. What are the key regulatory mechanisms currently in place to address contamination issues in the dairy sector in the North Rift region of Kenya, and how do they specifically target aflatoxins, antibiotics, pesticides, and acaricides in raw milk?
2. How does the Kenya Dairy Board enforce these regulations, and what are the primary methods used to ensure compliance among dairy farmers and processors in the North Rift region?
3. What processes are used to monitor and evaluate the effectiveness of the current regulatory mechanisms and enforcement practices in reducing contamination levels in raw milk?
4. What challenges and barriers does the Kenya Dairy Board face in implementing and enforcing these regulations effectively, and how are these challenges being addressed?
5. How does the Kenya Dairy Board collaborate with other stakeholders, such as dairy cooperatives, processors, and farmers, to enhance the effectiveness of regulatory mechanisms and enforcement practices in addressing contamination issues in the dairy sector?

Cooperative Checklist

1. Do you have any quality standards that your cooperative expects dairy farmers to meet regarding milk quality, especially regarding contaminants like aflatoxins, antibiotics, pesticides, and acaricides?
2. How does your cooperative ensure these standards are communicated effectively to member farmers?
3. What support does your cooperative provide to help farmers achieve and maintain these quality standards?
4. How does your cooperative collaborate with milk processors to ensure the milk supplied meets their quality requirements?
5. What are the key expectations and specifications that milk processors have from your cooperative regarding milk quality?
6. How does your cooperative gather feedback from milk processors on the quality of the milk supplied?
7. How does your cooperative address any concerns or issues raised by milk processors regarding milk quality or contamination?

Annex 4: NACOSTY Research License

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Date of Issue: 18/July/2024

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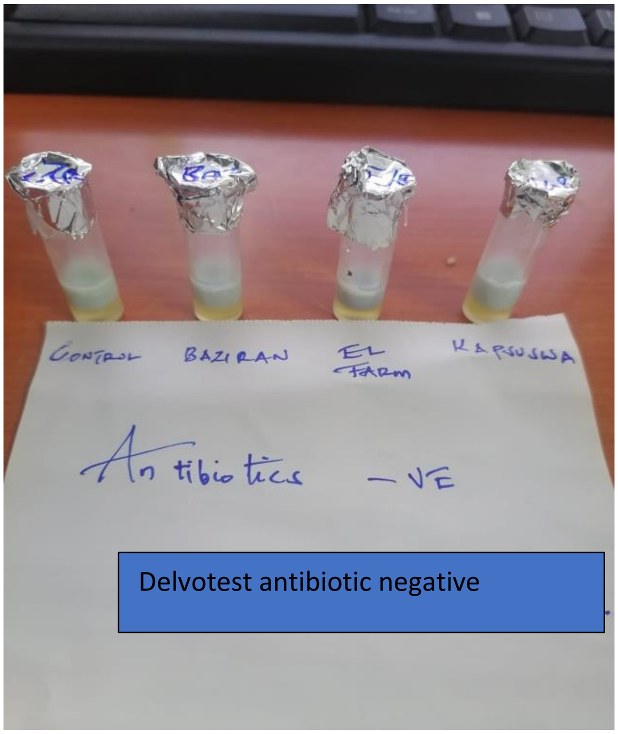
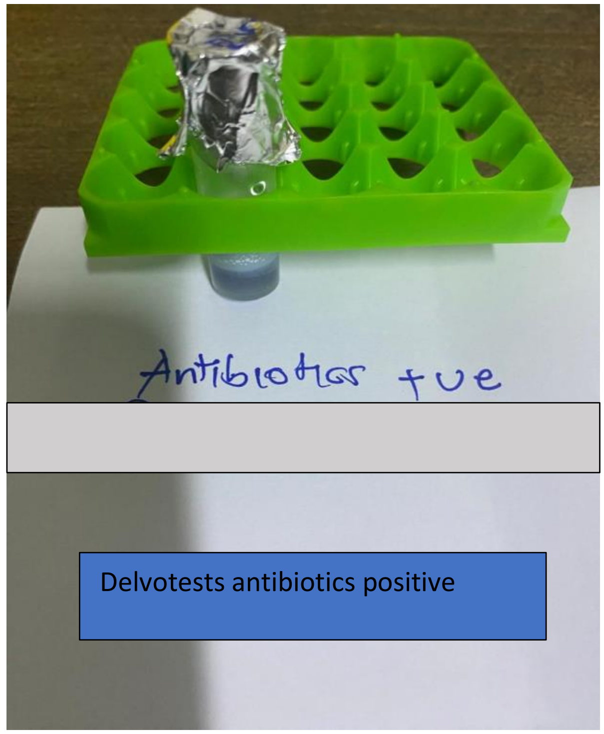
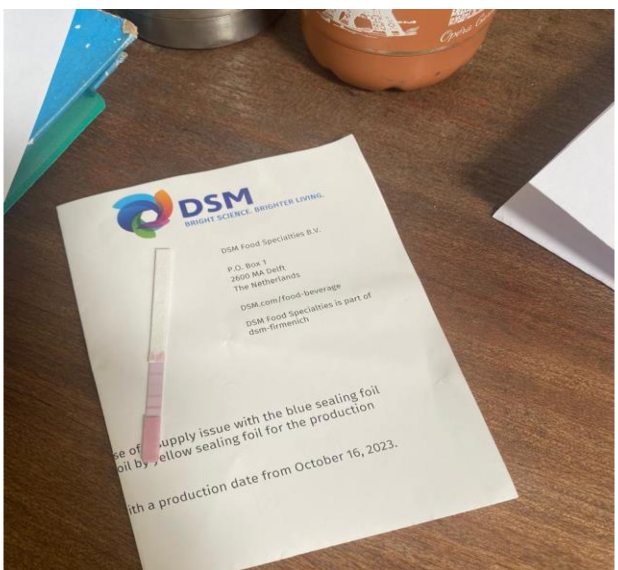
Annex 5: Photo Gallery



Delvotest antibiotic negative



Delvotests antibiotics positive

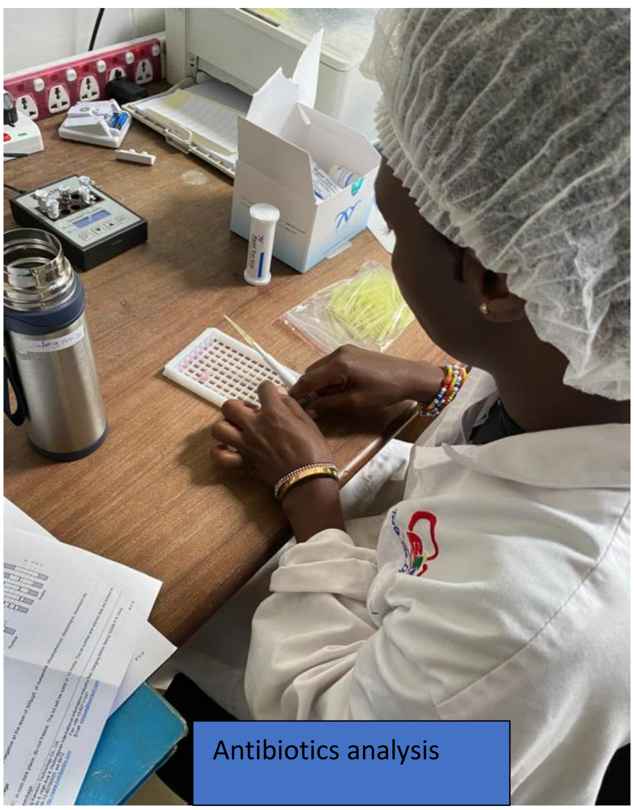


Antibiotic positive for B-lactams &Sulfonamides

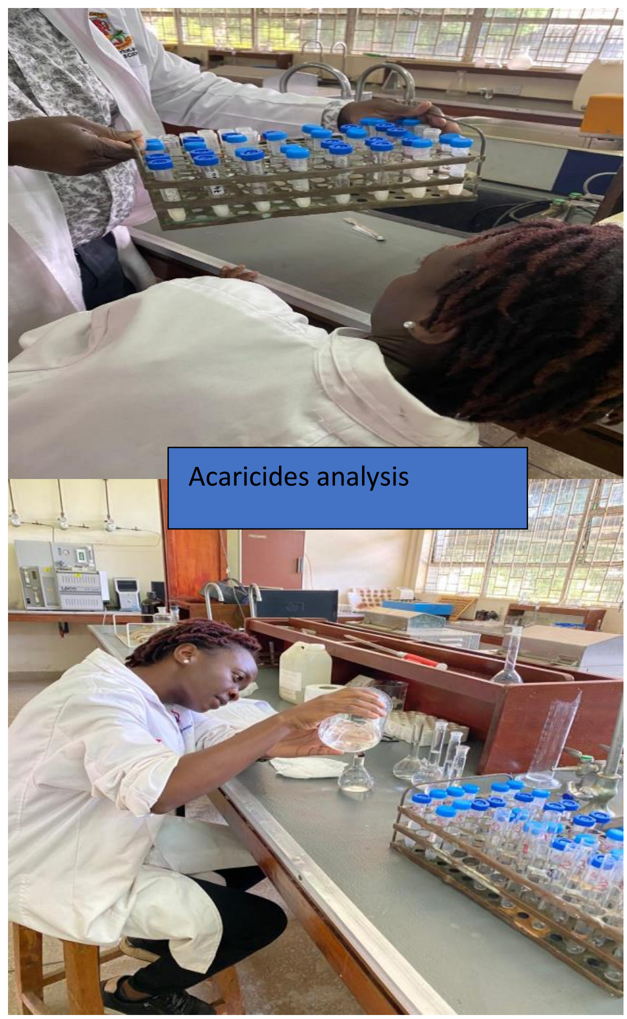

Commonly used antibiotics at the farm

Preparation of feed samples for aflatoxin B1 analysis

Analysis of aflatoxin B1



Antibiotics analysis



Acaricides analysis

Farm visits