Scotland's Rural College

Food safety and the informal milk supply chain in Kenya

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Abstract:

Background
Informal dairy supply chains are important in Sub-Saharan Africa, both in terms of employment and nutrition for poor population. Their safety has been debated in the literature, with those in favour to their legalisation, arguing that boiling milk reduces sanitary risks for its consumption and the nutritional impact offsets those possible risks. While, the opposing side, highlighting that boiling milk does not eliminate all the contaminants that are found, and the long term sanitary and health impact should be a major concern for regulatory enforcement.
The purpose of this case study, which focuses on food safety along a dairy supply chain in Kenya, the largest milk producer in Africa, is twofold: first, to review the different issues on food safety when consuming raw milk, and second, to extract lessons from a case study that follows an informal supply chain that operates in rural, peri-urban and urban areas in the Kiambu and Muranga counties in Kenya. This case study was based on semi-structure interviews to 29 stakeholders and participants of an informal dairy supply chain carried out in April-May 2019. The purpose of the interviews was to provide insights of the hurdles and food safety risks surrounding everyday activities of milk handlers.

Results
The results indicate that the informal dairy sector is associated with low-quality milk and food safety risks. These assumptions are linked to several factors such as lack of contact and control from the sanitary and health authorities, lack of awareness regarding milk safety from both consumers and the different supply chain participants; and the poor operating conditions the informal market has. Additionally, other aspects were the overall lack of hygiene, accountability, and infrastructure in the entire supply chain.

Conclusions
In conclusion, greater focus should be put on improving food safety quality along the chain (e.g., through ensuring the application of Good Handling Practices like the use of food grade containers and the introduction control points). The reform of Kenya's informal dairy market must focus on training to improve and increase the hygiene and safety practices of the informal operators to reduce the information gap that divides formal from informal.

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Response to Reviewers:	MAIN POINTS General: oMilk vending machines seem to be operating under the structure of a formal sector; i.e., they sell processed milk and are licensed by KDB; thus, why are they considered in the paper as informal? Response: Not all milk vending machine source from certified or registered suppliers. As show multiples actors in the system participate in both markets. This situation complicates mapping participants of the chain that exclusively participate in one type of market. oWould poor hygiene in the informal sector be a result of infrastructure, poor operating conditions, lack of awareness, lack of contact and control from the sanitary and health authorities? There is evidence of cause-and-effect relationship; however, the author doesn't show these. Response: The cause-and-effect relationship are discussed in section 5 in detail. oThe finding that "milk prices the final consumer pays do not reflect the added value that pasteurization offers in terms of milk quality and safety" is a good conclusion. However, the author would have gone a step further and offer the price paid in the formal sector per litre to offer a good price comparison between the two sectors. That could explain why consumers opt for informal milk. Response: Table 5 show the prices the consumer pays in different selling points. However, the price of milk at the supermarket was not presented considering that this type of location was not in the proximity of where the case study was conducted. oAvoid the use of very long sentences. For example, on page 3 lines 5-8, 34-38, 46-51. Review the entire document and break long sentences, make them clear and precise. Response: Changes made. oRemove all the double-spacing within the entire document. Response: The articles has single line spacing. oRemove the abbreviation SSA from the abstract and place it after sub-Saharan Africa in the introduction section. Then use the abbreviation consistently in the rest of the document. Response: Changes made. oLines 8-9 pg3: The two sentences are not very clear. What cluster of situations? The authors have only mentioned one; the delayed rainy season in 2019. Also provide a relevant reference(s) for the statement starting line 6-8, pg3. Response: Changes made. oLine 23 pg3: Revise smallholders' producers to smallholder producers. Response: Changes made. oLine 38-39 pg3: Check on sentence grammar. Response: Changes made.

oLine 47-48 pg 3: replace sub-Saharan Africa with SSA. See the third comment.

Response: Changes made.

oLine 45-51pg3: Provide a brief summary on the various reforms in the Kenyan dairy sector and also some of the challenges introduced by these reforms as stated.

Response: Changes made.

oLine 54-57 pg3: Revise the sentences. For example, the structure of this paper is as follows: Section 2 provides a review of food safety risks of consuming raw milk; Section 3 provides a literature review of the dairy sector in Kenya; Section 4 discusses the methodology; Section 5 presents the results and discussion, and Section 6 concludes and provides policy recommendations.

Response: Changes made.

oThe study mentions that Kenya is the largest producer of milk in Africa. Contrastingly the study only managed to get 29 respondents (<30) of which the authors failed to mention the location of the respondents. How many were from Kiambu and how many were from Murang'a?

Response: The number of respondents is justified considering the mentioned limitations on time, staff and financial support.

oOne question then abounds, using only a small sample with a non-scientific method of obtaining the respondents, can the authors justify using the study results to generalize the food safety risks within the dairy supply chain in Kenya?

Response: The authors are aware of the limitation of the case study. However, considering that the results from the limited number of studies done in the informal sector and the answers provided by the stakeholders from KEBS, KDB and a former chairman of the Kenya Veterinary Board are in line with the results from the interviews and the observations done on the field; this study can present an actual and realistic depiction of the intertwined interactions of the informal sector and the main challenges to ensure food safety along the chain.

Minor points
oWork on your punctuation in compound sentences
oMake your sentences clear
oAvoid wordy sentences
Response: The authors have done a revision on the article´s punctuation and structure.

Abstract
1.In your topic, you are talking of an informal milk supply chain, but in the background section page 2 line 5-9, you are saying that boiling of milk is adequate for its consumption, which is not a function of the supply chain, rather a value chain . Kindly get the proper definition of a supply chain.
Response: Proper thermal treatment (pasteurization) is a common process to achieve food safety. Boiling milk at home without the proper control is not the same as pasteurizing. The authors consider that in this case, boiling milk is not translated as a competitive advantage. Since the supply chain includes the conversion procedures or processes done to raw materials to get them to the market, heat treatment is part of the supply chain, and an alternative path milk follows with some of its actors

2.On page 2, lines 12-13, You indicate that the purpose of the case is to review the different issues on food safety when consuming raw milk, but if you proceed to the annexe on pages 22 and 23 you are targeting producers/sellers and buyer, but not consumers. Then how did you capture the different issues of food safety when consuming raw milk? In If maybe you did interview the producers, sellers, and buyers on raw milk consumption, where are the questions on milk consumption? On the same statement: do you mean consumption of raw milk or consumption of unprocessed milk? Raw milk is unprocess milk. The moment milk is pasteurized it become

simultaneously cooked and process.

Response: As mentioned before, the milk that is mainly sold in the informal sector in Kenya is in its majority sold raw. Some participants like milk bars can sell boiled. Boiling milk is not regarded as pasteurization. In the case study, consumers were also interviewed about their consumption practices as table 2 shows.

3.On page 2 lines 13-14, you are talking about rural, peri-urban, and urban areas. Where are they located?

Response: Map added for reference.

4.On page 2 lines 15-16 "This case study was assembled based on semi-structured interviews" Kindly paraphrase and check the grammar.

Response: Changes made.

5.Check on the grammar mistakes. For example, in the background section page 2, line 6 "in favour to" instead of "in favour of"

Response: Changes made.

6.In the result section of the abstract, lines 22-23 you are saying that the informal dairy sector is associated with low-quality milk and food safety risks. Which quality parameters did you use to qualify your statement? Other than milk, what other food did you consider in your study?

Response: The FAO, defines food safety as: "Food safety is about handling, storing and preparing food to prevent infection and help to make sure that our food keeps enough nutrients for us to have a healthy diet. Unsafe food and water mean that it has been exposed to dirt and germs, or may even be rotten, which can cause infections or diseases such as diarrhea, meningitis, etc ." For this case study food safety only applies to the object of study that is milk and the way it is handle in the informal supply chain that increase the risk of having unsafe milk.

7.In your conclusion page 2 lines 31-35, which are some of the good handling practices? You say there is a need to reform Kenya's informal dairy market and train to improve hygiene. Who does the reforms? Who is to be trained?
Response: The conclusion mentions that informal operators in general should be trained by the Government of Kenya. Good handling practices include hygienic practices, the use of correct containers and refrigeration. These examples are mentioned through the article.
Introduction
1.Abbreviation of words is done the first time they appear in the document. For example, on page 3, lines 5 and 48. Sub-Saharan Africa is supposed to be abbreviated in line 48 whereas it is supposed to be done in line 5. Check also page 7 line 4.

Response: Changes made.

2.Avoid long sentences in your work. Use short and precise statements for clarity. For example, you can paraphrase lines 2-8 on page 3 to read as follows, "Kenya which is in sub-Saharan Africa (SSA), suffers from food insecurity due to several intertwined reasons. Some of the reasons include climate change and poverty. For instance, in 2019, a delayed rainy season led to water scarcity causing food shortages limiting household food availability, decreasing dietary diversity, and amplifying malnutrition problems."

Response: Changes made.

3.Do proper citations for your manuscript. For example, on page 3 line 14, the comma between Kiamba et al. and the year is not supposed to be there. In other instances, you have italics in et al, e.g. page 4 line 50, while the others are not. Adopt the same citation for the whole manuscript.

Response: Changes made.

4.The use of the same vocabulary twice in one sentence is not appropriate. For example, on page 3 line 16, the word "sector", page 6 line 29-30 "practices" appears twice. Also, paraphrase lines 14-14 on page 3 to read well. The statement lacks clarity.

Response: Changes made.

5.Paraphrase line 21 on page 3 to read as follows, "The legal framework for the Kenyan dairy sector reforms began in 2004." Also, provide a citation to support your statement.

Response: Changes made.

6.Correct grammar on page 3 lines 22, 26, "was focused". Just write, "The purpose of the reforms focused…."

Response: Changes made.

7.Since your interest is in milk, I suggest you use milk safety instead of food safety for specificity.

Response: Food safety is a widely know term use like so involving a scientific method describing the best practices to prevent food-borne illness.

8.On page 3, from lines 34 to 38 is one sentence with so many different statements. Kindly paraphrase and use short sentences. This kind of comments on format, think it has to do more

Response: Changes made.

9.In line 45 page 3, you say that the importance of this case study has been to review all types of contaminants present in raw milk. How did you determine the contaminants in raw milk? Did you carry out laboratory tests?
Response: For this case study, the main point of evaluation was how the handling, distribution and storage practices done by the actors of the informal sector increase the likelihood of different types of risks.
Section 2. Food safety of consuming raw milk
1.I do not understand what you mean when you say "risks of consuming raw milk". Do people nowadays consume raw milk?
Response: Yes, there are various studies that showcase that consumption of raw milk is a common practice is diverse geographical locations in and out of African countries, here just one example of those studies: MacDonald, L. E. et al. (2011) 'A Systematic Review and Meta-Analysis of the Effects of Pasteurization on Milk Vitamins, and Evidence for Raw Milk Consumption and Other Health-Related Outcomes', Journal of Food Protection, 74(11), pp. 1814–1832. doi: 10.4315/0362-028X.JFP-10-269.

2.On page 4 lines 10 and 11, you are referring to a study, which says, "In the case of Kenya, raw milk is rarely consumed like so since it is boiled…." This statement contradicts your study. Check.

Response: Changes made.

3.The authors overgeneralize some elements with the milk value chain. For example, in page: 4 "In the case of Kenya, the microbiological quality of milk especially of that sold in the informal market is relevant, since various studies done in different regions of the country have established that milk does not comply with the standards set by the Kenyan Bureau of Standards (KEBS) (Omore et al., 2002; Wanjala et al., 2017)." This is a generalization of an entire milk value chain based on two studies in two districts of Kenya; the author needs to support this with more studies.

Response: There is limited information regarding the informal sector in Kenya. The available information as well as the authority stakeholders show that microbiological quality of milk is a central concern for food safety. Compliance of standards is one key

element that the informal sector lacks since they have very limited interactions with the authority or any control mechanisms.

4.Use footnotes to differentiate the terms on page 4 line14 and 15, "controlled temperatures, holding times and thermal processing".

Response: Changes made.

5.What do you mean by unsupervised and unsafe boiled milk on page 4 lines 17-18?
Response: Milk that do not follow good handling practices or pasteurization guidelines is generally consider as unsafe and associated with zoonoses.

Section 2.1
1.Page 4 lines 53 and 54 is not clear

Response: Changes made.

2.Page 4 line 2, do you mean exposed?
Response: Changes made.

Section 2.2
1.Use footnotes or endnotes to define some terms used in your manuscript. For example, enterotoxins.
Response: Changes made

2.On page 5 line 23, it is not clear, did you mean, "….food borne milk-related disease outbreaks?"

Response: Changes made

3.I do not understand the link between the informal milk supply chain and antimicrobial and drug residues. Kindly work on it to come out clearly.

Response: In that section is stablish that there is a direct link between the presence of antimicrobial and drug residues in milk and the common practice in the informal sector of using unauthorized animal and health service providers.

4.Page 6 lines 28-29 the sentence is incomplete, "smallholder..."

Response: Changes made

5.Page 6 line 33 what do you refer to as the "final product?" In the same sentence, you have double full stops.

Response: Changes made

6.In this section, you also need to do a review of the informal milk supply chains in line with food safety risks.
Response: The food safety risks have been review in detail throughout section 2 of the introduction. Each of the risks have been associated with a part of the informal supply chain.
7.Lines 4-6 check grammar and punctuation
Response: Changes made

8.Enterotoxins: List a few examples of the milk-related outbreaks
Response: Changes made

9.Write B. cereus. in full
Response: Changes made

10.Lines 14-17: Provide relevant reference(s) for the statements.
Response: Changes made

11.Line 20-22 pg 5: Provide an elaborate definition of what 'enterotoxins' are. Maybe in

a footnote.
Response: Changes made. Definition in Enterotoxin section.

12.Line 44-45 pg5: Define in a footnote or in parenthesis: 'teratogenic' 'hepatocarcinogenic' 'mutagenic'.
Response: Changes made

Section 3
1.Page 6 lines 50-53,58 expound on what you mean when you say that, "the sector suffered from poor judgment".

Response: Changes made

2.Page 6 line 52 do you mean, "the informal milk sector was declared illegal?"

Response: Changes made

3.Line 3 pg6: Consider revising the pronoun 'his' and replace with article 'the'. Same with line 8-10 rephrase 'according to them' to 'according to these studies'.

Response: Changes made

4.Line 10 pg6: Do the authors mean 'associated with?'

Response: Changes made

5.Line 9 pg 6: revise to 'Nairobi, Nakuru, and Narok'

Response: Changes made

6.Line 16 pg 6: Do you mean increment or increase?

Response: Changes made

7.Lines 14-17 pg6: Sentence is too long.

Response: Changes made

8.Lines 3 pg6: Check on punctuation.

Response: Changes made

9.Lines 28-38pg6: Elaborate further on the type of storage and packaging that the informal dairy farmers in Kenya are using that are not food grade nor aluminum as stated.

Response: Changes made

10.Lines 44 pg6: place the two referenced in brackets since they are placed end of sentence.

Response: Changes made

11.Lines 58-61 pg6: Consider revising the structure of sentences to be clear.

Response: Changes made

12.On page 7 line 2, you are talking of four processors but you end up naming only two.

Response: Changes made

13.On page 7 lines 20-22, Paraphrase to read well.

Response: Changes made

14.Line 4 pg7: Use abbreviation SSA

Response: Changes made

15.Line 19 pg7: Did you mean 'must' or 'most'?

Response: Changes made

16.Line 46-48 pg7: check on format of the reference.

Response: Changes made

17.Line 1 pg 9: Did you mean 'established'?

Response: Changes made

18.Line 7 pg 9 what does SPD stand for? It has not been defined earlier.

Response: Changes made

19.Line 7-11 pg 9: Sentence can be broken to two.

Response: Changes made

20.Use current literature especially on page 7 lines 33-35. "central districts of the Rift valley and Central province have changed with the current constitution"

Response: No current literature on the region was found.

21.On page 8, lines 36-38 Paraphrase to remove word repetition.

Response: Changes made

22.On page 8, line 56 what do you mean when you say, "complex to understand ergo to comply"

Response: Changes made

23.Much of your work in section 3 (The dairy sector in Kenya) need to be in the introduction.

Response: Changes made
Section 4
1.On page 10 line 4 did you mean to say, "hurdles", or "handlers?"
Response: Hurdles because it refers to the obstacles that the system has.

2.Line 5 pg10: do you mean hurdlers or hurdles?
Response: Handlers because it refers to the operators.

3.The methodology section provides no description of the two study areas mentioned in the introduction (Kiambu and Murang'a). This description should include the current situation of the informal dairy chain within the areas in the context of this study.

Response: There is no information available of the context of the areas regarding the informal sector, that is why this case study is relevant to help fill that information gap.

4.Line 25-26 pg10: check on format of the reference.

Response: Changes made

5.On page 10 line 12, can you highlight what the case study protocol entails?

Response: The case study protocol was designed using the recommendations provided by Bryman (2015) and Yin (2012). The case study protocol included the overview of the project, the field procedures, the questions chosen and the guide for the report. The main reason for deciding to use this method was that it allows to retain a wholesome approach to the current situation of the dairy system in Kenya, especially of the informal sector

6.On page 10 lines 29-24, you indicate that the interviews were not based on statistical principles due to budget and time constraints. Is this not one of the limitations of your study? How then did you distribute your sample in the three areas you considered (rural, peri-urban, and urban)?

Response: Note that the purpose of the case study was to pursue an in-depth study of an informal dairy supply chain. There is no information about the population of informal dairy chains to in order to apply a statistical approach on the selection. Therefore, the focus consisted of applying the following rules: (1) Select a case that aligns with our topic of research (an informal dairy supply chain); 2. See if the case study has a "universal" applicability (based on other work done in Sub-Saharan Africa, e.g., Malawi, we chose to work on peri-urban informal dairy supply chains); 3. Ensure the case study is relevant in today's date (based on our knowledge of other informal supply chains in other countries, the characteristics of the selected chain were relevant to understand the case); 4. Choose a single case that functions as a sample (our focus was to pick a case that represented an informal supply chain and not whether it was representation of different areas of the country e.g., rural, peri-urban and urban).

7.If you did not follow statistical principles, are your results not going to be biased?

Response: As in any case study, we do not interpret it as a survey and therefore it does not cover all the potential cases. The purpose is to highlight some characteristics of informal dairy supply chains as regards food safety.

8.Paraphrase lines 29-30 on page 10

Response: Changes made

9.Page 10 line 44, did you mean interviewed?

Response: Changes made
10.You a missing the study area for your work (description and the map).

Response: Changes made

11.The authors overgeneralize some elements with the milk value chain.   For instance, on page 15: "Lastly, the selling facilities especially the milk kiosks and bars had some basic deficiencies like running water or electricity. Meaning that cleaning the containers and refrigerating the milk was not a possibility." This statement is contrary to the results. Yes, running water is a problem but did the researcher check if the sellers have improvised other methods to store water. The statement would be phrased to induce low hygiene levels while cleaning the containers but not lack of cleaning.

Response: Changes made
12.The variables for the study are missing.

Response: Changes made

13.Line 12: design or designed?

Response: Changes made

14.Line 37: revise to 'Jomo Kenyatta University of Agriculture and Technology (JKUAT).

Response: Changes made

15.Line 51 pg 11: I see no need to include this statement. The authors should go directly to discussing/ presenting the results

Response: Changes made

Section 5
1.Elaborate on the case study protocol method so that readers can understand how results are reported. At the moment the results are confusing.

Response: Changes made

2.Table 3 on page 12, Table on page 13, Table 5 on page 14, contains a summary of the interviews. Where are the results of the study? The summary of the interviews are the results of the study.

Response: Due to confidentiality reasons and considering the length of the article, the detailed interviews are not included, and the authors opted for a summary of the key findings. The anonymous interviews are available from the authors upon request.

3.On page 14 line 2, you are saying that lack of accountability is reflected in the way milk goes from one actor to the other, you need to conceptualize these actors in a flow chart for readers to understand your work.

Response: Changes made
4.This section is confusing. Kindly work on it
Response: Changes made
5.Line 58 pg 14: do you mean 'milk stored'?

Response: Changes made
6.Line 1-5 pg 15: The sentence is not very clear. Also check on the tenses used. Line 5, check on the formatting of the reference.

Response: Changes made

7.Line 36-37 pg 15: Check on grammar "as mentioned before…" The authors also state 'one of the biggest challenges…' yet there are two challenges mentioned in that sentence.

Response: Changes made

8.Line 39-40, 53-54, 57-60, line 1 pg 16: Check on grammar and consider revising the long sentences to be clear and precise.

Response: Changes made

Section 6
1.Align your conclusion in line with the study objectives.
Response: Changes made

Section 8
1.In your acknowledgments, you say that the paper is based on work done as part of the MSc. Thesis in Food Security by Ms. Zavala-Nacul (University of Edinburgh) and from the Dfid-ESRC project "Assessing the contribution of Dairy Sector to Economic Growth and Food Security in Malawi" (ES/J009202/1). How then do you have a study area in Kenya and not in Malawi where the project is implemented?
Response: As mentioned, the works done in Malawi was a reference for this case study. We use that previous study to evaluate its applicability in other informal sectors.
References
1.You have used relevant research, and it has a homogeneous format, but look at the in-text citations and work on them.

	Response: Changes made
Additional Information:	
Question	**Response**
Is this study a clinical trial?<hr><i>A clinical trial is defined by the World Health Organisation as 'any research study that prospectively assigns human participants or groups of humans to one or more health-related interventions to evaluate the effects on health outcomes'.</i>	No

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1

Abstract

Background

Informal dairy supply chains are important in Sub-Saharan Africa (SSA), both in terms of employment and nutrition for poor population. Their safety has been debated in the literature, with those in favour to their legalisation, arguing that boiling milk reduces sanitary risks is enough to make it adequate for its consumption and the nutritional impact offsets thosehe possible sanitary risks. While, the those opposing side to it, highlighting that boiling milk does not eliminate all the contaminants that are found, and the long term sanitary and health impact should be a major concern for regulatory enforcement.

The purpose of this case study, which focuses on food safety along a dairy supply chain in Kenya, the largest milk producer in Africa, is twofold: first, to review the different issues on food safety when consuming raw milk, and second, to extract lessons from a case study that follows an informal supply chain that operates in rural, peri-urban and urban areas in the Kiambu and Muranga counties in Kenya. This case study was assembled based on semi-structure interviews to 29 stakeholders and participants of an informal dairy supply chain carried out in April-May 2019. The purpose of the interviews was to provide insights of the hurdles and food safety risks surrounding everyday activities of milk handlers.

Results

The results indicate that the informal dairy sector is associated with low-quality milk and food safety risks. These assumptions are linked to several factors such as lack of contact and control from the sanitary and health authorities, lack of awareness regarding milk safety from both consumers and the different supply chain participants; and the poor operating conditions the informal market has. Additionally, other aspects were the overall lack of hygiene, accountability, and infrastructure in the entire supply chain.

Conclusions

In conclusion, greater focus should be put on improving food safety quality along the chain (e.g., through ensuring the application of Good Handling Practices like the use of food grade containers and the introduction control points). The reform of Kenya's informal dairy market must focus on training to improve and increase the hygiene and safety practices of theeir informal operatorsion to reduce the current information gap that divides formal from informal. with the participants of the informal supply chain.

Keywords - Informal milk supply chains, food safety, Kenya, Sub-Saharan Africa.

2

Food safety and the informal milk supply chain in Kenya

1. Introduction

Kenya, located in Sub-Saharan Africa (SSA), suffers from food insecurity due to several intertwined reasons. According to the regional overview of the FAO, three major drivers affecting food security are climate change, conflict and economic slowdowns (FAO, 2019) such as climate change and poverty.; for instance, Iin 2019, a delayed rainy season led to water scarcity. This situation causeding food shortages limiting household food availability, decreasing dietary diversitydiversity, and amplifying malnutrition problems (FEWS NET, 2019). The most vulnerable households in crisis reduced their meals to one per day with maize, beans, oil, and sugar as the key staples. This cluster of situations (environmental, social, and economic) worsens the general status of food security in the country (FEWS NET, 2019).

Agriculture in Kenya is an important economic pillarsector that contributes to 24 per cent of the Gross Domestic Product (GDP). Within the agricultural GDP, Kiambi et al., (2018) who studied the Nairobi informal sector area, indicated that the dairy sector represents 12 per cent of the agricultural GDP and it is known to be one of the major sources offor nutritional security, especially for the lower-income groups. Moreover, the informal sector represents 70 per cent of the dairy's jobs and 86 per cent of the milk market (Kaitibie et al., 2010). The informal sector involves those actors that participate in the supply chain but are not registered or licenced to operate (Kiambi et al., 2020).

The legal framework of the Kenyan dairy sector was reformed at the beginning of 2004. The purpose of the reform was focused on the economic importance that the informal sector (i.e., those trading in raw milk) had for smallholders' producers. It fomented the revision of policies to decriminalize their activities and encourage their registration with the respective authorities (Kaitibie et al., 2010). Before then, milk regulation was focused on large-scale production that only represented the minority of the dairy sector. However, the reform was accused of being a pro-poor policy that empowered more the informal sector rather than focusing on the development of the formal one (Kaitibie et al., 2009). In recent years, due to lobbying power from the private sector, there has been pressureed to go back to the pre-2004 regulatory system that illegalizes the trade of raw milk (Mwere, 2019), which is associated with low-quality milk and food safety risks.

It should be noted that in contrast with dairy supply chains in developed countries (e.g., (Antonioli & Santeramo, (2021)Antonioli and Santeramo, 2021 and their cited literature) and despite their importance in continents such as Africa, iInformation about the actual functioning of informal dairy supply chains is limited;, in particular, when consideringly from a detailed food safety point of view.. From the food safety position, the case of informal chains is interesting because it differs from cases of food fraud such as the melamine contaminated infant formula in China (e.g., (Yang et al., 2020) Yang et al., 2020) as they operate openly and consumers knowingly purchase the raw milk (i.e., there is no asymmetric information).

Hence, tTand the purpose of this studyis is the reason behind the current case study, which focuses mainly on the Kenyan counties of Kiambu and Muranga, is to and attempts to present a picture of all the links involved in the informal milk food chain and itstheir food safety issues (note that aspects related to supply chain management e.g., trust or business performance as in Susanty et al. (2017) (Susanty et al., (2017) were not considered). Some of the studieda Aspects that were factors studied were: factors such as ccontact and control with the sanitary and health authorities, awareness regarding milk safety from both consumers and the different supply chain participants; and the

general operating conditions of the informal market has. –Additionally, other aspects revised werewere hygiene, accountability, and infrastructure ofin the entire supply chain.

The importance of this case study has been to review all types of contaminants present in raw milk and that represent public health risks. In addition, the value of the results is meaningful because Sub-Sahara African (SSA) countries see the reform of the Kenyan dairy sector as an example and a way to progress their own sectors.; i.e., Iif the SSA countries want to legalise their informal sector they need to consider all the aspects, benefits, and hurdles that this sector provides. Additionally, they also need to examine, and the challenges introduced by the Kenyan reform and its compliance. For example, criminalizing the informal sector and ostracizing it from the aid of the sanitary authorities (Kiambi et al., 2020).

The structure of this paper is as follows: It starts with a review of food safety risks of consuming raw or unpasteurized milk, proceeding with a next a review of the literature review on the dairy sector in Kenya is presented. Afterwards, the This is followed by methodology used in the paper is presented: i.e., methods and data, continued by the. The results, and discussion are then presented and f.Finally the , conclusions are stated.

2. Food safety risks of consuming raw or unpasteurizedraw milk

Raw milk quality and safety depend oin several factors, generally, they can be derived from having and maintaining good agricultural practices, good veterinarian practices and good hygienic and handling practices (Smigic et al., 2012). Healthy milk comes from healthy cows, but milk quality can easily decrease if the proper conditions are not kept while milking and handling the product.

In the case of Kenya, raw milk is rarely consumed like so since it is boiled by the majority of the consumers (approximately 96 per cent) (Omore et al., 2002). It is well documented that the adequate thermal processing or pasteurization[1] helps reduce mainly the microbiological risks associated with milk consumption (Macdonald et al., 2011; Oliver et al., 2009). However, boiling milk at home without maintaining ahaving controlledstandardized temperatures during a define period of and holding times is not regarded as the equivalent toof pasteurizingroper thermal processing. Additionally, there are other typese of contaminants that are thermostable and remain mostly unaltered. Therefore, the consumption of low quality, unpasteurizedsupervised and unsafe boiled milk could pose a high public health risk.

2.1 Microbiological risks

Milk is a rich substrate. Its physicochemical composition and water content make it prone to the proliferation of spoilage bacteria and pathogens. High milk quality is associated with a low number of somatic cells and a low bacteria count. It is free of antibiotic residues and human pathogens (Oliver et al., 2009). Fresh milk from a healthy cow has a low microbial load (less than 1000 per mL). When milk is not handled properly and is stored at room temperature, rather than ion refrigerated conditions, this load can increase 100 fold (Ssemukasa & Kearney, 2014).

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[1] "Pasteurization of milk is defined as the heating of every particle of milk to a standardized temperature for a defined period of time without allowing recontamination of that milk or milk product during the process" (Macdonald et al., 2011)

4

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Raw milk can be a vehicle of transmission of a broad range of human pathogens. According to Oliver *et al.* (2009), the most commonly reported pathogens associated with milk are *Listeria* and *Salmonella.* However, other zoonotic pathogens that are present in the cattle gastrointestinal system can also contaminate the milk if the correct practices are not implemented like *Campylobacter, Yersinia*, Shiga-toxin-producing *Escherichia coli* (STEC) or Verocytotoxin-producing *Escherichia coli* (VTEC) and *Staphylococcus aureus* (Artursson et al., 2018). Ano~~O~~ther known food-borne pathogen is *Bacillus cereus*, a spore-forming, well-adapted and highly resistant contaminant that can also produce biofilms (Bartoszewicz et al., 2008; Huang et al., 2020). Biofilms are surface based microbial communities that are used as a survival mechanism by different bacteria to adapt to extreme environmental conditions like heat, freezing, etc (Huang et al., 2020).

~~Other~~ I~~i~~mportant pathogens, particularly relevant in the case of raw milk are *Coxiella burnetii, Mycobacterium tuberculosis, Mycobacterium bovis*, that ~~–~~are the infectious agents causing illnesses like brucellosis, tuberculosis, typhoid, paratyphoid and diphtheria (Ssemukasa and Kearney, 2014; Wanjala et al., 2017; Artursson et al., 2018). Most of the pathogens can cause gastrointestinal problems.

In the case of Kenya, the microbiological quality of milk e~~s~~pecially of that sold in the informal market is relevant, since the limited available~~various~~ studies done in different regions of the country have established that milk does not comply with the standards set by the Kenyan Bureau of Standards (KEBS) (Omore et al., 2002; Wanjala et al., 2017) and smallholder farmers tend to have low knowledge level and negative attitudes to milk quality standards (Nyokabi et al., 2021). ~~Milkborne~~Milk borne diseases are directly associated with the consumption of low-quality milk. Therefore, the higher consumption of unpasteurized milk can lead to higher chances of a ~~milkborne~~foodborne milk-related disease outbreak (Oliver et al., 2009; Smigic et al., 2012).

As discussed before, milk in Kenya is mostly boiled before~~prior to~~ consumption. ~~But, I~~i~~t~~ is vital to highlight that even if ~~the~~ milk undergoes through~~is expose to~~ some thermal treatment, t~~,~~ there are still health risks posed to the consumers.~~:~~ F~~f~~or instance the prevalence of thermoduric bacteria and ~~,~~ the presence of spores (Bartoszewicz et al., 2008). Additionally, ~~and the fact that~~ if the bacteria load is too high , boiling milk, ~~thermal treatment~~ with~~out~~ the correct standardized times and temperatures, ~~uncontrolled time and temperature conditions~~ might not be ~~might not be~~ sufficient to eliminate them (Banik et al., 2014). ~~Additionally~~T~~,~~ there are other non-microbiological heat resistant contaminants that can affect milk safety.

2.2 Chemical risks

There are three main sources of chemical contamination in milk: first, toxins from bacteria and moulds; second, residues from antimicrobial agents like antibiotics; and third, the use of adulterants (Oliver et al., 2009; Ondieki et al., 2017; Ssemukasa & Kearney, 2014). The study of these chemical contaminants is particularly relevant in the case of Kenya since most of them cannot be removed or eliminated via thermal treatment. ~~(~~Nyokabi et al. ~~(~~2021), mentioned that smallholder farmers tend to participate in the informal system and that especially those with low knowledge levels have negative attitudes towards respecting antibiotics treatment withdrawal. They assume antibiotics are diluted in the bulking tanks or destroyed when the milk is boiled, making antimicrobial presence a recurring problem.

Enterotoxins

5

Enterotoxins are produced by certain bacteria. This type of toxins are harmful substances associated with food borne illness that affect the digestive system causing symptoms such as cramps, nausea, emesis, or diarrhoea (Bartoszewicz et al., 2008). The most common enterotoxins associated with milk come from Staphylococcus aureus known as staphylococcal enterotoxins. These enterotoxins are responsible for foodborne outbreaks across the world and are among the most common causes of gastroenteritis (Enquebaher et al., 2015; Oliver et al., 2009). Oliver et al. (2009), mentioned some outbreaks associated to the consumption of raw milk in the United States for example in 2008 in the state of California where 16 cases were confirmed with *Campylobacter* spp.

These microorganisms can produce their toxins in various stages along the production chain, particularly, during unchill storage. Even if *Staphylococcus aureus* is destroyed with thermal treatment its toxins endures (Artursson et al., 2018). Another toxin-producing microorganism is *Bacillus cereus*. This spore-forming microorganism can tolerate heat treatment and remain dormant and capable of producing toxins. Its toxins are mainly associated with gastrointestinal problems like emesis and diarrhoea (Bartoszewicz et al., 2008; Huang et al., 2020).

Aflatoxins

Aflatoxins are heat resistant and are regarded as the most important mycotoxin affecting human food and animal feed. Aflatoxicosis is associated with areas where there are climate stressors on plants (like droughts) and poverty (Coppock et al., 2018). The most common aflatoxin in milk is aflatoxin M1 (AFM1). AFM1 is a metabolite produced from aflatoxin B1 (AFB1) and excreted through milk or urine. AFB1 is produced mainly by *Aspergillus flavus* and *Aspergillus parasiticus* and it enters the cow's diet via contaminated feed (Lindahl et al., 2018). AFB1 has the highest degree of toxicity and is even classified in group 1 of human carcinogens by the International Agency on Cancer research. Both aflatoxins are considered teratogenic (affect the development of the embryo), hepatocarcinogenic (produce liver cancer) and mutagenic (cause damage in genetic material) (Anyango et al., 2018).

Aflatoxigenic fungi contaminate the crop preharvest primarily when the plants have adverse growing conditions; and then aflatoxins can be produced pre and postharvest, especially when the grains are stored in poor conditions where the fungus has a warm temperature and high moisture to develop (Coppock et al., 2018).

Antimicrobial and drug residues

Antimicrobial agents residues like sulfamethazine, gentamicin, tetracyclines are associated with public risk concerns mainly linked to allergic reactions that can vary in severity from skin rashes to anaphylaxis (Kang'ethe et al., 2005). In addition, the consumption of antimicrobial agents with regularity can lead to drug resistance affecting especially the population with immunodeficiencies for instance children, pregnant women and elderly people, causing long term effects on population health and disease control (Ondieki et al., 2017; Ssemukasa & Kearney, 2014).

According to the findings of Omore et al. (2002), most of the milk samples taken from the informal market from urban and rural Nairobi and Nakuru were contaminated with drug residues which limits were above the maximum level recommended by the international

6

food standards. In addition, Ondieki et al. (2017), reported the same kind of positive results for the region of Lamu. Kang'ethe et al. (2005), also reported a high prevalence of antibiotic and antibacterial residues in the milk samples from contrasting markets like Nairobi, Nakuru and Narok. Moreover, according to these studies, this risk is associated with the common practice of using unauthorized animal and health service providers.

Adulterants

In the case of adulteration, some common adulterants are water to augment the volume or the use of salts or urea to increment the solid content, these practices lower the nutritional value and can be a source of cross-contamination in the finished product (Ondieki et al., 2017). Other adulterants include colourants to cover any quality deviation, preservatives like chlorine and hydrogen peroxidase to extend the shelf life of the mixture of low-quality milk sourced from other animals. Milk adulteration or fraud is not only an economic issue but is also linked with health problems, like the use of urea can lead to renal problems for the consumers (Azad & Ahmed, 2016) and increasing microbial risk and pathogenic presence.

2.3 Physical Contamination

Hygienic milk handling and good farm practices are two areas that need to be improved in the dairy market in Kenya especially for the smallholder. Milk handling and good manufacturing practices have also a key role in maintaining milk safety. The use of the proper tools and the correct storing and packaging materials help reduce the presence of foreign objects in the milk ready to be consumed (Kurwijila, 2006). The most common materials used in the informal market in Kenya is cheap plastic. The recommended options are food-grade plastic or aluminium (Nyokabi et al., 2021; Omore et al., 2002). Physical hazards or foreign matter can cause harm that ranges from lacerations inside the mouth, throat, and gastrointestinal system to choking and asphyxiating. Foreign matter can also lead to cross-contamination or be a vector for microorganism development (Liu, 2018).

3. The dairy sector in Kenya

Kenya's milk sector contributes significantly to the livelihood of many households. As pointed out by Thorpe et al. (2000) and Kaitibie et al. (2010). According to Kiambi et al.(2020), the sector represents the source of livelihood for more than 2.6 million people and has an economic value of 230 million US dollars. The history of the Kenyan milk sector can be divided into four periods. First, the pre-independence period (before 1963) where dairy was mainly led by large scale colonialists and export oriented. Second, the after-independence I period (1967-1978) when the policy to include indigenous Kenyans was created. Third, the after-independence II period (1979-2004) when the sector suffered from bad management decisions and corruption that led to the development and propagation of the illegal informal sector. Fourth, the current administration (2004 onward) with the inclusion of a pro-poor policy that legalizes the informal market and decriminalizes the activities of the smallholder producers. However, population growth, urbanization and the rise in the demand keeps the sector developing and evolving (Kiambi et al., 2020).

The informal sector that represents 70 per cent of the dairy's jobs and 86 per cent of the milk market (Kaitibie et al., 2010). It is composed of all those actors that participate in this food system but are not registered or do not have a licence to operate (Kiambi et al., 2020). The formal

sector is mainly dominated by a few top ~~the top 4~~ processors. ~~with~~ Brookside Dairy Limited (Brookside) and New Kenya Co-operative Creameries LTD (New KCC) being the most important (Thorpe et al., 2000). However, SSA ~~sub-Saharan Africa~~ dairy and Kenya have become, in recent years, a new frontier of expansion to international companies such as Danone, Nestle and Unilever. For instance, in 2014, Danone bought 40 per cent of Brookside stakes planning an aggressive market takeover (Vidalon, 2014). The interest of private investors has had regulatory consequences. In 2018, a new regulation was proposed to make the trade of raw milk illegal again and to strengthen the role of processors and licences participants consequently going back to a 2004 panorama (Mwere, 2019).

In this section, the different parts of the supply chain will be presented to provide an updated picture of the system and the elements involved in it. Special focus will be given to the informal sector since most of the milk sold in the country follows through this path.

Milk comes mainly from cattle (84 per cent), camels (12 per cent) and goats (4 per cent). Milk cattle is mainly constituted of improved exotic breeds and their crosses and ~~of~~ indigenous zebu. While the improved breeds (Friesian–Holstein, Ayrshire, Guernsey, Jersey) provide mo~~u~~st of the milk, the zebu is better adapted to the environment and plays a key role in the more arid parts of the country (Muriuki, 2003). Whole fresh cow milk production has increased since the 90s going from 1.9 million tonnes in 1996 to 3.5 million tonnes in 2017: with an average yield of 6129 hectograms per animal for the last ten years (FAOSTAT, 2019). It should be noted that production is affected by climatic alterations like prolonged droughts, the rise in production costs and social problems like the displacement of farmers from high productive agricultural areas (Kenya Agricultural Research Institute, 2012).

Milk production systems can be divided into two main categories: high or market production and arid and semiarid systems (Bosire et al., 2015). ~~–~~Market production is mainly located in high altitude regions with a humid production system; 60% of the national production is located in the central districts of Rift Valley and Central province (Muriuki, 2003). This system is dominated by smallholder dairy farms that have mainly exotic-local breed crosses and a cut and carry feeding system. On the other hand, the arid/ semiarid system has a pastoralist subsistence production with an extensive grazing feeding system. This type of dairying is located in the north and south Rift Valley, eastern and coast regions (Muriuki, 2003; Bosire et al., 2015).

Kenya´s dairy value chain is mainly driven by small scale actors that operate independently but that are highly interconnected. This sector has a wide range of participants from authorities like the Kenya Dairy Board (KDB) and the Veterinary board to farmers of all sizes, dairy cooperatives, traders, hawkers, processing companies, cooling centres, retailers, etc. that are continuously interacting and developing their ~~own~~ channels, coordination mechanisms and rules (Kiambi et al., 2018, 2020).

Milk in Kenya flows through two main types of markets: the formal which sells mainly pasteurized milk and the informal that sells mostly raw milk (Figure 1). The formal market is operated by dairy enterprises that have a license, a well-defined legal framework, fixed facilities and are inspected regularly. Some key participants are processing companies and cooperatives (Kiambi et al., 2018; Nyokabi et al., 2018). This sector relies mainly on formal agreements between large-scale producers and ~~the~~ processors. The price setting is fixed by the processors with a lack of transparency or participation from the farmer (Nyokabi et al., 2018). By contrast, the informal dairy market is generally characterized for having limited infrastructure, with precarious access to clean water, electricity, sanitation, and refrigeration facilities, with no adherence to safety

regulations. Additionally, they operate without a licence, have limited support from the public sector and are alienated from participating in the formal market. This sector depends on transitions done on the spot, lacking formal contracts and contractual engagement (Alonso et al., 2018; Nyokabi et al., 2018).

Figure 1. Milk marketing channels in Kenya
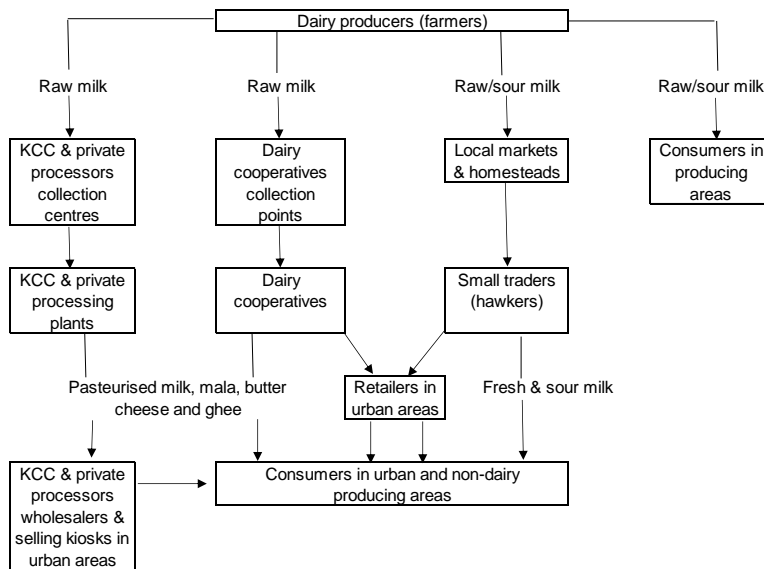
Source: Nyariki, 2009

Some of the main drivers for actors to participate in the informal market are: it is considered as an easy business with no barriers to entry, there is always a demand for unpackage raw milk and milk process can be set on the spot (Alonso et al., 2018; Nyokabi et al., 2018). Kiambi et al. (2020), mentioned that there are also many barriers that smallholders face and demotivated them to participate in the formal sector; like the lack of coherence between policy and practice, creating a fragmented regulatory system that adds complexity and additional operational costs without an appreciable benefit.

On a positive level, informal milk markets can be considered as a source of jobs for a more unprivileged sector of the population that needs access to cheap milk and money. In addition, farmers can have an unrestricted choice regarding whom to sell so they can access better prices when compared to the formal market (Nyariki, 2009). Adversely, this market has created some

9

challenges for the public sector, mainly related to quality control and food safety e.g., milk that is rejected by the formal market can be sold here at a lower price without any verification.

According to Alonso et al. (2018), informal traders consider that licensing can be costly, and the regulations are complex to understand hampering their compliance~~ergo to comply~~. In the light of this situation, the KDB with the help of the KEBS and the sanitary authority has implemented a series of training programs focusing on the importance of hygiene practices, introducing simple quality tests and assessing ~~on~~ regulation compliance (Alonso et al., 2018). Regardless, Kiambi et al. (2018), mentions that licensing and participating in the formal market is not a guarantee of food safety, since many established and trained traders continue to operate with similar unrecommended practices mirroring those of the informal sector.

Before 2004, the milk regulation was focused on large-scale production that only represented the minority of the dairy sector. However, there was a change largely due to the creation and implementation of the Smallholder Dairy Project (SDP) that focused on the sustainable development of this type of producer~~s~~. S~~P~~DP had two main phases: the first (1997-2000), highlighted the critical role that the informal market had on the livelihood of people and how being neglected by the public sector led to public risk hazards, this phase also involved improving farming practices, bringing innovation into handling and transport. The second phase (2000-2005) focused on understanding the importance of the sector and fomenting the revision of policies to decriminalize their activities (Kaitibie et al., 2010). However, this was not an easy transaction and the country had mediatic "Milk wars" and was accused of having pro-poor policies that empowered more the informal sector rather than focusing on the development of the formal one (Kaitibie et al., 2009).

The main policy change was the Legal notice 102 that expanded the types of licenses that could exist and re-established the licence application procedures. These licenses try to ensure better quality for the consumers by forcing traders to meet hygienic conditions and comply with sanitation and health standards. Thanks to this change, KDB was able to interact more freely with this market, start training and licencing programs. In addition, the relationships between smallholders and health regulators improved by reducing harassment from the authority and disincentivising bribing (Kaitibie et al., 2009, 2010). Some of the regulations that affect the sector are~~:~~ the Dairy Industry Act CAP 366 that gives power to the KDB as the authority in charge of licencing and supervising milk handling, quality and safety along with the food system; the Public Health Act, Chapter (CAP) 242, the Drugs and Chemical Substance Act, CAP 254, and the Meat Control Act, CAP 354 (Kiambi et al., 2020). Furthermore, KEBS has also set a series of programs to aid in the compliance of standards. The standards are mainly divided into 4 types: compositional, microbiological~~,~~. ~~a~~Antimicrobial residues and aflatoxins. ~~T~~the main ones that address milk quality and safety (till 2019) are shown in Table 1~~, that address milk quality and safety~~.

Table 1. Main standards for milk active to the 2019

Standard	Name
KS 12-1&2:1976	Determination of fat content in liquid milk - Part 1: Rose Gottlieb method (Reference method) - Part 2: Gerber method (Not for reference).
KS 13-1&2:1976	Determination of total solids in milk - Part 1: Gravimetric method - Part 2: Density method. / Milk and milk products
KS ISO 4833-1:2013	Microbiology of the food chain-Horizontal method for the enumeration of microorganisms Part 1: Colony count at 30 ℃ by the pour plate technique. / Milk and milk products

KS ISO 4833-2:2013	Microbiology of the food chain - Horizontal method for the enumeration of microorganisms Part 2: Colony count at 30 ºC by the surface plating technique. / Milk and milk products
KS 33-1&2:1977	Determination of the presence of preservatives and pesticide residues in dairy products - Part 1: Determination of the presence of preservatives in milk - Part 2: Determination of pesticide residues in da / Veterinary drug Residues and Antimicrobial Resistance in Food
KS 37:1977	Code of hygienic practices in the dairy industry for milk carriers. / Milk and milk products

Source: KEBS, 2019

4. Empirical analysis

The purpose of this section is to provide an overview of the case study done in the Kiambu and Muranga counties in Kenya. This case study had the objective to observe closely how the dairy supply chain operates in rural, peri-urban and urban areas. It aims to contribute to the development of a holistic view of how the informal market functions while providing meaningful insights into the hurdlers and food safety risks surrounding everyday activities of milk handlers by conducting a series of interviews with different participants and stakeholders of the sector.

4.1 Methods

The case study protocol was designed using the recommendations provided by Bryman (2015) and Yin (2012). The case study protocol included the overview of the project, the field procedures, the questions chosen and the guide for the report. The main reason for deciding to use this method was that it allows to retain a wholesome approach to the current situation of the dairy system in Kenya, especially of the informal sector. The semi-structured questionnaire developed (Annex) for the interviews focussed on covering general topics that were transversal throughout the entire supply system (e.g., pricing, quality keeping and common food safety problems). Then, they include differentiated sections for each type of participant and their faced challenges. The interviewed included various actors of the supply chain from farmers of different production sizes to cooling tanks operators and administrators, to the consumers and the authorities.

These interviews were not based on statistical principles, but they were convenience sampling focused on the desire to collect as much information as possible given the budget and time constraints. Semi-structured interviews and informal discussions were used to engage with the participants while they were doing their routine milk operations.

Since the focus of the study was the informal market, most of the interviewed were without any prior appointment. All the information was written down considering recording was not an option due to the setting being too noisy in most of the cases. Word of mouth was a helpful way to find participants in the region and to connect with the different links of the supply chain.

The case study team had four members: a chauffeur that was acquainted with the region and three masters' students, 2 of them from the Jomo Kenyatta University of Agriculture and Technology (JKUAT) that help translating some of the responses and making the people interviewed more comfortable, and the main author.

11

Limitations of the study are that some participants especially those from the informal market did not feel comfortable sharing personal information or answering some key questions. For these cases, that information was left as a blank and an informal approach was taken to try to extract other relevant data. Additionally, since many people ple interviewed did not speak English, the information presented also relies on the translation made in situ by the master students previously mentioned. Another important limitation is that people from the peri-urban and rural areas were open and willing to participate in the interviews for free; while the people encountered in the urban Nairobi, reject answering the questions if a monetary compensation was not included. For this reason, this study does not include interviews from the informal market in Nairobi city.

Note that the purpose of the case study was to pursue an in-depth study of an informal dairy supply chain. There is no information about the population of informal dairy chains to apply a statistical approach on the selection. Therefore, the focus consisted of applying the following rules: (1) Select a case that aligns with our topic of research (an informal dairy supply chain); 2. See if the case study has a "universal" applicability (based on other work done in Sub-Saharan Africa, e.g., Malawi, we chose to work on peri-urban informal dairy supply chains); 3. Ensure the case study is relevant in today's date (based on our knowledge of other informal supply chains in other countries, the characteristics of the selected chain were relevant to understand the case); 4. Choose a single case that functions as a sample (our focus was to pick a case that represented an informal supply chain and not whether it was representation of different areas of the country e.g., rural, peri-urban and urban).

The case study area is shown in Figure 2, with Kiambi county indicated in red and Murang'a in purple. Kiambu County is in the central region of Kenya. This county has a high population growth rate of 2.81% and an influx of people working in Nairobi but living here. The county is ongoing industrial development and a growing urban population (Kiambu County Official Website, 2021). Murang'a County is bordered to the south by Kiambu. The county has 6 agro-ecological zones where tea, forestry and tourism are the most important activities. The lowlands have an adequate climate for dairy farming and agricultural production (Murang'a County Official Website, 2021).

Figure 2. Map of case study area

Source: Own elaboration

12

4.2 Data

In total 29 interviews were carried out in April-May 2019; Table 2 provides an overview of the participants and the role they have in the sector. As this Table shows, there can be more than one participant that does similar functions on different scales or that have multiple roles. For instance, there are some that perform a double or triple role like farmers that are owners of a milk bar or farmers that can participate in the formal and informal sector at the same time by having different buyers.

Table 2. Number of participants interviewed and their roles in the milk sector

Role	Number of interviewees	Function of each participant
Farmers	7	Big scale production farmer (180 producing cows)
		3 medium-scale farmers (Own more than 5 producing cows)
		3 smallholder farmers (less than 5 producing cows
Transporter	1	Double role as a farmer and as a transporter between farms and the cooling tank
Cooling tank / bulking tank Do not pasteurize	3	Site operator of the facilities in the cooling tank
		The administrator of government own cooling tanks in the county (Stakeholder)
		The administrator of privately own cooling tanks in the county (Stakeholder)
Processor /distributor Pasteurize	1	Pasteurizes milk and delivers to milk vending machines.
Milk kiosk	3	Owner or salesperson of the milk kiosk that sells directly to the final consumer
Milk bar	4	Double role as farmers and as owners of the milk bar that sells their own milk directly to the final consumer
		Salesperson of privately own milk bar that sells directly to the final consumer
Milk vending machines	3	2 owners of small shops that operate a milk vending machine
		Supervisor of a supermarket that operates a milk vending machine
Consumers	5	School girl administrator responsible for purchasing the milk for the staff and the students.
		4 final consumers for personal consumption
Authorities	2	Representatives of KDB and KEBS (Stakeholder)
		Former chairman of Kenya Veterinary Board (Stakeholder)

Source: Own elaboration

5. Results and discussion

The purpose of this section is to present the results of the analysis and discuss them.

5.1 Results

The key findings of the interviews are presented here in a series of tables separated according to the type of participant (stakeholders, farmers, transporter, etc.). The first differentiation done was between stakeholders and those regarded as general actors The interviews conducted were divided into two groups: stakeholders and general participants. In this section, a summary of the most important findings is presented in a series of Tables divided by participant[2]. Stakeholders are the authorities while general actors are the rest of the links in the supply chain. Table 3 includes the information from the stakeholders, Table 4 presents the information from the first stage in the supply chain: the farmers and producers., and Table 5 encompass the information from the different selling points.

Considering thatSince thethe focus of the case study is understanding the way the informal sector operates, those participants that participate were mainly infrom the formal sector, like the milk processors, are not included in the overview here shown. Each table covers the key topics that affect each of the participants in the supply chain.

Throughout all the interviews conducted milk quality and safety seem to be two concerns that all actors have in common. As Table 3 shows, the authorities emphasize that one of the main drivers for the growth of the informal market is the lack of awareness of the consumer regarding the importance of consuming safe milk that is safe. Additionally, they also mention that milk pricing can be a factor that encourages the participation of the consumer in the informal sector. since Tthe implementation and maintenance of quality is an a expensivecostly endeavour that increases production costs. The added value of safe milk is not always reflected in the final tends to increase the final milk price or in the consumers choice. Consumers with low-income need low-cost milk to be able to afford it.

Table 3: Summary results of the interviews with authorities

| Topic | Stakeholders | |
	KDB and KEBS	Former chairman of Kenya Veterinary Board
Challenges the sector faces	• Lack of proper regulatory framework • Challenges developing quality standards • Understanding Ceosts and technical implications of complying and implementing standards • Lack of market accessdirect interaction with all the level of the supply chain • Lack of awareness on the relevance of milk safety	• Lack of regulation of veterinary practices according to the law • Milk safety hazards that affect public health like the presence of contaminants as mycotoxins and adulterants • Unsanitary milk handling practices throughout the supply chain
Drivers for growth of the informal market	• Milk pricing (what the consumer can afford) • and the cost of Ceompliance has no added value and is not reflected in prices.	• Lack of control on the operation of hawkers that can operate freely. • Less accountability and binding responsibilities. • Cheap to operational costs

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[2] Due to confidentiality reasons and considering the length of the article, the detailed interviews are not included, and the authors opted for a summary of the key findings. The anonymous interviews are available from the authors upon request.

	• Less accountability of the suppliers (no legal consequences if the law is infringed). • Participants do not understand that every step in the chain is a control point important to ensure quality.	

Source: Own elaboration

Tables 4 and 5 show that, all the interviewees ed, regardless of their size, consider that hygiene is one of the most relevant aspects to consider for ensur eing quality. However, sSome smallholders did not have access to the correct facilities or public services like running water complicating hygienic handling. For transport and storage, mMost of the smallholder participants use plastic containers. To clean these containers the common practice is to use regular and clean them with soap and water or with hot water, soap soap, and bleach. There is no after testing to evaluate possible residues.

The system follows many routes to reach the final consumers with actors participating in both markets simultaneously, interlinking the formal and informal system at different levels. Out of all the people interviewed; only a few participants, especially those that could be categorized as big scale in terms of production, have received adequate milk handling or quality training from certified authorities. On the same line S, small and middle actors have limited knowledge of some of the main risks associated with milk. For instance, few participants have heard about mycotoxins or knew about aflatoxins in milk.

The common usual selling price per litre for small farmers to cooperatives was is between 30-36 Kenyan shilling (KSH) per litre. Processors that pasteurize the milk reported buying the raw milk at 40 KSH/litre and selling pasteurized milk at 55 KSH/litre. Next, Following that supply chain, tthe milk vending machines owners reported their selling prices at 60-65 KSH/litre. Contrastingly, the milk kiosks and bars interviewed, that sold raw milk had a coinciding selling price of 60 KSH/litre. Hence, the final consumers pay a very similar price for raw or pasteurized milk.

Table 4: Summary results of the interviews with farmers and transporters

Topic	Actors			
	Farmers (7 interviewed)			Transporter (1 interviewed)
Size	Big scale of production farmer	3 medium scale of production farmers	3 smallholder farmers	Milk transporter and smallholder farmer
Production capacity	1300-1400 litres/day	145-160 litres/day	10-20 litres/day	
Refrigerated storage capacity	Yes	2 farmers: out of 3: Yes 1 farmer out of 3: No	No	No refrigerated transportation
Milk selling price per litre	50-60 KSH	30-36 KSH	30-36 KSH	To transport milk 3 KSH/L
Main buyers	Final consumer i.e., banks and schools.	1. For own consumption 2. A C cooling tank or cooperative	1. For own consumption 2. CA cooling tank or cooperative	KCC

			3. ~~BA~~ broker	3. ~~BA~~ broker	
Quality practices	• Check feed quality • Quality practices place in situ • Animals' health check routinely	1. Cleaning of the udder 2. Check regularly cow's health 3. Milk kept in cool condition after milking either inhouse or in a cooling tank	General mention of hygiene. No specific practice was reference.	1.Transports milk in an Aluminium can. 2.Collects milk as soon as milked	
Receive training	Yes	Yes	Yes, but not from certified authority	No	

Source: Own elaboration.

~~The informal milk market is the one that operates outside of the legal framework. KDB and KEBS representatives agreed that lack of compliance in the regulation, followed by the lack of awareness of the consumers are two relevant factors that directly impact the quality of the milk sold, especially of unpacked raw fresh milk. The generalize opinion of the participants is that handling milk with hygiene is directly linked to having a good quality product.~~The informal milk market is the one that operates outside of the legal framework. KDB and KEBS representatives agreed that two relevant factors that directly impact the quality of the commercialized milk, (especially of unpacked raw fresh milk) are the lack of compliance in the regulation and the lack of awareness of the consumers about safety risks. The general opinion is that handling milk with hygiene is directly linked to good quality. However, the observed situation demonstrated that some of the adopted practices mainly of the informal sector reflected the lack of capacitation and training that affects the system. Additionally, the lack of testing is also evident since almost none of the participants relied in certified laboratory results to ensure quality or safety of their products.

The lack of vertical integration of milk pricing is another factor that is worth mentioning. The milk bought raw or pasteurized in formal and informal places had remarkably similar prices. The cost of compliance and pasteurization is not shown in the final price, displaying they have no added value for the consumer. ~~Milk pricing is another relevant aspect that is directly connected to milk safety since the milk bought raw or pasteurized in formal and informal places have remarkably similar prices, so the cost of compliance is not reflected in the final price.~~

Table 5: Summary results of the interviews with milk kiosk, ~~bars~~bars, and milk vending machines

Topic	Participants		
	Milk kiosks (3 interviewed)	Milk bar (4 interviewed)	Milk vending machine (3 interviewed)
Milk buying price per litre	40-50 KSH	Not disclose	Not disclose
Milk selling price per litre	60 KSH	50-60 KSH	60-65 KSH
Supplier	• Direct from farmers • Hawkers	3 out of 4 - sourced from own production 1 out of 4 sourced from hawker	Processor
Milk quality checks in situ	• No testing was done but they all mention trusting their suppliers • Organoleptic test		
Sell raw milk	Yes	2 out of 4: Yes	No

		2 out of 4: No	
Storage with refrigeration	1 out of 3: Yes 2 out of 3: No	2 out of 4: Yes 2 out of 4: No	Yes, inside the machine
Main buyers	Final consumer		
Quality measures in the facilities	• Hygiene • Clean milk containers and measuring cups with soap and warm water. • Use of bleach to clean.		
Attended milk handling training	No	1 out of 4: Yes 3 out of 4: No	Yes, and a license to operate from KDB.
Main problems to ensure milk quality	Not having the correct facilities like running water for proper cleaning.		Problems with electricity

Source: Own elaboration.

5.2 Discussion

From a food safety perspective, to ensure that a certain product is safe, a systematic approach is necessary. Quality assurance requires that all the elements involved in the production comply twitho quality standards and that all the possible risks are foreshadowed and prevented (Ssemukasa & Kearney, 2014). Some of the risks found in the system are associated with the lack of awareness and accountability, absence of proper training, insufficient infrastructure, and milk pricing.

The actors interviewed from both types of markets highlighted the relevance that hygiene and quality have on safety. Yet, there is a lack of unification of what these terms mean or what do they encompass when applied to real life. Hygiene is a broad term that has an open interpretation. For farmers, hygiene should consider the conditions of the udder, the handler, and the container. However, some farmers especially smallholders did not have access to water which complicates and sometimes precludes the cleaning procedures.

Other sanitation problems involve the material of the containers and cleaning procedures used. Most of the smallholders use plastic containers and they clean them with soap and water or with hot water, soapsoap, and bleach. Residues of soap and bleach can become milk pollutants and affect human health (Ondieki et al., 2017). Additionally, if plastic containers are not properly clean biofilms can form and become a source of microbial contamination for any milk stored in them (Oliver et al., 2009). Ensuring milk quality when there are numerous steps and a lack of control in between them is challenging especially when milk handling involves many participants that are not qualified or aware of the risks associated with their daily activities.

The aforementioned complexity of the milk chains makes traceability a challenge. Lack of accountability is reflected in the way milk goes from one actor to the other without being properly tested. Figure 1 and Table 2 show the flow of the milk market and the main actors in Kenya, exemplifying how milk exchanges follow many types of paths and there are limited control points along them. The absence of accountability is also evident or by how rejected milk just gets resell but not risk analysis is done to prevent the events from reoccurring - (Nyokabi et al., 2018; Roesel & Grace, 2015). For instance, when milk from a transporter is rejected in the cooling tank; its disposal becomes their responsibility. Since their livelihood depends on this money, they sort alternative solutions like selling to hawkers that then distribute into the informal markets. These situations harm have a negative impact on the milk safety for consumers in the informal market; as Roesel and Grace (2015) stated: "what formal reject informal eats" (pp 28). Kiambi et al. (2020) also mentions that food safety is also compromised when milk becomes scarce and the consumer

17

especially those with low-income accepts low quality milk over nothing. Many of these risk situations could be avoided if there was more awareness of the hazards and the actors had access to reliable sources of information. Additionally, this situation could be avoided if the consumption of pasteurized milk was prioritized over raw milk ensuring a more stable milk flow with prolonged shelf life that is less dependent on~~f the~~ seasonality.

Training is a good way to create a web of informed actors (Alonso et al., 2018). As the case study shows, those participants that have had ~~the~~ capacitation seem to include more quality measures than those who have not. ~~; F~~for instance, the milk bar owner that mentioned going to training~~s~~ regularly had better handling practices when compared with the others i.e., washing the equipment between uses, refrigerating the milk and having a veterinary certification. This was also discussed in the interviews with KEBS and KDB. They asserted that training the sellers is key since they can have a ~~a~~ direct impact on the quality the consumers get. Some sellers that opt to act in the informal market have better prices or have more gains by compromising the quality and jeopardizing the consumer's health. Another problem regarding this issue is that even if capacitation is provided not all actors have access to it or are willing to participate for fear of retaliation or harassment from the corresponding authorities.

Another aspect that affects transversely the system is the lack of infrastructure. Infrastructure deficiencies can be categorized into four main areas: transportation, quality testing facilities, cooling facilities and selling facilities. As ~~the~~ mention before, one of the biggest challenges the sector faces are the distance from producing to processing to selling sites and the logistics involved in getting and keeping quality milk. There are in general not adequate ~~transportation~~ vehicles with refrigeration to move the milk from one place to the other. Milk that is not chilled increases the possibilities of spoilage and favours microbial growth (Artursson et al., 2018; Oliver et al., 2009). Cooling tanks have a triple function of bulking, chilling and acting as a quality control point. Nonetheless, visiting some of these facilities and witnessing how some of the tests are conducted is evident that not all locations can fully satisfy these purposes. Most of the tanks visited lacked the equipment and an adequate site for quality testing. Lastly, the selling facilities especially the milk kiosks and bars had some basic deficiencies like running water or electricity. Meaning that cleaning the containers following Best Handling Practices and refrigerating the milk was not a possibility.

Finally, milk pricing plays a pivotal role in milk safety (Ondieki et al., 2017). Some actors that participate in the formal sector like the cooling tanks have fixed prices throughout the year. These situations have positive outcomes like ensuring providers a fixed income from the milk sold. On the offside, milk is impacted by seasonality, during the drought season farmers have better offers from independent brokers and divert their milk to them. For that reason, the milk flow in the tank becomes irregular and complicates having fixed selling volumes. This ~~Which~~ consequently creates shortages for the formal system and makes process milk more expensive having further favoured the informal system, this situation was also mentioned by Nyokabi et al. (2018). Ano~~O~~ther situation regarding milk pricing that favourites the informal market is the difference between milk that goes through short versus long supply chains. When farmers sell their milk to cooling tanks, they get 30 to 36 KSH per litre. After pasteurization, that milk reaches the market with a price of 60 to 65 KSH per litre. In comparison, the farmers that sell raw milk directly to final consumers get 50 to 60 KSH per litre. Consequently, raw milk and pasteurized milk have similar prices. It is understandable why processors complained about having to pay extra fees for getting licenses or having to establish extra quality tests to comply with the regulations that are costly if they do not have the added value reflected on the selling price since the consumers are not willing to pay extra.

18

6. Conclusions

The purpose of this case study has been to provide information about ~~the~~ food safety along an informal dairy supply chain. The informal dairy sector is normally associated with low-quality milk and food safety risks. In the case study conducted the stakeholders stated that these assumptions are linked to several factors: first, the lack of contact and control from the sanitary and health authorities; followed by the lack of awareness regarding milk safety from both consumers and the different supply chain participants; and lastly, the poor operating conditions the informal market has.

Additionally, some ~~other~~ risks recognized with the case study were the overall lack of hygiene, accountability and infrastructure in the entire supply chain. Another interesting conclusion was that the milk prices the final consumer pays do not reflect the added value that pasteurization offers in terms of milk quality and safety. Raw milk and pasteurized unpacked milk tend to have very similar prices that are mainly dependable on the vendor.

Overall, the review of the safety issues related to the consumption of unpasteurized~~raw~~ milk indicates that there are contaminants that are not eliminated by boiling milk; however, several of these~~is~~ can be improved with better handling along the supply chain. A key aspect of the reform of Kenya's informal dairy market was ~~not just~~ the formalisation of raw milk traders and ~~but also~~ their training to improve the hygiene and safety of their operations. This needs to be reinforced by the authorities. Interestingly, the Government of Kenya announced in February 2021 the inauguration of a National Dairy Laboratory to conduct quality surveillance and safety compliance. This activity needs to be completed with further training to the participants of the informal supply chain.

The value of the results is meaningful because SSA countries see the reform of the Kenyan dairy sector as an example and a way to progress their ~~own~~ dairy sector. If the SSA countries want to legalise their informal sector they need to consider all the aspects, ~~benefits~~benefits, and hurdles that this sector provides, and the challenges introduced by the Kenyan reform and its compliance.

7. List of abbreviations

SSA   Sub-Saharan Africa
GDP   Gross Domestic Product
STEC   Shiga-toxin-producing Escherichia coli
VTEC   Verocytotoxin-producing Escherichia coli
KEBS   Kenyan Bureau of Standards
AFM1   Aflatoxin M1
AFB1   Aflatoxin B1
New KCC   New Kenya Co-operative Creameries LTD
KDB   Kenya Dairy Board
SDP   Smallholder Dairy Project
CAP   Chapter
KSH   Kenyan shilling
AFB1   Aflatoxin B1
AFM1   Aflatoxin M1
CAP   Chapter
GDP   Gross Domestic Product
JKUAT   Jomo Kenyatta University of Agriculture and Technology
KDB   Kenya Dairy Board
KEBS   Kenyan Bureau of Standards
KSH   Kenyan shilling
New KCC   New Kenya Co-operative Creameries LTD
SDP   Smallholder Dairy Project
SSA   Sub-Saharan Africa
STEC   Shiga-toxin-producing Escherichia coli

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8. Declarations

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8. Annex

Base interview Template

Name		Age	
Location			
Occupation:			
Milk buying price		Unit	
Milk selling price		Unit	
Minimum buying unit		Unit	
Minimum selling unit		Unit	
To producer/sellers & buyers			
Why do you participate in the dairy sector?			
How did you become involved?			
Since when are you involved?			
To sellers or producers			
How many litters can you produce daily?			
Who are your main buyers?			
What practices do you have that assure milk quality?			
What happens when one of your animals get sick?			
Have you had any training in milk handling?			
To buyers/ consumers			
How often do you buy milk?			
What do you do with that milk?			
How do you store the milk?			
How do you check the quality of the milk you are buying?			
What happens if the milk you bought has poor quality?			
Where do you sell?			
What quality measures you use?			
Do you have any handling training?			
Any certification?			

Which are the main problems with milk?	
What do you do with the milk you cannot sell?	
Why do you think consumers buy your product?	

Source: Own elaboration