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MICROBIAL QUALITY AND SHELF-LIFE OPTIMIZATION OF LOCAL MILLET DRINK "*ZOOMKOOM*''

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JUNE, 2022

DECLARATION

Student's Declaration

I, Linda Adu Gyamfi declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

Signature: ……..……

Date:……..……

Supervisor's Declaration

I hereby declare that the preparation of this work was supervised in accordance with guidelines for supervisors of thesis as laid down by the University of Education, Winneba.

Name of Supervisor: Ms. Kutum Comfort Madah

Signature: ……..……

Date:……..……

DEDICATION

This thesis is dedicated to the Almighty God for granting me journey mercies and strength to complete my Master's programme successfully and to Mr. Owusu Akuming Francis of (blessed memory) for your support and encouragement throughout my study period.

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ACRONYMS

ANOVA	:	Analysis of Variance
AOAC	:	Association of Official Analytical Chemists
ASLT	:	Accelerated Shelf -Life Testing
BGA	:	Ball Grid Array
CDC	:	Centre for Disease Control and Prevention
CFU/g	:	Colony Forming Unit /gram
E. COLI.	:	Escherichia Coli
FAO	:	Food and Agriculture Organization
FDA	:	Food and Drug Authority
GOV	:	Government
GSA	:	Ghana Standard Authority
HDLs	:	High Density Lipoproteins
HPLC	:	High-Perfomance Liquid Chromatography
ICRISAT	:	International Crop Research Institute Semi-Arid Tropics
IPA	:	Importance Performance Analysis
ISO	:	International Organization for Standardization
KNUST	:	Kwame Nkrumah University of Science and Technology
MA	:	MacConkey Agar
ML	:	Millilitre
MSA	:	Mannitol Salt Agar
NGO	:	Non-Government Organization
PCA	:	Plate Count Agar
S. AUREUS	:	Staphylococcus. Aureus

SAT	:	Semi-Arid Tropics
SPSS	:	Statistical Package for Social Sciences
TCC	:	Total Coliform Count
U.K	:	United Kingdom
U.N	:	United Nations
USD	:	United State Dollar
XLD	:	Xylose Lysine Deoxycholate
YEA	:	Yeast Extract Agar

ABSTRACT

This research was aimed at improving the shelf-life of millet drink, zoomkoom. This drink is one of the Ghanaian traditional drinks which is gaining popularity since a significant section of the populace either produce or patronize it on a daily base or occasionally. The production and consumption rates are influenced by shelf- life of the millet drink. The objectives of this research were to assess the safety and microbial quality of the drink; determine the nutritional composition of the drink; determine and improve the shelf -life of the drink and determine consumer preference of the improved drink. Field survey and experimental design were adopted as a research design for this study. The population for this study was purposively and conveniently selected and consisted of farmers and sellers of millet grain, producers, retailers and consumers of millet drink. The snowball sampling technique was used to select the sample size of 100 participants for the study. The field survey was done in conveniently selected communities in the northern region of Ghana. The laboratory test was carried out at Microbial Biotechnology and Food and Quality laboratories of Kwame Nkrumah University of Science and Technology. Observation, questionnaire and interview were used to collect data from the field survey. Two samples (market and laboratory controlled) were assayed for the laboratory analysis. Both samples were subjected to nutritional, proximate and mineral analysis using AOAC (2000). Shelf-life of the drink was determined using two different concentrations of 0.025% and 0.05% of potassium sorbate (E202) at different temperatures of 0°C, 5°C, 25°C and 40°C for 15 days. Findings from the study indicated very poor microbial quality of the millet drinks sampled from the market with aerobic counts in the range of 7.1×10^{6}cfu/ml and9.5×10^{6}cfu/ml beyond the safe and acceptable limit of 1.0×10^{4}cfu/ml for ready to eat foods as specified by the International Organization for Standardization (ISO) and adopted by the Ghana Standards Authority (GSA) and Food and Drugs Authority (FDA) of Ghana. The nutritional worth of zoomkoom was assessed to determine the dietary benefits of the drink to consumers. The drink was found to be predominantly water based with a moisture content of 84.79±0.71% thus making it a good source of hydration to the consumer. The drink had low fat, protein and fibre contents of 0.29±0.11%, 0.41±0.14% and 0.014±0.002% respectively. The carbohydrate content was found to be 14.41±0.43% and an energy content of 61.87±2.97kcal/g. Though refrigeration extends the shelf-life of the millet drink from less than a day to 3 days, the preservative further extended the shelf-life to 10 days and 15 days at room temperature using 0.025g/100g and 0.05g/100g respectively which indicates ten-fold increase and beyond shelf-life improvement thereby making this intervention suitable for solving the present challenge of short shelf-life and keeping quality of the drink. Finally, the study indicates that consumer acceptability is not significantly influenced by the appearance of the millet drink in the two packaging materials (glass and plastic bottles) as well as a preservative; potassium sorbate (E202).

CHAPTER ONE

INTRODUCTION

1.0 Overview

The chapter one of this study deals with the background to the study, statement of the problem, purpose and objective of the study, research questions and research hypotheses, significance of the study, limitations and delimitation of the study and the general layout of the study.

1.1 Background to the Study

Traditional foods and drinks have been the reserve of a large population of Ghanaians despite the influx of foreign delicacies due to urbanization and globalization of economies and states. Ghana has a wide array of traditional foods and drinks which are largely distributed amongst the vast diverse ethnic settlements due to the multiethnic structure of the country. Traditional foods and drinks are patronized by a significant section of the populace both occasionally and daily and are gradually gaining popularity as part of the menu of multinational and intercontinental food and hospitality establishments (Botchway, 2018).

Over the past years, many local drinks have been produced in our Ghanaian local communities from locally available food commodities such as cereals and grains - millet, corn, sorghum; nuts- cashew, coconut; fruits- pineapple, mango and orange. Notably among these Ghanaian local drinks are pito, palm wine, asana, aliha, zoomkoom, sobolo and samia.

One of such local drinks which is gaining more popularity is the millet drink "zoomkoom" which is mostly consumed by the natives of the northern, Savana and

Oti regions of Ghana but is gradually gaining popularity in the south. According to the interpretation of the name “zoomkoom” in the Nabt local dialect means flour water from the construction “Zoom” meaning flour and “koom” meaning water.

The 100% millet drink has an interesting and pleasant aroma, very spicy, a smooth texture/feel and sweet taste. The millet drink owes its subtle sweet taste to the naturally occurring sugars, which are formed by the transformation of the millet starch from its polysaccharide polymer to simple sugar monomer units during the fermentation process. The drink has a versatile usage from breakfast servings as beverage to refreshments at events and occasions.

Customarily, the millet drink is offered to (unexpected) guests as a token of hospitality along with water particularly in the northern sectors of the country where it is native. In recent times zoomkoom is gaining more popularity even in the southern part of Ghana as a nourishing drink served during social functions while others also use it for commercial purposes as a trade for income generation.

Millet is thought to have originated from North Africa, specifically in Ethiopia, where it has been consumed as a staple grain since prehistoric times and still serves as an extremely important staple food in many African countries. As with most grains, millet is available in markets throughout the year (Matelijah, 2019). Millet is used as a staple food for people living in drought prone Africa (SAT) for its high tolerance and prevalence in such regions.

Millet is considered as a “nutri-cereal” because of its high fibre, protein, B-vitamins (especially niacin, B6 and folic acid), phosphorus, magnesium (a trace which acts as an antioxidant), and may benefit people suffering with arthritis. Millet is suitable for

dietary energy demands due to its high calories and nutritious value e.g. cysteine, lysine and methionine (ICRISAT, 1996). Millet has been shown to help in controlling diabetes and the associated health conditions particularly high blood pressure due to the relatively lower levels of triglycerides and high levels of HDLs. The major economic use of the crop is to function as food for man, feed for livestock and raw material in the brewing industries to produce both alcoholic and non-alcoholic beverages (Agyiri, 2016).

Despite the rich craft in producing local drinks, Ghanaian communities will need to rely on modern technology if they plan to successfully address the short shelf-life span of locally produced drinks and the fear posed in terms of its health and safety.

1.2 Problem Statement

The nutritious nature of the millet grains makes it a good food source for not only man but microorganisms as well which take advantage of the nutrients of the grain to proliferate. The high moisture content of the millet drink creates additional conducive and preferable habitat for these opportunistic microorganisms to proliferate and in the process ferment the drink as well as initiate spoilage.

The findings of research by Imoukhuede, Adepeju and Akinsuro (2018) show poor microbial quality of locally produced millet drinks with the identification of pathogenic bacteria such as *Escherichia coli, Staphyllococus aureus*, etc. putting consumers at risk of bacterial infections and its associated health conditions.

The issue of malnutrition especially in northern region is a pressing health concern in Ghana which calls for immediate dietary interventions. Millet is a staple grain grown in the northern part of Ghana and therefore holds the potential as an economical and

readily available diet for such intervention and therefore the need to determine the nutritional composition and the dietary value of millet drink as a potential dietary intervention especially for handling malnutrition problem in the northern part of Ghana.

In Ghana, people who are into the production of millet drink (zoomkoom) either on commercial scale or for domestic use are faced with the challenge of rapid spoilage of the product within 24 hours of production if not stored or refrigerated. This poses a big challenge to the preference of the drink as the cost of refrigeration particularly on regular large scale is not economical for the average small-scale entrepreneur accompanied with the imminent loss of the product in times of prolonged power outage, a phenomenon which is common in a developing economy like Ghana. Access to stable electricity for domestic use is a challenge particularly in the Northern-Savanna regions where urbanization is low, thus making domestic storage of the drink under refrigeration conditions a challenge.

One cannot overlook the health issues associated with consuming spoilt food products, particularly the common cases of food poisoning from the consumption of microorganism infested foods that lead to adverse health effects with accompanying symptoms. The sensory and organoleptic parameters which appeal to consumers to patronise the product are affected when they spoil or are kept refrigerated for long thus ma king the product unpopular and unappealing. The poor keeping quality of the millet drink has been a major challenge limiting the commercialization and mass patronage of the product, thus the need for interventions and ways to improve the keeping quality and extend the shelf-life of the product. There is opportunity for Ghanaian locally made drinks like millet drink to position itself on the larger global

market, however, due to low market awareness, poor product image and wide suspicion of low quality and safety standards, this locally made drink is still unable to exploit the lucrative market opportunities out there. Upon a thorough survey and investigation about the problems associated with the preservation of zoomkoom, this study investigated and exploited using the scientific method, better and improved keeping practices that improved the shelf-life of the millet drink "zoomkoom".

1.3 Purpose of the Study

The purpose of this study was to optimize the shelf-life and enhanced the microbial quality of the millet drink "zoomkoom".

1.4 Objectives of the Study

The objectives of the study were to:

1. assess the production of zoomkoom.
2. evaluate the microbial quality and safety of the millet drink "zoomkoom".
3. determine the nutritional composition of the millet drink "zoomkoom".
4. determine and improve the shelf-life of the millet drink "zoomkoom".
5. evaluate the consumer acceptability of the improved product.

1.5 Research Questions

1. What processes are involved in the production of millet drink?
2. How do these processes affect the microbial quality and safety of the millet drink?
3. What is the nutritional composition of the millet drink?
4. In what ways can the shelf-life of the millet drink be enhanced?
5. Which one of the millet drinks (regular and improved) will consumers prefer?

Research question one, two and four were formulated in a hypothesis form as follows;

H_0: There is no statistically significant relationship among the processes involved in the preparation of millet drink and its microbial quality and safety.

H_0: There is no statistically significant relationship between the use of preservatives and the shelf-life of millet drink.

1.6 Significance of the Study

The study has provided data on the microbial quality and safety of zoomkoom which boosts consumer confidence and may eventually increase patronage of the product, and has also served as a pointer to policy makers and stake holders to create public awareness and also serve a prompt to producers to adopt safer and better production practices to ensure an acceptable and safe product.

The use of the preservative (E202) which enhanced the shelf-life of zoomkoom has also helped to reduce the losses attributed to the spoilage of the product while in storage and also save the cost of electricity involved in cold storage of the product making it ideal for locations where access to stable electricity is a challenge, particularly in the northern sector of the country where the drink is most popular and patronized. This has also proved to consequentially create employment as more people will be encouraged to venture into the production and sale of the drink for income generation thus adding value to the millet chain.

1.7 Delimitation of the Study

Contextually, the study focused on improving the shelf-life, safety and preparation of millet drink from areas in northern region. Specifically, the study assessed the microbial quality and safety of the millet drink “zoomkoom” as available on the

market, determined the nutritional composition and value of the millet drink "zoomkoom" and again determine ways of improving the shelf-life of the millet drink to enhance consumer's acceptability of the improved product.

The study was delimited to six districts (namely; Savelugu, Tolon, Kumbugu, Tamale Metro, Sangerigu and Mion) of the northern region, Ghana. Northern region has Tamale as the regional capital. It is divided into 16 districts (11 ordinary districts in addition to 1 metropolitan and 4 municipality (ghanadistrict.com). It was the largest of the ten regions covering an area of 70,384 square kilometers until December, 2018 when the Savannah and north east regions were created from it. It bordered on the north by the north east region, on the east by the eastern Ghana-Togo international border, on the south by Oti region and on the west by Savannah region. It is much drier than southern areas of Ghana, due to its proximity to Sahel and the Sahara. The vegetation consists predominantly of grassland, baobabs or acacia and shea tree. The only water systems are a few seasonal streams, rivers which dry up during the dry season. The other water bodies include dugouts, dams, pipe borne water and borehole. Economic activities revolve around farming and trading (Ghana Statistical Service, 2014). The dorminant ethnic group is Mole-dagbon English, Dagbani and dagare languages been the dorminant.

The six districts from northern region were targeted and selected for this study mainly for the nativity of the millet drink to the area as well as availability of the raw materials, mainly millet thus providing a large pool of consumers to sample from for data collection as well as a large distribution of producers and samples of the product for sampling.

1.8 Limitation of the Study

As it has always been with most research works, it is expected that the researcher has encounter some limitations in the course of the study. One of such limitations was financial constraints. The major financial challenge was with the issue of laboratory analysis of proximate and shelf-life in the food science and microbiological laboratory of Kwame Nkrumah University of Science and Technology in Kumasi, especially in the area of shelf-life test, the researcher could not afford the cost of prolong shelf-life which however led to accelerated shelf-life within the period of three weeks.

There was also the problem of transportation cost as the researcher has to travel around the selected communities for the study for market samples of millet drinks to be collected. The market samples were transported from Tamale to KNUST, Kumasi on ice for the period of eight hours in an ice-chest.

Again, time constraint was also a limitation that is worth mentioning since the researcher had to make frequent trips to KNUST Microbiological and the food science laboratory especially during the shelf-life analysis and preparation of the controlled samples respectively.

Furthermore, some respondents did not keep to their appointment with the researcher due to the fact that most of them were retailers of the millet drinks and needed to sell their drinks in shops and marketplaces.

Additionally, there was the challenge of getting respondents to readily give accurate information since the researcher was seen by the producers and retailers as a potential competitor. Other respondents also entertained the fear that the researcher was from foods and drugs authority to investigate their activities and report them to the media

and as a result inaccurate information was given just to please the interviewer. Most respondents were not also familiar with the English language.

Notwithstanding these impediments, the researcher was able to address them by first establishing good rapport with the respondents, so that they could express themselves freely. The respondents were also assured of neutrality and confidentiality. The language barrier was overcome by using the Ghanaian language that the respondents were familiar with.

1.9 Organization of the Study

This study was organized in five chapters, the introduction, literature review, materials and methods, results and discussion and ultimately the conclusion. Chapter one (1) deals with the general introduction to the study comprising background to the study, problem statement, research objectives and research questions, significance of the study, the limitations and delimitation of the study, and the organization of the study. Chapter two (2) follows suit with details on literature from acclaimed scientific and social bodies of knowledge as well as other publications relating to the topic. This assessed and analysed various research works carried out on millet thus uses, processing, its nutritive value; microorganisms and shelf-life. It further elaborated on the theoretical, conceptual and empirical review of other researchers' works on the topic, giving rise to some key findings and conceptual framework that guided the study. Chapter three (3) focused on the materials and methods used for the research captioning research design, the population, sampling and collection of data, laboratory analysis and statistical computation of the data obtained, followed suit by Chapter four (4) which details the findings of the study along with their significance and interpretation in the light of other related findings. Chapter five (5) stands as the

concluding chapter with the final submission on the findings of the study coupled with some recommendations for future research in the area of study and topic.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

Chapter two of this thesis is the literature review which focused on an in-depth and comprehensive review of relevant and related literature comprising of researchers' thesis and published research articles in scientific journals. This chapter captures the theoretical and conceptual framework; literature on millet, millet drink, shelf-life, accelerated shelf-life testing (ASLT).

2.1 Theoretical Framework

Kano's theory of attractive quality was the theory adopted for this study. This theory was used because the study focused on optimizing and improving millet drink based on consumer preferences. According to Kano et al. (1984), products are now developed based on what customers' desire, and thus attractive quality creation has become crucial. Product development was previously producer-oriented, but has now switched to being led by the customer. From customers' perspective, the Kano et al. (1984) model has been used to understand customer needs by identifying and classifying the quality attributes. Product quality is typically determined by customers, with their satisfaction as an indicator for the direction in which a product should be developed. This indicator is considered valuable by governments, and national customer satisfaction indexes have thus been established in many countries (Shahin & Kitapci, 2013). Within product development, attractive quality creation has become paramount, and quality engineering and management has transitioned from production-oriented to quality control-oriented, thereby satisfying customer needs (Witell et al., 2011).

Many studies on customer satisfaction have been published in recent decades. Martilla and James (1977) investigated automotive services and used importance-performance analysis (IPA) to develop corporate strategies. They integrated the analysis of two dimensions (importance and performance) to evaluate quality attributes that were crucial to customers but did not result in the expected performance and thus needed to be improved. Kano et al. (1984) investigated TV and lamp products, and observed that customers' product awareness was not simply one-dimensional. Accordingly, they developed a two-dimensional quality model. They considered that quality attributes and customer satisfaction had an asymmetric and nonlinear relationship, and that for a product, it must-be and attractive quality attributes must be considered in addition to its one dimensional quality attributes. Numerous researchers have further studied Kano's model, giving explanations about customer satisfaction (Luor et al., 2015). The two-dimensional quality model developed by Kano has been used during product development and design (Shen, Tan & Xie, 2000), and using Kano's model to examine customers' preference for product functions and classify quality attributes is conducive to decision analysis in a product development project.

2.2 Conceptual Framework

The conceptual framework of the study is presented in relation to certain customer desires that is attractive quality which are more likely to influence customer satisfaction of a product as adopted by Shen et al. (2000). The customer desires which affected their preference for the product (zoomkoom) under study are organoleptic quality, safety and shelf-life as diagrammatically presented in Fig 2.1.

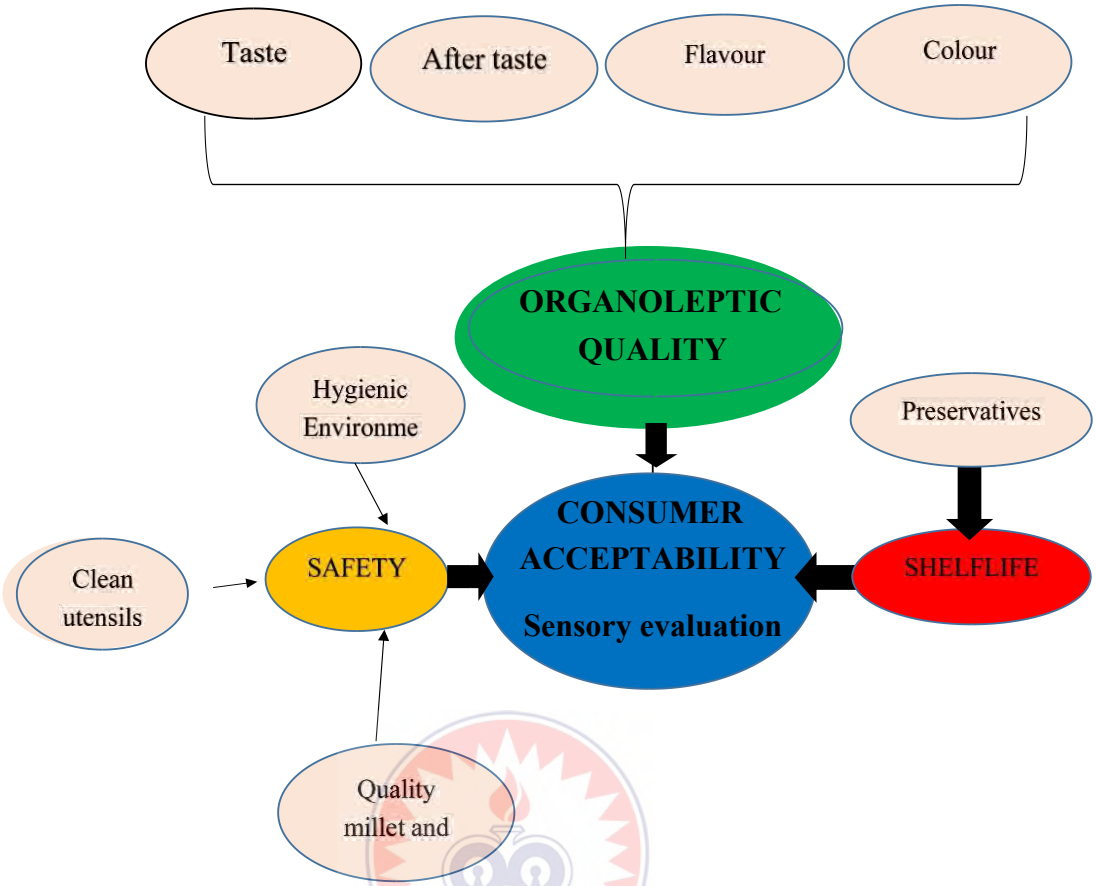

Figure 2.1: Factors that influence consumers' preferences for product acceptability (Student's own construct based on Kano's theory)

The figure above was constructed from Kano's theory of attractive quality and product development for consumer satisfaction. Based on a brief survey by the researcher, it was discovered that, producers and consumers were dissatisfied with the poor keeping quality of the millet drink. Consumers were dissatisfied with the hygienic practices and the preservation of the millet drink. Upon realization of consumer dissatisfaction with these quality attributes (taste, flavour, colour, aftertaste-forming the organolypetic properties of the consumer) was given consideration in order to improve the quality attributes of *Zoomkoom*. The consumer's acceptability for this study was based on factors such as safety which included clean utensils,

quality ingredients, hygienic environment and shelf-life which included the use of the preservative E202(potassium sorbate). These factors coupled with the improved protocols used by the local producers, however helped with a better product (controlled) than what was been sold in the market.

2.3 Overview of Millet

In the agricultural production around the world, drought- resistant crops are of high importance, of which millets are one of these. Africa is known to be the major producer of numerous cereals such maize, pearl millets, sorghum, teff, wheat and African rice and widely cultivated. In Sudan and Ethiopia, wheat is widely cultivated. With agriculture being drive for growth in Africa, the cereals stated above are the major staple foods for the African population. Millets are cereal crops with small seeds that have a short season of growth and are resistant to infectious diseases (Devi et al., 2011). Millets grow at a fast rate and are able to grow between two to fifteen feet tall. Growth is seen five to seven weeks after sowing. Millets complete their growth cycle in two to four months (Collet, 2013). Majority of millets are sown between May and June, with maturity seen from September to October. In situations of famine, millets are able yield produce, hence are tagged as famine crops (Kalleshwaraswamya, 2018). Millets have their grains enclosed in an indigestible hull. This hull is removed to expose the grain (Whole grains council,2013). In well drained loamy soils and sandy soils, millets show best growth. This characteristic of millets made it possible for it to grow in West African desert areas. (Baltensperger, 2002). Belonging to the family Poaceae, millets have many varieties and are categorized based on their grain size into major millets and minor millets. The major millets are pearl millets, which are also known as bajra in India, and common millet.

The minor millets are foxtail millet, barnyard millet, proso millet, brown top millet, finger millet, little millet and kodo millet.

Table 2.1: Millet varieties in the world

Millet	Scientific Name	Common names	Areas of Production	Use
Sorghum	Sorghum bicolor	Great millet, jowar, cholam, jola, jonna, urra, Egyptian millet, feterita, Guinea corn, jwari, juwar, milo, shallu, gaoliang, kaoliang, kafir corn, dura, dari, mtama,solam.	USA, Nigeria, Sudan, Mexico, Ethiopia, India, Argentina, China, Niger, Australia	USA, Nigeria, Sudan, Mexico, Ethiopia, India, Argentina, China, Niger, Australia
Pearl millet	Pennisetumglaucum	Bajra, cattail, bulrush, candlestick, sanyo, munga, seno	India,Western& Central Africa, Eastern & Southern Africa	Grown for food grain in Asia and Africa, for fodder in Americas
Finger millet	Eleusine coracana	Ragi, African,bird's foot, rapoko, Hunsa, wimbi, bulo, telebun, koracan, kurakkan	India, Ethiopia, Nepal, Uganda, Malawi, Burundi, Sri Lanka, Rwanda	Grown for food grain and beer making in Asia and Africa
Foxtail millet	Setaria italic	Italian, German, Hungarian, Siberian, kangani, navane, thanahal.	China, Myanmar, India, Eastern Europe	Grown for food grain and fodder

Proso millet	**Panicum milliaceum**	**Common, hog, broom, samai, Russian, panivarigu, panic, maha meneri**	**Russia, USA, Ukraine, South Korea, Kazakhstan, France, Poland, Belarus, India, Iran**	**Grown for food grain and bird seed**
Little millet	Panicum sumatrense	Blue panic, heen meneri	India	Grown for food grain
Kodo Millet	Paspalum scrobiculatum	Varagu, bastard, ditch, naraka, water couch, Indian paspalum, creeping paspalum, amu	India	Grown for food grain
Barnyard millet	Echinochola crus-galli	Japanese, sanwa, sawan, Korean, China, Malaysia	India, Japan,	Grown for food grain kweichou

Source: Karnataka State Department of Agriculture, 2018.

In China, the two earliest domesticated crops before wheat and rice was foxtail and common millets. Rice and wheat crops could not adapt to growth with little water, which these millets could (Lu, 2009). According to Freckman (2002), the different varieties of millet arise from the different types of panic grass and barnyard grass. These grasses were known to thrive in harsh climates and could grow between one to three meters tall.

2.3.1 History of millets

Urbanization and industrialization has led to the large scale cultivation of rice and wheat, reducing the importance placed on millets. One of the oldest foods known to humans were millets (Karnataka State Department of Agriculture,2018). In the 'Hoe' and 'Plow' age, millets were among the first crops to be cultivated. Archaeological plant findings around the world, one of the earliest plants to have existed is the millet crop. Around 5000 BC, millets were heavily relied on by the inhabitants of north-central China.

2.3.2 Pearl millets

About 97% of the world's production of millet is from developing countries, with India being the largest producer of all varieties millets in the world (pearl millets being the most) (McDonogh, 2000). In India, the production of millet is centered in Maharashtra, Uttar Pradesh, Rajasthan and Gujarat (Basavaraj,2010). The most consumed millet variety is the pearl millet which produces large seed compared to the other millet varieties (FAO & ICRISAT, 1996). Their grains are ovoid and are three to four millimeters long. The average productivity of pearl millet in India is 930 kg/hectare (ICRISAT, 2015).

According to Manning (2011), pearl millets were domesticated between 2500 and 2000 BC in West Africa's Sahel zone. Currently, this region which includes Chad, Gambia and Burkina Faso, have 33% of their population consuming millets daily (FAO, 1995). Pearl millet can withstand growth in harsh conditions. In cereal production, pearl millets represent 19% of cultivation area and are grown in the Africa's semi-arid regions. Pearl millets have a carbohydrate content of 63.2%, crude fat and protein content of 7.8% and 13.6% respectively (Ali *et al*.,2003). They are rich in proteins, fibre, iron and phosphorus, and have numerous health benefits (Karnataka State Department of Agriculture, 2018).

There is a high dependence on pearl millet for food in the Northern part of Namibia (Dendy, 1995).

2.3.3 Uses of millets

Many African and Asian countries, use millet as one of their major ingredients in foods and some beverages. Some of these foods include unleavened roti, bread, injera, mangisi, fura, zoomkoom and dhebra (Chandrasekara et al., 2012). Millets can be

cooked just like rice, without having to be processed into flour. Eastern cultures (Chinese and Russian) have a traditional food called millet porridge, in which the millet is cooked after dehulling. The Russians prefer taking their millet porridge with milk and sugar whilst the Chinese use beans and squash to eat theirs (FAO, 1995).

In Nepal millets are used to make a spiritual drink called Tongba. This drink is done by dehulling the dried millet and cooking the grains. After cooling, yeast is added to make the cooked millet ferment for three days, after which the brown liquid is poured in a bamboo container for a month, until the fermented millet (Jaand) starts oozing out. The drink is usually served warm. In Ghana, millet is been used for so many dishes such as masa, hausa koko, tuo-zaafi (t.z), pito, brukina etc.

Millets also serve as food for livestock and is better choice for animal feed compared to sorghum. The overall body weight gains of chicks studied was higher when fed with millets compared to maize (Andrews, 1992).

2.3.4 Nutritive value of millets

According to a study done by Parameswaran and Sadasivam (1994), millets, compared to other major cereals, have a very high nutritive value and contain antioxidants, vitamins, carbohydrates and fats. The hulls of millet are rich in B-complex vitamins but are not consumed since they are removed to give way to the grain (FAO, 1995). Millets are good for the strengthening of the nervous system due to the high amount of lecithin they possess (Karnataka State Department of Agriculture, 2018). Millets also possess high levels of micronutrients, essential amino acids and phytochemicals. They are also rich in ash content. (Singh et al. , 2012). Pearl millets are rich in phosphorus and iron (FAO, 1995). A study by Chandrasekara and Shahidi (2011) identified over fifty phenolic compounds in whole millet grain,

using HPLC-tandem mass spectrometry. Even though millets are known to contain antioxidants, the variety of the millet determines the amount of antioxidant the millet possesses. The processing of millets may lead to an increase or decrease in antioxidant activity. A study in which finger millets were malted for ninety-six hours, showed an increase in the antioxidant capacity (Rao & Muralikrishna, 2002).

These same finger millets showed a decrease in antioxidant activity after being roasted (Hedge & Chandra, 2005). Millet grain extracts have been proven to possess antimicrobial activity. The growth of *Macrophomina phaseolina, Fusarium oxysporum* and *Rhizoctonia solani* were inhibited by the protein extracts of pearl millets and other varieties of millets (Radhajeyalakshmi et al., 2003). Millets are good for the prevention of cancer, heart related diseases, celiac disease, diabetes and delay gastric emptying (Gupta et al., 2012). The low glycemic index of millets, make them important in fighting the problem of diabetes. Studies have shown that the occurrence of *diabetes mellitus* is minimal in countries that use millets as staples (Karnataka State Department of Agriculture, 2018). Millets function as prebiotic for the micro-flora in the gut of humans, as well as keeping the colon hydrated to prevent the occurrence of constipation, when consumed. High levels of tryptophan in millet lead to the production of serotonin when consumed (Karnataka State Department of Agriculture, 2018). Millets aid in the regeneration of membranes, useful in brain function and protect the liver due to the presence of phospholipids such cephalin and lecithin.

2.3.4.1 Carbohydrates

The breakdown of the carbohydrates in millet are starch (60-75%), free sugar (2-3%) and non-starchy polysaccharides (15-20%). Sucrose, glucose and fructose, makes up the free sugars. The dietary fibres present in millets are pectinacious material,

cellulose and hemicellulose. The cell walls matter of the kernel and the aleurone layer are responsible for the insoluble dietary fibre present in the millet (Ushakumari et al., 2007).

2.3.4.2 Protein

A study done by Geervani and Eggum (1989), has shown that, glutelin, albumins, globilins and prolamin are found in millets. Prolamin and glutelin make up the highest proteins in millet. In pearl millet the concentration of prolamin ranges from 22.8 to 31.7% (Hulse et al., 1980). In finger millets, the glutelin content ranges from 12.4 to 28.2% of the total protein, whilst foxtail millets contain 6.7% glutelin. Some millets such as teff and kodo, have a high lysine content. Pearl millet have a higher net protein utilization value, compared to the minor millets (Singh et al., 1987)

2.3.4.3 Lipids

Fat content amongst the variety of millet is highest in foxtail, proso and pearl millet, with a fat content of 5%. In finger and kodo millets, the fat content is 1% and have the lowest fat content amongst the millet variety. The fat in millets can be found in their endosperm and bran. A study done by Twinomuhwezi et al. (2020), showed that, millets contain 78% to 82% of unsaturated fatty acids, whilst the saturated fatty acids make up 17.9 to 21.6% of the total grain fat. The lipids which have been extracted from millets so far are glycolipids (sterolglycosides, cerebrosides, and digalactosyldiacy lglycerol), phospholipids and neutral lipids. The major phospholipid found in millet is lysophos phatidylcholine with phosphatidylcholine, phosphatidic acid, lysophosphatidy lethanolamine, phosphatidylglycerol, phosphatidylserine and phosphatidylinositol, being in small amounts (Twinomuhwezi et al., 2020).

2.3.4.4 Vitamins

In mature millet grains the vitamin C content has been shown to be low. Millets have high levels of B complex vitamins with the exception of Vitamin B12 , and vitamin E. Compared to soybean and corn oil, millets have low levels of tocopherol. Millets have a reduction in vitamin A and vitamin E, when their fats are refined (Bieri & Evarts, 1974).

2.3.5 Anti nutrients in millets

Millets contain anti-nutrients which reduce the absorption of essential minerals and slows down the absorption of nutrients. Commonly called phytochemicals, these anti nutrients include tannins, polyphenols, oxalic acid and phytates. These anti nutrients can be eliminated by some of the processing operation in millets. The hulls of pearl millets for example, have some quantities of goiterogenic substances that inhibits the function of thyroid, leading to the development of goitre. Techniques such as soaking, malting fermentation and germination, takes care of these anti-nutrients and makes the minerals in the millet readily available for use when consumed (Karnataka State Department of Agriculture, 2018).

2.4 Challenges Faced by the Farmers in the Production of Millet

The increase in demand for millets in Africa over the last fifty years, is reflected in the increase in cultivation area for millets. Unfortunately, most farmers in Africa cannot catch up with the increasing demand for millets, due to challenges faced in its cultivation. Global warming in Africa has led to the decline in millet production. Farmers who depend on agriculture are highly affected. A study done by Nelson et al. (2009) has shown that, for the agricultural sector to adapt to climate change, the cost involved is over USD 7 billion.

Another problem worth noting is the issue of rapid population growth in Africa, especially in the dryland areas. Increase in the growth of the African population is directly proportional to the increase in demand for food. Most lands needed for cultivation are not turned into places of habitation. The most food insecure places in Africa are the East and Southern Africa, and the West and Central Africa, due to the presence of dryland in these areas (UN Human Development Indices).

Policies of most government do not support the production of cereals in Africa. Aside this, there is little or no funding the agricultural sector, hence cultivation of these cereals is done on small scale basis and there is no effective technology development. Some crops such as wheat and rice, involve high levels of mechanization for their production and without funds for these, the cost of producing these crops becomes high.

These problems can be solved when the production of seeds, the crop development process and technology delivery systems are strengthened. Empowering farmers to manage their natural resource base by making use of integrated soil fertility and crop livestock systems management, also helps the challenge.

2.5 Processing of Millet

The quality of millet makes it suitable for processing and is categorized into primary and secondary processing. The primary processing involves wetting, dehulling and milling whilst fermentation, malting, extrusion, flaking, popping and roasting make up the secondary processing (Obilana, 2003). Most millets are milled by hand grinding, with milling by machine following. Millets which are milled traditionally retain more of their nutrients compared to those milled mechanically (Obilana, 2002).

2.6 Beverages

Among the top ten foods that provide several nutrients after consumption, one of these are beverages (Zohouri et al., 2004). Beverages can be categorized into hot drinks, alcoholic drinks and milk drinks (Roethenbaugh, 2005). Soft drinks, fruit juices and milk are the most consumed beverages (Rampersaud et al., 2003). Beverages are also classified into non-alcoholic (contains little or no alcohol) and alcoholic (contains ethanol) drinks (Roethenbaugh, 2005). Usually drinks are not considered food but because of the nutritional value of most beverages (of cereals) in Africa, they are considered as food (Sawadogo-Lingani et al., 2008). Some of these beverages have become rooted in the African culture, forming part of the etiquette in most households. Some of these beverages are made from millet which include zoomkoom, koko, drink, brukina, pito, and mangisi.

2.6.1 Zoomkoom

The emergence of the millet species 'Okashana 1' from India, has led to Burkina Faso producing over a million tons of millet per year (FAO, 1996) prepared from whole grain millet, zoomkoom is a popular non-alcoholic beverage in Burkina Faso. It is street vended and mainly sold in Koudougou, Bobo-Dioulasso and Ouagadougou. Some individuals prefer using sorghum in the making of zoomkoom (FAO, 2012). After an overnight soak of the millet grains in water, washing of the soaked grains begins the preparation of zoomkoom. The washed grains are mixed with mint and ginger and grinded to form a dough. The dough is then diluted with water and filtered to obtain zoomkoom. Tamarind juice and sugar is added for taste (Soma, 2014). A study done by Tapsoba et al. (2017) showed that zoomkoom contained high levels of coliform bacteria and thermotolerants. Fermenting zoomkoom at the dough stage,

inhibits the growth of coliform bacteria. In the processing and preservation of traditional foods, fermentation is one of the methods used (Yao et al., 2009). Compared to unfermented zoomkoom, fermented zoomkoom has the lowest load of coliforms (Tapsoba et al., 2017). In the soaking phase of zoomkoom preparation, a conducive environment is created for the growth of spores, bacteria yeasts and moulds. Fermenting the dough for 10 hours, acidifies the dough, decreases the pH and decreases the growth of these pathogenic microorganisms (Tawaba et al., 2013; Adinsi et al., 2015).

2.6.1.1 Nutritive value of zoomkoom

The millet drink, zoomkoom contains minerals such as phosphorus, calcium, iron and magnesium and are a rich source of protein (25.83%) and lipids (6.48%) (Tapsoba et al., 2017). A study done by Soma *et al*., (2019), showed that the use of starter cultures (for controlled fermentation of zoomkoom) in the preparation of zoomkoom improved the nutritional value of the millet drink. Minerals such as magnesium, iron and calcium had a significant increase, as well as protein and fat content.

2.6.2 Pito

Pito, a popular cereal food drink, is one of such food product that is widely locally brewed and consumed among the people of Northern Ghana. It is made from fermented millet or sorghum. It can be served warm or cold, and usually in calabash. It can alcoholic or non-alcoholic due to the fermentation process. It is sometimes used as a traditional beer in performing certain traditional rites such as marriages, naming ceremonies and burial ceremonies, parties and other social gatherings (Sanni & Lonner, 1993). It is prepared by soaking the millet, milling into powder, soaking powder and straining the mash when it settles. The remaining mash is boiled and

allowed to ferment for 24hours. Once fermentation is completed the mixture is boiled again and the mixture is strained to separate the liquid from the mash and then served in calabash.

2.6.3 Brukina

Brukina is a healthy, tasty drink made from fresh cow milk and crushed millet. A little bit of sugar and salt is added to give it a unique taste and is best served chilled. It can be found at most bus stations and market in the southern part of Ghana (Botchway, 2018).

Brukina is a nutritious product rich in proteins, carbohydrates, minerals and essential vitamins (Tawiah, 2015).

2.6.4 Koko

Koko is a millet beverage popularly consumed by the people in West Africa as breakfast, lunch or in between meals. Huasa koko as popularly called is prepared with millet dough, ginger and other natural spices. It is usually enjoyed with Ghanaian fried bean bun called koose or bread. The first step to making koko is by soaking pearl millet in water overnight. The steep water is discarded and the millet grains are wet milled with spices such cloves, black pepper and ginger (Lei and Jacobsen, 2004). After milling, water is added until a thick slurry is formed. The slurry after being sieved and fermented is sedimented for two to three hours (Campbell, 1994). The liquid top layer is decanted is boiled for two hours after decantation. The sediment is finally added until the preferred consistency is reached (Lei & Jacobsen, 2004). Milk, groundnut and sugar is added to koko for a desired taste.

2.6.5 Fura

Millet flour is used in the preparation of fura and is cherished by the people in the Sahel region of Africa (FAO, ICRISAT, 1996). The millet grain is ground in a locally manufactured disc attrition mill after being slightly moistened with water. The grain is then dehulled in after sun drying, ground in a hammer mill and sieved. The flour together with powered black pepper, ginger and water, are mixed and kneaded into a dough, with the help of a mortar and pestle. The dough is shaped into balls by hand and cook for thirty minutes. Still hot, the ball is kneaded until an elastic mass is obtained. This smooth, elastic mass, is molded into balls of fura (Jideani et al., 1995).

2.6.6 Mangisi

Mangisi is a beverage prepared from naturally fermented millet mash and is enjoyed by several rural African families. Preparation steps of mangisi varies from region to region. In one method, after malting the finger millet, it is milled and the flour is mixed with water. After boiling the mixture for eighty minutes, the mash formed is cooled, diluted and strained. After straining, the mixture is made to stand for several hours, whilst spontaneous fermentation occurs, producing mangisi (Zvauya et al., 1997).

2.7 Shelf-life

Every consumer of a product has a high expectation that the quality of food consumed is maintained from the time of purchase to the time of consumption. One of the means to ensure that the quality of a product is maintained before its use, is to study its shelf-life. Shelf-life is the period between which a food product is safe and acceptable for a consumer, without an appreciable change in its physical, chemical, organoleptic and microbial characteristics (Earle and Earle, 2008). In the evaluation of shelf-life, the

packaging, processing, storage and analysis of the food product, must be taken into consideration (Steele, 2004).The quality of food is rapidly compromised when foods are stored under unfavorable conditions such as high relative humidity and high temperature (Labuza, 2001). According to Zoller et al. (2013,) 35% of perishable foods undergo rapid spoilage when their temperature is not carefully managed.

2.7.1 End of shelf-life

The end of product's shelf-life is specific to the consumer, the market and the products itself (Sciortino et al., 2016). Food with a long shelf-life have their end of shelf-life being determined by reduction of the nutritional value of the food product. Some of the labile nutritional compounds undergo degradation with time, and this begins depreciation in the sensory quality as well (Bell, 2002). Defect in sensory quality leads to discoloration and bad odor given off by the product; this marks the end of shelf-life in food products that are highly perishable (Aiello *et al.,* 2012). Sensory quality is positively correlated to the level of microorganism responsible for food spoilage. This is due to the fact that most perishable foods which undergo spoilage have a large number of spoilage microorganisms being present (Vaikousi et al., 2008). Shelf-life of food products can be determined using finger printing kinetics (Grauwet et al., 2014) and global stability index (Achour, 2006).

2.7.1.1 Expiration and best before dates

According to the Codex Alimentarius (2014), the two categories of date which should be found on food products correlate with the quality of the product and the food health safety of the product. Food products which have the quality compromised are usually represented by an expiration date, which is usually stamped on the package of the product. The term "use by date" are the expiration date labels given to food

products which are perishable, whilst “best before” is used for products which have a long shelf-life (Wang & Li, 2012). Research have found out that, consumers dispose of food products whose expiration dates are near, due to the need to maintain good health (Newsome et al., 2014). Some consumers on the other hand, do not even check the expiration dates of food products. In date labeling of food products, two labeling techniques are used. They are the open date labeling and the closed date labeling. The open date labeling makes use of easy-to-understand terms, for consumers and those in the supply chain. These terms include, ‘best if used by’, freeze by, ‘baked on’, ‘minimum durability’ and ‘sell on’. Close date labeling makes use symbols, letters and numbers, which reveals the identity of the product, the production site and time of production. In the event of product recall, closed date labeling is essential (National Institute of Standards and Technology, 2013).

2.7.1.2 Degradation process

Storage conditions of food products, period of storage and the composition of the food product are factors responsible for decay in food products (Wang & Li., 2012). In evaluating the possible causes of food decay, and in the quest to increase the shelf-life of food products, mathematical models are employed (Van Boekel et al., 2010**).** The fixed order kinetics and the Weibull distribution function are models used to describe the process of nutrient degradation in food products (Corradini & Peleg, 2004; Peleg et al., 2016). The kinetics data shows how food deterioration reaction occurs as a function of time and is the simplest shelf-life testing technique (Corradini & Peleg, 2004). In describing deterioration in sensory and chemical quality, the Weibull model is sought for (Spada et al., 2012). The microbial growth models are also considered in shelf-life estimations. The equation for this model is

$$\mathbf{Y(t)} = \log \frac{N(t)}{N0}] = \frac{a[T]}{1+\exp\,[k[T](tc[T]-t)]} - \frac{a[T]}{1+\exp\,[k[T](tc[T])]}$$

where N(t) is the momentary and N0 initial microbial counts. [T], k[T] and tc[T] are temperature dependent coefficients (Corradini & Peleg, 2005).

2.8 Microorganisms

Microorganisms are ubiquitous and can be found everywhere. They can grow under extreme conditions, and can withstand radiation levels ten thousand times higher than humans. All over the world and can survive in a variety of extreme conditions. Numerous microorganisms can be found in humans and animals, with most preferring to be in the soil and in water. These microorganisms include protozoa, algae, bacteria, viruses and fungi. The microorganisms which play a role in food, are categorized into two. They are the microorganisms that bring about food preservation and those that are responsible for food spoilage.

2.8.1 Microorganisms in foods

The microorganisms in food processing industries, which bring about losses include yeast, molds and bacteria (Frazier, 1958). Most bacteria, as well as virus and parasites are responsible for the occurrence of foodborne illness. Viruses do not have the ability to grow in foods to cause spoilage but their presence in foods could lead to illnesses. Some these bacteria include *Clostridium perfringens, Campylobacter* spp, *Bacillus cereus, Listeria monocytogenes*, *Staphylococcus aureus* and *Escherichia coli* O157:H7 (Gram et al., 2002). According to the U.S. Centres for Disease Control and Prevention (CDC), the most common organism which are responsible for most of the foodborne illnesses are *Salmonella, Campylobacter*, *E. coli* O157:H7, norovirus and *L. monocytogenes*.

Microorganisms are grouped according to their ability to tolerate oxygen, ability to resist heat and chemicals, their appearance, the genetic sequences they possess, the materials used as foods and the biochemical reactions they are able to perform (Herbert et al., 2000). These organisms are found on the surface of almost every fresh food product. These microorganisms are able to gain access into some of these tissues when their surfaces are bruised, and secrete enzymes which results into decomposition. The decomposition involves the breaking down of carbohydrates, starch and pectin, making the food product change in color and become unpleasant for consumption (James, 2000).

2.8.1.1 Bacteria

Out of all the microorganisms, bacteria are the most troublesome in the area of food processing. They are the smallest living organisms known and their bodies are made up of a single cell. Bacteria cannot be seen with the unaided eye, but can be seen with the help of a microscope. Under the microscope, they appear in several shapes and colors. They are either rod-shaped or round in shape. Bacteria can be categorized into spore forming bacteria and non-spore forming bacteria. In the growth cycle of some bacteria, spores are the resting stage. These spores ensure that the organism is able to withstand environmental stress. *Bacillus anthracis, B. cereus, C. botulinum* and *C. perfringens* are the major spore-forming bacteria. The difficulty in controlling these organisms in the food processing industry is high because of the prevalence of the organisms in the environment. Sanitizing solutions used in the food processing industries are not effective enough for bacterial spores, since these spores are able to survive in these solutions for more than three hours (Herbert et al., 2000).

Inappropriate heating and cooling of food products in the food processing industries, can lead to the formation of vegetative spores, which start reproducing.

2.8.1.2 *Salmonella Spp*

Salmonella are motile organisms which do not form spores and present in ready to eat products, poultry, raw eggs and beef (Rasooly, 2006). They are rod shaped, gram negative bacterium, which show growth in low pH environments. All of their strains are pathogenic to humans, with *Salmonella enteriditis, Salmonella Newport, Salmonella Heidelberg* and *Salmonella typhimurium,* being linked with foodborne associated illnesses. In humans and animals, salmonella species which survive digestion, find their way into the intestinal tract. They symptoms these organisms induce are headache, fever, vomiting and diarrhea.

2.8.1.3 Escherichia coli

Just like *Salmonella, E. coli* is a motile, rod shaped, gram negative bacterium. Some strains of this organism, can cause sicknesses in humans. The O26, O45, O121, O111 and O103 are a few of the disease-causing strains of *E. coli*. The common illnesses caused by *E. coli* are hemorrhagic colitis and hemolyic uremic syndrome. E. coli is present in raw vegetable, raw milk and raw beef (Christian, 2000).

2.8.1.4 Molds

Molds are spore forming microorganisms, that are larger than bacteria. They can be found in dust, the soil, on foods and on the walls of buildings. With suitable conditions of temperature, moisture and air, growth of these organisms will be seen. Molds are tolerant to cold environment and some highly concentrated acids. The molds responsible for food spoilage are *Rhizopus, Aspergillus flavus, Aspergillus*

parasiticus and *Penicillium* (Gram et al., 2002). Certain mold strains secrete toxins called aflatoxins, which contaminate peanuts, corn and milk. These aflatoxins are G1, G2, B1 and B2. The most toxic of them is the B1. Concentrated ammonia is used to inactivate aflatoxins. Growth of molds can be curbed through thermal processing since molds cannot tolerate heat.

2.8.1.5 Yeast

Yeasts are organisms which also cause food spoilage and are also beneficial in some food processing industries. They have an egged shaped, larger than bacteria but smaller than molds, and are single-celled. Yeasts are usually present in sugar-containing liquid foods, as well as foods that contain acids (Fowell,1967). Yeast are able to tolerate a small amount of heat. Yeast are responsible for the swelling of canned food containers, as a result of carbon dioxide production, which is a byproduct of the digestion. Aside this, yeasts are useful in the production of bread and wine (Herson, 1964).

2.8.2 Microbial growth in vegetables

Bacteria and molds are usually found growing on the surface of vegetables. Bacteria cannot withstand acidic environment and most vegetables are not acidic in nature, hence permit the growth of some of these microorganisms (Christian, 2000). These bacteria leave vegetables with an unpleasant appearance due to the breakdown of the vegetable's pectin material. This material is responsible for maintaining the structure of the vegetable. Breaking down pectin leaves the vegetable looking pale and soft as a result of loss in structure. The warm environment produced when vegetables are put together, favors the growth of some of these spoilage organisms. These microorganisms are also responsible for the bad taste and smell emitted by the

vegetables. Lactic acid produced when microorganisms break down the soluble sugars present in the vegetables, brings about the smell and bad taste. To preserve these vegetables, they are storage at cool dry places (Rasooly, 2006).

2.8.3 Microbial growth in fruits juices

Numerous methods have been devised to prevent food spoilage and notable of these is keeping the food product under cold storage. This method of storage has been widely used to preserve fruit and food products. Storing foods at this low temperature, retards the growth of these food spoilage organisms, as some of them cannot withstand low temperatures (Fowell, 1967). Another method used is the application of fungicidal coatings on the surfaces of fruits, to prevent the growth and activity of yeast and molds (Lund & Eklund, 2000). These yeasts and molds, if not eliminated, find themselves in fresh fruit juices, converting the sugars into carbon dioxide and alcohol. At times, yeast is intentionally added to fruit juices to initiate the production of wine, but in the vein where the microorganism is not added but find its way into the juice, it brings about losses. Aside the fungicidal coating, pasteurization is employed to remove all the harmful organisms. This method is usually done by heating the fruit juices in bulk at a particular temperature and for a particular time period. The method of pasteurization varies from juice to juice, and is dependent on the sugar content and **the acidity value of the fruit juices.**

2.8.4 Controlling food spoilage

Food becomes distasteful and unappealing after going through metabolic process which alters their sensory quality. This metabolic process is known as food spoilage (Martorell et al., 2005). These reactions are initiated by microbes, which use the food as sources of carbon and energy. The main types of food spoilage are physical

(staling, fragmentation of components and loss of moisture) and chemical spoilage (enzymatic browning and lipid rancidity). Post-harvest decay of foods by organisms are caused by relative humidity and high temperatures (Lindow & Brandl, 2000). Food spoilage by microorganisms are held back by food preservation processes. These preservation techniques are needed, since areas where foods are sold, are distant from the sites of production. These processes include addition of preservative agents such as benzoic acid and sorbic acid, regulated heating, use of food additives and refrigeration (Arneborg, 2000).

2.8.5 Accelerated Shelf-life Testing (ASLT)

Shelf-life can be determined by two methods, namely, direct and indirect method. The accelerated shelf-life testing is one of the indirect methods for determining shelf-life. ASLT was introduced to reduce the time spent in the shelf-life determination of long-term storage goods (Labuza & Schmidl, 1985). Prior to ASLT, the shelf-life studies on long lasting food products, lead to the late introduction of products in the market for consumers, due to its time-consuming nature. In ASLT, storage temperature which is one of the determining factors for food deterioration, is increased. Increasing the temperature, proportionally accelerates the rate of deterioration. The results obtained at this temperature can be used to deduce the shelf-life estimates for the product kept under the recommended storage condition. ASLsT relies on the Arrhenius model and the fixed order kinetics for the rate of product deterioration (Labuza & Schmidl, 1985). The Arrhenius model shows the relationship between the changes in temperature to the rate of chemical reaction. It is represented by the equation, k= $_t$exp is the rate constant, Ea is the activation energy, R is the gas constant $_t$], where —□ (8.3144 J th), and T is the absolute temperature (Kelvin, K) (Corradini and Peleg,

2007). Compositional factors of the food product must be kept constant in the event of ASLT (Hough, 2010).

CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter highlights the procedures followed to improve the shelf-life of millet drink (zoomkoom), in the six districts of northern region. It entails the research approach and design, population of the study, sample and sampling technique, instrumentation, validity and reliability of instrument, pilot testing of the instrument, procedure for data collection, data analysis procedure, materials and methods-preparation of millet drink (control), microbial quality assessment of samples, nutritional analysis, sensory and acceptability analysis and shelf-life determination.

3.1 Research Design

This study was conducted using the mixed method approach. The qualitative study comprised observation and interview. The quantitative aspect adopted the survey conducted using questionnaire to obtain information on the knowledge and practices of producers and retailers of zoomkoom and the experimental study on the zoomkoom to determine the microbial quality and safety, the sensory and organoleptic properties of the millet drink and the shelf-life of the drink.

According to Johnson and Christensen (2017), mixed research design is used to collect both numeric and text data in order to expand and strengthen the conclusion of a study. Bryman (2006), also expounded the rationale for using mixed research design in the following aspects;

1. Credibility- Refers to as suggestions that employ both approaches to enhance the integrity of findings.

2. Context- Refers to cases in which the combination is justified in terms of qualitative research design providing contextual understanding coupled with either generalizable, externally valid findings or broad relationship among variables uncovered through a survey.
3. Illustration- Refers to the use of qualitative data to illustrate quantitative findings, often referred to as putting "meat on the bones" of "dry" quantitative findings.
4. Utility or improving the usefulness of findings- refers to a suggestion which is more likely to be prominent among articles with an applied focus that combining the two approaches will be more useful to practitioners and others.
5. Confirm and discover- this entails using qualitative data to generate hypothesis and using quantitative design to test them within a single research.
6. Diversity of views- this includes two slightly different rationales, namely combining researchers' and participants' perspective through quantitative and qualitative research designs respectively and uncovering relationships between variables through quantitative research design while also revealing meanings among research participants through qualitative research (Bryman, p.106).

3.2 Population

The study population consisted of people six districts of northern region particularly all producers, retailers and consumers of millet drink as well as farmers and sellers of millet grains. These categories of respondents were targeted due to the fact that they were concerned with the handling, production, sales and consumption of millet drinks as well as providing relevant-detailed information about the shelf-life and safety of the millet drink for analysis.

The six districts (Mion, Savelugu, Sagnerigu, Tolon, Kumbungu and Tamale metropolitan) was chosen due to convenience and nativity of the millet drink as well as availability of the raw materials, mainly millet thus providing a large pool of consumers, retailers, millet farmers and sellers to sample from for data collection as well as a large distribution of producers and samples of the product for sampling.

3.3 Sample and Sampling Technique

According to Saunders et al. (2009), a sample size of 50 reduces bias, but if a sample size is 100 or more, the degree of accuracy of findings is higher. It was however difficult to get a record indicating the number of producers, retailers of millet drink to create a sample frame, based on that a sample size of 100 respondents was used due to Gacula and Rutenbeck (2006) assumption that correct sample size for consumer's evaluation is between 40 and 100 respondents. In determining the 100 respondents (producers-25, retailers-25, consumers-30, farmer-10 and seller of millet grain 10) from 6 districts for this study, both probability (simple random sampling) and non-probability techniques such as convenience, purposive and snowball sampling. These techniques are further explained below.

Firstly, the convenience sampling was used to select six districts out of the 16 districts in Northern region. This was based on the fact that data were easily and quickly collected since they were accessible and closer to the researcher. The 16 districts were too large and impossible to include every individual participant due to the nature of this study. Secondly, purposive sampling technique was used to select the communities with the highest number of retailers, producers and consumers of millet drinks as well as farmers and sellers of millet grain in the targeted districts for this study. Purposive sampling technique was used to hand pick 15 communities to be

included in the sample on the basis of the researcher's own judgement of the typicality or possession of the particular characteristics been sought (Creswell, 2012). Again, the researcher decision on this sampling technique was influenced by the fact that the researcher needed to be better informed about the topic at hand before embarking on experimental study (shelf-life and microbial) of the millet drinks (Creswell, 2012).

Thirdly, snowball sampling technique was used to identify the producers, retailers, consumers of millet drinks as well as the sellers and farmers of millet grains. It was however difficult to get a record indicating the number of producers, retailers of millet drink to create a sample frame, based on that the researcher adopted the snowball sampling technique since most of the producers introduced the researcher to consumers who patronize millet drinks as well as sellers and farmers of millet grain and vice-versa. This therefore made it easier for the participants that the researcher first came in touch with to recruit other participants for this study. Ethically, the first participant identified by the researcher was not asked to identify other potential participants but rather was asked to encourage others to come forward for this study. However, at a point "cold-calling" (Glen, 2018) was used to identified some of the participants. According to Glen (2018), "cold –calling" is where individual participants are named. The researcher later resulted in this because there was no risk of shame or other ethical problems as far as the information needed for this study was concern. Below is the summary of the total number of respondents recruited for this study.

Table 3.1: Total number of respondents recruited for the study from the six districts

S/N	District s	Communities	Producers of millet drink	Retailers of millet drink	Consumer s of millet drink	Millet grain sellers	Millet grain farmers	Total respondents
1	Mion	Sang	2	2	3	1	-	8
2	Kumbun gu	Kumbungu	2	2	3	1	1	9
3	Tolon	Nyankpala	2	2	3	1	-	8
		Tolon	2	2	2	1	2	9
4	ıvelug u	Savelugu	3	3	2	2	4	14
5	agneri gu	Jisonayili	5	5	4	2	-	16
		Nyohini	4	2	3	-	3	12
		Kukuo	4	4	3	-	-	11
		Kpalsi	3	2	2	1	-	8
6	Tamale metro	Zogbeli	2	2	3	2	-	9
		Dungu	3	3	2	1	-	9
		Lamashegu	5	5	3	3	2	18
		Fuo	4	2	3	3	-	12
		Bamvim	5	2	2	-	-	9
		Sangani	4	3	2	-	3	11
Total	**6**	**15**	**50**	**41**	**40**	**18**	**15**	**164**

Source: Researcher's computations, 2020.

The summary of the above shows all the respondents delineated which constituted the total sample size for this study as presented in table 3.2 below:

Table 3.2: Sampled participants for the study

S/N	Participant in the study	Number
1.	Producers of millet drink	25
2.	Retailers	25
3.	Consumers	30
4.	Sellers of millet grain	10
5.	Farmers of millet grain	10
	Total	**100**

3.4 Instrumentation for Data Collection

The major instruments for collecting the research data for this study were questionnaire, unstructured interview and observational guide and experimental method. These data collection instruments are discussed.

3.4.1 Unstructured Interview

The unstructured interview was used due to the fact that the research needed to probe by asking open-ended questions as recommended by Creswell (2012) that they are primarily qualitative. English language and the local dialects that the respondents were familiar with were used. Hundred respondents were interviewed. The hundred respondents were sampled randomly by using simple random technique through the lottery method for the interview. The interview tool was used during the market survey with the producers, retailers, consumers and sellers of millet grains since most of the respondents were not in the position to either read or write. Though the researcher did not use any structured interview guide but was able to established a rapport with respondents, getting respondents to open-up and express themselves in

their own way (Creswell, 2017). The following guided the researcher to conduct the interview in a more unstructured way as proposed by Kvalve (1996).

i. **Knowledgeable**-The researcher been familiar with topic was able to stay focus during the interview in order to achieve the meet the demands of this study.

ii. **Structured**-Though, there wasn't a designed interview guide but researcher outlined the procedure of the interview.

iii. **Clear**- All questions delved by the researcher were simple, easy and short and were spoken in distinctly and a more understandable way taken the background of respondents into consideration.

iv. **Gentle**: The researcher was tolerant, patient and thoughtful when some respondents gave provocation and unconventional opinions.

v. **Steering**- The researcher was focused by controlling the course of the interview to avoid deviations from the topic.

vi. **Critical**- In the course of each interview session, the researcher tested the reliability and validity of information that the interviewee offered by probing further as and when needed in a friendlier manner.

vii. **Remembering** – Most of the information provided by the respondents were retained through the play-back of the audio-taped which was used to record the responses of respondents by first seeking the consent of all respondents.

viii. **Interpreting**- Inferences was easily made out of all the information the respondents offered.

3.4.2 Participant observation

Participant observation was used during the traditional preparation of the millet drinks by the indigenous producers from the 15 communities of the 6 districts of northern region. This was intended to determine if data captured on what respondents (25 producers of millet drink) say they do during the preparation and preservation of millet drink oppose to what they actually do. The instrument was also designed to capture the processes each producer of millet drink goes through during the preparation of the drink. It was also used to gather information on how each millet drink producer prepare and preserve the millet drink. The researcher deemed it necessary to observe the first hand, the practices that are carried out by the millet drink producers which in effect helped to verified and clarified views about safety practices employed by millet drink producers in the area of sorting, washing, soaking, milling of millet ; mixing, bottling and preservation of millet drink; handling of tools and utensils used for the preparation of the drink and personal hygiene practices employed during the preparation of the millet drink. A manual checklist was prepared and designed by the researcher and used during the field survey (Appendices B).

The observational checklist was graded under the heading: good, satisfactory, partially satisfactory and unsatisfactory with the rating scale from 4-1 respectively. There were 5 items on the observational checklist which were grouped into two. The first part (1-3) dealt with the processes involved in preparation of millet drink by the traditional producers which included; pre-treatment of millet before milling, milling of millet and handling of millet drink during mixing and bottling. The second part (4 & 5) focused on food and personal hygiene practices employed by the producers of millet drink to ensure microbial-free drink. These items were assessed during the observation of each zoomkoom producer visited during the market survey so as to

ascertain the safety precautions taken by the producers in order to prolong the shelf-life of millet drinks they produced.

3.4.3 Experimental method

The experimental method was also used during the laboratory analysis of both the market samples and laboratory prepared millet drink (controlled) for microbial, nutritional and shelf-life assessment through laboratory experiments. A sensory evaluation test was also done on the market and controlled samples during the laboratory analysis of both.

3.5 Validity and Reliability of Data Collection Instruments

The validity of the data collection instruments being the questionnaire, interviewers guide and observational checklist was evaluated prior to deployment for use in the study. The validity was assessed focusing on a three-point measure being the content validity, construct validity and criterion-related validity. The content validity of the instruments was assessed through subject matter expert review. The draft of the instruments was subjected to review by the researcher and experts to assess how genuine the questions asked are in relation to the subject matter with ethical considerations. The measure of validity was judged on the extent to which the items and questions adequately and accurately measure the trait the researcher intends to measure.

The construct and criterion-related validity of the tools were assessed using correlational analysis of the data obtained from the pretest of the instruments. The correlation coefficient was used as the measure of validity using the concurrent validity method by comparing the outputs of the structured questionnaire with the observational checklist and interviewers guide.

The reliability of the instruments was assessed using the internal consistency reliability checks where the score of items that measure a construct or trait was statistically assessed using the Cronbach's alpha value as determinant.

3.6 Pilot Study

In order to establish the validity and reliability of the data collection instruments, a piloting was carried out using a sample size of 10 participants from a community (Tampion) in Nanton district of the northern region. The community as well as the participants for the pilot study were purposively selected with the main study in mind as guide. The participants comprised of retailers and producers of the millet drink as predetermined in the study population. The data collection was carried out following same procedures as used for the main study (Section 3.10). Statistical evaluations were carried out using the data obtained from pre-testing of the instruments. The Statistical Package for Social Sciences (SPSS version 22) software was used for the validation.

3.7 Procedure for Data Collection

Both the interview and observation were conducted personally by the researcher. The researcher used English language and the local dialects that respondents were familiar with to conduct the interview. An introductory letter was collected from the department head of home economics education, Winneba in order seek for permission to undertake this study.

The entire data collection took a period of six months. A period of two months was used for conducting the interview. Respondents from a community each were interviewed separately. The communities with the least (8-9) respondents were first to be visited and two days were used to conduct the interviews in such communities.

However, communities with respondents between 9 to 12 were visited within 2-4 days during the interview session.

The Ghanaian dialects that respondents were conversant with were used. Most of the responses received during the interview were recorded with tape and notes of responses were also jotted.

The researcher first, established a good rapport with each of the respondents and further explained the rationale for this study to each of the respondents before conducting the interview. Each respondent was interviewed within 20-25minsutes.

After the interviews, dates were fixed with only the producers of millet drinks for observation to be made. The field observation was made within a period of three months. The lengthy period for the observation was as a result of low patronage of the drinks by consumers hence producers not producing the drinks frequently. It took some producers two to three weeks to produce new drinks so the researcher needed to prolong the frequency of visiting for observation in order to obtain accurate information.

A sensory evaluation test was conducted at KNUST with six trained personnel and fourteen untrained panelists. The panelists were given a sensory evaluation (Appendices A) form to complete.

3.8 Ethical Concers

Ethics in research provides guidelines for the responsible conduct of the research. In addition, it educates and monitors scientists conducting research to ensure a high ethical standard (libguides. library. cityu). Ethics when applied to social research is concern with creation of a trusting relationship between those who are researched and

the researcher. To ensure that trust is established, it is essential that communication is carefully planned and managed (kirklees.gov.uk). According to Resnick and Chirchu (2018), ethics in research help to ensure that the public can trust the research and also make researchers accountable for their actions.

Bryman and Bell (2007) outlined ten points which represent the most important principles related to ethical considerations in dissertations as follows;

i. Research participant should not be subjected to harm in any ways whatsoever
ii. Respect for the dignity of research participants should be prioritised.
iii. Full consent should be obtained from the participants prior to the study.
iv. The protection of the privacy of research participants has to be ensured.
v. Adequate level of confidentiality of the research data should be ensured.
vi. Anonymity of individuals and organizations participating in the research must be ensured .
vii. vii. Any deception or exaggeration about the aims and objectives of the research must be avoided.
viii. Affiliations in any forms, sources of funding as well as any possible conflict of interests have to be declared.
ix. Any type of communication in relation to the research should be done with honesty and transparency.
x. Any type of misleading information as well as representation of primary data findings in a biased way must be avoided.

With regards to the above guided ethical principles in research, the researcher discussed with the respondents the purpose of the study and assured each respondents of trustworthiness in term of promises made not to disclose their identity and responses provided for this study. None of the respondents was coerced or intimidated with any misleading or exaggeration Though the interview was conducted without a structured guide, a consent form was first read out and explained to respondents for them to consent to the study before the interview commenced messages to lure any respondent but rather, the rights of respondents to partake the study was duly explained to the respondents.

All schedules made with the respondents for both the interview and the observation as well as scheduled trips to KNUST for the laboratory analysis were duly followed. In few cases, where the respondents were busy and could not honour their scheduled meetings for the interview and observation, the researcher respected the views of respondents and further reached a consensus with respondents for the study to be conducted. All data collected through the interview, observation and laboratory test are credibly and accurately reported in this study without alterations and falsification.

3.9 Data Analysis Procedure

The data obtained from the survey and interview were collated using Microsoft office excel, 2006 as the data entry and management software. The data was exported to SPSS, version 22 and analyzed. Descriptive analysis was carried out to establish the percentages, modal and median values of the responses where applicable. In some cases, correlational analysis was carried out to establish relationship between responses that represent similar traits as means of validation and reliability checks. No

analysis of variance (ANOVA) was carried out as the responses were not numerical (quantitative) nor assigned any numerical labels.

3.10 Quantitative Study

The quantitative study comprised the survey using questionnaire to obtain precise information on the demographics of the people involved in the zoomkoom trade including producers and retailers as well as gather information on their knowledge of the business and practices adopted in the production, storage and sale of the millet drink. The questionnaire was sectioned into three (3) with the first gathering the demographic data such as age, gender and educational background, whereas the second focused on the knowledge and experience in the trade with the third section gathering information on the practices used in the production and sale of the millet drink. The experimental study on the zoomkoom was conducted to determine the microbial quality, nutritional value, sensory and organoleptic properties of the millet drink. The shelf-life of the drink was also determined and optimized under the quantitative aspect of the study.

3.11 Materials and Methods

This covers the materials and consumables used in the preparation of the laboratory control samples, the media for microbiological analysis, reagents for the proximate and physicochemical analysis and the methods used in conducting the respective analysis.

3.11.1 Ingredients

The ingredients used include sugar, ginger, cloves, pepper corn, pearl millet dough which were obtained from the Tamale central market.

3.11.2 Tools, equipment and chemicals

The tools and equipment used in the preparation of the millet drink include wooden ladle, funnel, a home Binatone food processor, plastic and breakable bottles with corks, ice chest, Milton sterilizing tablets, hand gloves, food nets, plastic sieves, measuring cups and digital measuring scale, plastic and stainless-steel mixing bowls, permanent markers, masking tape.

3.12 Methods

An introductory letter was collected from the department of Food and Nutrition education, Winneba Campus and presented at the Microbial Biotechnology and Food and Quality laboratory of KNUST. The topic for this study was explained and dates were fixed for both the proximate and shelf-life analysis. A fee was charged and part payment was made for the experiment to commence during the stipulated date

The laboratory analysis was done on two major samples of drinks. The first samples (market sample) which consisted of two bottles each of millet drinks from a producer each making a total of 38 bottles of millet drinks from the nineteen producers who were interviewed form the twelve communities and the second samples were the (controlled samples) which was prepared in the laboratory by the researcher.

The market samples from the traditional producers were transported on ice in a sterilized ice chest for seven hours from Tamale to Microbial Biotechnology laboratory of the department of biochemistry, KNUST for the shelf-life estimation and quality assessment as well as the food and quality laboratory of the department of food science and technology, KNUST for the proximate and nutritional analysis.

All agars and characterization media used for the laboratory analysis were prepared according to the manufacturer's protocols as stipulated on the labels. All tools, equipment, utensils and ingredients for the controlled samples in the laboratory were sterized and treated respectively.

The standard method of Association of Official Analytical Chemist (AOAC) 2000) was used to analysed the proximate, mineral and moisture determination.

3.12.1 Preparation of millet drink (Control)

The whole millet grains (1 Kg) were sorted by sieving to separate the grains from the sand and stones and then washed. The spices; ginger (50g) together with the mint (50g) were washed and soaked together with the pearl millet at room temperature for fourteen hours and subsequently drained in a colander. The grain-spice mix was milled using a home food processor at high speed for 20minutes.

The dough obtained was mixed with sterile water obtained from boiling clean tap water for 30 minutes in a ration of 500g:10000ml. The resulting solution was stirred for uniform mixing using the wooden ladle. The mixture was sieved to separate the grain chaff from the solution to obtain a fine textured solution after three successions of sieving. The millet drink was sweetened with the addition of sugar (25g in 500ml) and stirred to fully dissolve and mix thoroughly to obtain the final product.

3.13 Microbial Quality Assessment of Samples

The microbial quality assay was conducted on the samples obtained from the retailers as well as the control sample prepared in the laboratory to determine the safety and degree of contamination of the product as an index of food quality assurance.

3.13.1 Chemical reagents

The agars used were products of OXOID Laboratories, Basingstoke Hampshire, England. They included, Mannitol Salt Agar (MSA) for isolation of S*taphylococcus,* Brilliance *E. coli* selective agar for the isolation of *E. coli* and MacConkey agar (MA) for total Coliform count, Plate Count agar (PCA) for total aerobic count and Yeast Extract agar (YEA) for yeast and mold count.

3.13.2 Media preparation

All agars and characterization media used in this study were prepared according to the manufacturers protocol as stipulated on the labels.

3.13.2.1 Preparation of mannitol salt agar

Agar powder (111 g) of mannitol salt agar was suspended in 1 litre of distilled water and brought to boil to dissolve completely. The molten agar was sterilized by autoclaving at 121°C for 15 minutes and brought to cool to 50^0C and dispensed into sterile Petri dishes to set subsequent to sterility checks after a 24-hour incubation period.

3.13.2.2 Preparation of MacConkey agar

Agar powder (26 g) of MacConkey agar was suspended in 500ml of distilled water and brought to boil to dissolve completely. It was sterilized by autoclaving at 121°C for 15 minutes and allowed to cool to 50^0C and poured into sterile Petri dishes.

3.13.2.3 Preparation of *E. coli* agar

Agar powder (18 g) of Brilliant *E. coli* select agar was suspended in 500ml of distilled water and brought to boil to dissolve completely and allowed to cool to 50^0C and poured into sterile Petri dishes.

3.13.2.4 Preparation of plate count agar

A weighted mass of 9g of plate count agar was dissolved in 500ml of distilled water and melted to completely dissolve using a microwave oven for a period of 5 minutes. The molten agar was sterilized by autoclaving at 121^0C for 15 minutes subsequent to cooling to 50^0C and dispensing into sterile Petri dishes. The agar plates were allowed to set at room temperature and subjected to sterility checks overnight.

3.13.2.5 Preparation of XLD agar

For XLD, 26.5g solute was dissolved in500ml of distilled water with pH adjusted to 7.4 ± 0.2. It was then melted at 100 °C for 15 minutes after which it was poured into petri dishes for it to solidify. This medium was also used for salmonella analysis.

3.13.3 Serial dilution

Serial dilution was done to reduce a dense culture of cells to a more usable concentration. A weighted mass of 5g of each food sample was weighed and placed in 45ml of sterile peptone water solution. Serial dilution was performed to obtain a six-fold dilution (10^{-6}) by transferring one milliliter (1ml) of the stock into nine milliliters (9ml) of sterile diluent and repeated for subsequent dilutions.

3.13.4 Quantitative analysis

The quantitative assay was carried out to determine the microbial population in the samples as an index of food safety as well as predictors in the shelf-life estimation. The parameters considered were total aerobic count, total Coliform count, yeast count and mold count.

3.13.4.1 Determination of Total Aerobic Count (TAC)

The total aerobic count was carried out by spread plate method on Plate count agar (PCA).

Aliquots of hundred microliters (100□l) from each of the dilutions were inoculated into Petri dishes containing PCA. The inoculum was evenly spread with a sterile bent rod and allowed to dry for 15 minutes at room temperature. The plates were inverted and incubated at 37 ºC for 24 hours

3.13.4.2 Determination of Total Coliform Count (TCC)

Aliquots of one hundred microliters (100□l) from each of the dilution were inoculated into Petri dishes containing MacConkey agar. The inoculum was evenly spread with a sterile bent rod and allowed to dry for 15 minutes at room temperature. The plates were inverted and incubated at 37 ºC for 24 hours.

3.13.5 Qualitative analysis

The qualitative assay was carried out to isolate and identify specific organisms of interest mainly food pathogens which are indicator of food quality and safety. The organisms considered in this study include *Staphylococcus aureus*, *Escherichia coli* and *Salmonella typhi*. These Gram positive and negative food pathogens were selected as indicators of human-food contact contamination as well as indicators of hygiene and aseptic practices.

3.13.5.1 Determination of *Staphylococcus aureus*

Staphylococcus species were isolated and enumerated by spread plate method and grown on Salt Mannitol Agar (SMA). One milliliter aliquot from each of the dilution was inoculated into already prepared Petri dishes of MSA. The inoculum was evenly

spread with a sterile bent rod and allowed to dry for 15 minutes at room temperature. The plates were inverted and incubated at 35 ºC for 24 hours. After incubation yellow colonies were counted and recorded as *Staphylococcus* counts.

3.13.5.2 Determination of *Escherichia coli*

The presence of *Escherichia coli* was determined by spreading an aliquot of 0.1ml of stock dilution of the samples on sterile plates of Brilliant *Escherichia coli* selective agar and incubating at 37^0C for 24 hours. The presence of E. coli was confirmed with the observation of purple colonies

3.13.5.3 Determination of *Salmonella typhi*

The presence of *Salmonella* species was elucidated by following a three-step assay; pre-enrichment, enrichment and culture. The food sample (5g) was inoculated into 45ml of 1% peptone and incubated overnight at 37^0C. An aliquot of 100µl of the pre-enriched sample was transferred into 9ml sterile Rappaport Vassiliadis broth and further incubated for 24 hours. Aliquots of 10µl was transferred unto plates of XLD and BGA and incubated for another 24 hours at 37^0C. The plates were observed for the appearance of colonies with black spots on XLD and red colonies on BGA for Salmonella species.

3.14 Nutritional Analysis

The zoomkoom samples were nutritionally analyzed for proximate and minerals by applying standard method of AOAC (2000).

3.14.1 Moisture determination

The moisture content of the drinks was calculated by the Association of Official Analytical chemist (AOAC) 2000). Two grams (2 g) of fresh samples was accurately

weighed in a clean (crucible) of a known weight. It was immediately put in a conventional oven at 105 °C for 6 h. The crucible was then put inside desiccator over a period of 30 minutes and allowed to cool. Afterwards, the crucible with its content was weighed. The percent moisture was then calculated using the following formula:

$$\% \text{ moisture} = \frac{(W2-W3)\times 100}{W2-W1}$$

Where: W_1 = Weight of crucible, W_2= Weight of crucible + sample,

W_3 = Weight of crucible + dry sample.

3.14.2 Crude protein determination

The protein content was determined by the Association of Official Analytical chemist (AOAC, 2000). A mass of two grams (2 g) of the sample were weighed into a digestion tube. Five grams (5 g) of catalyst and 1 glass bead together with 10 mL concentrated sulfuric acid will also be added. Digestion tubes were placed in the digester. Digestion commenced initially at a temperature of 400ºC in order to avoid bubbling and boiling to achieve a clearer solution. An Erlenmeyer flask of measure (250 mL) containing 50 mL of 4% boric acid was placed in distillation unit for 10 min with the condenser tip extended below the surface of the acid solution. A 100 mL water as well as 70 mL (50% sodium hydroxide) excess was added to the digests during the distillation process to ensure complete release of ammonia. Titration on the distillate with standardized 0.1 M hydrochloric acid until pinkish colorization was obtained. Result was noted to the averaging 0.05 mL volume and calculated nitrogen and hence protein content

$$\%\text{Total Nitrogen} = 100 \times \frac{(sample\ titre\ value - Blank\ titre\ value) \times 0.1 \times 0.01401}{\text{sample weight} \times 10}$$

% Protein = %N × 6.25

3.14.3 Crude fibre

The crude fiber content was determined by the Association of Official Analytical chemist (AOAC, 2000). A mass of five (5) grams of sample was taken from the zip lock bags and defatted using the AOAC standard before subjecting to analysis. Two (2) g of beetroot cupcake samples were weighted into a flat bottom flask and 200 mL of boiling sulphuric acid (1.25%) was added for 30 min. The resulting solution will be filtered through cheese cloth using a funnel and then washed with hot water until it was free from the acid. The residue on the cloth was transferred into a flask and 200 mL of boiling sodium hydroxide solution (1.25%) was added. The flask was immediately connected to the digestion apparatus and boiled for 30 min. The flask was then removed and immediately the followed by filtration of the solution rinsed thoroughly with distilled boiling water. The residue was rinsed with 15 ml of alcohol. It was transferred into porcelain crucibles and dried at 105°C in an oven for 24 h. It was cooled to room temperature in a desiccator and weighed. The cauldron and its weight were burned in a mute heater at 550°C. It was cooled to room temperature in a desiccator and weighed. The difference between the two weights was recorded and the percentage crude fiber calculated as

$$\%\text{Crude Fibre} = \frac{(\text{weight of sample before ashing} - \text{weight of sample after ashing}) \times 100}{\text{weight of flour sample}}$$

3.14.4 Crude fat determination

The known mass of the sample was weighed into a flask and 5ml of ammonia added and shaken for a minute to denature proteins present. This was followed by 45ml of Petroleum ether and shaken for 3 minutes with intermittent release of pressure from gas buildup. About 5ml of ethanol was used as emulsifier with intermittent shaking for 2 minutes. The solvent phase was collected and evaporated in pre-weighed flasks in a hot air oven at 80^0C for 15minutes. The flasks were cooled in desiccators and reweighed for final weights. The Milk fat content was calculated using the formula:

$$\text{Milk fat} = \frac{\text{(wt. of flask + oil) – (wt. of flask)}}{\text{wt. of sample}} \times 100$$

wt = weight

3.14.5 Ashing

The ash content was determined by the Association of Official Analytical chemist (AOAC, 2000). Clean empty crucible will be placed in a muffle furnace at 600°C for an hour. It was cooled in a desiccator and then weighed (W_1). Sample of about 1.0 g was weighed (W_2) and transferred into the crucible. The example was lighted over a burner with the assistance of blowpipe, until scorched. At that point the cauldron was put in a suppress heater at 600°C for 6 hours to finish oxidation of all-natural tissue in the specimen. After the procedure, cauldron was cooled in the desiccator and the weight was noted W3. Percent rough fiery remains was computed and recorded as

$$\%\,\text{Ash} = \frac{(W3 - W1) \times 100}{W2 - W1}$$

Where: W_1 = Weight of porcelain crucible,

W_2= Weight of porcelain crucible + slices, W_3 = Weight of porcelain crucible + Ash.

3.14.6 Determination of carbohydrate and energy

The carbohydrate content of the drinks was determined by subtracting the sum of the moisture, protein, fat, ash and fiber contents from 100. The energy content was then calculated by multiplying the protein, carbohydrate and fat contents by factors of 4, 4 and 9 respectively.

3.15 Sensory and Acceptability Analysis

Some sensory parameters such as taste, appearance, color, smell, aftertaste and overall acceptability of the products were assessed to establish consumer preference and acceptability of the millet drink as well as to assess the consumer acceptability of the effect of the preservative on the sensory attributes of the drink.

The sensory assessment was carried out by the 6 trained personnel at the laboratory with the assistance of 14 untrained panelists during each sample section thus a total panel number of 20. The assessment was done with the aid of a sensory assessment form (Appendix 1). The assessment was done using a nine-point hedonic scale from ‘dislike extremely’ to ‘like extremely’ in ascending order from 1-9. The samples for the sensory test were coded in a random fashion to disguise the identity of the products from the panelists to avoid any misjudgment or partiality based on intended preference

3.16 Determination of Shelf-life

The shelf-life of the product was determined using both microbiological and physicochemical indicators. The microbiological parameters used include the total aerobic count, total Coliform count, yeast count and mold count. The physicochemical parameter used was the pH of the drinks.

3.16.1 Sample preparation for shelf-life study

The shelf-life study was carried out using two models; model 1 being the samples obtained from the market and model 2 being the control sample. The samples were divided into three treatment sets with each set comprising twenty (20) different containers with 60ml of the sample. The samples were treated with 0.025% and 0.05% of potassium sorbate while the last set was left untreated. The summary of the treatments is provided in Table 3.3

Table 3.3: Summary of preservative concentrations used in treatment of samples

Treatment	Model 1	Code	Model 2	Code
Sorbate (0.025)	Control	B	Retail	F
Sorbate (0.05)	Control	C	Retail	E
No preservative	Control	A	Retail	D

The samples were stored 0^0C, 5^0C, 25^0C and 40^0C for 15 days with a 3 days sampling interval thus giving a total of five sampling points. The different treatments and storage conditions gave a sample size of twelve (12) per each sample point for analysis resulting in a total of 60 samples across the period (1×3×4×5 factorial) per model.

3.16.2 Microbial, physicochemical and sensory analysis in shelf-life study

The microbial analysis carried out in the shelf-life study included the total aerobic count, yeast count, mold count and total Coliform count. The tests were conducted as described above in section 3.5 under their various headings and specifications with no modifications.

The physicochemical parameter considered in the study was the pH of the drinks across the storage period. The pH was taken using the pH meter (Metller Tolledo) at a temperature of averagely 28^0C. The reading was done in triplicates.

Some sensory parameters were also assessed over the storage period and these include the aroma/smell, appearance and overall acceptability of the milk drink as the days progressed. A 5-member panel of trained personnel was used for this assessment using a sensory form displayed in Appendix 2.

3.16.3 Mathematical modeling and statistics

The data obtained was used in the shelf-life estimation using the Statgraphics Centurion software under simple and multiple regression analysis. The Polhemus model for shelf-life prediction was used at 80% prediction level.

3.17 Data Analysis

All data reported in the study are means of analysis reports carried out in triplicates with the values reported along with their standard deviations. The Graphpad Prism 5.0 software was used for processing the data obtained from the microbial load assessment at 95% confidence interval using One-way ANOVA and Two-way ANOVA tools with

Bonferonni Post Hoc analysis. Variations were considered significant between blocks at P values lesser than 0.05 and not significant at P values greater than 0.05.

The data from the sensory analysis of the millet drink was analyzed using the SPSS software using the One-way ANOVA tool and a Tukey Post Hoc analysis at 95% confidence interval. The difference in the response of the panel to the various sensory parameters were considered as significantly different at P value less than 0.05 and not as significantly different at P value greater than 0.05.

CHAPTER FOUR

PRESENTATION OF RESULTS AND DISCUSSION

4.0 Overview

This chapter presents respondents results on the knowledge and practices of the production, sales and consumption of millet drink during the survey as well as the laboratory result of microbial quality, nutritional composition and shelf-life of both market samples and laboratory control samples of millet drink. Data from the survey was analysed using triangulation method, where data from different instruments; questionnaire, interviews and observations were analysed to ensure validity of the results. Thus, both quantitative data and qualitative data were analysed separately and the results verified against each other to ensure validity of the results. In all, 100 respondents were targeted, and all the 100 actually participated in the study, representing 100 percent response rate.

4.1 Survey

The survey was carried out in 16 different communities from six districts shown in table 3.1. The objective of the survey was to gather information on the demographics, level of knowledge of the producers on the millet, treatment, safe production practices, preservation methods and impact of quality and safety of product on consumer preference.

Table 4.1: Demographic data of respondents in the survey on production and sales of zoomkoom

Parameter	Frequency (n=50)	Percent (%)
Age		
<20yrs	5	10
20-30yrs	10	20
30-40yrs	29	58
>40yrs	6	12
Gender		
Male	4	8
Female	46	92
Level of Education		
Primary	6	12
Senior High	1	2
Tertiary	1	2
Technical	0	0
No formal education	42	84

The data obtained from the survey indicates that majority of persons involved in the production and sales of the millet drink are between the ages of 30 and 40 years putting them in the active working-class age of adults occupying 58% of the study population with young adults between the age of 20 and 30 years forming the next majority of 20%.

The study shows the trade is dominated by females with 92% while males recorded 8% participation. Level of education reveals 84% of the participants have had no form of formal education while 16% have obtained formal education. Of the respondents with formal education, 12% have had education only to the basic level, while 2% were educated to the senior high level. Only 2% of the respondents have had higher education to the tertiary level.

Table 4.2: Occupational dynamics of study participants

Statement	Frequency (n=50)	Percent (%)
What role do you play?		
Producer	3	6
Retailer	9	18
Both	38	76
How long have you been in the trade?		
1-5yrs	39	95
6-10yrs	2	5
10-15yrs	0	0
>15yrs	0	0
Have you had any formal training in the production of the drink? n=41		
Yes	0	0
No	41	100

The study shows 76% of the respondents were involved in the production and retailing of zoomkoom while 18% were involved in the retailing of the drink from wholesale purchase from producers. The study again revealed 95% of the respondents had been in the trade for periods between 1-5 years while 5% have been in the trade for longer periods of 6-10 years. Considering the expertise and knowledge base of the producers, the study reveals none of the producers have received any formal training and education in the production and safe operating procedures involved in the production of the drink.

Table 4.3: Processes in the production of zoomkoom

Statement	Frequency n=41	Percent (%)
How do you get the millet for production?		
Farm	1	3
Market	37	90
Supplier/middle man	3	7
How do you pretreat the millet?		
Washing	9	22
Sorting	1	2
Sorting and washing	31	76
Do you use a commercial mill?		
Yes	38	93
No	3	7
Source of water used in production		
well / borehole	4	10
Pipe	37	90
Surface water	0	0
Do you treat the water before use?		
Yes	8	20
No	33	80

The production of the millet drink is very crucial in determining of the durability and quality and the findings of the study shows 90% of the producers obtain the raw material (millet) from the local market with only 3% obtaining it directly from the farm. The survey shows 76% of the producers to wash and sort the millet prior to milling for production. The mills used in production are predominantly commercial (93%) as per the findings of the survey. The water for production is of utmost concern as it forms about 85% of the product and the study shows 10% of the producers used underground water from dug wells and boreholes whereas 90% used pipe water in the

production of which 20% treated the water prior to use while a majority of 80% did not.

4.2 The Observation Study

The observational study was to determine if the knowledge of the producers reflects in their practices as well as to identify the possible lapses in the production and sources of errors that contribute to the short shelf-life of the product.

Table 4.4: Observation of zoomkoom producers from 16 communities of the selected districts of Northern region

S/N	Item Checked	Good	Satisfactory	Partially Satisfactory	Unsatisfactory
A	Processes involved in the preparation of millet drink.				
1.	Pre-treatment of millet before milling.	5	2	8	10
2.	Milling of millet.	2	3	5	15
3.	Handling of millet drink during mixing and bottling.	1	3	9	12
B	Food and personal hygiene practices to ensure microbial- free drink.				
4.	Treatment of water for mixing milled Millet for the drink.	2	1	2	20
5.	Personal hygiene practices	5	2	13	5

Source: Field observation, 2020. Adu Gyamfi, 2022

The field observation was embarked on under two main headings (A-processes involved in the preparation of millet drink and B-Food and personal hygiene practices to ensure microbial- free drink). Each heading had sub-headings which were graded with certain criteria. With regards to the first heading-A, it had the sub-headings which include pretreatment of millet before milling, milling of millet and handling of millet drink during mixing and bottling. The second heading-B, also had the sub-headings like treatment of water for mixing of milled millet and personal hygiene

practices employed during the preparation of millet drink. The first sub-heading (pre-treatment of millet before milling) under heading 'A' was graded based on the ideal treatment given to millet before milling such as washing, sorting and soaking. Out of the 25 producers, 5 were rated good due to the fact that, they washed, sorted and soaked the millet before milling. Two were graded satisfactory because the millet was sorted and soaked without washing before milling. Eight were partially satisfactory owing to the fact that the millet was washed and soaked without sorting before milling. Ten were graded unsatisfactory since the millet was only soaked without sorting and washing. The second sub-heading (milling of the millet) of heading "A" was graded based on the use of commercial mill or blender and the condition of these food processors. Two out of the 25 producers used blenders at home which were well kept and was only meant for the purpose of blending the millet for the zoomkoom and so were graded good. Three were satisfactory because they used blenders at home but the blenders were multi-purpose ones but were however washed and rinsed before use. Five out of 25 producers were graded partially satisfactory due to the fact that they used commercial mill but insisted for any food particles to be removed and washed before milling the millet. Fifteen were graded unsatisfactory because they used commercial mill of which no attention was paid to hygienic state of the machine. The last sub-heading (handling of millet drink during mixing and bottling) of heading "A" was rated with the criteria such as the use of bare hands or hand gloves, the type of bottle used and how bottles are treated before use. Based on these criteria only one was graded good due to the fact that new bottles were used, bottles were rinsed before used and hand gloves were used during bottling. Three were graded satisfactory because, they used new bottles, rinsed bottles before use but did not use hand gloves during bottling. Nine which were rated partially satisfactory was as a result of using

new bottles without hand gloves and rinsing bottles before use. Twelve were graded unsatisfactory was due to the fact that old bottles were used but only rinsed them and bottling was done with bare hands. The second heading "B" had the first sub-heading (treatment of water for mixing milled millet for the drink) was graded based on sterilizing the water for mixing the drink. Two were graded good because they boiled the water, allowed to cool and strained before use. Only 1 was graded satisfactory due to the fact that the water was boiled, cooled but not strained before used. Two were graded partially satisfactory because they heated and used the water whilst hot without cooling. Twenty were graded unsatisfactory because no treatment was given to the water before use. The last sub-heading under "B" (personal hygiene practices employed during the preparation of millet drink) was rated under covering hair, removing rings on fingers and washing hands before commencing the preparation of the drink. Five out of the 25 were graded good due to the fact that they covered their hair, washed their hands and removed rings from their fingers before commencing the preparation of the drink. Two were satisfactory because they covered hair, washed hands but did not remove the rings on their fingers before commencing the preparation of the drink. Thirteen were graded partially satisfactory because they only covered their hair without washing hands and removing rings from their fingers before commencing the preparing the millet drink. Five were graded unsatisfactory because they did not pay attention to any personal hygiene practices.

4.3 Microbial Quality and Safety of Millet Drink

The microbial quality and safety of the millet drink was assessed using both quantitative and qualitative indexes. The total aerobic count, total coliform count, yeast and mold counts made up the quantitative assay while test for *Escherichia coli, Salmonella aureus* and *Salmonella* made up the qualitative assays.

4.3.1 Quantitative quality assessment

The findings of the study indicate very poor microbial quality of the millet drinks sampled from the producers with aerobic counts in the range of 7.1×10^{6}cfu/ml and 9.5×10^{6}cfu/ml which all fall beyond the safe and acceptable limit of 1.0×10^{4}cfu/ml for ready to eat foods as stipulated by the International Organization for Standardization (ISO) and adopted by the Ghana Standards Authority (GSA) and Food and Drugs Authority (FDA) of Ghana. The total Coliform counts of the products also failed the quality test with counts in the range of 8.8×10^{3}cfu/ml and 9.4×10^{4}cfu/ml which also exceed the safe limit of 1.0×10^{1}cfu/ml.

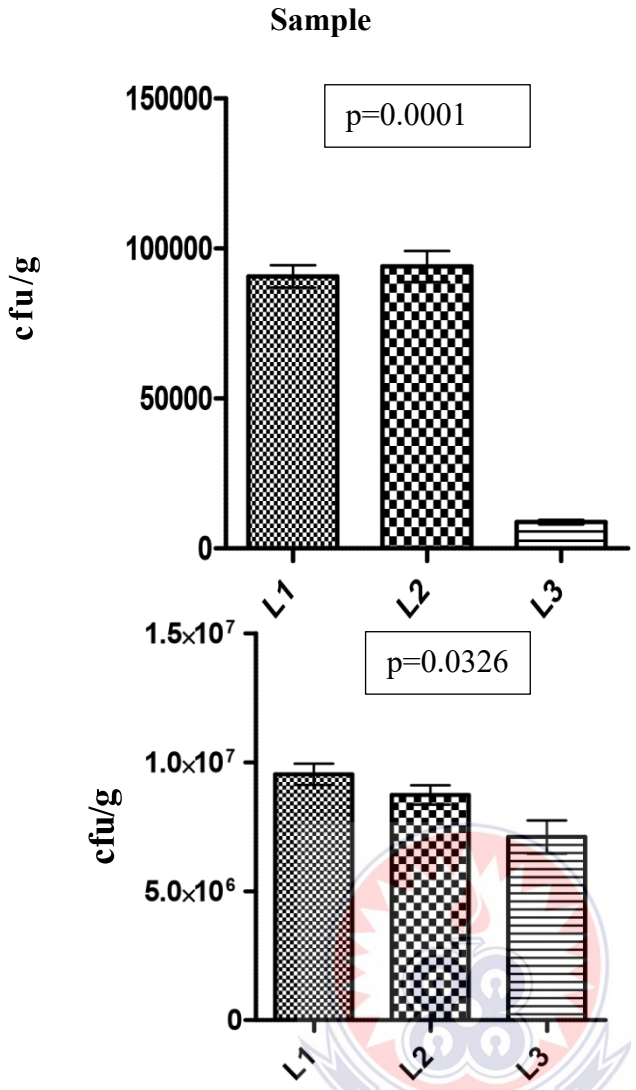

Figure 4.1: A and B Total Coliform (A) and Total aerobic (B) counts of zoomkoom sampled from markets of six districts in the northern region

The L1, L2 and L3 as indicated in Figure 4.1 above represent the samples of millet drinks obtained from the six districts of the northern region. In all a total sample of 30 bottles of zoomkoom were collected. The 30 samples were later pooled into pools of 3 according to the various districts with common traits with regards to the millet drink. The L1 represented the samples of millet drinks pooled from the first and second districts, L2 indicated the samples pooled from the third and fourth districts as well as L3 been samples pooled from the fifth and sixth samples.

The statistics of the data gathered shows significant difference ($p<0.05$) in the aerobic counts of the samples obtained from the various producers as well as significant difference ($p<0.05$) in the Coliform count of the drinks from the various producers as shown in (Table 4.5) below.

Table 4.5: Statistics of total aerobic and coliform counts of zoomkoom

Two-way ANOVA		
Source of Variation	**% of total variation**	**P value**
Interaction	1.30	0.0162
Column Factor	1.50	0.0103
Row Factor	95.89	< 0.0001

The yeast counts were also beyond the safe limit of 1.0×10^2cfu/ml as can be observed in Figure 4.1. The statistics of the data shows no significant difference ($p>0.05$) in the yeast count of the samples from the various producers in the selected districts.

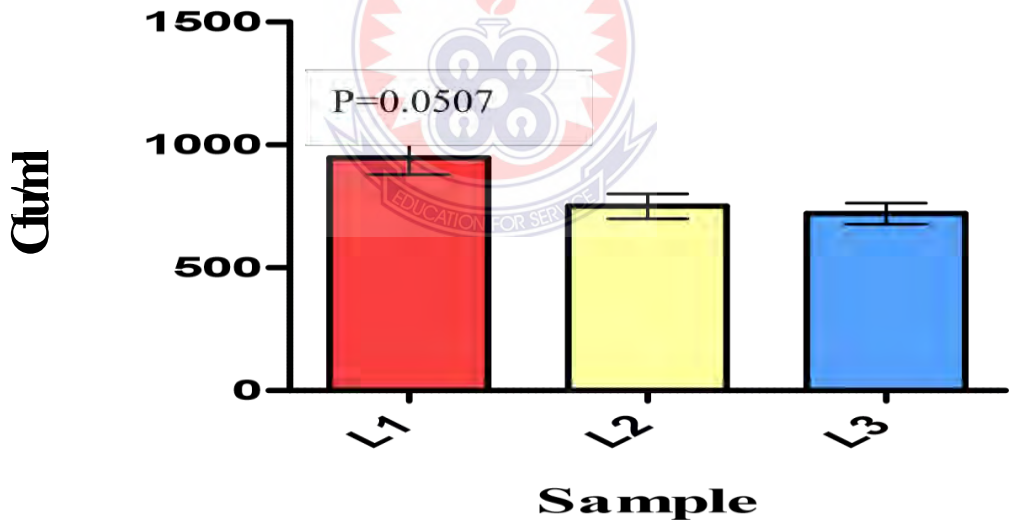

Figure 4.2: Yeast count of zoomkoom samples from selected districts in the Northern Region

Table 4.6: Microbial quality of Zoomkoom drinks obtained from selected districts in the Northern Region

Parameter	L1	L2	L3
Total aerobic count	$9.5\times10^{6}\pm7.09$	$8.7\times10^{6}\pm6.51$	$7.1\times10^{6}\pm11.14$
Total Coliform count	$8.8\times10^{4}\pm3.61$	$9.4\times10^{4}\pm8.89$	$8.8\times10^{3}\pm12.29$
Yeast	$9.4\times10^{2}\pm11.59$	$7.5\times10^{2}\pm8.72$	$7.2\times10^{2}\pm7.54$
Moulds	<10	<10	0.00

These tests were selected based on FDA standard for food safety. They are the tests required by FDA to determine whether ready –to-eat foods like millet drink is safe or not for consumption. The total aerobic count is an indication of the total bacterial population present in the food sampled for the study. This test (TAC) gives an idea of how the food is contaminated a food is by counting all the bacterial present in a food. A higher count is an indication that the food is highly contaminated and vice versa.

Total coliform count is an indication of faecal contamination. Their presence in food is a sign of poor hygiene and a transfer of faecal matter along the production chain by the food handler.

The yeast and mould counts were used to give the overall population of yeast and mould present in the millet drink which is an indication of fermentation, with high yeast count been a sign that the food is likely to be fermented and cause spoilage.

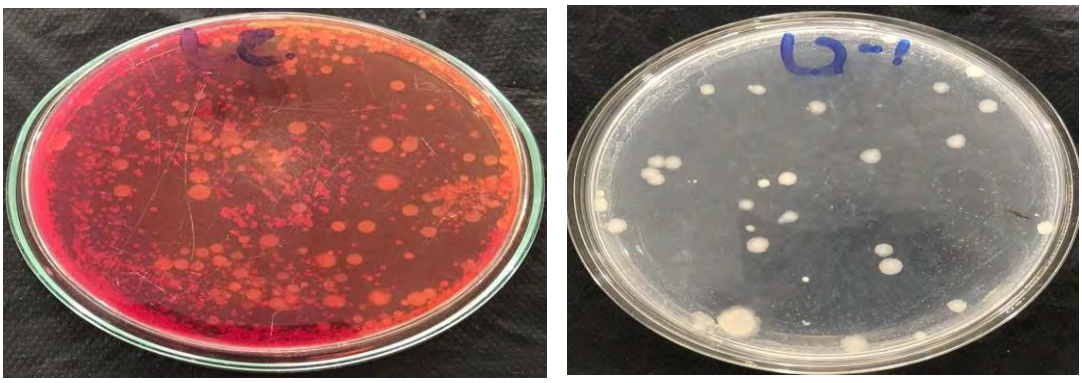

Plate 1: Total Coliform Count (A) and Total Aerobic Count (B) of zoomkoom samples

4.3.2 Qualitative food quality assessment

The pathogenic food microorganisms were assayed qualitatively as an index of the quality and safety of the zoomkoom drinks available on the market for everyday consumption by unsuspecting consumers. The results indicate the presence of *Escherichia coli* and *Staphylococcus aureus* in some of the samples assayed and at disturbing contamination levels. The results however show *Salmonella* species were totally absent in all the samples.

Table 4.7: Food pathogens found in zoomkoom drinks

Samples	*Escherichia coli*	*Staphylococcus aureus*	*Salmonella*
L1	-	++	-
L2	+++	+	-
L3	-	+	-

(+) Presence (-) Absence

The *Staphylococcus aureus* also known as pathogenic bacteria or disease causing bacteria. Their source is from human contamination so their presence in food is an indication of a lot of human contact during the food production.

The presence of *Escherichia coli* is a sign of poor hygiene and faecal matter present in the food. This test is graded based on their presence (+) or absence (-).

The poor microbial quality of the zoomkoom drinks sold on the markets of the selected districts increase the health risk of consumers thus exposing to risk of infections and food related illnesses along with their associated complications and symptoms.

The significant difference ($p<0.05$) in the microbial contamination levels is evident in the comparison between the samples obtained from the local producers and those obtained from the stores as retail from established producing enterprises. The results a relatively lower contamination levels in the products from the established enterprises as opposed to the locally produced ones though generically all fail to meet the quality and safety requirements (Table 4.7).

4.3.3 Food quality assessment of laboratory control sample

The control sample was prepared following standard hygienic protocols then subjected to quality assessment. Findings did show relatively much superior microbial quality and safety as opposed to the test samples obtained from the market. The aerobic count recorded was $9.6 \times 10^3 \pm 11.53$ cfu/g which falls within the International Organization for Standardization (ISO) and Food and Drugs Authority (FDA) specification for ready to eat foods. No pathogenic food bacteria (*E. coli*, *S.aureus* and *S. typhi*) was detected in the sample as well as yeast and moulds. The control sample is classified as safe and wholesome for consumption according to the FDA specification (Table 4.8)

Table 4.8: Microbial quality of control zoomkoom

Parameter	Control sample	Specification
Total aerobic count	$9.6\times10^{3}\pm11.53$	1.0×10^{4}
Total Coliform count	$2.7\times10^{1}\pm3.61$	1.0×10^{2}
Escherichia coli	None detected	0.00
Staphylococcus aureus	None detected	0.00
Salmonella typhi	None detected	0.00
Yeast	$1.6\times10^{1}\pm3.56$	1.0×10^{2}
Moulds	0.00	1.0×10^{1}

4.4 Nutritional Assessment of Zoomkoom

In Table 4.9, the nutritional significance of zoomkoom was assessed to determine the dietary benefits of the drink to consumers. The drink was found to be predominantly hydrated and water based with a moisture content of 84.79±0.016% thus making it a good source of hydration to the consumer. The drink had low fat, protein and fibre contents of 0.29±1.3%, 0.38±0.14% and 0.014±2.3% respectively. The carbohydrate content was determined to be 14.40±0.27% and an energy content of 61.87±0.5kcal/g.

Table 4.9: Nutritional properties of zoomkoom drink

Parameter	L1	L2	L3
Moisture	85.54±0.12%	84.69±0.02%	84.14±0.33%
Ash	0.04±0.01%	0.06±0.02%	0.17±0.08%
Crude fat	0.24±0.009%	0.22±0.001%	0.42±0.002%
Crude protein	0.25±0.02%	0.43±0.23%	0.47±0.18%
Crude fibre	0.015±0.004%	0.01±0.001%	0.016±0.002%
Carbohydrate	13.91±0.13%	14.58±0.42%	14.72±0.25%
Energy	58.82±0.24kcal/g	62.02±0.53kcal/g	64.76±0.72kcal/g

4.5 Determination of Shelf -Life

The shelf-life of the product was determined using microbiological and physicochemical parameters. The microbiological indicators used include the aerobic count and yeast count since fermentation of the product is the major spoilage mechanism. The pH of the product was considered as index of fermentation due to the production of organic acids.

4.5.1 Determination of shelf -life of zoomkoom

As could be seen in Figure 4.3, the durability and storage integrity of the millet drink was assessed under varying storage temperature conditions (5^0C, 25^0C) using varying concentrations of potassium sorbate (0.025% and 0.05%). The samples used for the assessment were the control product (C) prepared in the laboratory and a sample obtained from the market (S) as test sample using microbiological and physicochemical indicators.

The findings of the study indicate that the preservatives to have an effect on the shelf-life of the millet drinks with the statistics showing significant difference ($p<0.05$) in the shelf-life of the Zoomkoom with preservatives as opposed to the drinks without preservatives. The trend shows an increase in shelf-life duration with increase in concentration of preservatives as well as an increase in keeping quality with decrease in temperature. The longest shelf-life was recorded for the product treated with 0.05g/100g at both refrigeration and room temperatures.

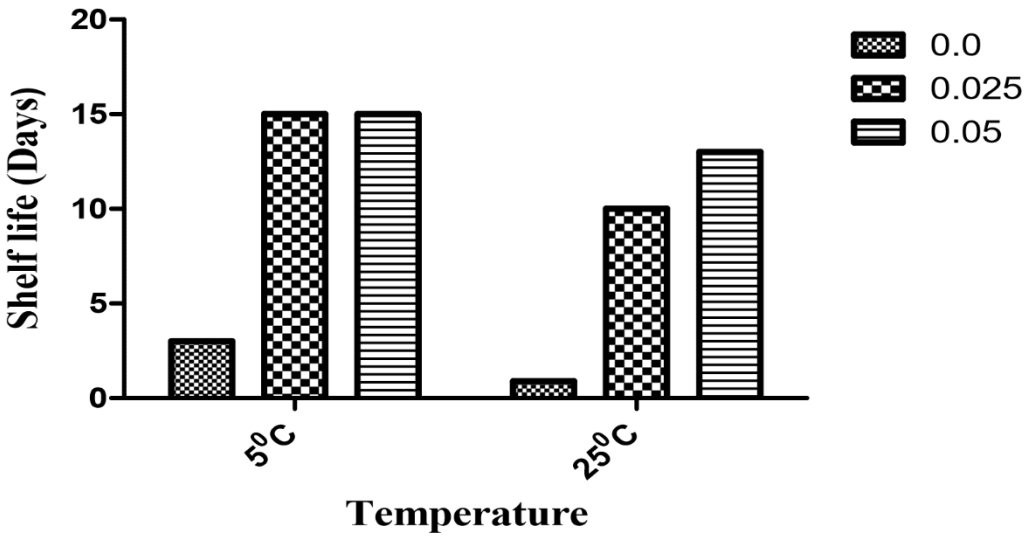

Figure 4.3: Shelf-life of zoomkoom

Using the shelf-life of the control at room temperature as baseline, the results indicate a 70% improvement in keeping quality when refrigerated and 91% - 94% when treated with preservatives (Fig 4.4).

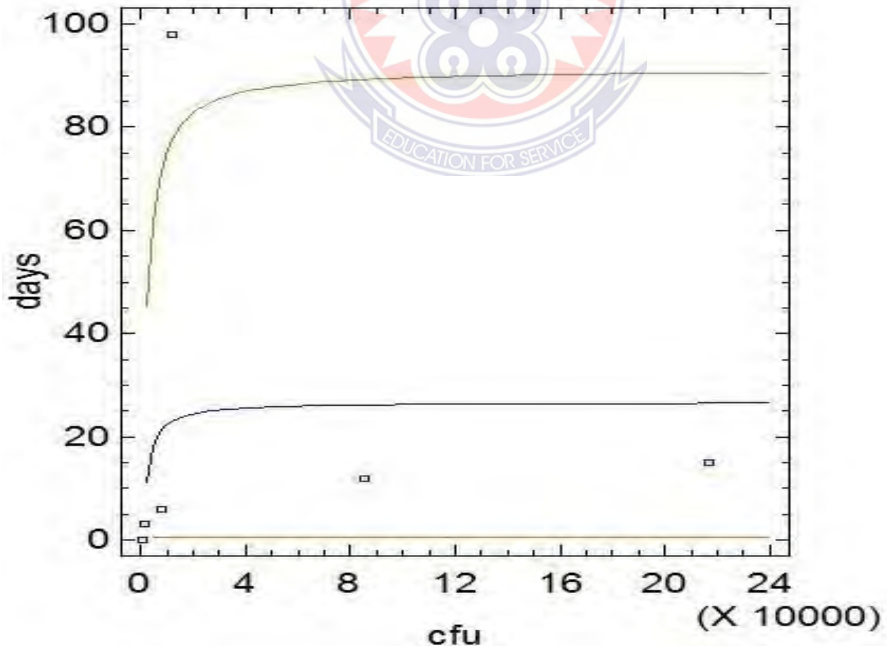

Figure 4.4: Model fitting for the estimation of shelf-life for Zoomkoom

4.6 Determination of Consumer Acceptability of the Improved Drink

Consumer acceptability was assessed using two packaging materials (glass and plastic bottles) and a preservative; potassium sorbate (E202).

4.6.1 Impact of packaging on consumer acceptability of product

The kind of packaging used in the presentation of the finished product was considered in the consumer acceptability and durability of the millet drink in the study. The survey conducted on the appearance of the two packaging materials (glass and plastic bottle) shows the panelist liked the glass bottle package with a mean score of 6 which corresponds to "like" on the 9-point hedonic scale used in the assessment. The panelist scored the plastic bottle packaging on a mean score of 5 which corresponds to "like slightly" on the hedonic scale used in the study.

On the judgment of acceptability of the packaging material, the panelist scored the glass packaging on a point of 7 corresponding to "like moderately" while they scored the plastic on a point of 6 corresponding to "like" on the hedonic scale.

As indicated in Table 4.10, the statistics however indicate that there was no significant difference ($p>0.05$) in the response of the panelists to the appearance and acceptability of the millet drink in the two packaging materials which points to the assertion that the type of packaging material used does not contribute significantly to the acceptability of the product.

Table 4.10: Statistical analysis of sensory responses from panelist on packaging material

		Sum of Squares	Df	Mean Square	F	Sig.
Appearance	Between Groups	6.400	1	6.400	1.621	.211
	Within Groups	150.000	38	3.947	-	-
	Total	156.400	39	-	-	-
Overall acceptability	Between Groups	1.600	1	1.600	.724	.400
	Within Groups	84.000	38	2.211	-	-
	Total	**85.600**	**39**	**-**	**-**	**-**

The findings of the study led to the selection of the plastic bottle package as the model material for the study as some participants indicated in their comments, they preferred the plastic bottle due to ease of handling as the glass demanded extra care in handling and opening of the bottle.

4.6.2 Effect of preservative (E202) on sensory indicators of zoomkoom

The acceptability of a product is very essential in determining the commercial value and public patronage and thus the acceptability of the zoomkoom drink after optimization for durability using potassium sorbate (E202) was determined using a nine-point hedonic scale to assess the panel judgment on the taste, color, smell, aftertaste, appearance and overall acceptability of the drink.

The results show the preservative to have had a positive impact on the preservation the taste of the drink after 24 hours of storage with the panelists grading the control sample with preservative with a score of 5 which corresponds to “like slightly” on the hedonic scale while the control sample without preservative was graded on a score of 4 corresponding to “neither like nor dislike”. The responses of the panelists on the smell, color, appearance and aftertaste were all in the same grade of which

corresponds to “like slightly” on the scale. The overall acceptability score of the samples puts the control with preservative at 6 while that without preservative was graded on a score of 4 corresponding to “like” and “neither like nor dislike” respectively thus affirming the positive impact of the preservative on the acceptability of the drink. This finding informed the assessment of the preservation prowess of the preservative on the drink since its use does not affect the consumer acceptability of the product.

A model product obtained from the market was also subjected to treatment using the preservative and assessed for consumer acceptability and the findings corroborated the performance of the preservative with the lab control sample. The panelists graded the products with and without preservative on a scale of 4 and the overall acceptability on a scale of 6 corresponding to “like” on the scale. This par scoring affirms the notion that the preservative in the drink does not negatively affect consumer acceptability and sensory uniqueness of the drink.

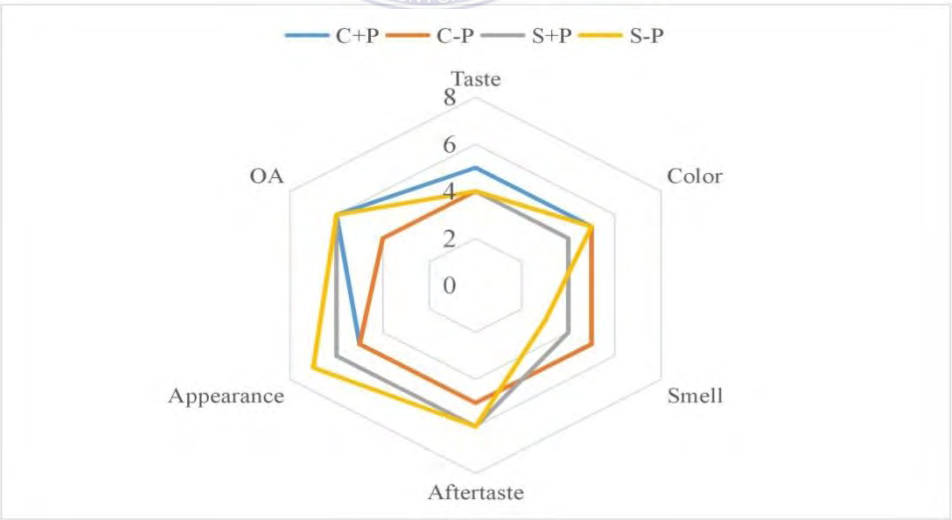

Figure 4.5: Sensory scores of formulations of Zoomkoom drink with Preservative (E202)

The statistical analysis of the data shows there is significant difference ($p<0.05$) in the score of the overall acceptability of the control samples treated with and without preservative, with the data indicating a higher preference for the sample with preservative. Considering the product sampled from the market, the statistics show no significant difference ($p>0.05$) in the overall acceptability of the product treated with and without preservative, which also suggests a neutral response of the consumer to the product treated with preservative thus a likely positive acceptance of the product when preserved using potassium sorbate (E202).

The positive response of the panelist to the drink when preserved with E202 informed the next stage of the study which involved assessing the preserving capacity of the preservative on the drink at varying concentrations and storage conditions.

CHAPTER FIVE

DISCUSSION

5.0 Overview

This chapter gives detailed interpretation of findings in chapter four (results of this study) with regards to the survey, observation and experimental study conducted on millet drink, zoomkoom.

5.1 Demographic Data from Respondent of the Survey on Production and Sales of Zoomkoom

The findings of the survey indicate the Zoomkoom trade is female dominated with 92% majority. This is typical of the cultural dynamics of the locality as the males are more prone to jobs such as farming and herding while females engage in domestic and trading activities (Ameleke et al., 2020). The results again show the majority (78%) of the people involved in the trade to be in the young adult and working class of the societal structure aged between 20 and 40 years. This implies that the active working population on whose wing's industrialization thrives are involved in the Zoomkoom trade. This paint a picture of great potential for the future of the trade if measures are put in place and investments are made to encourage the youth in entrepreneurship taking the production and sale of the millet drink as a focal point in business.

The production and sales of the millet drink is a predominantly informal trade with 84% of the people having no form of formal education or training in the business of production of the drink with 12% having only basic education. The low and lack of education could be a major contributing factor to the challenge of low patronage, poor quality of the drink and poor keeping quality and shelf-life of the drink. With some

education and training opportunities offered to the industry players being manufacturers and sales persons, more advanced and modern technologies could be adopted to optimize production to meet acceptable standards in terms of product quality, packaging, branding and product certification. This will boost consumer confidence and increase patronage of the drink. Cereals have been a major staple food for humanity for centuries and are processed into diverse food products. Natives of the northern region of Ghana process millet into the Zoomkoom drink for domestic and commercial consumption, despite the major challenge of short keeping quality.

The knowledge and practices of the producers have a significant impact on the safety and quality of the millet drink. The study indicated that majority (90) of the producers obtained their raw materials from the market with the minority dealing with the farmers and middle men. This firstly points out the impression that the production of the millet drink is done on a low scale by small scale enterprises and entrepreneurs as large companies and established firms deal primarily with farms and second party supply business for their raw materials rather than sourcing from the markets. Again, the quality of the raw materials used in the production of the millet drink is influenced by the market quality and practices of the traders. Information gathered from some participants indicated that the traders do adulterate the millet by adding stones to increase the volume. This deception according to them does not only cost them financially as the millet grains after sorting tends to be lesser than what they had bargained and purchased but also the time used in the sorting adds to the overall production time not to mention the additional labor effort as the sorting is done manually. The quality of the millet drink also gets affected as the inefficiency of the sorting process leads to some stone particles ending up in the final product which affects the organoleptic properties of the drink such as mouthfeel of the drink.

5.1.1 Practices employed by producers of zoomkoom drink during the field observation

The practices engaged by the producers of the millet drink as revealed in this study indicates that the millet grains are pre-treated through washing and sorting (Table 4.3) by majority of the producers to ensure a safer and quality product. The source of water used in this process is predominantly pipe water which is pre-treated by 20% of the producers to further purify. These measures in theory are to ensure a safe and microbial sound drink for consumer satisfaction. The use of commercial mills by majority of the producers is mainly due to the economic justification of relatively cheaper cost of production using the commercial mill than operating a private mill. The high cost of operating a private mill is attributed to the purchasing, installation, electricity and maintenance cost of the mills. Again, due to the short storage time of the drink, mass production is not economically feasible thus discouraging producers from heavily investing in the business. This makes the use of commercial mills for the production on a lower scale more feasible and the best alternative.

Millet and other cereal foods despite their nutritional function, serve as rich substrate for the proliferation of microbes both pathogenic and non-pathogenic. This has been the basis for the development of food products such as fermented dough in kenkey and porridge. This understanding calls for great hygiene and the use of aseptic techniques in the production of such products.

5.2 Microbial Quality and Safety of Market Sampled Zoomkoom

The results after microbial quality assay on the Zoomkoom drinks obtained from the markets indicated the products were of poor microbial quality with the aerobic counts exceeding the acceptable and safe threshold of 1.0×10^5cfu/g. The finding of the study

agrees with results obtained by Kagambega et al. (2019) in a work carried out in Burkina Faso on microbial quality of traditional drink including Zoomkoom. They reported high loads of aerobic bacteria in the range of $1.19x10^4$cfu/g, though lower than the loads reported by this study. Soma *et al*., in 2019, reported aerobic counts in the range of 1.0×10^6cfu/g from Zoomkoom in Burkina Faso which tallies with the findings of this study. The aerobic count gives the index of the overall bacteria load of the product and gives the degree of contamination and colonization of the product by opportunistic bacteria. The source of the contamination could be first attributed to the raw materials used in the production being the millet, spices and water. The study by Soma et al., in 2019 highlighted the spices predominantly mint and ginger as a major source of contamination of the drink and the finding of the present study supports this claim as the control sampled was of a much better quality when steps were taken to properly clean the ginger before use. The raw materials, mainly spices and cereals (millet) are obtained from the local market whose quality cannot be standardized and assured. On these local markets food and food products are exposed to the immediate environment and atmosphere harbouring all manner of insects and rodents which are agents of contamination. The handling and storage of these food products is highly unhygienic as the unprotected hand is mostly used in handling without proper sanitary measures such as good hand washing practice and use of gloves and sanitizers as revealed by the observation study (Table 4.4). This exposes the zoomkoom to direct contamination from pre-contaminated hands. In a production line, the quality of raw material plays a major role in determining the quality of the final product as well as the processes involved in the preparation of the millet drink.

The process of production does not permit the direct application of heat thus the state of the raw materials is translated directly to the product complemented by the

production process. The results from the observation study clearly point out the ineffectiveness of the pre-treatment procedures practiced by few of the producers of millet drink but claimed by majority of the producers during the survey to be pre-treating the millet. A critical look at the process of making the 'Zoomkoom' drink highlights some major and critical points of probable contamination. The first has to do with the treatment and processing of the millet for production. The first stage involves the manual sorting of the grains for unwholesome ones which is subject to human limitations and errors thus allowing for some unwholesome grains to find their way into the final product.

Next is the soaking of the grains in water which upon observation and thorough consideration is a key factor and point of contamination in the production process. The water used mostly upon interrogation is from sources such as surface water, underground water and predominantly pipe born water. These water bodies are not sterile and thus serve as potential sources of contamination particularly *Escherichia coli* and other Coliforms (Gorbach et al., 1971). The vessels used in the soaking themselves appeared unkept and again the soaking is carried out with the bare unprotected hands thus handling during soaking becomes another point of contamination in the production process.

The next stage in the processing of the millet is milling which is also a potential source/point of contamination due a couple of factors. The commercial mill operators particularly within the local communities are known to operate under very bad sanitary conditions and practices. The mills are seldom cleaned and even with the findings revealed by observation depicts that very few of the respondents observed during milling of the millet insisted for the milling machines to be washed before

milling their millet which was done without detergents and antiseptics. The ideal practice is to flash the system with hot water and detergents after work to kill all microorganisms and remove food particles within crevices in the milling parts to avoid formation of biofilms but these practices are ignored by most of local operators leading to cross contamination of samples as the milling process goes on. Again, the water used in the milling process upon observation was highly unwholesome judging by the physical characteristics such as transparency, color and presence of solid matter. The vessels that housed the water were improperly kept and the water was left at the mercy of flies and other insects, all these being factors of contamination indicating the unwholesome state of the water. As discussed earlier the human factor once again is featured here as the grains are handled with the bare hand both pre and post milling which also points to a possible point of contamination (Yang & Slavik, 2008).

Coliforms are a class of organisms which are of prime importance in the area of food safety as they have been implicated in a couple of food poisoning and contamination cases recorded across the globe (Tchekessi et al., 2014) This makes some Coliforms pathogenic and of concern to health and safety of consumers. The family of Coliforms consists of organisms such as *Salmonella* spp. particularly the *S. typhi* which is the causative organism of typhoid which is one of the food borne illnesses very difficult to treat (Thiruvengadam et al., 1973). Other Coliforms are *Klebsiella pneumoniae* which causes pneumonia, *Enterococci* spp., and the infamous *Escherichia coli* responsible for diarrhea experienced from food contamination. This causes most countries to have a sharp eye for Coliforms in foods with the standards ranging from 0 to 10 cfu/g as the tolerable limits but in Ghana the Coliform must be zero (< 10). The results obtained upon the assessment of the millet drink showed high Coliform counts

(Table 4.5), which is clearly an indication of the poor personal hygiene practices exhibited by the traditional zoomkoom producers during the observation.

This is a factor of interest as the drink is consumed without further processing by the consumer thus putting the consumer at high risk of contamination upon consumption as this class of organisms is deemed pathogenic. One typical Coliform that is of significance in food safety is *Escherichia coli* and is mostly used as the indicator for faecal contamination and human induced contamination. The detection of *E. coli* strains particularly the pathogenic strains in food is deemed a high alert factor thus the acceptable or tolerable limit of *E. coli* being set at 0cfu/g by the ISO and AOAC. The *E. coli* assay of the millet drink revealed an alarming phenomenon of high contamination levels in 33% of the samples. This raises health alerts as the organism in question is deemed pathogenic. This analogy is also raised by Ekici and Dumen (2019) who reported the alarming health implication of E. coli in food. The factors resulting in *E. coli* contamination could be attributed to the human interface and factors observed during the study. These factors resulting from poor sanitary practices such as use of bare hands during the bottling of the drink, use of already used bottles (not properly treated before use), hair not been covered during mixing and bottling of the millet drink could be a possible source of contamination of market sampled drinks by E. coli.

Staphylococcus aureus was detected in all the samples assayed which raises concern as to the safety of the drinks for consumption as ready to eat foods on the market. *S. aureus* is a human pathogen is transmitted to food from mostly human and environmental contamination thus their presence in the sample's points to poor hygiene and safety practices of the producers.

The intervention study carried out following standard procedures in the laboratory produced a drink that is wholesome for consumption with good microbial quality (Table 4.7). This tells that if producers of Zoomkoom are encouraged to adopt hygienic practices and aseptic techniques before, during and after production, the quality and safety of the drinks can be assured to increase consumer reliability and confidence in the product for patronage.

5.3 Shelf-life Determination and Improvement of the Shelf-life of the Millet Drink

The preservative used in the study (E202) did not have any significant impact on the organoleptic properties of the drink as well the overall acceptability of the drink. This neutral effect of the preservative on the drink implies the consumer preference for the drink is not affected by the addition of the preservative. This makes (E202) potassium sorbate ideal for use as a preserving agent.

The finding of the study confirmed the report of the study participants on the product not lasting for 24 hours post production as the estimated shelf-life was determined to be 21 hours (Table 4.6). This is due to the presence of opportunistic bacteria and yeast that take advantage of the nutrients and moisture of the drink to proliferate. The proliferation of these microorganisms rises from the biochemical life processes they undergo which results in by products that are organic and chemical substances such as organic acids, alcohols and peptides. These secondary products affect the organoleptic and physicochemical properties of the drink resulting in an altered product with an off taste, smell, appearance and aftertaste.

The bacteria and yeast biomass when consumed can lead to a series of physiological and metabolic changes in the host through the production of toxins, both endotoxins

and exotoxins. These toxins cause reactions known as symptoms associated with an ill state of the host body referred to as food poisoning. This makes the consumption of spoilt foods dangerous to the health of the consumer.

The shelf-life of the millet drink increased to 72 hours when kept refrigerated which is an improvement over the 21-hour duration at room temperature. This is attributed to the low temperature associated with refrigeration. The biochemical life processes of the microorganisms are affected by factors such as temperature, pH, concentration and biological catalysts (Gillooly et al., 2001). As typical of reactions, rate increase with increasing temperature and vice versa thus the low temperature of refrigeration slows down the rate of biochemical life processes of the microorganisms thus bringing them to their inactive and dormant state in their growth cycle. This accounts for the relatively longer shelf-life of the drink when stored refrigerated (Gillooly et al., 2001). Though the refrigeration can somehow improve the keeping quality of the drink, it comes at an extra cost in the production and sale as it demands refrigerators powered by electricity. Another challenge with refrigeration as an intervention is the unstable supply of electricity in Ghana with power outages lasting hours into days. This calls for generators as backup power supply for constant electricity which is not feasible for small enterprises and producers of the millet drink.

A more suitable intervention is thus needed to extend the shelf-life of the millet drink at a lower cost with minimum technological application for easy use by the producers and retailers who are predominantly untrained and without formal education (Table 4.1). The use of the preservative potassium sorbate increased the shelf-life of the millet drink from less than a day to 10 days using 0.025g/100g and 15 days using 0.05g/100g at room temperature. This implies the product can last for two (2) weeks

without refrigeration at room temperature. The results show the shelf-life of the product to be the same when stored refrigerated and at room temperature using 0.05g/100g concentration. However, at 0.025g/100g the refrigerated samples lasted longer recording 13 days as opposed to those kept at room temperature which lasted for 10 days. The effect of temperature is clearly seen in this case study as microbial growth is influenced by mass, time, temperature and surface area (Gillooly et al., 2001), thus if these conditions are not optimized the rate and efficiency of the growth is affected. At optimal temperature (room and body temperatures 25^0C and 37^0C), the rate of growth of these organisms is high and efficient. This however is reduced upon decreasing temperature (Gillooly et al., 2001), thus slowing the rate of proliferation and increasing the shelf-life.

The phenomenon of extended shelf-life with the addition of preservatives as well as the reduction in microbial population is due to the antimicrobial properties of these preservatives. Potassium sorbate is used in food as preservative based on its ability to inhibit or delay growth of numerous microorganisms including yeast, molds and bacteria (Stopforth, Sofos & Busta, 2005). Sorbates act on microorganisms by inhibiting cell metabolism. They inhibit specific enzymes, inhibit nutrient uptake and affect various processes involved in transport functions, cell metabolism, growth and replications (Stopforth, Sofos & Busta 2005). Potassium sorbate produces sorbic acid when dissolved in water and is known to be effective up to a ph of 6.5 even though it becomes more effective at relatively lower ph level. The effectiveness of the microbial inhibition action of sorbates also depends on species or strains of microorganisms, additives, temperature of storage and concentration of sorbate. It has been reported that potassium sorbate can have both a bacteriostatic (at <0.3%) and a

bactericidal (at >0.3%) activity against wide range of microorganisms (Stopforth, Sofos & Busta, 2005).

Potassium sorbate extended the shelf-life of the millet drink by a factor 10 -15, thus making it last 15 times (15×) longer at room and refrigeration temperature. This can help reduce the loss on the part of the producers as a longer shelf-life will mean the product can be still sold as wholesome to the consumer after at least four (10) days postproduction even at room temperature. This comes in handy to the local producers who might not have access to refrigeration facilities and thus had to run at losses when the product is not sold immediately after production. It even becomes better with refrigeration facilities and this will be to the benefit of the producer in terms of income generation and reducing losses.

The consumer also stands to benefit as the eminent health threat one is exposed to upon consuming spoilt food is salvaged with the extension of the shelf-life of the drink. The consumer now is at the advantage of not consuming the product immediately upon purchase under the duress of spoilage upon prolonged keeping but can now purchase and consume at convenience with no threat to health and associated risks.

It of importance to note, that these preservatives cause no deleterious effects in humans when consumed in small amounts (Chichester & Tanner, 1972). They are not harmful in the right doses due to a couple of factors including detoxifying mechanisms by the body.

5.4 Consumer Acceptability of the Improved Millet Drink

The keeping quality and storage duration of food is a very important factor in consumer preference and patronage. A product that lasts at room temperature is most preferred as no additional cost is required for refrigeration. The major challenge with Zoomkoom production and sales as gathered from the study is the short shelf-life of the drink thus resulting in rapid product spoilage with associated financial loss to producers and retailers.

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6. 0 Overview

This chapter deals with the summary of the findings of the study, gives conclusion on the findings and recommends other ways of improving the shelf-life of millet drink "zoomkoom" with regards to the analysis of data gathered from the field survey and laboratory experiment. The study was conducted to optimize and improve the shelf-life of millet drink "zoomkoom".

6.1 Summary of the Study

The specific objectives of the study were to:

1. assess the production of zoomkoom.
2. evaluate the microbial quality and safety of the millet drink "zoomkoom" as available on the market.
3. determine nutritional composition and values of the millet drink.
4. determine and improve the shelf -life of the millet drink.
5. evaluate consumers' acceptability of the improved millet drink.

The study employed mixed method approach using observation, interview and questionnaire to obtain information on knowledge and practices of producers and retailers of the millet drink and experimental study was used to determine the microbial quality, safety and shelf-life of the millet drink.

A sample size of 100 respondents comprising retailers, producers and consumers of millet drink and farmers and sellers of millet grain from 6 districts of the Northern region.

In carrying out the study, both probability and non-probability sampling techniques were used to select the respondent.

The data obtained from both the quantitative and qualitative study were processed and analysed using SPSS, version 22 and Graphpad prism 5.0 software for data obtained from the microbial load assessment.

6.2 Summary of the Findings

The following are the summary of the findings of the study:

6.2.1.1 Objective 1: Assessing the production of zoomkoom

1. The study established that majority of producers and retailers of millet drink are predominantly females who are within the active working population (20 and 40 years).
2. The study also revealed that majority of the respondents (84%) had no formal education.
3. None of the producers of millet drink had obtained formal training with regards to safe procedures of zoomkoom production.
4. Majority of the millet drink producers relied on commercial milling machine due to cost of owning a private milling machine or blender at home purpose for processing millet for drink.
5. Majority of the producers either washed millet before milling or soaked without sorting.
6. Few producers washed, sorted and soaked millet before milling.

6.2.1.2. Objective 2: Assessing microbial quality and safety of millet drink as available in the market

Majority of the producers (21 out of 25) used old bottles (which were washed and rinsed) with bottling of drinks been done with bare hands. Few (4 out of 25) producers used new bottles, rinsed and bottled with food gloves.

The millet drink sampled from the market failed the microbial test whilst the Laboratory control sample was safe and wholesome for consumption according to the FDA specification (Table 4.7)

6.2.1.3. Objective 3: Determine nutritional composition and values of the millet drink.

The drink was found to be predominantly hydrated and water based with a moisture content of 84.79±0.71%.

The drink had low fat, protein and fibre contents of 0.29±0.11%, 0.41±0.14% and 0.014±0.002% respectively.

The carbohydrate content was determined to be 14.41±0.43% and an energy content of 61.87±2.97kcal/g.

6.2.1.3 Objective 4: Determine and improve the shelf -life of the millet drink.

The finding of the study confirmed the report of the study participants on the product not lasting for 24 hours post production as the estimated shelf-life was determined to be 21 hours (Table 4.6). The shelf-life of the millet drink increased to 72 hours when kept refrigerated which is an improvement over the 21-hour duration at room temperature.

Potassium sorbate extended the shelf-life of the millet drink by a factor 10 -15, thus making it last 15 times (15×) longer at room and refrigeration temperature.

The preservative used in the study (E202) did not have any significant impact on the organoleptic properties of the drink as well the overall acceptability of the drink.

6.2.1.4 Objective 5: Evaluate consumers' acceptability of the improved millet drink

The appearance and acceptability of the millet drink in the two packaging materials which points to the assertion that the type of packaging material used does not contribute significantly to the acceptability of the product. The preservative used in the study (E202) did not have any significant impact on the overall acceptability of the drink.

6.3 Conclusions

First of all, the study assesses the microbial quality and safety of millet drink available on the market as unsafe since fails the quality assessment due to poor hygienic practices such as manual soaking and sorting carried out with unprotected hands, milling and bottling handled with bare hands by most of the zoomkoom producers. The Laboratory control sample is classified as safe and wholesome for consumption according to the FDA specification (Table 4.7) due to standard hygiene protocols that were followed.

The Zoomkoom drink is a potential natural and economical drink with market employing predominantly the female adult population. The majority of producers operate on a small scale sourcing raw materials mainly millet and spices from the markets which are processed using commercial mills.

Secondly, the study determines the nutritional significance of zoomkoom to be predominantly hydrated and water based with a moisture content of 84.79±0.71% thus making it a good source of hydration to the consumer.

The drink contains low fat, protein and fibre contents of 0.29±0.11%, 0.41±0.14% and 0.014±0.002% respectively. The carbohydrate content is 14.41±0.43% and an energy content of 61.87±2.97kcal/g making it essential for people with high calorie intake.

Thirdly, the study shows that the effect of the preservative (E202) is positive on the shelf-life and has no impact on the organoleptic and sensory attributes of the drink thus not affecting consumer preference in anyway.

Though refrigeration extends the shelf-life of the millet drink from less than a day to 3 days, the preservative further extends the shelf-life to 10 days and 15 days at room temperature using 0.025g/100g and 0.05g/100g respectively which indicates ten-fold increase and beyond shelf-life improvement thereby making this intervention suitable for solving the present challenge of short shelf-life and keeping quality of the drink.

Finally, the study indicates that consumer acceptability is not significantly influenced by the appearance of the millet drink in the two packaging materials (glass and plastic bottles) as well as a preservative; potassium sorbate (E202).

6.4 Recommendations

The following recommendations were made as measures to help improve the shelf-life of millet drink:

1. In view of the findings of the study, it is recommended that further study be done on alternative methods of shelf-life improvement. One such alternative is the production of convenient zoomkoom flour as premixed product which comes as ready to eat with the addition of water. This holds potential to improving the shelf-life due to the low moisture content of the flour.

2. Also, the foods and drug authority can liaise with NGO's to carry out food safety awareness campaigns and training for producers and retailers of millet drinks in the various communities to minimal poor quality millet drink production.

3. Since the drink was found to be predominantly hydrated and water based with a moisture content of 84.79±0.71% thus making it a good source of hydration to the consumer and also with the carbohydrate and energy content been 14.41±0.43% and 61.87±2.97kcal/g respectively, it can be recommended for manual workers as a source of energy instead of relying on other energy drinks which may have adverse effects on the body.

4. District Assemblies should liaise with youth centered NGO's to invest and advocate youth entrepreneurship in the production and sales of the millet drink as a focal point in business since majority of those engaged in the trade are within the active age range (20-40years).

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APPENDICES

APPENDIX A

Introductory Letter

UNIVERSITY OF EDUCATION, WINNEBA
FACULTY OF SCIENCE EDUCATION
DEPARTMENT OF HOME ECONOMICS EDUCATION
P. O. Box 25, Winneba, Ghana
+233 (03323) 21177

HED/A13/VOL.3/175

27th November, 2019

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

INTRODUCTORY LETTER
LINDA ADU GYAMFI

We write to introduce, Linda Adu Gyamfi, an MPhil student with index number (8180100001) in the Department of Home Economics Education, University of Education, Winneba, who is conducting a research titled: "**Microbial quality and shelf life optimization of local millet drink "*zoomkoom.*"**

We would be very grateful if you could give her the assistance required.

Thank you.

Yours faithfully,

PROF. PHYLLIS FORSTER
HEAD OF DEPARTMENT

APPENDIX B

Sensory Evaluation of Zoomkoom

UNIVERSITY OF EDUCATION, WINNEBA

(GRADUATE STUDIES)

Sensory Evaluation of Zoomkoom

Panelist No:……. Date: ……./……/2020

INSTRUCTIONS:

i. Please observe the sample and indicate your observation on the sheet provided. Please add any additional comment at the bottom of the sheet.

You have been presented with nine cups of zoomkoom with varying percentages of preservatives. You are to kindly evaluate the taste, color, smell/flavor, aftertaste, appearance and overall acceptability.

Please, evaluate the samples in the nine-point hedonic scale produced below where 1-dislike extremely to 9-like extremely.

Key

1-Dislike extremely 2- Dislike very much 3- Dislike slightly 5- like slightly 4-Neither

like nor dislike 6-like Sensory evaluation table	7- like moderately 8- like very much 9- like extremely
Sample Taste Color	Smell /flavor Aftertaste Appearance Overall acceptability

001

002

003

004

Please, leave a comment:

……

……

……

APPENDIX C

Observation Guide

For 16 Producers of Millet Drinks In The 12 Communities Of Northern Region

Source: Adapted from Roller and Lavrakas, 2015. Applied Qualitative Research

Community visited: Date:……..Start time: ……Stop time:……..

S/N	Items Checked	Good	Satisfactory	Partially satisfactory	Unsatisfactory
A	PROCESSES INVOLVED IN THE PREPARATION OF MILLET DRINK				
	Pretreatment of millet before milling.				
	Milling of millet.				
	Handling of millet drink during mixing and bottling.				
	FOOD AND PERSONAL HGYIENE PRACTICES TO B ENSURE MICROBIALFREE DRINK				
	Treatment of water for mixing of milled millet.				
	Condition of tools and equipment used for preparing the drink				
	The state of the refrigerator for preservation of the drink.				
	Cover hair during preparation of drink.				

Design: A total quality framework approach. New York: Guilford press.

APPENDIX D

UNIVERSITY OF EDUCATION, WINNEBA

(GRADUATE STUDIES)

Evaluation of packaging of Zoomkoom Panelist No:……. Date: ……/……/2020 INSTRUCTIONS:

You have been presented with two samples of zookoom presented in two packaging materials.

You are to kindly evaluate the appearance and overall acceptability.

Key

1-Dislike extremely 2- Dislike very much 3- Dislike slightly 5- like slightly 4- Neither like nor dislike 6-like 7- like moderately 8- like very much 9- like extremely

Sensory evaluation table

Sample Appearance Overall acceptability

P1

P2

UNIVERSITY OF EDUCATION, WINNEBA

(GRADUATE STUDIES)

Evaluation of packaging of Zoomkoom Panelist No:……. Date: ……/……/2020 INSTRUCTIONS:

You have been presented with two samples of zookoom presented in two packaging materials.

You are to kindly evaluate the appearance and overall acceptability.

Key

1-Dislike extremely 2- Dislike very much 3- Dislike slightly 5- like slightly 4- Neither like nor dislike 6-like 7- like moderately 8- like very much 9- like extremely

Sensory evaluation table

Sample Taste Color Smell /flavor Aftertaste Appearance Overall acceptability

P1

P2

APPENDIX E

Questionnaire for Zoomkoom Producers and Retailers of 12 Communities in the 16 Districts of the Northern Region

INTRODUCTION

I am a graduate student of the department of Home Economics, science education of the University of Education, Winneba. I am conducting this study to obtain information on your background as a producer or retailer of millet drink. The information gathered, will be treated as personal and all responses will be held confidential.I would be grateful if you will assist in this study by answering this questionnaire.

Please kindly tick [√] where applicable in the boxes provided against the responses which best suit your background profile for this study.

Demographic profile of respondents

Gender: Female [ ]

Male [ ]

Please select the category that includes your age?

Under 20years [ ]

21 – 30years [ ]

31- 40years [ ]

41 and above [ ]

What is your level of education?

Primary [ ]

JHS [ ]

SHS [ ]

Technical [ ]

Vocational [ ]

Tertiary [ ]

No formal education [ ]

What role do you play in the trade of zoomkoom?

Producer [ ]

Retailer [ ]

Both [ ]

How long have you been in the trade of zoomkoom?

1-5years [ ]

6-10years [ ]

11-15years [ ]

16years and above [ ]

Have you had any formal training in the production of millet drink?

Yes [ ] No [ ]

APPENDIX F

Processes involve in the Preparation of Millet Drink (Zoomkoom)

Sorting Process

Drying Process

Soaking Process

Milling Process