ENRICHING OF GOAT MILK MOZZARELLA CHEESE WITH SOLUBLE FIBER FROM *Acacia senegal* var. *kerensis*

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EGERTON UNIVERSITY

OCTOBER, 2018

DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not, wholly or in part, been presented for the award of a degree in any other university.

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Recommendation

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DEDICATION

With honor, I dedicate this thesis to my mother, wife and sons. Thanks for your prayers, motivation, inspiration and support throughout this work.

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Above all, praise, glory and honor go to the Almighty God for His unending grace, favor, love, and guidance during my study. I am greatly thankful to Egerton University for accepting me as a student to pursue this degree. This work would not have been complete without the guidance and support of my supervisors, Prof. Symon M. Mahungu and Dr. Mary Omwamba, to whom I owe this thesis and I would forever be grateful. I would also like to thank the Eastern Africa Agricultural Productivity Project (EAAPP) through the Kenya Agricultural and Livestock Research Organization (KALRO) for funded this research work.

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ABSTRACT

Mozzarella cheese is prepared using milk from various herbivores. Mostly, it is prepared using milk from sheep, cow and goat. However, due to consumers' demand for healthier foods, cheese processors have been innovatively preparing unique cheeses. Mozzarella cheese is one of the preferred ingredients for use on pizza. Goat milk is a good source of protein and calcium, possessing unique characteristics with a high proportion of small milk fat globules that contain a higher concentration of short chain, medium chain, and polyunsaturated fatty acids than cow's milk. Its use in Mozzarella cheese can therefore impart significant health benefits to consumers. However, despite these unique qualities, goat milk is underutilized in Kenya and therefore, enhancing it with soluble fiber from gum arabic will expand the health benefit. Gum arabic is an excellent source of soluble dietary fiber, which can be used to boost fiber levels in cheese and other dairy products. The aim of this study was therefore to investigate the feasibility of enriching goat milk Mozzarella cheese with soluble fiber from Acacia senegal var. *kerensis* without altering adversely its functionality and sensory properties. *Acacia senegal* var. *kerensis* powder at 2, 3 and 4% was incorporated into the goat milk mozzarella cheese during the salting process at room temperature (20 to 25 ^{o}C). The functional properties of the cheese; meltability, stretchability and free oil formation were determined. Sensory evaluation was conducted using untrained sensory panel to evaluate the consumer acceptability of the made cheese. Keeping quality was also determined through total viable counts (TVC), Lactic acid bacteria (LAB), yeast and molds counts and coliforms count following approved Association of Official Analytical Chemists (AOAC) methods. The results indicated that the use of gum arabic in Mozzarella cheese up to a level of 3% improved the stretchability and meltability while reducing the free oil formation phenomenon. Compared to the control there was no significant reduction ($P \geq 0.05$) in fat content as well as the moisture content of the cheese with addition of gum arabic . However, there was a significant ($P < 0.05$) reduction in protein content and an increase in fiber content of the resulting cheese. Overall liking was best for samples containing gum arabic at a level of 3%. Bacterial load at the beginning was below 2.0 log cfu/g for TVC, LAB and yeast and molds and below 1.0 log cfu/g for non-fecal coliform counts for all samples. Nevertheless, during storage, the load for all microorganisms analyzed increased steadily to reach 5 to 8 log cfu/g. Resulting shelf life was 8 days for all cheeses based on TVC. However, based on non-fecal coliforms count, the cheese containing 3% gum arabic gave the longest shelf life of 5 days. The results of this work indicate that the use of gum arabic enriched goat milk

Mozzarella cheese with soluble fiber hence improving its nutritional quality as well as its functional properties. To the best of my knowledge, this is the first report on the functional and sensory characteristics of goat milk mozzarella cheese containing gum arabic from *Acacia senegal* var. *kerensis*.

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ABBREVIATIONS

ANOVA:	Analysis of Variance
CMP:	Caseino macro peptide
EPS:	Exopolysaccharides
FAO:	Food and Agriculture Organization of the United Nations
FAOSTAT:	Statistics Division of FAO
FO:	Free oil
GLM:	Generalized Linear Model
GMP:	Glyco-macro peptide
IDFA:	International Dairy Foods Association
ITC:	International Trade Center
JECFA:	Joint FAO/WHO Expert Committee for Food Additives
KEBs:	Kenya Bureau of Standards
LSD:	Least Significant Difference
MoLD:	Ministry of Livestock Development
MoLFD:	Ministry of Livestock and Fisheries Development
SAS:	Statistical Analysis System
TPA:	Texture Profile Analyzer
USDA:	United States Department of Agriculture
WHO:	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background information

Cheese is a dairy product derived from milk that is produced in a wide range of flavours, textures and forms by coagulation of the milk protein casein. It is a nutrient-dense food made from cows, buffalo, goats, or sheep milk**.** Most cheese are not eaten alone, but as part of another food. Cheese can be classified on the basis of their country of origin, fat content (milk type), and texture, manufacturing technique, physical appearance like shape or moisture content. Mozzarella cheese belongs to a class of 'Pasta filata' family, which involves the principle of skilful stretching of the curd in hot water to obtain smooth texture in cheese. The cheese is soft, white, unripened, that may be consumed shortly after manufacture. The specific melting and stretching characteristics of Mozzarella cheese is highly appreciated in the manufacture of pizza in which it is a key ingredient (Atanu, 2001).

Mozzarella cheese as in other cheeses can be prepared with milk from various animals such as cow, buffalo, goat and ewe (Calandrelli, 2001). In Kenya, it is made majorly from cow's milk. Goat milk is a good source of protein and calcium, possessing unique characteristics with a high proportion of small milk fat globules. Its fat portion contains significantly higher concentrations of short chain, medium chain, and polyunsaturated fatty acids than cow's milk (Kris, 2002). However, it is underutilized in Kenya. Mozzarella cheese has many health benefits; it is a good source of protein, vitamins and minerals. Consumption of Mozzarella cheese may protect against gout, a painful condition that results in the buildup of uric acid crystals in the joints. The calcium found in Mozzarella cheese also has its contribution in body weight loss and provides protection against breast cancer and metabolic syndrome, which is a group of conditions that increase the risk of developing heart disease or stroke (Ibrahim, 2003).

Mozzarella cheese production has continually increased because of demand in the pizza industry (Kindstedt, 2004). Prevalence of obesity in the world has prompted the reduction of high fat diet consumption and an increase in the consumption of dietary fiber (Noronha, O'Riordan, and O'Sullivan, 2007). Increased awareness of people on fitness and healthy lifestyle has led to an increased demand for low-calorie foods in particular for low and reduced fat cheeses (Konuklar, Inglett, Warner, and Carriere, 2004). Therefore, cheese processors have innovatively been preparing unique cheeses. These cheeses are geared towards meeting the unique tastes and needs of the consumers, for example; reducing fat, replacing fat with fat mimetics, and enriching cheese with nutrients (McMahon *et al*., 1996; Mistry *et al*., 1996; Ryhänen *et al*., 2001). A reduction in fat content of cheese can be achieved by replacing it with several ingredients that provide the functionality (meltability, stretchability and free oil formation) of the missing fat. Hydrocolloids, such as gum arabic, and carbohydrate-based fat replacers have been used safely as thickeners and stabilizers especially in dairy products such as sauces and dressing formulations. However, water-soluble ingredients such as soluble fiber tend to be washed away with whey, further altering the composition of whey and resulting in less or no retention of that ingredient in cheese (Lee and Brummel, 1990). Therefore, to make cheese a source of fiber, measures have to be taken to not only add fiber to milk but also get maximum retention in cheese (Fagan *et al*., 2006).

Gum arabic , an edible, dried, gummy exudate from the stem and branches of *Acacia senegal* is rich in non-viscous soluble fiber (Williams and Phillips, 2000; Doi *et al*., 2006; Phillips *et al*., 2008; Phillips and Phillips, 2011). In Kenya, gum arabic comes from *Acacia senegal* var. *kerensis*. In the food industry, gum arabic is used as an emulsifier, stabilizer and a thickening agent mainly in soft drinks, syrup, gummy candies and marshmallows as well as a source of soluble fiber in low calorie and dietetic beverages (Verbeken *et al*., 2003). The purpose of these innovations were meant to meet the unique needs from the consumers. However, no reports are available on the incorporation of gum Arabic from *Acacia senegal var. kerensis* as a source of soluble fiber in goat milk Mozzarella cheese.

Therefore, the aim of this study was to investigate the feasibility of enriching goat milk Mozzarella cheese with gum arabic from *Acacia senegal* var. *kerensis* as a source of fiber without affecting the functionality and acceptability of this cheese. The findings of this work have potential to create a market for locally available goat milk and gum arabic from *Acacia senegal* var. *kerensis* playing a critical role in improving the standard of living of communities living in arid and semi-arid lands of Kenya where these products are found.

1.2 Statement of the Problem

Consumer trends all over the world show a demand of novel foods that contain superior nutritional and therapeutic properties in comparison to existing products. Processing activities lower the amount of fiber in food depriving them of its many health benefits. Gums exhibit hypocholesterolemic and hypotriglyceridemic effects. Gum fibers have gel-forming properties known to reduce elevated low-density lipoproteins (LDL) cholesterol without affecting the high-density lipoprotein (HDL) cholesterol fraction. Part of the fear among consumers of dairy products is their relatively high levels of saturated fats associated with an increase in LDL cholesterol in the body. The LDL cholesterol increases the risk of cardiovascular diseases. There is increasing consumption of products containing cheese, such as pizza, in Kenya. Gum arabic is used as an emulsifier, stabilizer and a thickening agent in the food industry. Moreover, gum arabic has high levels of soluble fiber (85%). Therefore, successful incorporation of this gum in cheese, will add the dietary fiber in the mozzarella cheese while reducing the fat content making it more nutritious. Currently, however, there is no documented information on the effect of this gum on the functional and sensory properties of the cheese.

1.3 Objectives

1.3.1 General Objective

The general objective of this study was to contribute to food security in Kenya through utilization of gum arabic from *Acacia senegal* var. *kerensis* in the value addition of goat milk Mozzarella cheese.

1.3.2 Specific Objectives

1. To prepare goat milk Mozzarella cheese containing different levels of gum arabic from *Acacia senegal* var. *kerensis.*
2. To determine the functional properties (meltability, stretchability and free oil formation) of the cheese containing gum arabic from *Acacia senegal* var. *kerensis.*
3. To determine the proximate composition and shelf life of the cheese containing gum arabic from *Acacia senegal* var. *kerensis.*
4. To determine the consumer acceptability of the goat milk Mozzarella cheese containing gum arabic from *Acacia senegal* var. *kerensis*.

1.4 Hypotheses

1. There is no significant difference between the prepared goat milk Mozzarella cheese containing different levels of gum arabic from *Acacia senegal* var. *kerensis* and the one without gum arabic.
2. There is no significant effect in the functional properties (meltability, stretchability and free oil formation) of goat milk Mozzarella cheese with addition of gum arabic from *Acacia senegal* var. *kerensis.*

3. Gum arabic from *Acacia senegal* var. *kerensis* has no significant effect on the proximate composition and shelf life of goat milk Mozzarella cheese containing gum arabic from *Acacia senegal* var. *kerensis.*
4. There is no significant difference in consumer acceptability between goat milk Mozzarella cheese containing gum arabic from *Acacia senegal* var. *kerensis the* one without gum arabic.

1.5 Justification of the study

Mozzarella cheese is a good source of protein and calcium, but it is also calorie-dense and high in saturated fats. Incorporating gum arabic in its manufacture would be a great way to enhance its nutritional benefits. This study gives information about the effect of incorporating gum arabic on the functional and sensory properties of cheese, whose consumption is increasing in Kenya. Incorporation of the gum in cheese will contribute to the sustainability of goat farmers with the use of goat milk aiding in addressing the market challenge for goat milk. Most of the goats are reared in arid and semi-arid lands where gum arabic is found hence this work will contribute to their improved standard of living by creating a market for these produce.

CHAPTER TWO
LITERATURE REVIEW

2.1 Goat milk production

There are more than 200 different goat breeds worldwide; six primary breeds dominate the dairy goat arena: Alpines, Oberhaslis, Saanens, Toggenburgs, LaManchas and Nubians. While all breeds generally do well in most parts of the world, the first four breeds listed are well suited to cooler climates since their origins can be traced to Swiss mountain regions. LaManchas and Nubians hail from tropical and desert climates where it is warmer, and they tolerate hot summer conditions better than the Swiss breeds. There is limited processing of goat milk in East Africa. Small-scale farmers milk individual goats or small groups of goats by hand and usually the milk is used for domestic consumption or sold locally. Cheese making is conducted on a small scale. Occasionally butter and ghee (rendered butter) are produced from goat milk (Kris, 2002).

In the developing countries, goats make a very valuable contribution, especially to the poor in the rural areas. The importance of this valuable genetic resource is underestimated and its extent of contribution to the livelihood of the poor is inadequately understood and is often neglected in comparison with cattle and sheep. The world total numbers of goats and sheep are 861.9 and 1078.2 million, respectively (FAOSTAT, 2008). The largest number of goats is observed in Asia, followed by Africa, representing about 59.7% and 33.8%, summing up to 93.5% out of the total number of the world, respectively. The ratios of goat to sheep in Africa, Central America and Asia are approximately equal, indicating the considerable importance of goat populations in these parts of the world, especially to the poor and landless peasants. Goats are mainly kept to produce milk, meat or fiber (Mohair and Cashmere) (FAOSTAT, 2008).

Dairy goat is considered the cow of the poor. The goat eats little, occupies a small area and produces enough milk for the average unitary family, whereas maintaining a cow at home cannot be afforded by the home owner, hence, the growing popularity of goat as the poor person's cow (Kris, 2002). Dairy goats produce about 15.2 million metric tons (MT) of milk, accounting for about 2% of the world total amount of milk produced by livestock species (FAOSTAT, 2008). The developing countries produce approximately 83% of the total amount. In Europe, goat breeding is strongly oriented towards milk production, with only 3% of the world goat population producing about 15% of the world's goat milk, which is mostly used for cheese production (Lejaouen and Toussaint, 1993). Since 1990, interest in dairy goats has been steadily increasing, as manifested by the increase in milk production from about 10 million MT in 1990 to about 15.2 million MT in 2008. Marketing of goat milk and its products is still in its infancy. So far, there have been no marketing efforts attempted on a broad scale. As reported by Dubeuf and Boyazoglu, (2009) and Luo, (2009), less than 5% of the total milk produced by goats is marketed. The potential of goats for sustainable supply of milk and meat for human consumption is unquestioned, and their contribution to improved nutrition of rural people is likely to increase. At the same time, goat cheese consumption is likely to increase also in developed countries. This is attributed to the image of goat cheese being a product of natural farm conditions compared with milk and milk products from high yielding dairy cattle in large industrial farms. Goats, especially dairy ones, are an ideal species for poverty reduction and economic development for the poor in developing countries. Several reasons make goats particularly attractive for poverty reduction and improvement of family food security and livelihood of the poor in developing countries for example, the weak, women or children can easily tend them (Dubeuf and Boyazoglu, 2009).

The livestock population in Kenya is approximately 60 million heads, comprising indigenous genotypes, exotic breeds and crossbreds. The major livestock species consist of 9 million Zebu and 3.5 million exotic and grade cattle, 8 million sheep, 11 million goats, 850,000 camels, 330,000 pigs, over 29 million chicken and 470,000 rabbits (MoLD, 2008-2012). Goats, therefore, form an important integral component of the livestock sector and play a crucial role in the economic and social lives of many Kenyans, contributing meat, milk, skins and manure for crop farming (MoLFD, 2007). Dairy goats have been introduced in most parts of Kenya by various development and non-governmental organizations, among them the Heifer Project International-Kenya, which has implemented a community-based dairy goat project to improve the nutrition security and incomes of small-scale resource-constraint farmers (Ogola *et al.*, 2009). The total annual milk produced in Kenya is about 5.31 million litres, of which approximately 83% is produced by cattle and the rest by goats and camels (MoLD, 2008-2012). However, goat milk production still remains at the subsistence level in various parts of the country (Ogola *et al.*, 2010). Goat milk is more nutritive and has medicinal value over that of the cow; it has smaller fat globules size, which is more digestible, compared to cow milk (Haenlein, 2004). Goat milk differs from cow milk in that the butterfat globules are smaller, so they disperse more easily, making goat milk naturally homogenized. Unlike cow milk, the cream will not separate on its own, so goat milk products are much smoother and creamier (Kris, 2002).

2.2 Cheese production

Goat cheese has a tangy flavor as that of goat milk and because goat milk is leaner than that of cows, goat cheese tends to be leaner as well. For this reason, many dieters craving cheese will use goat cheese as a substitute, crumbling it on salads or melting it on cooked dishes. Goat cheese softens when exposed to heat, although it does not melt in the same way that many cow cheeses do. Cheese made from goat milk has more protein than cheese made from cow milk. It is "kidney friendly" and suitable for those with Chronic Kidney Disease (CKD) as it is very low in potassium (Kris, 2002).

2.2.1 Fat Mimetics

Some carbohydrates suggested for use as fat mimetics include acid or enzymatically hydrolyzed starches, inulin, low methoxy pectins, guar, locust bean gum, xanthan gum, carrageenan, gum arabic , micro-crystalline cellulose (Voragen, 1998). The functionality of the carbohydrate-based fat substitutes is based on their ability to increase viscosity, to form gels, provide mouth feel and texture, and to increase water-holding capacity. Carbohydrate-based fat replacers, in general, are soluble up to 80% giving viscous solutions, which behave Newtonian. Because of its high Tg (glass transition temperature, 110^{o}C), they contribute to increased stability of low-fat foods, especially texture. They also function as a cryoprotectant, freezing point depressor and give an overall cooling effect to the food (Craig *et al.*, 1996). The chemical stability of carbohydrate-based fat mimetics is comparable with the stability of (non-digestible oligosaccharides (NDOs) and depends upon the type of constituent sugar residues, ring form and anomeric configuration, type of linkages and degree of branching. It also depends upon their solubility. At low and high pH and high temperature, they are liable to degradation. Since they are polysaccharides, their participation in maillard reactions is negligible. The degree of polymerization of these polysaccharides range from 1 to 100 with a molecular weight average of 10 (Craig *et al.*, 1996).

2.2.2 Low Fat Cheeses

Even though consumers are repeatedly advised to reduce their dietary fat consumption, they are not willing to sacrifice taste or functionality in the foods they eat (Verbeke, 2006). Strategies for changing the nutritional profile of cheese include reducing fat (reduced fat or low-fat cheese), replacing fat with fat mimetics or replacers, and enriching cheese with nutrients (McMahon *et al.*, 1996; Mistry, 2001; Ryhanen *et al.*, 2001). Reducing and replacing fat in cheese is not an easy job. Fat is an important component in cheese as it contributes to desirable flavor and texture. However, there is a desire to produce reduced fat or low-fat cheese as a way of lowering overall caloric intake. A common problem in low-fat cheeses is that the texture becomes rubbery with minimal breakdown during chewing. This implies that a basic understanding of what regulates the rheological and fracture properties of cheese microstructure may shed some light on how texture can be improved (Everett and Olson, 2003).

2.2.3 Improvement of Cheese by Incorporating Micronutrients

Another aspect of improving cheese is adding micronutrients or healthy ingredients to it. However, water-soluble ingredients tend to be washed away with whey, such as soluble fiber, altering the composition of whey and resulting in less or no retention of that ingredient in cheese. For Mozzarella cheese, fat not only plays vital role in texture maintenance but also provides proper melting during baking of a pizza. In milk, fat exists in emulsified form and so it is speculated that the same form of fat is present in cheese or as pools of fat filling the voids in the cheese protein matrix (Everett and Olson, 2003). Upon heating the cheese, the amount of fat present influences the melting properties of cheese. When cheese is heated, the fat in the cheese becomes liquefied and a portion of the fat can escape from the cheese body and appear as an oil film. Such fat is referred to as “free oil” and tends to increase with the fat content of the cheese, and as cheese is held for longer time in storage (Kindstedt and Rippe, 1990). Too much free oil can be detrimental to the appearance of a food product containing the cheese and too little fat cause quick dehydration resulting in improper melting of cheese (Tunick *et al.*, 1993; McMahon *et al.*, 1996).

Fat has an important role in the development of flavor, texture and appearance of cheese (Sipahioglu *et al.,* 1999). Removal of fat from cheese causes textural, functional and sensory defects such as rubbery texture, lack of flavor, poor meltability and undesirable color (Fife *et al.,* 1996; McMahon *et al.*, 1996; Sipahioglu *et al.,* 1999; Mistry, 2001). Numerous strategies have been proposed in order to improve texture of low-fat cheeses such as making process modifications; starter culture selection and use of adjunct cultures; and use of fat replacers (Drake and Swanson, 1995). With cheese, the successful manufacture of low-fat cheese requires strict attention to many factors that impact flavor, texture and body characteristics (Johnson, 2003).

The average American consumes 14 g of dietary fiber a day, which is considerably less than the recommended level. The current recommendations, according to the 2010 Dietary Guidelines for Americans, are 14 g of fiber per 1000 calories consumed. Fiber faces the major problem of retention in cheese if added in milk prior to cheese making. The incorporation of soluble dietary fiber into cheese may result in the development of both a nutritionally and technologically superior product (Fagan *et al.*, 2006). Low-fat cheeses enriched with dietary fibers may have high nutrition profile and health benefits but question remains unanswered about their sensory quality and consumer expectations. Fiber enrichment has been very common for bread and other cereal based foods (Wang *et al.*, 2002) and these products have been very well accepted by consumers for their color, texture, and aroma. Presently, incorporation of dietary fiber especially inulin and low methoxy pectin to dairy products, is limited to yoghurt and ice cream.

2.3 Factors that influence cheese quality

2.3.1 Milk Quality

The composition, microbial load, and indigenous enzymes of milk are important factors in cheese manufacture as they influence the quality attributes of cheese. Proteins, lipids, and lactose constitute the macro constituents of milk while micro constituents include calcium and citrates with calcium chiefly determining the cheeses technological properties (Fox *et al.*, 2000). These factors also influence the casein to fat ratio, total solids, lactose, and mineral content, the moisture content and acid development in the finished cheese (Traordinary, 2001).

Early lactation and late lactation milk is not suitable for Mozzarella cheese manufacture because the concentration of whey and salts is higher. Plasmin concentration is also higher during late lactation and it hydrolyzes casein-yielding cheese of low quality (Rowney *et al.*, 1998). Mozzarella cheese made using the late lactation milk is softer and has a lower viscosity and higher moisture content. This is attributed to more whey proteins in milk having hydrophilic properties and higher pH (Lucey *et al.*, 1992).

Cheese flavor and texture are influenced by the fatty acid composition of milk fat and its firmness decreases with increasing amounts of long chain fatty acids (Svanborg, 2006). Mozzarella cheese made with low melting point fraction of milk fat, has higher free oil levels than that made with butter oil or higher melting point fraction milk fat (Papalois *et al.*, 1996). Psychotropic bacteria when present in milk produce heat resistant lipases and proteases. They reduce the yield of cheese and produce off flavors in ripened cheese (Skeie, 2007). The genetic variation of casein in different milks is important in cheese quality. Genetic variation of kappa- casein has no significant effects on cheese functionality but influences cheese yield and curd formation (Walsh *et al.*, 1998).

2.3.2 Milk processing

The fat and protein content of milk influence the yield and quality of cheese. Variation in composition of milk is reduced by standardization depending on the type of cheese being manufactured. Milk fat reduction in Mozzarella cheese manufacture has been explored due to its popularity in pizza. Fat reduction in food is linked to lowered risks of coronary heart disease and certain types of cancers (Woteki and Thomas, 1993).

Pasteurization of milk intended for cheese manufacture is used to kill undesired microorganisms before milk is transformed into cheese. Pasteurization reduces microbial load, increases cheese yield, and quality. It also facilitates ripening at higher temperatures (Ordonez *et al.*, 1999). Normal pasteurization is done at a temperature time combination of 72^{o}C /15 second and influences curd formation negatively (Guinee *et al.*, 1997; Singh and Waungana, 2001). It also increases cheese yield because of elevated moisture content and effective recovery of whey proteins. Higher pasteurization temperatures results in reduced firmness of low fat cheese (Guinee *et al.*, 1998).

Mozzarella cheese from pasteurized milk has better functional properties than raw milk cheese. Melting and stretching properties of Mozzarella cheese made from high temperature treated milk has the lowest functional properties. The Rheological properties of such cheese can be improved by addition of 0.01% calcium chloride (Gosh and Sing, 1990).

2.4 Gum Arabic

Gum arabic is described by the joint FAO/WHO expert committees for food additives (JECFA) as a dried exudate obtained from the stem and branches of *Acacia senegal* (L), or *Acacia seyal* (*fam, leguminosae*) (FAO ,1999). The gum is a pale white to orange-brown solid, which breaks with a glassy surface texture. The dried gummy exudates from the stem and branches of *Acacia senegal* and *Acacia seyal* are edible and rich in non -viscous soluble fiber (William and Phillips, 2000). Chemically, gum arabic is primarily composed of a high molecular weight polysaccharide calcium, magnesium and potassium which yield arabinose, galactose, rhamnose and glucoronic acid on hydrolysis. It has been assigned E number E414 (FAO, 1999). The backbone is composed of 1, 3-linked b-D-galactopyranosyl units. The side chains are composed of two to five 1, 3-linked b-D-galactopyranosyl units, joined to the main chain by 1, 6-linkages (FAO, 1999). The chemical composition of gum arabic can vary with its source, the age of the trees from which it was obtained, climatic conditions and soil environment. Gum arabic is a branched-chain, complex polysaccharide, either neutral or slightly acidic, found as mixed calcium, magnesium and potassium salt of a polysaccharidic acid (arabic acid). The major amino acids present in the protein of an ArabinoGalactan (AG) and an Arabinogalactan-Protein Complex (AGP) are hydroxyproline, serine and proline. Gum arabic is primarily indigestible to both humans and animals. It is not degraded in the small intestine, but fermented in the large intestine by microorganisms to short-chain fatty acids, particularly propionic acid (Badreldin *et al.*, 2008; Abdul-Hadi *et al.*, 2010).

Gum arabic has important dietary functions in the body. It is a good source of soluble dietary fiber, which is more than 85% on a dry basis. It boosts fiber levels in any food product because of its low viscosity without big changes in the finished viscosity (Mary, 2011). It is extremely soluble in water making it a unique hydrocolloid. Gum arabic can yield solutions of up to 50% concentration forming highly viscous, gel like mass similar in character to a strong starch gel. It is very stable in acidic conditions and its high solubility makes it suitable for use in citrus and cola flavor oil emulsions (Panda, 2010). Its functional uses include emulsification, stabilization and as a thickener (Joint FAO/WHO Expert Committee on Food Additives, 2005). Gum arabic has been found useful in the dairy industry. In yoghurt making, the gum from *Acacia senegal* var. *kerensis* has been reported to exhibit water binding properties that are required to function as a stabilizer in low fat yoghurt (Mugo, 2012) as well as ice-cream and beverages (Belitz *et al*, 2009). However, the use of gum Arabic from *Acacia senegal* var. *kerensis* in goat milk Mozzarella cheese is yet to be reported.

2.5 Dietary Fibers

In the year 2000, the Committee of the American Association of Cereal Chemists (AACC) defined dietary fiber (DF) as the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine (Tungland and Meyer, 2002). It is now also defined as "edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the small human intestine" (Mongeau, 2003). Dietary fiber includes cellulose and lignin, hemicellulose, pectins, gums, and other polysaccharides and oligosaccharides associated with plants. Dietary fibers promote beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and/or blood glucose attenuation (AACC, 2000). Supplementation of the diet with gum arabic soluble fibers lowers serum urea nitrogen in rodents and patients with chronic renal failure (Bliss *et al.*, 1996). This is because of increased colonic bacterial fermentation of gum arabic providing them with energy for growth and nitrogen incorporation. This increases fecal bacteria mass and nitrogen excretion. Several studies have suggested that fermentable fiber can increase fecal output by stimulating microbial growth, with the production of short-chain fatty acids and other products (Stephen and Cummings, 1980).

The current recommendations by the Dietary Guidelines for Americans (2010) suggest 14 g of fiber per 1000 calories consumed. Food manufacturers can claim health benefits in cheese containing 5 g or more per 30 g serving. If it contains ≥ 2.5 g of fiber per 30 g serving, it can be considered as a good source of fiber (Anderson *et al.*, 2005; Kranz *et al.*, 2006). With increasing improvements in lifestyle and medical limitations for some consumers, there is increasing expectation to buy cheese with added benefits (Davis *et al.*, 2010). Cheese is now investigated as a possible carrier for functional ingredients, which has been only consumed through fruits and vegetables such as antioxidants, polyphenols, dietary fibers, and hydrocolloids (Han *et al.*, 2011). Chemically, dietary fiber consists of non-starch polysaccharides such as cellulose and many other plant components such as dextrins, inulin, lignin, waxes, chitins, pectins, beta-glucans and oligosaccharides. Dietary fiber can be soluble or insoluble. Insoluble dietary fiber includes cellulose and lignin which occur in whole grains (especially wheat bran), and hemicellulose (partly soluble) found in whole grains, nuts, seeds, fruits and vegetables (Nevid *et al.*, 1998). Soluble fiber (e.g. inulin, pectin, polydextrose) is not digested in the human gastro-intestinal tract; however, some action by bacteria occurs in the lower digestive tract. Such fibers are described as being a prebiotic (Schrezenmeir and De Vrese, 2001). Soluble fiber, being prebiotic, also absorbs water to become a gelatinous substance that passes through the body (Jennings, 2009), and hence has an effect on stool weight (Bennett and Creda, 1996). However, it has been suggested that fermentable fiber can increase fecal output by stimulating microbial growth, with the production of short-chain fatty acids and other products (Stephen and Cummings, 1980).

Few fibers are adapted for use in dairy foods where the flavor, color, body, and texture are quite subtle. Some soluble fibers have also been shown to boost calcium absorption (Berry, 2004) and act as prebiotics to promote the growth of beneficial intestinal bacteria such as *Bifidobacteria* and *Lactobacillus acidophilus* (Mitsuoka, 1990). Some carbohydrates suggested for use as fat mimetics include acid or enzymatically hydrolysed starches, inulin, low methoxy pectins, guar, locust bean gum, xanthan gum, carrageenan, gum arabic , micro-crystalline cellulose (Voragen, 1998). Soluble dietary fiber acts as substrate food for micro flora, which improves host health (Shrivastva and Goyal, 2007). Its intake has been associated with protective effects against C-reactive protein (CRP) an independent predictor of future cardiovascular diseases and diabetes. An inverse relationship exists between dietary fiber and CRP concentration (Ma *et al.*, 2006). Studies have also indicated that dietary fiber protects against inflammatory bowel diseases such as Crohns disease and ulcerative colitis, by increasing production of short chain fatty acids which act as immunodulators in the inflamed intestine and proportion of beneficial bacteria that make up the gastro intestinal micro flora (Galvez *et al.*, 2005). Examples of soluble fibers include Xanthan gum, Carrageenan, Guar gum, Gum karaya, Gum tragacanth, Gum arabic , Pectin, β–Glucan, and alginate (Sharma *et al.*, 2006.)

2.6 Preparation of Cheese

2.6.1 Acidification

The rate and time of acidification is important in the manufacture of good quality cheese. Acidification is crucial in the manufacture of most types of cheeses. It serves the following functions; control and prevent the growth of spoilage and pathogenic organisms, affect the activity of coagulant during manufacture and ripening, solubilizes colloidal calcium phosphate which effect the cheese texture, promote syneresis and hence, determine cheese composition and influence activity of enzyme which ultimately affect the flavor and quality (Fox *et al.*, 2000; McSweeney, 2007). Milk acidification can be through production of lactic acid by starter cultures or addition of acid or amidogens used when starter cultures are not used for some special varieties such as Mozzarella cheese (Fox *et al.*, 2004).

2.6.2 Coagulation

Coagulation of the casein component of milk protein results in a gel, which entraps fat. This is achieved by; limited proteolysis by selected proteinases (mainly rennet), acidification to pH 4.6 and acidification to pH 5.2 in combination with heating to 90^0C. Rennet coagulation occurs in two stages; proteolysis stage, where the casein micelle is destabilized by hydrolysis of *k*-casein to yield *para-k*-casein micelles and secondary calcium mediated stage where para-casein micelles undergo limited aggregation. This stage requires quiescent conditions and temperatures beyond 20^oC. K-casein hydrolysis majorly involves the cleavage of the peptide bond, phe105-met106 that is particularly sensitive to hydrolysis by acid proteinases. This cleavage produces a *para*-*k*-casein common to all caseins and a glyco-macro peptide (GMP) or caseino macro peptide (CMP) (Fox *et al.*, 2000; Skeie, 2007). After 85% of total *k*-casein is hydrolyzed, the stability of the micelle is reduced resulting in formation of three-dimensional networks called coagulum (Fox *et al.,* 2000). Rennet coagulation is influenced by protein and fat levels, pasteurization temperatures, cooling and cold handling of milk, homogenization, rennetting temperatures, pH, rennet concentration and calcium concentration (Fox *et al.*, 2000). Reduction of colloidal calcium phosphate makes coagulation difficult. No curd formation occurs if temperatures are below 20^{o}C irrespective of the degree of hydrolysis and calcium concentration (Fox and McSweeney, 1998). The residual lactose is metabolized quickly into L-lactate (Parente and Cogan, 2004). Nonstarter lactic acid bacteria metabolize unfermented lactose (McSweeney and Fox, 2004). Organic acids are the major products of lactic acid bacteria during carbohydrate catabolism. The organic acids are important in flavor development of the cheese. Soluble citrates present in the milk are lost during whey drainage. Colloidal citrate concentration prevents complete removal of citrate with whey (McSweeney and Fox, 2004). Lipids also contribute to flavor of cheese as they provide the short chain fatty acids, which have strong and characteristic flavor, polyunsaturated fatty acids that are oxidized to form strongly flavored aldehydes (Fox *et al.*, 2000).

2.6.3 Proteolysis

This is a biochemical process during ripening of many cheese varieties (Feeney *et al.*, 2002). The degree of proteolysis in low moisture Mozzarella cheese is crucial in the development of its functional properties (Lucey *et al.,* 2003). Proteolytic enzymes in cheese are from milk, rennet, LABs and secondary cultures. Residual coagulant and endogenous proteases (plasmin) are majorly responsible for proteolysis of Mozzarella cheese during the first two weeks of storage (Barbano *et al.*, 1995). Rennet enzymes are extensively denatured in Mozzarella cheese because of high temperature cooking. Starter cultures play important functions in primary and secondary proteolysis. During secondary proteolysis, products of primary proteolysis are degraded to small peptides and amino acids. Starter culture may contribute to the initial hydrolysis of intact casein (Barbano *et al.*, 1995). There is evidence of plasmin activity in Mozzarella cheese during ripening because of degradation of b-casein with formation of *y*-casein.

Major factors influencing the chemical properties of cheese include the state of the casein micelles. They involve molecular interactions within and between and the content of calcium linked with these particles and the degree of proteolysis (Lucey *et al.*, 2003). The factors are predisposed by different environmental conditions that include pH development, temperature, and ionic strength. The stretch ability of cheese is related to the high concentration of intact casein and the critical concentration of Calcium and Phosphorous. The decrease in firmness and fracture stress is due to the initial hydrolysis of *alpha s1*-Casein at the Phe23- Phe24 peptide bond because of residual chymosin that results in a marked weakening of para-casein matrix (Fenelon *et al.*, 2000). *β*-Casein generally undergoes markedly less breakdown than *α*s1-casein during storage in most of the cheeses, including Cheddar, Gouda, and Mozzarella (Yun *et al.*, 1993). The individual casein in milk especially *αs1*-casein, become progressively more susceptible to rennet-induced proteolysis at pH 6.6, as the level of micelle calcium phosphate is reduced. This is attributed to increased accessibility of caseins to rennet because of the disruption of micelles on the removal of colloidal calcium phosphate (Tam and Whitaker, 1972).

2.7 Functional Properties of Mozzarella Cheese

Mozzarella cheese is a mild, white fresh cheese made by a special process where the curd is dipped into hot whey then stretched and kneaded to the desired consistency. At one point, Mozzarella was made only from water buffalo milk. Now, it is usually made with cow's, goat and ewe milk. There are two forms, regular and fresh. Regular Mozzarella is available in low-fat and nonfat forms and has a semi-soft, elastic texture and is drier than fresh Mozzarella. Fresh Mozzarella is made from whole milk and has a softer texture and sweet, delicate flavor and is typically packed in water or whey (Sulieman *et al*., 2012).

As an ingredient in food, cheese must satisfy certain performance requirements determined by the function in a particular food application (Kindstedt *et al.*, 2004). Functionality is determined by its rheological, physicochemical, and micro-structural properties. These characteristics affect the behavior of cheese in food systems during preparation, processing, storage, cooking, and consumption. Cheese improves the quality and organoleptic properties of food in which they are used (Fox *et al.*, 2000). Low moisture cheese is mostly used as an ingredient in pizza. Its functional properties are important determinants of the quality and acceptability of low moisture Mozzarella cheese (Kindstedt *et al.*, 2004). It is manufactured in blocks ranging from 2.3 to 9.5 Kg and then shredded or diced before use in pizza. Pasty, soft or wet Mozzarella cheeses are not shredded effectively as the machines become clogged resulting in shreds with ragged edges and deformed geometry. Such cheese may undergo excessive matting after shredding making it difficult to handle, store and apply uniformly on the product. Dry and firm cheese takes longer to shred and fracture excessively producing shattered shreds and fines very difficult to handle (Kindstedt *et al.*, 2004).

The composition and structure of Mozzarella cheese strongly influences its functional properties especially stretchability, meltability, browning and free oil formation. Cheese functionality, is also determined by milk pretreatment, pH and moisture content, fat and minerals and the level of proteolysis (Guinee *et al.*, 2002).

2.7.1 Meltability

This is the ability of cheese particles to flow in a continuous uniform melted mass (Kindstedt, 1993). Fat content and protein-protein interactions with water are the major determinants of Mozzarella meltability. Several researchers concluded that the type of the protein matrix plays an important role in determining Mozzarella cheese melting properties (Guo *et al.*, 1997; McMahon and Oberg, 1998; McMahon *et al.*, 1999). McMahon *et al.*, (1999) suggested that proteins absorb serum from the surrounding, thinning accumulation and enhancing melt by water transfer from the fat-serum channels to the protein matrix during cheese ripening. This results in decreased hydrophobic interactions within the protein matrix. Milk homogenization before cheese-making decreases the size of fat globules offering higher buffering in the casein matrix and as a result, meltability is decreased. Yun *et al.*, (1998) found no significant effects on meltability of low moisture part skim Mozzarella cheese prepared by incorporation of nonfat dry milk. Rudan *et al.*, (1999) suggested hydrophobic surface coating to provide low fat Mozzarella cheese appropriate melt characteristics during pizza baking. Imm *et al.*, (2003) found no significant differences in the functional properties of Mozzarella cheese prepared from goat and bovine milk. The study found that the meltability of ripened cow and goat cheeses were not different when fat content of both milks were standardized.

2.7.2 Stretchability

Stretchability is the tendency of a thing to form extended fibrous string (Kindstedt, 1993). Mozzarella cheese, a type of pasta filata product possesses this property making its use as toppings on pizza possible. The curd is transformed into molten mass by heat during cheese making. Plasticization requires para-casein matrix arrangement and combination of fat and moisture into larger pools parallel to the protein fibers (Fox *et al.*, 2000). The heat treatment applied to Mozzarella cheese during stretching influences the microbiological and proteolytic properties during refrigerated storage. When processing temperatures do not exceed 60ºC, thermophilic starter bacteria and residual coagulant are not destroyed and are active during ripening. When temperature exceeds 66ºC in the curd during stretching, inactivation of starter bacteria and rennet may occur, and it may influence functional properties of cheese. Kneading and stretching of curds during cheese making develop arrangement of curds. The pH of curd, whey and colloidal phosphate content of Mozzarella cheese significantly affect its stretchability (Kiely *et al.*, 1992). Proteolysis during ripening increases the porosity of casein matrix and stretchability (Tunick *et al.*, 1997). Protein to protein and calcium to protein interactions undergo partial reversal as calcium dissociates and water interacts with the Para-casein fibers during ripening. This induces microstructure changes and the development of a more flowable, stretchable, and less chew melted consistency.

2.7.3 Free oil

Free oil formation is also known as fat leakage and oiling off. This is the affinity of liquid fats to detach from melted cheese. The liquid fat then builds up in pools at the surface of the cheese. Oiling off is caused by the release of free oil from the body of melted cheese. Excessive oiling off results in pools of liquid at the surface and throughout the body of the melted cheese giving the cheese a greasy appearance and mouth feel generally regarded as undesirable. Moderate release of free oil contributes to desirable melting characteristics by creating a hydrophobic film. Free oil formation is a severe quality defect of Mozzarella cheese. The oil oozes off from the lapse of casein matrix allowing the fat globules to combine and move to the surface of the cheese in free oil pockets (Rowney *et al.*, 1999). Modified Babcock test and Gerber apparatus have been used to estimate free oil formation (Kindstedt and Rippe, 1990). Free oil formation process depends on fat globule size, degree of agglomeration and position within the casein matrix. The melting profile of milk fat has also been correlated with free oil content of Mozzarella (Rowney *et al.*, 1998). Addition of emulsifying salts to Mozzarella cheese causes a change in the polymorphic framework of cheese (Tunick *et al.*, 1989). Kindstedt *et al.*, (1992) found that a little salt concentration in Mozzarella cheese decreases free oil formation because of decreased emulsification of fat by casein due to less Sodium/Calcium exchange. In contrast, intensification of salt content would decrease the fat overflow at some point in melting.

In other investigation, Kindstedt and Rippe, (1990) reported a reduction in free oil formation because of proteolysis after refrigerated storage. Conversely, other researchers stated a significant rise in free oil when samples of cheese were frozen (Apostolopoulos *et al.*, 1994). Kindstedt and Rippe 1990 and McMahon *et al.*, 1993 concluded that higher cheese fat result in excessive oiling off while a lack of available fat have less oiling off which produce tough and rubbery melted cheeses. Release of free oil has been shown to reduce significantly when the milk or cream fraction of the milk is homogenized before cheese making. Imm *et al.*, (2003) observed a significantly larger amount of free oil in bovine Mozzarella cheese than caprine throughout storage.

2.7.4 Cheese Texture

The textural characteristics of the cheese are determined by the combined structural properties of the protein matrix and the fat droplets immersed in the former (Lobato-Calleros *et al.*, 2007). Rheological and textural properties of cheese are affected by many factors. Some of these factors also have an effect on flavor, appearance, and functional properties important to consumers. Texture is a very important property used to discriminate many cheese varieties. There is a close relationship between the body and texture and other qualities such as eye formation, taste and shelf life. A soft and elastic texture is crucial for regular eye formation. The high pH (5.20 - 5.30) after the lactic acid fermentation is very important for a long elastic texture. As fat content is reduced, more non-interrupted protein zones compose the cheese structure. Consequently, a high degree of cross-linking of protein molecules occurs resulting in three-dimensional networks exhibiting high resistance to deformation (Lobato-Calleros *et al.*, 2006). Texture characteristics are more important in determining the differences in cheese samples than taste and flavor attributes (Wendin *et al.*, 2000). Antoniou *et al.*, (2000) grouped and distinguished French cheeses based upon instrumental and sensory measurements of texture. Texture can be assessed by visual and perceptible elements of a material.

Many studies use the texture profile analysis (TPA) and similar uniaxial compression tests at a temperature range from 10 to 20°C to characterize hardness and firmness of cheese. Mozzarella cheese has shown a significant softening trend with increasing age and level of proteolysis (Kindstedt *et al.*, 1995) with increasing fat or moisture content (Rudan *et al.*, 1999) and with decreasing calcium content and pH (Guinee *et al.*, 2002). Complexes of texture require mechanical deformation to measure the response and correlation with results from sensory panels (Kilcast, 1999).

CHAPTER THREE
MATERIALS AND METHODS

3.1 Research site

The study was conducted at the Guildford Dairy Institute, Egerton University, Kenya (0°22'11.0"S, 35°55'58.0"E) and Jomo Kenyatta University of Agriculture and Technology, Kenya (1°5'33"S 37°0'28"E).

3.2 Materials

Goat milk was sourced from the Tatton Agriculture Park at Egerton University while gum arabic was from Isiolo, Kenya.

3.3 Preparation of Goat Milk Mozzarella Cheese

Preparation of goat milk Mozzarella cheese was as shown in Figure 1. Ten liters of high quality goat milk was pasteurized at 63^{o}C for 30 minutes and then cooled to 32^{o}C. To adjust the pH to 5.1-5.3, 16 - 18g (0.16-0.18%) of citric acid was added to the milk. Liquid rennet (2 ml) diluted with 40 ml of water was also added to enhance curd formation. The curd was cut after 15 minutes to facilitate drainage of whey and the temperature increased to between 43 and 45^{o}C for another 15 to 30 minutes with continuous stirring. The whey was then drained and the curd hand squeezed to remove the excess whey. This was followed by microwaving for 1 minute, and then hand working and stretching. Salting was done at 1.6% and addition of *Acacia senegal var. kerensis* powder at 2, 3 and 4% into the cheese. Finally, the curd was microwaved for 30 seconds and then worked into ovoid shapes (Zeng, 2004).

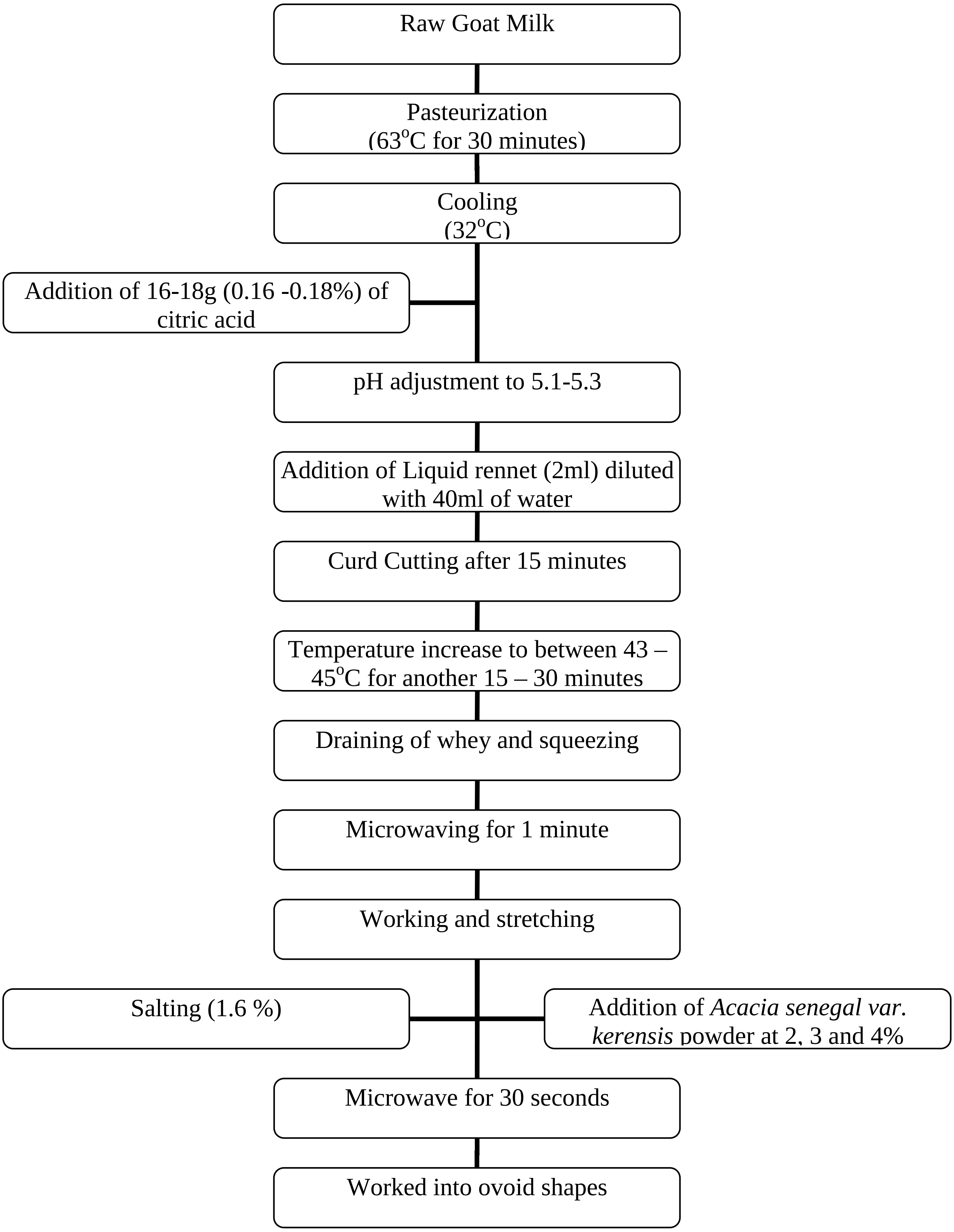

Figure 1. Flow diagram for the preparation of goat milk Mozzarella cheese

3.4 Determination of Functional Properties of Cheese

3.4.1 Free Oil Determination

Free Oil, (FO) formation was determined following the Babcock procedure as described by Kindstedt and Rippe, (1990). Eighteen grams of shredded goat milk Mozzarella cheese sample was weighed into 50% Paley-Babcock cheese bottles. The prepared bottles were placed in a boiling water bath for 4 minutes to melt the samples after which 20 ml of distilled water (57.5^{o}C) was added and the samples centrifuged at 0.224g (27.87π rads/s or 13.93Hz) at 57.5^{o}C for 10 minutes. A mixture of methanol and distilled water, mixed in equal proportions, was added to attain a final volume in the calibrated portion of the neck. The samples were centrifuged for 2 minutes and then rocked gently for 10 seconds to dislodge any trapped oil droplets. The bottles were centrifuged again for 2 minutes, rocked for 10 seconds, and then centrifuged for a final 2 minutes. The bottles were tempered in 57.5^{o}C water bath for 5 minutes before addition of glymol to facilitate reading of the calibrated neck. FO was read directly from the calibrated neck and reported as a percentage in cheese.

3.4.2 Determination of meltability

The Schreiber test as described by Muthukumarappan *et al*., (1999) was used to determine the meltability of cheese. Five grams of cheese, formed into a 35 mm in diameter, 21 mm high disc, was heated in a forced-air convection oven (110°C) for 5 minutes. The sample discs were formed by boring the cheese block using a stainless-steel ring (35-mm i.d. and 25-mm high). The increased melted area in the cheese was determined using a graph paper. The ratio of the melted cheese area and original area was taken as an indicator of cheese meltability.

3.4.3 Determination of stretchability

Stretchability test was done according to Kosikowski, (1982). A sample of 10 g cheese was placed in a 250 ml beaker containing ¾ of its volume of hot water maintained at 80 to 83^{o}C in a water bath and held for 3 minutes. A glass rod was then inserted into the molten cheese sample and pulled out slowly after 3 turns by hand to ensure proper adherence of the product to the glass rod. Cheese thread formation was observed when the rod was gradually lifted. The length of the thread formed before it snapped was taken as the stretchability parameter.

3.5 Proximate Analysis

3.5.1 Determination of Crude Fiber Content in the Cheese

Total dietary fiber content was estimated following the AACC method 32-05 (AACC, 1995).

The determination was done by gelatinizing duplicate samples (previously defatted) with heat stable alpha amylase, digesting with protease and amyloglucosidase to remove protein and starch, and diluting the aqueous digest with four volumes ethanol to precipitate soluble dietary fiber. The residual was filtered, washed with 78% ethanol, 95% ethanol, and acetone; dried; and weighed. One duplicate was analyzed for protein, the other incinerated at 525^{o}C to determine ash. The total dietary fiber collected was corrected for method blanks, which included protein and ash determinations. The weight was then reported as a percentage of fiber in cheese.

3.5.2 Determination of Crude Fat Content

Determination of fat content of the cheese was done following the ISO 3433:2008 (IDF 222:2008) method. Of the prepared Gerber acid (mixture of 90% sulphuric acid and 1% Amyl alcohol), 10 ml were added followed by cold distilled water to reach the 6 mm mark on the butyrometer. Then, 3 grams of grated cheese sample was weighed and added into the butyrometer followed by addition of 1 ml of amyl alcohol. Afterwards, the butyrometer was shaken to dissolve all the contents after securely corking it. Finally, centrifugation was done at 1100 RPM and the butterfat content read directly from the stem of the butyrometer.

3.5.3 Determination of Crude Protein Content

Crude protein was determined using the Kjeldhal method (AOAC method 920.123), where nitrogen (N) content was multiplied by 6.38 to convert it to crude protein (AOAC, 2000). One-gram cheese sample was placed in a flask and potassium sulphate, concentrated sulphuric acid and a metal catalyst added (Nickel). The flask was placed tilted at an angle in the digester, brought to boiling point and retained until the solution was clear; then heating continued for 30 minutes more. This was followed by neutralization through addition of concentrated NaOH to free ammonia gas which was trapped with hydrochloric acid solution with an appropriate indicator. Back titration of excess hydrochloric acid was done using sodium hydroxide solution. Total crude protein (CP) was then calculated as shown in equation 1 and 2.

$$N\% = \frac{[(A * Na) - (B * Nb)] - (Ab * Nb) * 1.4007}{S} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where,

N = % Nitrogen content

A = Amount of acid in ml

Na = Normality of the acid

B = Titre value for the blank in ml

Nb = Normality of the base

Ab = Amount of base in ml

S = Weight of the sample in grams

Crude protein = 6.38 x % Nitrogen, *(Where, 6.38 is the conversion factor)*……………(2)

3.5.4 Determination of Moisture Content

The moisture content in Mozzarella cheese was determined following the AOAC method 926.08 by drying samples in oven kept at 103±1°C until a constant weight of dried cheeses was obtained (AOAC, 2000). First, enough amount of sand was put in a dish to cover bottom of dish and a glass rod placed in it. The dish was placed in an oven at 103°C for at least 1 hour and then cooled in desiccators (W1). Approximately 2g of grated cheese sample was weighed (W2), mixed with sand carefully using the glass rod and placed in an oven at 103°C for at least 5 hours. It was then allowed to cool in a desiccator and the weight recorded (W3). Moisture was calculated by using equation 3:

$$\%\text{Moisture Content} = \frac{W1 + W2 - W3}{W2} * 100 \qquad \text{……………. (3)}$$

3.6 Sensory Evaluation of Cheese

Sensory analysis was conducted using a selected consumer panel of 50 untrained panelists. They were asked to indicate their preference of the goat milk mozzarella cheese samples on a 5-point hedonic rating scale {like extremely (5), like moderately (4), neither like nor dislike (3), dislike moderately (2) and dislike extremely (1)} for overall acceptability (Meilgaard *et al*., 2006).

3.7 Shelf Life of Goat Milk Mozzarella Cheese

To determine the keeping quality of Mozzarella cheese, cheese samples were stored at refrigeration temperatures for a period of 20 days and sampling done on day 0, 5, 10, 15, and 20 to determine the microbial quality. Preparation of test samples, initial suspension, and decimal dilutions for microbiological examination was performed according to the International Standard ISO 8261:2001. Petrifilm plates (3M™) for total viable counts were used following AOAC method 991.14 (AOAC, 2005b). Inoculated plates were incubated at 30^oC for 24 hours. For total coliforms counts, petrifilm plates ($3M^{TM}$) were inoculated and incubated at 37^oC for 24 hours following AOAC method 990.12 (AOAC, 2005a). Lactic acid bacteria (LAB) was plated on petrifilm plates ($3M^{TM}$) for TVC using De Man, Rogosa and Sharpe (MRS) broth as a diluent. These were then incubated anaerobically in the jars HP 11 (Oxoid, Milan, Italy) at 30^oC for 3 days. Petrifilm plates ($3M^{TM}$) for yeast and mold counts were used for yeast and mold counts. Inoculated petrifilms were incubated at 25^oC for 48 hours.

3.8 Statistical Analysis

The experiment was laid out in a Completely Randomized Design (CRD) in 3 replications. To increase on precision, the experiment was repeated 4 times. The treatments were the different levels of gum arabic (2, 3 and 4%) incorporated.

Statistical Model

$$Y_{ij} = \mu + T_i + \varepsilon_{ij}$$

Where, Y_{ij} = observation of the i^{th} treatment and the j^{th} replication

μ = overall mean

T_i = effect of i^{th} treatment

ε_{ij} = Random error term

Data on functionality tests, proximate analysis, sensory analysis and shelf life analysis was analyzed using Statistical Analysis System (SAS) Software, version 9.1.3 (SAS, 2006). Analyses of variance were performed using Generalized Linear Model (GLM) procedure. Significant differences were determined at 5% level of significance and means separated using Least Significant Difference (LSD) test to evaluate the influence of gum arabic addition on the functional properties and acceptability of goat milk Mozzarella cheese. The data were presented as mean ± standard deviation (SD).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Effect of gum arabic level on the functional properties of goat milk Mozzarella cheese

The results of functional properties of goat milk Mozzarella cheese containing gum arabic from *Acacia senegal* var. *Kerensis* are presented in Table 1.

4.1.1 Meltability

Meltability is the ability of cheese particles to flow in a continuous uniform melted mass (Kindstedt and Fox, 1993). Addition of gum arabic had non-significant effect ($P \geq 0.05$) on the meltability of mozzarella cheese. However, meltability score increased with increase in gum arabic level (Table 1). Thus, gum arabic has the potential of improving the meltability of goat milk mozzarella cheese when added at higher levels. According to Fife *et al*., (1996), low fat cheeses and part-skim mozzarella cheese do not melt. Reduction of fat content in mozzarella cheese reduces the meltability value. However, in this study, despite the reduction in fat content, there was no effect on the meltability value. This is possibly because gum arabic can give the functionality of fat in cheese. Thus, gum arabic at low levels can be used as a fat replacer with minimal alteration in meltability of mozzarella cheese. This is in agreement with Oberg *et al*., (2015) who used modified cornstarch and xanthan gum as fat replacers in low fat mozzarella cheese where they improved the meltability of the resulting cheese.

Table 1: Functional properties of goat milk Mozzarella cheese containing gum arabic

Gum arabic level (%)	Meltability (mm)	Free oil (%)	Stretchability (cm)
0 (Control)	15.67 ± 1.27^{a}	5.92 ± 0.74^{a}	43.83 ± 0.75^{c}
2	16.43 ± 1.40^{a}	5.08 ± 0.86^{ab}	45.50 ± 1.38^{b}
3	16.60 ± 1.13^{a}	4.25 ± 0.61^{bc}	47.33 ± 1.21^{a}
4	16.73 ± 1.05^{a}	3.75 ± 0.52^{c}	41.33 ± 1.21^{d}

Means are presented as Mean ± Standard deviation. Means in the same column with different letters are significantly different ($P < 0.05$) using Least Significant Difference test.

4.1.3 Stretchability

Stretchability is defined as the ease and extent to which melted Mozzarella can be drawn to form string (Gunasekaren and Mehmet, 2003). There was a significant increase ($P < 0.05$) in stretchability with gum arabic level increase up to 3%. However, increasing gum arabic level beyond 3% resulted in a decrease in stretchability (Table 1).

Similar results were observed when xanthan gum was added in mozzarella cheese. According to Oberg *et al*. (2015), xanthan gum functioned best as a fat mimetic, producing a low fat string cheese that most closely visually resembled commercial string cheese made using low-moisture part skim (LMPS) milk. Fat mimetics act through binding extra water, which creates a lubricity similar to full-fat products. However, they cannot replace the non-polar properties of fat such as flavor carrying capacity (McMahon *et al*., 1996). Gum arabic has been found to have strong water binding ability in yoghurt (Mugo, 2012) and meat products (Mwove *et al*., 2016; 2017). Therefore, it was able to bind moisture in mozzarella cheese resulting in stretchability improvement in the final goat milk mozzarella cheese.

Further increase to 4% gum arabic significantly ($P < 0.05$) reduced the stretchability score. The stretch properties of mozzarella cheese depend on the interactions between casein micelles. The more the casein network is interconnected, the more the cheese stretches. On the other hand, if the interaction between casein micelles is lost, the stretchability of mozzarella cheese is decreased (Johnson, 2000). Adding more gum beyond 3% may have reduced the casein-casein interaction and thus the decrease in stretchability. Furthermore, according to Johnson (2000), fewer interactions would result in better melting properties which is observed at 4% gum level.

4.1.2 Free Oil Formation

Free oil formation/oiling off is regarded as a defect of this type of cheese when melted on top of a pie. The excessive free oil in Mozzarella cheese is of major quality problem. There was a significant decrease ($P < 0.05$) in free oil formation with an increase in gum arabic level (Table 1). Control samples had the highest free oil formation. However, this was not significantly different ($P \geq 0.05$) from the sample containing 2% gum arabic . Comparison between the amount of fat and the free oil formation for goat milk mozzarella cheese containing gum arabic is presented in Figure 2.

There was a significant positive correlation ($r = 0.68283$; $P = 0.0002$) between free oil formation and the fat content of goat milk mozzarella cheese (Appendix 1). The slight reduction in fat content and increase in gum arabic level caused a significant ($P < 0.05$) reduction in free oil formation. Kindstedt *et al*., (1992) reported similar results when addition of a little emulsifying salt to mozzarella cheese resulted in a decrease in free oil formation.

The Addition of emulsifying salts to mozzarella cheese causes a change in the polymorphic framework of cheese due to the emulsifying properties of the salts (Tunick *et al*., 1989) and thus the decrease in the free oil formation.

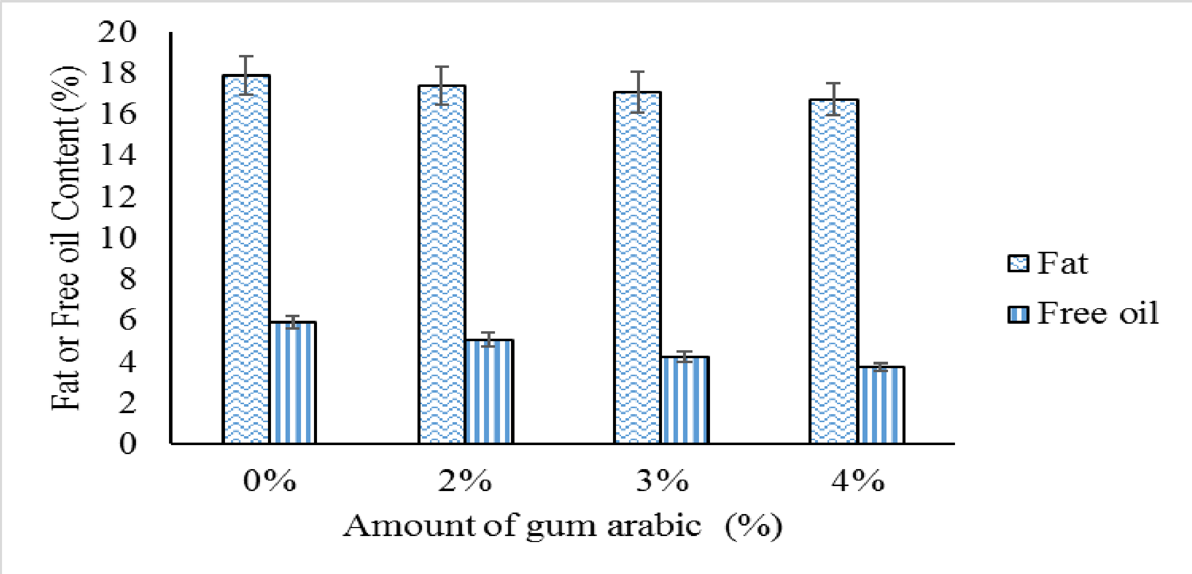

Figure 2. Comparison between the fat content and free oil formation in goat milk Mozzarella cheese.

Gum arabic has been found to have both hydrophilic and amphiphilic properties that enhance its ability to bind water as well as fat in food products (Randall *et al*., 1988; Ray *et al*., 1995; Mugo, 2012). The reduction of free oil formation in goat milk mozzarella cheese containing gum arabic can be attributed to the emulsifying abilities of gum arabic .

4.2 Effect of gum level on the proximate composition of goat milk Mozzarella cheese

The results of proximate composition of Mozzarella cheese containing gum arabic are presented in Table 2.

Addition of gum arabic slightly reduced the moisture content of the resulting mozzarella cheese although the difference was not significant ($P \geq 0.05$) add Mwoves work on water binding of gum arabic two papers. Similar results were reported when xanthan gum was used as a fat mimetic in low-moisture part skim (LMPS) mozzarella cheese without any increase in moisture content (Oberg *et al*., 2015). The reduction in moisture content may be attributed to the water binding capacity of gum arabic (Mugo, 2012; Mwove *et al*., 2016; 2017). Further study can be conducted to utilize the gum in solution form since it has shown an increase in moisture content when guar gum was added in solution form (Oliveira *et al*., 2011). The moisture content values of 41–44% (Table 2) are in the range of cheese classified as low moisture mozzarella cheese (Jana and Mandal, 2011).

Table 2: Proximate composition of goat milk Mozzarella cheese containing gum arabic

Gum arabic Level (%)	Moisture (%)	Protein (%)	Fat (%)	Fiber (%)
0 (control)	43.50 ± 3.22^{a}	28.28 ± 1.90^{a}	17.92 ± 2.29^{a}	0.00 ± 0.00^{d}
2	42.40 ± 1.63^{a}	27.32 ± 1.30^{ab}	17.42 ± 2.27^{a}	1.74 ± 0.16^{c}
3	42.01 ± 3.05^{a}	27.25 ± 1.07^{ab}	17.08 ± 2.40^{a}	2.44 ± 0.08^{b}
4	41.01 ± 1.91^{a}	26.07 ± 1.15^{b}	16.75 ± 1.94^{a}	3.41 ± 0.30^{a}

Means are presented as Mean ± Standard deviation.Means on the same column with different letters are significantly different ($P \geq 0.05$) using Least Significant Difference test.

The protein content of mozzarella cheese ranged between 26.07±1.15 to 28.28±1.90%. This was higher but comparable to the work of Osman *et al*., (2009) for cow milk mozzarella cheese. In their study, they reported the protein content of mozzarella cheese to be 23.33±2.12%. There was a significant decrease ($P < 0.05$) in protein content with addition of gum arabic. Control samples with no gum had the highest protein content which was not significantly different ($P \geq 0.05$) from the samples containing 2 and 3% gum arabic . Addition of gum arabic to 4% resulted in more reduction in protein content, which was significantly different ($P < 0.05$) from the control sample. This was expected since gum arabic has very low protein content (4.55%) as compared to cheese. There was a decrease in the stretchability of the resulting cheese confirming the connection between the protein content and the stretchability of mozzarella cheeses. This is because the melt and stretch of cheese, are determined by the interaction of casein molecules (Lucey *et al*., 2003).

Addition of gum arabic in mozzarella cheese significantly ($P < 0.05$) increased the amount of dietary fiber. At 4% gum arabic level, highest significant ($P < 0.05$) fiber content was recorded to be 3.41±0.30%. This is because of the high levels of fiber in gum arabic. Analysis of gum arabic used in this study showed that it had dietary fiber content of 78.099%. Since milk is deficient in dietary fiber, addition of gum arabic resulted in a significant increase in fiber levels in the resulting cheese. Therefore, the use of gum arabic in goat milk mozzarella cheese has the potential of not only reducing the fat content but also enriching cheese with fiber thus making it healthier.

4.3 Effect of Gum Level on the Sensory Quality of Goat Milk Mozzarella Cheese

The results of sensory properties of Mozzarella cheese containing gum arabic from *Acacia senegal* var. *Kerensis* are presented in Table 3.

Texture liking was highest in the 3% gum arabic containing cheese with a mean of 4.00±1.09 which was not significantly different ($P \geq 0.05$) from the one with 2% gum arabic . Further addition to 4% negatively affected the texture of the resulting cheese. According to Lobato-Calleros *et al*., (2006) as fat content is reduced, more non-interrupted protein zones compose the cheese structure. Consequently, a high degree of cross-linking of protein molecules occurs resulting in three-dimensional networks exhibiting high resistance to deformation. Oberg *et al*., (2015) indicated the use of xanthan gum at a level of 1% to improve the texture of mozzarella cheese as compared to control samples with no gum. In addition, the use of guar gum and gum arabic have been reported to improve the texture of cheese (Lashkari *et al*., 2008).

Flavor liking was highest in the gum arabic containing samples as compared to the control samples. Samples with 2% gum arabic were rated higher followed by 3% samples which were not significantly different ($P \geq 0.05$) from each other. Control samples and the sample containing gum at 4% were not significantly ($P \geq 0.05$) different although 4% samples had a higher rating. These results indicate an improvement in the flavor of the resulting product unlike the results of McMahon *et al.,* (1996) who argued that a reduction in fat would affect the non-polar properties of fat such as flavor carrying capacity. However, these results are true when gum level was increased to 4%. It appears that the reduction of fat content in the 4% gum arabic containing sample affected the flavor carrying capacity of the fat. Other researchers have reported the ability of gum arabic to encapsulate flavors and aromatic compositions in food products (Kennedy *et al*., 2011) which may explain the retention of flavors in goat milk mozzarella cheese.

Table 3: Sensory properties of goat milk Mozzarella cheese containing gum arabic

Gum arabic Level	Sensory Attributes			
	Texture	Flavor	Color	Overall Acceptability
0%	3.44 ± 1.30[b]	3.38 ± 1.29[b]	3.82 ± 0.96[ab]	3.30 ± 1.40[b]
2%	3.94 ± 0.84[a]	4.30 ± 0.91[a]	4.02 ± 0.82[ab]	4.08 ± 0.90[a]
3%	4.00 ± 1.09[a]	4.16 ± 0.96[a]	4.16 ± 0.68[a]	4.06 ± 0.82[a]
4%	3.40 ± 1.14[b]	3.70 ± 1.20[b]	3.70 ± 1.04[b]	3.80 ± 1.14[a]

Means are presented as Mean ± Standard deviation.

Means on the same column with different letters are significantly different ($P \geq 0.05$) using Least Significant Difference test.

Color liking was highest at 3% gum arabic which was not significantly different ($P \geq 0.05$) from 2% and the control sample. The sample containing 4% gum had the lowest rating. According to Mistry, (2001), low fat cheeses have undesirable color as compared to their full fat counterparts. Despite the minimal reduction in fat content, the liking for color was high for gum arabic sample at 3% addition. This means that, gum arabic can be used at this level with minimum effect on the color of goat milk mozzarella cheese. However, further addition seems to affect the color rating since more fat was replaced at 4% gum addition. Overall, samples containing gum arabic were significantly ($P < 0.05$) liked more as compared to the control. Samples with 2% gum arabic had the highest liking although not significantly different ($P \geq 0.05$) from the samples containing gum arabic at 3 and 4% in that order. This means that gum arabic has potential for improving the appeal of goat milk mozzarella cheese. Similar results were reported for other dairy products including yoghurt and ice cream (Mugo, 2012; Belitz *et al.*, 2009).

4.4 Effect of Gum Level on the Initial Microbial Quality of Goat Milk Mozzarella Cheese

Initial bacterial load for goat milk Mozzarella cheese containing gum arabic are presented in Table 4. Bacterial load at the beginning was below 2.0 log cfu/g for TVC, LAB and yeast and molds and below 1.0 log cfu/g for coliform counts for all samples. These counts are below the counts of bacteria recommended by the Kenya Bureau of Standards (KEBS) for Mozzarella cheese (KEBS, (2015), (KS 2193: 2015)). According to the standards, Mozzarella cheese should have at most, 4.3 log cfu/g for TVC, 1.0 log cfu/g of non-fecal coliforms, and 2.0 log cfu/g of yeast and mold counts. There were significant differences ($P < 0.05$) in the counts for TVC, LAB, coliforms and yeast and molds between various treatments. TVC was significantly ($P < 0.05$) higher in the control samples as compared to all gum arabic containing samples. LAB were close to TVC in numbers and significantly ($P < 0.05$) higher in the control samples. This may indicate that the gum resulted in an inhibition effect on LAB and not the other bacteria (Coliforms and Yeast and Molds). Yeast and mold counts were significantly ($P < 0.05$) higher in the sample containing gum arabic at 4% followed by 3% which was not significantly different from the control. The sample containing gum at 2% had the lowest yeast and mold counts. In addition, coliform counts were higher in the gum containing samples as compared to the control. According to Irkin, (2010), the microbiological quality, safety and shelf life of cheeses depend on manufacture and handling environment. The initial counts of bacteria would therefore be depended on the processing of the cheese as well as packaging and storage of the cheeses. The high numbers of LAB and yeasts and molds counts as compared to the TVC could be attributed to the low pH, the acidity and salt concentration of the cheese where some of these microorganisms survive better.

Table 4: Initial Microbial Counts on Goat Milk Mozzarella Cheese

		Microbial counts (CFU/g)			
	KEBs STD	**0% Gum**	**2% Gum**	**3% Gum**	**4% Gum**
Coliform	1.0	0.573 ± 0.013^{b}	0.635 ± 0.434^{a}	0.602 ± 0.011^{a}	0.613 ± 0.011^{a}
LAB	-	1.830 ± 0.015^{a}	1.245 ± 0.252^{c}	1.571 ± 0.012^{b}	1.598 ± 0.025^{b}
TVC	4.3	1.914 ± 0.011^{a}	1.467 ± 0.321^{b}	1.794 ± 0.039^{b}	1.792 ± 0.007^{b}
Yeast and Molds	2.0	1.319 ± 0.022^{b}	1.057 ± 0.004^{c}	1.333 ± 0.025^{b}	1.489 ± 0.024^{a}

Means are presented as Mean ± Standard deviation.

Means on the same column with different letters are significantly different ($P \geq 0.05$) using Least Significant Difference test.

4.5 Effect of Gum Level on the Shelf Life of Goat Milk Mozzarella Cheese

The growth of microorganisms in goat milk Mozzarella cheese containing gum arabic is presented in figures 5, 6, 7 and 8. During the 20 days of storage, microbial load for all microorganisms analyzed increased steadily to reach counts between 5 – 8 log cfu/g. Generally, at the termination of the experiment, counts of microorganisms in control cheese samples were more than in all gum arabic containing samples. It appears therefore that the rate of growth of bacteria in the control samples was higher than in the gum arabic containing samples.

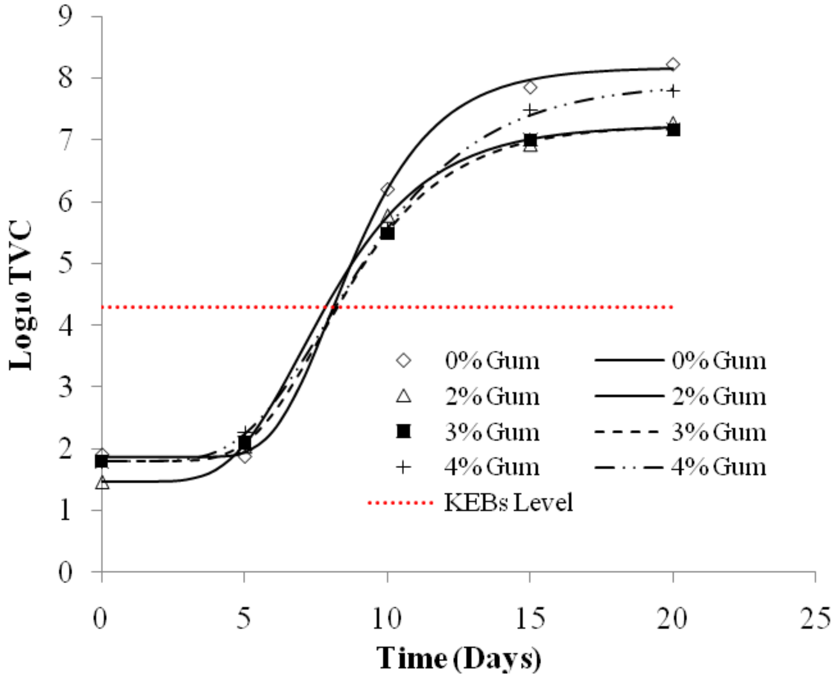

Figure 3. Growth of Total Viable Count (TVC) in samples of goat milk Mozzarella cheese. KEBs = Kenya Bureau of Standards

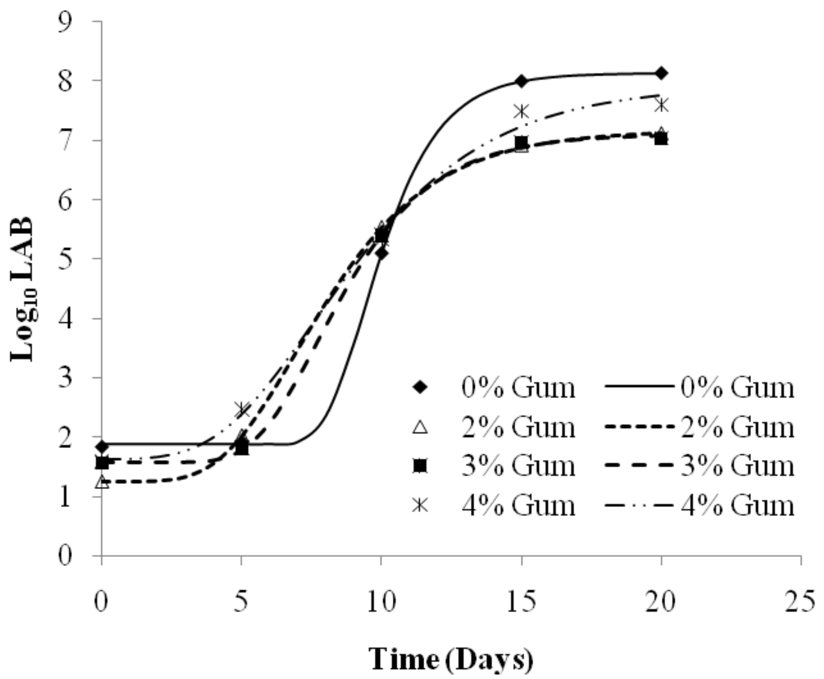

Figure 4. Growth of Lactic Acid Bacteria (LAB) in samples of goat milk Mozzarella cheese

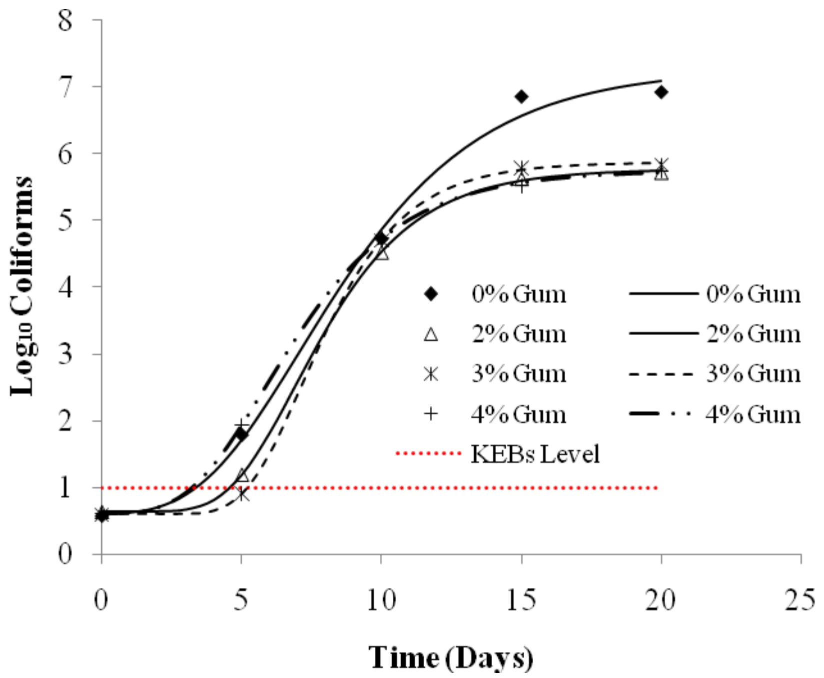

Figure 5. Growth of Coliforms in samples of goat milk Mozzarella cheese

KEBs = Kenya Bureau of Standards

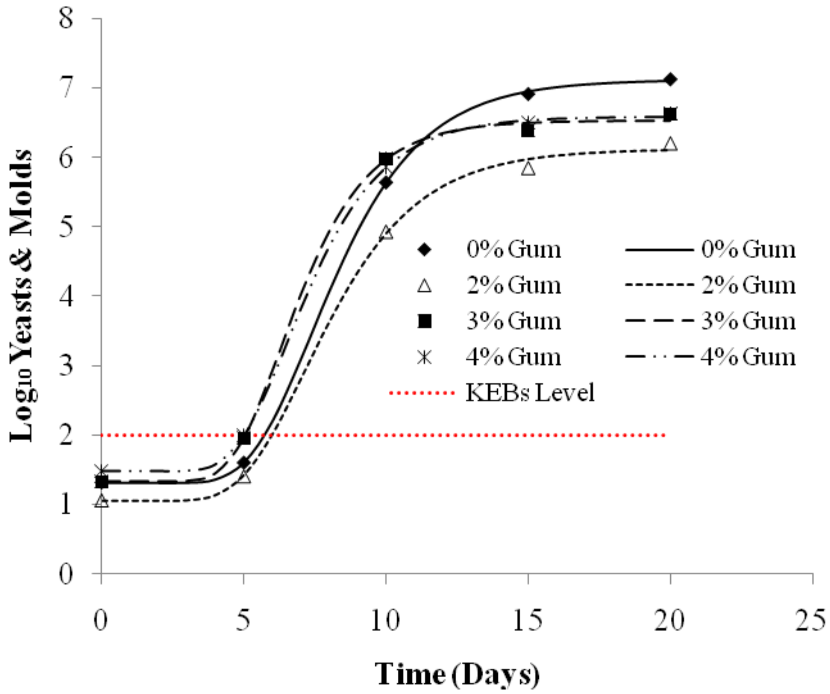

Figure 6. Growth of Yeasts and Molds in samples of goat milk Mozzarella cheese

KEBs = Kenya Bureau of Standards

Table 5. shows the estimated shelf life based on the KEBS specifications for maximum bacterial load in Mozzarella cheese (KS 2193: 2015). Based on the TVC, shelf life was found to be 8 days for all samples. In addition, based on coliforms and yeast and mold counts, the range of shelf life for samples containing gum arabic from 0 - 4% was about 3-5 days and 5 - 6 days, respectively.

Table 5: Estimated shelf life based on KEBS specifications for TVC, Coliforms and Yeast and molds counts in Mozzarella cheese

Gum arabic level	**Shelf Life in Days**		
	TVC	**Coliforms**	**Yeast and Molds**
0% Gum (Control)	8.132	3.309	5.656
2% Gum	7.869	4.497	5.984
3% Gum	8.286	5.150	5.043
4% Gum	8.196	3.184	4.993

TVC = Total Viable Count

The cheese samples containing gum arabic at 3% would keep longer than all other samples. Shelf life based on the yeast and mold counts showed a possible loss in keeping quality with increase in gum arabic level. As earlier reported, addition of gum seemed to increase the yeast and mold counts in the cheese samples. This means that the gum arabic could be a possible source of yeast and mold contamination in the cheese although more studies are required in this area. The quality of cheese, as well as cheese shelf-life and safety, are largely determined by the composition and evolution of microorganisms contained in it (Irkin, 2010; Irlinger and Mounier, 2009). The short shelf life of Mozzarella cheese is always attributed to microbiological spoilage. Often, this spoilage is caused by the growth of coliforms, *Pseudomonas spp*. and by psychrotrophic bacteria growing on the cheese surface (Cantoni *et al.*, 2003).

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

1. Results indicate that gum arabic from *Acacia senegal* var. *kerensis* can be used to enrich goat milk Mozzarella cheese with minimal alteration on resulting cheese.
2. The use of gum arabic up to a level of 3% improved the functional properties; meltability and stretchability while reducing the free oil formation.
3. Addition of gum arabic resulted in an increase in the fiber content of the cheese and a reduction in fat, protein and moisture content of the cheese at 2, 3 and 4% level. Resulting shelf life of Mozzarella cheese was between 3 – 8 days. The cheese samples containing gum arabic at 3% keep longer than all other samples based on total viable count and coliform count.
4. The use of gum arabic from *Acacia senegal* var. *kerensis* improved the consumer acceptability of the resulting goat milk Mozzarella cheese. Sample containing gum arabic at a level of 3% was rated best in terms of overall acceptability.

5.2 Recommendations

1. There is potential for commercialization of the goat milk Mozzarella cheese containing gum arabic from *Acacia senegal* var. *kerensis* which can improve the standard of living of communities in arid and semi-arid lands of Kenya where the raw materials are found. Therefore, farmers and agro-pastoralists living in the dryland areas and the relevant ministries involved in rural development and agriculture in Kenya should work to strengthen the capacity and ability of gum collectors and other stakeholders to produce and collect large quantities of high quality gum arabic for utilization by cheese manufacturers.

2. There is need for more research work on the effect of gum arabic to the microbial quality of goat milk mozzarella cheese to clearly show the contribution of gum arabic in the microbial profile of mozzarella cheese.

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APPENDICES

Appendix 1. Correlation between proximate and functional properties

	Protein%	**Fat%**	**Moisture %**	**Meltability**	**stretchability**
Fat%	0.000				
Moisture%	-0.103	0.713			
Meltability	0.103	-0.389	-0.225*		
stretchability	-0.034	0.176	0.262	-0.202	
Free oil	0.000	0.683	0.565***	-0.483**	**0.188***

* Significant at 0.05, ** Significant at 0.001 and *** Significant at 0.0001

Appendix 2. Sensory score card

Panelist No. ____________________ **Date: ________________**

Instructions: You are provided with four Mozzarella cheese samples. Taste each at a time and indicate your preference using a tick.

	Sample	**Like Extremely**	**Like moderately**	**Neither like nor dislike**	**Dislike moderately**	**Dislike extremely**
Appearance/ Colour						
	XYZ					
	SRQ					
	FTR					
	WVK					
Texture						
	XYZ					
	SRQ					
	FTR					
	WVK					
Taste/ Flavour						
	XYZ					
	SRQ					

	FTR					
	WVK					
Overall acceptability						
	XYZ					
	SRQ					
	FTR					
	WVK					

Appendix 3. Mean squares table for functional properties

Source of variation	DF	Mean Square		
		Meltability	Stretchability	Free oil Formation
Treatment	3	1.356^{ns}	39.000***	5.444***
Error	20	1.487	1.350	0.483
R^2		0.120	0.813	0.628
CV		7.454	2.611	14.636

CV - Coefficient of Variation, R^2 – Coefficient of Determination

Appendix 4. Mean squares table for proximate composition

Source of variation	**DF**	**Mean Square**			
		Fat	**Protein**	**Moisture**	**Fiber**
Treatment	3	1.486^{ns}	4.904*	6.323^{ns}	6.220***
Error	20	4.975	1.941	6.508	0.030
R^2		0.043	0.275	0.127	0.987
CV		12.899	5.117	6.040	9.159

CV - Coefficient of Variation, R^2 – Coefficient of Determination

Appendix 5. Mean squares table for sensory attributes

Source of Variation	DF	Mean Square			
		Colour	**Texture**	**Flavour**	**Acceptability**
Treatment	3	2.098*	5.085**	8.952***	6.593**
Error	196	0.784	1.220	1.212	1.189
R^2		0.039	0.060	0.102	0.078
CV		22.552	29.894	28.334	28.617

CV - Coefficient of Variation, R^2 – Coefficient of Determination, DF – Degrees of Freedom

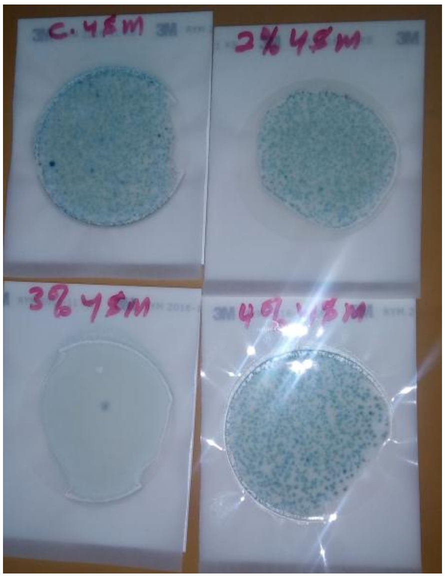
Appendix 6. Photos

Temperature monitoring, Curd cutting and stirring before whey removal

Working goat milk Mozzarella cheese containing gum arabic

Ready Mozzarella cheese containing gum arabic at different levels

Stretchability parameter measurement of goat milk Mozzarella cheese



Growth of Yeast and Molds in Petrifilm plates (3M TM) in samples containing gum arabic

Growth of coliforms in Petrifilm plates (3M TM) in samples containing gum arabic

Total viable bacteria growth in Petrifilm plates (3M ^{TM}) in samples containing gum arabic

Appendix 7. Published Research Paper

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African Journal of Food Science

Full Length Research Paper

Preparation and analysis of goat milk mozzarella cheese containing soluble fiber from *Acacia senegal* var. *kerensis*

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Mozzarella cheese is one of the preferred ingredients for use in pizza. Goat milk is a good source of protein and calcium, possessing unique characteristics with a high proportion of small milk fat globules that contain a higher concentration of short chain, medium chain and polyunsaturated fatty acids than cow's milk. Its use in mozzarella cheese can therefore impart significant health benefits to consumers. However, despite these unique qualities, goat milk is underutilized in Kenya. Gum arabic is an excellent source of soluble dietary fiber, which can be used to boost fiber levels in cheese and other dairy products. Thus, the aim of this study was to investigate the feasibility of incorporating gum arabic as a source of fiber in goat mozzarella cheese without affecting the functionality of the cheese. Gum arabic powder at 2, 3 and 4% was incorporated into cheese during the salting process at room temperature (20 to 25°C). The functional properties of the cheese: stretchability, free oil formation and meltability were then determined. Sensory evaluation was conducted using 50 untrained sensory panelists on a 5-point hedonic scale. The results indicated that the use of gum arabic in mozzarella cheese up to a level of 3% improved the stretchability and meltability while reducing the free oil formation phenomenon. Texture, flavor, color and overall acceptability were also rated as best for samples containing gum arabic at a level of 3%. The results showed that the use of gum arabic can improve the functional properties, nutritional quality as well as sensory quality of goat milk mozzarella cheese.

Key words: Gum arabic, dietary fiber, mozzarella cheese, goat milk, functional properties.