QUALITY CHARACTERISTICS OFSUGAR-REDUCEDJAM CONTAINING GUM ARABIC FROM *Acacia senegal* var. *kerensis*

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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

This thesis has been submitted for examination with our approval as the official University supervisors.

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DEDICATION

With humility I dedicate this work to God who has seen me through the whole academic journey through His grace and divine providence. May this work bring Glory to His name and be of help to many who will read and apply the knowledge thereafter.

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ABSTRACT

Gum Arabic (GA) has been used over centuries in food processing for functions such as emulsification, stabilization, encapsulation, bulking and thickening. However, use of GA from *Acacia senegal* var. *kerensis* in sucrose reduced jam has not been reported despite its potential functional properties.Reducing caloric intake from sucrose is advisable for people with metabolic syndrome but reducing the amount of sugar in jam has an effect on the physico-chemical properties of the product. Thus, other co-solutes must be added to counter the effect and maintain the quality of the jam. Therefore, the objective of this study was to use gum Arabic from *Acacia senegal var. kerensis* in formulation of a reduced sugar jam from plums and pineapple fruits. The jams were analyzed for physico-chemical and rheological properties, sensory attributes and shelf-life. The experiment employed a completely randomized design in a factorial arrangement. Data obtained was analyzed using PROCGLM procedure of the statistical analysis system version 9.1.3. The main effect of the study was the level of gum Arabic at 15% and 20%, level of sugar content, 30% and 35%, and the type of fruit. A control product was prepared for the two sugar levels but without gum Arabic. Jam with gum Arabic had higher ash (1.7%), fibre (0.57) and vitamin C content (1.4mg/100g) at $p<0.05$. Moisture content reduced as gum level increased from 49.44% (control) to 40.12% (20% gum). On sensory parameters, fruit type significantly affected the color at $p<0.05$. Plum jam was preferred in colour. Gum Arabic significantly affected the taste at $p<0.001$ with the control having a score of 6.21 compared to 5.82 and 5.68 for jam containing 15% and 20%GA, respectively. Pineapple jam containing 30% sucrose was preferred to one with 35% sucrose.The jam was shelf stable for longer than the anticipated storage time of one month. Sucrose content was reduced from the maximum allowed content of 65% to 35% and 30% for plum and pineapple jam,respectively, while retaining the total soluble solids above 60˚ Brix. Therefore, it is possible to reduce the amount of sugar by 50% by adding 15% GA from *Acacia senegal* var. *kerensis* and maintain acceptable physico-chemical, rheological, sensory and shelf-life of the pineapple and plum jam. The products of this work can be used as a dietetic jam for people who are conscious about high caloric intake from sugar and individuals with metabolic syndrome.

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LIST OF ABBREVIATIONSAND ACRONYMS

ASLT	Accelerated Shelf Life Testing
CBI	Centrum tot Bevordering van de Import uitontwikkelings landen (Centre for the Promotion of Imports)
EFSA	European Food Safety Agency
FAO	Food and Agriculture Organization of the United Nations
FBG	Fasting Blood Glucose
FOS	Fructooligosaccharides
HMP	High methoxylated pectin
KEBS	Kenya Bureau of Standards
KEFRI	Kenya Forest Research Institute
LMP	Low methoxylated pectin
USDA	United States Department of Agriculture
WPI	Whey Protein Isolate

CHAPTER ONE
INTRODUCTION

1.1 Background Information

Jams, jellies, marmalades and preserves are products obtained by cooking fruits with addition of sugar mostly sucrose in high quantities (up to 65% by weight). These products are thick or jelly to some extent(Albrecht, 2010).The Kenya Bureau of Standards (KEBS, 2018) defines jam as a product brought to a suitable consistency, made from whole fruit, pieces of fruit, unconcentrated and/or concentrated fruit pulp or fruit puree, of one or more kinds of fruit, which is mixed with foodstuffs with sweetening properties, with or without the addition of water. The term 'jam', 'marmalade' and 'preserve' are used distinctively in the English-speaking regions whereas in other regions 'jam' and 'preserve' are used interchangeably. A preserve in English language refers to a product containing cooked or gelled whole fruit (Wolf, 2016).

Preparation of jams, marmalades and jellies are technologies that have been used over many years to preserve fruits for use during off season (Naeem *et al*., 2017). This technology was initially done at household level in the 19th century by midwives to preserve fruits for use during winter. As sugar became more affordable and the chemistry of pectin was better understood, the practice was up-scaled to industrial levels. This led to many people affording to process or buy the jams, jellies and marmalades (Sinha *et al*., 2012).

Main ingredients in fruit jam manufacture include; fruit pulp, sugar/sucrose, thickeners (mostly pectin), and citric acid (Sharma *et al*., 2006). These ingredients have specific functional properties that are fundamental for quality of the jam. Sugar is the common sweetener used in jam processing. Apart from the sweetness, sucrose adds to the soluble solids content thus affecting the physicochemical characteristics of jam and also retards microbial growth thus increasing the keeping quality. Sugar activates pectin to initiate gel formation especially when using high-methoxyl pectin which cannot form gel with less than 55% sugar as a co-solute (Robert *et al*., 2005; Sinha *et al.*, 2012).

Low sugar jams are produced with commercial pectin prepared specifically for that purpose. These jams however are susceptible to mold growth. Efforts to replace sucrose with other low calorie sugars like fructose, sorbitol, maltitol and lactitol as well as sweeteners like saccharin and cyclamate have been done with a significant change in rheological profile of the jams

(Nabors, 2012). However, with modification of formulations and process, an acceptable product can be obtained (Vilela *et al*., 2015).

To address some of the shortfalls reported in low or reduced sugar jam and/or offer an alternative, this study explored partial replacement of sugar with gum Arabic from *Acacia senegal* var. *kerensis.* No reports on the utilization of gum Arabic from *Acacia senegal var. kerensis* in jams were available. Therefore, the current study reports its utilization in preparation of sucrose-reduced pineapple and plum jams. The reduction in sucrose content was up to 50% of the content normally incorporated during the preparation of jam.

1.2 Statement of the Problem

Jams are among the most popular products made from fruits and are also widely consumed across the world. However, most jams in the market are prepared with a lot of sugar with some going to 60-70% by weight. This automatically locks out consumers who have metabolic syndrome and other non-communicable diseases. As a result, recent studies on sugarless or low sugar jams used non-caloric sweeteners or other sugar substitutes but reported either reduced total solids or changes in texture of the jam. Low total solids content produces a syrupy jam because gel formation is poor. To overcome these, there is need to come up with alternative sugar substitutes that can bind water, add to the total solids content and retain the expected quality parameters of jam. Gum Arabic from *Acacia senegal var. kerensis* is a strong water binding agent that can be used to reduce water activity which is a fundamental function of sugar in jam making. The gum will also act as an emulsifier, stabilizer and possibly encapsulate flavor of the fruits. The study thus aims to tap on these functional properties to come up with a sugar-reduced pineapple and plum jam to address the aforementioned problem.

1.3 Objectives

1.3.1 Broad Objective

To contribute to nutrition security and wellbeing through development of sugar-reduced jam containing gum Arabic from *acacia senegal* var. *kerensis* a jam product that will help reduce consumption of high calories from added sugar.

1.3.2 Specific Objectives

i. To determine the effect of sugar substitution with gum Arabic from *Acacia senegal var. kerensis* on the physicochemical and rheological properties of the sugar reduced jam.

ii. To evaluate the effect of sugar substitution with gum Arabic from *Acacia senegal var. kerensis* on the sensory properties of the prepared jam.

iii. To determine the shelf-life of the sugar reduced jam containing gum Arabic from *Acacia senegal* var. *kerensis*.

1.4 Hypotheses

i. Substitution of sugar with gum Arabic from *Acacia senegal* var. *kerensis* has no effect on physicochemical and rheological properties of the sugar reduced jam.

ii. Substitution of sugar with gum Arabic from *Acacia senegal* var. *kerensis* has no effect on the sensory properties of the prepared jam.

iii. Gum Arabic from *Acacia senegal* var. *kerensis* has no effect on the shelf life of the sugar reduced jam

1.5 Justification of the Study

Jams are widely used in many parts of the world. Many companies are manufacturing jams to meet the demand of the domestic and the export markets. New jam brands are entering the markets replacing the older brands. This creates new niche markets and encourages production of high-quality products. Therefore, innovatively developing a new jam product with reduced sucrose content will cater for diabetic populations. The product will also cater for the consumers who avoid high sucrose products, yet require the nutritional benefits conferred by fruit products. This product will not only add to variety of jams in the market but also for other products containing added Acacia gum var. *kerensis*. Such a scenario will open a wider market for the gum. The soluble fibre in the jam will be enhanced with the addition of gum Arabic. Pectin and other hydrocolloids like gum Arabic are known to be beneficial in slowing glucose absorption and in lowering insulin secretion (Nielsen, 2010). Jams also make other foods more palatable by improving their taste and texture. Thus, the use of reduced sucrose jam will bring a new perspective to diabetic diets which are considered tasteless and unpleasant.

CHAPTER TWO
LITERATURE REVIEW

2.1 Jam Preparation

Key ingredients in fruit jam manufacture include; fruit pulp, sugar and glucose syrup, thickeners (mostly pectin), and citric acid. In case of low methoxyl pectin gels calcium is also added. Other optional ingredients that do not necessarily change the physicochemical characteristics of jams include spices, buffering agents, antifoaming agents and preservatives (Sharma *et al*., 2006). Each of the ingredients has a functional characteristic that justifies its use. Any modification to the various ingredients either addition or reduction has a significant effect to the final product and thus if any alterations need to be done, careful considerations have to be made. Jams, jellies and marmalades are mainly distinguished by the form in which the fruits are incorporated. In jams the fruit material is crushed or ground while in jellies only the fruit juice is used after straining. Marmalades are clear jellies in which pieces of fruits (mostly citrus peels) are incorporated in the mixture (Robert *et al*., 2005). Irrespective of their form, all of them are either sugar-acid pectin gels or low methoxyl pectin calcium gels.

As mentioned above there are four main ingredients that are essential in jam preparation; Sugar, fruit, pectin and acid. The types of sugar used can be in various forms and from different sources for example invert sugar is usually used to prevent crystallization post process, cane or beet sugar can be used, highly refined sugar is also preferred in some jams because of the low tendency to recrystallize (Javanmard & Endan, 2010;Sinha *et al*., 2012). Glucose syrup is sometimes used together with sucrose (Sinha *et al*., 2012).

Jam manufacture can be divided into three main steps: the first step involves mixing all the ingredients together followed by evaporation of water until the desired solids level is obtained and finally pasteurization is done for the final product. However, in an effort to make more consistent products with better sensory profile and rheological properties which are essential in jams and any fruit spreads especially with the modern demand of high quality products several modifications from the traditional processes have been done. In order to have a precise pH control for instance, citric acid is added much later in the process (Robert *et al*., 2005). Volatile flavoring agents are also added in the later stages to ensure the flavors are retained in the final product. Most companies use low temperature or vacuum evaporation followed by pasteurization to ensure microbiological safety of the product (Sharma *et al*., 2006).

The fruits are cut into small pieces and mashed then mixed with sugar and cooked. The sugar to fruit ration is usually 55 and 45 parts respectively. However, the ratios might be altered depending on pectin and natural sugar content of the fruit (Morris, 2004). Citric acid is added at 5g/kg of the mashed fruits to improve the sugar-acid balance of the final product as well as to aid in inverting sugar so as to prevent recrystallization of the sugar during storage of the product (Javanmard & Endan, 2010). The mixture is then cooked while continuously stirring to prevent sticking on the pan until a thick consistency is achieved. The ready jam is then filled hot in clean, sterilized dry containers, sealed airtight, cooled and stored (Vibhakara & Bawa, 2012).

Jams, marmalades, and similar fruit spreads have the same manufacturing process apart from gelation which is the principal difference between them. In all of them for instance, pectin solution is prepared by adding pectin to hot water and heating while stirring until it becomes a homogenous solution. The pectin solution is then added to the mashed fruits, sugar is added and citric acid is also added at this stage to bring the pH to around 3 which is the desired pH for gel formation. The mixture is heated with continuous stirring until °Brix of about 55 is reached. The mixture is then cooled in container to 35°C where gelation is completed (Javanmard & Endan, 2010). The process however differs depending on whether it is batch processing or continuous but the principal remains. The containers with jam can be pre-sterilized and jam filled while still hot or sterilization can be done in the cans after filling.

2.2 Purpose of Jam Manufacture

Food preservation for future use or to control post-harvest losses has been a concern for man over centuries. Jam processing is one of the many techniques that have been employed for long to preserve fruits for use especially during off season and to make good use of surplus fruits, increase diversity of products as well as to enhance transportation to distant places (Khan *et al.*, 2016; Perumpuli *et al.*, 2018). The shelf stability is achieved through a combination of hurdles to prevent spoilage by intrinsic enzymes and spoilage microorganisms. The hurdles include; thermal processing, control of water activity and pH, and finally proper packaging (Wolf, 2016). In most cases, jam is not eaten alone as the case may be with jellies rather it is used as a condiment with other foodstuffs. It is usually used as a spread on bread and other baked goods to enhance taste, texture and appeal of the product on which it is applied. Therefore, it is a commodity that finds use in most breakfast staples in the world over and in some desserts

2.3 Nutritional Benefits

The different fruits used in jam making and the preparation method used determine the nutritional and health benefits the jam confers to the consumer. Fruits like plums and pears contain sugar alcohol sorbitol which aid in osmotic water transfer into the stomach thus acting as a laxative. Fruits are also good sources of water-soluble and insoluble fibre which help in disease prevention like colon cancer, circulatory related diseases and metabolic diseases (Sinha *et al*., 2012). Many studies done on jams prepared from different fruits have a focus on the health benefits conferred by fruit consumption. Plums are one of the well-studied fruit with regards to health benefits in the overall immune system, muscular and nervous system. This can be attributed to the fact that plums are high in fiber, potassium, magnesium, vitamins, carbohydrates and antioxidants. They also stimulate the bowel and reduce liver enlargement (hepatomegaly) (Viktorija *et al*., 2013). The skin of plums is used in plum jam preparation and this gives the jam a higher quantity of fibre, vitamins and antioxidants and a more rich color than fruits where only the pulp is used (Culetu *et al*., 2013). Fruits also contain vitamins which are essential in maintaining good health. Fruit products such as jam are therefore a good source of these vitamins especially if processed in a way that retain more vitamins. Vitamin C is required for normal metabolic function of the body. It is necessary therefore to determine how much vitamin C a jam product retains at the end of the production process and consequently determine the dietary allowance that is contributed by the jam upon consumption (Khan *et al*., 2006).

However, some nutritional issues of jams are of concern for many consumers because jams are regarded as high energy conserves. The energy is mainly provided by the high quantities of sugar which is added as an ingredient and also from sugars found in the fruits used. Studies have been carried out to reformulate jams and produce high quality products yet retain the sensory characteristics which consumers expect from fruit spreads (Vibhakara & Bawa, (2012); Culetu *et al*., (2013); Viktorija *et al*., (2013); Vilela *et al*., (2015); Priya & Prakash, (2017).

2.4 Jam Quality Assessment- Physicochemical and Sensory Parameters

The general requirements adopted by Codex Alimentarius Commission (CAC) in 2009 and amended in 2017 on jam quality states that: The end product should be of an appropriate gelled consistency, having normal color and flavor appropriate to the type or kind of fruit ingredient used in the preparation of the mixture, while taking into account any flavor imparted by optional ingredients or any permitted coloring agents used. It shall be free from defective materials normally associated with fruits.

Product specifications for exporting jam, jellies, purees and marmalades as specified by Ministry of foreign affairs in the Centre for the Promotion of Imports from Developing countries (2018), gives three basic contents to look for in any jam product; fruit content (higher fruit translates to higher quality), content of permitted additional ingredients (sweeteners, pectin) and consistency (homogenized, with fruit pieces, with seeds or seedless). Generally, a jam should have a total concentration of solids of at least 65% that is contributed by 55parts of sugar and 45parts of prepared fruit (Sinha *et al*., 2012). This general rule however, does not apply for those jam products where sugars are entirely or partially replaced (Culetu *et al*., 2013). Such products may have dry solids between 30%-50% (Viktorija *et al*., 2013).

Obtaining the desirable quality parameters of any fruit jam involves a proper balance of the pH based on extracted or added acids, sugar and pectin (Wolf, 2016). These quality parameters are controlled by the different ingredients and their different functionality: the parameters are, (a) pH which should be in the range of 2.9-3.2 using citric acid. This level of acidity is essential for gelation, flavor and shelf life of the product since it deters growth of spoilage microorganisms that cannot survive at such low pH. (b) Water activity is also a significant parameter that ensures long shelf life by preventing microbial growth. The water activity range is between 0.82 and 0.84. (c) Amount of sugar in the jam is an important parameter both for rheological properties of jam and nutritional quality. The amount of sugar will directly affect the firmness of the gel as well as the amount of calories per unit weight of the jam. Spreadability, mouth feel, firmness and cohesiveness are determined by many factors including quality of the raw materials, processing time and temperature and cooling (Culetu *et al*., 2013). Spreadability parameters of interest include; stickiness, hardness, shear and adhesion work (Amos, 2017). Understanding the flow behavior of jam under different processing conditions like temperature provides insight to determining what processing conditions are optimal for obtaining a good product. Rheological behavior models of jam can be developed as affected by temperature, shear rate, composition of fruit jams and type of hydrocolloids, pH and time (Javanmard & Endan, 2010).

Sensory characteristics of jam, that is, appearance, flavor (taste and aroma) and texture can be influenced by processing practice applied apart from the natural sensory attributes of the fruit ingredient. Although it can be difficult to come up with an internationally agreeable sensory quality for all fruit jams, basic parameters can be based on color, sweetness and natural fruit identity. As reported by Koppel *et al*. (2010), sensory properties of 25 commercially available strawberry jams from 11 countries indicated three clusters of jams: (a) sweet, red-colored jams holding a high fruit content (b) jams containing artificial aromas and granular structure and (c) brown-colored jams that were somewhat bitter, sour and astringent. Consumers expect products with sensory characteristics that closely relate to the original ingredients used. Jams in specialty category (low sugar, sugar-free, added fibre, dietetic jams) however, may present a slight difference from conventionally manufactured jams with regard to the expected sensory characteristics (Vilela *et al*., 2015).

2.5 Analytical Techniques Used in Jam Quality Assessment

The main analytical parameter measured in jam is the refractive index. The index reflects the concentration of soluble solids in the final product. This can be done in two ways; (a) using a manual refractometer and (b) using an automated refractometer. In the manual one it is mandatory to read the refractive index using a representative sample of the whole batch at 20°C to avoid fluctuations. In case this is not possible readings should be corrected while taking the temperature into account. Automated refractometer on the other hand is attached to the cooking equipment and the °Brix of the product is monitored continuously until it reaches the recommended reading of 55% (Rosenthal & Narain, 2011). Rheological analysis carried out with Texture Analyzer to determine hardness of the sample (Koppel *et al*., 2011).Other analyses done on jam are proximate for protein, carbohydrates, fats and pH level. Kjeldal is used for proteins, Fehling method is used for carbohydrates and Soxhlet method is used to extract fats and a pH meter is used to determine the pH level. The concentration of sugars and organic acids can be analyzed by High Pressure Liquid Chromatography (HPLC) (Koppel *et al*., 2011).

2.6 Functions of the Various Ingredients.

There are four main ingredients in jam making; fruit, sugar, pectin and acid. Other ingredients however, can be added to enhance taste, texture, nutrients, variety among other reasons. The section below explains in more details the functions of the major ingredients.

2.6.1 Fruits

Traditionally, only few varieties of fruits were used; peach, plums, pineapples, mangoes, strawberries, grapes and oranges. However, in recent studies more fruit varieties and even vegetable jams, marmalades and jellies have been developed to meet consumer demand for diversity and quality products. Whichever the fruit is used, the jam making process follows same basic principles. However, modifications are effected depending on the type of fruit, maturity and the product quality desired. Fruit is the main ingredient of jam and thus the product name corresponds to the type of fruit or mixture of fruits used. Jam can be prepared from fresh fruits (gives best jams), frozen, chilled or cold stored fruits, fruits or fruit pulp preserved by heat, sulfited fruit or pulp and dried fruits. It can be prepared from a single fruit or a mixture of fruits with the first named fruit taking 50% of the total fruit material used (Vibhakara & Bawa, 2012).

2.6.2 Sugar

Sucrose commonly referred as table sugar or refined sugar is the common sweetener used in jam processing and it influences several quality parameters of jams. Apart from the sweetness added to fruits, sucrose adds to the soluble solids content thus affecting the physicochemical characteristics of jam and also retards microbial growth thus increasing the keeping quality. Sugar activates pectin by causing dehydration of the pectin molecules. This facilitates the approach of the polymer chains and enables a cross linkage of the hydrogen bridges that initiates gel formation especially when using high-methoxyl pectin which cannot form gel with less than 55% sugar as a co-solute (Robert *et al*., 2005; Sinha *et al.,* 2012). The amount of sucrose used depends on the concentration of pectin either naturally in the fruit or added.

Low sugar jams are produced with commercial pectin prepared specifically for that purpose. These jams however are susceptible to mold growth. Attempts to replace sucrose with other low calorie sugars like fructose, sorbitol, maltitol and lactitol as well as sweeteners like saccharin and cyclamate have been done with a significant change in rheological profile of the jams. However, with modification of formulations and process, an acceptable product can be obtained (Vilela *et al*., 2015). A study by Albrecht (2010), suggests that a part of the sugar can be replaced with corn syrup or honey but if added in excess it can mask the fruit flavor of the jam.

2.6.3 Pectin

Pectin is one of the fundamental ingredients in jam making. In the food industry pectin is used as gelling and/or thickening agent but in jam it is mostly desirable for gel formation. Pectin can be extracted from citrus fruits and apples but also from other plant materials like sugar beets and sunflower (Einhorn-Stoll *et al*., 2012). Some fruits contain pectin and may not need any addition. However, the ripeness of the fruit will determine how much pectin a fruit contains. Under-ripe fruits contain higher amounts than overripe ones thus it is advisable to mix the two categories when making jam. For fruits with very low pectin levels commercial pectin is added in the specified rates by manufacturers.

To maintain consistency and high product profile it is advisable for jam manufacturers especially on industrial scale to use added pectin rather than depend on native pectin in fruits (Robert *et al*., 2005). This not only guarantees product uniformity and larger yield but also the product has higher nutrient and natural flavor retention because lower temperatures are used to achieve the desired gelation. Use of added pectin also eliminates the need to test jams for proper gelling (USDA, 2015).

Pectin molecules are mainly galacturonic acid backbone with side chain of neutral sugars. The galacturonic acid molecules are partly methoxylated. Pectin is further classified on the degree of methoxylation also known as degree of esterification (DE). Degree of esterification above 50% is referred as high-methoxylated pectin (HMP) whereas below 50% is referred as low-methoxylated pectin (LMP) (Einhorn-Stoll*et al*., 2012). Gelation mechanism of pectins is mainly governed by the degree of esterification. For instance, LMP (less than 50% degree of esterification) gelation, results from non-covalent interactions between galacturonic acid residues of pectin backbone and divalent cations like calcium. Therefore, affinity of pectin chain to calcium ions increases with decrease in the degree of esterification and with increase in polymer concentration. In HMP on the contrary, gelling is based on chain-chain interaction rather than chain-solvent interaction. Hydrophobic and hydrogen bonding exert most influence as opposed to electrostatic interactions. Low water activity is therefore paramount in gel formation in HMP systems thus high sugar amount is used but can also be replaced by other solutes that mimic sugar functions of reducing the water activity (Sharma *et al*., 2006)

2.6.4 Acidulants

Control of pH is critical in proper gel formation especially when using high methoxylpectins. Apart from flavor imparted by acid-sugar balance, the pH may be adjusted to control the rate of gel setting and modify the degree of sugar inversion. For instance, rapid-set pectins with high degree of esterification will gel at slightly higher pH of 3.4 while for slow setting it is 3.1. Different acids can be used in jam processing depending on the desired flavor outcome. Citric acid is preferred for most fruits whereas malic acid is preferred for apples and tartaric acid for grapes. Gelation occurs within a specific range of hydrogen ions concentration, the optimum for jams being pH 3. Beyond pH4 no gelation occurs in the specified soluble solids range (Sinha *et al*., 2012).

2.7 Various Innovations Done Over Time in Attempt to Improve the Quality of Traditional Jams

To meet global demand and keep competitive edge in the modern market for healthy and nutritious food products, food scientists and processors constantly work on innovative varieties of products and processing techniques. The fruit and vegetable jam product segment has undergone extension with regard to:

2.7.1 Variety of fruits and vegetables

Different varieties of fruits and vegetables are used for manufacture of jams apart from the traditionally used fruits; for instance, apples, pawpaw, mango, grapes, muskmelon, pear, sapota, apricot, peach, loquat, guava, plum, black-plum fruit (Vitex doniana), watermelon, kiwi fruit, star fruit, cola pachycarpa fruit, beetroot (*Beta vulgaris*) among others (Umeh & Nwadialu, 2010; Ajenifijah & Aina, 2011; Sinha *et al*., 2012; Darkwa & Boakye, 2016; Perumpuli 2018). Use of fruit blends that confer health benefits has been reported. Olugbenga *et al*. (2018), reported an increase in mineral and vitamins content of a blend of banana, watermelon and pineapple jam as compared to jams in the market which were used as control.

2.7.2 Heating methods

Cooking products for a long time especially due to large batch sizes lead to a decrease in product quality. This is caused by the destruction of important flavors and colors and the production of Maillard compounds (Avasoo & Johansson, 2011). Alternative processing techniques that reduce nutrient loss especially the prolonged high heat used during jam processing are underway. Using vacuum vessels has an effect on reducing boiling temperature to between 65-80°C as compared to 104°C for conventional open pan cooking which enhances flavor retention, prevent sugar condensation and reduce overall energy use in production (Sinha *et al*., 2012).

Application of high pressure in jam preparation has been widely studied in Japan. This technique results in jams of superior color and flavor, high vitamin C retention and significant reduction of microorganisms. Whereas traditional processing techniques involved mixing all ingredients together, modern demands for quality consistence has necessitated addition of some ingredients at different times in the cooking process (Robert *et al*., 2005).

2.7.3 Food-grade waste utilization

Products developed from food grade agro-waste. Souad *et al*. (2012), did a study on preparation of jam from watermelon rind which is a waste produced by many hospitality industries and which has found very little use in a beneficial and environmentally friendly way. These workers reported that jam with 50% water melon rind and 50% sugar scored best in sensory parameters, gelling property, soluble sugar stability and pH stability. They also concluded that the jam could be shelf stable for over three months under ambient room temperature and recommended the commercialization of the product.

2.7.4 Dietetic jams

Such jams have sugar replaced with fructose and other sugar substitute sweeteners (CBI, 2018). Other low sugar jams that have been developed use gelatin as a thickening agent, sweet fruits, apple juice, spices and/or low calorie sweetener are used to impart a sweet flavor. Such jams can also be prepared using modified pectin or gums. One type of modified pectin allows reduction of sugar by one third whereas low-methoxyl pectin requires a source of calcium for gelling (Albrecht, 2010). Sorbitol which is absorbed slowly in the blood stream has been suggested as an alternative to sucrose for use in low calorie and sugar free products for diabetics (Vilela *et al*., 2015).

2.7.5 Sucrose replacement

Alternative sweeteners like saccharin, honey, invert sugar syrup, acidulants, colorants and flavoring agents that enhance the sensory attributes of the jam have been used (Vibhakara & Bawa, 2012). Priya and Prakash (2017), reported the use of fructooligosaccharides (FOS) as a mild sweetener, thickener and a prebiotic. They also reported the use of oligosaccharides to reduce Maillard browning reaction which is common in jam processing.

Another study done by Vilela *et al*. (2015), reported replacement of sucrose with fructose, sorbitol or FOS with a potential reduction in glycemic index, calories and fibre enriched. The study reported a 51%-68% decrease in energy value for FOS and sorbitol formulations while that for fructose produced close results with sucrose jam. Another study found that using sorbitol as a sweetener can replace 100% sugar for production of low sugar mango jam without significant effect on sensory quality but with a decrease in hardness as sorbitol concentration increased (Vilela *et al*., 2015).It is on this basis of sugar replacement that the current study is informed.

2.8 Rheological Properties of Jam

Rheology is the study of deformation and flow of substances. Understanding the rheological properties of a food product is important as a tool of quality control (Basu *et al*., 2007). It helps design processing parameters, handling and storage of a product (Javanmard & Endan, 2010). Rheological properties of a food also contribute to how it is perceived by consumers and it can be used to relate sensory parameters to instrumental measurements (Basu *et al*., 2007). For instance consumers relate Newtonian behavior to sliminess while shear thinning is related as non-slimy mouth-feel (Bourne, 2002).

Fruit or vegetable jam is a multi-component product that exhibit complex rheological properties. Javanmard & Endan (2010), reported rheological behavior of jam as a factor of; temperature, shear rate, composition of fruits, type of hydrocolloids, pH and time. From their study they found that all the mentioned parameters significantly affect the viscosity of jam and general rheological properties. Other factors that affect viscosity of a product are concentration of solute, suspended matter and molecular weight of solute (Bourne, 2002). There is an inverse relationship between temperature and viscosity, whereas for solute concentration a direct non-linear relationship is observed. Molecular weight of solute versus viscosity exhibits a non-linear relationship. Suspended matter however, shows a non-Newtonian behavior and can lead to plastic or dilatant flow. Fruits product like jam, juices and concentrates contain a two phase system (serum and solids) thus most of them exhibit both Newtonian and non-Newtonian behavior due to the suspended particles as well as the presence of hydrocolloids like pectin (Bourne, 2002; Javanmard & Endan, 2010).

There are various methods that can be used to determine the rheological properties of jam. The choice of the method depends on the need that is, the kind of information one wants to obtain for specific product. A rheometer is the common instrument however a viscometer can also be also used to give certain properties of the product. Time dependency of a product for instance can be obtained from a viscometer by simply plotting the change in viscosity as a function of time. The four major time dependency flow behaviors are thixotropic, shear thinning, rheopectic and shear thickening. Other parameters that can be obtained are the gel point and time sensitivity of a product. These are done by plotting the log of viscometer reading as a function of time and torque value as a function on time, respectively (Brookfield laboratory manual).

2.9 Gum Arabic

Gum Arabic (GA) is a plant exudate from Acacia trees. The most common Acacia species that produce gum are *Acacia senegal* and *seyal*. Gum Arabic has been used for centuries in different communities for various applications including; eating as food, medicine, adhesive in arts and in pharmaceuticals and cosmetics in modern day (Ali *et al*., 2008; Mujawamariya *et al*., 2012; Dauqan & Abdullah, 2013; Williams & Phillips, 2016; Musa *et al*., 2018).

2.9.1 Source of Gum Arabic

Gum Arabic is the most ancient and well known of all gum types. The term gum 'Arabic' was coined by European merchants who imported it from Arab ports. There are almost 900 acacia species that are capable of producing gum of different quality and quantity. These trees are located mainly in the tropical regions (Dauqan & Abdullah, 2013). *Acacia senegal* trees are prominent in a broad band stretching across sub-Saharan Africa also called the 'Gum belt'. Other regions are southern Africa and India (Mujawamariya *et al*., 2012)

2.9.2 Properties of Gum Arabic

Gum Arabic is branched chain polysaccharide that is either neutral or slightly acidic. It is found as a mixture of calcium, magnesium and potassium salt of a polysacharidic acid (Ali *et al*., 2008; Dauqan & Abdullah, 2013). Variations in the chemical composition of gum Arabic are mainly influenced by its source (tree variety), age of tree, climatic conditions and soil environment (Dauqan & Abdullah, 2013). Gum Arabic has been given E-Number 414 by JECFA and is defined as a dried exudation obtained from the stems of Acacia *senegal* (L.) Willdenow and *Acacia seyal* Delile (FAO, 1998). Gum Arabic falls in the category of a heterogeneous group of long chain polymers called hydrocolloids. The polymers contain polysaccharides and proteins. Hydrocolloids have a characteristic property of forming viscous dispersions and /or gels when dispersed in water. The presence of numerous hydroxyl (-OH) groups significantly increase their affinity for binding to water molecules (hydrophilic). They also produce dispersion exhibiting properties of a colloid and consequently they are termed as hydrophilic colloids or hydrocolloids (Saha & Bhattacharya, 2010).The hydrophilic property is due to the carbohydrate component of the gum. Gum Arabic also has a protein component which gives it characteristic hydrophobic properties. The hydrophilic polysaccharide portion functions to inhibit flocculation and coalescence of molecules via initiating electrostatic and steric repulsions in food systems, whereas the hydrophobic region functions as an emulsifier by adsorption onto the surface of oil droplets (Musa *et al*.,2018).Hydrocolloids can either be thickeners or gelling agents and are used in

foods to modify the rheology of food system that is viscosity and texture which further imparts a desired sensory property in the food product.
Among the thickening agents to which GA is one of them include; gum tragacanth, gum karaya, xanthan, starch, modified starch, locust bean gum and carboxymethyl cellulose (Saha & Bhattacharya, 2010).Gum Arabic functional properties are closely related to its structure of the protein and carbohydrate components as described above which determines for instance, solubility, viscosity, degree of interaction with oil and water in emulsion and encapsulation ability (Mariana *et al*., 2012). It is so far the most water soluble of the natural gums and their solutions are of considerably low viscosity. It is also odorless, colorless and tasteless thus suitable for use in foods without masking natural taste of other ingredients (Sinha *et al*., 2012).

Despite the many studies done on *Acacia senegal* var. *senegal* gum in various applications only a few studies have been done on variety *kerensis* which is mainly found in Kenya. It is interesting to note that variety *kerensis* has some superior functionality as compared to variety *senegal.* Chikamai *et al*. (1996) proved that the gum from Kenya has a potential to give superior functionality to that of Sudan in terms of emulsification properties because of the higher protein content (2.9%) compared to variety *senegal* (1.9-2.3%). It also gels at lower concentration due to the fact that variety *kerensis* has a higher intrinsic viscosity. Variety *kerensis* gum has a gyration (Rg) radius of 40nm compared to 25nm of variety *senegal* (Mugo, 2012). These properties are attributed to the presence of hydrophilic sugar residues and the hydrophobic protein component in the arabinogalactan protein which contributes to the adsorption into air/water or oil/water interfaces. The gum is also soluble in cold or hot water which gives it low viscosity Newtonian solution properties even at high concentrations (20%-30% w/w basis). Other properties of variety kerensis that have been reported include antioxidant properties which retard water soluble vitamins degradation, encapsulation of flavors and aromatic compounds and appreciable amount of fibre (Mwove *et al.,* 2016).

2.9.3 Application of Gum Arabic

About 80% of GA goes to food industry (Mujawamariya *et al*., 2012). Among the wide range of applications in food industry include using gum as; thickener, stabilizer, adhesive, binding agent and emulsifier in food and beverages. It is also used in non-food industries; textile, pottery, lithography, cosmetics and in pharmaceutical industries (Ali *et al*., 2008; Dauqan &

Abdullah, 2013; Williams & Phillips, 2016). It is also used as an ingredient in different treatments of hemorrhage, stomach ulcers and obesity (Mujawamariya *et al*., 2012; Williams & Phillips, 2016). GA is mainly used in confectionery industry to produce clarity for instance in some gums, it also prevents sucrose crystallization and provides a controlled release of flavor and melting in the mouth. In low calorie candy it is used to substitute for the loss of texture, mouth feel and body which results from sugar reduction or replacement with sweeteners that do not confer the same functionality as sucrose. In toffees and caramels it is used as an emulsifier to retain a uniform distribution of fat in the product. In jellies GA provides a fibrous texture that mimics that of fruits (Dauqan & Abdullah, 2013). The acacia gum fibre level and ability to improve mouth feel and enhance flavor release are guaranteed for 1 year with a pH level down to 2.8 in finished products (Imeson, 2010).

A study by Mujawamariya *et al*. (2012), reported a 5000-15000 tons deficit of gum supply in the market especially in Europe due to the continual increase of applications. Very few studies have been done on the use of acacia gum *Acacia senegal* var. *kerensis* especially in product development. Mwove *et al*. (2016) reported using variety *kerensis* in preparation of extended beef round which scored highest overall preference compared to samples injected with curing brine containing soy protein concentrates. Other products in which variety *kerensis* has been successfully used are low fat yoghurt and ice-cream where the gum was used as a binder and a stabilizer respectively.

2.9.4 Nutritional Properties of Gum Arabic

Gum Arabic is a dietary fibre which is derived from dried exudates of *A. senegal*. It contains high molecular weight heterogeneous polysaccharides. The human digestive system is not able to digest this polymer and thus it travels through the small intestines without any breakdown (Williams & Phillips, 2016). However, it undergoes fermentation induced by microorganism in the colon and consequently broken down into short fatty acids particularly propionic acid that are absorbed in the colon and used energetically in metabolism. Some of the by- products are excreted as gas during respiration. No detectable amount is found in the fecal matter (Ali *et al*., 2008; Dauqan & Abdullah, 2013).

Although the European Food Safety Agency (EFSA) in 2012 ruled that it will not allow any definite health claims to be made about Acacia gum on the grounds of insufficient data (Phillips, 2013), the agency did not either refute the health benefits reported and more studies have been done on the same to substantiate the claims. A recent study for instance by Rasha *et al*. (2017), on metabolic effects of GA (*Acacia senegal*) in patients with Type II Diabetes found that GA improves patients' poor glycemic control by reducing the fasting plasma glucose (FPG) and HbA1c. It also improved lipid profile of the test group whereby Low Density Lipoproteins (LDL-Cholesterol) decreased by 5.95%, total cholesterol by 8.28% and triglycerides by 10.95% from baseline levels. HDL-Cholesterol increased significantly by 19.89%. Body Mass Index (BMI) of the test group also decreased by 2.06% at $P<0.05$ over the three months period of consuming 30g of GA per day. Azzaoui *et al*. (2015), reported use of GA in products which additional fiber is required for instance in nutrition bars, baked products, juices and beverages especially dietetic and low calorie varieties.

2.9.5 Can Sugar Be Replaced With Gum Arabic?

Sugar/ sucrose plays fundamental functional roles in good quality jam production. Apart from imparting sweetness, sugar adds to the texture, bulkiness and control of viscosity (Sinha *et al*., 2012). Replacing sugar with another pectin co-solute would mean modification of conventional procedures including temperatures, time and other ingredients so as to balance the sensory and physical quality of the final product. Previous studies on interaction of pectin with other hydrocolloids including guar gum, locust bean gum, potato maltodextrin, oxidized starch and gum Arabic have demonstrated that there are significant interactions between polysaccharides complexes. Of interest is the complex formed between areas containing Homogalacturonan in the LMP and gum Arabic fibrils. The interactions were likely hydrophobic associations and not ionic which produce gels with differing properties (Sharma *et al*., 2006).

Culetu *et al*. (2013), reported a significant change in the water activity of sugar free plum jam that occurred over the storage period. The total soluble solids were lower than in added sugar jams. These factors affected the physicochemical and microbiological stability of the jam. The jams also required a longer processing time so as to allow extraction of pectin from the fruit matrix since the jam had no added ingredient. However, in case of using gum Arabic as a sugar replacement some of these problems may be controlled. The total solids will be high because there is addition of gum and the water activity will be lower because gum is a good hydrocolloid. Thus, gum Arabic offers an alternative to sugar for the two functions. The fact that little or no sugar is added and the sweetness of the jam is dependent on the natural sugar in the fruits, the concentration of fruits per unit yield could be higher to obtain an acceptable sweetness in the product.

2.10 Microbial Safety of Processed Fruit Products

Processed fruit products exhibit predominance of different microorganisms than those found in fresh or minimally processed fruits. This is due to the wider range of physical and chemical treatments employed to enhance the keeping quality of the products. Among the most dominant microorganisms in such products are the thermal tolerant microbes especially bacterial and fungal spores. Jams have reduced water activity as well as high concentration of solids which is further enhanced by thermal treatment of about 60-82°C that inhibit growth of xerotolerant fungi and bacteria (Sinha *et al*., 2012).

Sulphurous acid is mostly used as a chemical preservative in jams. As reported by Olielo(2014), sulphurous acid in plum jam in the Kenyan market was within the standard Maximum Residue Limit (MRL) of 100ppm with only 19ppm whereas strawberry jam had 337ppm which was much higher than MRL standard. He also found 125cfu/g in the total plate count (TPC) test and 10cfu/g yeast and molds for plum jam which is given 10^6 and 100cfu maximum limit in the Kenyan standards respectively. In strawberry jam he reported 5cfu/g in TPC and 10cfu/g for yeasts and molds which have a maximum limit of 10^6 and 100cfu/g respectively indicating that both products passed for microbial safety.

2.11 Shelf-life of Fruit Jam

Shelf life of a food product is the finite length of time after production and packaging during which the product retains the required level of quality under well-defined storage conditions. The level of quality allows the product to be acceptable for consumption (Nicoli, 2012). Primary shelf life refers to the time within which the product remains acceptable before pack opening whereas secondary shelf life is the time the product's quality level is acceptable after pack opening. Most conventional jams have a shelf life of at least two years in well-defined storage conditions which in most cases is room temperature and away from direct light. Therefore jam is a stable product that has medium to long shelf life. However, most dietetic, low calorie and reduced sucrose jam are semi-perishable and fall under short to medium shelf life (Phimolsiripol & Suppakul, 2016). Several studies have reported a shelf life of several weeks to several months and in most cases under refrigeration temperatures (Mesquita *et al*., 2012; Banas *et al*., 2018; Perumpuli *et al*., 2018; Sutwal *et al*., 2019). Changing formulation of a product may reduce or increase the shelf life of a product due to possible changes in chemical or physical form of the final product (Singh & Cadwallader, 2004). Therefore it is important to have the shelf life of a new product estimated rather than use existing data of similar products in the market or in data bases. In cases where product deterioration rate is very slow an accelerated shelf life testing (ASLT) can be applied (Calligaris *et al*., (2012); Phimolsiripol & Suppakul, 2016). The important effect of temperature on reaction rates has long been recognized. Raising the storage temperature will accelerate many ageing processes and this is the basis of many of the accelerated methods. The most prevalent and widely used model is the Arrhenius relation, derived from thermodynamic laws as well as statistical mechanics principles. The Arrhenius relation, developed theoretically for reversible molecular chemical reactions, has been experimentally shown to hold empirically for a number of more complex chemical, microbiological and physical phenomena (Singh & Cadwallader, 2004). Accelerated shelf life estimation saves time and money by giving a hint and point out the measureable, limiting parameter and the weakness of a products shelf-life on an early stage. This initial data gives information on whether the study should be ended on an early stage or to be continued at full-time length. ASLT involves the use of higher testing temperatures in food quality loss and shelf-life experiments and extrapolation of the results to regular storage conditions through the use of the Arrhenius equation, which cuts down testing time substantially. A reaction of average activation energy (Ea) of 20kcal/mol may be accelerated by 9 to 13 times with a 20 °C increase in the testing temperature, depending on the temperature zone (Singh & Cadwallader, 2004).

2.12 Prospects for Jam Market

Europe is the largest market for jams, marmalades, jellies and purees representing 50% of total world imports. This market is expected to increase as indicated by annual growth rate of 6% in quantity and 8% in value from 2012 through 2016. The value of jams, jellies, purees and marmalades reached 1.22 billion Euros and 613 thousand tonnes in 2016. Growth rate of import from developing countries recorded was higher than from European Union Member States (CBI, 2018). This could be attributed to the different varieties of fruits from developing countries that are not found in Europe thus creating a market for new preferences to consumers. This is an opportunity for developing countries create a competitive market by adding value to their indigenous fruits and create a market niche for their unique brands apart from those already found in the European countries.

The global trend for healthier living is likely to expand the market for fruit products with higher nutritional quality thus calling for improved product quality and diversity and also novel foods. According to a report by Ministry of foreign affairs department in Netherlands (CBI, 2018) the developing countries that export jams, jellies and marmalades are Turkey, Serbia, Mexico, Mali, and India with Mali recording an annual growth of 145%, Mexico 66%

and India 52%. The same report suggests some trends for jams, jellies marmalades and purees that are in demand: Low sugar and low calorie, consumption of super-fruits like berry fruit without added sugar, organic, no preservatives/no additive, gluten free, locally produced among other specifications. Using gum Arabic from *Acacia senegal var. kerensis* to substitute sugar partially or completely can be a viable alternative to come up with a good quality low sugar/calorie fruit jam.

CHAPTER THREE
MATERIALS AND METHODS

3.1 Research Sites

The work was carried out at the Guildford Dairy Institute, Department of Dairy and Food Science and Technology, Egerton University and at the Kenya Forest Research Institute's Laboratory at Karura, Nairobi.

3.2 Materials

Fruits (plums and pineapple) were bought from the wholesale open market in Nakuru. Sugar, cooking pans, wooden spatula, blender, cotton wool, citric acid, knives, food grade containers and jugs were bought in supermarkets in Nakuru. Glass jars were bought from Arichem limited, Kenya, while low methoxyl and high methoxyl pectins were obtained from Promaco ltd (Nairobi, Kenya). Gum Arabic from *Acacia senegal* var. *kerensis* was obtained from KENECT Ltd. (Nairobi, Kenya). Sorbic acid and other chemical reagents and culture media were obtained from Kobian Scientific (Nairobi, Kenya). The fruits were checked for peak ripeness, firm texture and with no wounds or pests.

3.3 Preparation of Jams

The fruits were washed in 5ppm chlorinated water and rinsed with portable running tap water. Pineapples were peeled using knives and then diced into small pieces. A blender was used to blend each of the fruits into a homogenous pulp. Plums were blanched to enable easy peeling, followed by de-seeding and blending. Open pan cooking was used for all treatments whereby the cooking temperature was in the range of 90-105°C. The mixture of fruit pulp and the gum were boiled for an hour while continuously stirring for the first 15 min and at 10min intervals thereafter. The pH was regularly determined and adjusted to around 2.9-3.2 with a Brix of at least 55ºand a maximum of 65°. The range is due to different fruits used that is pineapple and plums which have different pH, and the difference in Brix is due to different levels of GA used.

The first trial batch was concentrated using the open-pan jam processing but substituting 100% (of the allowed maximum of 65%) sugar with 30% gum Arabic for the plum and pineapple jam. The preliminary trials showed that 30% gum Arabic content was the theoretical maximum amount above which, the viscosity of the solution was expected to change sharply from a Newtonian to a non- Newtonian flow behavior. The sugar was decreased gradually while systematically reducing the gum until only two optimal levels for gum (15% and 20%) and sugar(30 and 35%), respectively, were obtained based on preliminary sensory analysis. A control was prepared for the two fruits without addition of gum Arabic and the two levels of sucrose content (30% and 35%).However, for viscosity measurements, the level of gum Arabic was measured from 10% to 20% in order to obtain a good curve and determine the effect of gradual increase of gum Arabic on the viscosity of the jam. The second treatment (for the two fruits) varied in time at which gum Arabic was added. The first addition was done together with fruit pulp, the second one when the total soluble solids reached 45°Brix, while the third was added at 55°Brix together with low-methoxyl pectin, citric acid and sorbic acid (Vanessa *et al.*, 2013). This treatment was only meant for screening and was not considered a factor in sensory analysis. All the treatments were carried out in triplicate. The jams were then filled in clean, sterilized and dry glass jars while hot and covered with sterilized lids. The jars with jam were cooled in water to room temperature. The effectiveness of vacuum sealing was checked by pressing the lids. If the lids popped upon pressing the container was deemed not well sealed. Hence, the filling was repeated after reheating the jam followed by refilling in clean jars. Some of the jam filled glass jars were stored under refrigeration while some at ambient temperature (Darkwa & Boakye, 2016).

3.4 Proximate Analysis

3.4.1 Determination of Moisture Content

Total dry matter was determined using the AOAC Official Method 950.46 (AOAC, 2000). Sand pan technique was used to prevent surface crust formation. Clean dry sand was weighed together with a short glass stirring rod. The sand and the sample were admixed with the stirring rod left in the pan then the samples were oven dried at 105 ºC to a constant weight which took at least 6 hours. The weights of the sand and sample were 20g and 3g respectively, as adopted by Nielsen (2010). Calculation for moisture and total solids content was done as shown in equation 1 and 2 below.

$$\%Moisture\ (wt/wt) = \frac{wtofwaterinsample}{wtofwetsample} \times 100 \quad (1)$$

$$\%Total\ solids\ \left(wt/wt = \frac{wtofdrysample}{wtofwetsample}\right) \times 100 \quad (2)$$

3.4.2 Determination of Ash Content

Ash content was analyzed by gravimetric method using a muffle furnace as described in Method 920.46, (AOAC 2000). Approximately 5g of sample wereweighed into a tared crucible and placed in cool muffle furnace. The furnace was ignited to 550°C for 12hours (or overnight). The furnace was then turned off to cool to below 250°C and the crucibles removed safely with tongs and quickly placed in desiccator. The desiccator was covered until the crucibles were cool enough for weighing. The ash content was calculated as shown in equation 3.

$$\%\ ash(drybasis) = \frac{wtafterashing - tarewtofcrucible}{originalsamplewt \times drymattercoefficient} \times 100 \qquad (3)$$

Where: dry matter coefficient = % solids/100 (Marshal, 2010).

3.4.3 Determination of Crude Protein

Protein analysis was done using Kjeldahl Method 955.04of AOAC (2000) as described by Chang (2010).

Sample preparation and digestion

The sample was mixed into a homogenous consistency and 0.3g accurately weighed and placed in a Kjeldahl flask. Concentrated sulfuric acid (2.8g/800mL) and a catalyst (selenium tablets) were added and digestion initiated till a clear solution was formed. A reagent blank was run parallel with the sample.

Neutralization, distillation and titration

The digest was then diluted with water and neutralized with 0.1N sodium hydroxide. The ammonia formed was distilled into 4% boric acid solution containing 3drops of methylene blue and methylene red indicators. Borate anion was titrated with 0.1N HCl and calculations done as described in equations 4 and 5:

Moles of HCl= Moles of NH_3= Moles of N in the sample

$$\%\mathrm{N} = 0.1N\mathrm{HCL} \times \frac{Correctedacidvolume}{gofsample} \times \frac{14g\mathrm{N}}{mol} \times 100 \qquad (4)$$

Corrected acid volume= (ml std. acid for sample - ml std. acid for blank)

14= atomic weight of nitrogen

Conversion factor of 6.25 was used to obtain percent crude protein since most proteins contain 16% nitrogen.

$$\%\mathrm{N} \times 6.25 = \%\ \mathrm{protein} \qquad (5)$$

3.4.4 Determination of Total Fat Content

Solvent extraction (Soxhlet) method 991.36, of AOAC (2000) was used with modifications as reported by David & Wayne (2010).Approximately 2g of pre-dried sample were weighed into a pre-dried extraction thimble and covered with glass wool. Dry boiling flasks were weighed and 25ml petroleum ether put in them. The boiling flask, Soxhlet flask and condenser were assembled. Extraction of fat was done under reflux at 60°C for about 8 hours using petroleum ether. The boiling flasks with extracted fat were then dried in an air oven at 100ºC for 30 minutes, cooled in a desiccator and weighed (David & Wayne, 2010). Percentage fat content was calculated as shown in equation 6:

$$\%Fat\ content = \frac{weightofflaskafterextraction - weightofflask}{weightofsample} \times 100 \qquad (6)$$

3.4.5 Determination of Crude Fibre

The crude fiber content in the samples was estimated as described in AOAC Official Method 984.04 (AOAC, 2000). Approximately 2 gm of sample was weighed and digested using sulphuric acid followed by sodium hydroxide solution for 30 minutes, and washing for 2 – 3 times after each digestion. Filtration was done through a Whatman filter paper size 40. The residue was then washed with hot water and the contents transferred into a crucible. The crucible and its contents were then dried in an oven at 105 ºC for 3 hours and its weight recorded. The dried sample in a crucible was then ignited in the furnace at 600 ºC for 2 – 3 hours and weighed again. The crude fiber content was determined as shown in equation 7:

$$\%Crude\ fiber = \frac{A-B}{C} \times 100 \qquad (7)$$

Where, A is the weight of crucible + dry residue, B is the weight of crucible + ash and C is the weight of the sample.

3.4.6 Carbohydrate Analysis

Total carbohydrate

Total carbohydrate content was calculated by subtraction of the percentage sums of the weights of moisture, total fat, ash content and crude protein from 100% (Nielsen, 2010).

$$Total\ caborhydrate = 100 - (\%\ Moisture\ content + \%\ Protein + \%\ Fat + \%\ Ash)$$

3.5 Determination of Soluble Solids and pH

Total soluble solids calculated in °Brix was determined using a bench-top refractometer. The refractometer was standardized to zero mark using distilled water. The sample was placed on the sample holder and the refractive index and ºBrix read (Ajenifijah & Aina, 2011). The pH was determined using a bench-top microprocessor pH meter from Hanna instruments. The pH meter was first calibrated using buffers of pH 4.0 and 7.0 before dipping the electrodes in the sample aliquot to take the pH readings (Nielsen, 2010).

3.6 Determination of Vitamin C

The total vitamin C content was determined using 2,4-dinitrophenylhydrazine Spectrophotometric method described by Khan *et al*. (2006) and Al-Ani *et al*., (2007). The method is based on the principal of oxidation of ascorbic acid to dehydroascorbic acid and subsequent transformation of the dehydroascorbic acid to diketogulonic acid. This was followed by coupling with 2,4-dinitrophenylhydrazine to give stable colored osazones with an absorbance of 500-550nm. The absorbance of the color formed was proportional to the quantity of ascorbic acid plus dehydroascorbic acid present in the sample.

Reagents and standards preparation

To prepare 5% metaphosphoric acid-10% acetic acid solution, 15g of solid metaphosphoric acid was dissolved in a mixture of 40ml of glacial acetic acid and 450ml of distilled in a 500ml volumetric flask. The mixture was then filtered and collected. 10% Thiourea solution, 85% sulphuric acid and 2,4-dinitrophenylhydrazine were also prepared. Standard vitamin C solution was prepared by dissolving 0.05g standard crystalline ascorbic acid in a 100ml distilled water to prepare 500ppm standard solution.

Sample preparation

Ten grams of sample was homogenized with 50ml of 5% metaphosphoric acid-10% acetic acid solution. The mixture was then transferred into a 100ml volumetric flask and shaken gently until a homogenous dispersion was obtained. It was then diluted up to the mark by the 5% metaphosphoric acid-10% acetic acid solution. The solution was then filtered and the clear filtrate collected for vitamin C analysis.

Procedure

Few drops of bromine water were added to the filtrate until the solution became colored. A few drops of thiourea were then added to remove the excess bromine and thus a clear solution was obtained. The 2,4-dinitrophenylhydrazine solution was added with all standards and with the oxidized ascorbic acid. The total vitamin C content was then determined by coupling the reaction of 2,4-dinitrophenylhydrazine dye with vitamin C followed by spectrophotometry determination of λ_{max}at 521nm. Absorbance of the standards was taken to construct a calibration curve of the concentration versus the corresponding absorbance. The concentration in parts per million (ppm) were converted to mg/100g as provided by FAO/INFOODS, (2012).

3.7 Rheological Properties

The methods applied in this study were obtained from Brookfield Engineering Labs publication unless otherwise stated. Viscosity of the jam was determined using Brookfield DV-E viscometer whose principle of operation is to rotate a spindle immersed in a fluid through a calibrated spring. The viscous drag of the fluid against the spindle is measured by the spring deflection. LVDV-E model was used and only LV4 (Code 64) spindle was used for all samples. The speeds used varied from 0.5-2.5 RPM for different samples due to the difference in their viscosity. The viscosity measurements were taken in a 400ml container and the guard-leg was used as instructed by the manufacturers. The percentage torque and viscosity (mPas) were taken at 30 seconds intervals for ten minutes at 21 ℃. Three factors were determined in relation to flow behavior over time: First factor was the time at which gum Arabic was incorporated to the jam. That is, at the beginning together with sugar at a 15° Brix, at a Brix of 40° and lastly at a Brix of 55° together with pectin. The second factor was the type of fruit (pineapple and plum) and the third factor was the concentration of gum Arabic in percentage w/w from 10, 15 and 20. Time dependency behavior of the jam was determined vis-a-vis the three factors mentioned above. Graphs of apparent viscosity versus time were plotted to obtain the type of time dependency (Bourne, 2002). To predict the gel point of the jam products, graphs of log viscosity was plotted against time whereas graphs of the percentage torque were plotted to determine time sensitivity of the jam products.

3.8 Microbial Analysis

The Association of Official Analysis Chemists International (AOAC, 2000) methods were used for microbial analysis. The analysis was done in triplicates to evaluate the presence of spoilage and pathogenic microorganisms as well as survival of other microorganisms in the reduced sugar jam. The media was obtained in powder form and prepared as per manufacturer's instructions. Twenty five grams of the sample was added in 225ml peptone water and thoroughly homogenized. Serial dilution followed and inoculation on plates done in three replicates. Total Coliform Count (TCC) was enumerated by pour plating on McConkey agar and incubating for 24 hours at 37^{o}C. Plate Count Agar (PCA) was used to determine the Total viable counts (TVC) by incubating at 37^{o}Cfor 48hours. Yeast and molds determination was done using Potato Dextrose Agar (PDA) supplemented with 0.01% chloramphenicol and incubating for 5-7 days at 25ºC.

3.9 Sensory Evaluation

Sensory parameters were determined using 30 semi-trained panelists and a hedonic scale of 7 points. The parameters evaluated were; taste, color, texture/spreadability, mouth feel and overall acceptability. The rating scale was ranged from like extremely (7), like moderately (6), like slightly (5), neither like nor dislike (4) dislike slightly (3) dislike moderately (2) and dislike extremely (1). Samples of jam were served with white sugarless bread at room temperature. Consent for participation in the sensory evaluation was sought before commencing the exercise.

3.10Shelf-Life Determination

Effect of temperature and time on the pH and microbiological quality of the jam were evaluated. The jam was divided into three lots; one lot was stored in a refrigerator at 4±2 ºC, room temperature 25±2 ºC and elevated temperature of 40±2 °C. This was done with modifications borrowed from Calligaris *et al*., (2012); Phimolsiripol & Suppakul, (2016). Yeasts and molds, and the pH evaluation were done on days 0, 7, 14, 21 and 28 for the three lots using the methods described in the microbial analysis section 3.8.

3.11 Treatment Variables

The first variable was the levels of gum 15% and 20%, second variable was sugar30% and 35% on weight basis. The third variable was the type of fruits used that is, plums and pineapples.

3.12 Statistical Analysis

The experiment employed a factorial experiment with three factors in a completely randomized design.

Statistical model: $Y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha\beta_{ij} + \beta\gamma_{jk} + \alpha\gamma_{ik} + \alpha\beta\gamma_{ijk} + \mathcal{E}_{ijk}$

Where:

Y_{ijk} = the response from, i^{th} level of gum Arabic, j^{th} level of sugar and k^{th}type of fruit

μ = the overall mean responses,

α_i=the effect of i^{th} level of gum Arabic;

β_j = the effect due to the j^{th} level of sugar;

γ_k= the effect due to the k^{th} type of fruit;

$\alpha\beta_{ij}$ = the interaction between the thei^{th} level of gum and j^{th}level of sugar;

$\beta\gamma_{jk}$=the interaction between j^{th} level of sugar and k^{th} type of fruit;

$\alpha\gamma_{ik}$ = the interaction between the i^{th} level of gum Arabic and k^{th} type of fruit;

$\alpha\beta\gamma_{ijk}$ = the combined effect of the three variables *i, j*and k; and

ε_{ijk} = the random error component of the treatments.

The different sample treatments were analyzed using PROCGLM procedure of the statistical analysis system version 9.1.3 (SAS, 2004) to perform analysis of variance and determine the least squares means for each variable. The main effect of the study was the level of gum Arabic at 15% and 20%, level of sugar content 30% and 35%, the different stages at which gum Arabic was added in the pulp and the type of fruit. Significance was established at $p<0.05$ level of significance and means separation was done using Tukey's honestly significance difference (HSD).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Effect of gum Arabic on physicochemical and rheological properties of sugar reduced jam.

The results for the total soluble solids and pH of the jam are discussed in section 4.1.1 below. Time dependency rheological behavior of the various jam products are presented in plots below.

4.1.1 Physicochemical properties

The total ºBrix attained for all the products containing 15% and 20% gum Arabic were range 62 and 65, respectively, which is within the stipulated range of 60-65ºBrix or greater for conventional jam (CAC,2017; KEBS, 2018). However, the control products with no gum had a 45º brix. Various studies have reported most sugar reduced or low sugar jam as having ºBrix in the range of 30-50 (Viktorija *et al*., 2013; Perumpuli *et al*., 2018). Codex Alimentarius standards for sugar reduced is 40-65ºBrix or less (CAC, 2017, KEBS, 2018). Therefore, gum Arabic added the total soluble solids of the jam products. Gum Arabic has been successfully used in various products to substitute for bulk and texture of sugar reduced and fat reduced products like confectioneries and cheese respectively,(Saha & Bhattacharya, 2010; Dauqan & Abdullah, 2013).

The pH for the products was in the range of 2.9-3.3 which was within the range of 2.8-3.3 at which high-methoxy pectin has optimal functionality for gel formation (Berk, 2016). The pH value is given in range because different fruits differ in pH and it is also possible to have different batches of the same fruit differing in pH. Therefore, food grade acids or bases have to be added until the value falls within the stipulated range. This therefore makes it impractical to come up with one figure for the pH because the jam making process is not automated. Gum Arabic solution has a pH of 4.5-5.5 whereas, that of fruit is highly dependent on type of fruit. Therefore, to come up with the standard pH value for jam one has to use either a food grade acid or a base. In this study citric acid was used in pineapple jam to reduce the pH. Adding citric acid to lower the pH in jam did not affect the functional properties of gum Arabic with regard to emulsifying properties and viscosity. This is because gum Arabic is stable in acidic conditions as used in acidic soft drinks and emulsions (Dauqan & Abdullah, 2013).

4.1.2 Rheological properties

Plot of time dependency of the jam products vis-à-vis the stage at which gum Arabic was added during the jam processing is shown in figure 4.1. The flow behaviour as a factor of time at which gum was incorporated is similar for both fruits and thus only plum jam shown in figure 4.1. The stage at which gum Arabic was added during the jam processing was determined by the ºBrix of the pulp plus sugar. V1 denotes a brix of 55º, while V2 and V3 denote brix of 45º and 15º, respectively. V8 is the control product without gum. The flow behaviour of the products show differing rates of shear thinning behaviour as observed with the decrease of viscosity as a function of time. V3 has the lowest viscosity and the curve flattens out rapidly exhibiting Newtonian flow behaviour. Adding gum Arabic at a lower ºBrix of 15º meant cooking the gum for a long time before the desired total solids of above 65º brix was obtained. The proteins in the gum were therefore denatured and the functionality of the gum impaired. Chikamai *et al*. (1996) reported a loss of emulsification ability of gum Arabic as a result of prolonged heating at high temperature. Li *et al*. (2011) also reported that removal of the alabinogalactans proteins from a solution of gum Arabic resulted in Newtonian flow behaviour. The jam also had visible defect whereby the solid phase floated leaving a layer of the serum phase at the bottom. V2 shows a strong shear thinning flow behaviour compared to the others and a substantially higher viscosity as depicted by a larger area under the curve (Bourne, 2002). V2 can also be said to be more time sensitive with regards to shearing as observed by the Brookfield engineering laboratory publication (More Solutions to Sticky Problems). V8 shows a steady shear thinning and a lower viscosity than V2. The curve is also smooth compared to the other three which show some lump-up and lump-down as a result of structural build up and breakdown when shear is applied. The smooth curve is because only one hydrocolloid (pectin) is used and thus no interactions of hydrocolloids which affect the structuring of polysaccharides in food systems.

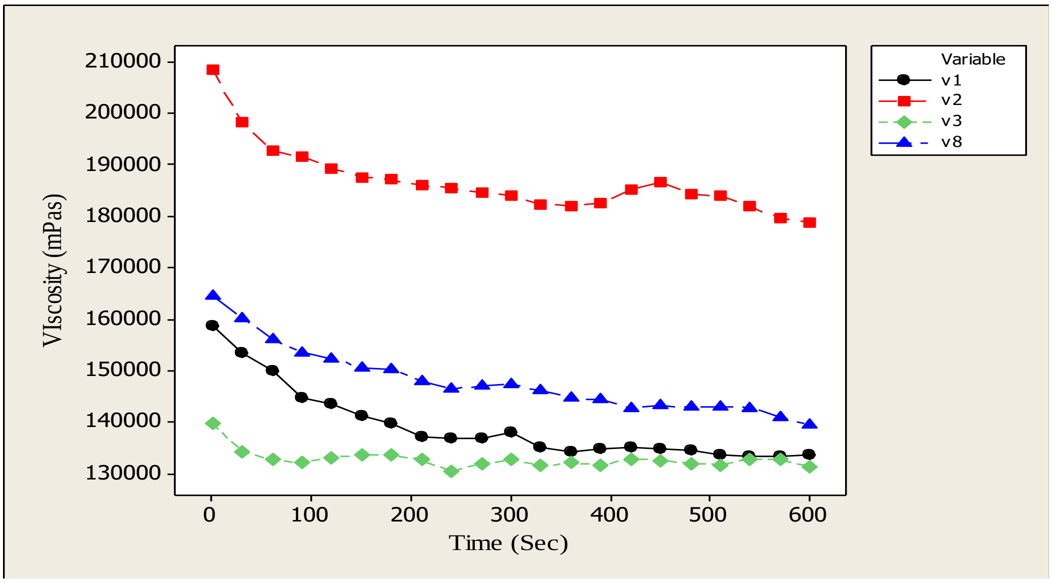

Figure 4.1: Shear thinning of the different jam products as °brix increases from 15° (V3), 40°(V2) to 55°(V1) brix with time. V8 is a control product without GA with 55% sugar

Considering that all other parameters were held constant it is evident that adding gum at different cooking stages had significant effect on the final product. The curve does not plateau either as observed in V1 and V3. Li *et al*. (2011) reported that shear thinning behaviour of gum Arabic originates from the presence of arabinogalactans proteins (AGP) complex and the higher the content the stronger the shear thinning. AGP molecules interact in solution and form intermolecular micelles by hydrophobic interaction of polypeptides. However, upon applying shearing the AGP micelles surrounded by alabinogalactans molecules disassociate into smaller entities that result in shear thinning. These findings by Li *et al*. (2011), could explain why adding gum at a ºBrix of 45 gave a higher viscosity as there was enough time for interaction of molecules to happen and the consequent stronger shear thinning behaviour when stress was applied. The proteins were however not denatured as seen in V3 because the jam product cooked for a considerably shorter time before the desired soluble solids of 65º was attained. Chikamai *et al*. (1996) also reported that protein denaturation in gum Arabic is a factor of processing time and temperature in heat processing. V1 on the other hand has a lower viscosity compared to control and it shows a shear thinning behaviour which plateaus after 5 minutes and moves more to a Newtonian kind of behaviour. Adding gum together with pectin give the ingredients little time to interact and thus the gum did not increase viscosity as much but it should be noted that the viscosity was closer to the control product (V8) thus this product was chosen for further analysis. This observation can also be explained by the fact that only a few amino acids are attached to the peripheral positions whereas majority of proteins are located at deep-seated locations within the complex gum macromolecules as reported by Badreldin & Christina (2016). Therefore, more time would be needed for those proteins to interact and increase viscosity. However, in this study viscosity increase was not considered as a benefit to the product rather the aim was to develop a product as close to the conventional product as possible but with less sugar. V8 which was the control used in viscosity measurement contained 55% sugar and no gum Arabic. This was used as a control to compare what is in the market in terms of viscosity. There are no set standards for viscosity of jam and thus it was deemed necessary to use a conventionally made jam to estimate the viscosity range of the new product.

Effect of gum Arabic concentration on the flow behaviour of plum jam

The plot for time dependency of jam with different concentrations of gum Arabic that is, 10%(V9), 15%(V10) and 20%(V12) is shown in figure 4.2. V8 is the control product without gum. The viscosity for all the products containing gum Arabic was generally higher than the control product. The flow behaviour for all the concentrations is shear thinning. However, it should be noted that though the viscosity is expected to increase as the concentartion of gum increased as suggested by Bourne (2002), different shear rate was used for jam with 20% gum as it could not run at the set standard of 2RPM and therefore a 1.5RPM shear rate was used. According to Bourne (2002) such results are common if one uses the concept of apparent viscosity as used in this study. In this concept a fluid may appear to have different viscosity from another fluid of same viscosity depending on shear rate at which the test is performed.

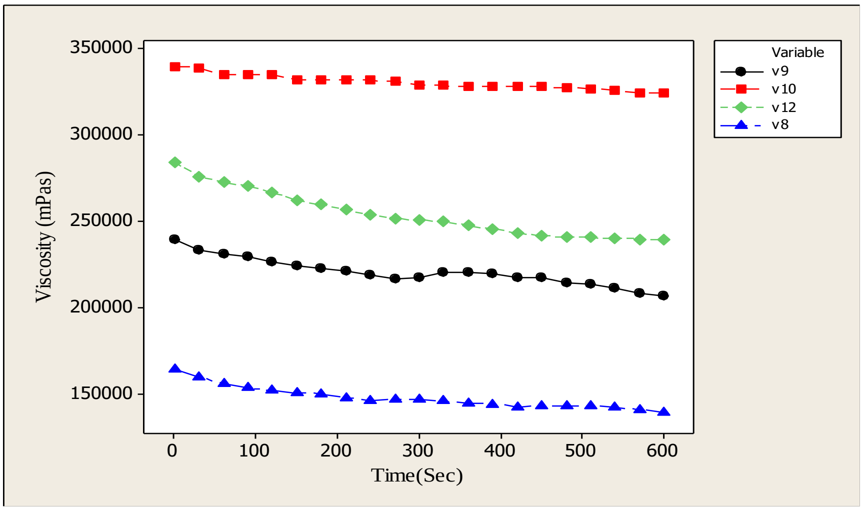

Figure 4.2: Plot of time dependency as a factor of gum Arabic concentration in jam. V9= 10%, V10= 15%, V12= 20%, V8= Control

Effect of fruit type on the flow behaviour of the jam

The viscosity flow behaviour as a function of time for the two fruits (pineapple and plum) is shown in figure 4.3. Pineapple jam had a higher viscosity compared to plum jam. Pineapple jam showed an immediate shear thinning while plum jam showed an immediate rheopectic or shear thickening which was followed by steady shear thinning. Bourne, (2002) described such behaviour as structural viscosity whereby the peak in the curve was as a result of some shear stress needed to start the product flowing before breakdown of some soft structure. Food matrix affects how ingredients interact in a food system and therefore regardless of concentration of one may observe different viscosity measurement for different products. Similar observation was reported by Tatay *et al*. (2016). According to their study tomato juice gave more structured samples characterised by denser matrix compared to apple juice regardless of concentration and type of thickener used. Javanmard & Endan (2010) also reported similar findings when comparing the rheological properties of various fruit jam products. In their study they found that if a jam contained pulp particles it exhibited a different texture and a firmer consistency which also prevented syneresis although the particles did not participate in the gelling system. This would translate to a change in viscosity despite the concentration of the gum being constant.

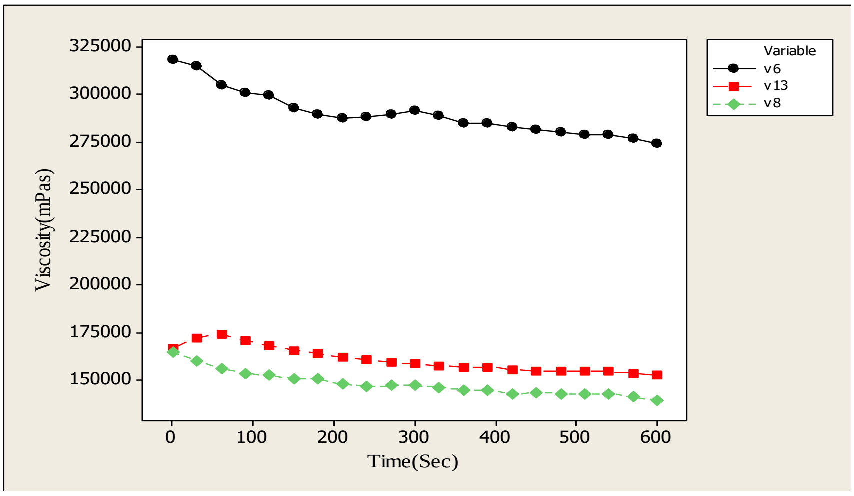

Figure 4.3: Plot of viscosity as function of time for the different fruits used in jam. V6 = Pineapple, V13 = Plum jam, V8 = Control

Plots of log Viscosity versus time for the two factors (stage of adding gum in the process and concentration of gum) are shown in figures 4.4 and 4.5, respectively. From the observation all the curves show a steady and almost linear shear thinning for the various factors. These graphs were plotted to predict if the jam is likely to gel at some point. If a thixotropic or shear thinning curve shows a steep slope gelling is likely to occur at some point but if the line curves and plateaus, gelation is unlikely. A steady state plateau in viscosity indicates equilibrium between structure breakdown and rebuilding in the food sample. The observation for the jam shows the latter behaviour and therefore the products are stable and the spreadability quality is expected to remain constant over storage time. Similar results were reported by Frank (2013), in a study to predict the stability of fruit juice blend. The study reported that a pronounced plateau value towards a low frequency stands for higher elasticity. This indicates a higher degree of internal structure which translated to a more stable juice product in which there would be no settling of particles as a result of too thin concentrates or too thick concentrate that would be hard to mix over time. Gum Arabic is known to have a Newtonian flow up to 30%w/w in solution beyond which the flow behaviour changes to non-Newtonian (Mwove *et al.*, 2016). However, in some food systems this observation is different and the maximum concentration expected to change to a non-Newtonian is lower than 30%. In this study, the maximum concentration obtained was 20%w/w above which the product became adhesive like and unpalatable.

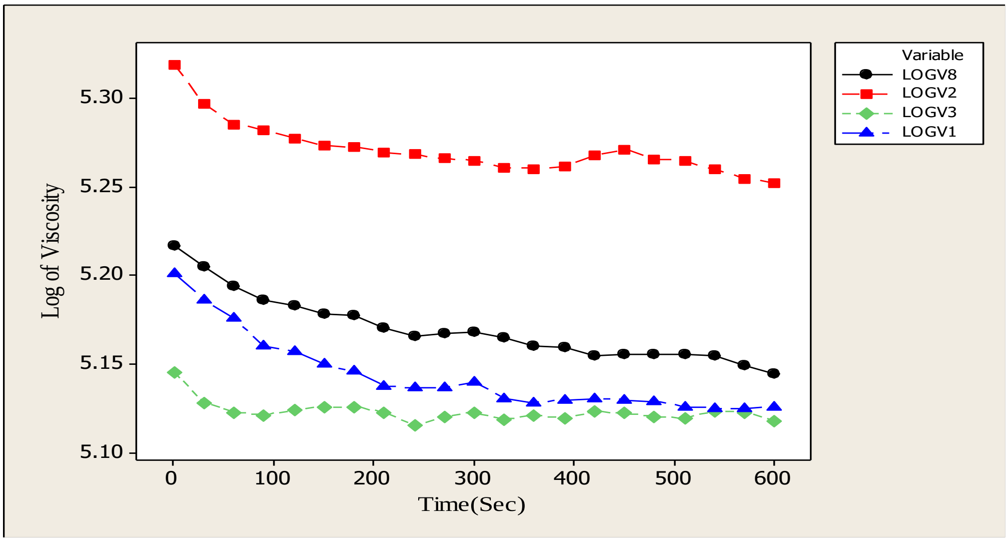

Figure 4. 4: Determination of gel point as a factor of different stages of adding gum Arabic in heating process. LogV3= 15°Brix, LogV2=40°Brix,Log V1= 55°Brix LogV8= Control

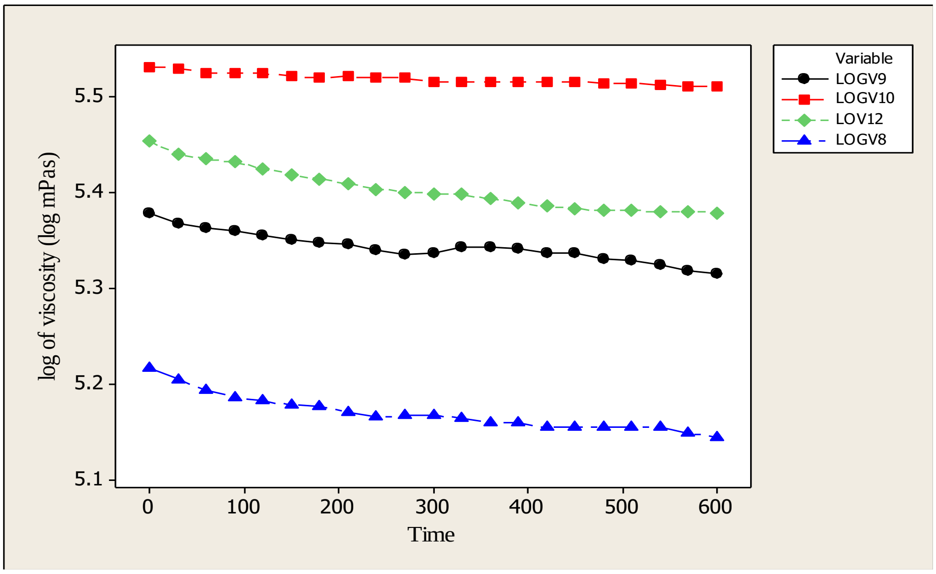

Figure 4.5: Determination of gel point as a factor of gum Arabic concentration in jam: LogV9= 10%, LogV10= 15%, LogV12= 20%, LogV8= Control

4.2 Effect of gum Arabic substitution on proximate composition of sugar reduced jam

The effects of fruit type, sugar levels and gum levels on proximate composition and vitamin C content are shown in table 4.1. Vitamin C is considered a vital micronutrient in fruits and fruit products and thus its inclusion in the analysis was deemed necessary although not considered a component in proximate analysis (Khan *et al.*, 2006). The measurements for all the parameters are given in percentages weight by weight (w/w) except vitamin C whose concentration is in mg/100g of the sample products.

Products with plums as a fruit had higher moisture, fat, fibre, ash and vitamin C content compared to the pineapple products. Different fruits have different nutrient composition and thus such findings are expected. Naeem *et al*. (2017) assessed four different types of jam and reported differences in the respective nutrients. The moisture content was noted to decrease with increase in gum levels. This observation is in line with the high water holding capacity of the gum since it contains hydrophilic sugar residues (Mwove *et al*., 2016). This observation also supports the potential for the gum to be used in reducing water activity.

Table 4.1: Effect of fruit type, sugar levels and gum levels on proximate composition and vitamin C content of the jam

Proximate composition (%)	Fruit type		Sugar levels (%w/w)		Gum levels (%w/w)		
	Pineapple	Plum	30	35	0	15	20
MC	43.99^{b}±0.92	45.09^{a}±0.94	44.60^{a}±0.95	44.48^{a}±0.93	49.44^{a}±0.19	44.07^{b}±0.18	40.12^{c}±0.17
Protein	0.20^{a}±0.01	0.15^{b}±0.00	0.18^{a}±0.01	0.17^{b}±0.01	0.19^{a}±0.01	0.19^{a}±0.01	0.15^{b}±0.00
Fibre	0.45^{b}±0.02	0.51^{a}±0.03	0.49^{a}±0.02	0.48^{a}±0.02	0.47^{b}±0.03	0.57^{a}±0.02	0.40^{c}±0.02
Ash	1.28^{b}±0.12	1.39^{a}±0.12	1.34^{a}±0.12	1.34^{a}±0.12	0.61^{b}±0.02	1.69^{a}±0.01	1.70^{a}±0.03
Fat	0.07^{b}±0.01	0.12^{a}±0.01	0.10^{a}±0.01	0.08^{a}±0.01	0.08^{b}±0.01	0.12^{a}±0.01	0.07^{b}±0.01
CHO	54.46^{a}±0.82	53.36^{b}±0.82	53.91^{a}±0.83	53.91^{a}±0.82	49.67^{c}±0.22	54.33^{b}±0.18	57.73^{a}±0.36
Vit.C	0.74^{b}±0.04	1.61^{a}±0.07	1.20^{a}±0.11	1.14^{b}±0.12	0.92^{c}±0.10	1.40^{a}±0.17	1.20^{b}±0.13

Data are presented as mean ± standard error. Analysis was done in three replicates.

a – c Means within a row with the same superscript letters are not significantly deferent (*P*> 0.05).

The interaction between plums and the two different levels of sugar gave higher proximate composition values compared to the pineapple fruit except for protein and carbohydrate as shown in Table 4.2 below. This observation is due to the differences in the nutrient compositions of the two fruits. Another explanation is the one reported by Capuano *et al*. (2019). These researchers reported that the differences in food matrices are also responsible for apparent variability observed in certain physico-chemical behavior of foods proximate composition. Therefore, food quality depends on how compounds in the food interact via chemical and/or physical reactions. The same argument can be used to explain the higher vitamin C content in plum jam compared to pineapple jam. Burdurlu *et al*. (2006) stored grapefruit, tangerine, lemon and orange juice at three temperatures. These workers reported that the reaction rate constant was higher in lemon than in orange juice at 28 ºC whereas at 45 ºC the opposite was observed. The degradation constant of vitamin C was similar for tangerine and grapefruit and intermediate for those of orange and lemon juice.

Table 4.2: Effect of interaction between different fruits used and different levels of sugar used on proximate composition and vitamin C content of the jam

Fruit	Sugar	Moisture	Protein	Fibre	Ash	Fat	CHO	Vit. C
Pineapple	30	$44.07^{b}\pm1.36$	$0.21^{a}\pm0.02$	$0.46^{b}\pm0.03$	$1.28^{b}\pm0.16$	$0.05^{c}\pm0.18$	$54.40^{a}\pm1.21$	$0.79^{b}\pm0.03$
	35	$43.91^{b}\pm1.32$	$0.20^{b}\pm0.02$	$0.44^{c}\pm0.02$	$1.28^{b}\pm0.18$	$0.08^{b}\pm0.02$	$54.53^{a}\pm1.17$	$0.68^{c}\pm0.03$
Plums	30	$45.14^{a}\pm1.37$	$0.16^{c}\pm0.01$	$0.51^{a}\pm0.04$	$1.39^{a}\pm0.18$	$0.11^{a}\pm0.01$	$53.42^{a}\pm1.20$	$1.61^{a}\pm0.10$
	35	$45.05^{a}\pm1.36$	$0.15^{d}\pm0.00$	$0.52^{a}\pm0.04$	$1.39^{a}\pm0.17$	$0.12^{a}\pm0.03$	$53.30^{a}\pm1.20$	$1.61^{a}\pm0.10$

Data are presented as mean ± standard error. Analysis was done in three replicates.

a – d Means within a column with the same superscript letters are not significantly different ($P > 0.05$).

The effect of interactions between different levels of sugar used and different levels of gum Arabic on proximate composition and vitamin C content are shown in Table 4.3. Products that had 30% sugar and 15% gum had higher protein, fibre and Vitamin C while 30% sugar and 0% gum had the lowest in ash and carbohydrates. However, the products containing no gum had higher moisture content of 49.50±0.3% as would be expected since the gum is a stronger water binder. Vitamin C content was higher for products with gum compared to the control. Gum Arabic and sugar do not have detectable amount of vitamin C and therefore the amount in the product is from the fruits used. However, gum Arabic is a good encapsulation agent especially in heat processing as reported by Saleh *et al*. (2016). These workers reported that gum Arabic was the most efficient in encapsulation of vitamin C compared to whey protein isolate (WPI) or a mixture of gum and WPI. The encapsulation prevented degradation of vitamin C over the storage time of three months at 25 ºC and 37 ºC. Williams & Philips (2016) also demonstrated the protective effect of polysaccharides on thermal sensitive micronutrients. Their work combined thermo-mechanical analysis and UV-visible spectroscopy to investigate the controlled release of thermal sensitive vitamins embedded in high-solids gelled samples and concluded that the diffusion rates of bioactive compound are moderated in accordance with the structural relaxation of the bio-polymeric matrices. This then accounts for the observed higher values of vitamin C in samples containing gum Arabic

Table 4.3: Effect of interactions between different levels of sugar used and different levels of gum Arabic on proximate composition and vitamin C content of the jam

Gum	Sugar	MC	Protein	Fibre	Ash	Fat	CHO	Vit C
0	30	$49.50^{a}\pm0.30$	$0.19^{ab}\pm0.01$	$0.47^{c}\pm0.04$	$0.61^{c}\pm0.03$	$0.08^{c}\pm0.02$	$49.61^{d}\pm0.34$	$0.92^{d}\pm0.15$
	35	$49.39^{a}\pm0.28$	$0.18^{b}\pm0.02$	$0.47^{c}\pm0.05$	$0.62^{c}\pm0.03$	$0.09^{bc}\pm0.02$	$49.74^{cd}\pm0.30$	$0.92^{d}\pm0.15$
15	30	$44.24^{b}\pm0.24$	$0.20^{a}\pm0.03$	$0.58^{a}\pm0.02$	$1.69^{b}\pm0.01$	$0.10^{b}\pm0.02$	$54.08^{c}\pm0.22$	$1.48^{a}\pm0.21$
	35	$43.90^{c}\pm0.28$	$0.19^{ab}\pm0.02$	$0.56^{bc}\pm0.03$	$1.69^{b}\pm0.01$	$0.14^{a}\pm0.00$	$54.08^{c}\pm0.27$	$1.32^{b}\pm0.28$
20	30	$40.08^{d}\pm0.28$	$0.16^{c}\pm0.00$	$0.40^{d}\pm0.03$	$1.70^{a}\pm0.04$	$0.07^{c}\pm0.01$	$57.55^{b}\pm0.69$	$1.19^{e}\pm0.19$
	35	$40.16^{d}\pm0.23$	$0.15^{c}\pm0.01$	$0.40^{d}\pm0.02$	$1.70^{a}\pm0.04$	$0.07^{c}\pm0.01$	$57.92^{a}\pm0.25$	$1.20^{c}\pm0.19$

Data are presented as mean ± standard error. Analysis was done in three replicates.

a – d Means within a column with the same superscript letters are not significantly different ($P > 0.05$).

The effect of interaction between different fruits used and different levels of gum Arabic on proximate composition and vitamin C content are shown in Table 4.4. Interaction between the fruit and the gum level affected the proximate composition significantly. Products with plums and 15% gum had higher fibre, fat and Vitamin C composition. Ash content increased as the level of gum increased for both fruits. Gum Arabic is rich in calcium, magnesium and potassium ions thus the increase in mineral content of the jam products (Williams & Phillips, 2016). Fat content remained fairly low for all products and the results are similar to those reported by Barcelon *et al*. (2015), Naeem *et al*. (2017) and Perumpuli *et al*. (2018). Generally, in terms of all the attributes, pineapple without gum Arabic had least of the components as seen in Table 4.4.

Table 4.4: Effect of interaction between different fruits used and different levels of gum Arabic on proximate composition and vitamin C content of the jam

Fruit	Gum	MC	Protein	Fibre	Ash	Fat	CHO	Vit. C
Pineapple	0	$48.80^{b}\pm0.01$	$0.22^{b}\pm0.00$	$0.37^{e}\pm0.01$	$0.55^{f}\pm0.00$	$0.04^{e}\pm0.00$	$50.39^{d}\pm0.02$	$0.86^{d}\pm0.07$
	15	$43.61^{d}\pm0.25$	$0.25^{a}\pm0.01$	$0.52^{c}\pm0.02$	$1.67^{c}\pm0.01$	$0.09^{c}\pm0.02$	$54.39^{c}\pm0.13$	$0.86^{d}\pm0.07$
	20	$39.57^{e}\pm0.11$	$0.14^{d}\pm0.00$	$0.45^{d}\pm0.00$	$1.62^{d}\pm0.01$	$0.07^{d}\pm0.02$	$58.61^{a}\pm0.06$	$0.77^{e}\pm0.02$
Plums	0	$50.08^{a}\pm0.04$	$0.16^{c}\pm0.00$	$0.57^{b}\pm0.01$	$0.67^{e}\pm0.00$	$0.13^{b}\pm0.00$	$48.95^{e}\pm0.05$	$1.26^{c}\pm0.01$
	15	$44.53^{c}\pm0.01$	$0.14^{d}\pm0.00$	$0.62^{a}\pm0.00$	$1.72^{b}\pm0.00$	$0.14^{a}\pm0.00$	$54.26^{c}\pm.36$	$1.94^{a}\pm0.01$
	20	$40.67^{d}\pm0.06$	$0.16^{c}\pm0.00$	$0.35^{f}\pm0.00$	$1.78^{a}\pm0.00$	$0.07^{d}\pm0.00$	$56.86^{b}\pm0.50$	$1.62^{b}\pm0.01$

Data are presented as mean ± standard error. Analysis was done in three replicates

a – f Means within a column with the same superscript letters are not significantly different ($P > 0.05$).

Three level interactions between the fruit, sugar level and the level of gum Arabic substitution is presented in Table 4.5. The product with plums, 15% gum Arabic and 30% sugar had higher amount of vitamin C. However, vitamin C in the two jam products was low compared to the amount found in the respective fresh fruits. Uckiah *et al.* (2009) reported a significant loss of vitamin C (46.8%) in pineapple jam as a result of processing compared to other products like pineapple juice and pineapple sorbets. Vitamin C is sensitive to water, heat and oxygen. Chemical reactions increase by two to four times for every 10 ºC increase in temperature this explains the faster oxidation of vitamin C considering the high temperature and time used in jam cooking. This was further intensified by the vigorous and continuous stirring of the products to mix ingredients and prevent sticking on the pan. Product with plums, 20% gum 30% and 35% sugar had higher ash content. Moisture content was higher for plum jam with a decreasing trend as the gum increased. Generally, low sugar jam contains higher moisture content compared to conventional jam products. Moisture content can be used as an indirect measure of shelf life of a product. Naeem *et al*. (2017) reported moisture content in the range of 31-33% for four types of Malaysian conventional jam products. The current study recorded moisture content in the range of 39%-50% with the ones without gum Arabic recording highest moisture content. Barcelon *et al*. (2015) reported a moisture content of 46% in a jam formulation containing 2:8 parts of sugar to fruit respectively. Sutwal *et al*. (2019) also recorded significantly high moisture content (76%) for stevia sweetened jam and 33% for the control jam which had sugar in place of stevia. Similar results were also reported by Rafael, *et al.* (2018), in which a low calorie jam had a moisture content of 67%. Therefore, adding gum Arabic gets a product closer to the conventional product. Products without gum had lower fibre and carbohydrate content (Table 4.5). Gum Arabic is a polysaccharide composed of the sugars D-galactose, L- arabinose, L-rhamnose and D-glucoronic acid in the ratio of 3:3:1:1 (Wustenberg, 2015). This explains the reason for an increase in carbohydrate and fibre content in product containing the gum. However, the amount of carbohydrate content is lower than that reported in other high sugar jam products (Naeem *et al*., 2017). Therefore, the jam in this study would give fewer calories per serving as compared to ones in the market.

Table 4.5: Effect of interaction between different fruits used, levels of sugar and levels of gum Arabic on proximate composition and vitamin C content of the jam

Fruit	Gum	Sugar	MC	Protein	Fibre	Ash	Fat	CHO	Vit. C
Pineapple	0	30	$48.83^{c}\pm0.00$	$0.21^{c}\pm0.00$	$0.37^{f}\pm0.01$	$0.55^{f}\pm0.00$	$0.04^{c}\pm0.00$	$50.37^{b}\pm0.01$	$0.59^{g}\pm0.01$
		35	$48.77^{c}\pm0.01$	$0.22^{c}\pm0.01$	$0.36^{f}\pm0.03$	$0.56^{f}\pm0.01$	$0.05^{c}\pm0.00$	$50.4^{h}\pm0.03$	$0.57^{g}\pm0.01$
	15	30	$43.93^{e}\pm0.43$	$0.26^{a}\pm0.01$	$0.55^{c}\pm0.03$	$1.67^{c}\pm0.01$	$0.06^{bc}\pm0.01$	$54.09^{f}\pm0.00$	$1.01^{d}\pm0.01$
		35	$43.28^{f}\pm0.12$	$0.24^{b}\pm0.00$	$0.50^{d}\pm0.01$	$1.66^{c}\pm0.00$	$0.13^{a}\pm0.00$	$54.69^{e}\pm0.02$	$0.70^{f}\pm0.06$
	20	30	$39.45^{i}\pm0.00$	$0.15^{e}\pm0.00$	$0.46^{e}\pm0.00$	$1.63^{d}\pm0.02$	$0.07^{b}\pm0.03$	$58.73^{a}\pm0.02$	$0.77^{e}\pm0.01$
		35	$39.69^{h}\pm0.20$	$0.14^{f}\pm0.00$	$0.45^{e}\pm0.00$	$1.62^{d}\pm0.01$	$0.07^{b}\pm0.03$	$58.48^{a}\pm0.02$	$0.76^{e}\pm0.01$
Plum	0	30	$50.17^{a}\pm0.03$	$0.16^{d}\pm0.00$	$0.57^{b}\pm0.01$	$0.66^{e}\pm0.02$	$0.13^{a}\pm0.00$	$48.84^{j}\pm0.01$	$1.25^{c}\pm0.00$
		35	$50.00^{b}\pm0.00$	$0.15^{e}\pm0.00$	$0.58^{b}\pm0.11$	$0.67^{e}\pm0.03$	$0.13^{a}\pm0.00$	$49.06^{i}\pm0.00$	$1.26^{c}\pm0.01$
	15	30	$44.54^{d}\pm0.00$	$0.14^{f}\pm0.01$	$0.62^{a}\pm0.00$	$1.72^{b}\pm0.01$	$0.14^{a}\pm0.00$	$55.06^{d}\pm0.07$	$1.94^{a}\pm0.00$
		35	$44.52^{d}\pm0.00$	$0.13^{g}\pm0.00$	$0.63^{a}\pm0.01$	$1.73^{b}\pm0.00$	$0.14^{a}\pm0.00$	$53.36^{g}\pm0.99$	$1.62^{b}\pm0.03$
	20	30	$40.70^{g}\pm0.10$	$0.16^{d}\pm0.00$	$0.35^{g}\pm0.01$	$1.78^{a}\pm0.02$	$0.07^{b}\pm0.00$	$56.36^{c}\pm0.99$	$1.61^{b}\pm0.01$
		35	$40.63^{g}\pm0.07$	$0.16^{d}\pm0.00$	$0.36^{g}\pm0.03$	$1.79^{a}\pm0.01$	$0.07^{b}\pm0.00$	$57.36^{b}\pm0.02$	$1.62^{b}\pm0.01$

Data are presented as mean ± standard error. . Analysis was done in triplicate. a – j Means within a column with the same superscript letters are not significantly different at $P > 0.05$

4.2 Effect of gum Arabic on the sensory acceptance of the sugar reduced jam

The means for the sensory attribute versus fruit type, sugar levels and gum levels are presented in Table 4.6. The fruit 2 (plum) had the highest liking compared to the fruit 1 (pineapple) in all parameters except the mouth feel. However, there was no significant difference in the general acceptability of the jam from the two fruits. This observation is similar to that reported by Abdullah & Cheng (2001). These workers reported that despite there being significant difference in various sensory attributes of different fruit formulations containing pineapple, papaya and carambola in varying ratios, the overall acceptability had no significant difference. The results indicate that there was no significant difference in the sensory attribute for the different levels of sugar used. A 5% difference is minimal and thus not noticeable in terms of sweetness but it could have a significant effect on the sugar acid balance that gives an overall acceptable product.

In terms of spreadability and mouth feel, the panel least liked the jam with 20% gum Arabic but the one with 15%GA had no significant difference at $p<0.05$ for the two parameters. Gum Arabic had an effect on mouth feel of the jam as the gum level increased as shown in Table 4.6. This is probably due to the increase in viscosity as concentration of gum increased. Preininger (2006) reported that perceived thickness increases rapidly as the concentration of a polysaccharide in solution goes above their coil overlap concentration. This is the point at which a polymer network is formed as a result of entanglement of the molecule chains. Similar observation was also reported by Soibe *et al*. (2015). Mwove *et al*. (2016) also reported a decrease in expressible moisture in beef extension due to increase in water holding capacity as gum level increased. This observation by Mwove *et al.* (2016) could also explain the difference in mouth feel of the jam as gum level increased. Increase in viscosity/thickness further decreases the flavor and sweetness perception. A study by Hollowood *et al*. (2002) on the effect of hydroxypropyl methylcellulose (HPMC) on flavor perception found that, concentrations below the HPMC coil overlap concentration had no effect on flavor perception. However, above the concentration of coil overlap the flavor and sweetness perception decreased significantly. This could explain why the jam with 20% gum scored lower in taste as well.

Table 4.6: Effects of fruit type, sugar levels and gum levels on sensory attribute of pineapple (1) and plum (2) jam

Sensory Parameter	Fruit Type		Sugar Levels		Gum Levels		
	0	2	30	35	0	15	20
Colour	$5.94^{b}\pm0.09$	**$6.18^{a}\pm0.07$**	$6.10^{a}\pm0.08$	$6.03^{a}\pm0.09$	$6.15^{a}\pm0.11$	$5.91^{a}\pm0.11$	$6.13^{a}\pm0.09$
Spreadability	$5.52^{b}\pm0.11$	$5.93^{a}\pm0.09$	$5.76^{a}\pm0.11$	$5.69^{a}\pm0.09$	$5.93^{a}\pm0.12$	$5.98^{a}\pm0.11$	**$5.27^{b}\pm0.12$**
Taste	$5.77^{b}\pm0.10$	$6.03^{a}\pm0.08$	$5.96^{a}\pm0.09$	$5.84^{a}\pm0.10$	**$6.21^{a}\pm0.11$**	$5.82^{b}\pm$o.11	$5.68^{b}\pm0.12$
Mouth Feel	$5.76^{a}\pm0.09$	$5.68^{a}\pm0.10$	$5.78^{a}\pm0.09$	$5.66^{a}\pm0.09$	$5.96^{a}\pm0.11$	$5.68^{ab}\pm0.12$	**$5.52^{b}\pm0.11$**
Overall acceptability	$5.75^{a}\pm0.10$	$5.93^{a}\pm0.08$	$5.93^{a}\pm0.09$	$5.76^{a}\pm0.09$	$6.15^{a}\pm0.10$	$5.72^{b}\pm0.11$	**$5.66^{b}\pm0.11$**

Data are presented as mean ± standard error.

a - b Means with the same letters across the row for each factor are not significantly different at $P>0.05$

The means of different sensory attributes for interaction between the different fruits used and different levels of gum Arabic are presented in Table 4.7. Interaction between the fruit and the gum level did not affect how the color was scored as compared to control. Fruit 2 (plum) with 20% and the same fruit without gum scored 6.27 whereas fruit 1 (pineapple) scored 6.03 and 6.00 for 0% and 20% gum, respectively. For spreadability, fruit 2 with 0% and 15% and fruit 1(pineapple) with 15% gum Arabic scored higher (5.88 to 6.07). Spreadability is a factor of rheology of the product. This observation is attributed partly by the gum as well as the different matrix of the fruit used and the overlapping effect of the molecules in the system (Saha & Bhattacharya, 2010).

Generally, fruit 2 without gum Arabic scored higher for taste and overall acceptability as shown in Table 4.7. This may due to the fact that the jam without gum Arabic had low brix (45°) and therefore low methoxyl pectin was used as compared to the others in which high esterified pectin was used. This is likely to influence the interaction of the matrix in the system and therefore, affect the sensory quality of the final product (Javanmard & Endan, 2010). However, it should be noted that the jam without gum Arabic had high level of syneresis over time which was not captured during the sensory evaluation because the jam was freshly made.

Table 4.7: Effects of interaction between the different fruits (pineapple (1) and plum (2) and different levels of gum Arabic (15% and 20%) on sensory attributes of the jam

Fruit	Gum Level	Color	Spreadability	Taste	Mouth feel	Overall
1	0	$6.03^{b}\pm0.17$	$5.80^{b}\pm0.19$	$6.17^{ab}\pm0.16$	$6.07^{a}\pm0.13$	$6.05^{ab}\pm0.17$
	15	$5.80^{b}\pm0.16$	$5.88^{ab}\pm0.17$	$5.77^{b}\pm0.17$	$5.85^{ab}\pm0.14$	$5.75^{b}\pm0.16$
	20	$6.00^{b}\pm0.16$	$4.88^{c}\pm0.18$	$5.37^{c}\pm0.19$	$5.35^{c}\pm0.16$	$5.45^{c}\pm0.17$
2	0	$6.27^{a}\pm0.14$	$6.07^{a}\pm0.16$	$6.25^{a}\pm0.14$	$5.85^{ab}\pm0.16$	$6.25^{a}\pm0.12$
	15	$6.02^{b}\pm0.14$	$6.07^{a}\pm0.15$	$5.87^{b}\pm0.13$	$5.52^{bc}\pm0.18$	$5.68^{b}\pm0.14$
	20	$6.27^{a}\pm0.07$	$5.65^{b}\pm0.15$	$5.98^{b}\pm0.15$	$5.68^{b}\pm0.16$	$5.87^{b}\pm0.13$

Data are presented as mean ± standard error.

a – c Means with the same letters within the column are not significantly different at $P>0.05$.

The means of different sensory attributes for interaction between the different fruits used and different levels of sugar used in jam making are presented in Table 4.8. Fruit 2 with 35% sugar level was preferred most in all sensory attributes. This can be explained by the fact that the sharp acidity taste of the plum jam was masked by the addition of sugar and the sugar-acid balance was better achieved. This observation is in agreement with the report by Koppel *et al.* (2011). Fruit 1 with 35% sugar level was scored low in all the sensory attributes. Pineapples are generally sweeter than plums and the 35% sugar felt too sweet for a sugar reduced jam. Similar findings were reported by Masmoudi *et al*. (2010). On the contrary, Alves *et al*. (2008) found that jam consumers prefer sweeter products as opposed to those with lower sweetness. As for general acceptability fruit 1 with 30% sugar, fruit 2 with 30% and 35% sugar were preferred.

Table 4.8: Effects of interaction between pineapple (1) and plum (2) and different levels of sugar (30% and 35%) on sensory attributes of the jam

Fruit	Sugar Level	Color	Spreadability	Taste	Mouth feel	Overall
1	30	$5.98^{b}\pm0.13$	$5.74^{b}\pm0.16$	$5.96^{a}\pm0.14$	$5.93^{a}\pm0.13$	$5.93^{a}\pm0.14$
	35	$5.91^{b}\pm0.14$	$5.30^{c}\pm0.14$	$5.58^{b}\pm0.12$	$5.58^{b}\pm0.12$	$5.57^{b}\pm0.13$
2	30	$6.22^{a}\pm0.09$	$5.77^{b}\pm0.14$	$5.96^{a}\pm0.12$	$5.63^{b}\pm0.13$	$5.92^{a}\pm0.11$
	35	$6.14^{ab}\pm0.10$	$6.09^{a}\pm0.11$	$6.11^{a}\pm0.11$	$5.73^{ab}\pm0.14$	$5.94^{a}\pm0.11$

Data are presented as mean ± standard error.

a –c Means with the same letters within the column are not significantly different at $P>0.05$

Table 4.9 presents the means on the interaction between sugar levels and the gum Arabic levels used. Jam that had 30% sugar and 0% gum and 35% sugar and 20% gum had the best score in terms of color. This may be due to several factors perceived by the panelists. The jam without gum Arabic had a brighter color which could be appealing. This observation is similar to that of Alves *et al*. (2008). This phenomenon can also be explained by the fact that the brighter red color is close to that of commercial jams in which the pulp is generally bleached by preservatives used prior to jam processing and thereafter, food color is added. The added red color is generally brighter than the original color of the plum puree. The jam with 35% sugar and 20% gum Arabic on the other hand had a deeper intensity in color for both fruits due to increased opacity as the total soluble solids increased. This therefore gave an impression of higher fruit content. This observation is in agreement with that reported by Miguel & Belloso (1999) and Koppel *et al*. (2010). Jam with 30% sugar, 0% and 15% gum level were best in terms of spreadability. Those with 30% sugar and 0% gum level scored higher in all attribute hence liked more. As mentioned earlier, jam without gum Arabic had lower total soluble solids, hence the use of low esterified pectin. Robert *et al*. (2005; Guichard *et al*. (2006), reported that the level of esterification has a significant effect on flavor perception. This is as a result of delayed diffusion of flavor from the gel to the taste buds and thus taste perception may be influenced by diffusion as opposed to taste reaction. At constant concentration, high methoxyl pectin reduced flavor intensity compared to low methoxyl pectin. This phenomenon may in part explain the higher score in overall acceptability for jam without gum Arabic as shown in Table 4.9 below.

Table 4.9: Effects of interaction between different levels of sugar used (30% and 35%) and different levels of gum Arabic (15% and 20%) on sensory attributes of the jam

Sugar	Gum Level	Color	Spreadability	Taste	Mouth feel	Overall
30	0	6.27^{a}±0.14	6.23^{a}±0.17	6.37^{a}±0.14	6.18^{a}±0.14	6.42^{a}±0.13
	15	6.00^{b}±0.13	6.02^{ab}±0.16	6.00^{b}±0.12	5.75^{b}±0.15	5.80^{b}±0.13
	20	6.03^{b}±0.15	5.02^{d}±0.18	5.50^{c}±0.18	5.42^{b}±0.17	5.57^{c}±0.18
35	0	6.03^{b}±0.17	5.63^{bc}±0.17	6.05^{b}±0.16	5.73^{b}±0.15	5.88^{b}±0.15
	15	5.82^{b}±0.17	5.93^{b}±0.16	5.63^{c}±0.17	5.62^{b}±0.18	5.63^{bc}±0.17
	20	6.23^{a}±0.10	5.52^{c}±0.16	5.85^{b}±0.16	5.62^{b}±0.15	5.75^{bc}±0.12

Data are presented as mean ± standard error.

a – d Means with the same letters within the column are not significantly different at P >0.05

The means of the different sensory attributes for interaction between fruits, sugar level and levels of gum Arabic used are presented in Table 4.10. The product with fruit 1 (pineapple), 30% sugar and 0% gum Arabic scored higher for general acceptability. Products with fruit 2 (plum), 30% sugar and 15% gum Arabic were scored less in all the attributes but fruit 1 with 30% sugar and 20% gum Arabic was most disliked. Plums have a higher acidity and therefore the tangy taste is more pronounced at lower sugar level. Sugar balances the acidity of jam by masking the tangy taste. Therefore 30% sugar is not feasible in plum jam. Pineapple jam with 20% gum was more viscous and sticky. This made it difficult to spread on bread without tearing the bread and thus the lower score in spreadability.

Table 4.10: Effects of interaction between fruits (pineapple (1) and plums (2)), sugar level (30%and 35%) and levels of gum Arabic (15% and 20%)on sensory attributes of the jam

Fruit	Sugar	Gum Arabic	Color	Spreadability	Taste	Mouth feel	Overall
1	30	0	6.27^{a}±0.19	6.47^{a}±0.22	6.67^{a}±0.12	6.57^{a}±0.12	6.57^{a}±0.16
		15	5.87^{b}±0.19	6.13^{b}±0.20	6.00^{bc}±0.18	6.00^{b}±0.18	5.93^{c}±0.19
		20	5.80^{b}±0.27	4.63^{e}±0.29	5.20^{e}±0.29	5.23^{d}±0.26	5.30^{e}±0.30
	35	0	5.80^{b}±0.27	5.13^{d}±0.24	5.67^{cd}±0.26	5.57^{cd}±0.20	5.53^{d}±0.27
		15	5.73^{b}±0.26	5.63^{c}±0.26	5.53^{d}±0.28	5.70^{cd}±0.22	5.57^{d}±0.26
		20	6.20^{a}±0.18	5.13^{d}±0.22	5.53^{d}±0.23	5.47^{d}±0.20	5.60^{d}±0.15
2	30	0	6.27^{a}±0.20	6.00^{b}±0.25	6.07^{b}±0.23	5.80^{bc}±0.24	6.27^{b}±0.20
		15	6.13^{b}±0.16	5.90^{b}±0.25	6.00^{bc}±0.15	5.50^{d}±0.23	5.67^{d}±0.18
		20	6.27^{a}±0.10	5.40^{c}±0.20	5.80^{c}±0.21	5.60^{cd}±0.22	5.83^{cd}±0.19
	35	0	6.27^{a}±0.20	6.13^{b}±0.19	6.43^{a}±0.16	5.90^{b}±0.22	6.23^{b}±0.12
		15	5.90^{b}±0.22	6.23^{ab}±0.16	5.73^{cd}±0.21	5.53^{d}±0.28	5.70^{d}±0.23
		20	6.27^{a}±0.10	5.90^{b}±0.22	6.17^{b}±0.21	5.77^{c}±0.23	5.90^{cd}±0.19

Data are presented as mean ± standard error.

a – d Means with the same letters within the column are not significantly different at $P>0.05$

4.3. Effect of gum Arabic on shelf-life of the sugar reduced jam

Effect of temperature and time were evaluated on the pH of the jam as well as microbiological quality as shown in Table 4.11. There was no detectable microbial growth on the samples for either fruits neither for the three temperatures (refrigeration, room and elevated temperature) at which the jam was stored for the anticipated period of 28 days. The total soluble solids remained high at ̊Brix of above 60 unlike most sugar reduced or low sugar jam that attain a brix of 30^{o}-40^{o} and therefore prone to microbial growth. The use of sorbic acid as a preservative also enhanced the hurdle effect of keeping the product safe. Sorbates exhibit a wide range of antimicrobial activity especially against yeast and molds which are culprits in sugar reduced jam (Somogyi, 2005). Apart from sensitizing the microbial cells to heat, sorbic acid is effective against viable cell recovery from heat injury (Worobo & Splittstoesser, 2005). Similar findings have been reported by Mesquita *et al.*(2013). Priya & Prakash (2017) found that there was no detectable microbial growth in reduced sugar jelly in which they added fructooloigosacccharide and used sodium benzoate as a preservative.

However, they stored the jelly at a lower temperature 32 ºC for their accelerated shelf-life as compared to 40 ºC in the current study. The two workers detected some growth on the 15th day onwards which was not the case in the current study. Sutwal *et al*. (2019), found an increasing level of total viable count within 28 days of storage although the counts were below the acceptable limit according to their state standards. In Kenya the standards allowed for total plate count is 10^6cfu/g (KEBS, 2018). Their study did not use sugar/sucrose at all and the total soluble solids were very low and thus the short shelf life.

The pH of the products remained within the recommended range of 2.9-3.2 for all fruits and for the different temperature treatment except a 0.01 drop for the one incubated at 40 ºC which was not statistically significant. This is probably due to dissociation of the acids used in the formulation as the activation energy increased with increase in temperature.

Table 4.11. Predicted microbial growth and pH at different storage temperature and time

Parameters	Temp °C	Day 0	Day 7	Day 14	Day 21	Day 28
Y&M	4	Nil	Nil	Nil	Nil	Nil
	20	Nil	Nil	Nil	Nil	Nil
	40	Nil	Nil	Nil	Nil	Nil
TVC	4	Nil	Nil	Nil	Nil	Nil
	20	Nil	Nil	Nil	Nil	Nil
	40	Nil	Nil	Nil	Nil	Nil
TCC	4	Nil	Nil	Nil	Nil	Nil
	20	Nil	Nil	Nil	Nil	Nil
	40	Nil	Nil	Nil	Nil	Nil
Ph	4	3.2^a 3.0^b	3.2^a 3.0^b	3.2^a 3.0^b	3.2^a 3.0^b	3.2^a 3.0^b
	20	3.2^a 3.0^b	3.2^a 3.0^b	3.2^a 3.0^b	3.2^a 3.0^b	3.2^a 3.0^b
	40	3.2^a 3.0^b	3.2^a 3.0^b	3.2^a 3.0^b	3.2^a 3.0^b	3.2^a 2.9^b

Key: ^{a} Plum, ^{b} Pineapple

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

i. It is possible to reduce the amount of sugar in jam by up to 50% or more by substituting for viscosity, bulk and total soluble solid with gum Arabic from *Acacia senegal* variety *kerensis*. The study has shown that adding 15% gum is able to increase the total °Brix to above 60 and thus proven economical in making jam as the total amount of fruit remains 45%w/w which is equal to the amount in most conventional jam.

ii. By reducing the amount of sugar in plum and pineapple jam to 35%w/w and 30%w/w respectively, it is possible to obtain an acceptable jam with regards to sensory quality. Addition of gum Arabic enhanced the quality of the jam especially on spreadability and texture.

iii. Jam containing 15% gum Arabic 30% and 35%w/w sugar content supersedes the anticipated short shelf life of sugar reduced jam and is shelf stable at room temperature. Therefore it does not need refrigeration to prevent mold growth which is common in most low sugar jam. The hurdle effect of hot-filling, packaging in airtight glass jars, addition of preservative (sorbic acid), increase in total soluble solids which consequently reduce moisture content and maintenance of good manufacturing practices contributes to the longer shelf-life observed in the study.

5.2 Recommendations

Industries should explore the use of gum Arabic from *Acacia senegal var. kerensis* as an alternative sugar substitute, bulking agent, water binder among other functional benefits thus offering consumers healthier products

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APPENDICES

Appendix I: Sensory evaluation scorecard sample

Tray number…………………………….

Name/gender ……………………………

In front of you is a coded sample and pieces of bread. Spread the sample on the bread and taste then tick ✓ how much you like or dislike the sample as per the attributes given. You can taste the same sample more than once. Rinse your mouth with the water provided after each test.

Score rating	Description	Color	Texture/ Spreadability	Taste	Mouth-feel	Overall acceptability
7	Like extremely					
6	Like moderately					
5	Like slightly					
4	Neither like nor dislike					
3	Dislike slightly					
2	Dislike moderately					
1	Dislike extremely					

Give any comments about the product…………………………............................

....

Appendix II: Pictorial

Plate0.1 Reduced sugar jam without gum Arabic showing syneresis after three weeks of storage

Plate0.2 Jam containing gum (left) and without gum (right)

Plate0.3 Jam in which gum Arabic was added earlier in the cooking showing floating of solids

Appendix III: Statistical outputs

Table 1: Anova table of mean square errors for the different sources of variation for the different dependent variables of the jam.

S.O.V	D.o.F	MC	Protein	Fibre	Ash	Fat	CHO	Vit. C
Fruit	1	10.88^{***}	0.02^{***}	0.04^{***}	0.11^{***}	0.02^{***}	10.98^{***}	6.81^{***}
Sugar	1	0.13^{ns}	0.00^{*}	0.00^{ns}	0.00^{ns}	0.00^{ns}	0.00^{ns}	0.03^{***}
GA	2	262.77^{***}	0.01^{****}	0.09^{***}	4.71^{***}	0.01^{***}	196.61^{***}	0.69^{***}
Fruit*sugar	1	0.01^{ns}	0.00^{ns}	0.00^{ns}	0.00^{ns}	0.00^{ns}	0.14^{ns}	0.03^{***}
Fruit*GA	2	0.10^{ns}	0.01^{ns}	0.07^{***}	0.01^{***}	0.01^{***}	2.21^{***}	0.12^{***}
Sugar*GA	2	0.13^{ns}	0.00^{ns}	0.00^{ns}	0.00^{ns}	0.00^{ns}	0.61^{ns}	0.02^{***}
Fruit*GA*sugar	2	0.18^{ns}	0.00^{ns}	0.00^{ns}	0.00^{ns}	0.00^{ns}	2.34^{***}	0.02^{***}
Reps	2	0.08^{ns}	0.00^{*}	0.00^{ns}	0.00^{*}	0.00^{ns}	0.20^{ns}	0.00^{ns}
Error	22	0.06^{***}	0.00^{***}	0.00^{***}	0.00^{***}	0.00^{***}	0.25^{***}	0.00^{ns}
R2	**-**	***99.74***	***97.86***	***97.39***	***99.95***	***85.34***	***98.68***	***99.66***
CV	**-**	***0.56***	***4.38***	***4.41***	***1.05***	***2.82***	***0.93***	***3.12***
MSD	**-**	***0.174***	***0.005***	***0.015***	***0.010***	***0.014***	***0.347***	***0.025***

Key: S.O.V = Source of variations in the model, D.o.F = Degree of freedom, R^2 = coefficient of determination, CV = coefficient of variation, MSD = minimum significance difference, ns = not significant, *= p<0.05 and ***=p<0.001

Table 2: Anova table of mean square for the main factor and factorial effect for different dependent variables of the jam.

S.O.V	D.o.F	Colour	Spreadability	Taste	Mouthfeel	Overall
Fruit	1	5.14^{*}	14.80^{***}	6.40^{*}	0.47^{ns}	3.03^{ns}
Sugar	1	0.47^{ns}	0.34^{ns}	1.11^{ns}	1.46^{ns}	2.67^{ns}
GA	2	2.19^{ns}	18.96^{***}	9.16^{***}	5.97^{*}	8.66^{***}
Fruit*sugar	1	0.003^{ns}	13.23^{***}	6.40^{*}	4.67^{ns}	3.40^{ns}
Fruit*GA	2	0.02^{ns}	2.99^{ns}	2.76^{ns}	3.80^{ns}	1.76^{ns}
Sugar*GA	2	1.69^{ns}	9.09^{****}	4.80^{*}	3.17^{ns}	3.85^{*}
Fruit*sugar*GA	2	1.45^{ns}	4.06^{ns}	3.96^{ns}	2.64^{ns}	2.85^{ns}
Reps	29	2.77^{***}	1.79^{ns}	2.00^{ns}	2.76^{ns}	2.74^{***}

Error	319	1.09***	1.53***	1.37***	1.35ns	1.16***
R^2	**-**	***21.68***	***23.51***	***20.59***	***21.47***	***24.89***
CV	**-**	***17.25***	***21.63***	***19.84***	***20.32***	***18.46***
MSD	**-**	***0.22***	***0.26***	***0.24***	***0.24***	***0.22***

Key: S.O.V = Source of variations in the model, D.o.F = Degree of freedom, R^2 = coefficient of determination, CV = coefficient of variation, MSD = minimum significance difference, ns = not significant, *= p<0.05 and ***=p<0.001

Appendix IV: Publication

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Sensory Analysis of Sugar Reduced Jam Containing Gum Arabic from *Acacia senegal* var. *kerensis*

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Abstract

Reducing sugar in jam has an effect on the physico-chemical as well as sensory properties of the jam. To compensate for some of the functional properties lost, other co-solutes may be used. Therefore the objective of this study was to use gum Arabic from *Acacia senegal* var. *kerensis* in formulation of a reduced sugar jam from plums and pineapple fruits. The innovatively prepared jam was subjected to sensory evaluation by a semi-trained panel. Twelve formulations were prepared in factorial arrangement in a completely randomized design. The products were rated using a seven-point hedonic scale for colour, taste, texture/spreadability, mouth feel and general acceptability. Data were analysed using SAS, 2004 (version 9.1.3) to perform analysis of variance and determine the least squares means for each variable. The main effect of the study was the level of gum Arabic at 15% and 20% w/w, level of sugar content at 30 and 35% w/w, and the type of fruit. A control product was prepared for the two sugar levels but without gum Arabic. Significance was established at $p < 0.05$ level, while the means separation was done using Tukey's honestly significance difference (HSD). The results obtained showed that Fruit type significantly affected the color at $p < 0.05$, while gum Arabic and the interactions did not significantly affect the color (at $p < 0.05$). Fruit type, gum Arabic and their interactions with sugar affected the spreadability and it was highly significant at $p < 0.001$ while gum Arabic significantly affected the taste at $p < 0.001$. The best formulation for most attributes was 15% gum for the two fruits, 30% sugar for pineapple and 35% sugar for plum jam. It was therefore possible to reduce the amount of sugar by 50% of the commercially available jam while substituting it with 15% gum Arabic which qualifies the quantity necessary for an ingredient in food formulation. This is the first time that such work of innovatively preparing a jam with a sugar re-

Appendix V: NACOSTI Research Permit

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