QUALITY CHARACTERISTICS OF FRUIT JAMS AND MARMALADES 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 been presented for the award of a degree in Egerton University or any other institution.

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Recommendation

This thesis has been submitted with our approval as university supervisors.

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DEDICATION

With honour, I dedicate this thesis to my daughter, Rita Ajaya, my sisters Dr. Susan Imbahale, Everlyne Savulenze, Nancy Imbahale, Ann Mudora and Lindah Kavulani and my brother Alex Imbahale and their families as well as Mr. Anzeze.

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ABSTRACT

Jams and marmalades are some of the most popular fruit products because of their relatively low cost, all year long availability and appealing sensory properties. These products are described as gels with pectin as the gelling agent used in its formulation. Gels are a form of matter intermediate between a solid and liquid consisting of polymeric molecules cross-linked to form tangles. Under mechanical stress, pectin gels may be damaged leading to the release of colloidal water termed as syneresis. This study was aimed at solving the challenge of syneresis by integrating pectin with gum arabic. Gum arabic from *Acacia senegal* var. *kerensis* was added in the range of 1-5% as an additive in the fruit spreads. Different fruits were used to make the jam (red Plums and Pineapples) and marmalade (Orange and Lemon) with gum Arabic (1%, 2%, 3%, 4% and 5%). Jam and marmalade without any gum Arabic was also prepared as a control in the study. Proximate composition and Microbial analysis were carried out using approved AOAC methods whereas sensory evaluation was carried out using a semi trained panel. Syneresis was measured using centrifugation method. Results for microbial analyses indicated that the products were safe for consumption having no detectable growths for TVC, TCC and yeast and moulds. From the study, gum arabic has no significant effect at $p<0.05$ level of significance on the microbial safety as well as the proximate composition of the formulated jam and marmalade. The attributes analyzed in sensory evaluation included taste, texture, spreadability, aroma, flavour, colour and general acceptability. The jams and orange marmalade with 5% gum arabic inclusion level performed best in terms of the general acceptability. Lemon marmalade was most preferred for general acceptability at 4% level of gum arabic inclusion. Viscosity was analysed on the jam and marmalade with results indicating shear thinning for the formulated products. From this study, gum Arabic which was meant to reduce the level of syneresis played a role on the texture of the product as the concentrations of gum changed. Gum arabic reduced syneresis in the fruit spreads. This is the first report on preparations of jams and marmalades with reduced syneresis due to the utilisation of gum arabic from *Acacia senegal* var. *kerensis*.

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LIST OF ABBREVIATIONS AND ACRONYMS

AOAC	Association of Official Analytical Chemists
FAO	Food and Agriculture Organisation of the United Nations
HM Pectin	High Methoxyl Pectin
JECFA	Joint FAO/WHO Expert Committee on Food Additives
KEBS	Kenya Bureau of Standards
KEFRI	Kenya Forest Research Institute
LM Pectin	Low Methoxyl Pectin
PCA	Plate Count Agar
PDA	Potato Dextrose Agar
TCC	Total Coliform Counts
TVC	Total Viable Count

CHAPTER ONE
INTRODUCTION

1.1 Background Information

Most fruits are seasonal and their shelf life is limited. Thus, fruits must be processed in order to keep the quality (Scibisz & Mitek, 2009) and be available throughout the year. A common fruit preservation process is conversion of the fruits to jams and marmalades. Fruit jams are defined as the product made from whole fruit, pieces of fruit, unconcentrated and/or concentrated fruit pulp or fruit puree which is mixed with foodstuffs with sweetening properties with or without sugar (KEBS, 2018). Jam can be made from one or more kinds of fruits. The fruit marmalades are defined as the product obtained from a single or mixture of citrus fruits and brought to suitable consistency. Marmalade may be made from whole fruit or fruit pieces, which may have all or part of the peel removed, fruit pulp, puree, juice, aqueous extracts and peel and is mixed with foodstuffs such as sweetening agents with or without addition of water (KEBS, 2018).

The most common fruit jams in Kenya include the mixed fruit jam, plum jam, and pineapple jam. The marmalades are prepared from citrus fruits, oranges and lemons. Fruit spreads such as jams and marmalades are some of the most popular fruit products due to their low cost, appealing sensory properties and all year long availability. Processing of fruits includes preservation by methods such as the addition of sugar and boiling to make a jam or marmalade, fermentation to make wine and drying to make dried fruit snacks. Most common fruit spreads are usually produced by cooking fruits with sugar and other ingredients such as pectin, flavourings and colorants (Rababah *et al.,* 2010). The pectin, either commercial or natural acts as a gelling agent to give it body and consistency (Madhav & Pushpalatha, 2002).

The structure of jam is determined by the equilibrium obtained between the sugar, pectin and acid contents in the fruit jams. It is essentially a property of the soluble solids contents. Appropriate total soluble solid substances, acidity and calcium content are all vital for pectin gelation (Javanmard and Endan, 2010; Rababah *et al.,* 2015). Other gelling agents that have been used in the manufacture of jams and fruit fillings include inulin, gellan gum, gelatin, and modified starch. In a study by Cropotova *et al.* (2015), gellan gum (0%, 0.3% and 0.6%), inulin (4%, 6% and 8%) and pectin (0.5%, 0.8% and 1.1%) were used to increase the stability of fruit fillings during freezing. It was observed that the amount of hydrocolloids had a significant influence (p<0.05) on the ability of the fruit filling to hold water both before and after freezing.

It was observed that gellan gum had a great effect on syneresis resistance. This was attributed to the low-acyl gellan gum having a positive effect on water-holding capacity of fruit fillings (Cropotova *et al*., 2015).

The ingredients for the preparation of jam and marmalade must be added carefully. For an ideal jam/marmalade formation, it should be with the composition of 1% pectin, about 65% sugar and adequate acid concentration to yield a pH of between 3.1 and 3.4 (Vibhakara & Bawa, 2012). Pectin if too much will make the spread too hard. Too much sugar will make it too sticky. Addition of lemon juice or other acid ingredients to fruits that are low in acid will be helpful to ensure proper gelling. Sugar largely contributes in flavour promotion and helps preserve the jam and marmalade. If the amount of sugar is reduced, the gel would not form and yeast and mould may grow in the fruit spread. The proportion of sugar and fruit varies according to the type of fruit and its ripeness in order to achieve the required °Brix (Albrecht, 2010).

Good quality jam and marmalade usually has a typical sweet-sour flavour, a bright colour and a pleasing, consistency which is neither an intermediate of solid and liquid. However, jam and marmalade quality is affected by many factors including fruit cultivar, degree of fruit ripeness, its formulation, the processing procedure, the type of jars used and storage conditions (Haffner *et al*., 2003; Rababah *et al.,* 2015). The right amount of acid is crucial for gel formulation. When less acid is present, the gel will not set while too much acid will result in the gel to lose liquid (weeping/syneresis) (Albrecht, 2010). The name and description of syneresis was given by Graham in 1864. He described it as the phenomenon of breaking up of gels on long standing or when disturbed. The jelly product, instead of consisting of one homogeneous load, becomes segregated into solid lumps surrounded by a thin liquid (Cropotova *et al.,* 2015). The disjointing of the liquid phase in fruit fillings is unfavourable and often occurs when the hydrocolloid network is not able to firmly retain water (Cropotova *et al*., 2015). Mechanical disturbances during handling, transportation and shelf life will cause rapture of the gel causing syneresis. Long standing and temperature fluctuations also contribute to syneresis of gel networks (Speiciene *et al*., 2008).

Rheological behaviour of fruit jams and marmalades is influenced by different parameters such as composition, the fruit type, and process technology used (Speiciene *et al.,* 2008). Gels are characterised as a form of matter intermediate between a solid and a liquid. They consist of polymeric molecules cross-linked to form tangles, interconnected molecular network immersed in a liquid medium. The water acts as a solvent, influences the nature and magnitude of the intermolecular forces that maintain the integrity of the polymer network. As a result the polymer network holds the water, preventing it from flowing away in acid medium. Pectin with sugar affects the pectin water equilibrium and resulting in a network of fibres throughout the jelly (Saha & Bhattacharya, 2010).

Gelling agents are used in the food industry in a wide range of products. They have been used in both traditional and novel food products and this use is increasing rapidly with the increase of convenience foods (Saha & Bhattacharya, 2010). An ultimate gelling agent should not interfere with the odour, flavour, or taste of the product to which it is added (Saha & Bhattacharya, 2010). It is important to know the optimum conditions for the onset of gelation in technological processes involving gelling food products. Physically, the vital stage of gelation may be monitored from the loss of fluidity in the food product or from the rise of the elastic property of the growing network.

Pectin is among the earliest hydrocolloid used in jam processing to increase its stability. Under mechanical stress, the pectin gel network may be broken leading to the release of colloidal water (Cropotova *et al*., 2015). This challenge can be solved by integrating pectin with other stabilizers that have thickening properties like gum Arabic from *Acacia senegal* var. *kerensis.* A study by Mwove *et al.* (2016) reported a strong water binding ability of the gum Arabic from *Acacia senegal var. kerensis* when used in cured beef. Various hydrocolloids of interest in the food industry can be blended to provide a wide range of novel functional properties (Cropotova *et al.,* 2015).

Gum Arabic is a branched-chain, complex polysaccharide, either neutral or slightly acidic, found as mixed calcium, magnesium and potassium salt of a polysaccharidic acid. Gum Arabic is highly soluble in water compared to other natural gums and their solutions are of relatively low viscosity (Al-Assaf *et al*., 2007). Other advantages of gum Arabic are its absence of odour, colour, and after-taste. Gum from *Acacia senegal* var. *kerensis* has been used in extended beef rounds as a water binder (Mwove *et al.,* 2016). In the study, the level of gum arabic from *Acacia senegal* var. *kerensis* used in curing brines significantly ($P < 0.05$) affected the processing characteristics of cooked extended beef rounds. The cook yield significantly ($P < 0.05$) increased with increase in gum arabic level. Gum arabic from *Acacia senegal* var. *kerensis* has also been used to improve the functional qualities of goat milk mozzarella cheese (Kiiru *et al.,* 2018). The gum added to mozzarella cheese had no significant effect ($P < 0.05$) on the meltability of cheese. However, the samples that contained 4% gum arabic had the highest meltability value. From the same study, there was a significant increase (P <0.05) in stretchability with gum arabic level increase upto 3% (Kiiru *et al*., 2018). Gum arabic from *Acacia senegal* var. *kerensis* has been used as a stabilizer in low fat yoghurt at 0.6% to reduce syneresis in low fat yoghurt (Mugo *et al*., 2012). The gum has also been used in enhancing the baking properties of wheat-plantain composite flour to make a softer and springier bread (Soibe *et al.,* 2015). In these study, gum arabic had a significant effect (P < 0.05) at all levels of plantain incorporation for water holding capacity, the foaming capacity as well as the bulk density. However, little or no studies have been done on the use of gum from *Acacia senegal* var. *kerensis* as a water binding agent in jam and marmalades to prevent syneresis.

Fruit jams and marmalades are preserves processed from different types fruits through concentration to enhance their availability throughout the year. The fruit spreads are a good source of various energy, dietary fibre and vitamins. Non-gelling agents such as gum Arabic and gelling agents such as pectin can be used in combination to achieve increased viscosity or superior qualities of food gels, thereby increasing the overall product quality and stability. The blending of different polysaccharides offers an alternative route to the development of novel textures. The major interest of this study was to reduce the level of syneresis in fruit jam and marmalade by using gum arabic from *Acacia senegal* var. *kerensis*. There is limited information on the utilization of gum Arabic as a water binding agent in fruit jams and marmalades. Therefore, the objective of this study was to develop quality fruit jams by using gum Arabic from *Acacia senegal* var. *kerensis* as a water binding agent and to study the physico-chemical, and consumer acceptability of the fruit jams incorporated with various levels of gum Arabic.

1.2 Statement of the Problem

Syneresis may be caused by several factors although the primary one is the failure of water binding agent. Pectin is the most used water binder and gelling agent in fruit jams and marmalades. Therefore, there was need of exploiting other alternatives of reducing syneresis in fruit jams by using alternative water binding agents. One of such alternatives was to utilize gum Arabic obtained from *Acacia senegal* var. *kerensis* as a water binding agent to prevent syneresis in fruit jams as well as marmalades. Gum Arabic from *Acacia senegal* var. *kerensis* is locally available in Kenya. Gum Arabic has been used as a water binding agent, thickener, emulsifier in food industry and as a filler material in (textile, cosmetic) and pharmaceutical products. Limited information exists about the utilization gum arabic from *Acacia senegal* var. *kerensis* in fruit jams and marmalades.

1.3 Objectives

1.3.1 General Objective

The general objective of this study was to contribute to food security via preparation of quality fruit jams and marmalades with reduced syneresis containing gum arabic from *Acacia senegal* var. *kerensis.*

1.3.2 Specific Objectives

i. To determine the level of syneresis of the fruit jams and marmalades containing gum Arabic from *Acacia senegal* var. *kerensis*.
ii. To evaluate the microbial quality of the jams and marmalades containing added gum Arabic from *Acacia senegal* var. *kerensis*.
iii. To evaluate the consumer acceptability of the jams and marmalades prepared using gum Arabic from *Acacia senegal* var. *kerensis*.

1.4 Hypotheses

i. Gum Arabic from *Acacia senegal* var. *kerensis* has no significant effect on the level of syneresis in fruit jams and marmalades.
ii. Gum arabic from *Acacia senegal* var. *kerensis* has no significant effect on the microbiological quality of fruit jams and marmalades.
iii. Gum Arabic from *Acacia senegal* var. *kerensis* has no significant effect on the consumer acceptability of fruit jams and marmalades.

1.5 Justification of the Study

This study was justified on the need to reduce syneresis in jams and marmalades which will contribute to food security by availing quality fruit products attracting more consumers. Gum Arabic is used as a food additive owing to its functional qualities. There is limited information on use of gum Arabic from *Acacia senegal* var. *kerensis* in the fruit processing industry. The use of gum Arabic in food processing will impact positively on the socio-economic stability of Kenyan dryland communities and improve fruit processing in Kenya. This will be through the increased demand for gum from *Acacia senegal* var. *kerensis* which will result in afforestation as well as increased earnings for the communities in the Kenyan dry lands. This innovative development of consumer driven products that meet specific quantifiable consumer needs will play a vital role towards achieving part of the social economic pillar of the Kenya's vision 2030 that recognize the critical role played by value addition on the socio-economic advancement of the society.

CHAPTER TWO
LITERATURE REVIEW

2.1 Processing of Fruits

Fruits are important foods with excellent taste, nutritional and functional properties. Several types of fruits have been utilized in the production of value-added food products such as jams and marmalades. Fruit jams and marmalades are produced by the preservation of fruits through heating and are canned or sealed to extend their shelf lives. Jams and marmalades are considered as preserves (Albrecht, 2010). Fruits are now considered as an important item of trade as they have gained an extremely large market potential. Post-harvest losses of fruits and vegetables are more serious in not only developing countries but also those in well-developed countries. About 10-15% of fresh fruits and vegetables wrinkle and stale, lowering their market value and consumer acceptability. Minimizing these losses can increase the supply of fruits and vegetables. Fruits are in general accepted as being rich in vitamins, minerals and dietary fibre and therefore are fundamental ingredients of a healthy diet (Rababah *et al*., 2015).

Tropical fruits contain excellent colour as well as flavour. The development of products with high proportions of fruit in their formulations will provide good functional and nutritional properties to the product as well as contribute to the diversification of the market possibilities. This is the case if they are attractive, practical and have a long shelf life (Martin-Esparza *et al*., 2011; Viana *et al.,* 2014). Processing of fruits is the best way of exploiting the surplus production of fruits during seasonal gluts. Processing helps in transforming perishable fruits into durable form. Processing helps in reducing food losses through increasing value addition of fruits. Processing of fruits into products can be accomplished by preservation using heat treatment, aseptic packaging and preservation of fruits by removal of heat, quick freezing, and preservation by removal of moisture, addition of safe chemicals and minimal processing. Processing of fruits can be done to make a variety of products such as jellies, jams, marmalades, fruit preserves which can be consumed as snacks, fruit juices, smoothies, fruit wine and fruit salads (Vibhakara & Bawa, 2012).

2.2. Jam and Marmalade

Jams, marmalades, jellies and preserves are food products with many textures, flavours and colours. They all consist of fruits preserved mainly by addition of sugar and they are thickened or jellied to a suitable consistency. Fruit jellies are unique semi-solid mixture of fruit juice and sugar that are clear and firm enough to hold their shape. Jam is a product of intermediate moisture that is prepared using the pulp of fruits, sugar, pectin, acid and other ingredients that are brought to boiling to allow the conservation of such products for long periods of time. This kind of processing allows the association of fruits and to create new flavours (Viana *et al.,* 2014). Jams were first produced as an effort to preserve fruit for consumption during off-season. Jam and marmalade can be defined as a product with a total soluble solid content of 45^{o} Brix and consists of at least 40% fruit content (Mohd *et al.,* 2015). Jams will hold their shape, but are less firm than jellies. Jams and marmalades are made from crushed or chopped fruits, pectin as a gelling agent and sugar. Preserves are made of small, whole fruits or uniform size pieces of fruits in clear, thick, slightly jellied syrup. Marmalades are described as soft fruit gels with small pieces of fruit or citrus peel evenly suspended in a transparent jelly (Mohd *et al*., 2015). For successful jams, jellies and other fruit products, a proper ration of fruit, pectin, acid and sugar is essential (Vibhakara & Bawa , 2012).

According to Kenya Bureau of Standards, Jam is the product brought to a suitable consistency, made from the whole fruit, pieces of fruit, the 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 (KEBS, 2018). Citrus marmalade is the product obtained from a single or a mixture of citrus fruits and brought to a suitable consistency. Marmalade may be made from one or more of the following ingredients: whole fruit or fruit pieces, which may have all or part of the peel removed, fruit pulp, puree, juice, aqueous extracts and peel and is mixed with foodstuffs with sweetening properties with or without addition of water (KEBS, 2018).

2.3 Jam and Marmalade Preparation

Jam is made by boiling fruit with an adequate amount of sugar to a fairly thick texture which helps to hold the fruit tissues in place by making the texture firm enough. Jam can be prepared from one kind of fruit or two or from more kinds of fruits to make mixed jams. Mixed fruit jams associate the characteristics of two or more fruits. This allows the achievement of a product with higher nutritional value and congenial sensory properties and thereby adding value and creating the possibility of conquering a greater space in the consumer market (Viana *et al*., 2014). Ripe fruits are selected for jam making which provide desirable flavour and colour to the final product.

Pre-treatments like washing, peeling and pulping are performed after which sugar addition is done having some ratio as fruit pulp. In jams and marmalades manufacturing, the sugar and fruits are mixed in almost similar proportions. The resultant product is then cooked to produce a delicious gel substance that possesses adequate storage capabilities (Vibhakara & Bawa, 2012).

2.4 Methods used in Manufacture of Jam and Marmalade

Using extreme thermal treatment, the mix is concentrated to gain the necessary ultimate total solid content (Igual *et al.,* 2013). The disadvantage to this process is that it imparts unsavory flavour, colour and nutritional values to the product. This is ascribed to the extreme heat developed and lengthy period of processing (Mohd *et al*., 2015). There is a method that uses microwave energy that provides a swift heating procedure compared to the conventional heating methods. Generally, by using other methods other than the conventional means, processing time can be reduced and that may contribute to a better and more appealing product (Igual *et al*., 2013; Mohd *et al*., 2015). Application of heat during the making of jams is done for the following reasons; to attain sugar equilization (even distribution of the soluble ingredients between the surrounding gel and the individual fruit pieces). Heating preserves the product by deactivating enzymes and killing yeasts and moulds present in the raw material. Heating concentrates the product by evaporation of water and de-aerates the product leading to a superior appearance (no air bubbles, deeper colour). Heating achieves improved chemical stability through decreased oxidation of flavour and colour components. It is important to control processing and holding times at higher temperatures carefully to avoid the unwanted effects such as loss of flavour and colour, sucrose inversion and browning reactions (Suutarinen, 2002).

2.5 Quality Parameters for Jam and Marmalade

High quality fruit is always recommended for jam and marmalade preparation. It is impossible to make a high quality jam or jelly from fruits of lower quality. Improper handling of fruits may lead to quality defects in the jam. Manufacturers desire jam to hold as much flavour and colour as possible. The aroma of the jam is strongly subject to the aroma of the fruit. Processed products such as jams tend to have lower nutritional values as compared to fresh fruits. A good example is on vitamin C content; jams usually have lower vitamin C content compared to the fresh fruits because of exposure to the heat generated during processing (Jawaheer *et al*., 2003).

High contents of soluble solids and ascorbic acid are attributed to undesirable flavour attributes of jams. High levels of ascorbic acid have an adverse effect on colour stability. Colour degradation in jams is correlated to flavour deterioration. Food properties of jam such as colour, acidity, total soluble solids, texture, total phenolics, antioxidant activity and anthocyanins can be influenced during storage (Rababah *et al.,* 2011). Anthocyanins are a group of phenolics that are responsible for the colour of many vegetables, fruits and flowers such as orange, red and blue. The stability of anthocyanin depends on various factors such as pH value, presence of oxygen, enzyme activity, temperature, sugar and ascorbic acid contents. The equilibrium obtained between the pectin, sugar, and acid contents affects the strudture of jams and is essentially a property of the soluble solids contents.

Jam firmness develops through combination of hydrogen bonds and the hydrophobic interactions which are liable for the gel formation of high methoxy (HM) pectin. Fruits that have fiber content or are high in pectin need less pectin in their jam formulation. The formulation of jam varies due to the composition of the matrix ingredients which have an impact on the rheology of the jam produced. Any small alterations in the jam matrix, such as replacing part of the sugar with other sweeteners or using different pectins, can alter the food matrix constituents. As a result of changes in the interactions, jam quality will be dramatically affected (Javanmard & Endan, 2010).

Syneresis in jams and marmalades is described as the phenomenon where liquid is expelled from the gels. Syneresis marks the upper limit of the liquid holding capacity of foods and is an indicator of quality as it affects consumer acceptability. Syneresis can be caused by an imbalance in the ratio of sugar, acid and pectin or external factors such as external pressure (Cropotova *et al*., 2015). External pressure further increases the pressure to counteract the effect of the osmotic pressure triggering the release of visible liquid from the gel known as syneresis. Water vapour absorption is also an external factor that may trigger syneresis. Water vapours may be absorbed from the surrounding into a gel that eventually swelled to the point of producing an excessive internal pressure that induced syneresis. Mechanical disturbance of the gel also causes syneresis in gels. Mechanical disturbance involves external pressure, breaking and cutting open the gel structure to expose and facilitate the release of entrapped liquid (Speiciene *et al*., 2008). Temperature is also a major factor that may cause syneresis in gels. Temperature affects polymer ad particlees association, disassociation and configuration by changing the magnitude of hydrogen bonding and hydrophobic interaction. Temperature affects osmotic pressure, the network presure and the structure of the gel (Mizrahi, 2010).

It is recommended that the preparation of jam and marmalade be done following hygienic and good manufacturing practices such as the use of clean sterilised cans, clean surfaces and equipment and avoiding cross contamination (Vibhakara & Bawa, 2012). Microorganisms in a food material vary mainly with the water activity, oxygen tension, temperature, and pH value. Processed food products of thermal processing is normally at a water activity of no lower than 0.85, in a low oxygen environment, and under room temperature storage. The pH of food is the most critical factor in the selection of target microorganisms in food processing point of view. Foods may be categorised in three categories based on the pH value i.e. High-acid foods of pH< 3.7, acid or medium acid foods of pH between 3.7 and 4.5 and low acid foods with pH above 4.5. Low acid foods are sterilised under the most severe conditions. This is followed by the acid foods and high acid foods are the least severly treated. Jam and marmalades are some of the fruit products that are canned and are acid or high acid foods with a pH value below 4.5 (Vibhakara & Bawa, 2012).

The Kenya Bureau of standards set at a maximum growth of microrganisms of 50 cfu/g of total plate count. Standards for Enterobacteria in fruit spreads are set at Nil. The microorganisms under thus class include *Escherichia coli, Shigella, Vibrio cholera* as well as *Staphylococcus aureas* (KEBS, 2018). Enterobacteria bacteria are used as indicator organisms for hygiene during handling and preparation of food. *Clostridium botulinum* is the original target microorganism in thermal processing of low acid foods. *Clostridium botulinum* is a heat resistant, spore forming, highly toxic, anaerobic bacterium. The microorganism is used as an indicator microorganism in the sterilization of low acid foods (Vibhakara & Bawa, 2012).

Hot filling and exhaustion is a technique used during jam packaging to help minimise contamination of the jam and marmalade by microorganisms. Jams and marmalades are susceptible to moulds growth due to the high sugar concentration as well as low pH. Prior to the preparation of these fruit spreads, the fruits should be free from pesticide residues and heavy metal contaminants (KEBS, 2018).

2.6 Ingredients used in the preparation of fruit jams and marmalades.

2.6.1 Sucrose

Generally, sugar takes up more than 40% of the total weight and 80% of total solids in a jam. The sugar has a number of functions in the jam other than its sweetening effect. Sugar contributes to the total soluble solids, an effect which is essential for the physical, chemical and microbiological stability of the jam. Sugar provides body and mouth-feel to the fruit spreads. Sugar improves appearance (colour and shine) and permits gelation of HM-pectin possible. The added sugar acts as a dehydrating agent for the pectin molecules, facilitating closer contact between the chain molecules. The sucrose binds with the available moisture making it unavailable for microbial activity. This will reduce the water activity of the jam increasing its shelf life through microbial safety. Replacing sucrose with other sugars has an influence on the gelling properties of pectin and the texture of gels (Suutarinen, 2002). This is because of the different water activities of the other sweeteners at similar soluble solids contents. This could also be due to substance specific differences in the stabilizing effect generated by the hydrophobic interaction (Suutarinen, 2002). The amount of sugar required to obtain a gel with the desired firmness will depend on the type of pectin used and the pH of the mixture. Over 50% of sugar is needed to facilitate gel formation of HM-pectin. Higher sugar content tends to reduce spoilage by reducing the water activity to approximately 0.8 and to increase fruit jam stability in transit. On the other hand, too much amount of sugar will flocculate pectin from the solution thereby preventing proper gel setting leading to weeping of the jams. At above 67% sugar content, the rate of osmotic dehydration does not increase significantly (Speiciene *et al*., 2008).

2.6.2 Acids

Acid is added to jam for two main reasons; reduce the pH to a value giving suitable gel formation and increase of total acidity in order to enhance the fruit flavour. The acids are usually added in form of a solution in water. Acid usually added to the batch as late as possible after the boiling temperature has been reached but just before the filling process. The acid works by suppressing the dissociation of the free carboxyl groups and as a result, the presence of negatively charged pectin molecules. The acid also permits the formation of hydrogen bond bridges between undissociated carboxyl groups. Without buffering, some variation in flavour and the intensity of flavour might be expected. This is because the acid will migrate from the fruit pieces to the medium. Preservatives are active in their undissociated form (acid form). The undissociated acid is able to permeate the cell membrane of the microorganisms and interfere with enzyme systems in the cell to stop further growth. Since both acids and pectin are sparingly soluble in water, they are always added as solutions (Suutarinen, 2002).

2.6.3 Pectin

Pectin is the most frequently used hydrocolloid in the preparation of jams and jellies. Pectin is a class of complex hetero-polysaccharides found in the cell walls of higher plants. The pectin in plants function as a hydrating agent and cementing material for the cellulosic network (Vibhakara & Bawa, 2012). When pectin-rich plant materials are heated with acidified water, the protopectin is released and is hydrolysed into pectin that is readily soluble in water. This happens in plant tissues during ripening of fruits with the aid of an enzyme protopectinase. As the ripening of fruit proceeds, more of the insoluble protopectin is converted into soluble pectin (Saha & Bhattacharya, 2010). In jam making, pectin is used in an amount of about 1% of the total amount of ingredients. Commercial pectin is mostly used in the production of jams and is usually produced from either citrus fruits (containing 25% pectin) or from apples containing 15-18% pectin (Suutarinen, 2002).

Pectin mainly consists of D-galacturonic acid units joined in chains by means of α (1-4) glycosidic linkage. The uronic acids have carboxyl groups, some of which are naturally present as methyl esters and others which are naturally present as methylesters and others which are commercially treated with ammonia to produce carboxamide groups (Sundar *et al*., 2012). The solubility of pectins in aqueous solution depends on the degree of methylation, molecular weight, counter ions present in the solution, temperature and pH. Pectin solubility is better when the degree of methylation is higher, however, it decreases when polymer size increases (Gawkowska *et al*., 2018). An increase in temperature in weakly acidic and neutral conditions may cause the degradation of pectin and a change in solubility as a result β-elimination reaction. The mechanism of the β-elimination reaction is related to the cleavage of the glycosidic bond at C-4 and the removal of the hydrogen atom at C-5 of the galacturonic acid unit. As a result of this reaction, a double bond is formed. The β-elimination reaction is accelerated by an increase in temperature and pH, a high degree of methylation, the presence of monovalent salts and the presence of EDTA. In food technology, the β-elimination occurs during thermal processing of food at $pH>4.5$ and causes a loss of texture and a decrease in the viscosity of the food products (Sila *et al*., 2009).

The degree of esterification of the pectin molecule is defined as the ratio of esterified galactouronic acid units to total galactouronic acid units in the molecule. Pectins with a degree of esterification of above 50% are referred to as High-methoxyl (HM) pectins. Pectins with a degree of esterification of below 50% are referred to as Low-methoxyl pectins. Commercial LM-pectins are produced from plant material containing HM-pectins. The presence of calcium ions is critical to obtain gel formation in systems containing low methoxyl pectins. LM-pectins may form gels at much lower solids concentrations compared to HM-pectins. Low methoxyl pectins can withstand greater variations in pH without affecting gel formation. LM-pectin gels may melt when heated (Suutarinen, 2002).

Gel formation of pectin is caused by free carboxyl groups on the pectin molecules and between the hydroxyl groups of neighbouring molecules. In a neutral or only slightly acidic medium of pectin molecules, most of the unesterified carboxyl ions are converted to unionized carboxylic acid groups. The decrease in the number of negative charges lowers the attraction between pectin and water molecules. The decrease in negative charges also lowers the repulsive forces between pectin molecules. Sugar competes for water and further decreases hydration of the pectin. These conditions decrease the ability of pectin to stay in a dispersed state. On cooling, the unstable dispersing of less hydrated pectin forms a gel. The gel is characterized by a continuous network of pectin holding the aqueous solution. The rate of gel formation is also affected by the degree old esterification (Sundar *et al.,* 2012).

2.7 Other gelling agents

Gelatin is a water soluble protein derived from the initial degradation of collagen from animal skin and bones. Gelatin jellies have a rather soft or rubbery texture. The gels from gelatin form reversibly on cooling a gelatin solution. The protein molecules are cross-linked to form a network by junction zones, where the protein chain have partly refolded in the collagen triple helix structure (Saha & Bhattacharya, 2010). Gelatin is used in the confectionary industry for stabilization and foam formation, control of sugar crystallization and emulsification. It is widely applied for is thermo-reversible properties to influence the texture and mouthfeel of food products such as ice cream.

Agar/alginates are the major structural polysaccharides of algae formed by agarose and agaropectin. Agar jellies have a characteristic 'shortness' that may be modified by the addition of gelatin, gum Arabic, pectin, starch etc. Due to its unique gelling charateristics, it is widely applied as an ingedient in foodstuff, for cell and tissue culture and biotechnolgy uses such as support for electrophoresis. Alginates with a high ration of poly-β-D-mannuronic acid (M) and poly-α-L-guluronic acid (G) form weak, forbid gels whereas low M/G alginates give transparent, brittle and stiff gels. The strength of agar gels depends on the nature of the divalent cation. Agar gels are reversible whereby they melt by heating and gel again when cooled (Saha & Bhattacharya, 2010). Modified starch is starch that has undergone one or more varieties of treatment to alter its physical properties and or functionality. Modified starches are used to improve texture of products, extending the body of products and are used to modify the gelling effect of other starches.

Gellan gum has also been used as gelling agent in fruit preserves. Gellan gum has high stability to high temperatures and has been used in making fruit fillings in pastry. However, gellan gum works best in the presence of another stabilizer with good water-holding properties. This is due to the tendancy to syneresis which adversely affects the quality of spread as well as pastry leading to undesirable finished products (Cropotova *et al*., 2015). Intergration of pectin with other hydrocolloids in jams can be used to create a synergistic network with better functionality and stability in food products. In this respect, various hydrocolloid blends are of special interest for the food industry to provide a wider range of new and better functional properties (Cropotova *et al.,* 2015).

2.8 Gum Arabic

Gum Arabic is the dried gummy exudates from the stems and branches of *Acacia senegal* and *Acacia seyal*. Gum arabic is edible. Gum Arabic is considered acceptable as a food additive and conforms to the specification prepared by the joint FAO/WHO (JECFA) experts committee on food additives and adopted by the Codex Alimentarious commission (FAO, 1998). Gum Arabic is basically indigestible to both humans and animals. It is not broken down in the small intestine, but fermented in the large intestine by microorganisms to form short chain fatty acids such as propionic and butyric acid (Eqbal & Aminah, 2013). Gum Arabic is rich in non-viscous soluble fiber (Badereldin *et al*., 2008; Abdul-Hadi *et al*., 2010; Azeez, 2011).

Gum Arabic is collected during the dry seasons by herdsmen and women groups (pastoralists) in the arid regions (Lelon *et al.,* 2010; Mugo *et al.,* 2012). Colour varies from colourless to shades of yellow, amber, red and dark brown but good quality gums are spherical or oval shaped pale to orange in colour with a matt surface texture (Chikamai *et al*., 1996). The gum is then crushed into smaller pieces giving them a paler color with a vitreous appearance (Eqbal & Abdulla, 2013). Gum Arabic is commonly used in the pharmaceutical as a suspending agent for insoluble drugs and in the food industries as emulsifier and stabilizer (Abdul-Hadi *et al*., 2010). Age of the tree, its source, climatic conditions and soil environment from which gum Arabic is obtained will cause a variation in the chemical composition on the Gum Arabic.

The chemistry of gum arabic from a proximate analysis perspective reveals it as a high molecular weight polysaccharide which on hydrolysis with dilute acids yields D-galactose, Larabinose, L-rhamnose and D-glucuronic acid and its 4-O-methyl ether. The protein content is relatively small and varies between 1.9-2.3%. Eighteen amino acids have been identified with hydroxy-proline, proline, serine, threonine and leucine accounting for 82% of the total. Fourteen cations have been identified, which makes it exist as partly neutralised salt of acidic polysaccharide. The cations include calcium, potassium, sodium and magnessium, that are the most abundant. However, the above parameters are typical of Gum Arabic from *Acacia senegal* var. *senegal*. Gum from *A. senegal* var. *kerensis* has higher protein (2.9%). It is more branched and readily forms a gel at lower concentrations compared to var. *senegal* (Chikamai *et al*., 1996). The ability to gel at lower concentrations can be attributed to variety *kerensis* having a higher intrinsic viscosity. Variety *kerensis* also has a gyration radius of 40nm compared to 25nm of variety *senegal* (Mugo, 2012). The gum is also souble in cold or hot water which gives it low viscosity and Newtonian solution properties even at high concentrations. These properties make variety *kerensis* widely applicable in food without changing the food attributes like texture, smell and taste.

Gum Arabic belongs to the wider Arabinogalactan-protein family. It is made up of three major components that are similar in the proportion of various sugars but differ in their molecular mass and protein content. The main component is an Arabinogalactan (AG) with a molecular mass of 1.27×10^5 and deficient in protein, the second component is an Arabinogalactan protein complex (AGP) with a molecular mass of 1.45×10^6 and containing 50% of the total protein. The Arabinogalactan protein is the main component responsible for the functionality (emulsification and stabilization properties) of the gum. The third component (1.2% of the total) is the glycoprotein with a molecular mass of 2.5×10^5 and contains about 25% of the total protein.

Exudate gums such as gum arabic are used in a large number of applications, with the major sector being in the food industry. There is also considerable non-food applications. Gum Arabic is being extensively used for industrial purposes such as a stabilizer, a thickener, an emulsifier and an encapsulating in the food industry. Gum is also used to a lesser extent in textiles, ceramics, lithography, cosmetic and pharmaceutical industry. In the food industry, gum Arabic is mostly used in confectionery industry, bakeries, dairy products, beverages and as a microencapsulating agent (Mariana *et al*., 2012). The pH of the gum arabic solutions is normally around 4.5-5.5, however maximal viscousity is found at pH 6.0. Gum Arabic has exceptional emulsifying properties. In the emulsification process, the carbohydrate units balance the emulsion by electrostatic and steric repulsion whereas the hydrophobic polypeptide backbone strongly adsorbs at the oil-water interface. Emulsifying properties generally improve with increasing molecular weight and protein content. The heterogenous nature of the gum makes it an exemplary emulsifier (Verbeken *et al.,* 2003).

2.8.1 Food Applications of Gum Arabic

Gum Arabic has for a long time been used in wine gums, where it generates a clarity that is higher than can be obtained with other hydrocolloid. Gum arabic prevents the crystallization of sucrose and provides a controlled flavor release. Gum also slows down melting in the mouth and as a result making the wine gum lasting. It provides the appropriate texture to candies; whereby the candies are easily deformed in the mouth but do no stick to the teeth (Eqbal & Abdullah, 2013). Gum Arabic is used in lower-calory candies to compensate for the loss of texture, mouthfeel and body, resulting from the replacement of sugars by artificial sweeteners. It is used as a coating agent and as a pigment stabilizer in chewing gums. Gum arabic is also used in toffees and caramels as an emulsifier to maintain a uniform distribution of the fat across the product. Gum Arabic is used to provide a fibrous and fruit-like texture in jelly products (Wyasu & Okereke, 2012).

The solubility and stability of gum arabic in high acid environments makes it widely applied in the manufacture of soft drinks as an emulsifier. It is ideal for use in citrus and cola flavor oil emulsions that are used in beverages and soft drinks. Gum Arabic can also form a stable cloud in drinks imitating the effect of added fruit pulps and juices. It is an ideal source of soluble fiber in low-calorie and dietetic beverages. Gum arabic from *Acacia senegal* variety *kerensis* has been used in low fat yoghurt to reduce syneresis and in mozerella cheese to increase the functional properties such as stretchability. Gum Arabic is added to powdered beverage mixes to produce the same opacity, appearance, mouth feel and palatability as natural fruit juices (Wyasu & Okereke, 2012). In dry food products, gum Arabic is an efficient encapsuation agent because of its high water solubility, low viscousity and excellent emulsification properties. Gum Arabic inhibits the extraction of proteins from the meat into the gravy hence is used to prevent gelation in canned gravy based pet foods (Eqbal & Abdullah, 2013). Gum Arabic has also successfully been used to extend beef rounds to improve its quality (Mwove *et al.,* 2016).

2.9 Analytical Techniques in Fruit Jams and Marmalades

2.9.1 Determination of Total Soluble Solids

The main analytical parameter measured in jam is the Total soluble solids and is analysed using a refractive index. The index reflects the concentration of soluble solids in the final product. This can be done in two ways; using a manual refractometer and 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^{o} Celsius 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 68^{0}Brix (Rosenthal & Narain, 2011).

2.9.2 Syneresis Measurement

Syneresis can be described as densification due to the expulsion of fluid in a system. It is an active process that is dependent on the interaction forces between the structural elements of the system and external driving forces, such as hydrostatic pressure differences (Wu *et al.,* 2019). Methods for determining syneresis are available to obtain quantitative data as well as to accelerate the process. These methods may include one or a combination of filtration, centrifugation and capillary suction (Mizrahi, 2010). A widely used approach in studying syneresis is through accelerated measurements such as centrifugation. The weight or the volume of the liquid loss by syneresis is measured directly by its volume or by the weight changes of the remaining solids. In a method described by Charoenrein (2008), thawed flour gel samples were analysed for syneresis by centrifugation method. The samples were removed from syringes and put in centrifuge tubes with closed screw caps. The samples were then centrifuged at 8000g for 15 minutes. The supernatant was decanted and the residue weighed. The percentage of syneresis was calculated as follows:

$$\%Syneresis = \frac{Weigt\ of\ the\ separated\ liquid\ from\ gel}{Total\ weight\ of\ gel\ before\ centrifuging} \times 100 \text{……..……………….. (i)}$$

Centrifugation at various speeds is used to apply an eternal force that helps to push the liquid out of the gel. However, centrifugation may be disputable when spontaneous syneresis is tested (Mizrahi, 2010). The magnitudes of the forces involved in the force balance governing syneresis are not necessarily accelerated proportionally, which may lead to different conclusions in accelerated compared to non-accelerated tests. The above method has been used in various studies such as in determining the syneresis in yoghurt made from reconstituted non-fat dry milk in a study to determine the relationship between microstructure and susceptibility to syneresis). Centrifugation method has also been used determining syneresis in low fat yoghurt containing gum arabic from *Acacia senegal* variety *kerensis* as a stabilizer (Mugo, 2012) as well as in determining the effect of freezing on microstructure and degree of syneresis in differently formulated fruit fillings (Cropotova *et al*., 2015). The method has recently been used to quantify syneresis in set yogurt containing green tea and green coffee powders (Donmez *et al*., 2017).

NMR based methods have been used to assess syneresis as a non-destructive technique. This helps to learn about a possible correlation between 'free' or 'slightly bound' water with potential syneresis (Mizrahi, 2010). The application of this method remains to be a challenge due to the high cost of the equipment thus limiting many researchers to using alternative cheaper methods for measuring syneresis.

Syneresis can also assessed by varying the hydrostatic pressure of the gel at the surface of the gel sample and the bottom of the scoop. This is done at room temperature. For this method, 3D printed containers which have two chambers, a smaller inner tube and a larger outer reservoir. The tubes may vary in height of between 1 cm and 4.5 cm while the diameter is 2 cm. The inner tubes are sealed at the bottom with a filter paper with a pore size of 4µm. The gel sample is poured into the container both inside and outside the inner tube and let to rest for a certain period of time until the sample has reached a quasi-steady state. This storage period allows the microstructure to fully form. During the storage period, the container is covered with a screwed lid and sealed with parafilm to prevent evaporation. After this period, the material in the inner tube is removed by aspiration to establish a hydrostatic pressure difference. The accumulated fluid is then measured as a function of time (Wu *et al*., 2019).

2.9.3 Rheology in Jam and Marmalade

Rheology is the study of deformation and flow. The procedure of making jam is a complex process with a several variables that affect the quality of the final product. It is important to be well-versed about rheology to enhance the technology of different types of jam. Fruit jams and marmalades rheological behaviour is influenced by different parameters such as the composition of the jam, temperature, shear rate and the technology of the process (Javanmard & Endan, 2010). There is a significant change in apparent viscosity throughout the heating process of jams. Shear rate is described as the velocity gradient in a fluid which is a result of the shear stress implemented. Shear rate is represented by the symbol γ and the unit is stated as the reciprocal seconds (1/s). Shear stress is the force that is applied to the substance tangentially. The rheogram is the plot where shear stress is against shear rates. Shear stress and shear rates are directly proportional in Newtonian fluids. In this case, the rheogram will be a straight line with the graph beginning at the origin. There is no direct relationship between shear rate and shear stress in non-Newtonian hence, when the shear rate increases the shear stress will either increase or decrease. Jams and marmalades are gels containing hydrocolloids such as pectin as the gelling agent the model is assumed to be non-Newtonian. Most jams and marmalades exhibit breakdown during shearing which indicates shear thinning or pseudo plastic behaviour.

2.9.4 Sensory analysis

Sensory analysis is a scientific discipline to objectively analyse the sensory properties of food using human senses: vision, hearing, smell, taste and touch. The test must be included as a guarantee of the quality of foods. Sensory analysis provides important advantages such as to determine the perception of a product by consumers and allows to translate consumer wishes (Beinner *et al.,* 2010). Discrimination tests are used where the participants just need to be partly trained or do not need training at all whereas descriptive tests require a trained panel. Discrimination analysis comprises the simplest tests for sensory evaluation and are heavily used. Discrimination analysis in sensory evaluation can be classified into overall difference tests and attribute difference tests. In the overall difference, the participants are asked if they can recognize any existing difference between samples. In attribute difference tests, the participants are asked to focus on a specific attribute (Svensson, 2012).

Discrimination analysis is appropriate in product development. This is convenient when investigating new possibilities in product recipe reformulation or processing without establishing a detectable change for the consumer. Heavy training is not needed for participants in a discrimination sensory test. However, the participants should preferably be familiar with the test procedure and should be screened for sensory acuity. A suitable sample size, to be able to document clear sensory differences when performing discrimination tests is 25-40 participants (Lawless & Haymann, 2010). In cases where the differences between the samples are large, the discrimination tests can be performed with as few as six participants (Svensson, 2012).

CHAPTER THREE
MATERIALS AND METHODS

3.1 Raw Materials and Experimental Sites

Fresh mature fruits were procured from the local municipal market in Nakuru, Kenya. The fruits (red plums, pineapples, oranges and lemons) were transported to Egerton university, Department of Dairy, Food Science and Technology, Guildford Institute. Gum arabic from *Acacia senegal* var *kerensis* was bought from Kennect Limited, Kenya. Jam was prepared from red plums and pineapples while marmalade was prepared from oranges and lemons at the Egerton University Food Pilot Plant. Sensory evaluation was conducted using a semi-trained panel. Laboratory analyses were carried out in the Department of Dairy, Food Science and Technology, Egerton University and at the Kenya Forest Research Institute (KEFRI) Laboratories in Karura Forest station, Nairobi.

3.2 Preparation of Jam

The fruits were washed thoroughly with water containing 1% chlorine and rinsed (Vibhakara & Bawa, 2012). They were then peeled, and weighed using a weighing balance. Fruits were cut into pieces using clean sharp stainless steel knives and blended to make the puree. The puree was weighed using a weighing balance, transferred to a heating pan and heated to soften any pieces remaining. Sugar was then added to the fruit pulp at the ratio of 55:45 respectively. The pH was checked using a pH meter (HANNA, 211; USA) and adjusted to pH 3.2 using citric acid or Sodium bicarbonate (Pradip Enterprises and Promaco Limited, Nairobi, Kenya). The mixture was let to cook to the desired °Brix of 68°. Pectin was added at the rate of 1% in solution form, where water and sugar were used to the mixture to prevent clumping (Javanmard & Endan, 2010). Different proportions of gum Arabic (1.0%, 2.0%, 3.0%, 4.0% and 5.0%) were added to the product. Boiling was done while stirring until the desired °Brix of 68° was reached after which the heat was turned off. The end point of the process was determined using a refractometer. Hot filling was done in clean sterile glass jars and covered with sterilized caps. Jars were filled to atleast 90% full, leaving not more than 1.25cm headspace. The headspace was exhausted by the hot jelly product by releasing steam thus creating a vacuum seal (Vibhakara & Bawa, 2012). The filled jars were cooled using cold water. A control jam was prepared with all the ingredients except gum Arabic for comparison between the jam containing gum Arabic.

Marmalade Preparation

The fruit (orange and lemon) peels were cut into small pieces after pulping and the peels added to the fruit pulp during boiling. Boiling was done until the desired °Brix of 68° was reached. The ready marmalade was filled into clean, dry and sterilised glass jars while hot, then sealed with lids and inverted to sterilise the lids. After 2 minutes in the inverted position, the containers were cooled gradually by immersion in cold water. The control was prepared without gum Arabic.

3.2.1 Physico-chemical parameters

pH

A pH meter (HANNA intruments, Model 23044) was calibrated with a standard buffer solution 4.0 and 7.0 and rinsed using distilled water the pH will be measured by directly inserting the elecrodes into a 10 ml beaker containing the sample and the values were read and recorded from the pH meter. The pH meter was then rinsed using distilled water immediately after use before proceeding to the next sample. This was done in triplicates.

Total soluble Solids

A bench refractometer was used to analyse the total soluble solids. Samples were analysed in triplicates. Samples were placed on the sample holder of the refractometer that was standardized to the zero mark using distilled water. The readings on refractive index and °Brix were taken. Distilled water was used to rinse the refractometer immediately after use but before proceeding to the next sample.

3.2.2 Proximate Analyses

Moisture Content

Determination of moisture was done according to the oven method (AOAC 2000, Method 950.46). Approximately two grams of the fruit spread sample was accurately weighed and transfered into aluminium dishes. The samples were then dried in a dry air oven (Wisd 23 oven-Horizontal Flow, Dalhan Scienctific Wisd) at 105°C to constant weight and cooled in a dessicator. The amount of moisture in percentage was calculated as follows:

$$\%Moisture\ content = \frac{weight\ of\ pan + wet\ sample(g) - weight\ of\ pan + dry\ sample(g)}{weight\ of\ sample\ (g)} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots..(ii)$$

Crude protein

Crude protein content (N x 6.25) was determined according to the Kjeldahl method (AOAC 2000, Method 955.04) with slight modifications. About 0.5g of known dry matter content was accurately weighed in a nitrogen free filter paper, folded carefully and placed in a Kjeldhal flask. One tablet of Kjeldhal catalyst and 20 mL of concentrated sulphuric acid was added to the flask. The mixture was digested in a fume cupboard for about 2 hours until a clear solution was obtained. A blank sample of only a filter paper and sulphuric acid was also digested. After cooling, enough distilled water was added to increase the volume of the mixture to three-quarters of the Kjeldhal flask. Two to three drops of phenolphthelein indicator (5%) was added and the Kjeldhal flask connected to the distillation unit and unto it added enough 40% sodium hydroxide solution to change the color of the solution. Distillation was carried out until a drop of distillate did not react with Nessler's reagent placed in a test tube. The distillate was collected in a 400 mL conical flask containing 50mL of 0.1 mol/L hydrochloric acid solution and 2-3 drops of methyl orange indicator. The excess hydrochloric acid solution in the distillate was back titrated with 0.1 mol/L sodium hydroxide.

$$\%\mathrm{N} = N\ \mathrm{HCl} \times \frac{Corrected\ acid\ volume}{g\ of\ sample} \times \frac{14g\mathrm{N}}{mol} \times 100 \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (iii)$$

Where; *N* HCl= normality of HCl, in mol/ 1000 ml

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

14 = atomic weight of Nitrogen

Crude protein cntent was calculated by multiplying the % nitrogen content with a factor of 6.25.

Ash Content

Ash content was determined using AOAC (2000) method 920.39 using the maffle furnace (Wisethermo Wisd 23 Model FH14). Two grams of the predried samples were accurately weighed and placed into silica crucibles. The analysis was done in triplicates. The samples were ashed in a muffle furnace at 550°C for 3 hours. The ash was then cool ed in a dessicator to room temperature and weighed. Ash content was calculated as a percentage of the dry matter of the sample.

$$\%Ash\ content = \frac{weight\ of\ crucible + ash(g) - weight\ of\ crucible(g)}{weight\ of\ sample} \times 100 \quad \dots (iv)$$

Crude Fat

Determination of fat content of the jam and marmalade was done by ether extraction using Soxlet system (Soxtec TM 2055 FOSS) AOAC Official Method 991.36 (AOAC, 2000). The samples were first be predried at 95-100°C under pressure ≤ 100mm Hg for about 5 hours (AOAC Method 934.01). Approximately two grams of the predreid sample was weighed into a predried extraction thimble, with porosity permitting a rapid flow of petroleum ether. The sample was then be covered with fat free glass wool. The predried boiling flask was weighed. Sixty mililiters of petroleum ether was poured into the flasks and adjusted to the Soxlet extractor where extraction process took place for approximately one hour. The extraction flask was dried in a hot air oven at 105 °C for 30 minutes and reweighed at room temperature.

Calculation of crude fat was as follows;

$$\%Fat\ content = \frac{weight\ of\ flask\ after\ extraction - weight\ of\ flask}{weight\ of\ sample} \times 100\% \quad \dots(v)$$

Vitamin C

Vitamin C was determined using AOAC Method 967.21, 45.1.14 (Nielsen, 2010). Two grams of the sample were weighed accurately and homogenized in metaphoric acid or acetic acid solution (15g HPO_4 and 40mL HOAc in 500 mL H_2O). The sample extract was then filtered and diluted appropriately to a final concentration of between 10-100 mg Ascorbic acid/100 mL. A standard solution was prepared by dissolving 50mg of L-ascorbic acid in 100 mL of water. Titration of three replicates of the samples was carried out with the standard solution with 2,6-dichloroindophenol solution to a pink endpoint lasting at least 10 seconds. Results were recorded for calculation as follows;

$$Mg\ Ascorbic\ acid\ per\ gram = C \times V \times \frac{DF}{Wt} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.(vi)$$

Where: C= mg Ascorbic acid

V= ml dye used for titration of diluted sample

DF= dilution factor

Wt= sample weight, g

Carbohydrate Determination

Carbohydrate content was calculated as weight by difference between 100 and summation of other proximate parameters.

$$Carbohydrate = 100 - (\%moisture + \%protein + \%fat + \%ash + \%fiber) \quad \dots(vii)$$

Crude Fiber

The crude fiber content in each sample was estimated as described in AOAC (2000) Official Method 984.04. Two grams of the predried sample was weighed using a weighing balance (Shimadzu ATX 224) and digested using sulphuric acid for 30 minutes followed by sodium hydroxide solution in a clean dry beaker at the same ratio. The mixture was then filtered through a sintered glass funnel at a reduced pressure. The residue was then washed with hot water, scrapped with a glass rod to transfer everything as practically as possible to a pre-weighed Aluminium foil. The sample was dried at 105°C for 2 hours in an oven. The dried sample was ignited in the muffle furnace (Wisethermo Wisd 23-Model FH-14) at 535°C for 2-3 hours and cooled in a dessicator and weighed. The weight of the residue will be recorded.

$$\% \, Crude \, fiber = \frac{weight\ of\ crucible + dry\ residue(g) - weight\ of\ crucible + ash(g)}{weight\ of\ sample\ (g)} \times 100 \quad ...(viii)$$

Syneresis measurement

Syneresis of the fruit jam and marmalades was determined using centrifugation method described by Cropotova et al., (2015). Twenty grams of the fruit spread was weighed and placed in a centrifugation tube and centrifuged at 3000 rpm for 20 minutes at room temperature. The method was modified to adjust the time to 30 minutes. After centrifugation, the exudate was weighed and the degree of syneresis was determined as follows:

$$Syneresis\ (\%) = \frac{Total\ weight\ of\ separated\ liquid(g)}{Total\ weight\ of\ fruit\ spread\ sample\ (g)} \times 100 \quad \ldots\ldots\ldots\ldots\ldots(ix)$$

3.2.3 Microbial Quality Assessment

Microbial Analysis

The microbiological analysis was done following AOAC Official Methods (AOAC, 2000) to determine the presence of spoilage and pathogenic organisms in the jam and marmalade with gum Arabic from *Acacia senegal* var. *kerensis*. All samples were analysed a day after formulation when the fruit spreads had set. Approximately 10 grams of the fruit spreads was weighed asceptically and blended with 90 ml of sterile peptone water for 2 minutes. Sterile peptone water was used to carry out serial dilutions of the samples. For each dilution, three replicate plates were prepared. Total viable counts were determined by pour plating Plate Count Agar (PCA, Oxoid,UK) and incubating at 37 °C for 24 hours. Yeast and mold counts were done by pour plating onto potato dextrose agar (PDA, Oxoid, UK) followed by incubation at 25 °C for 5 days. Coliforms were determined by pour plating Mac Conkey agar (Oxoid, UK) and incubating at 35 $^{\circ}$C for 24 hours. Results were expressed as CFU g^{-1}.

3.2.4 Sensory Evaluation

An inhouse panel of thirty was randomly recruited for sensory and acceptability evaluation of the formulated fruit jams using a 7-point hedonic scale. The panelists were first asked to consent on the tests and will be asked to complete a demographic questionnaire. Acceptance testing was used to determine how much each sample was liked based on the 7-point hedonic scale for a set of atttributes: overall liking, flavor, texture, spreadability, colour, aroma and taste where; 7= like extremely, 6= like moderately, 5 = like slightly, 4 = neither like nor dislike, 3 = dislike slightly, 2= dislike moderately, 1= dislike extremely (Appendix I). In addition, consumers were asked what they like and dislike about each sample in the comment section of the score sheet. The panelists evaluated samples in individual testing booths. All samples were evaluated under standard room flourescent lighting.

3.2.5 Viscosity Analysis

The viscosity of each sample was determined at room temperature using a Brookfield digital viscometer (DV-E, Brookfield Engineering Laboratories, USA). A suitable spindle (spindle LV 64) and rotational speed was selected for the study. The guard leg of the instrument was detached and not used in the analysis of the samples. The spindle attached to the viscometer and gently pushed up on the viscometer coupling screw avoiding any side movements. The spindle was held securely while screwing on the viscometer. The viscometer was then lowered into the sample material until the meniscus was in the middle of the immersion mark and rotated in the fluid sample. The spindle was removed and cleaned after every sample analysis. The device gave the viscosity of the fluids directly (mPa).

3.3 Experimental Design

The experiment employed a comletely randomized design (CRD) in a factorial arrangement. The first factor was the type of fruit which were in 4 levels; pineapples, plums, lemons and oranges while the second factor was the gum Arabic levels (0%, 1.0%, 2.0%, 3.0%, 4.0% and 5.0%) as shown in a layout of Appendix II. The level of 0% which represents the standard jam was the control for the study. The work was done in three replications.

3.4 Statistical Data Analysis

The statistical model for the experiment was:

$$Y_{ijkl} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \varepsilon_{ijkl}$$

Where;

Y_{ijkl} = the observation on the response variable;

μ = the overall mean;

α_i = the effect due to the i^{th} fruit;

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

$\alpha\beta_{ij}$ = the interaction effect between the i^{th} fruits variety and j^{th} gum Arabic level; and

ε_{ijkl} = the random error associated with Y_{ijkl}.

Data obtained from the study was analysed using the PROC GLM procedure of the Statistical Analysis System (SAS Institute Inc., 2006) software Version 9.1. Study hypotheses were tested by performing analysis of variance (ANOVA). The level of significance was established at $P<0.05$ confidence level and means separation was done using Tukey's Honestly significant difference (HSD) method.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Effect of gum Arabic on syneresis of Jam and Marmalade

There was no separation of exudates in all the samples of jam and marmalade. A modification on the procedure by Cropotova *et al*. (2013) was made by increasing the duration of rotation in the centrifuge to check for the occurrence of syneresis. The modification had no effect on the release of colloidal water since no separation was observed. In this method, centrifugation increases the pressure of the gel internal liquid thus cooperating with the network pressure to counteract the effect of the osmotic pressure. This is contrary to observation made on the control jam and marmalade prior to centrifugation whereby there was a thin liquid film observed on the jam. The jam and marmalade containing gum arabic from *Acacia senegal* variety *kerensis* did not have visible liquid separation as indicated in table 1 below.

Table 1: Level of Syneresis in fruit spreads

Level of Gum (%)	Level of syneresis (ml)
0	0
1	0
2	0
3	0
4	0
5	0

Gum arabic therefore helped solve the challenge of syneresis from qualitative analysis. There is a challenge on quantitative analysis of syneresis in jam and marmalade using centrifugation method as the method did not quantify the level of syneresis.

The internal solvent in food systems is a solution of sugars, salts and soluble polymers. Thus the liquid observed in syneresis contains the same solutes as those inside the gel (Mizrahi, 2010). This indicates that the liquid expelled may not be necessarily water as in polymer-water systems. Thus from this experiment, gum Arabic which was meant to be a water binder only played a role on the texture as well as viscosity of the product by changing its viscous phase as the concentrations of gum changed. Wu *et al.* (2019) made a similar observation in low fat mayonnaise and to validate this, a series of experiments were carried out. The purple colour during iodine test confirmed the presence of starch in the expelled fluid. Thermo-gravimetric analysis and gel permeation chromatography indicated that a higher proportion of the soluble starch left together with the fluid during the scoop syneresis experiment (Wu *et al*., 2019).

In a study by Mugo (2012) there was a significant decrease in syneresis at ($p< 0.05$) when starch was used together with gum arabic in low fat yoghurt. This was attributed to the modifications as a result of the gums in the starch water holding capacity and competition of the gum with the starch for free water available in the system. Starch granules have been shown to imbibe water during the gelatinization process acing as active fillers thus contributing to the gel strength of the acid milk gel (Mugo, 2012). Tesch *et al.* (1999) observed that syneresis may have been triggered by water vapour absorbed from the surrounding into a gel that eventually swelled to the point of producing an excessive internal pressure. The excessive pressure is the result of the driving force for water absorption into the gel. The gel has the high osmotic pressure of the low-molecular co-solutes (salt and sugars) rather than that of the polymer itself. This finding may also suggest the possibility of intra-gel liquid transfer that may be caused by temperature gradients. The intra-gel liquid transfer may be caused by the effect of temperature on the internal solution osmotic pressure. This may also be as a result of mass separation of the low molecular co-solutes that is induced by the temperature gradient (Mizrahi, 2010).

Syneresis is also linked to the osmotic difference between the polymer matrix and the surrounding solution. Hydrocolloids tend to crosslink at higher concentrations and similar molecules may be able to wrap around each other by forming helical junction zones. These junctions form without loss of hydrogen bonding but reducing conformational heterogeneity and minimising hydrophobic surface contact with water so releasing it for more energetically favourable elsewhere. To overcome the entropy effect and form a stable link, a minimum number of links is required. A junction zone which if helical will require a complex helix (Batzer & Kreibich, 1981). Syneresis may occur in jams, jellies and marmalades where junction zones grow slowly with time the interactions eliminate water.

Syneresis can be caused by mechanical disturbance involving external pressure applied on the gel resulting in breaking and cutting open the gel structure to expose and facilitate the release of entrapped liquid. Chemically and physically cross-linked gels can be quite heterogeneous given the use of two hydrocolloids and fruits in this experiment. Internal spaces may be part of the initial gel or the voids can be formed by the anisotropic shrinkage of the heterogeneous structure. In such cases, the phase separated liquid within the gel and may require some additional internal pressure in order to force the liquid out to be observed as syneresis. In cases where the pores through which the liquid is expelled are of capillary sizes, it should be expected that there will be a threshold of internal pressure below which the liquid will not start to flow, thus no syneresis will be observed. This could also explain why there was no observable liquid separation in the jam and marmalade during the measurement of syneresis using centrifugation method. Kunitz (1928) observed that the why dry unstable gelatine gels did not show syneresis until dipped in water or smashed with a spatula. This observation was attributed to the capillary threshold pressure phenomenon. Similarly, it explains the technique developed by Lodiate *et al.* (2000) to commence syneresis in milk curd by wetting of the surface.

An increase in the internal pressure is expected to develop in the area of sharp concave edges of the gel product is another aspect of surface tension in syneresis. The sharp concave edges can be introduced when scooping of the jam or marmalade spread. This extra pressure may help the already existing internal pressure to overcome that of the capillary threshold and thus enhances the appearance of syneresis (Mizrahi, 2010). As a result, keeping the product surface flat and dry can be considered as one of the measures to delay syneresis in jellies, jams and marmalades.

4.2 The microbial quality of Jams and Marmalades containing gum Arabic

Microbiological assessment was done on all the formulated samples the following day after setting the jam and marmalade. The fruit spreads without gum arabic and those with gum arabic from *Acacia senegal* var. *kerensis* all were not detected as indicated in Table 2 below.

Table 2: Microbiological growth in the fruit jam and marmalade

Level of Gum	**Microbial counts**		
	TVC	TCC	Yeasts and Moulds
0	Nil	Nil	Nil
1	Nil	Nil	Nil
2	Nil	Nil	Nil
3	Nil	Nil	Nil
4	Nil	Nil	Nil

The use of gum arabic from *Acacia senegal* var. *kerensis* had no effect on the microbiological quality of the fruit spreads. The assay was done to ensure that the product was safe during handling, consumption during sensory evaluation. Total plate count of microbial population is considered as an index of quality of food products (Shakir *et al.,* 2009) whereas total coliform counts are an indication on the handling and safety of the food product. Fungal spoilage is of significant impact in processed foods as they proliferate in foods with very limited water availability. Acidified foods products contain organic acids that may support the growth of fungi. These acids are degraded by fungal metabolism increases the pH of the product and can support the growth of pathogenic bacteria (Snyder & Worobo, 2018). Jams and marmalades are characterized by the very low pH of about 3.2. Both pineapple and red plum jam, microorganisms were below detectable limits. Total coliform counts, yeast and molds, as well as total viable counts were all negative for pineapple jam and red plum jam. The packaging of jam is done through hot filling in sterilized glass jars to prevent spoilage of the product. The hot jelly product also sterilized the glass container. Jam contains high sugar content giving it low water activity. The sugar not only contributes to the flavour of the product but also reduces the chances for growth of microorganisms (Vibhakara & Bawa, 2012). This results correlate well with another study where gum Arabic from *Acacia senegal* var. *kerensis* was used to extend beef hams. The study found that the growth of microorganisms was below detectable limits (Mwove *et al*., 2016). In another study, plum jam was found to have 125 cfu/g where as strawberry jam a total plate count of had 5 cfu/g which was below the kenyan standards for jam of 10^4 maximum growth per gram (Olielo, 2014).

The low microbial counts in the fruit spreads could have been due to the sorbic acid that was used. In this study, sorbic acid was used at the level of 0.01% to reduce mould growth. The use of artificial preservatives is reported to have an impact on the microbial growth readings. Brandao *et al.* (2018) observed that the yeast and mould counts during storage of the dietetic functional cerrado fruit jam was within the limits advocated by legislation, which is 104 cfu/g, indicating that the jam obtained were in accordance with the hygienic standards (Brandao *et al*., 2018). Similar results were obtained by Policarpo *et al*. (2007) studying the quality of green umbu jam. Mesquita *et al*. (2013) who evaluated sugar free guava jam also detected mold and yeast values below the limit established by the standards.

4.3 Effect of gum Arabic on the Proximate and Vitamin C analyses of Jams and Marmalades

4.3.1 Marmalades

From Figure 1 below, generally the proximate composition orange fruit products had the highest composition compared to lemon. However lemon had higher moisture content compared to the oranges.

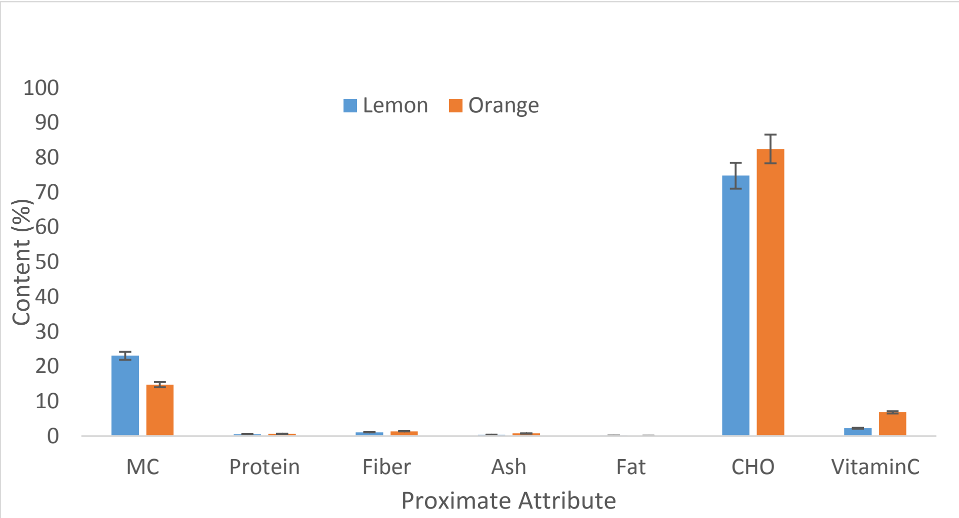


Figure 1: Means of different proximate composition of fruits used in Marmalade making

In terms of Ash, fibre and protein content there was no significant difference at $p<0.05$ in the different levels of gum Arabic. The product with 4% gum Arabic had the highest vitamin C contents as seen on table 3 below.

Table 3: Means of different proximate composition from different levels of gum arabic used in marmalade making

Gum	MC	Protein	Fiber	Ash	Fat	CHO	VitaminC
0	$19.68^{b}\pm1.91$	$0.62^{a}\pm0.09$	$1.14^{f}\pm0.06$	$0.28^{a}\pm0.02$	$0.11^{a}\pm0.01$	$78.18^{b}\pm2.04$	$4.05^{d}\pm0.93$
1	$27.72^{a}\pm1.49$	$0.59^{a}\pm0.07$	$1.75^{a}\pm0.21$	$0.22^{a}\pm0.02$	$0.25^{a}\pm0.17$	$69.47^{c}\pm1.71$	$3.63^{e}\pm0.96$
2	$13.08^{e}\pm0.89$	$0.68^{a}\pm0.06$	$1.17^{c}\pm0.05$	$1.93^{a}\pm1.61$	$0.07^{a}\pm0.01$	$83.07^{a}\pm1.38$	$6.07^{a}\pm1.13$
3	$17.6^{cd}s\pm0.80$	$0.56^{a}\pm0.04$	$1.39^{b}\pm0.09$	$0.27^{a}\pm0.04$	$0.06^{a}\pm0.01$	$80.09^{ab}\pm0.76$	$3.43^{e}\pm0.91$
4	$17.02^{d}\pm3.03$	$0.58^{a}\pm0.07$	$1.17^{c}\pm0.24$	$0.32^{a}\pm0.05$	$0.07^{a}\pm0.01$	$80.84^{ab}\pm2.77$	$5.40^{b}\pm1.25$
5	$18.35^{c}\pm3.35$	$0.37^{b}\pm0.05$	$0.86^{d}\pm0.27$	$0.30^{a}\pm0.06$	$0.08^{a}\pm0.00$	$80.06^{ab}\pm3.08$	$4.63^{c}\pm1.01$

Means within a column with the same superscript letters are not significantly different at $p< 0.05$.

Interaction between the fruit and the gum level affected significantly the different proximate composition (Table 4). Lemon with 1% gum Arabic had higher amount of fibre, fat and moisture content while oranges with 2% gum level had higher ash and vitamin C content. Citrus fruits such as oranges and lemons are available worldwide at a reasonably affordable price. Citrus fruits are considered as healthy foods and good sources of Vitamin C. Vitamin C must be consumed steadily since it is not stored in the body in significant amounts. Vitamin C is a cofactor of several enzymes responsible for the biosynthesis of collagen. Scurvy is a disease caused by inadequate Vitamin C as a result, inability to synthesize collagen (Berk, 2016). It is also an important antioxidant in the human body and is the most ample water-soluble anti-oxidant in the human body. According to Polyera *et al*. (2003), the thermally pasteurized juice had higher ascorbic acid losses compared to the juice stabilized by high pressure treatment (Polydera *et al*., 2003). This is true for the case of jam and marmalade since they are thermally processed resulting in the low amounts of vitamin C.

Table 4: Means of different proximate composition between different fruits used and different levels of gum arabic in marmalade

Fruit	Gum	MC	Protein	Fiber	Ash	Fat	CHO	Vitamin C
Lemon	0	$23.93^{c}\pm0.12$	$0.82^{a}\pm0.02$	$1.26^{e}\pm0.03$	$0.24^{b}\pm0.02$	$0.13^{b}\pm0.01$	$73.61^{d}\pm0.14$	$1.97^{j}\pm0.03$
	1	$31.03^{a}\pm0.09$	$0.50^{d}\pm0.12$	$2.21^{a}\pm0.12$	$0.17^{b}\pm0.01$	$0.42^{a}\pm0.34$	$65.67^{f}\pm0.32$	$1.50^{k}\pm0.12$
	2	$15.07^{g}\pm0.12$	$0.60^{c}\pm0.12$	$1.14^{f}\pm0.01$	$0.43^{b}\pm.01$	$0.05^{b}\pm0.01$	$82.71^{b}\pm0.22$	$3.53^{g}\pm0.09$
	3	$19.00^{e}\pm1.15$	$0.47^{de}\pm0.01$	$1.19^{f}\pm0.01$	$0.36^{b}\pm0.01$	$0.09^{b}\pm0.01$	$78.89^{c}\pm1.20$	$1.40^{l}\pm0.12$
	4	$23.80^{d}\pm0.12$	$0.43^{e}\pm0.01$	$0.64^{h}\pm0.01$	$0.43^{b}\pm0.01$	$0.06^{b}\pm0.01$	$74.64^{d}\pm0.13$	$2.60^{h}\pm0.12$
	5	$25.83^{b}\pm0.07$	$0.26^{f}\pm0.01$	$0.24^{i}\pm0.01$	$0.42^{b}\pm0.01$	$0.08^{b}\pm0.01$	$73.17^{e}\pm0.08$	$2.37^{h}\pm0.03$
Orange	0	$15.43^{g}\pm0.28$	$0.41^{e}\pm0.01$	$1.02^{g}\pm0.03$	$0.32^{b}\pm0.01$	$0.08^{b}\pm0.00$	$82.74^{b}\pm0.27$	$6.13^{d}\pm0.07$
	1	$24.40^{e}\pm0.38$	$0.69^{bc}\pm0.01$	$1.30^{e}\pm0.06$	$0.27^{b}\pm0.02$	$0.07^{b}\pm0.01$	$73.27^{e}\pm0.37$	$5.77^{e}\pm0.12$
	2	$11.10^{h}\pm0.12$	0.76 ± 0.04	$1.19^{f}\pm0.10$	$3.43^{a}\pm3.28$	$0.08^{b}\pm0.01$	$83.43^{b}\pm3.05$	$8.60^{a}\pm0.10$
	3	$16.27^{f}\pm0.15$	0.65 ± 0.03	$1.59^{c}\pm0.05$	$0.18^{b}\pm0.01$	$0.04^{b}\pm0.00$	$81.28^{b}\pm0.22$	$5.47^{f}\pm0.12$
	4	$10.23^{j}\pm0.12$	0.72 ± 0.03	$1.70^{b}\pm0.01$	$0.22^{b}\pm0.01$	$0.09^{b}\pm0.01$	$87.04^{a}\pm0.17$	$8.20^{b}\pm0.12$
	5	$10.87^{i}\pm0.09$	0.48 ± 0.01	$1.47^{d}\pm0.03$	$0.17^{b}\pm0.00$	$0.07^{b}\pm0.01$	$86.94^{a}\pm0.12$	$6.90^{c}\pm0.06$

Means within a column with the same superscript letters are not significantly different at $p< 0.05$.

4.3.2 Jam

Fruit significantly affected all the proximate parameters at $p<0.05$ except the proteins. Gum Arabic and the interactions between gum levels and the fruit level significantly affect all the proximate composition content at $p< 0.05$ except Vitamin C which was not significant at $p<0.05$ for both gum and the interaction. From the Figure 2 below, jam products made from the red plum fruit had higher proximate components compared to the pineapple except the carbohydrates where jams from pineapple had higher composition.

Studies on different fruit jams and moisture content was reported a range of 31.23-33.36% Mohd *et al*. (2015) while Emelike and Akusu (2019), reported a range of 23.29-45.21% with pineapple jam being the lowest with 23.41% at $p < 0.05$. In a study where jam was made from water melon fruit and pawpaw juice, the moisture contents of the formulated jam was reported to vary between 30.60 to 34.70% (Adedeji, 2017). A value of 29% moisture content, similar to the findings of this study on red plum jam was recorded in a study of the proximate analysis and physic-chemical analysis of fruit jam from *Baccaurea angulata* peel (Gindi *et al.,* 2019). A moisture content of 20.30% was recorded for jam developed from papaya and goose-berry (Gupta *et al*., 2016). The results from this study are equally within the range observed from the different studies.

There was no significant difference at $p <0.05$ on the protein and fat contents of the jam made from different fruits (Figure 2). Fruit jams are known to have low protein content depending on the fruit used to make the jam. In a study where *Baccaurea angulate* peel was used to make jam, the crude protein content was 0.11% whereas crude fat content was 0% (Gindi *et al*., 2019). Jam made from sour sop recorded a high protein content of 0.73% which was attributed to the high protein content of the sour sop fruit with a value of 15.6% as compared to the other fruits (Emelike & Akusu, 2019). Adedeji (2017) also reported low fat contents in jam from watermelon and pawpaw juice ranging from 0.40±0.03 to 0.32±0.03% at $p<0.05$. The low fat content is an indication that the jam samples can keep for a long period of time at the right temperatures and moisture without spoilage by oxidative rancidity.

There was a significant difference in the crude fibre content of the formulated fruit jams based on the fruits used. Pineapple jam recorded a low crude fibre content (1.16±0.17) % as compared to red plum fruit jam with a fibre content of (1.69±0.17) % as indicated in the table below. Dietary fiber increase feacal output, lowers fecal pH and increases significantly the daily excretion of butyrate of the consumers which are putative markers of colonic health in humans

(Cummings *et al*., 1996). Fibre is important in food since it helps in lowering the serum cholesterol, control blood sgar and increase bulk stool and other ailments of the gastrointestinal tract of humans (Adedeji, 2017). High fibre jam was also reported by Gupta *et al*. (2016) who incorporated gooseberry to papaya jam which is effective in controlling oxidation of low density lipoproteins (LDL) which releases free radicals and cause coronary artery disease or artherosclerosis (Gupta *et al.,* 2016). Solebo and Aina (2011) reported a crude fibre value of (1.25±0.07) % at $p<0.05$ for jam made from black plum fruit and are in range with the above studies. From the results below, the high content of fibre in plum jam can be a possible explanation to the higher moisture content of the red plum jam compared to puneapple jam which had less fibre.

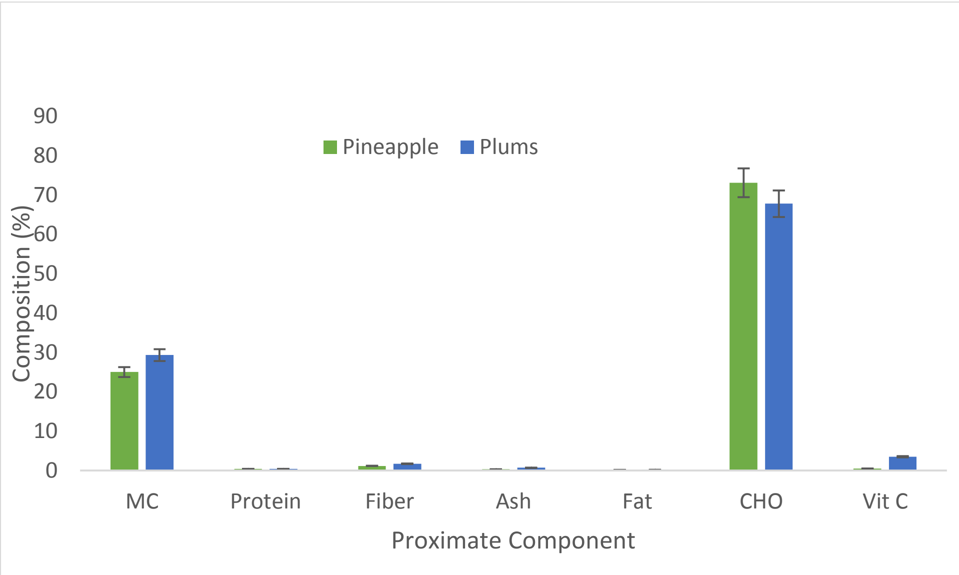


Figure 2: Means of proximate composition of different fruits in jam making

From the table 5 below, jam product with 3% gum Arabic had higher of the proximate composition. Also, there was no significance difference ($p<0.05$) in the Vitamin C composition at different levels of gum Arabic addition. This could be attributed to the fact that gum Arabic being a poor source of vitamin C. This is contrary to the findings of Nwaokoro and Akambi (2015) who observed that the juice blends containing hydrocolloids had a higher concentration of vitamin C when stored at ambient temperature. However, there was a decrease in the vitamin C content during the period of storage. From that study, it was concluded that hydrocolloids help to prevent oxidation of vitamin C in bevarages leading to the higher values obtained in the study (Nwaokoro & Akambi, 2015).

Table 5: Means of different proximate composition from different levels of gum arabic used in jam

Gum	MC	Protein	Fiber	Ash	Fat	CHO	VitaminC
0	$27.72^{b}\pm0.50$	$0.56^{a}\pm0.05$	$2.07^{a}\pm0.25$	$0.49^{ab}\pm0.08$	$0.10^{b}\pm0.01$	$69.07^{c}\pm0.60$	$4.88^{a}\pm3.65$
1	$27.62^{bc}\pm0.50$	$0.20^{c}\pm0.02$	$1.53^{b}\pm0.32$	$0.59^{a}\pm0.15$	$0.12^{b}\pm0.01$	$69.96^{b}\pm0.11$	$1.65^{a}\pm0.48$
2	$27.90^{b}\pm0.68$	$0.17^{c}\pm0.01$	$1.33^{b}\pm0.15$	$0.45^{bc}\pm0.10$	$0.10^{b}\pm0.01$	$70.05^{b}\pm0.45$	$1.42^{a}\pm0.46$
3	$27.33^{c}\pm1.76$	$0.56^{a}\pm0.10$	$1.86^{a}\pm0.30$	$0.50^{ab}\pm0.11$	$0.15^{a}\pm0.01$	$69.60^{b}\pm2.24$	$1.48^{a}\pm0.45$
4	$29.08^{a}\pm2.13$	$0.39^{b}\pm0.03$	$1.20^{b}\pm0.30$	$0.58^{a}\pm0.12$	$0.15^{a}\pm0.02$	$68.60^{d}\pm2.53$	$1.37^{a}\pm0.36$
5	$23.25^{d}\pm2.26$	$0.43^{b}\pm0.02$	$0.54^{c}\pm0.05$	$0.37^{c}\pm0.05$	$0.16^{a}\pm0.01$	$75.25^{a}\pm2.27$	$1.15^{a}\pm0.29$

Means within a column with the same superscript letters are not significantly different at $p< 0.05$.

From the table 6 below, jams with 0% gum Arabic made of plums had higher Vitamin C content. Ash content was higher in products made of plums and 1% gum Arabic. In a similar study where hydrocolloids were used to stabilize juice blends, the ash contents of the juice blends with hydrocolloids had no significant difference from the juice blends without hydrocolloids at room temperature. It was also reported that hydrocolloids did not have an effect on the ash content of juice as they solubilize and therefore may not be detected (Nwaokoro & Akambi, 2015). This can be attributed to the findings in this study where the fruit spreads with hydrocolloids had no significant difference as compared to the fruit spreads without hydrocolloids. Jams made of pineapple without gum Arabic had higher fibre content as recorded in the table 6 below.

Table 6: Means of different proximate composition for interaction between different fruits used and different levels of gum arabic in jam making

Fruit	Gum	MC	Protein	Fibre	Ash	Fat	CHO	Vitamin C
Pineapple	0	25.93^{g}±0.07	0.68^{b}±0.01	2.62^{a}±0.06	0.31^{f}±0.01	0.08^{e}±0.01	70.38^{e}±0.05	0.40^{c}±0.06
	1	28.73^{d}±0.09	0.24^{f}±0.01	0.82^{h}±0.01	0.26^{g}±0.01	0.09^{e}±0.00	69.86^{h}±0.09	0.57^{c}±0.03
	2	29.40^{c}±0.06	0.16^{g}±0.01	1.06^{g}±0.00	0.24^{g}±0.01	0.08^{e}±0.01	69.06^{l}±0.06	0.40^{c}±0.12
	3	23.40^{i}±0.12	0.33^{e}±0.01	1.26^{f}±0.12	0.26^{g}±0.01	0.17^{b}±0.00	74.58^{b}±0.25	0.50^{c}±0.12
	4	24.33^{h}±0.18	0.45^{c}±0.01	0.54^{ij}±0.02	0.31^{f}±0.01	0.12^{d}±0.01	74.25^{c}±0.19	0.57^{c}±0.07
	5	18.20^{j}±o.12	0.41^{d}±0.01	0.65^{i}±0.03	0.28^{fg}±0.01	0.14^{c}±0.01	80.32^{a}±0.12	0.49^{c}±0.02
Plums	0	29.50^{c}±0.26	0.44^{c}±0.01	1.52^{e}±0.01	0.66^{d}±0.02	0.13^{cd}±0.01	67.76^{i}±0.26	9.37^{a}±6.82
	1	26.50^{f}±0.12	0.16^{g}±0.01	2.23^{c}±0.09	0.92^{a}±0.02	0.14^{c}±0.01	70.05^{g}±0.20	2.73^{b}±0.03
	2	26.40^{f}±0.21	0.18^{g}±0.01	1.60^{e}±0.21	0.66^{d}±0.09	0.13^{cd}±0.01	71.04^{d}±0.16	2.43^{bc}±0.09
	3	31.27^{b}±0.19	0.78^{a}±0.02	2.47^{b}±0.24	0.74^{c}±0.02	0.12^{d}±0.01	64.62^{j}±0.46	2.47^{bc}±0.18
	4	33.83^{a}±0.07	0.33^{e}±0.01	1.87^{d}±0.09	0.84^{b}±0.02	0.18^{a}±0.01	62.94^{k}±0.09	2.16^{b}±0.03
	5	28.30^{e}±0.20	0.45^{c}±0.03	0.43^{j}±0.02	0.46^{c}±0.06	0.19^{a}±0.01	70.17^{f}±0.18	1.80^{bc}±0.01

Means within a column with the same superscript letters are not significantly different at $p < 0.05$.

4.4 Effect of Gum Arabic on the Sensory Quality of Jam and Marmalade

4.4.1 Marmalade

Different sensory attributes were scored against the different fruits used to make the marmalade and results are as indicated in Figure 3. Lemon marmalade scored best for aroma (5.41±0.11) while orange marmalade scored best for flavour (6.11±0.06) and taste (5.92±.09) at $p<0.05$ level of significance. There was no significant differences ($p<0.05$) between the fruit type used to make marmalade in terms of colour, texture, spreadability and general acceptability. Lemon marmalade was preferred by the panelists as it scored best for aroma while orange marmalade scored higher for flavour and taste. Orange marmalade is not new in the Kenyan market. Lemon marmalade however, is rare in the Kenyan market. Lemon has a more harsh taste as compared to oranges. The pH of the fruits were also different whereby lemon fruit has a lower pH and thus required Sodium Bicarbonate to adjust the pH of the marmalade to a suitable range for gelling; pH 2.8-3.0. The pH of orange was found to be higher than the suitable range of pH 2.8-3.2 for making a stable gel for marmalades. The orange marmalade pH was using citric acid to lower the pH to suitable levels. There was no significant differences between the fruit type used to make marmalade in terms of colour, texture as well as spreadability at $p<0.05$. This can be attributed to the fact that both lemon and oranges are citrus fruits thus the marmalades from the fruits would be similar based on those attributes. The general acceptability of the orange and lemon marmalade was also quite similar as indicated in Figure 3.

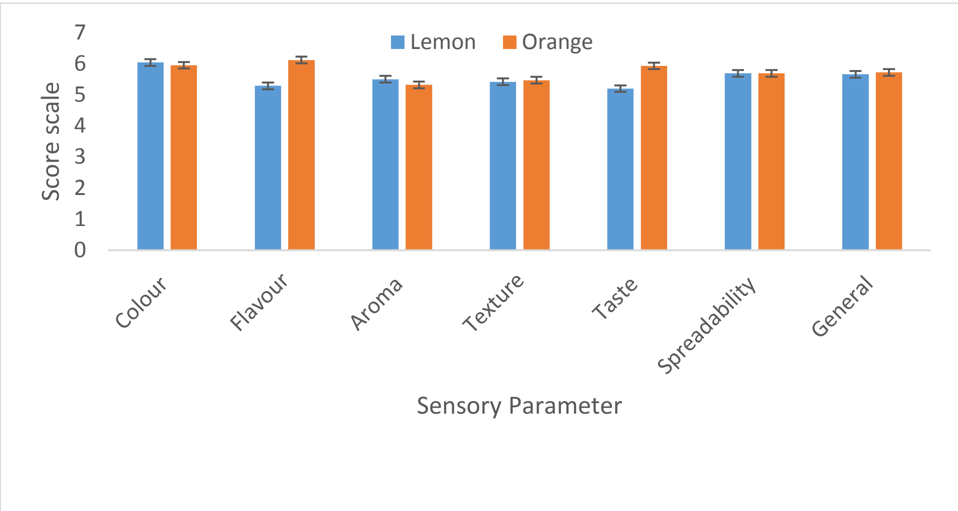


Figure 3: Means of sensory scores of different attributes in marmalades

The effect of different levels of gum arabic used in the preparation of orange and lemon marmalade is indicated in table 7 below. There was no significant difference at <0.05 on the level of gum Arabic used on colour and aroma. This is similar to findings by Mugo (2012) where gum Arabic from *Acacia senegal* var. *kerensis* was used on low fat yogurt whereby the gum did not have a significant difference at $p<0.05$ on colour and aroma. Similar results were also reported by Madhav *et al.* (2017) where gum Arabic did not have any effect on the taste and appearance of the beverage prepared. The marmalades containing 1% and 2% gum Arabic scored best in terms of flavour. Marmalades containing 2% and 3% gum arabic had the best scores for texture with 2% gum Arabic scoring best in terms of spreadability. However, the marmalades without any gum Arabic scored least in terms of the general acceptability. In a study where gum Arabic was used as a water binder in low fat skim yogurt, similar results were reported where the control skim yogurt had the lowest values in all aspects except appearance and taste (Mugo, 2012). From the same study, it was found that the addition of gum Arabic to skim milk yogurt improved the texture and body of the yogurt as well as the acceptability rating. This was attributed to the high molecular weight and gelling properties of *Acacia senegal* var. *kerensis* gum leading to a better mouth feel. The gel strength positively correlated with consumer acceptance of yogurt (Frost & Janhoj, 2007).

Table 7: Means for the different sensory attributes due to the effect of different levels of gum arabic

Gum level	Colour	Flavour	Aroma	Texture	Taste	Spreadability	General
0%	$5.80^{a}\pm0.10$	$5.35^{b}\pm0.16$	$5.20^{a}\pm0.21$	$4.83^{b}\pm0.22$	$5.55^{ab}\pm0.18$	$4.75^{c}\pm0.12$	$5.12^{b}\pm0.15$
1%	$5.87^{a}\pm0.10$	$5.83^{a}\pm0.15$	$5.43^{a}\pm0.19$	$5.27^{ab}\pm0.22$	$5.22^{b}\pm0.18$	$5.78^{ab}\pm0.15$	$5.68^{a}\pm0.12$
2%	$6.05^{a}\pm0.11$	$5.97^{a}\pm0.14$	$5.28^{a}\pm0.16$	$5.55^{a}\pm0.19$	$5.53^{ab}\pm0.15$	$6.10^{a}\pm0.12$	$5.87^{a}\pm0.15$
3%	$6.03^{a}\pm0.11$	$5.67^{ab}\pm0.15$	$5.32^{a}\pm0.18$	$5.55^{a}\pm0.17$	$5.50^{ab}\pm0.14$	$5.60^{b}\pm0.15$	$5.55^{a}\pm0.14$
4%	$6.05^{a}\pm0.11$	$5.73^{ab}\pm0.14$	$5.57^{a}\pm0.15$	$5.53^{a}\pm0.17$	$5.85^{a}\pm0.14$	$5.82^{ab}\pm0.16$	$5.92^{a}\pm0.12$
5%	$6.12^{a}\pm0.10$	$5.60^{ab}\pm0.12$	$5.60^{a}\pm0.14$	$5.87^{b}\pm0.14$	$5.70^{ab}\pm0.17$	$6.03^{ab}\pm0.14$	$5.93^{a}\pm0.12$

Means within a column with the same superscript letters are not significantly different at $p< 0.05$.

The results of the interaction between the fruit type and level of gum Arabic used to formulate the marmalades against different attributes are indicated as shown in the table 8 below. Lemon marmalade with 1% and 5% scored best for colour (6.23±0.12). Lemon marmalade with 5% gum Arabic further scored best in terms of aroma and texture at 5.60±0.14 and 5.93±0.12 respectively at $p<0.05$. Orange marmalade containing 2% gum Arabic scored best in terms of flavour, taste and spreadability while the orange marmalade with 4% gum Arabic scored best in terms of general acceptability. The marmalades containing gum Arabic at the levels of 2% and 3% scored best for texture. It was also observed that the marmalades having level 2% gum Arabic scored best in the attribute of spreadability. Texture is a very important parameter for sensory acceptance (Herbstreith & Fox, 2010). Texture depends largely on the composition of raw material such as the type of fruit, fruit quantity, and sugars used but also on the type of hydrocolloids used (Cropotova *et al*., 2015). For the purpose of spreading jam on slices of bread, it should be noted that jams with a lower elastic phase are more difficult to spread (Herbstreith & Fox, 2010). In the extreme case, this implies that jellies spread on bread slices with a knife will just break up from a large lump into many smaller pieces (Herbstreith & Fox, 2010). Gels with a higher viscous share will spread easily and form a coherent jelly layer on the bread. From the study, the increase in the concentration of gum Arabic led to an increase in the viscous share making it easier to spread.

Table 8: Means for the different sensory attributes due to the effect of interaction between levels of gum arabic and fruits

Fruit	Gum	Colour	Flavour	Aroma	Texture	Taste	Spreadability	General
Lemon	0%	5.80^{c}±0.13	4.50^{f}± 0.18	5.27^{c}±0.29	4.97^{d}± 0.35	5.23^{e}± 0.25	4.77^{e}±0.18	5.53^{c}± 0.19
	1%	5.90^{c}±0.15	5.50^{cd}±0.25	5.53^{ab}±0.27	5.37^{c}± 0.32	4.70^{g}± 0.22	5.63^{c}±0.19	5.53^{c}± 0.19
	2%	5.97^{bc}±0.18	5.67^{c}±0.23	5.57^{ab}±0.22	5.47^{c}±0.25	4.93^{f}± 0.19	5.97^{b}±0.17	5.60^{bc}±0.23
	3%	6.23^{a}±0.13	5.47^{d}±0.25	5.30^{c}±0.25	5.37^{c}±0.28	5.17^{cd}±0.17	5.93^{b}±0.22	5.50^{c}±0.24
	4%	6.03^{bc}±0.14	5.37^{d}±0.23	5.60^{ab}±0.21	5.37^{c}±0.19	5.47^{d}±0.21	5.63^{c}±0.24	5.60^{bc}±0.18
	5%	6.23^{a}±0.12	5.17^{e}±0.14	5.70^{a}±0.16	5.93^{a}±0.21	5.67^{c}±0.27	6.17^{ab}±0.19	6.13^{ab}±0.18
Orange	0%	5.80^{c}±0.15	6.20^{b}±0.13	5.13^{cd}±0.32	4.70^{e}±0.29	5.87^{b}±0.26	4.73^{e}±0.18	4.70^{d}±0.21
	1%	5.83^{c}±0.14	6.17^{ab}±0.13	5.33^{bc}±0.27	5.17^{cd}±0.30	5.73^{bc}±0.26	5.93^{b}±0.24	5.83^{b}±0.14
	2%	6.13^{ab}±0.13	6.27^{a}±0.15	5.00^{d}±0.21	5.63^{bc}±0.29	6.13^{a}±0.16	6.23^{a}±0.18	6.13^{ab}±0.19
	3%	5.83^{c}±0.17	5.87^{bc}±0.16	5.33^{bc}±0.25	5.73^{ab}±0.21	5.83^{b}±0.21	5.27^{d}±0.19	5.60^{bc}±0.15
	4%	6.07^{b}±0.15	6.10^{ab}±0.14	5.53^{bc}±0.22	5.70^{b}±0.28	6.23^{a}±0.16	6.00^{b}±0.22	6.23^{a}±0.15
	5%	6.00^{bc}±0.17	6.03^{b}±0.15	5.50^{b}±0.24	5.80^{ab}±0.18	5.73^{bc}±0.22	5.90^{b}±0.22	5.73^{bc}±0.14

Means within a column with the same superscript letters are not significantly different at $p< 0.05$.

4.4.2 Jam

It was observed that the effect of the type of fruit was highly significant on the flavour, aroma, taste, spreadability as well as general acceptability of the fruit jam. The level of gum used in the jam and the interaction of the gum and the fruit used to make the jam was highly significant on the spreadability of the jam at $p<0.001$. The means for the different sensory attributes due to the effect of different fruits are presented in Figure 4. Red plum jam recorded better scores compared to pineapple jam in terms of the flavour, aroma, taste, spreadability and general acceptability.

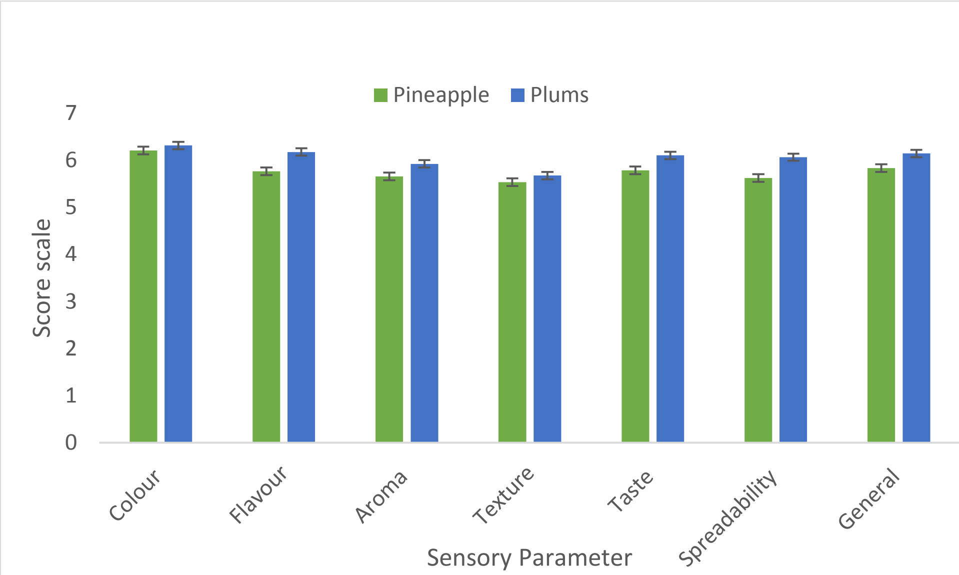


Figure 4: Means of different sensory parameters in jam

The means for the different sensory attributes due to the effect of different levels of gum Arabic are presented in Table 9. The level of gum used had no significant difference at $p<0.05$ in terms of colour, flavour, and aroma of the jam. This is attributed to the properties of gum Arabic making it suitable for use in the food industry as it is odourless and colourless (Soibe *et al*., 2015). However, the addition of gum Arabic at 5% level in jam scored best for texture, taste, spreadability and general acceptability at $p < 0.05$. Gum Arabic has a similar effect on jam as in marmalades in terms of texture and spreadability. Higher concentration of gum Arabic was preferred among the panelists. It is observed that an increase in gum Arabic in the jam increases the elastic phase therefore making the jam easy to spread on the bread giving it a smoother texture. Awad and Shokry (2018) reported no significant differences ($p < 0.05$) in the general acceptability of pumpkin jam made by varying the composition of pumpkin jam with orange juice. A similar study where pomegranate jam was made different spices and cloves indicated that there was no significant difference in the overall acceptability of the jams with spices at $p < 0.05$ (Shokry *et al*., 2018).

Table 9: Means for the different sensory attributes due to the effect of different levels of gum arabic

Gum	Colour	Flavour	Aroma	Texture	Taste	Spreadability	General
0%	$6.31^{a}\pm0.09$	$6.01^{a}\pm0.13$	$5.83^{a}\pm0.12$	$5.57^{ab}\pm0.13$	$6.15^{a}\pm0.11$	$5.97^{a}\pm0.14$	$6.07^{a}\pm0.12$
1%	$6.30^{a}\pm0.08$	$5.98^{a}\pm0.13$	$5.78^{a}\pm0.13$	$5.30^{b}\pm0.13$	$5.85^{a}\pm0.13$	$5.10^{b}\pm0.20$	$5.86^{a}\pm0.11$
2%	$6.28^{a}\pm0.09$	$5.77^{a}\pm0.11$	$5.73^{a}\pm0.14$	$5.62^{ab}\pm0.14$	$5.80^{a}\pm0.14$	$5.73^{a}\pm0.13$	$5.85^{a}\pm0.12$
3%	$6.28^{a}\pm0.08$	$5.91^{a}\pm0.11$	$5.77^{a}\pm0.14$	$5.63^{ab}\pm0.15$	$5.78^{a}\pm0.13$	$6.14^{a}\pm0.11$	$5.93^{a}\pm0.13$
4%	$6.06^{a}\pm0.09$	$6.03^{a}\pm0.14$	$5.72^{a}\pm0.13$	$5.67^{ab}\pm0.14$	$5.93^{a}\pm0.12$	$6.19^{a}\pm0.12$	$5.97^{a}\pm0.11$
5%	$6.29^{a}\pm0.09$	$6.10^{a}\pm0.11$	$5.91^{a}\pm0.13$	$5.81^{a}\pm0.13$	$6.14^{a}\pm0.12$	$6.92^{a}\pm0.15$	$6.25^{a}\pm0.10$

Means within a column with the same superscript letters are not significantly different at $p< 0.05$.

The means for the different sensory attributes due to the effect of interaction between the different levels of gum Arabic and the type of fruit are presented in Table 10 below. The jam prepared with plums and containing a level of 5% gum Arabic was much liked for all the attributes evaluated followed by the 3% gum Arabic level. For the jam prepared from pineapples, a similar observation was made. That is, the jam containing a level of 5% gum Arabic was highly scored for all the key variables (Table 10).

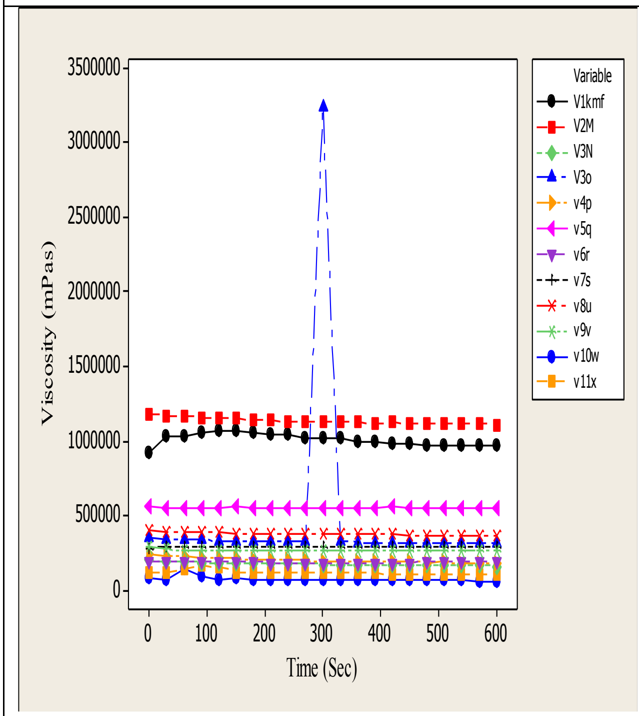
Table 10: Means for the different sensory attributes due to the effect of interaction of the different levels of gum arabic and the fruit

Fruit	Gum	Colour	Flavour	Aroma	Texture	Taste	Spreadability	General
pineapple	0%	6.13^{cd}±0.13	5.72^{cd}±0.20	5.65^{bc}±0.18	5.53^{bc}±0.19	6.03^{a}±0.16	5.50^{e}±0.22	5.95^{bc}±0.20
	1%	6.30^{bc}±0.13	5.80^{cd}±0.21	5.63^{c}±0.18	5.13^{d}±0.16	5.57^{d}±0.21	3.97^{g}±0.20	5.58^{d}±0.17
	2%	6.30^{bc}±0.12	5.60^{d}±0.14	5.73^{bc}±0.19	5.67^{b}±0.18	5.83^{c}±0.20	5.60^{d}±0.18	5.70^{cd}±0.20
	3%	6.20^{c}±0.15	5.65^{cd}±0.16	5.57^{c}±0.21	5.30^{cd}±0.21	5.43^{d}±0.16	5.82^{c}±0.17	5.67^{cd}±0.16
	4%	5.98^{d}±0.15	5.81^{c}±0.21	5.52^{c}±0.18	5.81^{ab}±0.19	5.81^{c}±0.18	6.27^{b}±0.18	5.87^{c}±0.16
	5%	6.28^{bc}±0.16	6.00^{b}±0.18	5.83^{b}±0.17	5.72^{b}±0.19	6.03^{b}±0.18	6.59^{a}±0.21	6.22^{ab}±0.15
Plums	0%	6.48^{a}±0.10	6.30^{a}±0.17	6.02^{a}±0.16	5.60^{bc}±0.19	6.27^{a}±0.14	6.43^{ab}±0.13	6.13^{ab}±0.13
	1%	6.30^{bc}±0.09	6.17^{a}±0.15	5.92^{ab}±0.18	5.47^{c}±0.20	6.13^{ab}±0.13	6.23^{b}±0.16	6.13^{ab}±0.13
	2%	6.27^{bc}±0.14	5.93^{ab}±0.17	5.72^{bc}±0.20	5.57^{bc}±0.22	5.77^{c}±0.21	5.87^{c}±0.19	6.00^{bc}±0.13
	3%	6.35^{b}±0.10	6.17^{a}±0.13	5.97^{ab}±0.17	5.95^{a}±0.19	6.13^{ab}±0.17	6.47^{ab}±0.12	6.18^{ab}±0.20
	4%	6.13^{cd}±0.10	6.27^{a}±0.17	5.93^{ab}±0.19	5.53^{bc}±0.20	6.05^{b}±0.16	6.10^{b}±0.18	6.07^{b}±0.16
	5%	6.30^{bc}±0.11	6.20^{a}±0.14	5.98^{ab}±0.20	5.90^{ab}±0.17	6.23^{ab}±0.18	5.27f±0.14	6.27^{a}±0.14

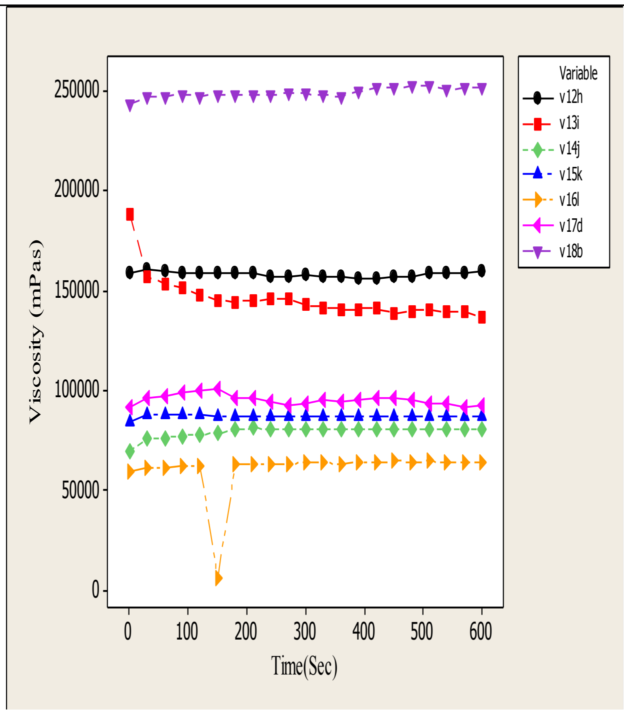
Means within a column with the same superscript letters are not significantly different at $p < 0.05$.

4.5 Effect of Gum Arabic on the Viscosity of Jam and Marmalade

Factors observed were the behavior of the different products in terms of shear thinning (graph a) and thickening (graphs b) for different marmalade and jam products.



a.



b.

Figure 5: Viscosity of jams and marmalades.

Key:V1KMF-Kenylon Mixed Fruit Jam; V2M-0% Gum arabic Pineapple jam, V3N- 1% Pineapple jam, V3o- 2% gum pineapple jam, v4p-3% gum Arabic pineapple jam, v5q-4% gum Arabic pineapple jam, v6r-5% gum Arabic pineapple jam; v7s- 0% gum Arabic plum jam, v8u-2% gum arabic plum jam, v9v-3% gum Arabic plum jam, v10W-4% gum Arabic plum jam, v11x-5% gum Arabic plum jam; v12h-1% lemon marmalade, v13i-2% lemon marmalade, v14j-3% gum Arabic lemon marmalade, v15k- 4% gum Arabic lemon jam, v16l-5% gum Arabic lemon marmalade, v17d-1% gum arabic orange marmalade, v18b-3% gum arabic orange marmalade.

From the above graphs, there is a general trend where the fruit spreads display a yield followed by thinning as the curves slope downwards. This is observed in the KMF which is the commercial jam used in the study for comparison as well as samples V10W, V11X, V6R, V3O and Sample V8U. Jam and marmalade are considered as structured fluids since they contain more than one phase therefore there rheological and viscosity properties are generally dominated by the interactions of the constituents. This is contrary to the results from sample containing 4% gum arabic in pineapple jam as it indicates a Newtonian fluid. Contrary also is sample with 3% gum arabic lemon marmalade that exhibits shear thickening with the viscosity increasing with time. The viscosity of a material is a mainly dependent on its composition. When the composition is modified, either by changing the proportions of the component substances, a change in viscosity is likely to occur. Pectin in jam and marmalade is supposed to immobilize the free water in the product by binding the water. Syneresis may result if the desired water binding effect is not completely achieved in the gel production, or during further processing of the gel. These gels show a tendency to shrink and to release fluid. The pectin chains approach each other too closely and squeeze the originally bound water out of the gel network causing syneresis (Herbstreith & Fox, 2010).

In a study by Javanard and Endan (2007), it was observed that mango showed non-Newtonian behavior with pseudoplastic characteristics. The mango jam samples used in the study exhibited yield stress. The apparent viscosity increased with the concentration of sago starch (Javanmard & Endan, 2010). From the same study, the decrease in apparent viscosity due to increase in temperature could be attributed to increase in the thermal energy of the molecules and consequently, increase in the intermolecular distances within the starch network. Increase in the apparent viscosity with sago starch concentration was explained by the increase in the amylose content. Nwaokoro and Akambi (2015) reported a decrease in viscosity of tomato carrot juice blend containing hydrocolloids. The juice blends containing hydrocolloids had a higher viscosity compared to the juice blends without hydrocolloids. The presence of hydrocolloids; carboxymethylcellulose and xanthan gum increase the viscosity of juice when stored at room temperature (Nwaokoro & Akambi, 2015). In low fat yoghurt containing gum arabic, it was observed that the apparent viscosity increased significantly ($p<0.05$) as the starch content was increased in the product. The gum used in the study (*Acacia senegal* var. *kerensis*) did not have an effect on the starch in the yogurt. Aggregation of the protainaceous components induced by heat treatment, increases the hydrodynamic volume and subsequently produced a hydrogel form with enhanced mechanical properties and water binding capability (Al-Assaf *et al*., 2007).

Gum Arabic from *Acacia senegal* gives rise to contact molecules with a relatively small hydrodynamic volume and as a consequence gum solutions only become viscous at high concentration. Gum solutions show evidence of shear thinning at very low shear rates even at concentrations in the dilute regime below the critical overlap concentration (Williams & Phillips, 2009). The viscosity of gum Arabic solutions (3%) was found to have increased over time when subjected to a constant shear. However, gum Arabic solutions (6%) develop weak gel characteristics on standing for 2 h period with the storage modulus increasing significantly and becoming larger than the loss modulus. Gum arabic is a polyelectrolyte, the solution viscosity decreases in the presence of electrolytes due to charge screening and at low pH when the carboxyl groups become undissociated (Williams & Phillips, 2009).

Clumps or flocs in a sample also occupy a certain volume in a food sample such as a marmalade containing peels of the fruits used. The viscosity of such clumps will end to be higher than the ordinary sample without the peels where the volume of clumps is much lower. This is due to the force required to break up the solid component of the gel matrix as observed by the sharp inclination on sample of plum jam and orange marmalade containing 0% gum arabic and plum jam with 4% gum arabic. When flocs are accumulated in a gel, the reaction of the aggregates to shear can result in shear thinning or pseudoplastic flow. The aggregates in a material may be deformed but remain basically intact at low shear rates. The aggregates may be broken down into individual flocs as the shear rate is increased, decreasing the friction and therefore viscosity. When the bonds within the aggregates are extremely strong, the system may display a yield value as observed in sample S and W. The magnitude of yield value depends on the force required to break the bonds. The shape of particles making up the dispersed phase is of importance in determining a system's rheology. Particles suspended in a flowing medium are constantly being rotated. If the particles are basically spherical as was the case of lemon marmalade, rotation of the spindle can occur freely. However, if the particles are needle or plate-shaped, the ease of spindle rotation is less predictable as is the effect with varying shear rate. This is the case in orange marmalade where the orange peels used were plate shaped making it difficult to analyze under the LV-64 spindle that was used in this study. The peels used in lemon marmalade were spherical in shape making it easier to analyze for viscosity using the same spindle.

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

i. Gum Arabic from *Acacia senegal* var. *kerensis* reduces the level of syneresis of fruit jam and marmalade by changing the texture of fruit spreads when used as an additive.

ii. Gum arabic from *Acacia senegal* var. *kerensis* has no significant effect on the microbial quality of the fruit spreads when used as an additive.

iii. From the study, it was concluded that the level of gum to be used in fruit jam i.e. plum and pineapple be at 5%, as this was the best level of inclusion preferred by the panelists. In marmalades, 4% gum Arabic would be the recommended level for orange marmalade while 5% will be the recommended level for lemon marmalade based on the general acceptability of the products.

5.2 Recommendations

i. Further research needs to be done on the rheology and shelf life of the products formulated using gum Arabic.

ii. There is need for developing better methods that can be used to quantitatively measure the degree of syneresis in fruit spreads.

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APPENDICES

Appendix I

Score sheet for a 7 Hedonic Scale Ranking (1=Extremely Dislike to 7= Extremely Like)

No. panelist………………………………… Name of Panelist…………………………….

Date…………………….

Instruction:- You are provided with coded samples, Kindly score and record each sample per your judgement of the attributes listed on thee left side of the table in the approprate box.

Attribute	**Hedonic Scale**	**Sample Codes**					
Colour	(1=Extremely dislike to 7= Extremely Like)						
Aroma	(1=Extremely dislike to 7=Extremely like)						
Texture	(1=Extremely dislike to 7=Extremely like)						
Taste	(1=Extremely dislike to 7=Extremely like)						
Spreadability	(1=Extremely dislike to 7=Extremely like)						
General Acceptability	(1=Extremely dislike to 7=Extremely like)						
General Comment							

Appendix II

Statistical layout for the experiment

INDEPENDENT VARIABLES																
Fruit	Gum level (%)	Reps	Proximate analyses					Sensory properties						Microbiology		
Plum			M.C	Protein	FATS	ASH	Carbohydrates	Color	Aroma	Texture	Spreadabilty	Taste	Overall Acceptability	Y&M	TVC	TCC
	0	3														
	0.5	3														
	1.0	3														
	1.5	3														
	2.0	3														
Pineapple	0	3														
	0.5	3														
	1.0	3														
	1.5	3														
	2.0	3														
Orange	0	3														
	0.5	3														
	1.0	3														
	1.5	3														
	2.0	3														
Lemon	0	3														
	0.5	3														
	1.0	3														
	1.5	3														
	2.0	3														

Appendix III: Mean square table for the main factor and factorial effect for different dependent variables of the jam

S.O.V	DoF	MC	Protein	Fibre	Ash	Fat	CHO	Vitamin C
Fruit	1	166.41^{***}	0.00^{ns}	2.50^{***}	1.72^{***}	0.01^{***}	253.74^{***}	81.41^{*}
Gum	5	24.10^{***}	0.17^{***}	1.74^{***}	0.04^{***}	0.00^{***}	35.38^{***}	12.21^{ns}
Fruit*Gum	5	50.97^{***}	0.08^{***}	1.53^{***}	0.04^{***}	0.00^{***}	51.51^{***}	12.93^{ns}
Reps	2	0.55^{***}	0.00^{ns}	0.03^{ns}	0.00^{ns}	0.00^{ns}	0.81^{***}	11.41^{ns}
Error	22	0.03^{***}	0.00^{***}	0.03^{***}	0.00^{***}	0.00^{***}	0.06^{***}	171.52
CV		0.59	5.96	13.09	11.74	11.90	0.37	47.27
R		99.89	99.10	96.12	96.61	89.30	99.79	47.27
MSD		0.11	0.02	0.13	0.04	0.01	0.18	2.36

Key: S.O.V = Source of variation; DoF = Degree of freedom; Reps = Replicates * = significant at p<0.05 and *** = significant at p <0.001

Appendix IV: Publication

Scientific Research Publishing

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Sensory Evaluation of Syneresis Reduced Jam and Marmalade Containing Gum Arabic from *Acacia senegal* var. *kerensis*

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Abstract

Jams and marmalades are some of the most popular food products because of their low cost, all year long availability and appealing sensory properties. These products are described as gels with pectin as the gelling agent used in its formulation. Gels are a form of matter intermediate between a solid and a liquid. They consist of polymeric molecules cross-linked to form tangles, and interconnected molecular network immersed in a liquid medium. However, the jams and marmalades require stabilization by hydrocolloids. The most common hydrocolloid stabilizer is pectin which is available as a low methoxy pectin or high methoxy pectin. Unfortunately, under mechanical stress, pectin gels may be damaged leading to the release of colloidal water. The release of the colloidal water is termed as syneresis. This problem may be solved by integrating pectin with other stabilizers having thickening properties. Jams were prepared using plums and pineapples while marmalades were prepared from oranges and lemons. Gum Arabic from *Acacia senegal* var. *kerensis* was added in the range of 1% - 5% which fell within the additives category. The prepared jams and marmalades underwent sensory evaluation using semi-trained panelists. The prepared jams and marmalades showed no evidence of syneresis. The jams and marmalades were subjected to a sensory panel who scored the different attributes against a 7-point hedonic scale. Gum Arabic at different levels was found to have a significant contribution to the consumer acceptance of the fruit spreads prepared. This is the first time that syneresis reduced jams and marmalades containing gum Arabic from *Acacia senegal* var. *kerensis* are being reported. Sensory evaluation was carried out on different fruit spreads used in the study to assess the impact of gum Arabic from *Acacia senegal* var. *Kerensis*. The parameters include taste, texture, spreadability, aroma, flavour, colour and general acceptability. Red plum jam and Pineapple jam had its best performance for general acceptability use at 5% level of gum Arabic whereas 4% gum Arabic level performed best for general acceptability for Orange marmalade and 5% level best for Lemon marmalade in terms of general acceptability.

Keywords

Gum Arabic, Syneresis, Jam, Marmalade

Appendix V: Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **274862**

Date of Issue: **07/January/2020**

RESEARCH LICENSE

This is to Certify that Miss.. Ruth Kavaya of Egerton University, has been licensed to conduct research in Nakuru on the topic: Analysis of Quality Characteristics of Fruit jam and marmalade containing Gum Arabic from Acacia senegal var. kerensis as a water binder for the period ending : 07/January/2021.

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