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Production of Jam from Millet supplemented with Prebiotic Hashab Gum Arabic

انتاج مربى من الدخن مدعمة بصمغ الهشاب كمحفز للبكتيريا الصديقة

A dissertation submitted to Sudan University of Science and Technology in partial fulfillment for the degree of B.Sc. in food science and technology

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الأية

قال تعالي :

(وَأَوْحَى رَبُّكَ إِلَى النَّحْلِ أَنِ اتَّخِذِي مِنَ الجِبَالِ بُيُوتًا وَمِنَ الشَّجَرِ وَمِمَّا يَعْرِشُونَ * ثُمَّ كُلِي مِن كُلِّ الثَّمَرَاتِ فَاسْلُكِي سُبُلَ رَبِّكِ ذُلُلاً يَخْرُجُ مِن بُطُونِهَا شَرَابٌ مُّخْتَلِفٌ أَلْوَانُهُ فِيهِ شِفَاءٌ لِّلنَّاسِ إِنَّ فِي ذَلِكَ لآيَةً لِّقَوْمٍ يَتَفَكَّرُونَ)

صدق الله العظيم

سورة النحل الأيه (68-69)

Dedication

To the soul of my fathers - be it in higher paradise

To our dear mother

To our loved brothers ……To my loved sisters

To our loved aunts & uncles

To our teacher's and friends

****

We dedication this work with love and respect

Omnia & Mahgob

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Abstract

This study was carried out to utilize millet (*Pennistum glaucum*) grains as a raw material for production of jam. The cleaned grains were weighted (200g), washed thoroughly with tab water to remove all residual dirty. Then the grains were soaked in boiling water for to remove bitter taste of the millet and soften mixture for easy homogenization. Soaked grains were blended by electrical blender (mixer) and sieved by gauze cloth. Whole millet beverage and beverage extract were used to produce two type of millet jam. Different analyses were carried out including: proximate composition, sugar, physicochemical properties, microbiological safety and sensory quality. Millet grains contained high level of protein, fat, crude fiber, and ash. There were significant ($p<0.05$) differences in components of jams due to variation in source and types of raw material involved in formulation process. Whole millet beverage jam recorded the highest levels of protein, ash, and fiber compared to other two types because the bran is rich source of nutrients. The supplementation with hashab gum also contributed in improving level of fiber in formulated jam. The energy values of millet formulated jams were lower than that of the control jam (Trobicana). There were significant ($p<0.05$) differences in different sugars profiles of jams. Jams formulated from millet based beverages contained high levels of total and none-reducing sugar as compared with the control (Trobicana) due to hashab gum supplementation. There were no significant ($p<0.05$) differences in hydrogen ion concentration, titrable acidity and total soluble solids between different jam products. The results obtained on aerobic total count, coliform, *E.coli*, salmonella and yeast and mold of jams indicate safety of different products. The result of sensory characteristics indicated that there was no significant ($p< 0.05$) differences in flavor, taste, texture, overall acceptability between different millet formulated jam and the control (Tropicana).Therefore, it is possible to produce jam from millet based having better nutritive value, acceptable, added functional properties from local available raw material (millet).

ملخص البحث

اجريت هذه الدراسة لاستخدام حبوب الدخن كمادة خام لانتاج المربى ,تمت نظافة حبوب الدخن وغسلت بالماء لازالة الاوساخ. ومن ثم غمرت في ماء مغلي لازاله الطعم المر وتليين الانسجة لتسريع عملية التجنيس تم خلط الحبوب بعد الغمر باستخدام الخلاط ومن ثم تمت التصفية بالقماش استخدم عصير الدخن الكامل والمستخلص لتصنيع نوعين من المربى اجريت تحاليل مختلفة تضمنت.

التحليل التقريبي السكريات الخصائص الفيزوكيمائية والسلامة المايكرو بايولوجيا والجودة الحسية ،احتوت حبوب الدخن علي مستويات عالية من البروتين الدهون الالياف والرماد .

هنالك اختلافات معنويه في مكونات المربات لتباين المصادر وانواع المادة الخام المستخدمة في خلطة التصنيع .

احتوت مربى عصير الدخن الكامل علي اعلي المستويات علي البروتين والرماد والالياف مقارنة بين النوعين الاخريتين لان الردة غنية بالعناصر, التدعيم بالصمغ ايضا ساهم في تحسين نسبة الالياف .

قيم الطاقة لمربات الدخن كانت اقل من عينة المربى التحكيميه (تروبيكانا) هنالك اختلافات معنويه في محتوى سكريات المربات.

المربات من الدخن احتوت نسب عالية من السكريات الكلية والسكريات غير المختزلة مقارنة بالعينة التحكيمية (تروبوكانا) وذلك لتدعيم عينات الدخن بصمغ الهشاب.

لا توجد اختلافات معنوية في الرغم الهيدروجيني الحموضة والجوامد الصلبة الكلية بين منتجات المربات .نتائج العدد الكلي الباكتيريا الهوائية الكلوفورم و الباكتيريا البرازية و السالمونيلا والخمائر والاعفان للمربات اشارت الي سلامة المربات .

نتائج التحليل الحسي اشارت الي عدم وجود فروقات معنوية في النكهة الطعم والملمس والقبول العام بين المربات لذلك من الممكن انتاج مربى من الدخن بخصائص غذائية محسنة مقبولة و مضافة قيمة وظيفيه من مواد خام محلية (الدخن) .

Chapter One

1.Introduction

Fruits and vegetables do not have a long shelf life in their un-processed forms. Un-processed fruits and vegetables are food commodities that are perishable. Thus, most kinds of fruits and vegetables are usually processed into jam, juices, jellies or pickles in order to extend their shelf life **(Singh, 2014**).

Different fruits will give each product its characteristic flavor and color. Normally, ripen fruits are used for producing better taste of jam. Acid is added into jams for both gel formation and flavoring purpose. The amount of acids added varies among fruits used for jam production. Usually, under-ripen fruits will need higher amount of acids besides acids, sugar is also another important ingredient for jam production. This is because sugars can help in preserving fruits, forming gel and also contributing in the flavor of jam **(Ingham, 2008).**

Pectin is a naturallyocurring thickening agent that is most often used in the jams a nd jellies products to help them gel and thicken. It is a carbohydrate found in anda round cell walls of plants. Pectin helps to bind the cells together. Most of the fruitscontain pectin. However, the amount of pectin contained in each fruit is Varies widely. Apples contain the most pectin, thus its pectin is used commercially to thicken many different types of products. Pectin generally needs some acids and a high sugar content to be activated. Thus, the commercially available pectin will include citric acid as an ingredient to help ensure it is working with the products successfully. Pectin can be in both powder and liquid forms **(Anonymous, 2012).**

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) Is an important crop in arid and semi-arid tropics of Asia and Africa, where it is cultivated for food, fodder and building materials? As a staple cereal, it represents the most common source of energy and micronutrients for millions of the world's poorest crop-livestock producers **(Fao-icrisat, 1996; Rao *et al.*, 2006)**. The West African Sahelian belt from the Sahara Desert to the Sudanian savanna zone is the centre of origin for pearl millet, which was domesticated some 4000 to 4800 years ago **(Harlan, 1971; Tostain, 1992; Oumar *et al.*, 2008; Manning *et al.*, 2011; Clotault *et al.*, 2012).**

In the western region of Sudan, pearl millet is grown as a grain crop for preparing fermented or unfermented pancake (‘Kisra’), stiff (‘Aseda’) or thin (‘Nasha’) porridges, and local alcoholic beer (‘Marisa’) or non-alcoholic (‘Abrei’ or ‘Hullu-murr’) beverages. Since the diets in this region are characterized by a strong

prevalence of pearl millet, high contents of bioavailable micronutrients in pearl millet grain could significantly contribute to the reduction of malnutrition.

Saeed and El-Mubarak (**1975**) reported that a highly acceptable jam was manufactured from kordufan water melon. Also, **Elfakia and Saeed** (**1975**) studied suitability of Guavas for jam processing. The ascorbic acid content of the jam was found to be 38.6 mg and 14.0 mg/100 g in white guava and pink guava. Also, the pectin content was found to be high in both types. **Saeed *et al*.** (**1976**) mentioned that, when Daleib (Borassus aethiopum L) was mixed with pumpkin, orange and mango for production of jams, the products where found with very good quality and acceptability indicating the great potentiality of Daleib in jam production as flavouring and coloring material. Although different raw materials were used in formulation of jam, production of cereal based jam was not much explored particularly in Sudan.

1.2 Main objective

To produce jam from millet grains supplemented with hashab gum arabic

1.3 Specific objectives

1. To determine proximate composition of millet grains.
2. To determine chemical composition of different jam formulated using millet grain.
3. To evaluate the effect of using whole millet beverage or its extract on quality and sensory characteristics of formulated jams.
4. To estimate safety and microbiological quality of millet based formulated jams.

Chapter Two
2. LITERATURE REVIEW

2.1 Jam

2.1.1 Definition of jam:

Jam is generally defined as a solid gel made from fruit pulp or juice, sugar and added pectin. The jam can be made from a single fruit or a combination of fruits. The fruit content should be at least 40% with a total sugars content of not less than 68% **(ICUC, 2004).**

Jam is an intermediate moisture food prepared by boiling fruit pulp with sugar (sucrose), pectin, acid, and other ingredients (preservative, coloring, and flavoring materials) to a reasonably thick consistency, firm enough to hold the fruit tissues in position **(Baker *et al*., 2005; Lal *et al*., 1998).**

Jam is a mixture brought to a suitable gelled consistency of sugars, the pulp and/ or purée of one or more kinds of fruit and water **(www.agriculture.gov.ie).** Generally, jam is produced by taking mashed or chopped fruit or vegetable pulp and boiling it with sugar and water. The proportion of sugar and fruit varies according to the type of fruit and its ripeness, but a rough starting point is equal weights of each. When the mixture reaches a temperature of 104 °C, the acid and the pectin in the fruit react with the sugar, and the jam will set on cooling **(Berolzheimer et al., 1959).**

2.1.2 Jam ingredients

For making a good jam three main ingredients are needed this are pectin, sugar, and citric acid. The pectin forms the gel structure which makes the jam firm rather than a runny pulp of juice. The sugar and acid are necessary to make pectin set into a firm gel **(Malcolum, 2005; Pradeep, 2013).**

2.1.2.1 Fruit:

Factors that have an influence on quality of jam consist of color content, taste, flavor, and texture and nutritional value. All the parameters mentioned are affected from the nature of the raw material and the processing conditions. The quality of the raw material and the manufacturing process are the indicators of the final products quality **(Nindo et al., 2005).** Fruits using in jam processing including: Citrus fruit (orange, grape fruit), mango, karkadi, pumpkin, water melon, other fruits or vegetables.

2.1.2.2Pectin (E440i):

Pectin is found in most fruits with different levels according to fruits type maturity. Unripe fruits have a lots of pectin which gives the fruit its firm and hard texture. As a fruits ripens, the pectin is broken down and so the fruit become soft and easy to eat. Some fruits provide enough pectin for jam or jelly making whilst others need to have pectin added from another source. Usually, fruit with high pectin content can be added to fruit with a low pectin content to give an adequate amount of pectin **(Kordylas, 1990; Pradeep, 2013).**

The different types of commercial pectin's, which are according to their application are:

- Rapid set pectin: Traditionally used for jams and marmalades.
- Slow set pectin: Used for jellies and for some jams and preserves, especially using vacuum cooking at lower temperatures. Also important for higher sugar products like bakery and biscuit jams, sugar confectionery, etc.
- Stabilizing pectin's: Used for stabilizing acidic protein products such as yoghurts, whey and soya drinks against heat processing.
- Low methyl ester and amidated pectin's: Used in a wide range of lower sugar products, reduced sugar preserves, fruit preparations for yoghurts, dessert gels and toppings, and savory applications such as sauces and marinades. Can also be used in low acid high sugar products such as preserves containing low acid fruits (figs, bananas) and confectionery.

2.1.2.3 Sugar:

Sugar is present in all fruits but it is not enough to preserve jam. In order to preserve the jam a higher sugar concentration is needed, also, it helps the pectin to form a firm gel structure. Normally, an equal amount of sugar is added to the fruit pulp or juice and then the excess water is evaporated to give the required sugar concentration **(Kordylas, 1990; Pradeep, 2013).** The added sugar acts as a dehydrating agent for the pectin molecules, permitting closer contact between the chain molecules **(Suutarinen, 2002).**

2.1.2.4Acid:

Acid is necessary for three purposes:

i. It helps the pectin to set into a firm gel.
ii. It prevents sugar crystallization.
iii. It improves jam color and flavor. All fruits contain organic acid which differ in the different fruit varieties. Some fruits provide enough acid for a good jam, while in

others acid should be added from another source. The organic acid are usually citric acid, malic acid and tartaric acids. These acids are available in powdered form if the powdered acids are not available, fruits with high acid content can be mixed with fruits with low acid content to give enough acid for a good gel formation, Lemon or lime juice is generally used. Also, some unripe fruit can provide a high acid content **(Kordylas, 1990 and Pradeep, 2013).**

2.1.2.5Gum Arabic (E414)

Is made from the sap of the acacia tree and is a mixture of saccharides and glycoproteins (proteins with attached sugar molecules). Commercially, most is extracted from trees in countries south of the Sahara desert in Africa, and the biggest producers are Chad, Nigeria and Sudan. Food uses include hard jelly sweets and soft drinks **(https://www.faia.org.uk, 2012).**

2.1.3 Jam making:

Jam making still is one of the most important methods for fruits preservation. Jam is usually prepared by cooking the whole fruits or fruit pulp with sugar and pectin to a suitable consistency (**Cruess, 1958; FAO, 1995 and Ranganna, 2001**).

2.1.4 Jam processing methods:

Jam can be commercially produced by using two methods. The first one is the open pan method which gives the product a traditional flavor with some carmelization of sugars. In the second commercial process, jam is produced under vacuum to reduce its boiling temperature to 65-80℃. The lower boiling temperature retaining more of the volatile flavoring compounds from the fruit, preventing sugar carmelization and of course reducing the overall energy required to make the product. All the ingredients must be added in carefully measured amounts as too much pectin will make the spread of jam too hard, while, too much sugar will make the jam too sticky **(Anwar, et.al. ,2010).**

2.1.5 Jam processing steps

2.1.5.1 Fruit Preparation:

Fruits for jam making should be fully mature, possess a rich flavor and be of the most desirable texture. Fruits are washed thoroughly with water to remove any adhering dirt. If the fruit has been sprayed with lead or arsenical sprays, it should be washed in a warm solution of 1% hydrochloric acid and then rinsed in water **(Giridhari Lal et al., 1986).**

All berries must be carefully sorted and washed. Strawberries must be stemmed; peaches, pears, apples, and other fruits with heavy skin must be peeled, while apricots, plums, and fresh prunes can be pitted by machine. Stone fruits such as plum and apricots require a very heavy pulping screen because of abrasive action

of the pits. Berries should not be softened by boiling before the addition of sugar, but need only to be crushed **(Cruess, 1948).**

2.1.5.2 Cooking:

Premeasured amounts of fruit and/or juice, sugar, and pectin are blended in steam cooking kettles and cooked until the mixture reaches the required thickenss and sweetness. Then, the flavouring agents may be added and the mixture is pumped to the filling machines **(Elsayaid, 2008).**

2.1.5.3 Filling Labeling and packaging:

Pre-sterilized jars are filled with premeasured amounts of jam. Then, automatically sealed under vacuum condition to insure the sterility of the end product **(Elsayaid, 2008).** The sealed jars are mechanically conveyed to a labeling machine. These labels must list truthful and specific information about the product. The jars are then packed into cartons for marketing **(Kopjar and Sajple, 2009).**

2.1.5.4 Storage:

The jam jars should be stored in a cool, dry, and dark place at temperature between 50 and 70 F. The product should be kept well for at least one year **(Kopjar and Sajple, 2009).**

2.1.6Jam quality and specifications

In general, good jam should be clear, bright with a characteristic color, well set but not too stiff and with distinct fruity flavor (**Saeed and El-Mubarak,1974**). According to the food processing regulations in the United States, jams should be made with 45 parts fruit or juice to 55 parts sugar. Also, the Federal Food and Drug Administration (FDA) mandates mentioned that all heat- processed canned

foods must be free from live microorganisms **(Codex, 2009).** Table 1 shows the specifications of some fruit jams.

Table 1: Chemical specification of some fruit jams

Type of jam	Moisture (%)	Sugar (%)	Vitamin-C[mg/100gm]
Berry, Strawberry, Raspberry	29.8	69	10-25
Stone fruits (Apricot, Peach)	29.6	69.3	10-35

Source: FAO (1995).

2.2 Cereal

Cereals can be defined as a grain or edible seed of the grass family, Gramineae **(Bender & Bender 1999).** Cereals are grown for their highly nutritious edible seeds, which are often referred to as grains. Some cereals have been staple foods both directly for human consumption and indirectly via livestock feed since the beginning of civilization **(BNF 1994).** Cereals are the most important sources of food **(FAO 2002)**, and cereal based foods are a major source of energy, protein, B vitamins and minerals for the world population. Generally, cereals are cheap to produce, are easily stored and transported, and do not deteriorate readily if kept dry.

Cereals are often classed as carbohydrate-rich foods, as they are composed of approximately 75% carbohydrate. Cereals contain about 6–15% protein **(Goldberg 2003)**. Although the germ is the richest source of lipids, overall, lipids are only a minor component of cereals, with the amount varying from a lipid content of 1–3% in barley, rice, rye and wheat, to 5–9% in corn and 5–10% in oats, on a dry-matter basis **(Southgate 1993)**.

Cereals are low in sodium and are a good source of potassium, in common with most plant foods. Wholegrain cereals also contain considerable amounts of iron, magnesium and zinc, as well as lower levels of many trace elements, e.g. selenium **(Lyons et al. 2003).** All cereals are a rich source of NSP. There are two types of NSP – insoluble and soluble – and, although both may help with weight control (by delaying food leaving the stomach), they have different effects in the body. The insoluble NSP content of most cereals is similar, while the composition of the

water-soluble NSP varies (**Wood 1997**). Cereals contain a range of substances, which may have health-promoting effects that are often referred to as phytochemicals or plant bioactive substances **(Goldberg 2003)**. Although flavonoids are only present in cereals in small quantities, a number of other antioxidants are present, including small amounts of tocotrienols, tocopherols and carotenoids. In laboratory studies, wholegrain breakfast cereals have been found to have an antioxidant content similar to fruits and vegetables **(Miller et al. 2000)** and one study suggests that the major contributors of overall antioxidant activity are bound phytochemicals **(Adom & Li 2002).** There are different types of cereal grains.

Millet

Millet refers to a number of different species, all of which are small-grained, annual cereal grasses **(Macrae et al. 1993; Bender & Bender 1999).** The most important type is pearl millet. A number of minor millets exist, including finger (or ragi), proso and foxtail but as these account for less than 1% of the grains produced for human consumption, they are less important in terms of world food production. However, these crops are important in certain locations in Africa and Asia, where major cereals cannot be relied on to provide sustainable yields **(FAO 1995).** Climatic and soil requirements, length of growing period, grain consistency, size and taste differ depending on the species**.**

2.2.1 Pearl Millet

2.2.1.1 Classification of Pearl Millet

Kingdom: plants

Sub kingdom: Tracheobionta (vascular plants)

Super division: Spermato photo (seed plants)

Division: Mangnoliophyta

Class: Liliopsida .Monocotyledons

Sub class: Commelinidae

Order: Cyperales

Family: Poaceae . Grass Family

Genus: Pennisetum . Fountain

Species: Pennisetum glaucum **(Bker,2003)**

2.2.1.2Pearl millet production in the Sudan

Pearl millet (*Pennisetum glaucum* (L.) R. Br), locally known as "Dukhun", is the one of the important corps of the Sudan, coming as the second most-important cereal crop, after sorghum, in both area and total production. It is the preferred staple foods crop for the majority of the inhabitants of western Sudan (kordofan and Darfur States). The average total area annually planted in the country is about 6 million feddans (2.5.million ha). About 95% of this area is found in Western Sudan. The grain is consumed as human food mainly in the form of porridge , called "aseeda" or in the form of a thin pancake called "kisra". The stalks can be used as feed for animals but they are mostly used as building material or fuel.

Since pearl millet is a drought and heat tolerant crop capable of producing grain regions of low soil fertility and limited moisture, where other summer cereals like sorghum and maize, may fail, it occupies the marginal low-rainfall areas of western Sudan. This is mainly due to it is extensive and more efficient root system, as well as it is high ability to produce tillers. Although the crop is grown in the areas where rainfall ranges between 200mm to more than 1000mm , most of it occurs in areas receiving 250-700mm.

In Western Sudan Region, most of the pearl millet production is centered in the extensive sandy soils "Goz" occupying the northern parts of the region. These are marginal areas with less than 400mm rainfall. In these areas pearl millet is the most extensively grown crop, and therefore a millet-based farming system prevails. However, the cultivation of the crop extends further south into the clay soils where rainfall goes up to 700mm. within these southern areas, usually locations of lighter and sandier soils are used for pearl millet.

2.2.1.3 Nutritional value of millet

Millets contain 60-70% carbohydrates, 7-11% proteins, 1.5-5% fat, and 2-7% crude fiber and are also rich in vitamins and minerals. They are excellent source of vitamin B, magnesium, and antioxidants. Millet is also a good source of other dietary minerals like manganese, phosphorus and iron. Millet proteins are good source of essential amino acids except lysine and threonine but are relatively high in sulphur containing amino acids methionine and cysteine. Apart from this, some essential fatty acids like linoleic, oleic and palmitic acids found in free form and monogalactosul, diacylglycerols, digalactosyl diacylglycerols, phosphatidylethanolamine, phosphatdyl serine and phosphatidyl choline in the bound form present in millets. Other fatty acids i.e. arachidic acid, behenic acid, erucic acid are found in trace amounts. Millet oil could be a good source of linoleic acid and tocopherols. Millet is an alkaline forming grain that is gluten-free.

Vitamin B such as Niacin, folacin, riboflavin, and thiamine and phosphorus are present in millets that play a key role in energy synthesis in the body.

Millets as a Healthy Food:

Millets serve as a major food component specifically among the non affluent segments in their respective societies. Various traditional foods and beverages such as roti, bread (fermented or unfermented), porridge, snack and fast foods, baby foods, millet wine, millet nutrition powder etc are made up of millets **(Chandrasekara et al.,2012)**. Millets are also rich sources of phytochemicals and micronutrients. Phytochemicals such as phenolics (bound phenolic acid-ferulic acid, free phenolic acid-protocatechuic acid), lignans, β-glucan, inulin, resistant starch, phytates, sterols **(Liu,2007)** , tocopherol, dietary fiber **(Devi et al.,2014)** and carotenoids are present in millets. The main polyphenols are phenolic acids and tannins, while flavonoids are present in small quantities; they act as antioxidant and play many roles in the body immune system **(Chandrasekara et al., 2010).**

Prebiotics are non-digestible food ingredients that beneficially affect the host by selectively stimulating the growth and activity of one or a limited number of bacteria in the colon **(Laminu et al.,2011)**. Millet's whole grain also shows prebiotic activity, which helps to increase the population of friendly bacteria that plays a key role to promote digestion. Malting induces important beneficial biochemical changes in the millet grain.The concepts of food consumption are changing from previous to present time. Previous emphasis has been on survival, hunger satisfaction, health maintenance and absence of adverse effects on health and current emphasis is on encouraging the use of nutraceutical foods which promise to promote better health and will being thus helping to reduce the risk of chronic diseases such as obesity, diabetes, CVD and cancer. Millets have nutraceutical properties in the form of antioxidants which prevent deterioration of human health **(Rao et al.,2011)**.

Millets have many nutraceutical properties that are helpful to prevent many health problems such as lowering blood pressure, risk of heart disease, prevention of cancer and cardiovascular diseases, decreasing tumor cases etc. Other health benefits are increasing the time span of gastric emptying, provides roughage to gastro intestine **(Gupta et al.,2012)**. Millet is an alkaline forming food. Alkaline based diet is often recommended to achieve optimal health, meaning when it combines with digestive enzymes. The soothing alkaline nature of millet helps to maintain a healthy pH balance in the body, crucial to prevent illnesses. Lower incidences of diabetes have been reported in millet consuming population. Millet phenolic inhibits like alphaglucosidase, pancreatic amylase reduce postprandial

hyperglycemia by partially inhibiting the enzymatic hydrolysis of complex carbohydrates **(Shobana et al., 2009)**. Inhibitors like aldose reeducates prevents the accumulation of sorbitol and reduce the risk of diabetes induced cataract diseases **(Chethan et al., 2008)**. Finger millet feeding controls blood glucose level improves antioxidant status**(Hegde et al., 2005)** and hastens the dermal wound healing process in diabetic rats**(Rajasekaran et al., 2004)**.

Millets are good sources of magnesium that is known to be capable of reducing the effects of migraine and heart attack. Millets are rich in phyto-chemicals containing phytic acid which is known for lowering cholesterol **(Coultably et al., 2011)**. Finger millet may prevent cardiovascular disease by reducing plasma triglycerides in hyperlipidemic rats **(Lee et al., 2010)**.

Celiac disease is an immune-mediated enteropathy triggered by the ingestion of gluten in genetically susceptible individuals. Millets are gluten-free, therefore an excellent option for people suffering from celiac diseases and gluten-sensitive patients often irritated by the gluten content of wheat and other more common cereal grains**(Saleh et al.,2013)**. Millets are known to be rich in phenolic acids, tannins, and phytate that act as “antinutrients” However; these antinutrients reduce the risk for colon and breast cancer in animals. Have demonstrated that millet phenolics may be effective in the prevention of cancer initiation and progression in vitro **(Chandrasekara and Shahidi, 2011).** Ferulic acid is very strong antioxidant, free radical scavenging and anti-inflammatory activity. Antioxidants significantly prevent tissue damage and stimulate the wound healing process **(Rajasekaran et al., 2004).**have reported good antioxidant effects of finger millet on the dermal wound healing process in diabetes induced rats with oxidative stress-mediated modulation of inflammation. The chemical reaction between the amino group of proteins and the aldehyde group of reducing sugars, termed as non enzymatic glycosylation, is a major factor responsible for the complications of diabetes and aging. Millets are rich in antioxidants and phenolics; like phytates, phenols and tannins which can contribute to antioxidant activity important in health, aging, and metabolic syndrome **(Hedge et al., 2002)**.

Millets fraction and extract have been found to have antimicrobial activity. Seed protein extracts of pearl millet, sorghum, Japanese barnyard millet, foxtail millet, samai millet and pearl millet were evaluated in vitro for its ability to inhibit the growth of Rhizoctonia solani, Macrophomina phaseolina, and Fusarium oxysporum. Protein extracts of pearl millet are highly effective in inhibiting the growth of all 3 examined phytopathogenic fungi**(Raelhajeyalakahmi et al., 2003)**.

2.2.1.4Millet application into food

Pearl millets are used largely to prepare traditional , thick or thin, fermented or unfermented porridges in Africa. The second major use in Africa is malting for the brewing of traditional beers and wines. In west African countries, e.g., Senegal, millet is used for making couscous, pap, and fritters. In Cameroon, pearl millet-based gruels and steamed cakes are prepared for feeding infants and preschool children. Malted pearl millet in combination with legumes has been used to prepare malted weaning foods. Pearl millet has also been used in composite flour with wheat for making bread. Up to 30% pearl millet was used successfully in making bread in Senegal. The nutritional advantages of pearl millet are its high fat content and a relatively high lysine content, comparable with that of high-lysine corn in some varieties. Antinutritional factors, however, have been reported in several studies. A thionamide-like substance has been identified that interferes with the formation of thyroid hormones, which in turn leads to undesirable goitrogenic effects.

CHAPTER THREE

MATERIALS and METHODS

3.1 Materials

3.1.1 Row materials

Millet grain were purchased from local cereal market in Omdurman (Khartoum State, Sudan). The grain were cleaned by removing the dirt , other seed , broken seed and foreign materials. Then the clean grain were stored in plastic bag till used.

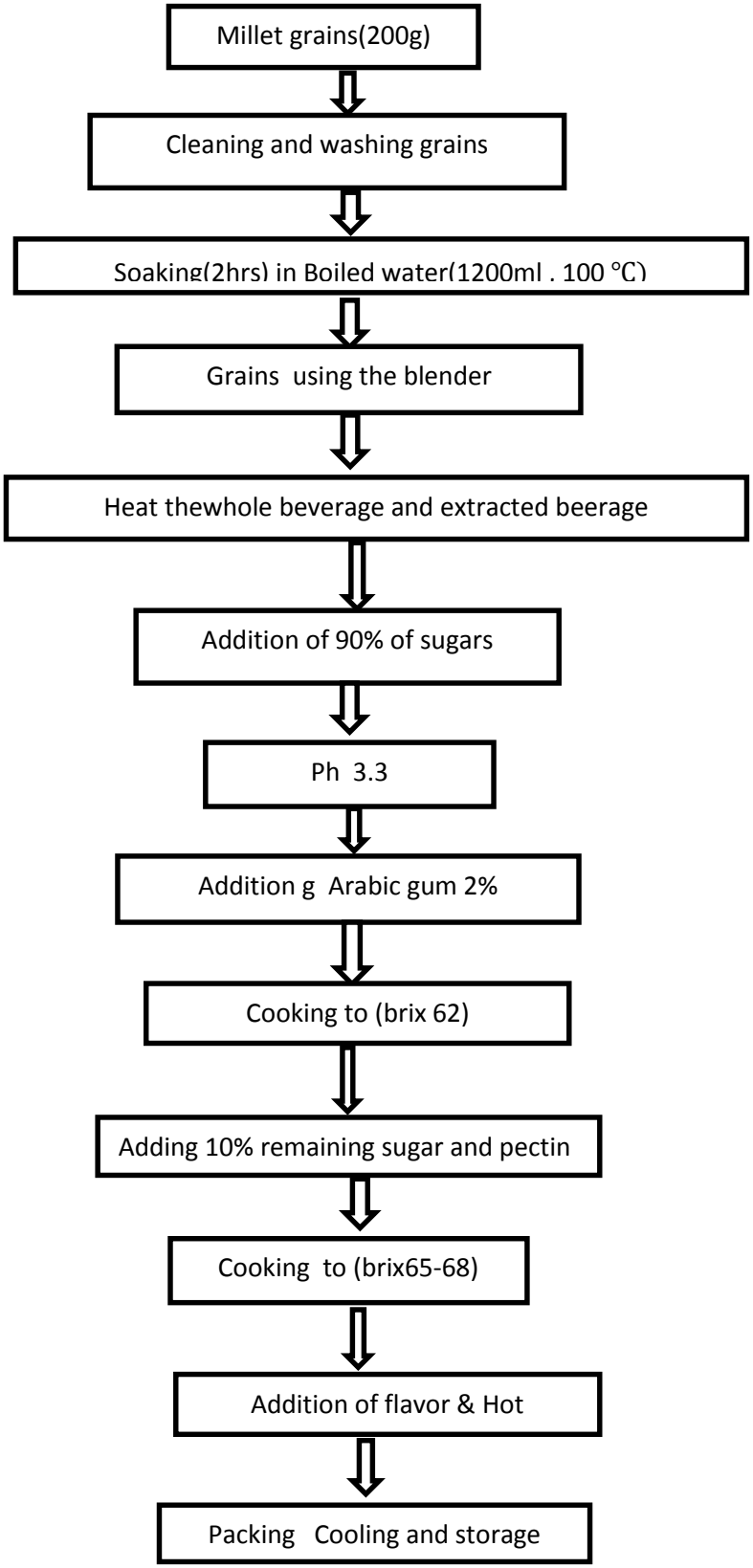
Other ingredients such sugar and Arabic gum were obtained from local market in Omdurman (Khartoum state), commercial pectin, citric acid and flavor were obtained from Saeed Food Factory in Khartoum north industrial area (Khartoum state). Equipment such as pan, spoon, blender, digital balance, heater, thermometer, gauze cloth and refract meter were available at quality control laboratory (Saeed Food Factory).

3.1.2Formulation

1. 200 (g) of millet grain
2. 1000 (g) sugar
3. 30 (g) gum arabic
4. 6 (g) citric acid
5. 8 (g) pectin
6. 1200 (g) water

3.1.3Processing of jam:

The cleaned grains were weighted (200g), washed thoroughly with tab water to remove all residual dirty. Then the grains were soaked in boiling water (1200ml) for 2hour to remove bitter taste of the millet; that increase shelf-life of the final product and soften mixture for easy homogenization. Soaked grains were blended by electrical blender(mixer) and sieved by gauze cloth. Whole millet beverage and beverage extract were used to produce two type of millet jam (flow diagram 1).



Flow diagram of jam processing steps

3.2 Chemical Composition of raw material

All the proximate analysis were carried out according to AOAC method (1990).

3.2.1 Moisture determination:

Moisture content was determined according to the Association of official's analytical chemists **AOAC (1990)** as follows: Tow grams of each sample were weighed in clean dry and pre-weighed crucible and then placed in an oven at 105℃ and left overnight. The crucible was transferred to desiccators and allowed to cool and then weighed. Further placement in the oven was carried out until constant weight was obtained. Moisture content was calculated using the following formula:

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

Where:

MC: moisture content

W1: weight of empty crucible

W2: weight of crucible with sample

W3: weight after drying

3.2.2 Fat content:

Fat was determined according to the method of AOAC (1990) using soxhelt apparatus follows:

An empty clean and dry exhaustion flask was weighed. About 2 gram of sample was weighed and placed in a clean extraction thimble and covered with cotton wool. The thimble was placed in an extractor. Extraction was carried out for 8 hours with petroleum ether. The heat was regulated to obtain at least 15 siphoning, the residual ether was dried by evaporation.

The flask was placed in an oven at 105℃ till it dried completely and then cooled in desiccators and weighed. The fat content was calculated using the following equation:

$$FC = \frac{W2 - W1}{Ws} \times 100$$

Where:

FC: fat content

W1:weight of extraction flask

W2: weight of extraction flask with fat

3.2.3 Crude protein:

Crude protein of sample was determined by using the micro-kjeldahl method according to AOAC(1990) as follows:

3.2.3.1 Digestion:

0.2 gram of sample was weighed and placed in small digestion flask (50ml). About 0.4gram catalyst mixture (96% anhydrous sodium sulphate and 3.5% copper sulphate) was added, 3.5ml of approximately 98%of H2SO4 was added. The contents of the flask were then heated on an electrical heater for 2 hours till the color changed to blue-green. The tubes were then removed from digester and allowed to cool.

3.2.3.2 Distillation:

The digested sample was transferred to the distillation unit and 20ml NaOH (40%) were added. The ammonia was received in 100ml conical flask containing 10ml of 2% boric acid plus 3-44 drops of methyl red indicator. The distillation was continued until the volume reached 50ml.

3.2.3.3 Titration:

The content of the flask were titrated against 0.02N HCl. The titration reading was recorded. The crude protein was calculated using the following equation :

$$CP\% = \frac{(T - B) \times N \times 14 \times 100 \times 6.38}{Ws \times 1000}$$

Where:

CP: crud protein

T: titration reading

B: blank titration

N: normality of HCl

Ws: Sample weight

1000: to convert to mg per hour

3.2.4 Ash content

Ash content of sample was determined according to the method of AOAC (1990) as follows: Tow grams of sample were placed in a clean dry pre-weighed crucible, and then the crucible was reignited in the furnace at 500℃ and allowed to cooling until a constant weight was obtained. Ash content was calculated using following equation:

$$AC\% = \frac{W2 - W1}{W3} \times 100$$

Where:

Ac: ash content

W1: Weight of empty crucible

W2: weight of crucible with ash

W3: weight of sample

3.2.4Crude fiber

Crude fiber was determined according to AOAC (1990). Two grams of defatted sample were treated successively with boiling solution of H2SO4 and KOH(0.26 N and 0.23 N,respectively).The residue was then separated by filtration, washed and transferred into crucible then placed into an oven adjusted to 105℃for 18 -24 hours.The crucible then with the sample was weighed and ached in a muffle furnace at 500℃ and weighed.

The crude fiber was calculated using the following equation:

$$CF = \frac{W1 - W2}{Ws} \times 100$$

Where:
CF: Crude fiber
W1: Weight of crucible with sample before ashing
W2: Weight of crucible with sample after ashing
Ws: Weight of sample

3.2.6 Calculation of carbohydrates

Carbohydrates were calculated by difference according to the following:

Carbohydrates=

$$100\% - [\text{Moisture}\% + \text{Protein}\% + \text{Fat}\% + \text{Ash}\% + \text{fiber }\%]$$

3.2.7 Total sugar, reducing sugars and non –reducing sugars

The total sugars, reducing and non- reducing sugars were determined according to Lane and Eynon titrometric method as described by Association of Official Analytical Chemists (AOAC, 1984).

Principle:

Reducing sugars in pure solution in plant materials after suitable pre-treatment (to remove interference substances) may be estimated by using copper sulphate as oxidizing agent in a standard Fehling's solution .

Sample preparation:

(A)Reducing sugars a sample of 10 ±1mg will be weighted and transferred to 250 ml volumetric flask. 100ml of distilled water will be carefully added and then neutralized with 1.0N NaOH to a PH 7.5 – 8.0. Then, about 2 ml of standard lead acetate (NO. 23500, BDH, England) will be added and the flask will be shacked and left to stand for 10 min. After that, 2 grams of sodium oxalate will be added to remove the excess amount of lead acetate and the solution will be made up to volume with distilled water 250 ml and filtered.

(B) Total sugars from the previous clear sample solution, 50 ml will be pipetted into a 250 ml conical flask and 5 gram citric acid and 50 ml distilled water will be transferred to 250 ml volumetric flask, neutralized with 20% NaOH solution in the presence of few drops of phenolphthale in (NO. 6606 J.T Baker, Holland) until the color of the mixture disappeared and the sample will be made up to volume before titration.

Procedure:
A volume of 10ml from the mixture of Fehling's (A)and(B) solutions will be pipetted into 250ml conical flask. Then, sufficient amount of the clarified sugars solution will be added from a burette to reduce Fehling's solution in the conical flask. After that, the solution will be boiled until a faint blue colur is obtained. Then, few drops of methylene blue indicator (S-d-FINE-CHEM LIMITED) will be added to Fehling's solution and titrated under boiling with sugars solution until brick-red color of precipitate cuprous 27 oxides will be observed. Finally, the titer volume will be recorded and the amount of inverted sugars will be obtained from Lane and Eynon Table and the total sugars, reducing and non-reducing sugars will be calculated on dry basis by using the following formulas:
Totalsugars{DM%}=
invertsugar(mg) $\times dilution\ factor\ \times 100\% titre \times sample\ weight(g) \times (100\% - moisture\%) 1000$
Reducing sugars {DM%}=
Invert sugar(mg)$\times dilution\ factor \times 100\% titre \times sample\ weight(g) \times (100\% - moisture\%) \times 1000$
Non-reducing sugars$\{\%DM\} = \{Total\ sugars\% - reducing\ sugars\%\}$

3.3Determination of physic-chemical properties of jam:

3.3.1 Total soluble solids (TSS %)

The total soluble solids as percent in the different samples were measured following the method described by **Onsa (2007)** by using a Hand-Refractometer. Principle: The index of refraction of substance is a ratio of the light velocity under vacuum to its velocity in the substance which is largely dependent on the composition, concentration and temperature of the sample solution. Procedure: After the adjustment of the Hand-Refrctometer (MASTER-500 Cat. No. 2363 Made in Japan) with distilled water, the sample (20C) was placed on the surface of the refractometer prism, then the prism was closed and the reading was recorded to the nearest (0.00) as TSS %.

3.3.2 Hydrogen ion concentration (pH)

The hydrogen ions concentration (pH) of the different samples was determined as described by **Ranganna (2001).** Principle: The pH value of the different samples was measured with a pH-meter. After standardization of the pH-meter electrodes with buffer solution, the reading of the sample is recorded as pH value. Procedure: After standardization of the pH-meter (AD1020 pH/mV/ISE &Temperature Meter)

with buffer solution (pH 4.01 and 7.01), the electrode of the pH-meter was rinsed with distilled water, immersed in the sample and left to stand until a staple reading was achieved. All the reading were expressed as pH to the nearest 0.01-pH units.

3.3.3Total acidity

Titrable acidity was determined according to **Ranganna (1979).** 50 g + 1 g sample was diluted to 100 ml, and boiled water 30 min then 20 ml of the diluted solution was titrated against (0.1N) sodium hydroxide using phenolphthale in solution (1%) as an indicator. The titrable acidity was calculated as percent citric acid according to the following equation:

$$\text{Titrable acidity (\%)} = \frac{[(\text{Titre} \times \text{N (NaOH)} \times \text{equivalent wt of cetric acid} \times 100)]}{\text{Sample volume (ml)} \times \text{initial wt of sample (g)} \times 1000} \times 100.$$

3.4 Microbial analysis :

Equipments: Test tubes, Petri dishes, Incubator and Colony counter.

Media Used: Plate count Agar, MacConkey broth, Potato dextrose Agar, EC Broth, Brilliant Green 2% Bile Broth and Peptone water.

Preparation of serial dilutions:

Aseptically 10 grams of the sample were homogenized in 90 ml of sterile diluent (0.1% peptone water). It was mixed well to give dilution (10-1). By using sterile pipette 1 ml was transferred to a test tube containing 9 ml of sterile diluent and it was mixed well to give dilution (10-2). Further, similar preparation of serial dilution was continued until the dilution (10-6). One ml of each dilution was transferred into sterile petri dishes. To each plate 15 - 20 ml of sterile melted plate count agar were added. The inoculum was mixed with medium and allowed to solidify. The plate were incubated at 37Ċ for 48 hours. Colony counter was used to count the viable bacterial colonies after incubation and the results were expressed as colony-forming unit (cfu/gram).

3.4.1 Total viable count of bacteria:

It was carried out by using the pour plate count Method as described by **Harrigan (1998).** Suitable medium for this purpose is plate count Agar.

3.4.2Yeast and mould count

From suitable dilation 0.1 ml was aseptically transferred onto solidified potato dextrose agar containing 1.5 ml of sterile (1 : 10) tartaric acid per 100 ml of medium to inhibit bacterial growth. The inoculum was spreader all over the plate using sterile bent glass rod. Plate were incubated at 28 c for 72 hours. By using colony counter colonies were counted and the results presented as CFU/gram.

3.4.3 Determination of coliform bacteria

It was carried out by using the Most Probable Number (MPN) technique.

3.4.3.1 Presumptive coliform test

1 ml of each of the three first dilutions (10-1 , 10-2 , 10-3) was inoculated in triplication of MacConkey Broth tubes containing Durham tubes. The tubes were incubated at 37c for 48 hours. The production of acid with sufficient gas to full the concave of the Durham tube is recorded as positive presumptive test **(Harrigan, 1998).**

3.4.3.2 Confirmed test for total coliforms

From every tube showing positive result a tube of Brilliant Green 2% Bile Broth was inoculated by using sterile loop. The tubes were incubated at 37 °Ċ for 48 hours. Then the tubes showing positive and negative result were record. The Most Probable Number of total coliform was found out by using the Most Probable Number (MPN) tables.

3.4.4Confirming *E.coli* test

From every tube showing positive result in the presumptive test inoculate a tube of EC Broth containing Durham tube. The tubes were incubated at 44.5 °Ċ for 48 hours. Tubes showing any amount of gas were considered positive. Then the Most Probable Number (MPN) were record. For further confirmation of E.coli tubes of EC broth which showing positive result were streaked on (E.M.B) agar Eosin Methylene Blue agar plates. The plates were incubated at 37Ċ for 48 hours. Colonies of *E.coli* are usually small with metallic green sheen on (E.M.B) agar **(Harrigan, 1998).**

3.5 Sensory evaluation of different jams

Sensory evaluation was conducted using a 5 point hedonic scale ranging from un-acceptable to excellent, 15 panelist's persons were selected randomly to perform consumer test where commercial trobicana jam was used as a control. All evaluation sessions were held at Deparmemt of Food Science and Technology, College of Agricultural Studies. All samples were presented in white disposable plastic cups and coded with three-digit numbers. Spoons were provided to the panelists and drinking water was provided for oral rinsing. The samples attributes assed were appearance,color, taste, texture , flavor and overall quality.

3.6Statistical analysis method

Data were statistically analyzed using Minitab Statistical Software for windows (Minitab, 2017). Analysis of Variance (ANOVA) as shown by **Sendecor and Cochran, 1987** were used. Probability of 5% will be used to indicate the significance difference according to Duncan's Multiple Range Test (Duncan's ,1959) and as described by **Mead and Curnow (1983)**

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1Chemical composition of millet grains

Approximate analyses of pearl millet were presented in Table (2). Moisture, protein, Fat , Crude fiber, Ash and Carbohydrate were found to be 7.9% ,17.50% , 4.9%, 3.15% , 1.30% , 65.45%.On the other hand **Mohammed (2018)** reported 7.37%,15.34%,5.94% , 1.13%, 1.14% and 68.79% for moisture, protein, fat , crude fiber, ash and carbohydrate, respectively. This different might be due to the genotype, level of mature (harvest time), or the climate condition or even type of planning soil.

4.2Chemical composition and caloric value of different millet jam products

Table (3) presented the chemical composition of different jam products. There were significant ($p<0.05$) differences in components of jams due to variation in source and types of raw material involved in formulation. From the result jams from millet beverage extract, whole millet beverage, and the control (Trobicana) were found to contain high level of carbohydrates amounting 68.5, 64.8, 70.47%, specifically. Whole millet beverage jam recorded the highest levels of protein, ash, and fiber compared to other two types because the bran is rich source of these nutrients. Jam formulated from millet beverage extract contained 1.35, 0.13 and 3.4% of protein, ash, and fiber, respectively. While the control jam Trobicana recorded 1.2, 0.21 and 2.8% of protein, ash, and fiber, respectively. All this result were comparable to that reported by **Babiker(2015)** which were 0.53- 0.46 protein, 0.7-0.71 ash and 0.22- 0.14 fiber, respectively. The supplementation with hashab gum also contributed in improving level of fiber in formulated jam. On the other hand, both millet jam samples were also found to provide low caloric value per 100g sample which were 283.18 and 273.59 calorie for millet beverage extract jam and whole millet beverage jam, respectively. These energy values are lower than that of the control jam (Trobicana) providing 289.92 calorie.

4.3Different sugars profiles of formulated millet jam products

As presented in Table 4 there were significant ($p<0.05$) differences in different sugars profiles of jams. Jams formulated from millet based beverages contained high levels of total and none-reducing sugar as compared with the control (Trobicana) due to hashab gum supplementation. While the reducing sugar level of the control jam was the highest (Table4).

4.4Physiochemical properties of different formulated millet jam products

There were no significant ($p<0.05$) in hydrogen ion concentration, titrable acidity and total soluble solids between different jam products (Table 5). From the results of different jam the hydrogen ion concentration (pH), titrable acidity (T.A %), total soluble solids (TSS %) of millet beverage extract jam were 3.11pH, 0.38% and 68.1 %, respectively. While for whole millet beverage jam values of 3.10 pH, 0.38% TA and 67.1% TSS were recorded. For control jam , (Trobicana) 3.11pH, 0.37 TA and 68.1% TSS were determined (Table 5). These results are in agreement with data reported **ICUC (2004), Hui (2006), Onsa (2007)** and **Nouredeen (2011). They stated that** good quality jam should contain 67-70% total soluble solids (TSS %), 3.2 -3.4 pH and 3 -0.8% titrable acidity (T.A %).

4.5Safety and microbial quality of different formulated millet jam products

The results obtained on arebic total count, coliform, *E.coli*, salmonella and yeast and mold were nil (Table 6). These findings indicate safety of different millet formulated jams, freedom from contamination with spoilage and pathogenic microorganisms.

4.6Sensory characteristics of different formulated millet jam products

The results in Table (7) show the recorded scores by the panelists for the different jam samples with respect to their appearance, color, taste, flavor, texture and overall acceptability. The result of sensory characteristics indicated that there was no significant ($p< 0.05$) differences in flavor, taste, texture, overall acceptability between different millet formulated jam and the control (trobicana).However, there were significant differences in colors and appearance between different jams.

Table 2: Chemical composition of millet grains

Component	Pearl millet
Moisture	7.9 ±0.141
Fat	4.9±0.00
Protein	17.500±0.849
Ash	1.300±0.141
Fiber	3.1500±0.0707
Carbohydrate	65.45±1.48

Values are mean ± SD for triplicates independent analysis.

Table 3: Chemical composition and caloric value of different millet jam products

Chemical components (%)	Types of formulated jams		
	Millet beverage extract	Whole millet beverage	Trobicana (commercial)
Moisture	26.15± 0.07^{b}	27.2 ± 0.21^{a}	24.9± 0.2^{c}
Fat	0.42 ±0.01^{ab}	0.51 ± 0.02^{a}	0.36 ± 0.03^{b}
Protein	1.35±0.07^{b}	2.45 ± 0.07^{a}	1.2 ± 0.0^{b}
Ash	0.13 ±0.01^{b}	0.75 ± 0.07^{a}	0.215 ± 0.007^{b}
Fiber	3.4 ± 0.2^{ab}	4.14 ± 0.06^{a}	2.8 ± 0.1^{b}
Carbohydrate	68.5 ± 0.4^{b}	64.8 ± 0.4^{c}	70.47 ±0.02^{a}
Caloric value	283.18	273.59	289.92

Values are mean ± SD for triplicates independent analysis.

Values that bear different superscript letter in the same raw are significantly different at $p<0.05$.

Table 4: Different sugars profiles of formulated millet jam products

Dfferent types of sugar	Types of formulated jams		
	Millet beverage extract	Whole millet beverage	Trobicana (commercial)
Reducing sugars	2.8 ± 0.1[b]	3.0 ± 0.1[b]	3.76 ± 0.12[a]
Non-reducing sugars	48.9 ± 0.8[a]	49.5 ± 0.2[a]	45.9± 0.4[b]
Total sugars	51.780 ± 1.004[a]	52.570 ± 0.141[a]	46.750 ± 0.325[b]

Values are mean ± SD for triplicates independent analysis.

Values that bear different superscript letter in the same raw are significantly different at $p<0.05$.

Table 5: Physiochemical properties of different formulated millet jam products

Types of formulated Jams	Different physiochemical properties		
	pH	TSS	Acidity
Millet beverage extract	3.11 ± 0.01[a]	68.1± 0.21[a]	0.38 ± 0.00[a]
Whole millet beverage	3.10± 0.00[a]	67.1± 0.21[b]	0.38 ± 0.00[a]
Trobicana (commercial)	3.11± 0.01[a]	68.1± 0.14[a]	0.37± 0.00[a]

Values are mean ± SD for triplicates independent analysis.

Values that bear different superscript letter in the same column are significantly different at $p<0.05$.

Table 6: Microbial quality of different formulated millet jam products

Types of formulated Jams	Different microbial groups				
	APC	Coliform	E.Coli	Salmonella	Yeast & Mould count
Millet beverage extract	Less than 1×10	Nill	Nill	Nill	Less than 1×10
Whole millet beverage	Less than 1×10	Nill	Nill	Nill	Less than 1×10

Values are mean ± SD for six independent analyses.

Table 7: Sensory characteristics of different formulated millet jam products

Types of formulated jams	Sensory characteristics					
	Appearance	Color	Flavor	Taste	Texture	Overall aceptability
Millet beverage extract	4.3± 0.4^{a}	4.1±0.7^{ab}	3.9±0.9^{a}	4.0±0.8^{a}	4.1±0.8^{a}	4.2± 0.7^{a}
Whole millet beverage	3.4± 1.2^{b}	3.5± 1.0^{b}	3.9±0.9^{a}	3.8±0.9^{a}	3.5±1.1^{a}	3.9± 0.8^{a}
Trobicana (commercial)	4.4± 0.7^{a}	4.7± 0.6^{a}	4.2±0.8^{a}	4.2±0.7^{a}	4.0±0.4^{a}	4.5± 0.6^{a}

Values are mean ± SD for 15 panelists Values that bear different superscript letter in the same column are significantly different at $p<0.05$.

CHAPTER FIVE
CONCLOUSION AND RECOMMENDATION

5.1 Conclusion

According to the finding of this study, millet is a good source of nutrient. It significantly improved levels of protein, fat and fiber in millet formulated jams. All processes jams including the control did not defer in physicochemical properties, sensory and were safe (free from pathogenic and spoilage microorganisms). Therefore it is possible to utilize millet based beverages in formulation of jam having similar sensory characteristics of chimerical one available in the market.

5.2 Recommendation

1. Increase the awareness of consumers on the high nutritional value and health benefits of millet grains.

2. Increase the economic value of millet by incorporation or formulation into different food products.

3. Further studies required to recommend millet jam to specific groups of people such as children, pregnant women and athletes.

4. More research is demanded to explore the nutritional and health benefits of millet jam.

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Appendixes

Appendix (1) Extract millet beverage jam (A)

Appendix (2) Whole millet beverage jam (B)

Appendix (3) sample (A) for panel test

Appendix (4) sample (B) for panel test