Sudan University of Science and Technology

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Nutritional Value of Black Mahlab Seeds (*Monechma ciliatum*) and its Effect on Quality Attributes of Supplemented Sorghum Kisra

القيمة الغذائية لبذور المحلب الأسود وأثره كمدعم على خواص الجودة لكسرة الذرة

By

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DEDICATION

To my Parents

my Husband

my Kids

my Sisters

my brothers

and all Friends

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Unlimited thanks to Allah who helped me and gave me health to complete this work. My deepest thanks and appreciation to my supervisors **Prof. Mahdi Abass Saad Shakak and Prof. Abdalbasit Adam Mariod** for their helpful, persistent encouragement, continuous support and advices and faithful guidance.

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ABSTRACT

The current study aims to investigate the effect of the three processing (boiling, roasting and germination) techniques on *Monechma ciliatum* (black mahlab) seeds nutritional value and then the effect of *M.ciliatum* raw and treated seeds as food supplement on sorghum flour Kisra quality and the possibility to produce high nutritional value Kisra using the advantage of the high percentage of protein, fat, minerals and fatty acids in the MC seeds and as the same time to be acceptable by consumers .

The results showed that, proximate composition of untreated *M.ciliatum* (UM), and boiled (BM), roasted (RM) and germinated *M.ciliatum* (GM) seeds. after boiling, roasting and germination processing techniques. Most of the nutritional factors of MC were increased by processing. Specifically, the three processing techniques increased the protein content, while boiling and roasting increased the fat content. In the same manner boiling and germination techniques increased the fiber content. Saturated fatty acids were increased by roasting and germination processes, while unsaturated fatty acids were decreased. Tocopherols were increased only in germinated sample. Amino acids composition was increased with the three processing techniques. Minerals were affected by the three processing techniques except Na% which was increased in germinated sample.

Kisra (a traditional stable Sudanese food) was prepared as control sample and kisra from sorghum flour supplemented with 10% of raw and treated *M.ciliatum* seeds flour, as a result of supplementation most of the nutrients contents were increased. Fat, fiber, protein and mineral contents and unsaturated fatty acid were increased while amino acids were decreased in Kisra supplemented with raw (untreated) and treated samples. Tocopherol

content wasn’t affected in kisra supplemented with raw or treated samples of *M.ciliatum* seeds. Kisra supplemented with roasted *M.ciliatum* seeds flour was the most acceptable product by the panelists.

مستخلص الدراسة

هدفت الدراسة الحالية إلى دراسة تأثير المعاملات الثلاث (الغليان، والتحميص ،والإنبات) على التركيب الكيميائي للمحلب الأسود ومن ثم تأثير إضافة مسحوق بذور المحلب الخام والمعالج إلى دقيق الذرة الرفيعة وأثر ذلك على الكسرة المصنوعة من طحين الذرة المضاف إليه نسبة 10% مسحوق المحلب الخام والمعالج وذلك للاستفادة من المكونات الغذائية الغنية في بذور المحلب في تدعيم دقيق الذرة الرفيعة والحصول على منتج (كسرة) ذات قيمة غذائية جيدة .

أظهرت النتائج أن معظم المكونات الحيوية (بروتين، دهون، كربوهيدرات، ألياف وأحماض أمينية) تزداد نتيجة المعاملات الثلاث(غليان وتحميص وإنبات) لبذور المحلب ، وبالتحديد فقد أظهرت النتائج أن جميع المعاملات تزيد من محتوى البروتين لبذور المحلب الأسود بينما الغليان والتحميص يزيدان من محتوى الدهون. كما يزيد كل من معاملات الغليان والإنبات من محتوى الألياف ببذور المحلب الأسود، وقد زادت الأحماض الدهنية المشبعة نتيجة لعملية التحميص والإنبات بينما انخفضت الأحماض غير المشبعة وزادت مركبات التوكوفيرولات(مشابهات فيتامين E) فقط في العينة المنبتة. كما نلاحظ زيادة في نسبة الأحماض الأمينية بالمعاملات الثلاث بينما انخفضت كمية المعادن نتيجة المعاملات عدا زيادة ملحوظة في كمية معدن الصوديوم في العينة المنبتة.

أظهرت نتائج تحليل الكسرة المصنوعة من دقيق الذرة المدعم بنسبة 10% من مسحوق بذور المحلب الأسود الخام والناتج عن المعاملات الثلاث زيادة في معظم العناصر الغذائية وبالتحديد زادت نسبة الدهون والألياف والبروتين ومحتوى المعادن والأحماض الدهنية غير المشبعة بينما انخفضت الأحماض الامينية ولم يتأثر محتوى التوكوفيرولات في كل العينات .

CHAPTER ONE

INTRODUCTION

The high cost of animal protein encourages researchers to work on legumes as available potential source with reasonable cost Sabaté, (2014) reported that producing one kg of beef protein needs eighteen times comparing with the same quantity from kidney beans. Replacing consumption of beef with beans reduce the environmental footprint, and decrease the prevalence of non-communicable chronic diseases.

There are many studies on the effect of cooking on the nutrients content of several seeds. Hefnawy (2011) results showed that cooking treatments causing decrease in carbohydrate, anti-nutritional factors (trypsin inhibitor, tannins and phytic acid) and minerals. Cooking treatments decreased the concentrations of lysine, tryptophan, total aromatic and sulfur-containing amino acids. Mariod *et al*., (2012a) reported that boiling and roasting processing techniques of safflower seeds increased fat and protein contents increased while moisture, carbohydrate and fiber contents were decreased and fatty acid compositions of treated samples slightly affected compared with the untreated ones.

Most of the studies found that during seeds germination chemical composition changes because biochemical activity produces essential compounds and energy, and some nutrients transform to bioactive components as a part of these changes. Patil, and Khan (2011) found that germinated brown rice has a potential to become innovative rice by preserving all nutrients in the rice grain for human consumption in order to create the highest value from rice, and said that germinated brown rice would improve the bread quality when substituted for wheat flour.

Monechma ciliatum is a small tropical herb belongs to *Acanthaceae*. It has a small hard seeds with back kernel, so it is locally known as El-Mahlab El-Aswad' in Sudan. This plant found in Western and southwestern parts of Sudan especially in the Nubian Mountain and Gabel Mara area, the seeds contain good amounts of fat, protein and minerals (Mariod *et al*, 2009).

There are some reports about the effect of boiling, roasting and germination on the nutrients content of different seeds, but no information is available of using any processing on *M.ciliatum* seeds.

Sorghum (Bicolor L. Monech) is the most important consumed cereal in Sudan. According to FAO production of sorghum in Sudan is about 3.86 million tons in 2017. The annual consumption of sorghum in Sudan is about 1.5 to 2 million tons which reflected in many dishes such as porridge or flat bread (Osman, 2010). Sorghum protein content is higher than that in corn, although its protein nutritional value is lower (Dowling *et al*, 2002). Sorghum is deficient in lysine, threonine and treptophan, rich in leucine, proline and glutamic acid (Duodu *et al*, 2003).

Much effort has been made to improve the amount and quality of cereal nutrients. These studies used different methods to improve the nutritional quality and properties of cereal-based foods. Genetic fortification and supplementation with nutrients rich source and processing technologies are the most effective methods (Chavan and Kadam, 1989). Supplementation, fortification or enrichment of cereals with legumes has been considered practical and sustainable approach of combating protein energy malnutrition in developing countries. Legumes contain high amount of protein, generally twice the level formed in cereal. Legumes particularly rich in amino acid lysine, yet usually deficient in the sulfur- containing amino acids like methionine (Shewry, 2007).

Objectives:

This research aims to fulfill the following objectives

1. To study the effect of boiling, roasting and germination on the chemical composition and nutritional contents of the *M.ciliatum* seeds.
2. To study the possibility of increasing the nutritional value of Kisra (Sudanese traditional sorghum product) using advantage of the high percentage of protein, fatty acids, minerals and other valuable components in the *M.ciliatum* (black mahlab seeds).
3. To study the sensory properties of the new developed kisra and determine the efficient process to produce acceptable supplemented kisra in terms of color, taste, smell, texture and appearance.

CHAPTER TWO

LITERATURE REVIEW

2.1 Black Mahlab (*Monechma ciliatum*)

2.1.1 Acanthaceae family

Acanthaceae family is derived from the *Scrophulariaceae* and contain large number of ornamental. Its leaves has high therapeutic applications due to their alkaloids contents (Sharma and Kumar 2016).

Most parts of the *Acanthaceae* family include valuable components specially leaves and seeds. Studies on many species of *Acantheceae* showed that leaves of *Adhatoda vesica Nees*. (*Acanthaceae*) are used in the treatment of bronchial diseases. leaves of *Andrographi spaniculata*are used to relieve bites of poisonous insects. Leaves paste of *Barberia grandicalyx Justicia betonica, Acanthus* used for treating reptiles snake bites and the ash of *pubescens* and *Justicia flava* leaves relieve dry cough, diarrhea, flu and ulcers (Hossain and Hoq, 2016).

Tando *et al*, (2015) study revealed that the microbial activities of *Andrograph ispaniculata* showed a significant antibacterial activity against *Bacillus subtilis, Staphylococcus aereus, Escherichia coli* and *Pseudomonas aeraginosa* compared with well-known antibiotics, also he reported that *Asteracantha longifolia L* revealed promising effects against *Burkholderia pseudomallei* strain1 and strain2 and *Staphylococcus aureuss.* The dichloromethane leaves extract of *Hypoestes serpens* (*Acanthaceae*) represent antifungal activity against *Cladosporium cucumerinum* and *Candida albicans* (Samy, 2011).

Studies on the seeds extracts and seedcakes of *M.ciliatum* showed that they are not less efficient than leaves in their contents of nutrients and medicinal components (Mariod *et al,* 2009).

2.1.2 Monchema genus

The genus Monechma Hochst., closely related to *Justicia L.*, is an African genus contain about 60 species most of them are found in tropical and sub-tropical regions specifically in Southern Africa. Monechma described as well-adapted plants to survival in a hard environment,

2.1.3 *Monechma ciliatum* (Black mahlab)

Monechma ciliatum is a species of Monchema genus plant that belongs to Acanthaceae mainly grows in tropical regions. It is found in western and south-western of Sudan where it is well known and traditionally used, it has a small brownish black seeds, this why the Sudanese people called it the black mahlab or El-Mahlab El-Aswad. Mariod *et al*, (2009) Studies reported that these seeds are rich in protein, fat and other essential nutrients. Also it has many benefits in traditional treatments and cosmetic uses (Oshi and Abdelkarim 2013).

2.1.4 Nutritional value and chemical composition of *M.ciliatum*

Developing countries are under the clutch of malnutrition due to a lack of protein rich food. Protein supply can be broadened by exploration and exploitation of alternative legume sources. Even though many wild legume landraces have been identified, their utilization is limited due to insufficient attention.

Protein content of the *M. ciliatum* seed as reported by (Mariod *et al*, 2009) is 21% with 783.3 mg/g N, as an essential amino acids. The *M.cilliatum* seeds content 13.15% fat with palmitic 4.5%, stearic 16.0%, oleic 47.3%, and linoleic 31.4% as the main fatty acids, and has a good amount of tocopherols as 45.2 mg/100g. The seeds of *M.ciliatumm* contains minerals and 17.1 mg GAE/g of total phenolic compounds (Mariod *et al*. 2009) . Hassan *et al*., (2018) examined *Monechma ciliatum* leaves and concluded they contains 14% Ash, 5.34 % Crude Protein, 4.14% Crude lipid, 3% Crude Fibre, available Carbohydrate 73.50%, Energy Value 352.63(kJ/100 g DW) and considerable amount of K , Na Ca, Mg, Cu, Fe, Mn as essential minerals. *M. ciliatum* leaves contains low levels of anti-nutritional content such as oxalate, phytate, nitrite, cyanide and tannins which were below established toxic levels.

2.1.5 *M.ciliatum* as animals feed

Ogunsan *et al*, (2011) studied the effect of *M.cilliatum* used in the diet of sheep and rabbits, different ratio of *M. cilliatum* were added to the animals daily meals. Their results showed that, increasing the level of supplementation of *M.cillatum* beyond 20% decreased the feed intake and increased live weight of the sheep and the effect of including *M. cilliatum* (MC) in the diet of rabbits when increasing the level of supplementation of MC beyond 10% generally has the same effects on the sheep and he reported that there no adverse effects in feeding MC to the animals. Hassan *et al*., (2018) concluded that high values of ash content of M.ciliatum leaves may indicate that they contain some nutritionally essential minerals that could develop growth of livestock. Therefore, dried leaves could be used as animal feed to supplement some vital mineral elements.

2.1.6 Antioxidant Activity of *M.ciliatum*

The practice of using herbal as food supplement and medicine has been accepted throughout the world. Studies concluded that consuming variety antioxidant compounds from natural source foods can help in treating serious health disorders. *M.ciliatum* has been used traditionally for treating many kinds of diseases. Studies conducted to support and prove these traditional usage reported that *M.ciliatum* leaves extract has powerful antioxidant effect due to the high content of total phenolic (Mariod *et al.*, 2010).

Mariod *et al*., (2009) studied *M.ciliatum* seeds extract antioxidant activity and revealed that, black mahlab seeds phenolic rich fractions (PRFs) had the highest antioxidant activity, thus it reduced the oxidation of bcarotene by hydro-peroxides from the extracts. Hassan *et al*., (2018) stated that *M. ciliatum* is a good source of various metabolites like steroids, flavonoids, phenolics, alkaloids theses antioxidants have a promising radical scavenging activity comparable to standard ascorbic acid and concluded that the leaves of the plant could be a potential source of natural antioxidant.

2.1.7 Antimicrobial activity of *M.ciliatum*

Traditional uses of *M.ciliatum* extracts against microbial diseases encourage researchers to conduct experiments to prove and support these traditional believes by identifying the effective components and the suitable amounts and methods that should be used to obtain the plant benefits.

Oshi and Abdelkarim, (2013), conducted a phytochemical screening from which they supported these traditional uses in the therapy of respiratory tract infections caused by a wide range of microbes and fungi. They found that the effect is due to seeds content of flavonoids, tannins, tritepens, and quinone's. These anti-microbial compounds affected *Staphylococcus aurous* which was sensitive to both water and ethanol extracts. *Klebsiella pneumonia* and *Pseudomonas aeruginosa* found to be insensitive to ethanol extract while fungi were found to be insensitive to all extracts used. The minimum inhibitory concentrations of the extracts against microorganisms were ranged from 12.5 to 25 mg/ml.

Assessment of antibacterial efficacy of different extracts of *Monechma ciliatum* leaves showed that *Staphylococcus aureus*, beta *Streptococcus haemolyticus* group A, *Pseudomonas aeruginosa* and *Escherichia coli* revealed remarkable sensitivity to petroleum ether extract. Petroleum ether extract exhibited the highest antifungal efficiency against all tested fungal species. Also Abdel Karim *et al*., (2017) examined the antimicrobial activity of the seeds oil of *M.ciliatum* and reported that it has significant effect on *Aspergillus niger* and *Candida albicans* fungi and *Staphylococcus aureus* bacteria . The oil found to be partially active against *Escherichia coli* and

Pseudomonas aeruginosa, however was inactive against *Bacillus subtilis*. Abuelgasim *et al*., (2015) studied the antimicrobial activities of extracts of *Monechma ciliatum* stem and leaves and reported that The concentration of the active antimicrobial constituents is different in leaves and stem of *Monechma ciliatum* so leaves methanolic extract was more effective with standard bacteria, Gram positive and Gram negative, while fungi was less sensitive to same extracts.

2.1.8 Medicinal uses of *M. ciliatum*

M.ciliatum was traditionally used as a remedy of general body pain, liver, cold, diarrhea and sterility. Shayoub, (2016) evaluated anti-malarial activity of *M. ciliatum* extract of different solvent against *Plasmodium falciparum* (Malaria) which known as one of the most common major health problems all over the world . The extracts of *M. ciliatum* seeds were screened for their anti-malarial activities against *Plasmodium falciparum* with different concentrations of 500, 250 and 125 μg/ml they resulted to have powerful anti-malarial activities.

Another study carried out by Mariod *et al*., (2010) on the effects of *M. cilliattm* methanolic extrat MCME at 10, 20 and 50 μg/ml on low density lipoprotein receptor (LDLR). They Conluded that MCME concentration played major role on its effect, and different doses showed significant differences in regulation of both LDLR and HMGCR genes, results showed that MCME effectively regulated the expression of LDLRand HMGCR genes influencing the cholesterol metabolism in HepG2cells. Eltigani., (2019) reported *M. ciliatum* seeds has an effective therapeutic agent to prevent periodontal diseases .

2.1.9 Cosmetical uses of *M.ciliatum* seeds

The traditional uses of *M.ciliatum* seeds for cosmetics purposes were referred to antioxidant activity of flavonoids, and tannins, these component consider as the effective substitutes in limiting the damage caused by free radicals of skin. The triterpenes and sterols are aromatic constitutes of medicinal plants. The high antibacterial activity against *Staphylococcus aureus*, *Bacillus subtilis*, *Klebsiella pncumoniae*, *Escherichia coli*, *Candida albicans* and *Aspergillus niger* of black mahlab seeds provides a scientific evidence for the traditional cosmetically uses of black mahlab seeds for skin and mucous membrane disorders (Oshi and Abdelkarim 2013).

2.1.10 Commercial uses of *M.ciliatum*

Abdelkareem, (2013b) formulated and studied a conventional dosage form (tablets) from *Monechma ciliatum* seed's ethanolic extract, using the wet granulation method. And prepared two formulae .Formula-1 by using starch as a binder and disintegrant, formula-2 by using polyvinyl pyrrolidine (PVP) and cross carmellose cellulose (CCS) as a binder and disintegrant the study concluded that Formula-1 would be quite effective than formula-2 tablets of extract and it was more acceptable .

2.1.11 Effect of processing techniques on food quality

Processing (including preparation) makes food healthier, safer, tastier and more shelf-stable. While the benefits are numerous, processing can also be detrimental, affecting the nutritional quality of foods. Blanching, for example, results in leaching losses of vitamins and minerals. Also, milling and extrusion can cause the physical removal of minerals during processing. The nutritional quality of minerals in food depends on their quantity as well as their bioavailability. The bioavailability of key minerals such as iron, zinc and calcium is known to be significantly affected by the fiber, phytic acid, and tannin content of foods. Concentrations of these constituents are altered by various processing methods including milling, fermentation, germination (sprouting), extrusion, and thermal processing. Vitamins, especially ascorbic acid, thiamin and folic acid, are highly sensitive to the same processing methods. The time and temperature of processing, product composition and storage are all factors that substantially impact the vitamin status of our foods (Reddy and Love, 1999).

2.1.12 Boiling, Roasting and Germination

Several methods are commonly used to modify the food properties and decreased the anti-nutritional components. In general physical and/or chemical changes during processing may differ depending upon the methods used .

Food boiling is the most common and simple method of cooking , during the boiling process food is cooked in heated water until get well cooked , then water can be thrown away or remained.

Roasting is a dry heat cooking method it can be done using oven, microwave, coal or any other heat source .roasting cause caramilization or browning the food surface, So it consider as flavor enrichment also roasting increase food shelf life .(Mbah *et al*, 2012).

Germination reported as an essential method that increase protein, fiber, vitamins and amino acids and also improve the functional properties of the seeds components and decreased anti-nutritional contents, (Kavitha and Parimalavalli , 2014).

2.2 Sorghum

Sorghum (Bicolor L. Monech) is the most consumed cereal in Sudan. According to FAO production of sorghum is about 3.86 million tons in 2017. The annual consumption of sorghum in Sudan is about 1.5 to 2 million tons which reflected in many dishes such as porridge or flat bread (Osman, 2010). Sorghum protein content is higher than that in corn, although its protein nutritional value is lower (Dowling *et al,* 2002). Sorghum protein known to have deficient in lysine, threonine and treptophan, rich in leucine, proline and glutamic acid (Duodu *et al*, 2002). The majority of Sudanese people depend on sorghum as a main component of their daily meals it is cooked in different ways according to preference and customs of specific region (Abdelrahim *et* *al.,* 2016). Sorghum consider as a rich source of macronutrients and micronutrients with high nutritional and health potential due to its antioxidants contents. Sorghum as a gluten free food it is used in formulation of several gluten free products, also its products are recommended as safe for people with celiac disease (Hamad *et al.,* 2019).

2.2.1 Sorghum chemical composition

2.2.1.1 Carbohydrates

Sorghum is considered as a rich source of carbohydrate, the carbohydrate content of three Sudanese sorghum cultivars is 75.20, 71.22 and 75.13%, in Dabar, Fakimustahi and Tetron, respectively. Carbohydrate content of Hamra, Shahla and Baidha is 78.34%, 69.65%, 68.81% respectively (Gassem and Osman, 2003). While Abdelrahman *et al.,* (2005) reported that carbohydrate content of two Sudanese sorghum varieties Wad Ahmed and Tabat were 71.40 and 80.70% respectively.

2.2.1.2 Protein

Generally the protein quality is critically important in developing countries where human diets consist mainly of cereals.

The protein content of sorghum is usually 11-13% but sometimes higher values are reported. Awadelkareem, (2002) reported that the protein content of Dabar and fatarita was 11.56 and 13.3% respectively. According to Mustafa and Magdi, (2003) the protein content of three cultivars Hamra, Shahla and Baidha were 14.80, 14.51, and 14.75, respectively. Abdelrahman *et al.,* (2005) analyzed two sorghum cultivars Wad Ahmed and Tabat and found that the protein content was 10.8 and 7.5%, respectively.

2.2.1.3Moisture content

According to Mohamed, (2000) moisture content of three sorghum varieties ranged from 6.0-6.7.8%. Mustafa and Magdi (2003) studied three cultivars Hamra, Shahla and Baidha found they were 8.33, 8.58 and 8.43%, respectively.

2.2.1.4 Ash content

Mohammed (2000) reported ash content of Dabar, Fakimustahi and Tatron were 1.74, 1.42 and 1.41%, respectively. According to Mustafa and Magdi (2003) the ash content of three sorghum varieties Hamra, Shahla, Baidha were 1.94, 1.97 and 1.90%, respectively. Abdelrahman *et al*.,(2005) reported that the ash content of two Sudanese sorghum cultivars Wad Ahmed and Tabat were 1.8 and 1.2%, respectively. Badi (2004) found that the ash contents of two Sudanese sorghum cultivars Wad Ahmed and Tabat were 1.8 and 1.2%, respectively.

2.2.1.5 Fiber content

Dietary fiber is that part of plant material in the diet which is resistant to enzymatic digestion which includes cellulose, non-cellulosic polysaccharides such as hemi-cellulose, pectic substances, gums, mucilage and a non-carbohydrate component lignin.

The dietary guidelines accompanying the Balance of Good Health encourage plenty of foods rich in starch and fiber. potential role for fiber in the prevention of diabetes was put forward over 30 years ago, and a high intake of cereal fiber has consistently been associated with a lower risk of diabetes (McKevith, 2004).

Gassem and Osman (2003) reported that the crude fiber of three cultivars Hamra, Shahla and Baidha were 2.26, 1.71 and 1.90%, respectively. The fiber content of two sorghum cultivars Wad Ahmed and Tabat were 2.7 and 2.3%, respectively results showed by (Abdelrahman *et al.*,2005).

2.2.1.6 Fat

Abdelrahim, (2016) analyzed three sorghum varieties Tabat, Hageen and Feterita) and found the fat content were 4.33, 3.58 and 4.47% respectively, While Abdelrahman *et al*, (2005) found that the fat content of Wad Ahmed and Tabat sorghum varieties were 3.5 and 3.4%, respectively.

2.2.1.7 Minerals

Mineral nutrients play a fundamental role in the biochemical and physiological functions of biological systems. Cereals may especially be an important source of essential minerals in view of their large daily intake both for human health and nutrition. Sorghum, among the cereals, is a major crop being used for food, feed and industrial purposes worldwide.

Calcium content

Total calcium content of two Sudanese sorghum cultivars Wad Ahmed and Tabat were 10mg/100g and 12.5 mg/100g respectively (Badi, 2004). The calcium content of Wad Ahmed and Tabat were 11 mg/100g and 11.7 mg/100g analyzed by Abdelrahman *et al.,* (2005).

Iron content

Badi (2004) reported that total iron content of Wad Ahmed and Tabat were 3.8mg/100g and 4.5mg/100g respectively. In of Grain quality of Sudanese wild sorghum by Abdelhalim *et al.* (2014) concentrations of total and bioavailable iron were found in the grains of Almahkara (3.17 mg/100 g) and Abusabiba (92.8 mg/100 g), respectively. They concluded that Almahkara and PQ-434 could be used as a potential source of iron.

Phosphorous content

Badi (2004) reported that the total phosphorous content of Wad Ahmed and Tabat were 303mg/100g and 288.3 mg/100g while Abdelrahman *et al.,* (2005) reported that the phosphorous content of two Sudanese sorghum cultivars Wad Ahmed and Tabat were 303 mg/100g and 283 mg/100g respectively.

2.2.3 Effect of fermentation on chemical composition of sorghum

Fermentation is method of food processing aimed at prolonging shelf-life and improving palatability. It also an important method for increasing in vitro protein digestibility (Murwan *et al.,* 2011). Fermentation increased the in vitro protein of Dabar and Tabat cultivars from 44.6 to 79.3% and from

36.8 to 80.1%, respectively, while reducing the tannin content of Dabar and Tabat cultivars from 0.22 to 0.06% and 1.6 to 0.04 % respectively.

In addition, fermentation helps to improve the nutritional value of the sorghum. However, there is no highly significant difference in mineral content between the unfermented and fermented sorghum cultivars (Murwan *et al.*, 2011).

Specifically on kisra fermentation has a real effect on the appearance and texture of and makes baking easy and kisra sheets very thin which consider as an advantage.

2.3 Kisra

Kisra is a traditional bread made of natural fermented dough of sorghum flour and baked in a very thin flakes in different sizes depend on the baking plate and the experience of producer preference. It is a Sudanese stable diet for most of most of population (Zaroug *et al*, 2014). It is eaten with different types of stew prepared from vegetables and meat.

2.4 The balanced diet

The balanced diet is known as a meal contain the required amounts of body building protein, energy giving (carbohydrates or fat), protective foods and minerals. The balance diet perform the essential functions within the body by providing heat and energy at the same time must contain the necessary nutrients for building and repairing the tissues (fat, protein, minerals, water, vitamins and cellulose), and supply the nutrients necessary to regulate the body processes. There is increasing evidences that protein – calorie malnutrition is the important reason for the child mortality and infection and other diseases in developing countries (Íguez, *et al.* 2011). Walish, (2019) said that athletes are recommended to follow a balanced diet to avoid a frank deficiency of a nutrient required for proper immune function.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

3.1.1 Seeds

Monechma ciliatum seeds (7 kg) were purchased from West Kurdofan state, En Nahud local market. Sorghum grain 10 kg of sorghum seeds were purchased from Jeddah, Kingdom of Saudi Arabia**.** Both sample seeds were hand-sorted to remove stones, broken seeds and foreign materials. Then carefully cleaned with tap water and stored in polyethylene bags at room temperature.

3.1.2 Chemicals and reagents

Most chemicals used in the laboratory work and reagents were obtained from Food and Nutrition faculty, King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia. Other chemicals were purchased from Saudi Chemical Company, Jeddah, KSA.

3.2 Methods

3.2.1 Boiling of *M. ciliatum* seeds

600 g of *M. ciliatum* seeds were divided in three beakers (1000-ml) then water was added to every beaker of 1:4 seed: water, (deionized water) then was put on magnetic stirred hot plate and was boiled to 100˚C for 40 min until the pieces were well cooked and tender. The boiled seeds were dried and ground in grinder (Moulinex, Japan), then stored in a deep freezer for further use and analysis.

3.2.2 Roasting of *M. ciliatum* seeds

According to Lee, *et al.* (2004) 500 g of clean dried *M. cilliatum* seeds were arranged in a single layer in aluminum foil dishes (12.8 cm) and then were put in electric forced air oven. The seeds were roasted at 180˚C for 20 min. The roasted *Monchema* seeds (RM) were allowed to cool to ambient temperature, then ground in an electric grinder (Moulinex, Japan) and stored in a deep freezer for further use and analysis.

3.2.3 Germination of *M. ciliatum* seeds

Following the method of Urban *et al*. (2005), the germination process was carried out, where 500 g black mahlab seeds were soaked in 2500 ml of0.7g/1 sodium hypochlorite solution for 30 min at room temperature. Seeds were then drained and washed with deionized water, and then soaked in deionized water for 5 h. The soaked seeds were kept between thick layers of cotton cloth and allowed to germinate. Germinated seeds were dried in hot air oven at 60˚C till constant weight, and then were ground into fine powder to pass through 5 mm sieve and stored for analysis. Control samples were ground following the same method mentioned above.

3.2.4 Proximate chemical analysis

The determination of moisture, ash, crude fiber and crude fat were carried out according to the AOAC (2005) methods, while total nitrogen was determined by the micro-Kjeldahl method. The nitrogen to protein conversion factor of 6.25 was used to calculate protein content. The proximate moisture, crude protein, ash, crude fat and crude fiber were summed up and subtracted from 100 to calculate carbohydrates.

3.2.4.1 Moisture content

Moisture content was determined in raw materials and end products according to the method described by the AOAC (2005). Three grams of samples were weighed accurately in clean preheated moisture dish of known weight by using sensitive balance. The uncovered sample and dish were kept in an oven provided with a fan at 105˚C for two hours. The dish was covered and transferred to desiccators, and weighed after reaching room temperature. The crucible was heated in the oven for another two hours and was reweighed. This was repeated until constant weight was obtained. The loss of weight was calculated as percent of weight and expressed as moisture content.

$$\text{Moisture content (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where: W_1 = weight of dish + lid.

W_2 = weight of dish + lid + sample

W_3 = weight of dish + lid + sample after drying.

3.2.4.2 Ash determination

The ash content of the samples was measured according to method of the AOAC (2005). A porcelain crucible was weighed empty, and then accurately two grams of samples were put in it. The samples and the crucible were placed in a muffle furnace at 550˚C for 6 hours until white grey or reddish ash was obtained. The crucible was removed from furnace and placed in a desiccator to cool, then was reweighed.

Ash content [%] = $(W_2 - W_1) \times 100$ / Sample weight

Where : W_1 weight of empty crucible.

W_2 = weight of crucible + sample after ashing

3.2.4.3 Protein determination

Crude protein was determined in all samples by micro Kjeldahl method according to the AOAC (2005). One gram of oven dried sample was weighed into 100 ml Kjeldahl flask. One gram of catalyst mixture (96% anhydrous sodium sulphate 4% cupric sulphate) and 20 ml of concentrated sulphuric acid were added. The sample and contents were heated on an electric heater. The sample was cooled. Diluted and was placed in the distillation apparatus. 20 ml of 40% NaOH were added, and was distilled for 7 min. The ammonia evolved was received in 10 ml of 2% boric acid solution, contained in a conical flask attached to the receiving end. The trapped ammonia was titrated against 0.02 HCI using a universal indicator (methyl red + bromocresol green). The protein% was calculated using the following equation:

$$Nitrogen\ [\%] = \frac{Volume\ of\ HCL * N * 14 * 100}{Weight\ of\ sample * 1000}$$

Protein [%} = Nitrogen [%] × 6.25

Where : Nitrogen [%] = crude nitrogen

Protein [%] = crude protein

N = normality of HCL.

14 = equivalent weight of nitrogen.

3.2.4.4 Fiber determination

The crude fiber was determined according to (AOAC, 2005), the steps were as follows: Two grams of an air dried fat- free sample were transferred to a dry 600 ml beaker. The sample was digested with 200 ml of 1.25% (0.26N) H_2SO_4 for 30 minutes, and the beaker was periodically swirled. The contents were removed and filtered through Buchner funnel, and washed with boiling water. The digestion was repeated using 200 ml of 1.25% (0.23N) NaOH for 30 minutes, and was treated similarly as above. After the last washing the residue was transferred to an ashing dish, and was dried in an oven at 105˚C overnight then was cooled and weighed. The dried residue was ignited in a muffle furnace at 550˚C to constant weight, and allowed to cool, then weighed.

The fiber percentage was calculated as follows:

$$Crude\ fiber[\%] = \frac{W_1 - W_2}{Sample\ weight} \times 100$$

Where: W_1 = The weight of oven dried sample.

W_2 = The weight of the ashed sample.

3.2.4.5Crude fat determination

The crude fat was determined according to the method of the AOCS (2006). The fat was determined for 10 g of oven dried ground sample. Extraction of the fat from each sample was carried out by Soxhtec, using hexane as a solvent for 1:30 hr. After recovery of the solvent, the fat was dried in the oven at 105˚C for2 hours, then allowed to cool in desiccators, and finally weighed. The sample was analyzed in triplicate, and then mean and standard deviation were calculated. The extracted oil was stored in cold room in dark glass bottle for further analysis. The percentage of the crude fat was calculated using the following equation:

$$\text{Fat [\%]} = \frac{W_2 - W_1}{\text{Weight of sample}} \times 100$$

Where:

W_1 = The weight of the empty dried flask

W_2 = The weight of the flask with the extracted fat.

3.2.4.6 Carbohydrates determination

According to AOAC (2005) available carbohydrates were calculated by difference. The summation of moisture, ash, protein, fiber and crude fat contents was subtracted from 100 to obtain the available carbohydrates by difference .

3.2.5 Minerals determination

0.03g ground sample was put in microwave vessel containing 5.0 ml of HNO3 and 2 ml of H_2O_2 (Suprapur, Merck), then it was heated to 205˚C for 15 min, to obtain fine digested mixture after that the mixture was left to cool to 25ºC and colorless solution was obtained. The solution was analyzed by inductively coupled plasma-mass spectrometry (ICP-MS). Liu, *et al*, (2013) method with some modifications was followed for minerals analysis.

3.2.6 Fatty acids composition

15.0 g of seed test were ground and their oil was separated utilizing Soxhlet contraption (Gerhardt) as indicated by AOCS Official strategies Am 2-93 (AOCS, 2003). The removed oil was methylated and changed over to methyl esters of the fatty acids as per the past technique, and afterward was investigated utilizing a Shi-madzu GC-2010 gas chromatograph with a DB-23 column (60m x 0.25mm i.d. also, 0.25 µm film thickness). Injector, column and indicator temperatures were 230, 190 and 240°C, individually. Split proportion was 80:1. Transporter gas was helium at 1.0 ml/min proportion.

3.2.7Amino acid composition determination .

The content of amino acids was determined using Amino Acid Analyzer (S 433 Saykam, Gennany). Sample containing 200 mg of protein in hydrolysis tube were acid hydrated with 5 ml 6NHCL and tightly closed the tube and incubated at 11˚C for 24 hours, solution was filtered through filter paper 125 mm, 200 ml of the filtrate was taken, the filtrate was evaporated at 140°C for about an hour, 1 ml of diluted buffer was add to dried sample. the amino acids composition of the hydrolyzed sample was determined with automatic amino acid analyzer (Mariod *et al*., 2009).

3.2.8 Determination of tocopherols

For tocopherols determination a solution of 250 mg oil of all studied samples in 25 mL n-heptane was directly used for the HPLC. The HPLC analysis was conducted using a Merck-Hitachi low-pressure gradient system, fitted with an L-6000 pump, a Merck-Hitachi F-1000 Fluorescence Spectrophotometer (detector wavelengths for excitation 295 nm, for emission 330 nm) and a D-2500 integration system; 20 µL of the samples were injected by a Merck 655-A40 auto sampler onto a Diol phase HPLC column 25 cm x 4.6 mm ID (Merck, Darmstadt, Germany) using a flow rate of 1.3 mL/min. The mobile phase used was n-heptane/tert, butyl methyl ether (99+1, v/v) (Balz, *et al*., 1992).

$$\text{Vitamin E, mg/kg} = \frac{C}{Ws} \times 10$$

Where : C = Concentration from standard curve (ppm)

Ws = Sample weight (g)

3.2.3 Composite flour preparation

M. ciliatum (black mahlab) untreated and three treated flour and sorghum flour were mixed separately. The ratios of *M. ciliatum* flour to sorghum flour were 1:10 for each sample.

3.2.4 Preparation of fermented dough

The fermented dough, known as (Ajin), was prepared in Sudanese traditional way as it was described by El Tinay *et al*, (1985), for each sample (500 g) was mixed with 700 ml of deionized water and previously fermented dough (50 g) in a plastic ware container. Fermentation was carried out for 24 h (Zaroug *et al*. 2014).

3.2.5 Preparation of kisra

The process of cooking the fermented dough is known as Aowasa, a small amount of the fermented dough a hot plate forming a very thin flake cooked for 1-2 seconds and then it is considered cooked ready for consumption. Fermented baked samples were dried in the shade, then ground to pass 0.5 mm and stored at 4°C in polyethylene bags. All results were expressed on a dry weight basis (Zaroug *et al.* 2014).

3.2.6 Sensory evaluation and analysis

Sensory evaluation was carried out for kisra made of sorghum flour (K) and flour supplemented with raw and treated *M. cilliatum*. Twenty five members of sensory panelists consisting of 11 males and 14 females who are regular consumers of kisra and familiar with the attributes, investigated the sensory qualities of the prepared normal kisra and supplemented kisra. Panelists were comfortably seated and served with separate plates of kisra. The kisra samples were coded, and water was provided. Panelists evaluated samples for color, taste, aroma, texture and overall acceptability characteristics on a 9 = point descriptive scale. (hedonic scale) and data were assessed by analysis of variance (ANOVA) (SAS, 2002).

3.2.7 Statistical Analysis

The examinations were performed with triplicate. The mean qualities and standard deviation (mean ± SD) were determined and tested utilizing Duncan's test ($P<0.05$). Measurable analysis of variance (ANOVA) was applied on all qualities utilizing Statgrafics® Statistical Graphics System version 18.1.12 (2019).

CHAPTER FOUR

RESULS AND DISCUSSTION

4.1 Effect of boiling, roasting and germination processes on *Monechma ciliatum* seeds.

Physical properties of *M. ciliatum* seeds (Figure 4.1) was studied, the average length of the seeds was about 4.0 mm and 100 seeds weighted about 3.0 g.

4.1.1 Proximate chemical composition

Proximate composition of untreated black mahlab (*Monechma ciliatum*) (UM), boiled black mahlab (BM), roasted black mahlab (RM) (Figure 4.2) and germinated black mahlab (GM) seeds are presented in Table 4.l.

Figure 4.1: Raw *M. ciliatum* seeds

Figure 4. 2: Roasted *M.ciliatum* seeds.

4.1.1.1 Moisture content

Untreated black mahlab (UM) seeds had 9.43% moisture content, moisture content after boiling and roasting was significantly decreased to 6.91, 6.41% respectively but after germination no significant changes it was 9.41%, , this outcome is inacceptable concurrence with Mariod *et al, (*2012a) who revealed moisture content of crude safflower seed was diminished, by boiling technique and increment of roasting time, and also with Kita and Figie, (2007) who detailed that, roasting process diminished moisture content of peanut while after germination there was no significant difference notified .

4.1.1.2 Fat content

The fat content of untreated and treated black mahlab seeds is shown in Table 4.1. The untreated black mahlab (UM) seed flour had fat content of 11.65% , after boiling and roasting technique fat content was significantly increased to 14.66% and 12.39% respectively, while no significant change after germination it was 11.30%. Boiling treatment showed highest fat content followed by roasting treatment. This result is disagreed with Onyeike and Oguike, (2003) who showed that, crude fat was highest in raw seeds and lowest in boiled seeds of groundnuts. Germination treatment fat content was slightly effected in agreement with (Li *et al*. 2014) who reported that germination slightly decreased fat content of peanut seeds.

4.1.1.3 Protein content

The protein content of untreated and treated black mahlab seeds is shown in Table 4.1. The results showed that, protein content found to be 22.29% in UM after processing it was found to be 23.89, 22.90 and 24.34% in BM, RM and GM, respectively. Protein content was significantly increased with boiling and germination processes while insignificantly increased with roasting process. This outcome is inacceptable concurrence with Mariod *et al*., (2012b) who reported that germination black cumin in general increased both oil and protein contents and Olanipekun, *et al.*, (2015) who reported that, the protein values of the flour from cooked kidney bean seeds were significantly higher than that of the raw seeds, while Doss, *et al*., (2011) reported that, processing techniques e.g. soaking and cooking of wild jack bean (*Canavalia ensiformis*) enhanced its protein content and protein availability. Also Mbah, *et al*, (2012) showed that boiling increased the protein content of Moringa seeds. The expansion in the protein estimation of the processed seeds might be because of separate of raw protein to amino acids during processing.

4.1.1.4 Fiber content

The fiber content of untreated and treated black mahlab seeds is shown in Table 4.1. fiber content was found to be 9.2% in UM after processing fiber content was 9.0 and 9.9% in RM and GM respectively there was no significant difference between control, roasted, and germinated samples, while it was significantly increased by boiling process 10.1, this result is agreed with Mbah, *et al*, (2012) who reported that boiling increased fiber of

Moringa seeds, and in contrast with Mariod *et al*, (2012a) who said that, fiber content of safflower was decreased because of boiling treatments.

4.1.1.5 Carbohydrate

The carbohydrate content of untreated and treated black mahlab seeds is shown in Table 4.1. Total available carbohydrate in untreated black mahlab UM seeds was 43.60%, After boiling, roasting and germination it is found to be 40.89, 45.62 and 41.39% and respectively Carbohydrate content significantly decreased in BM and GM seeds while significant increasing occurred in RM sample . Carbohydrate has the highest composition by percentage in all the samples, this result is agreed with Onyeike and Oguike, (2003) who reported that boiling and frying increase the total carbohydrate content of groundnut, this indicates that the *Monechma ciliatuim* flour is a good source of energy for consumers.

4.1.1.6 Ash Content

Table 4.1. showed the ash content of untreated and treated black mahlab seeds. The ash content of untreated black mahlab UM was 3.92% which was insignificantly affected by all processing treatment to be 3.95% in RM and 3.66%, 3.45% in GM and BM respectively.

Table 4.1 Approximate analysis for raw, boiled, roasted and germinated *Monechma ciliatum*.

Sample	Moisture (%)	Fats (%)	Carbohydrate (%)	Protein (%)	Fiber (%)	Ash (%)
UM	9.43 ± 0.03^{a}	11.56 ± 0.37^{a}	43.60 ± 0.7^{a}	22.29 ± 0.23^{a}	9.2 ± 0.22^{a}	3.92 ± 0.1^{a}
BM	6.91 ± 0.01^{b}	14.66 ± 0.31^{c}	40.89 ± 0.5^{b}	23.89 ± 0.29^{b}	10.11 ± 0.14^{b}	3.54 ± 0.1^{a}
RM	6.14 ± 0.11^{b}	12.39 ± 0.25^{b}	45.62 ± 0.7^{c}	22.90 ± 0.13^{a}	9.0 ± 0.23^{a}	3.95 ± 0.2^{a}
GM	9.41 ± 0.3^{a}	11.30 ± 0.08^{a}	41.39 ± 0.2^{b}	24.34 ± 0.17^{b}	9.9 ± 0.29^{a}	3.66 ± 0.1^{a}

Values are means of triplicate determinations. Means in the same column followed by the same superscript are not significantly different at $p<0.05$. UM: Untreated mahlab. BM: Boiled mahlab. RM: Roasted mahlab. GM: Germinated mahlab

4.1.2 Effect of processing on minerals

The results showed that *Monechma ciliatum* MC contains good amount of major and trace elements. Table 4.2 summaries the results of mineral composition of raw or Untreated UM , boiled BM, roasted RM and germinated GM *M.ciliatum* seeds. Concentrations of major and trace elements in raw MC seeds were significantly ($p<0.05$) higher than the processed seeds.

Table 4.2 reports how boiling, roasting and germination impact sodium, calcium, potassium, copper, iron, zinc, magnesium, manganese, selenium and phosphorus contents of the MC seeds in different concentrations. Generally the three processing treatments were varied in their effects on minerals contents of *M.ciliatum* seeds , roasting was the most retention method of mineral content .

Table 4.2 shows that Sodium (Na) content of UM untreated *M.C* was found to be 264.1 mg/kg after treatment this value was insignificantly decreased to be 251.6 mg/kg in BM and significantly decreased to 227.4 mg/kg in RM, while it was insignificantly increased to be 270.7 mg/kg GM .

Calcium (Ca) content was found to be 4911 mg/kg in UM after treatment it was significantly decreased to be 4158.5, 4666.3 and 3880.3 mg/kg in BM, RM and GM, respectively. Roasted sample was the highest in Calcium.

Potassium (K) content was found to be 7812.7 mg/kg in UM after treatment it was significantly decreased to be 4787.6 and 7140.0 mg/kg in BM and GM respectively, while insignificantly decreased to be 7702.6 mg/kg in RM. Roasted *M.ciliatum* was the highest in Potassium (K) content .

Copper content (Cu) was found to be 12.40 mg/kg in UM, after treatment no significant change in Cu content in the three samples , they were found to be 12.11, 11.53 and 11.73 mg/kg, in BM, RM and GM respectively.

Iron (Fe) content was found to be 166.5 mg/kg in UM, after treatment it was significantly decreased to be 59.2 and 89.6 mg/kg in BM and RM respectively and insignificantly decreased to be 162.2 mg/kg in GM. Germinated seeds was the highest in Fe content .

Zinc content was found to be 23.66 mg/kg in control sample UM, after treatment it was significantly decreased to be 19.67 and 21.36 mg/kg in BM and RM respectively and insignificantly decreased to 22.88 mg/kg in GM. germinated sample was the highest in zinc .

In control sample UM, Magnesium (Mg) content was found to be 4747.2 mg/kg after treatment it was significantly decreased to be 4387.6 and , 4367.3 mg/kg in BM and GM respectively, but no significant change in RM which was 4747.6 mg/kg. Roasted sample was the highest in magnesium.

In control sample UM, Manganese (Mn) content was found to be 93.19 mg/kg after treatment it was significantly decreased to 66.02, 84.79 and 67.36 mg/kg in BM, RM and GM, respectively. Roasted sample was the highest in Manganese.

From Table 4.2, selenium (Se) content was 0.56 mg/kg in control sample K, after treatment no significant change in boiled sample BM it was 0.54 mg/kg, but it was significantly decreased to be 0.26 and 0.41 mg/ kg in RM and GM respectively.

Phosphorus (P) content was 3059.5 mg/kg in control sample UM after treatment no significant change in GM it was 3002.7 mg/kg, while it was significantly increased to be 3118.8 and 3205.8 mg/kg in BM and RM respectively. Roasted sample was the highest in Phosphorus .

Table 4.2 Effect of boiling, roasting and germination on minerals content mg/kg of *Monechma ciliatum* seeds.

Sample	UM	BM	RM	GM
Na	264.1 ±0.02 [a]	251.6 ±0.012[a]	227.4 ± 0.02[b]	270.7 ±0.10 [a]
Ca	4911.2 ±0.01 [a]	4158.5±0.03 [c]	4666.3 ±0.02 [b]	3880.3 ±0.11[d]
K	7812.7 ±0.01 [a]	4787.6±0.010[c]	7702.6±0.01[a]	7140.0 ±0.07[b]
Cu	12.40 ±0.12 [a]	12.11 ±0.04[a]	11.53 ±0.13 [a]	11.73 ±0.03[a]
Fe	166.5 ±0.03 [a]	59.2 ±0.01[d]	89.6 ±0.04[c]	162.5 ±0.07[a]
Zn	23.66 ±0.01 [a]	19.67 ±0.03 [b]	21.36 ±0.03[c]	22.88 ±0.01[a]
Mg	4747.2± 0.02 [a]	4387.6 ±0.01 [b]	4747.6 ±0.03[a]	4367.2 ±0.05[b]
Mn	93.19 ±0.14 [a]	66.02 ±0.12[c]	84.79 ±0.07[b]	67.36±0.01[c]
Se	0.56 ±0.12 [a]	0.54 ±0.07[a]	0.26 ±0.01 [d]	0.41 ±0.03[c]
P	3059.5±0.03 [a]	3118.9 ±0.02 [b]	3205.8±0.11[b]	3002.7 ±0.12[a]

Values are means of triplicate determinations ± S.D. Means in the same row followed by the same superscript are not significantly different at $p<0.05$.UM: Untreated mahlab; GM: Germinated mahlab; RM: Roasted mahlab; BM: Boiled mahlab.

4.1.3 Fatty acids and tocopherols composition

The human body uses essential fatty acids (EPAs) to produce healthy cell membranes and benefit from their multiple biological roles, such as influencing the inflammatory cascade, reducing the oxidative stress, presenting neuro-protection and cardiovascular protection. Fatty acid levels have been appeared as a significant factor in various illnesses, that is the reason they have been utilized to distinguish potential biomarkers for a few pathologies, for example, polycystic ovary condition (PCOS) (Nagy, and Tiuca, 2017). Some preparing procedures can influence oils Fatty acid arrangement in food when treated with progressive heating (Lee, *et al*., 2004).

The fatty acid composition of untreated and treated MC seed oils (UM, BM, RM and GM) determined by GC presented in Table 4.3. The results showed that the major fatty acids in raw (untreated) *M.ciliatum* seeds (UM) oils were oleic, and linoleic, the found to be 44.87 and 16.84% respectively.

The results in Table 4.3 shows palmitic acid was significantly increased from 6.11% in untreated *M. ciliatum* seeds (UM) to 31.80% and to 21.80% in RM and GM respectively. Myristic acid was significantly increased from 0.14% in UM seeds to 4.46% and 8.43% in RM and GM respectively .

Oleic and linoleic acids were not affected by boiling technique while Oleic was significantly decreased from 44.87% in UM to 39.21% in RM and to 29.40% in GM , and linoleic significantly decreased from 16.84% in (UM) to 10.22 % in RM and 9.16% in GM respectively .

Total unsaturated fatty acids was found to be 68.118%, while saturated fatty acids was 31.402% in untreated sample UM, after boiling no significant change in both saturated fatty acids (SFA) and unsaturated fatty acids (UFA) composition of MC seeds oils.

Roasting and germination treatments significantly increased the total saturated fatty acids from 31.402 % to 45.659 and 54.472 % respectively, and decreased unsaturated fatty acids from 68.118 % to 54.941 and 41.474% This results support (Ghazzawi and Ismail, 2017) who reported that effects of roasting and frying on four nuts species (almonds, pine, cashew, and pistachio) were positive for saturated fatty acids profile, and partially agreed with Mariod *et al*. (2012b), who reported fatty acids of black cumin seeds was not change with boiling and roasting temperatures. Ghazzawi and Ismail, (2018) referenced that, howed that roasting and frying peanuts significantly increased their levels of essential fatty acids EFA**.**

4.1.4 Tocopherol

Tocopherol, a class of fat-soluble compound with vitamin E, is best known for its antioxidant activity. It is synthesized only in photosynthetic organisms and acts as a protective component. Tocopherol has also been found to be crucial for seed storage and germination (Maeda and Della, 2007). The nutritional benefits of vitamin E (alpha-tocopherol) and its importance as a daily part of the human diet has been well documented.

The content of total tocopherols in treated and untreated MC seeds oil is shown in Table 4.3. As general the total tocopherol concentration was decreased during boiling and roasting techniques as a result of heating temperature. But it was increased by germination process. From Table 4.3 the content of tocopherol of untreated MC (UM) oil was found to be 0.11 mg/100g this amount was affected equally by boiling (BM) and roasting (RM) and it was decreased to 0.10 in both, and it was significantly increased to be 0.18 mg/100g in germination (GM), this result agreed with Shi *et al*., (2019) who reported that, the roasting sesame seeds at 160ºC for 30 min, decreased steadily the total tocopherols and sesamolin.

Table 4.3 The effect of boiling, roasting and germination treatments on fatty acids (%) and tocopherols mg/100g *of Monechma ciliatum* seeds

Fatty acids		UM	BM	RM	GM
C12	Lauric	0.859±0.70[a]	1.807±0.23[b]	2.258±0. 14[c]	20.427±0.43[d]
C14	Myristic	0.140±0.64[a]	0.124±0.11[a]	4.462±0.10[b]	8.433±0.40[c]
C16	Palmitic	6.116±0.66[a]	6.495±0.24[a]	31.804±0.22[b]	21.806±0.63[c]
C18	Stearic	3.238±0.71[a]	3.236±0.31[a]	6.135±0.07[b]	3.806±0.53[a]
C20	Archidic	9.183±0.84[a]	9.020±0.41[a]	ND	ND
C22	Behenic	0.839±0.34[a]	0.829±0.23[a]	ND	ND
C23	Tricosanoic	7.033±0.81[a]	6.626±0.21[a]	ND	ND
C24	Lignoceric	3.994±0.33[a]	3.709±0.22[a]	ND	ND
C16:1	Pamitoleic	0.251±0.31[a]	0.270±0.37[a]	4.083±0.38[b]	2.177±0.84[c]
C18:1	Oleic	44.878±0.74[a]	44.420±0.22[a]	39.216±0.32[b]	29.408±0.43[c]
C18:2	Linoleic	16.480±0.43[a]	16.734±0.22[a]	10.264±0.54[b]	9.159±0.13[c]
C20:1	Eicosenoic	6.545±0.51[a]	6.453±0.45[a]	1.378±0.22[b]	0.730±0.22[c]
Saturated		**31.402**[a]	**31.846**[b]	**44.659**[c]	**54.472**[d]
Unsaturated		**68.118**[a]	**67.877**[a]	**54.941**[c]	**41.474**[d]
α-tocopherol		0.11± 0.04[a]	0.10±0.04[a]	0.10±0.01[a]	0.18±0.07[b]

Means in the same row followed by the same superscript are not significantly different at $p<0.05$.UM: Untreated mahlab. BM: Boiled mahlab . RM: Roasted mahlab. GM: Germinated mahlab.

4.1.4 Amino acid composition

Amino acids are categorized as acidic, basic and neutral amino acids. Some amino acids are not synthesized in the body and it is necessary to take them in diet. Such types of amino acids are called essential amino acids. Amino acids are necessary for protein synthesis and have various functions in the body. It is necessary to take them in the diet because their deficiency results in decrease formation of protein or protein is not formed as a result protein deficiency may occur and that ultimately leads to disease condition.

Data presented in Table 4.4 reports the amino acid composition of treated and untreated MC seeds. Generally total amino acids increased by boiling, roasting and germination, except methionine acid which was significantly decreased with roasting and totally absent with boiling and germination and lysine insignificantly decreased by roasting .

From Table 4.4 total amino acids (TAA) was found to be 22.291 g/100g in untreated black mahlab seeds, after treatments (TAA) was significantly increased to be 23.894 and 24.336 g/100g in boiled, and germinated samples respectively, but insignificantly increased to 22.899 g/100g in roasted sample. Roasted sample was the lowest in total amino acids that is due to the insignificant decrease of lysine acids. These results were in a good agreement with Mariod *et al*. (2012a) who observed boiled and roasted safflower seeds for the most part have extremely high absolute amino acids substance contrasted with the fresh examples. These outcome additionally was in acceptable concurrence with the consequences of Oluwaniyi *et al*., (2010) who found that the procedures of boiling and roasting of fishes for the most part have close (or somewhat higher) complete amino acid contents contrasted and the fresh samples, while these results were disagreed with those reported by Hefnawy, (2011) who found that cooking treatments decreased the concentrations of lysine, tryptophan, total aromatic and sulfur containing amino acids of lentils.

Table 4.4 Effect of boiling, roasting and germination treatments on amino acids composition of *Monechma ciliatum* seeds(g/100g).

Amino acid	UM	BM	RM	GM

Hydroxyproline	ND	ND	ND	ND
Aspartic acid	2.294±0.13	2.349±0.33	2.285±0.34	2.514±0.17
Serine	1.555±0.21	1.665±0.12	1.576±0.014	1.676±0.13
Glumatic acid	2.485±0.14	3.679±0.01	3.386±0.21	3.824±0.04
Glycine	1.165±0.06	1.224±0.02	1.243±0.03	1.229±0.02
Histidine	0.525±0.02	0.559±0.07	0.586±0.03	0.525±0.01
Arginine	2.532±0.04	2.930±0.03	2.889±0.11	2.889±0.13
Therionine	1.014±0.04	1.111±0.01	1.092±0.07	1.096±0.01
Alanine	1.130±0.01	1.207±0.07	1.170±0.17	1.213±0.04
Proline	1.157±0.01	1.276±0.06	1.198±0.14	1.306±0.23
Threonine	0.695±0.23	0.744±0.10	0.743±0.04	0.750±0.17
Valine	1.215±0.10	1.318±0.02	1.262±0.10	1.354±0.04
Methionine	0.300±0.23	ND	0.023±0.12	ND
Lysine	1.386±0.14	1.453±0.04	1.246±0.11	1.462±33
Isoleucine	1.009±0.01	1.123±0.06	1.061±0.10	1.124±0.12
Leucine	1.912±0.03	2.130±0.01	2.003±0.9	2.112±0.06
Phenylalanine	1.017±0.04	1.124±0.01	1.134±0.14	1.164±0.6
Total	**22.291**^{a}	**23.894**^{b}	**22.899**^{c}	**24.336**^{d}

Means followed by the same superscript are not significantly different at p<0.05.UM Untreated; GM: Germinated; RM: Roasted; BM: Boiled. Values are means ± SD

4.2 Effect of supplementation with untreated, boiled, roasted and germinated *Monechma ciliatum* on Kisra quality.

4.2.1 The proximate composition of unsupplemented and supplemented kisra

The proximate composition of kisra made of sorghum flour (K) and kisra supplemented with untreated *M. ciliatum* (UMK) , boiled *M. ciliatum* (BMK), roasted *M. ciliatum* (RMK) and with germinated *M. ciliatum* seeds flour (GMK) are presented in Table 4.5. (composite flour ratios were 1:10 *M.ciliatum* to sorghum flour).

4.2.1.1 Moisture content

In Table 4.5 the moisture content of K, was found to be 9.81, after supplementation with 10% of UM, BM, RM and GM was found to be 7.14, 8.10, 9.44 and 9.42%, respectively. supplementation with untreated UM and boiled BM significantly decreased Kisra moisture content while roasted RM and germinated GM had insignificant effect .

4.2.1.2 Fat content

In Table 4.5. the fat content of sorghum kisra was 1.57% after supplementation with 10% of UM, BM, RM and GM and it was significantly increased to 2.59, 2.57, 2.96 and 2.41% in UMK, BMK, RMK, and GMK, respectively. The result agreed with that reported by Alemu *et al*., (2017) who said that, supplementation whole wheat flour with Mushroom flour increased fat content and in contrast this result disagreed with Mohammed Nour *et al.*, (2014) who found supplementation of sorghum flour with Moringa leaves powder slightly decreased the oil content. Kisra supplemented with roasted *M. ciliatum* contained the highest fat content, that is referred to the initial fat content of *M. ciliatum*.

4.2.1.3 Protein content

In Table 4.5. the protein content of pure sorghum kisra was found to be 11.58% in UMK , after supplementation with 10% of UM, BM, RM and GM it was significantly increased to 13.58, 13.51, 13.31 and 12.95%, in BMK, RMK, and GMK respectively. This finding was agreed with Mohammed Nour *et al* (2014) who reported that protein content of raw sorghum flour was found to be 10.31% and after supplementation with 5, 10 and 15% Moringa leaves powder it was significantly increased to 11.87, 12.89 and 14.31%, respectively and Kayitesi, (2010) who showed that protein content of sorghum flour increased after supplementation with Marmra bean flour.

4.2.1.4 Fiber content

In Table 4.5 fiber content of unsupplemented kisra was found to be 1.68%. Supplementation of *M. ciliatum* flour with 10% UM, BM, RM and GM significantly increased the fiber content to 2.21, 2.64, 2.20 and 2.41%, in UMK, BMK, RMK, and GMK respectively. The increase in fiber content of supplemented kisra may be due to high content of fiber in *M. ciliatum* seeds. This study is in agreement with that reported by Alemu *et al*., (2017) who said that supplementation whole wheat flour with Mushroom flour increased the fiber content.

Figure 4.3: kisra and kisra supplemented with raw (MK),roasted (Rk), germinated (GK) and boiled (BK)*M.ciliatum*,(dried and ground).

4.2.1.5 Carbohydrate content

In Table 4.5 the carbohydrate content of unsupplemented kisra K was found to be 73.79% , after supplementation with 10% 0f UM, BM, RM and GM it was significantly decreased to be 72.58, 71.18, 70.32, and 71.11%, in UMK, BMK, RMK, and GMK respectively. Supplementation of kisra with untreated and treated mahlab decreased the carbohydrate content, and the UMK was the highest in carbohydrate.

4.2.1.6 Ash content

In Table 4.5 the ash content of unsupplemented kisra was found to be 1.57%, after Supplementation with UM, BM, RM and GM it was 1.70%, 1.67, 1.77, 1.70 %, in UMK, BMK, RMK, and GMK respectively, no significant change in ash content . This finding was disagreed with that reported by Mustafa, (2006) who reported that supplemented sorghum flour with pumpkins seeds flour increased the ash content.

In Table 4.5. the proximate analysis of *Monechma ciliatum* seeds revealed high content of fat, protein, fiber which explain supplementation of sorghum kisra with this seeds increased these biological compounds and hence improve its nutritional composition.

Table 4.5 Approximate analysis for sorghum kisra and kisra supplemented with untreated boiled, roasted and germinated *Monechma ciliatum*.

Sample	Moisture	Fat	Carbohydrate	Protein	Fiber	Ash
K	9.81 ± 0.02^{a}	1.57 ± 0.23^{a}	73.79 ± 0.51^{a}	11.58 ± 0.12^{a}	1.68 ± 0.4^{2a}	1.57 ± 0.07^{a}
UMK	7.14 ± 0.15^{b}	2.59 ± 0.37^{b}	72.58 ± 0.63^{b}	13.51 ± 0.34^{b}	2.21 ± 0.39^{b}	$1.70\pm0.\ 12^{a}$
BMK	8.10 ± 0.15^{c}	$2.57\pm0.33_{b}$	71.18 ± 0.77^{c}	13.84 ± 0.30^{b}	2.64 ± 0.33^{c}	1.67 ± 0.12^{a}

RMK	9.44±0.01^{a}	2.96±0.23^{d}	70.32±0.86^{d}	13.31±0.29^{b}	2.20±0.31^{b}	1.77±0.03^{a}
GMK	9.42±0.03^{a}	2.41±0.16^{c}	71.11±0.27^{c}	12.95±0.21^{c}	2.41±0.41^{c}	1.70±0.02^{a}

Means in the same column followed by the same superscript are not significantly different at $p<0.05$ .UM K (Kisra control); UMK: Untreated *Monechma ciliatum kisra*; GMK: Germinated *Monechma ciliatum kisra*; RMK: Roasted *Monechma ciliatum kisra*; BMK: Boiled *Monechma ciliatum kisra*. Values are means ± SD.

4.2.2 Minerals content

The minerals content of unsupplemented sorghum kisra and kisra supplemented with *Monechma ciliatum* is shown in Table 4.6. Although supplementation of Kisra with 10% of untreated and boiled , roasted and germinated *Monechma ciliatum* was slightly varied in their effect on kisra mineral content, in general kisra content of minerals was increased, This result was in agreement with Mustafa (2006) who reported that addition of both wheat and pumpkin flour increased the mineral content of sorghum flour.

Table 4.6 shows that Sodium (Na) content of sorghum kisra K was found to be 362.6, mg/kg after supplementation this value was significantly increased in UMK and BMK to 413.7 and 420.0 mg/kg, respectively, and was significantly decreased to 307.8, and 296.2 mg/kg, in RMK and GMK, respectively.

Calcium (Ca) content was found to be 174.4 mg/kg in K after supplementation it was significantly increased to be 554.8, 527.2, 565.0 and 459.5 mg/kg in UMK, BMK, RMK and GMK, respectively.

Potassium (K) content was found to be 4358.3 mg/kg in Kisra after supplementation it was significantly increased to be 4806.5, 4930.9 and 4706.3 mg/kg in UMK, , RMK and GMK, respectively and insignificantly increased to 4406.5 mg /kg in BMK.

In control (sorghum kisra) Copper (Cu) content was found to be 3.31 mg/kg, after supplementation it was significantly increased to be 4.90, 4.19, 4.32 and 4.26 mg/kg, in UMK, BMK, RMK and GMK respectively. Kisra supplemented with untreated *Monechma ciliatum* was the highest of copper .

Iron (Fe) content was found to be 67.61 mg/kg in (K), after supplementation it was insignificantly decreased to be 62.24, 60.46, and 61.40 mg/kg in UMK, RMK and GMK respectively and significantly decreased to 41.17 in BMK. Supplementation with untreated and treated *Monechma ciliatum* decreased the iron content. Kisra supplemented with boiled *Monechma ciliatum* was the lowest iron content.

Zinc content was found to be 15.94 in control sample K, after supplementation it was significantly increased to be 16.91 and 17.21 mg/kg in RMK and GMK GMK, respectively but, supplementation with untreated and boiled *Monechma ciliatum* was found to be 15.74 and 16.03 mg/kg closely with control kisra K.

In control sample K, magnesium (Mg) content was found to be 1592.0 mg/kg after supplementation with *Monechma ciliatum* seed flour it was significantly increased to be 1874.6, 1822.6, 1999.4 and 1868.1 mg/kg, in UMK, BMK, RMK and GMK respectively. Kisra supplemented with roasted *Monechma ciliatum* was the highest in Mg content.

In control sample K, manganese (Mn) content was found to be 14.55 mg/kg after supplementation with *Monechma ciliatum* seed flour it was significantly increased to 41.44, 20.84, 22.06 and 19.29 mg/kg in UMK, BMK, RMK and GMK, respectively. Kisra supplemented with untreated *Monechma ciliatum* was the highest in manganese content.

From Table 4.6, phosphorus (P) content was 2221.2 mg/kg in control sample K, after supplementation with *Monechma ciliatum* it was significantly increased to be 2673.3, 2491.6, 2480.0 mg/ kg in UMK, BMK, RMK and was decreased to 2140.5 mg/kg, in and GMK respectively. Supplementation with UM, BM and RM significantly increased the phosphorus content, while supplementation with GM decreased it. Kisra supplemented with untreated *Monechma ciliatum* seed flour was the highest in phosphorus content.

Table 4.6 Mineral content (mg/kg)of Kisra supplemented with untreated, boiled, roasted and geminated *Monechma ciliatum* seeds.

Sample	K	UMK	BMK	RMD	GMK
N	362.6 $\pm$0.12^{a}	413.7$\pm$0.27^{b}	420.0$\pm$0.55^{b}	307.8$\pm$32^{c}	296.2$\pm$0.33^{d}
Ca	174.7 $\pm$1.01^{a}	554.8$\pm$0.31^{b}	527.2$\pm$0.43^{c}	565.0$\pm$2.11^{b}	495.5$\pm$0.74^{c}
K	4359.6$\pm$1.21^{a}	4806.3$\pm$0.27^{b}	4406.5$\pm$0.32^{a}	4930.9$\pm$0.17^{c}	48706.3$\pm$1.07^{b}
Cu	3.31 $\pm$0.32^{a}	4.90$\pm$0.09^{b}	4.19$\pm$0.17^{c}	4.32$\pm$0.30^{c}	4.26 $\pm$0.23^{c}
Fe	67.61 $\pm$0.21^{a}	62.24$\pm$0.34^{b}	49.17$\pm$0.33^{d}	60.46$\pm$0.10^{c}	61.49$\pm$0.77^{b}
Zn	15.94$\pm$0.43^{a}	15.74$\pm$0.41^{a}	16.03$\pm$0.41^{a}	16.91$\pm$0.34^{b}	17.21$\pm$0.53^{b}

Mg	1592.0 ± 0.23^{a}	1874.6 ± 0.22^{b}	1822.6 ± 0.45^{c}	1999.4 ± 0.37^{d}	1868.1 ± 1.04^{b}
Mn	14.55 ± 1.21^{a}	41.44 ± 0.21^{b}	20.84 ± 2.12^{c}	22.06 ± 0.10^{c}	19.22 ± 1.03^{d}
Se	ND	0.06±0.02	0.03±0.01	ND	0.04±0.04
P	2221.7 ± 0.32^{a}	2673.3 ± 0.24^{b}	2491.6 ± 1.90^{c}	2480.0 ± 2.03^{c}	2140.5 ± 1.87^{d}

Means in the same row followed by the same superscript are not significantly different at p<0.05K (Kisra control); UMK: Untreated *Monechma ciliatum* kisra; GMK: Germinated *Monechma ciliatum kisra*; RMK: Roasted *Monechma ciliatum* kisra; BMK: Boiled *Monechma ciliatum* kisra, ND: not detected. Values are means ± SD.

4.2.3 Fatty acid and tocopherol composition of sorghum kisra and kisra supplemented with untreated boiled, roasted and germinated *Monechma ciliatum*

The fatty acid composition of sorghum Kisra K (unsupplemented) and Kisra supplemented with 10% of untreated *M.cilliatum* (UMK), boiled *M.cilliatum* (BMK), roasted *M.cilliatum* (RMK) and germinated *M.cilliatum* (GMK) are presented in Table 4.7. The results show that the major fatty acids in both supplemented or unsupplemented Kisra were, oleic, linoleic and palmetic. Supplementation with untreated *M.cilliatum* and treated *M.cilliatum* were varied in their effect on fatty acids content.

Supplementation with untreated and boiled *M.cilliatum* seeds had similar effect on sorghum Kisra fatty acids content , the two methods significantly increased Kisra saturated fatty acids(SFA) from 26.236 to 28.309% and 29.237%, respectively, at the same time these two processing methods increased Kisra unsaturated fatty acids (UFA) from 67.016% to

68.058% and 67.347%, respectively. This increasing is a result of increasing in C:23 from 0.122% in K to 4.101% and 4.153 % in UMK and BMK, and the increasing in C18:2 from 19.501 to 20.423 and 20.939% in UMK and BMK, respectively.

It was clear that Kisra supplemented with roasted and germinated MC was the lowest in saturated fatty acids content and the highest in unsaturated fatty acids. Saturated fatty acids as they were found to be 23.619% and 24.695 % in RMK and GMK respectively, while unsaturated fatty acids were found to be 74.936% and 73.273%. This increasing in unsaturated fatty acids is a result of the increasing in C18:3 from 19.501% to 31.666 and 30.468% in RMK and GMK respectively. Generally supplementation of kisra with roasted and germinated MC seeds can significantly increase its unsaturated fatty acids content.

4.2.4 Tocopherols

Sorghum Kisra α-tocopherols content was not affected by supplementation with untreated and treated MC. In Table 4.7 Tocopherols was found to be 0.8 mg/100g in kisra and the four supplemented samples.

Table 4.7 Effect of supplementation with untreated and treated *Monechma ciliatum* on sorghum kisra fatty acids and tocopherols content mg/100g.

Fatty acids	K	UMK	BMK	RMK	GMK
Lauric	0.107±0.00[a]	0.207±0.14[a]	1.285±0.21[b]	0.795±0.07[c]	1.362±0.17[b]
Myristic	0.208±0.33[a]	0.375±0.07[a]	0.144±0.11[b]	0.175±0.11[b]	0.587±0.00c
Palmitic	13.662±0.23[a]	13.903±0.21[a]	12.890±0.21[a]	10.702±0.11[b]	10.820±0.37[b]
Stearic	3.152±0.11[a]	2.239±0.06[b]	3.177±0.10[a]	2.737±0.54[c]	2.771±0.13[c]
Archidic	4.933±0.83[a]	4.825±0.11[a]	5.025±0.25[a]	4.115±0.23[b]	4.194±0.21[b]
Behenic	4.052±0.03[a]	0.565±0.00[b]	0.489±0.15[b]	0.413±0.23[c]	0.437±0.09[c]
Tricosanoic	0.122±0.43[a]	4.101±0.22[b]	4.153±0.17[b]	3.078±0.43[c]	3.083±0.07[c]
Lignoceric	1.923±0.09[a]	2.095±0.19[a]	2.075±0.22[a]	1.0664±0.81[b]	1.711±0.27[a]
Pamitdeic	0.380±0.53[a]	0.528±0.22[b]	0.353±0.22[a]	0.326±0.02[a]	0.387±0.05[a]
Oleic	43.920±0.17[a]	43.896±0.08[a]	43.360±0.17[a]	39.972±0.05[b]	39.391±0.02[b]
Linoleic	19.501±0.31[a]	20.423±0.11[b]	20.939±0.06[b]	31.666±0.33[c]	30.468±0.33[c]
Eicosenoic	3.215±0.77[a]	3.211±0.12[a]	3.317±0.15[a]	2.972±0.31[a]	3.027±0.51[a]
α-tocopherol	0.8±0.00[a]	0.8±0.02[a]	0.8±0.02[a]	0.8±0.04[a]	0.8±0.00[a]
Saturated	**26.236[a]**	**28.309[b]**	**29.237[b]**	**23.619[c]**	**24.965[c]**
Unsaturated	**68.016[a]**	**68.058[b]**	**67.347[b]**	**74.936[c]**	**73.273[c]**

Means in the same row followed by the same superscript are not significantly different at $p<0.05$ .K (Kisra control); UMK: Untreated *Monechma ciliatum* kisra; GMK: Germinated *Monechma ciliatum kisra*; RMK: Roasted *Monechma ciliatum kisra*; BMK: Boiled *Monechma ciliatum kisra*. Values are means ± SD.

4.2.5 Amino acids composition of sorghum kisra and kisra supplemented with untreated boiled, roasted and germinated *Monechma ciliatum*

Data presented in Table 4.8 shows the amino acid composition of kisra and kisra supplemented with 10% of untreated UMk, boiled BMk, roasted RMk, and germinated *Monechma ciliatum* GMk. Most of the amino acids were decreased in supplemented samples. Only Aspartic acid, Arginine and Lysine was insignificantly increased in all supplemented samples. This result disagreed with Awad alkareem *et al.,* (2011) who reported supplementation of sorghum flour with soybean protein showed a significant increase in lysine and threonine contents, with a slight increase in methionine. Total amino acids was found to be 15.584 g/100g in unsupplemented kisra K after supplementation they were significantly decreased to 13.508, 13.840, 13.310 and 12.945 g/100g in UMK, BMK, RMK and GMK, respectively.

Table 4.8 Effect of supplementation with untreated and treated *Monechma ciliatum* on sorghum kisra amino acid content g/100g

Amino acid	K	UMK	BMK	RMK	GMK
Hydroxyproline	ND	ND	ND	ND	ND
Aspartic acid	0.917±0.01	0.931±0.03	0.995±0.02	1.026±0.13	1.009±0.01

Serine	1.018±0.03	0.860±0.03	0.854±0.02	0.799±0.07	0.783±0.03
Glutamic acid	3.408±0.10	2.737±0.11	3.028±0.01	2.881±0.23	2.698±0.00
Glycine	0.599±0.03	0.547±0.04	0.473±0.03	0.487±0.06	0.502±0.00
Histidine	0.312±0.02	0.303±0.01	0.309±0.01	0.245±0.00	0.233±0.01
Arginine	0.782±0.02	0.940±0.02	0.975±0.03	0.936±0,07	0.893±0.02
Threonine	0.644±0.03	0.561±0.02	0.575±0.06	0.514±0.04	0.514±0.01
Alanine	1.455±0.01	1.085±0.03	1.074±0.03	1.130±0.05	1.106±0.03
Proline	1.316±0.03	1.069±0.06	1.045±0.06	1.040±0.05	1.038±0.03
Thyrosine	0.308±0.02	0.288±0.01	0.487±0.05	0.325±0.00	0.320±0.02
Valine	0.856±0.06	0.732±0.03	0.714±0.05	0.699±0.00	0.691±0.01
Methionine	0.105±0.04	ND	0.107±0.01	ND	ND
Lysine	0.142±0.01	0.492±0.04	0.144±0.00	0.364±0.03	0.342±0.00
Isoleusine	0.736±0.01	0.626±0.04	1.611±0.12	0.590±0.03	0.582±0.02
Leusine	2.192±0.21	1.720±0.02	1.658±0.14	1.696±0.02	1.670±0.04
Phenylalanine	0.794±0.11	0.618±0.02	0.788±0.07	0.5800.05	0.563±0.03
Total	**15.584[a]**	**13.508[b]**	**13.840[b]**	**13.310[c]**	**12.945[d]**

Means in the same row followed by the same superscript are not significantly different at p<0.05K K (Kisra control); UMK: Untreated *Monechma ciliatum kisra*; GMK: Germinated *Monechma ciliatum* kisra; RMK: Roasted *Monechma ciliatum* kisra; BMK: Boiled *Monechma ciliatum* kisra. Values are means ± SD

4.2.6 Sensory evaluation

Determining how products affect consumers' sense is one of the most important goals of the food industry . The benefit of healthy food will be reaped if our five senses accept it .

The sensory evaluation of Kisra made of pure sorghum flour (K) and flour supplemented with the untreated and treated *MC* was carried out and data was presented in Table 4.9. Analysis of variance showed significant difference between Kisra made of sorghum flour (control) and Kisa made of sorghum flour supplemented with 10% of untreated UMk, boiled BMk, roasted RMk and germinated *Monechma ciliatum* seeds flour GMk in terms of color, smell, taste , texture and general acceptability, but insignificant variation was observed in terms of color, between the kisra of sorghum flour (control) and composite flour supplemented with roased MC seeds flour RMK, this may be due to the effect of roasting on MC seeds color and flavor. To the performance of panelists, the majority gave the sensory performance for the color of kisra made of raw sorghum flour K followed by that flours supplemented with roasted MC seeds flour RMk, when the kisra supplemented with untreated UMK and germinated *Monechma ciliatum* seeds flour GMk had the same performance, while kisra supplemented with BM, had the lowest performance. Moreover high sensory performance for smell, taste, texture and over all acceptability were also recorded for kisra made of sorghum flour. This may be due to the black color of MC seeds which affected the supplemented samples. No significance differences was observed in smell, taste, texture and general acceptability values of kisra made from sorghum flour supplemented with RM and GM. Kisra supplemented with BM has the lowest score in all values. In general the control sample was more accepted followed by RMK, GMK, UMK and BMK. In general kissra made of sorghum supplemented with roasted *M.ciliatum* is the most preferred between the four supplemented samples, this result is in disagreement with Kayitesi (2010) who reported Combining sorghum meal with full-fat marama bean flour has the potential to improve the sensory quality of sorghum porridge and in agreement with Serrem *et al*., (2010) who said although the less acceptability of sorghum and bread wheat soy biscuits have considerable potential as protein rich supplementary foods to prevent Protein Energy Malnutrition in children.

Figure 4. 4: Common kisra and kisra supplemented with raw, raosted , germinated and boiled *M.ciliatum* seeds.

Table 4.9 Sensory evaluation of kisra made from sorghum flour and sorghum flour supplemented with treated *Monechma ciliatum*

Sample	Color	Smell	Taste	Texture	General acceptability
K	7.95±0.49	7.75±0.58	7.60±0.43	7.75±0.36	7.60±0.14
UMK	6.15±0.37	5.60±0.28	5.25±0.28	5.85±0.24	5.10±0.13
BMK	5.30±0.27	4.95±0.15	4.60±0.22	4.80±0.23	4.75±0.11
RMK	7.30±0.24	6.10±0.18	5.45±0.23	6.70±0.22	5.70±0.23
GMK	6.15±0.32	6.00±0.26	5.55±0.27	6.55±0.34	5.85±0.23

K (Kisra control); UMK: Untreated*Monechma ciliatum kisra*; GMK: Germinated *Monechma ciliatum kisra*; RMK: Roasted *Monechma ciliatum kisra*; BMK: Boiled *Monechma ciliatum kisra*. Values are means ± SD

CHAPTER FIVE

CONCUSION AND RECOMMENDATIONS

5.1 Conclusion

The three processing techniques (boiling, roasting and germination) made significant changes on chemical composition of *Monechma ciliatum* (black mahlab) seeds. Generally, most of the nutritional factors were increased with different concentration .

The three treatments increased protein and amino acids. Specifically in addition of protein and amino acids, boiling increased fat and fiber content and roasting has the most positive effect on fat content and saturated fatty acids .

Germination increased fiber content and Saturated fatty acids when unsaturated fatty acids was decreased .

Although the three treatments varied in their effect on minerals and mostly diminished the mineral content still MC has good amount of minerals in all samples .

M.ciliatum seeds flour showed significant positive effect as plant-based food supplement. Kisra made of composite flour made from untreated, boilied , roasted and germinated *Monechma ciliatum* seeds flour and sorghum flour with in ratio of 1:10 showed a significant increasing in its nutritional value compared with the pure sorghum kisra.

Kisra made of sorghum flour supplemented with 10% roasted *Monechma ciliatum* seeds flour was the most acceptable product by the panelists.

5.2 Recommendations

1. It is recommended that to use kisra supplemented with *M.ciliatum* as a good source of human nutrients in Sudan.
2. *M.ciliatum* could be an effective plant –based supplement to improve nutritional value of meals made of sorghum flour .
3. Dietary behavior of people who depend on sorghum as a main food should be changed to accept color changing and taste resulting from the addition of legumes to avoid malnutrition and nutrient deficiency diseases.
4. More studies on *M.Cilliatum's* nutritional and medicinal benefits are recommended.

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