BISCUITS FROM COMPOSITE FLOUR OF WHEAT AND SORGHUM

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1992

A Thesis Submitted to the University of Khartoum in Partial Fulfillment of the Requirements for the Degree of Master of Science (Agric.).

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May 2003

Dedication

To the soul of my father, and my brother Isam,

To my Sister & my second father Alrasheed,

To my sister's sons and daughters:

Mohammed, Khalid, Reem, Rana, and Rowa

With Love,

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to my supervisor *Prof. Paul Lado* for his supervision, guidance, and encouragement throughout the course of my study. I also extend a lot of thanks to my co-supervisor, *Prof. Abdelmoneim Ibrahim Mustafa*, for his unlimited help, advice and patience during the performance of this thesis.

Thanks are also due to technical staff members and workers in the Department of Cereal and Grain Technology, Food Research Center, at their forefront Mr. Babiker. I wish to thank the lab Technicians of the Department of Food Science and Technology, University of Khartoum, for their help.

I am also very grateful to the extended help from my friend Dr. Nabila Elamir Yousif.

Thanks are also extended to Almosharaf Biscuits Factory, for their training in biscuits processing and offering of the ingredients; and Sayga Flour Mills, and Albdreen Milling Factory, for their help in supplying me with wheat flours, special thanks to Miss Amani Alghali from Sayga Flours Mills.

Special thanks are extended to the computer staff at Ahmed Gasim Cardiac Center, for typing and assenting my thesis tirelessly and diligently and Mr. Abdelhamed Abdelrahim for helping me in printing thesis.

I am very grateful to my cherished mother for devoting most of her time looking after me, and for her constant encouragement in overcoming the difficulties that faced me during my study; also I extend my gratitude to my brother Ayman, for his financial help, further to the rest of my family who were a constant support to the success of this thesis.

Thanks are due to Mr. Salah Eddin Hamad, for helping me with the statistical analysis of the data, and for Mr. Mohammed Bushara, who gave me all possible assistance.

Thanks are also due to my sincere friends for their encouragement and support.

Above all this, I thank my **God Allah** for blessing me with knowledge, patience and health to prepare this thesis.

ABSTRACT

Indian and Australian imported wheat flours, Fakimustahi Sudanese sorghum flour, and 7 different oils and fats had been used in this study.

Proximate analysis was carried for wheats and sorghum flours. Free fatty acids analysis was done for the 7oils and fats. Rheological properties were studied for the two wheat flours with 0%, 20%, 40%, and 60% sorghum flours.

The results of the proximate analysis showed that, ash (14%), protein (15.47%), fat (3.01%) and the calculated energy (379.690 kcal/100g) for Fakimustahi sorghum flour were higher than for the Indian and Australian wheat flours. The Australian flour gluten content (36.03%) was higher than the Indian wheat flour (27.20%). The Indian wheat flour was higher in the value of fat acidity (59.70 MgKOH/100g), and carbohydrates (75.390%). The free fatty acids value for shortening (0.112) was higher than in alaseel (0.062) and cottonseed (0.042) but lower than in ghee (0.470).

The addition of sorghum flour affected the rheology of the wheat flour dough as reflected in the farinogram and extensogram, increasing the level of sorghum flour from 20% to 60% to wheat flours decreased the water absorption, dough development time, dough stability, the resistance and extensibility of the dough, and increased the dough weakening.

Because the two wheat flours were medium in hardness, L-cysteine was added to the wheat flours, yet the Indian wheat flour was relatively softer than Australian wheat flour.

The quality evaluation for biscuits made from Indian wheat flour showed that, biscuits made with ghee had the higher spread ratio (5.862). Biscuits with shortening and alaseel hydrogenated vegetable

oil showed the same spread ratio result (5.770). Organoleptic evaluation showed that biscuits made with shortening and alaseel were more acceptable than biscuits made with ghee or oils.

The spread ratio of biscuits made from Indian wheat flour with 10% and 20% sorghum flour using shortening, and with 10% to 70% sorghum flour using alaseel, gave biscuits with higher spread ratio than the biscuits made from wheat flour. Whereas, on using Australian wheat flour blended with 10 to 100 % sorghum flour using shortening showed higher spread ratio than pure wheat flour. Using alaseel there was insignificant difference ($P > 0.05$) among 0%, 10%, and 20% sorghum flour in biscuits spread ratio, though 10% sorghum flour was numerically higher than the control (0% sorghum flour).

The over all quality evaluation of biscuits made from wheat and sorghum flours showed high acceptability. Indian wheat flour blended with sorghum flour (Fakimustahi) ranged from 10% to 80% using shortening, or alaseel showed better biscuits, while using Australian wheat flour with sorghum flour ranged from 10% to 90% using shortening and from 10% to 30% using alaseel showed acceptable biscuits.

After storage, biscuits made from Indian wheat flour with 10% to 80% sorghum flour using shortening or alaseel gave better results, while using Australian wheat flour addition of sorghum ranged from 10% to 40% using shortening or alaseel showed acceptable biscuits.

Results indicates that biscuits made from Indian wheat flour with sorghum flour ranged from 10% to 80% were more preferable with good quality than that of biscuits made from Australian wheat flour with sorghum flour.

خلاصة الأطروحة

أجريت هذه الدراسة باستخدام نوعين من الدقيق المستورد (الأسترالي والهنـدي) دقيق الذرة السوداني (فكي مستحى)، بالإضافة إلي أنواع من الزيـوت والـدهون. تـم إجراء التحليل التقريبي على عينات دقيق الذرة والقمح، بينما قـدرت نسـبة الأحمـاض الدهنية الحرة في أنواع الزيوت والدهون المستخدمة. تمت دراسة الخواص الريولوجية لمخاوط دقيق القمح بنسب متفاوتة 0%، 20%، 40%، و60% من دقيق الذرة.

أوضحت نتائج التحليل التقريبي أن دقيق الذرة السوداني (فكي مستحى) يحتـوى على نسب أعلى من البروتين (15.47%)، الدهون (3.01%)، الرماد (1.417%)والطاقة (379.690 كيلوكالوري/100جم) مقارنة مع كل من دقيق القمح الأسترالي والهندي. وجد أن دقيق القمح الأسترالي (36.03%) يتميز على نظيره الهندي (27.20%) فـي نسـبة القلـوتين، بينمـا الحموضـة الدهنيـة (59.70MgKOH/100g) والكربوهيـدرات (75.390%) ذات محتوى أعلى في دقيق القمح الهندي مقارنة بالأسترالي ودقيق الـذرة السوداني. دلت الدراسة أيضاً على أن نسبة الأحماض الدهنية في دهـن Shortening (زيت نباتي مهدرج) (0.112%) أعلى من دهـن الأصـيل (زيـت نبـاتي مهـدرج) (0.062%) وزيت بذرة القطن (0.042%) ولكن أقل من محتوى السمن النباتى (ghee).

بأجراء الدراسة على الفارينوغرام والإكستنسوغرام أتضح أن إضافة دقيق الـذرة بنسبه المتفاوتة قد أثر على الخواص الريولوجية لعجينه دقيق القمح حيث وضح بزيـادة نسبة إضافة دقيق الذرة من 20% إلى60% إلى دقيق القمح، أن ذلك قد أدى إلى نقصان في كل من خاصية امتصاص الماء، زمن تكون العجينه، ثبات العجينه، وكل من مقاومـة وتمدد العجينه. بينما أدى ذلك إلى زياده في مستوى ضعف العجينه.

نسبة إلى تميز كلاً من دقيقي القمح الأسترالي والهندي بتوسطهما فـي مسـتوى الصلابة، فإن ذلك كان سبباً في إضافة الحمض الأميني إلـ سستيين، بـالرغم مـن أن الدقيق الهندي يتميز بمزيد في الضعف عن الأسترالي.

أظهرت الدراسة التقييمية لنوعية البسكويت المحتوى في صناعته علـى السـمن النباتى (ghee) بأنه ذو نسبة انتشار (5.862) أعلى من مثيلاته. دلـت دراسـة نـوعي

البسكويت اللذين يحتويان في مكوناتهما على الأصـيل والـ ـshortening، أن نسـبة الانتشار كانت متساوية في كليهما(5.770). لقد أظهر التقييم الحسي درجة القبول العالية لأنواع البسكويت المحتوية في تركيبتها على دهون الأصيل و shortening مقارنة بتلـك المحتوية على السمن النباتى والزيوت.

لقد ثبت أن أنواع البسكويت المصنعة من مخلوط دقيق لقمح الهندي بإضافة نسب 10% و20% من دقيق الذرة مع استخدام الـ shortening ومن 10% إلـى 70% دقيق ذرة في وجود الأصيل ذات نسبة انتشار أعلى من تلك التي تصنع من دقيق القمـح الصافي. بينما أظهر الدقيق الأسترالي المخلوط بالذرة بنسـب تتـراوح بـين 10% و 100% نسبة انتشار أعلى من دقيق القمح الصافي، أما استخدام زيـت الأصـيل فقـد أوضح عدم وجود فروقات معنوية وسط أنواع البسكويت المحتويـة علـى 0%، 10% و20% دقيق ذرة ، بالرغم من أن مخلوط 10% دقيق ذرة أعلى رقمياً مـن حيـث نسبة الانتشار، مقارنة بالقياسي.

من زاوية التقييم الكلى فإن أنواع البسكويت المصنوعة من مخلوط دقيـق القمـح والذرة أظهرت درجة قبول عالية. إذ أن أنواع البسكويت المصنوعه من مخلوط دقيق القمح والذرة بنسب تتراوح بين 10% و 80% ذرة مع استخدام الـ ـshortening أو الأصيل ذات جودة أعلى، بينما البسكويت المصنوع من الدقيق الأسترالي ودقيـق الـذرة بنسب من 10% حتى 90% ذرة مع استعمال الـ shortening من 10% إلى30% مع استعمال الأصيل وجدت قبولاً جيد.

بعد التخزين، وجد أن البسكويت المصنوع من دقيق القمح الهندي مع 10% إلـى 80% دقيق ذرة مستخدماً shortening أو الأصيل أعطى بسكويت جيد الأفضلية، بينما بسكويت مخلوط دقيق القمح الأسترالي في وجود 10% إلى 40% دقيـق ذرة مـع استخدام shortening أو الأصيل أظهر قبولاً جيد.

تدل النتائج على أن بسكويت مخلوط دقيق القمح الهندي مع الذرة في مدى 10% إلى 80% ذو نوعية جيدة مع تفضيله، على البسكويت المصنوع من القمح الأسـترالي ودقيق الذرة.

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CHAPTER ONE

INTRODUCTION

Cereal grains are the fruits of plants belonging to the grain class Monocotyledons (Kent, 1983; Walton, 1988), grass family Gramineae (Hoseney, 1986).

Cereals are the most important group of food crops produced in the world. Cereal crops are energy dense, containing 1000-1500Kj/Kg, about 10-20 times more energy than the most succulent fruits and vegetables. Nutritionally, they are important source of dietary protein, carbohydrates, the B complex vitamins, vitamin E, Iron, trace minerals, and fiber. In 2000, world cereal production amounts was 2049415 (1000MT). Major cereal crops produced worldwide include wheat, rice, maize, barely, sorghum, oats, millet and rye. Asia, America and Europe produce more than 80 percent of the world's cereal grains (FAO, 1999). Wheat, rice, sorghum, and millet are produced in large quantities in Asia, corn and sorghum are principal in America, and barley, oats and rye are major crops in former USSR and Europe (Chaven and Kadam, 1989). Kordylas (1991) reported that, the most important members forming the cereal group in Tropical Africa are maize (corn), sorghum, rice and millet.

Wheat (*Triticum Vulgare*) is considered as one of the main food crops in Sudan. It ranks after sorghum as a staple diet especially in urban centers. The importance of wheat is reflected in it's relatively high consumption which was increased from 419,000 MT to 920,000 MT per year during the period 1980-1992 (Mohamed, 1992).

Wheat is one of the oldest of all cultivated plants. Today, there are more than 50000 cultivars of wheat in existence and as a result wheat can be grown in a relatively wide range of climatic conditions, specially in temperate climates. It is susceptible to disease in warm, humid regions (FAO, 1999).

In 1999 and 2000, Sudan production of wheat was 172000 MT and 214000 MT respectively (FAO, 2000).

Wheat contributes considerably to the source of proteins in the diet; these proteins are unique among the cereal proteins because of their ability to form viscoelastic dough, which can be attributed to the formation of gluten when flour and water are mixed. The viscoelastic properties of the gluten in dough systems are generally considered important in determining the baking properties of the wheat flour.

In addition to using wheat flour in making bread, wheat entered into other use and encouraged the growth and development of many industries such as biscuits, cakes, macaroni, pastas and others (Ahmed, 1995).

Recently it was noticed that some people show symptoms of coeliac disease (gluten intolerance or gluten sensitivity) which is an example of a chronic food allergy (Gopinath, 2002).

Wheat produced in Sudan does not meet the consumption. For this reason more wheat is to be imported to supplement local production. The main reason for increasing wheat consumption is the continuous shift of people in eating habits from kissra to bread. (Mustafa, 1973).

Developing countries such as Sudan looking for an alternative to wheat, to stop the drive which cost them so much of their foreign currency. Some countries have successfully produced acceptable bread and biscuits from non-wheat flour (Mustafa, 1971). Among cereals, sorghum and millet were found to be the best substitute for wheat in composite flours. Biscuits were made from sorghum and wheat composite flours in Nigeria (Orewa and Iloh, 1989), in the Sudan, Mustafa *et al* (1971) and Alkhalifa (1998).

Sorghum (*Sorghum bicolor* (L.) Moench) is the most important cereal crop in Sudan, and ranks third among cereals for human consumption (Elkhalifa, 1993). Sorghum became the stable food for the majority of the Sudanese population (Mohamed and Awad 1975).

In 1999 Sudan sorghum production was 2347000 MT, while the production in 2000 was 2521000 MT (FAO, 2000).

In Africa and Asia where the people are typically poor and food resources are limited, sorghum is used as the major source of protein, Culwick (1951) reported that in Sudan up to 75% of the calories taken by the population of the Gezira irrigated area came from (Dura) sorghum.

Traditionally in developing countries, sorghum is reflected in many dishes such as porridge or flat bread (Rom et al (1992), “Kisra”, “Asida”, “Balila”, “Abri” and “Marisa” (Mohamed and Awad, 1975).

With the development and testing of new sorghum varieties, improved high yields and processing methods and introduction of new products, the use of this cereal may be further expanded (Badi, and Monawar, 1987).

In making biscuits, soft wheats were preferred due to the low level of protein that produces weaker glutens than those were derived from hard wheats. Consequently, the biscuit doughs lack the elasticity and extensibility of the bread doughs.

Excellent wheat flour gives biscuits with high spread ratio (diameter/thickness), uniformity in shape, light crust color, crispness, pleasant taste, smooth crust texture, than poor flour.

Objectives:

The objectives of this study were:

1. Utilization of sorghum flour in biscuits making.
2. Selection of a suitable fat/oil to be used in composite flour biscuits.
3. To study the shelf life of such biscuits under the room temperature (grocery condition) in Sudan.
4. To evaluate the quality of biscuits made from composite flours (wheat and sorghum).

CHAPTER TWO
LITERATURE REVIEW

2.1. General structure and chemical composition of cereal grain:

Botanically the cereal seed grain or kernel is covered by fibrous outer layer (bran or seed coat) to protect the grain from attack by insects. This protection is quite effective if there are no cracks on the surface (Kordylas, 1991). Therefore the kernel structure is important with respect to minimizing damage during grain harvest, drying, handling, storage, milling, germination and in enhancing nutritional value (Pomeranze and Bechtel, 1978). The seed coat surrounds the endosperm and embryo (germ). The endosperm is the main part of the kernel, which contains a large part of the food material- starch and protein. That is the part, which generally makes food grains important as food for both humans and animals. It provides food for the developing seed if it is planted, and food for the seed during storage. Wheats and sorghums grain contains the outer translucent and inner opaque endosperm, the proportion of which determines the endosperm texture. The peripheral endosperm is almost completely filled with protein bodies resulting in a tightly packed structure. The corneous hard or translucent endosperm protein of sorghum grain is similar, with starch granules packed in cages of protein that completely fill the cell. The soft or opaque endosperm is characterized by large inter-granular air spaces. Starch granules in this region of the endosperm are found covered with a thin layer of protein. Air spaces in the soft endosperm result in a less dense material, thus kernels with predominantly soft endosperm are less dense than hard kernels. The round loosely packed, starches granules and weakly adhering protein matrix, are responsible for the kernels soft character. The tightly packed, hard endosperm on the other hand, has strong protein- starch adhesion that results in a hard endosperm (Hoseney *et al*., 1974; Rooney and Sullins, 1977; Mazhar, 1993).

The embryo contains the life of the seed, and it is the part that develops into a new plant when the seed is planted. It contains most of the proteins present in the seed with some fat, vitamins, and minerals. (Kordylas, 1991) and starch, there is generally a gradient increasing protein and decreasing starch per cell from the inner to the outer region of the endosperm (FAO, 1999).

Anon, (1987) reported that the wheat kernel consist of endosperm, bran and germ. The endosperm constitutes about 83% of the kernel weight and it is the source of white flour and contains the greatest share of proteins in the whole kernel, as well as carbohydrates, iron and many B-complex vitamins, such as riboflavin, niacin and thiamin. Bran constitutes about 14.5% of kernel weight and it's included in whole-wheat flour, and is also available separately from nutrients in the whole wheat. The bran contains small amount of protein, larger quantities of B-complex vitamins trace minerals and indigestible cellulose material, (dietary fiber). The germ constitutes about 2.5% of kernel weight. Usually separated because of the fats, which limit the keeping quality of flour. Wheat germ can be purchased separately and included in whole-wheat flour. Hoseney, (1986) reported that the germ comprises 2.5-3.5% of the kernel, relatively high in protein sugar mainly sucrose and raffinose, oil and ash. It contains no starch but rather high in B and E vitamins and contains many enzymes.

Egan *et al* (1981) found that the wheat grain has the following composition: Endosperm 85%, bran 12.5% and germ 2.5%, while Kent-Jones and Amos (1967) reported that the average composition of wheat grain is approximately 85% endosperm, 2% embryo or germ and 13% husk.

Wheat cultivation in the Sudan dates back to more than 2000 years, but until 1940's production was confined to the northern region (16-22°N) where all inhabitants are traditionally wheat consumers. During the Second World War (1942/43) and because of the difficulties of importing wheat from abroad, great need had been felt for additional wheat to be produced from local resources. Hence 20,000 feddens of irrigated clays of central state (Gezira Scheme) were cultivated and the trial was considerably successful. The varieties grown were Giza 155 and Mexican. However, inspite of success no wheat was produced in Gezira scheme after the war was over. This was partly because it was possible to import wheat besides the Gezira tenants who have already developed a taste for their subsistence sorghum crop found it difficult to grow wheat. In addition to the above reasons land and irrigation water formerly allocated to wheat production were needed for other crops within the rotation. But after 1960's wheat growing area has been extended Southwards to warmer regions, to the irrigated scheme of central Sudan such as those in Gezira, New Halfa and White Nile (12-15°N)(Ali, 1987; Ishag and Ageep, 1991, Mohamed, 1992).

The sorghum kernel is flattened sphere grain approximately 4.0mm long, 3.5mm wide and 2.5mm in thickness. The kernel weight varies from 8-50mg (average 28mg)(Rooney and Clark (1968) and Kordylas (1991)). It involves four main parts, the bran (pericarp or outer cover), testa, the endosperm (storage tissue) and germ (embryo). Rooney and Sullins (1977) stated that the pericarp is composed of epicarp, mesocarp and endocarp, has low protein content and mainly composed of cellulose and starch. It includes wax and small starch granules in the mesocarp (Sanders, 1955 and Collier, 1963). Testa, the pigmented cells beneath the pericarp cells is generally attributed to the presence of polyphenols (Tannins); the endosperm consists of the aleurone layer, the peripheral, corneous and floury endosperms. The aleurone layer cells have spherical bodies that vary in size, containing no starch granules, but it contains proteins, minerals, water- soluble vitamins, enzymes and oil (Hoseney *et al*. 1974; Rooney and Sullins, 1977). Germ or embryo is surrounded by soft endosperm, rich in protein and oil (Rooney and Sullins, 1977).

The size, pigmentation, and other characteristics of the grains vary widely among varieties. The color of the grains varies from white, yellow and orange to red and brown. Their size and shape may be large, small, round or flattened. The husk differs in size, color texture and shape.

Hubbard *et al.* (1980) reported that, the relative proportion for medium- sized sorghum kernels, the bran, germ and endosperm were found to be 7.9, 9.8 and 82.3% respectively. Hulse *et al*. (1980) reported 7.3 to 9.3%, 7.8 to 12.1 and 81.1 to 84.6% for bran, germ and endosperm respectively.

Endosperm, the largest part of the kernel, is relatively rich in mineral matter, ash and oil content it is however, a major contributor to the kernel's protein, starch and B-complex vitamins (FAO, 1995).

The grains of many sorghum varieties have a dark layer in the central part containing the embryo sac, which gives a sour, bitter taste, and a dark unattractive color to flour produced from them. Yellow grains without the dark layer, however, give good quality flour, although the flour is sometimes coarse (Kordylas, 1991).

Proximate analysis provides a good initial impression of the relative value and utility impression of an agriculture commodity, and allows a basis of comparison between different species, plant parts and cultivation conditions (FAO, 1992).

Compositionally, a cereal consists of 12-14 % water, 65-75% carbohydrates, 2-6% lipids and 7-12% protein. Cereals are quite similar in gross composition being low in protein and high in carbohydrates (Eliasson and Larsson, 1993).

2.1.1. Moisture content:

Moisture content is one of the most important factors affecting the quality of cereals grains, since the amount of dry matter of grains is inversely related to the moisture content, (moisture contents has direct economic importance).

Pareds-Lopez *et al*, (1987) reported that, the moisture content of the Mexican wheat flour is 11.2%. However, Badi *et al* (1978) found that, the moisture content of Sudanese wheat flour harvested in 1975 ranges between 10-11%.

Eltinay, *et al* (1979) calculated the moisture content of three Sudanese sorghum varieties in the range of 6.5- 8.8%. Moreover, Neucere and Sumrell (1980) mentioned that the moisture content of 5 sorghum varieties were in the range of 12.07 and 13.36%, where as Inamdar, *et al* (1984) reported that the moisture content of sorghum cultivars SPV-107 and CSH-6 were 5.74 and 8.5% respectively.

Budair (1977) calculated the moisture content of three Sudanese sorghum varieties (on wet basis), Fetarita (7.10%), Dabar (6.00%) and Himaisi (6.5%). Hamad (1994) reported that, Hageen (7.6%), Dabar (7.2%) and Fetarita is (7.8%), and Elnour (1997) found that the moisture content for Dabar variety is 8.10% on dry basis.

2.1.2. Ash content:

Pratt, (1971) found that ash content has been considered as important indicator of flour quality, although the ash content of flour is not related to the final performance, but it gives some indication of the miller's skill and the degree of refinement in processing.

Zeleny (1971) reported that ash content is directly related to the amount of bran in the cereal grains, Egan, *et al* (1981) found that, the ash content of the whole wheat flour ranges between 1.2-1.8%. But D'appolonia and Young's (1978) reported 1.89% for ash content.

Alias and Linden (1991) reported 1.4%, lower than millet (1.5%), rye (1.8%) and barley (1.9%) but the same as brown rice and maize.

Pomeranze and Dikeman (1983) reported the ash content of hard red winter wheat flour in the range of 1.82-2.00%. Badi, *et al* (1978) showed that ash content of Sudanese wheat cultivars whole meal flour range between 1.38-1.84%, which is higher than the ash content of the Sudanese cultivars harvested (91/92), Nasser, Elneilain, Condor and Deberira, 1.24, 1.03, 1.21 and 1.21 respectively (Ahmed, 1995). Neucere and Sumrell (1980) found that the ash content of some sorghum cultivars were in the range of 1.35 to 1.83%, while Inamdar *et al* (1984) reported range between 1.75-3.31%. Alias and Linden (1991) reported 2.6% for the sorghum ash content, but Ronney (1973) reported range between 1.8-2.2%.

El Tinay *et al*. (1979) found that sorghum grain grown in Sudan contains 1.7-1.72% ash. Hamad (1994) reported the ash content for three Sudanese sorghum cultivars, Hageen, Dabar, and Fetarita, as 1.32, 1.39 and 1.73% respectively. Furthermore, Ahmed (1993) found the ash content of Feterita and Dabar to be 1.92% and 1.46%, respectively. But Elnour (1997) reviewed 1.65% for Dabar Sudanese variety. Also Arbab (1997) studied two Sudanese varieties, Gadam Elhamama (1.56%) is higher in ash than Karamaka (1.13%).

2.1.3. Protein content:

The proteins content of cereals are of great significance because 24% of the total protein in the average diet is derived from this source. Although a specific cereal does not contain all of the essential amino acids in favorable proportions for good nutrition, cereal proteins may be supplemented by other proteins sources such as milk, eggs, and meat, or by combining different types of cereals, with certain vegetables such as legumes and nuts. The protein content of true cereal products ranges from 6 to 18 percent.

Early workers divided the proteins of wheat into four solubility classes called Osborne fractions:

- Albumins: which is water-soluble.
- Globulins: which are soluble in salt solutions but insoluble in water.
- Gliadins: which are soluble in 70-90 percent alcohol.
- Glutenine: Which are soluble in neutral aqueous solutions, saline, or alcohol.

The respective protein fractions found in wheat are also applicable to other cereals and generally known as albumins, globulins, prolamins and glutelins (FAO, 1999), Among the Osborne fractions in cereals, the prolamin fractions have been the most studied. This fraction is called gliadin in wheat, Kafarin in sorghum, sacalin in rye, hordein in barley, avenin in oat, and zein in maize (Eliasson and Larsson, 1993).

The protein content of hard wheat is considerably higher than that of soft wheat, 11.5-18%, 9-14.5% and 8-11% for hard red spring, hard red winter and soft red winter respectively (Schruben, (1979); Kent-Jones and Amos (1967)).

George, (1973) found that the protein content of wheat is highly influenced by the environmental conditions, grain yield and available nitrogen as well as the variety genotype. Badi *et al* (1978) stated that protein content of the Sudanese wheat cultivars ranged between 11-14%. Also Ahmed (1995) found that the protein content of four Sudanese wheat cultivars, Nasser, Elneilain, Condor and Debeire, are 12.26, 10.93, 8.21, and 8.32 respectively.

Protein quality is defined in terms of its usefulness; the quality of protein needed for bread making differs considerably from that required for pastries or pasta product (Orth and Bushuk, 1972; and Schmidt, 1973 and Hoseney, *et al* 1969)

Zeleny, (1971) reported that the end use of flour is related to its protein content, so macaroni products protein content is 13% or more, for bread protein content ranges between (12-14%), while for biscuits it ranges between (8.5-10.5%) and for cake ranges between (9.0-9.5%).

The value that are reported for sorghum protein are more variable than those for the more common grains, partly because of wide variety difference, but largely because of the diversity of agronomic conditions under which crop is grown (Klopfenstein and Hoseney, 1995). The predominant proteins in the sorghum grain are prolamins and the large amount of prolamins is responsible for low nutritional value of sorghum grain protein

According to Martin (1984); sorghum protein content (usually reported as nitrogen× 6.25) may range from 8 to 16%, although values as high as 6 to 25% have been reported (Deyoe and Shelleberger, 1965).

Yousif and Magboul (1972) analyzed fifteen varieties of sorghum and found a variation in protein content to an extent of 80%, the protein content varied from 8.8 to 11.6.

Hamad (1994) studied the protein content of Sudanese varieties, he reported that Fetarita is higher (11.0%) than Dabar (9.6%) and Hageen (8.8%), also Budir (1977) reported Fetarita (13.18%) and than Dabar 10.79%). According to Arbab (1997) the protein content for two Sudanese varieties GadamElhamama and Karamaka is 11.15% and 12.46% respectively.

Eggum (1983) found 10.9%, 11.6%, 13.4% protein content of Tetron, Dabar and Fetarita varieties grown in Sudan, respectively.

Cereal proteins are nutritionally poor because they are deficient in essential amino acids such as lysine, threonine, and tryptophan (Chung and Pomeranz, 1985).

Protein in sorghum is considered to be low in quantity and quality (Hulse, *et al* 1980). Sorghum quality is limited by the low lysine content of its protein (Pickett, 1967). FAO (1995) reported that, lysine content vary from 71 to 212mg/gm of nitrogen. Singh and

Axtel (1973) identified two high- lysine Ethiopian sorghum varieties, Is 11758 and Is 11167. The average lysine content of the whole kernel of Is 11758 was 3.13g/100g protein and the total protein content of the kernel was 17.2%. Is 11167 contained 3.33g lysine per 100g protein and 15.7% protein.

The protein of sorghum inspite of its low lysine, contains high levels of leucine as compared to other cereals and this is responsible for the disease known as pellagra (FAO, 1981). Pellagra is frequently associated with sorghum and maize diets. Belavady and Gopalan (1965) showed that dogs fed 65% sorghum developed pellagra. Twenty-six patients with pellagra when given isoleucine showed reduced symptoms of pellagra. The incidence of pellagra has been attributed to the high amounts of leucine compared to isoleucine in sorghum prolamins.

2.1.4. Lipid content:

The lipids in the grain are present mainly in the germ and bran fractions, with little in the endosperm (Southgate, 1993)

The lipids include triglycerides and phospholipids, the latter making up to 4% of the isolated cereal oils. The fatty acid composition of the lipids in the different cereals shows some species difference, but all are rich in oleic and linoleic acid with linolenic acid making between 1-8% of the total fatty acids (Paul & Southgate, 1978). The major saturated fatty acid is palmitic acid (Haard and Chism, 1996).

Wheat contain 2-3% lipids (FAO, 1999). The distribution of lipid classes are similar in wheat, barely and rye which contain about 65-78% nonpolar lipids, 7-13% galactolipid and 15-26% phospholipids (Morison, 1984). In wheat, the glycolipids play an important role in gluten development during bread making (Pomeranz and Chung, 1978).

Alias and Linden (1991) showed that the crude fat for wheat is lower (1.9%) than rice (2.2%), sorghum (3.9%) oat (5.9%), maize (4.9%) and millet (4.7%).

Ahmed (1995) studied the oil content of Sudanese cultivars, Nasser, Elneilain, Condor and Debeire, as 1.19, 2.35, 2.14% and 3.36% respectively.

Inamdar *et al*. (1984) mentioned that the fat content of different sorghum cultivars are in the range of 3.2- 4.1%, lower than corn (4.3-5.6) (Peplinski, *et al*. 1992). Also Neucare and Sumrell (1980) calculated the fat % content of different cultivars in the range of 2.66-3.49%.

The germ and aleurone layers are the lipid rich fractions of the grain, with the germ contributing to about 80% of the total oil (Rooney and Serna-Saldivar, 1991).

Sorghum has a low level of saturated fatty acids, 7% palmitic and 5% stearic acid. On the other hand, it contains relatively high level of unsaturated fatty acids, mainly linoleic is 47%.

Budair, (1977) studied the crude fat for three Sudanese varieties, Feterita, Dabar, and Himaisi as 3.33%, 3.79% and 3.69 respectively. But Hamad (1994) reported that the Sudanese sorghum varieties Hageen is higher (3.73%) than Feterita (3.337%), and higher than Dabar (2.4%). Arbab (1995), studied the oil content for Sudanese sorghum varieties GadamElhamama and Karmaka, 3.50%, and 3.40% respectively.

2.1.5. Carbohydrates:

In general, carbohydrates constitute about 75% of the solid content of cereals. The three major groups of carbohydrates are sugars, starches and cellulose and related materials (Hulse *et al*., 1980).

2.1.5.1 Starch:

The principal carbohydrate of all cereals is starch, the amount of starch contained in a cereal grain varies but is generally between 60 and 75% of the weight of the grain. Thus much of the food that humans consume is in the form of starch, an excellent source of energy (Hoseney, 1986), representing 56% (oats) to 80% (maize) of the grain dry matter (Eliasson and Larsson, 1993).

Starch is composed essentially of glucose and small amount of minor constituents that do not affect the starch properties. Cereal starches contain low levels of fats between 0.5 and 1% (Hoseney, 1986). The presence of lipid in cereal starches is a distinguishing feature of these starches (Morison, *et.al*., 1984). Noncereal starches contain essentially no lipid. Besides low levels of other minerals, starches contain phosphorus (in form of phospholipids) and nitrogen (<0.05%)(Hoseney, 1986).

Starch is composed of large numbers of units of monosaccharide, glucose, linked by α-1,4 glucosidic bonds forming straight chains (amylose), and branched chains, linked by α-1,4 and α-1,6 glucosidic bonds (amylopectin)(Hulse *et al.*, 1980, Hoseney, 1986). Amylose is generally considered to have a molecular weight of about 100,000 and amylopectin, over 1 million (Medcalf & Gilles, 1968).

Cereal starches are similar in composition, having 74-79% amylopectin, 25-30% amylose, and 1% lipids (Hoseney, et.al. 1971). Normal cereal starches are about 25% amylose. In corn, varieties with amylose contents ranging from 0 to 75% are known Zuber (1965). For wheat, no wide variations in the amylose- amylopectin ratio have been found. Values ranging from 17 to 27% amylose have been reported (Deatherage, *et al.*, 1955), but most wheat starches appear to have an amylose content very close to 25% (Medcalf and Gilles, 1968).

Starch granules are embedded in the protein matrix. The arrangement of starch and protein in the endosperm results in the texture of grains that affects the processing properties and to the storage potentials (MacRitchie, 1980).

Starch the major form of carbohydrates in sorghum. The granules of corn and grain sorghum are very similar in size, shape, and gelatinization properties. With values ranging from 56 to 73%, the average starch content of sorghum is 69.50% (Jambunathan and Subramanian, 1988). Rooney (1973) reported the sorghum starch ranged from 70.20% to 75.30% and Miller (1958) gave range of 60.40

to 76.60% for sorghum starch content that is lower than the starch content for maize (78.80-87.20%)(Zoran, 1982).

Rooney and serna-Saldivar (1991) found that most sorghum starch containing 70 to 80% amylopectin and the remaining 20 to 30% is amylose. Waxy or glutenous sorghum varieties are very low in amylose, their starch is partially 100% amylopectin. Whistler and Smart (1953) reported 22 to 26% for sorghum amylose. While Badi (1973), reported 23% for sorghum and 17% for millet amylose.

The physico-chemical properties of the starch affect the textural characteristics of the food preparations made from grains (i.e. sorghum).

The behavior of starch in water is temperature and concentration dependent (Whistler & Passchall, 1967). Grain starches in general show very little up take of water at room temperature, and their swelling power is also small. At higher temperature water up take increases and starches granule collapse, which leads to solubilization of amylose and amylopectin to form a colloidal solution. This is the gelatinization stage. Genetic and environmental factors affect the gelatinization temperature of grain starch (Freeman, *et al*. 1968). Heat treatment of starch in a limited amount of water leads to swelling of the granules with very little loss of soluble materials and partial gelatinization.

On cooling, the gelatinized starch tends to return from the soluble, dispersed and

Amorphours State to an insoluble crystalline state (become less soluble). The phenomenon is known as retrogradation or set back; it is enhanced with low temperature and high concentration of starch. (FAO, 1995), retrogradation contributes to the gel structure of cooled starch pastes and has been considered significance for bread structure and stability. (Medcalf and Gilles, 1968). Amylose, the linear component of the starch, is more susceptible to retrogradation (FAO, 1995).

2.1.5.2. Fiber content:

Scientists defined dietary fiber as ‘ that portion of food which is derived from cellular walls of plants which is digested very poorly by human beings’ (Gorden, 1991). It consists of two major fractions, insoluble and soluble dietary fiber. Soluble dietary fiber (SDF) is of particular interest to many consumers because of its effects on blood cholesterol (Jenkins, *et al* 1993; and Marllett & Cheung, 1997), blood glucose (Wood, *et al* 1994; and Marllett & Cheung, 1997), and prevent heart diseases (Gorden, 1991). Insoluble dietary fiber has been linked to protection against colon cancer and other bowel disorders, such as constipation (Marrllett & Cheung, 1997).

Selvendran, (1984), conclude that the highest concentration of fiber found in the outer bran layers of the grains i.e. the crude fiber content increases with the amount of branny matter present. Fiber varies with ash but the relation is evidently not linear. Naturally since ash is contained mainly in the inner and fiber in the outer bran layer.

D’appolonia and Youngs, (1978) reported that crude fiber present about 40% to 43% of wheat straw, 35% of the bran and about 0.3% of the endosperm.

Fiber percentage in whole meal wheat flour ranges between 1.8-2.5% and flour 72% extraction rate between 0.1-0.3% (Egan, *et al* 1981).

Four Sudanese wheat cultivars harvested in 91/92, Nasser, Elneilain, Condor, and Debeire, have the following fiber content 2.04%, 1.75%, 2.34%, and 2.07% respectively. (Ahmed, 1995)

According to BachKnudsen and Muck (1985), the majority (82.2%) of the fiber in sorghum is insoluble. Sorghum contains 6.5-7.9% insoluble and only 1.10-1.23% soluble D-glucose, which comprise most of the soluble fiber. Inamdar, *et al* (1984) reported that the fiber content of some promising sorghum cultivars ranged between 1.10-1.80%. Alias and Linden (1991) reported that the crude fiber of sorghum (4.1%) is higher than maize (2.0%), oats (2.3%), and millet (1.5%). ElTinay, *et al*. (1979) showed that the crude fiber of Sudanese Sorghum cultivars Feterita, Dabar and Mayo is 1.20, 1.70 and 1.90% respectively. Also Hamad (1994) showed 1.78, 1.81, 1.33% for Fetarita, Dabar and Hageen respectively.

Elnour, (1997) reported that the fiber content for Dabar variety is 2.70% on dry basis, and 1.99% for defatted seed. Arbab (1995) studied the crude fiber of Sudanese sorghum varieties, GadamElhamama and Karamaka is 2.15% and 2.25% respectively.

Ali and Horland, (1991) reported that, the total dietary fiber (TDF) for whole sorghum flour's prepared from white Dura grown in Somalia contained about 12.60% to 12.80%.

2.2. Anti-nutritional and toxic components:

Cereals and other food plants may contain significant amounts of toxic or anti-nutritional substances. Most cereals contain appreciable amounts of phytates, enzyme inhibitors, and some cereals like sorghum and millet contain large amounts of poly phenols and tannins (Salunkhe, *et al* 1990).

2.2.1. Phytates:

Phytic acid is 1, 2, 3, 4,5 ,6, - hexaphosphate of myoinositol that occurs in discrete regions of cereal grains and accounts for as much as 85% of the total phosphorus content of these grains (Reddy, *et al.,* 1989).

Lehrfeld (1989) reported that phytic acid often occurs as phytin (Mg, Ca salts of phytic acid) and it presents 60- 90% of total phosphorus. The phytic acid is the major storage form of phosphorus (De Boland, *et al* 1975; McCance and Widowson 1935). Current interest in phytic acid is due to chelate di- and trivalent cations, particularly Fe, Na, Ca, and Mg, rendering them unavailable for use by the body (Davies and Nightingale, 1975; Radhakrishnan and Sivaprasad, 1980). Phytic acid also binds strongly with protein at pH level below the isolectric point (Cosgrove, 1966). Thus, the presence of phytic acid is considered detrimental to the nutritional quality of the grain.

The bran fractions contain the highest levels of phytate-p (5.67-16.90mg/g dry weight). Phytate constitutes 85- 95%, 79-89% and 56-95% of the total –P in the bran, whole grain and hulled grain, respectively, for traditionally hand- milled samples (Doherty, *et al* 1981).

In corn 90% of the phytate is concentrated in the germ (Maga, 1982), also millets phytate concentrates mainly in the germ fraction (Simwemba, *et al*, 1984). Phytate value of proso millets ranged from 0.17 to 0.47% (Lorenz, 1983), which is higher than the values of rice (0.10- 0.14%) (Barber, 1972).

Milling is one of the treatments done on sorghum before consumption, because in sorghum, bran and aleurone areas have significant phytate and total phosphorus reservoirs (Doherty, *et al*, 1982). Therefore high extraction – rate flour has much higher content of phytates than white wheat flour. Prolonged fermentation of couple of days (Sourdough fermentation) can almost completely degrade the phytate and thus increase iron absorption (Brune, *et al* 1992).

Dehulled sorghum grain lower the phytate in the range of 0.56 to 1.92mg/g in the dry weight (Doherty, *et al* 1981). Dehulling of proso millets resulted in 27-53% reduction in phytate content (Lorenz, 1983).

2.2.2. Poly- phenolic compounds:

Sorghum and other grains contain polyphenolics in the outer layers and in the endosperm. Many polyphenolics are colored and are responsible for bran pigmentations. Some sorghum genotype that are characterized by high concentrations of polyphenolic compounds, commonly referred to as tannins which occur mainly in the pericarp and testa layers of the caryopsis (Earp *et al*, 1983; and Glennie, 1983).

Sorghum has been classified as high (brown or reddish brown seed color) and low tannin types (Rooney and Serna-Saldivar, 1991).

Tannins protect the grain from insects (Woodhead, *et al.*, 1980), bird (bird resistant) (Bullard, *et al.*, 1980), and preharvest germination (Harris, *et al*, 1970).

Tannin- protein complexes can cause inactivation of digestive enzymes (amylases and possibly lipases and proteases) (Hulse, *et al*, 1980) and reduce protein digestibility by interaction of protein substrate with ionizable iron (Salunkhe, *et al*, 1990).

The presence of tannins in food can therefore lower feed efficiency, depress growth, decrease iron absorption, damage the mucosal lining of the gastrointestinal tract, alter excretion of cations, and increase excretion of proteins and essential amino acids (Reddy and Pierson, 1994). Dehulling, cooking and fermentation reduce the tannin content of cereals and other foods (FAO, 1999).

Hulse, *et al* (1980), determined the sorghum tannin content of 14 varieties, Atlas contains the level (0.003%), Early Sumac (0.167%), Schrock (0.159%) and Leoti Red (0.15%).

According to Arbab and Eltiney (1997), the tannin content of two Sudanese varieties, Gadam Elhamama and Karamaka is 0.35% and 3.10% respectively.

2.3. Utilization of Cereals for various food products:

Cereals have a variety of uses as food. Only two cereals, wheat and rye are suited for the preparation of leavened bread (Betchart, 1982; Chaven and Kadam, 1989). Wheat can also be used in preparation of cookies (biscuits), cakes, pastries, chappatis, pasta, .etc. (Southgate, 1993)

In Sudan, the use of corn as kisra bread is not common unless Dura is rare, it is commonly ground with other grains (Tothil, 1952).

Cereals are increasingly used as animal feed. More than 70% of the cereal crop produced in-developed countries is fed to livestock, whereas in developing countries, 68-98% of the cereal crops are used for human consumption (Betschart, 1982, Chaven and Kadam, 1989).

The recent idea of replacing all or part of the wheat in bread – making by other crops, started when some of the African countries requested the help of the Food and Agriculture Organization of the United Nations in making bread out of cassava. From this point research was began in the FAO, U.K., Holland, North and Soutj American and some of the African countries. Actually, replacement on wheat by other cereals in bread-making, first began after World War II but did not continue. (Mustafa, 1973)

In Sudan in order to over come the shortage of wheat flour among cereals, sorghum was found to be better substitute for wheat in composite flours (Idowu, 1989). Food Research Center at Shambat carried out intensive research to investigate the substitution of wheat flour by sorghum flour in 1969 to make bread (Alkhalifa, 1998), to stop the importation of wheat flour that costs them so much of their foreign currency, they are looking for an alternative to wheat to produce biscuits, for these reason using sorghum flour was used instead of wheat flour (Mustafa, 1971).

2.4. Manufacturing of biscuits:

Biscuits and cookies are widely available in many countries and are consumed by people from most low and high income groups.

Mahoney, (1982) reported the contribution of cereal foods to diets of 618 men and women aged 44-79 as follows:

Food type	Number Eating	Percent of population	K cal/day
Breads	610	99	181
Biscuits	521	84	52
Hot cereals & grains	514	83	36
Crackers	491	79	28
Cakes	479	77	64
Pastries	477	77	103
Pies & fruits	298	48	41

From the above table he conclude that biscuits are highly consumed (521) comparing to the other products, but lower than bread consumption (610).

The end product will vary not only in variety, but in quality through variation in the type and proportion of the ingredients. The kind and/or amount of leavening agent involved; the temperature of the ingredients when mixed and the extent and method of mixing, the baking and baking temperature …etc. (Stevenson & Miller, 1960).

2.4.1. Steps in processing biscuits:

1- Preparation and measuring the ingredients.
2- Mixing the ingredients.
3- Cutting and forming the biscuits.
4- Baking.
5- Packing.
6- Storage.

2.4.1.1. Preparing and measuring the ingredients:

The fundamental ingredients used in batters and dough are:

1- Flour
2- Sugars.
3- Liquid
4- Fats and oils.
5- Eggs.
6- Leavening agent.
7- Salt
8- Flavor.

The properties of cookie doughs and textural characteristics of baked cookies depend on proportions as well as on chemical and physical characteristics of these main ingredients. Development of successful cookie formula is still as experimental and empirical task affected not only by the formulation but also by the processing and machining steps. This effort can be assisted and greatly facilitated if, in addition to the functionality of ingredients, the changes and interaction that takes place during processing and the factors that affect them are understood (Faridi and Finley 1989, Kasarda et al, 1978, Manley, 1983, and Matz, 1968, Smith 1972, Wade, 1988).

2.4.1.1.1. Flour:

Cereals are rarely consumed as foods without form of processing kind (Kent, 1983).

a. Milling:

The purpose of most milling processes, even simply traditional household methods (Hulse *et al.*, 1980 & Munck, *et al.*, 1981), were:

a. To separate, as completely as possible the endosperm, which is required for the flour, from the bran and germ, which are rejected, so that the flour shall be free from bran specks, and of good color, therefore the palatability and digestibility of the product shall be improved and its strong life lengthened.

b. To reduce the maximum amount of endosperm to flour fineness, thereby obtaining the maximum extraction of white flour from the wheat.

a.1. Milling methods:

The two methods for grinding the grain are:

a.1.1. Traditional methods:

Cereals may be milled by crushing or grinding between two stones. Stone mills may resemble a pestle and mortar, in which the grain is crushed by pounding. More commonly a quern is used, in which the grain is crushed between two circular stones. One stationary and the other move by hand. Large mill stones are turned by animals or by waterpower. (FAO, 1970).

According to Scheuring *et al* (1983); and Reichert, *et al* (1981), during pounding of sorghum, additional water is added to soften the pericarp, which facilitates its removal.

This process is tedious and time consuming and the flour obtained is very low. The flour obtained for sorghum is only about 50 to 60% of the starting amount, and the flour contains about 30% moisture that make the flour unstable. To improve the stability pounding has to be repeated every other day (Kordalys, 1991).

Lathan, (1997) reported that wheat grain lost some of its outer coats but retains at least part of the germ including the scutellum in milling by using traditional method.

a.1.2. Mechanical methods:

The milling process to produce white flour follows specific steps. Wheat grains are separated into portions of different qualities by a series of crushing, pulverizing and sifting processes which separate fractions of differing fineness; it is also scoured to remove fuzz and other material adhering to kernels, next it is tempered by soaking to toughen the bran and condition the endosperm starch for milling. After being tempered for up to six hours, the grain is passed through a series of corrugated rollers placed for enough apart to crush the kernels onto coarse fragments and largely separate the seed coat from the endosperm. The process is known as breaking. At each crushing, some of the endosperm becomes sufficiently ground to pass through flour sieves as break flour. The coarse particles of endosperm left behind are called middlings. These are small enough to pass through sieves that remove most of the bran. Some bran particles, small enough to go through with the middlings are removed by air currents, a process called purification. Middlings may be bagged and sold as farina for use as breakfast cereal in creamed cereal porridge, or sold as semolina, which is used for making macaroni. After purification, each lot of middlings meant for flour making is further reduced by passing it between a series of smooth rollers, which further pulverize it to produce some flour and smaller particle middlings. Parts of the germ which were attached to the coarse middlings are flattened by the reducing rollers and are removed from the flour and fine middlings by sifting. Any remaining particles of bran are also sifted out because they resist pulverization more than the endosperm. The particles of bran and parts of endosperm separate from the middlings are known as shorts and are usually sold for animal feed.

Through this process of wheat milling, many batches of flour are obtained. About five batches of break flour are produced, and six or more sets of flour are obtained from the reduction of the middlings. These batches contain different amounts of bran and germ. Parts of pulverized endosperm also differ from batch to batch. Usually, the early produced flours, or break flours, and batches produced from the last middling reductions, are of inferior baking quality. These differences make it possible for several grades of flour to be produced from the same batch of wheat.

By calculation, about 82 to 85% of the wheat should come out as white flour, but with the present process of milling, only about 72 to 75% is separated in the form of white flour (Kordylas, 1991; and Champau and Carter, 1976).

The flour is generally bleached to improve flour quality. Bleaching replaces aging, which requires several months (Champau and Carter, 1976). For bread and all- purpose flours, the most common agent is benzol peroxide, which is added as dry powder and whitens flour over a two–day period. It has no improving effect and is thought only to bleach flour pigments. Cake flour is often treated with chlorine gas. A number of oxidizing agents are used as maturing agents. These include azodicarbonamide, acetone peroxide, chlorine dioxide, and potassium bromate. All of these reagents improve the bread making capacity of the flour. (Hoseney, 1986)

In Mali, as in most parts of West Africa, sorghum is decorticated as the first step in food preparation (Rooney and Kirleis, 1980), before this, the grain is washed thoroughly to remove dust, glumes, and small stones (Scheuring *et al*, 1983).

Dry milling of sorghum involved three operations, cleaning, decortication, and grinding (in Northern Nigeria) it is found that 20% decortication could be optimum. Tempering grain prior to decortication decreased the throughput, and increased the amount of broken grains, ash and fat contents of the product. For the grinding, a combination of roller stand with two passages and hammer mill were adopted. This grinding system can produce either brewers grits or flours, or both if needed (Obiana, 1990).

The Tangential Abrasive Dehulling Device (TADD), may also be used, the horizontal mounted grinding wheel is used for dehulling sorghum, because the abrasive surface used in the TADD affects the dehulling rate, efficiency, and reproducibility. Therefore, it is used commercially (Reichert, *et al* 1981).

By using the pearling technique (the grain is mixed with 2 to 3% moisture, after conditioning for a period of 5-10 min. It is polished in an abrasive type polishing machine used for polishing rice (i.e. McMill) improved the visual appearance and consumer acceptability of the grain, by removing the colored, bitter taste, rough bran and glumes from the endosperm. This technique is not suitable for sorghum varieties with soft endosperm (Desikachar, 1981).

Reichert, *et al* (1981); and Munck *et al* (1981) Demonstrated that decorticating efficiency is influenced by physical characteristics of the sorghum grain particularly its hardness.

b. Cereal hardness phenomenon:

Effectively it is conceivable that cereal quality largely depends on the ease of dehulling, i.e. extent of hardness or flexibility phenomenon, which particularly is of interest to process. Currently, two theories are proposed to explain hardness in wheat as concluded by MacRitchie (1980). While the first theory is based on continuity of protein matrix which physically traps the starch granules and causes difficulty in separating starch from protein and makes the grain harder. The second suggests that a water soluble matrix in wheat surrounding the starch granule is thought as to be responsible for the adhesion of the protein matrix to the starch (Barlow, *et al*, 1973). Grosh and Milner, (1959) found that wheat hardness decreases with increasing moisture content, while soft wheat showed increasing softness at higher moisture content, hard wheat showing little response.

During milling, a small but significant number of the starch granules in the flour are damaged. The level of damage varies with the severity of grinding and the hardness of the wheat. A soft wheat can be milled with essentially no starch damaged, the value may be 2-3%. People often state that damaged starch is necessary in bread making, damaged starch increases the water absorption of dough. It also produced weak sidewalls and sticky crumb if sufficient enzymes are available. Starch damage is a strong negative factor in soft wheat flour used as cookie flour. (Hoseney, 1986)

Manley (1983) reported that milling wheat can be described as hard, medium or soft, based on the physical character of wheat grain. Hard tend to have higher proteins, as probably spring wheats have vitreous endosperm (the white starchy center part from which flour is derived), in contrast, soft wheats produce a more fluffy type of flour with less damage starch and with lower water absorption. The protein levels are typically low and gives gluten that is less resistant and more extensible. The position of medium wheat is intermediate. Canadian and American hard red spring (HRS) wheats are good examples of hard wheats. European, some Australian and American soft red winter (SRW) wheats are examples of soft wheats. American hard red winters, Plate (South American), USSR and some Australian wheats are in the medium category.

Bread flours is usually made from hard wheat, because of the relatively high protein content and desirable gluten quantity (Gregory, *et al* 1990). While weaker flours are more desirable for making biscuits, cakes and other sweet mixtures (Kordylas, 1991). Hard wheat flour has an effect upon the texture of the products made from that flour, for example, cookies made from hard wheat flour are almost invariably hard in texture. (Hoseney, 1986).

Defrancisco, *et al* (1982) reported that wheat grain hardness has always been a major concern of millers because it determines grinding time and energy expenditure as well as the performance and appearance of the final product. Wheat grain hardness, also, concerns people in developing countries where such milling is done by hand with wooden or stone mortars or with hand-operated stone mills are, more or less, primitive methods (Vogel and Graham, 1979).

Scheuring *et al* (1983) examined local Guineese sorghum grain with thick and thin pericarps, obtained from markets at Ouagadougou, for the relationship between the pericarp thickness and the time required for mortar pestle decortication, he conclude that, as the pericarp thickness increased, decortication time decreased (26.4 to 11.0), and this due to the starch content. Also Eggum, *et al* (1981) reported that the hardness or softness of the endosperm is an important component in the concept of milling. As sorghum variety with soft endosperm is difficult to decorticate on such seeds tend to break, resulting in losses of fine endosperm particles to the full fraction. The soft part of the endosperm is clearly seen in cross sections of seeds as light area caused by the reflectance of closely embedded starch particles. Tran, *et al* (1981), emphasized that millers are interested in solving problems related to hardness of cereals because it influences the grinding time, sieving behaviour, energy consumption, fines of the flour produced, storability, insect infestation and more explicit the extraction rate.

Rooney, *et al*. (1977) defined that, sorghum hardness is the relative proportion of corneous to floury endosperm. Kernel hardness is related to more corneouse texture. The magnitude of grain hardness, as well as texture affects the processing properties. In the corneous endosperm starch- protein bond is strong enough, and makes the grain harder.

A comparison of number of methods of sorghum hardness evaluation showed that, the Particle Size Index (PSI) and Pearling Index (PI) provide a rapid and sensitive measure of physicomechanical properties of sorghum related to hardness.

b.1. Particles Size Index (PSI):

A procedure of determining a particle size index of hammer milled (screen aperture of 6.635m) sorghum grain reported by Sullins, *et al*, (1971) had undergo various reconstitution treatment.

Yamazaki and Donelson (1983) summaries that, there are no significant relationships between protein content and PSI within cultivars, and the particle size index for soft wheat was significantly associated with break flour yield obtained in milling the wheat. The particle size index data may be influenced by grain moisture content. Also Sullins *et al*, (1971) found that reconstituted sorghum grain with larger particle size indices had increased feed efficiency. Kirleis and Crossy (1981) conclude that, the lower the particle and size, the harder was the grain.

Yamazaki and Donelson (1983) tabulated the relationship between the particle size, moisture content and protein content of different wheat grain (at 11 moisture levels) cultivars:

Cultivars	Wheat class	Moisture content range %	PSI range %	Protein content range %
Purkof	SH	7.59- 14.67	8.60- 12.10	8.4- 15.5
Comanche	HRW	7.45- 14.74	8.53- 13.15	9.8- 15.4
Kawvale	SH	7.45- 14.80	10.38-16.43	8.2- 15.6
Clarkan	SRW	7.92-15.41	10.73-18.45	8.5-14.6
Blackhawk	SRW	8.07-14.90	12.50-19.05	8.4-15.5
Avon	SWW	8.20-14.90	12.60-19.45	8.7-13.5
Am.Banner	SWW	8.01-14.86	12.90-18.80	8.1-14.7

HRW : Hard Red Winter. SH: Spring Hard.

SWW : Soft White Winter. SRW : Soft Red Winter.

b.2. Pearling Index (PI):

Pearling, the attritional abrasion of wheat kernels by carborundum wheel, is a treatment also used to differentiate hardness among wheat (MC Cluggage, 1973). Hardness data obtained by this procedure is significantly correlated with those obtained by a PSI test (Bode, 1954).

Pearling Index data is influenced by moisture content and increasing the kernel hardness.

Pearling is measuring the bran toughening effect of water, whereas PSI is measuring the influence of water on endosperm friability or hardness (Yamazaki & Donelson, 1983).

Yamazaki and Donelson (1983) gave the relation between the pearling index, moisture content and wheat type at 11 moisture. The table below shows that.

Cultivars	Wheat class	Moisture content range (%)	PSI range (%)
Purkof	SH	7.59- 14.67	33.25-29.10
Comanche	HRW	7.45- 14.74	36.00-29.70
Clarkan	SRW	7.92- 15.41	38.70-33.40
Kawvale	SH	7.85-14.80	43.55-35.48
Blackhawk	SRW	8.07-14.90	46.45-38.05
Avon	SWW	8.20-14.90	49.33-41.25
Am.Banner	SWW	8.01-14.86	51.88-41.93

HRW: Hard Red Winter. SH: Spring Hard.

SWW : Soft White Winter. SRW : Soft Red Winter.

Sorghum grain with large kernel size appears to have pearling properties superior to grain with small kernels, given the same endosperm hardness.

A project was done in the Zaki Flour Mills, for cereal grains like wheat, maize, sorghum and millet. Sorghum was processed into flour of 200μ to 300μ particle grade and grits of 300-110μ particle grade through dry milling system. Flour of 200μ particle grade is used mainly by the biscuits manufacturers (Chiroma, 1990).

C. Flour yield:

The number of parts of flour by weight produced per 100 parts of wheat milled is known as the yield or percentage extraction rate (Kent, 1983). Thus 85 percentage extraction flour contain 85 percentage (by weight) of the whole grain, and 15 percentage have been removed (FAO, 1997).

The relationship between extraction rate and nutrient content is well established. The greater the extraction rate in the milling flour, the higher the percentage of the original nutrient content that is retained by the flour (Yamazaki *et al*, 1979; Gallagher, 1984; and FAO, 1997). According to Gallagher (1984), high flour yield is one criteria of good milling.

Kent- Jones and Amos (1967) reported the effect of different extraction rate on the nutritive value on wheat flour. The table below shows that.

	72%	80%	85%	95%
Moisture	13.0-15.5	13.0-15.0	13.0-14.0	13.0-13.5
Starch	65-70	64-69	64-68	63-67
Protein (N × 5.7)	8-13	9-14	9-14	10-14
Fiber	Trace-0.2	0.2-0.35	0.4-0.9	1.6-2.1
Fat	0.8-1.5	1.0-1.6	1.5-2.0	1.6-2.2
Sugar	1.5-2.0	1.5-2.0	2.0-2.5	2.0-3.0
Mineral (Ash)	0.3-0.6	0.6-0.8	0.7-0.9	1.4-1.6

Ahmed, (1995) invested that, the protein content of Sudanese wheat cultivars decreased with decreasing the extraction rate. The protein content of wheat flour obtained by 72% extraction rate ranges between 9.73 and 10.39% which is lower than 100% extraction rate which ranged from 8.21 to 15.32%. FAO (1970) summarized the nutrient composition of wheat flour at different extraction rates 100%, 85%, 80%, and 70%, is 13.6, 12.5, 12.0, and 11.4% for protein, 2.5, 1.5, 1.4, and 1.2% for Oil, 1.50, 0.92, 0.72, and 0.44% for ash, and for fiber is 2.2, 0.33, 0.20 and 0.10% respectively.

Hamad (1994), summaries the effect of different extraction rates, different time on the removed bran and broken kernels for sorghum varieties. Increasing the extraction, decrease the removed bran, broken kernel, and losses, also the decortication time (sec.). Hageen variety has a greater extraction rate (harder) followed by Dabar then Fetarita. The result showed in the following table:

Sample	Decortication time.(Sec.)	Extraction rate %	Removed Bran %	Broken kernels %	Losses
Hageen	30	92.30	6.08	1.00	0.25
	60	84.25	10.00	1.58	4.14
	90	76.25	17.75	2.08	3.92
Dabar	30	91.75	6.o8	0.67	1.50
	60	84.00	12.58	1.17	2.25
	90	76.08	19.33	2.17	2.92
Fetarita	30	87.33	13.92	2.42	-
	60	76.25	18.17	3.67	1.92
	90	62.83	29.83	5.33	2.00

Mustafa (1978), studied the effect of different extraction rates on Sudanese Sorghum variety, (Dadar), harvested 72/1973, he concluded that, the decortication rate was uniformly giving descending contents of ash, protein and fat with ascending decortication rate (i.e. descending extraction rate). This conclusion was shown below:

Extraction rate of flour	% moisture (Dry matter)	% Ash	% Protein (N× 6.25)	% Fat	% Fiber
100% B.	10.05	1.24	12.0	4.3	1.4
100% P.	8.40	1.22	11.5	4.3	1.9
80% B.	9.10	1.07	12.0	3.7	0.7
80 % P.	8.00	0.94	12.1	3.3	0.7
75% B.	9.40	0.94	11.6	3.3	0.6
70% B	9.80	0.82	11.6	2.7	0.4
65% B.	9.55	0.76	11.2	2.6	0.5
50% B.	9.65	0.49	10.7	1.6	0.3

Note : B. : Buhler Product , P. : Pin Mill Product.

Mohammed (2000) reported the chemical composition of Sudanese sorghum variety, Fakimustahi, at different extraction rates

Extraction rate of flour	% moisture (Dry matter)	% Ash	% Protein (N× 6.25)	% Fat	% Fiber	Carbohydr-ates
100%	6.70	1.41	15.49	3.83	1.62	75.20
90%	6.00	1.31	15.4	2.57	0.74	73.99
80%	6.00	0.91	15.30	2.52	0.61	74.67
70%	6.5	0.83	14.84	1.57	0.56	75.54
60%	7.00	0.67	13.66	1.29	0.53	76.86

Hulse *et al*, (1980) reported that the nutrient loss was greater in Buhler mill than the traditional pestle and mortar, because more germ and bran were removed than the traditional process, but there was a greater loss of raw material from the traditional mill mainly because the grains are thrown out of the mortar during pounding. Desikachar (1981), mentioned that using both the laboratory Buhler mill and commercial roller mill, a highly refined sorghum flour is obtained.

FAO study on the milling of sorghum and millet in Niger, Senegal, and Sudan (Perten, 1977), they concluded that roll mills are not appropriate for sorghum milling because the bran and germ of sorghum and millet pulverize easily to fine powder which is difficult to separate from the fine flour.

Lathan (1997), reported the advantages of low- extraction flour over high- extraction flours from the trade point of views as that they are whiter, and more popular, they have less fat, and hence less tendency to become rancid, and less phytic acid, which means that the minerals from associated food are absorbed better and they have better baking qualities.

The disadvantages of low extraction flours to the consumer, they contain less B vitamins, minerals, fiber and proteins than high extraction flours.

D. Flour Color:

Flour colour, a measure of bran contamination, is measured with the Kent-Jones and Martin colorimeter. The higher contamination, the criterion of product quality and play a major role in the acceptance or rejection of food products. Flour colour was important to the Romans, who prided themselves on making the finest, whitest flours. Even today many people still equate flour colour with quality for use in food products. If sorghum is to compete with wheat and maize products in urban areas, highly refined product will be required (Murty and Rooney, 1981)

The wheat flour depends upon variety, environment, and the condition of the grain. “Hard” milling wheat, despite higher flour yield, usually produce flour whose color is somewhat better than comparable “Soft” milling varieties where the yield of flour is lower.

The colour of flour can be seriously affected by imperfect development of the grain, and by weathering. The first cause may simply involve lack of endosperm, but it is often associated with the second, in which the outer layers of the bran become partially separated loss their nature and exhibit brittleness during milling, which will spoil the color of the flour. The same circumstances can cause post-ripening moulds to develop on the chaff; which may be transferred to the bran of the grain and may ultimately penetrate the endosperm. Since such moulds normally discolour and blacken the bran and presumably denature it, they greatly facilitate its breakdown during milling and, because of the discolouration, spoil the colour of the finished flour (Gallagher, 1984).

Murty and Rooney (1981), reported that, the accepted colour is conditioned by what people are used to, and unaccustomed variability is often viewed with distrust.

In general, white sorghum grains produced the most acceptable colored food products, but considerable variation in color of some products was acceptable. Thus it is important to measure color of grain, flour, and the food products in an efficient manner (Murty and Rooney, 1981).

E. Types of wheat flours:

Wheat flour ranges in protein (gluten) and carbohydrates (starch) from soft to hard, within certain limits, various types of flour may be interchanged in different recipes by altering the proportions of the non-flour constituents of the mixture (Bennion, 1980).

e1. Whole wheat flour:

May also be called “Graham flour” or “entire wheat” or “cracked wheat”, it contains essentially the entire wheat kernel, i.e. whole- wheat flour means the whole kernel is used (Bennion, 1980).

Limited amounts of malt and chemicals for bleaching and aging may be added to any of these. They may be made from either hard or soft wheat (Stevenson and Miller, 1960).

The keeping quality of whole wheat flour is lower than that of white flour because it contains fat from the germ that may became oxidized on storage (Bennion, 1980).

e.2. White flour:

These flours are made from wheat that have been ground and sifted through a sifter screen (bolted). Variation in quality of wheat flours may be due to the type of wheat used, the conditions under which the wheat was grown, the size of the flour particles, the completeness of the milling, and the substances added during the milling process (Stevenson and Miller, 1960).

e3. Bread flour:

Bread flour is a white flour made chiefly from hard wheat. It contains a relatively high percentage of protein that will develop into gluten with very strong, elastic properties when the flour is made into dough. Bread flours have a slightly granular feel when it is touched and does not form a firm mass when pressed in the hand. It may be bleached or unbleached. Bread flour is used chiefly by the commercial baker for yeast breads (Bennion, 1980).

e4. All purpose flour:

All- purpose flour is sometimes called family flour or general-purpose flour. It is a white flour, usually made from a blend of wheats to produce a protein content that is lower in gluten strength than that of bread flour. It contains enough protein that it can be satisfactorly used for making quick breads, pastry, cookies and certain cakes (Bennion, 1980 and Stevenson and Miller, 1960).

e5. Pastry flour:

Pastry flour is a white flour that is usually made from a soft wheat and containing a lower percentage of protein than found in all-purpose flour. Its chief use is for baking pastries and cookies, and is used primarily in the commercial baking industry (Bennion, 1980).

e6. Cake flour:

Cake flour prepared mainly from soft wheat. The protein content of cake flour is very low in comparison to the other types of flour and it is usually highly bleached with chlorine. The high starch content and weak quality of gluten produced from cake flour makes it desirable chiefly for the preparation of delicate, fine- textured cakes (Bennion, 1980).

e7. Self- raising flour:

Either all purpose or cake flour may be self –rising after adding a complete chemical leavening agent. This is usually a mixture of sodium bicarbonate (Soda) and calcium acid phosphate. Self- rising flours are commonly used in preparation of baking powder biscuits, cakes, ginger bread, and many others products (Bennion, 1980, and Stevenson and Miller, 1960).

e8. Enriched flour:

Enriched flour is white flour to which specific B vitamins and iron have been added (Bennion, 1980). Optional ingredients are calcium and vitamin D (Bennion, 1980; and Wolf *et al* 1979).

e9. Non wheat flours:

Flours other than wheat are commonly used in quick breads as well as in yeast breads, e.g. corn meal, can be used in several types of quick breads (Bennion, 1980; and Badi, et.al, 1978), it is chief protein, zein, has non-of the properties of the gluten of wheat (Bennion, 1980). Rice flour is used in refrigerated biscuits manufacture to prevent sticking, in bakery foods, as a thickener, in waffle and pancake mixes as a water absorbent (Kent, 1983). Also triticale flour has a low protein, low glutenin, low free sulfydryl groups content and high prolamin percentage, this best quality makes the flour suitable for preparing cookies (Anon, *et al*,1996).

e10. Composite flours:

The term "Composite flours" ought not to be restricted but should comprehend by mixture of different flours used to produce a traditional or an adopted exotic food.

In 1970 the Tropical Products Institute published the proceeding of a symposium on the use of non-wheat flours in bread and baked goods (Hulse, *et al* 1980).

In Sudan, like most African countries South of Sahara, it is confronted by rapidly growing problems of satisfying the ever-increasing demand for wheat and its products such as bread. In order to make composite flour program possible, it is necessary that the milling industry be promoted to produce high quality flour from non-wheat materials in sufficient quantities (Idow, 1989).

Olataunji, *et al* (1989) reported that substitution 20% and 50% wheat by sorghum flour can give an acceptable bread and biscuits, respectively.

Priyolkar (1989) reported that substitution of wheat flour up to 25% with sorghum flour in production of short, hard dough biscuits and wafer was cost effective without affecting quality, breakage, and plant efficiency.

Eh (1999) reported that biscuits produced from 65% millet flour and 35% pigeon pea flour resulted in high nutritional value, highest scores for flavour, texture and general acceptability.

In Sudan the predominant diet is kisra, which is the conventional staple type of sorghum meal. The principal aim of the composite flour programme is to make use of local raw materials to produce acceptable food products in an economical way (Idow, 1989).

The rate of substitution of wheat flour depends on the production method when composite flour is used for biscuit –making- eighty percent substitution is feasible without serious deterioration of biscuits quality when depositing or moulding method is used, while 20% or even lower can produce an acceptable quality biscuit made by the cutting method. But Orewa and Iloh (1989) mentioned that 50% substitution by using moulding method, gives good result.

The important quality criteria of non-wheat flours used in the composite flour products are its particle size, which should be almost the same as that of the wheat flour. For the production of long shelf life biscuits, decorticated maize flour or cassava starch were recommended with a view to lower fat content as low as possible (UNECA, 1985).

Elkhalifa (1998), concluded that in biscuits the addition of sorghum flour decreased the weight, and addition of dissolved cysteine (90ppm/100g blend) to 30% sorghum gives the greater weight (9.27) than 20% (9.06) with cysteine (60ppm/100g) and 10% (8.87) with cysteine (30ppm/100g). The thickness of the biscuits in general increased in 20% (0.74) and 30% (0.82) blends while increased in all blends by the addition of cystein 10% (0.84), 20% (0.84) and 30% (0.86). The spread ratio (width/thickness) decreased for all types of biscuits except biscuits made from 10 to 20% blends. This is due to the decrease in width and thickness of these two types as the spread ratio is the ratio of width of biscuits to the thickness of biscuits. Baba (1995) reported that when cystein was added to wheat flour used in cream cracker it effects the physical characteristics of the product by reducing the thickness of the crackers and the weight.

The texture of the biscuits was not affected so much by incorporation of the sorghum, but when cystein was added to the blends the biscuits became more softer and, there was a decrease in the texture of the three blends by 26, 40, and 39% for the 10, 20, and 30% blends respectively.

The crumb colour was affected by the increase of the percentage of sorghum in the blends, at high percentage of sorghum flour the crumb colour became dull white in colour, the texture became harder in the 20 and 30% blends. The presence of sorghum affects the mouthfeel which leads to residual taste in the mouth. The over all quality of the biscuits was reduced by addition of sorghum flour.

The addition of cystein results in the improvement of physical and sensory characteristics. The crumb colour was affected by the addition of cysteine, also the addition of cysteine made the biscuits softer, and does not affect the mouth feel. The over all quality of the biscuits was reduced by addition of sorghum flour but presence of cysteine in the blend improved the quality mainly in that containing 20% sorghum with 60ppm/100g cystein, and 5 to 10% of sorghum flour for bread making.

Several problems are associated with the industry. Although the cost of flour decreased by the substitution of wheat with sorghum, prices of other items such as fat and sugar increased during the last years. (Orewa and Iloh (1989).

f. The criteria of good biscuits flour:

f1. Suitable protein quality:

Zeleny (1971) reported that, the quality of wheat is usually judged by its suitability for particular end use.

According to Harper (1983), Gallagher (1984) and Bennion (1980) there are different criteria between the wheat flour used to produce bread or biscuits. Wheat flour suitable for bread making must contain adequate levels of protein of the right quality. Approximately 80% of the grain protein are in the endosperm and when mixed with water the majority of these properties form a complex known as gluten. Gluten has elastic properties and retains carbon dioxide gas bubbles as they form in the loaf volume during baking. This gives rise to the open- textured loaf. Therefore is required for bread- making, where as protein flour with extensible gluten is required for biscuit and cake manufacture. Non-elastic is more preferable in manufacturing of biscuits. Wheat varieties producing elastic glutens are known as "Strong" wheat; varieties producing extensible glutens are known as "Weak" varieties.

Either bread flour, pastry flour or cake flour can be used to made hard and soft cookies. Hard flours may cause some types of cookies to lack spread while cake flour may cause some cookies to spread too much.

f2. Reasonable low protein quality:

The quantity of protein is highly variable, few samples in grown wheat contain less than 7%, but some can be found with more than 14% (Gallagher, 1984).

Protein content of grain is influenced mainly by the amount of nitrogen fertilizer applied to the soil and the time of up take. Choice of variety is also an important determinant of protein levels, and wet weather during the development of the grain increases nitrogen uptake. Also high drying temperatures can denature grain protein and cause loss of protein quality (Harper, 1983 and Gallagher, 1984).

Also Gallagher (1984) reported the range of 8 to 10% protein is often ideal for the production of biscuit flour. For the European biscuits (cookies) the maximum protein content is 9.5% (Harrel, 1959).

f3. Medium to low α- amylase activity:

Two forms of starch- hydrolysing enzymes are known to be present, ∝- amylase and β- amylase (Gallagher, 1984). Sorghum α-amylase is secreted from the scutellum- sorghum contains moderate to very limited β- amylase activity (Dyer and Novellie, 1966). Alpha-amylase activity in sorghum starts 36hr after germination (Aisien and Palmer, 1983; Aisien, 1982).

The enzyme α-amylase breaks α-1,4 glycosidic bonds on a nearly random basis. The result of the enzyme action is, therefore, to rapidly decrease the size of large starch molecules and thereby reduce the viscosity of starch solution or slurry (Hoseney, 1986). So alpha-amylase provides fermentable sugar for yeast fermentation to produce bread with softer crumb and greater volume (due to carbon dioxide production) and improves grain and texture (Ahmed, 1995). But Greenaway (1969) found that high alpha- amylase activity on the other hand makes thin graves and bread with small loaf volume.

Alpha-amylase levels are lowest in the dry ripe dormant grain and highest in sprouted grain (Harper, 1983).

In biscuits manufacture, because of the addition of more sugar and fat and less water than in bread making, higher level of Alpha amylase activity can be tolerated in the flour (Gallagher, 1984).

The falling number (Hagberg) Test is used to determine alpha amylase levels. This test records the time taken for a plunger to fall through a prepared slurry of flour. The result is expressed as the time in seconds taken for the plunger to fall, plus 60 in seconds (Harper, 1983).

2.4.1.1.2. Sweeteners:

Sweeteners may be regarded as the most ubiquitous class of ingredients in cookies. No cookie formula is without some form of sweeteners. The quantity of sweeteners added is usually such that it has significant effects on the texture and appearance of the product as well as on the flavor. (Matz, 1968)

Sucrose is a non- reducing disaccharide, which upon hydrolysis, yields two molecules of reducing sugars, one of glucose and one of fructose. (Kulp, 1994).

It is used in all biscuits (cookies) recipes for many purposes, nutritive sweetener, tenderizing (the most popular one), colouring, flavouring, preservation, and as a means of controlling spread.

Sucrose has a tenderizing effect because it interfaces with the development of gluten in batter or dough, since less water is available for the gluten. The volume of many flour mixture is increased by the addition of optimal amounts of sugar because the gluten structure is tenderized and expand more easily under the pressure of leavening gas (Kent & Evers, 1994).

Sucrose products produced and sold in United States are classified in four categories: granulated, liquid, brown sugars, specialty products (Kulp,1994).

- **Granulated sugar:**

As the sugar granulations become finer (i.e. decreasing mean particle size) the cookie will spread less (Kissell, *et al*, 1973). According to Abboud, *et al*, (1985), sugar particle size did not affect cookie spread except at the coarsest size (greater than 35 mesh), also Kulp (1994) record that powdered sugar causes the greatest spread since the powdered sugar is more readily soluble, and the sugar in the liquid product is completely dissolved in water. Coarse sugars increase surface darkening of cookies as more coarse sugar, when melting, migrates to the surface where it caramelizes and increases the colour of the surface.

Surface texture is also affected by granulation of sugar used. Coarse sucrose, because of its migration to the surface after melting, tends to cause a crack or checkerboard pattern on the surface of the cookies, such as in sugar cookies (Schanot 1981)

- **Liquid sugars:**

Cannot replace completely solid sucrose since sucrose is not sufficiently soluble in the amount of cookie dough water.

- **Brown Sugar (Soft sugar):**

Is a blend of sucrose and crystals covered with refined molasses (Schanot 1981 a, b). Is used to obtain a certain flavor and yields biscuits product that tend to remain moist longer than those with granulated sugar (Bennion, 1980). Total sugar content ranges from 90 to 95%, and moisture from about 2 (the lightest type) to 4% (the darkest type) (Matz, 1968)

Sucrose- syrup dough exhibited prominent yielding and flow behaviour, and the extensional viscosity decreased with increasing sucrose content (Baltsavias, *et al* 1999a). Also sucrose syrup slightly enhanced the brittle character of biscuits, compared with crystalline sucrose, indicating that sucrose were not the fracture- including agent defects (Baltsavias, *et al* 1999b).

Curley and Hoseney (1984) reported that, the replacement of granular sucrose with high- fructose corn syrup (HFCS) in sugar- snap cookie affect dough reheology (stickiness), surface cracking, and the characteristic snap associated with this type of cookie. A soft sticky dough results when sucrose is replaced with HFCS; the significance of this change is dependent on the amount of corn syrup substituted, If small amounts of sucrose are replaced with corn syrup, the typical cracked surface of the backed cookie is lost, and a smooth surface results. Measurement of water loss during baking show no difference between cookie baked with 100% sucrose and with 50% HFCS. The rate on internal water diffusion might cause the difference in surface characteristics of the cookies. Sugar cookies develop a characteristic "snap" within five days after baking. The time required for the snap to develop increases with increasing levels of corn syrup. This delay in snap development appears to coincide with sugar recrystalization.

The concentration of sugar in sugar- flour- water solution affects the gelatinization temperature of the starch. Spies and Hoseney, (1982) mentioned that, as the concentration of sugar increased, the gelatinization temperature of the starch also increased. Because the interaction between starch- sugar affect the amount of water (i.e. As the water activity of a sugar solution decreased, gelatinization temperature of starch in the solution increased), therefore increasing the energy required for gelatinization.

Nishibori and Kawakishi (1992) found that the difference in physical properties- volume expansion, form, colour and surface condition in cookies made with various sugars result from the difference in melting point temperature and solubility.

Fructose produces the most favorable physical properties and flavor.

2.4.1.1.3. Liquids:

Liquids have various uses in flour mixtures therefore are necessary in all recipes.

Various liquids may be used in flour mixture including water, potato water, milk, fruit juice, coffee and the water content of eggs (Bennion, 1980).

Water is necessary to moisten the flour protein to form gluten structure. Also during heating promotes the gelatinization of starch. Water can dissolve certain constituents, such as sugars, salts and baking powder. Water also contributes to dough consistency and helps to control the temperature of the dough or batter (Bennion, 1980; Stevenson and Miller, 1960; and Kordylas, 1991).

Addition of milk helps the product to be brown during baking, also adds nutritive value to the product (Kordylas, 1991). Skim milk is normally used in bakery products. It is defined as milk from which a sufficient portion of the fat has been removed to reduce the fat content below that of 3.25%. More specifically skim milk is the product obtained in the separation of cream from milk (Morris, 1958)

Stevenson and Miller (1960) reported that the moistness or dryness of baked product depends on its liquid content.

2.4.1.1.4. Fats and oils:

Fats and oils have been known as important baking ingredients for centuries. Indeed, "Shortening" is a baker's term, fat in a bakery item. (Bennion, 1980; and Stauffer, 1998). They are probably the most important ingredients used in biscuit manufacture. They are the third component after flour and sugar but they are considerably more expensive (Manley, 1983).

Fats and oils are triglycerides of fatty acids, that is, three fatty acid molecules combined chemically by ester bonds with one glycerol molecule to yield a molecule of fat or oil. The fatty acids are straight chain compounds bearing a single carboxyl group. Naturally occurring fatty acids almost always have an even number of carbon atoms between 4 and 26. If the fatty acid contains double- bond linkages, it is classified as unsaturated. Such compounds tend to be considerably more reactive than saturated fatty acids and they melt at lower temperature than their saturated counterparts. (Matz, 1968)

Shortenenings, (tenderize) the texture play an important role in the efficient processing of many bakery products (Bennion, 1980; and Stauffer, 1998).

Shortening has four primary functions in cookies, lubrication, aeration, eating quality and spread. (Kulp, 1994)

Fats are capable of coating flour particles forming layers or masses physically separate different parts of the dough structure and prevent them from coming together. This ability interferes with gluten formation and gives tenderness to the product by causing it to break crumble easily. This ability is known as the shortening power of fats. When fat is distributed in thin layers of flour, it produced flakiness in the biscuits, however, over development of gluten results in flaky tough crumb. Flakiness is desirable when piecrust are prepared (Bennion, 1980 and Kordylas, 1991).

Fats that are very plastic usually have greater shortening power than harder, less plastic fats. Lard have more shortening power than most hydrogenated fats (hydrogenation is the process by which hydrogen is added directly to points of un-saturation in the fatty acids). Hydrogenation of fats has been developed as a result of the need to convert oils to solid fats and to increase the stability of the fat or oil to oxidative rancidity, (Matz, 1968), butter and margarine oils that are high in polyunsaturated fats usually give more tender pastries than lard (Bennion, 1980).

Matthhews and Drawson (1963) reported the performance of six fats and oils (corn oil, cottonseed oil, soybean oil, lard, and two hydrogenated vegetable fats) in pastry and in baking- powder biscuits. Taste panel evaluation of tenderness and flakiness showed highly significant correlation with physical measurements. The oils were more efficient shortening agents in pastry, and the solid fats in baking-powder biscuits. Pastry was nearest optimum in quality characteristics at the 45% level of oil, and at the 51% level of solid fat. In baking – powder biscuit, a level of fat between 25 and 38% was optimum for all six fats. For good-quality pastry, even distribution and high specific gravity of oil droplets or fat crystals are important. In baking-powder biscuits, however, plasticity and low specific gravity, as well as fine crystals of fats, are essential for good shortening ability.

Butter is water in oil emulsion (W/O) containing approximately 80-81% milk fat (butterfat), and 14% water. One to five percent airs are incorporated into butter during its processing. Butter is considered the best of all shortening from a flavor standpoint. The creaming quality of butter is rather poor. Products made with butter are generally lower in volume and have a coarse grain than those made with a high quality shortening with good creaming characteristics (Lee, 1975). Bennion (1980) mentioned that, the temperature of fat affect plasticity, at temperature of 180°F (64°C) butter is less plastic than at temperature of 22°C to 28°C (72 to 83°F), at higher temperature, butter tends to become very soft or completely melted.

Baltsavias (a,b) *et al.* (1999), reported that, the reduction of fat content increased the modulus and the fracture stress of biscuits and the relative magnitude of this effect depends on the fat type.

Bennion, (1980) reported that, oils and melted fats do not cream or take no air and they, therefore, do not add to the leavening in mixtures. Oils and melted fats are dispersed by stirring, but fats require creaming with sugar to distribute them. The creaming processes soften the fat to produce an emulsion.

Fat contributes flavour to many baked products, formed by the reactions of the triglycerides and fatty acids with protein sugar and air.

At high concentrations, these flavour compounds became objectionable (when the fat has been abused) (Stauffer, 1998).

2.4.1.1.5. Eggs:

Eggs, as well as flour, are the structural ingredients in baking. Eggs provide leavening; add colour, texture, flavour and richness to the batter.

They are important in helping to bind all the other ingredients together. Beaten eggs are a leavening agent as they incorporate air into the batter, which will expand in the oven and cause the cake to rise.

They help to distribute shortening in the mixture by means of their power to emulsifying. Owing to their fat content, eggs also add some shortening to mixture, no substitute has been found for the desirable flavour of eggs in flour products.

Fresh egg Yolk adds tenderness and colour to baked goods (Bennion, 1980; and Kordylas, 1991).

Also eggs add some nutritive value to the baked product. The egg white is mostly protein. The institute of Home Economics defines a serving of eggs as 2 medium eggs, provide a quantity of protein equal to that obtained from 3 ounce of cooked meat. The protein content of whole eggs is consistently 12.8% (Stevenson and Miller, 1960). In fact, egg proteins are often used as standard for measuring protein quality. Furthermore, eggs are good source of essential fatty acids, a high amount of unsaturated fatty acids, all vitamins except vitamin C and most of the minerals needed in our diets (Froning, 1994). The egg yolk is rich in fat (11.5%), vitamins and minerals (Stevenson and Miller, 1960).

Cold- storage of eggs of good quality and frozen eggs yield desirable baked products. Eggs help to retard evaporation from baked products, and prevent them from quickly going stale (Bennio, 1980; and Koedylas, 1991).

2.4.1.1.6. Leavening agents:

Most day present flour mixtures are leavened to make product that is light and porous. This has been done in flour mixtures by the incorporation or formation, in the product, of gas that expands during preparation and subsequent heating.

According to Bennion (1980) and Kordylas (1991), there are three leavening agents:

a. Air:

Air is incorporated into flour mixture by sifting, creaming shortening or fat, beating eggs or beating the mixture itself. Air incorporated into a dough type mixture gives only a small increase in volume, but imparts a fine “grain” to the product.

b. Water vapour:

Water vapour as a leavening agent is formed in quantity sufficient to leaven a mixture, when liquid and flour are present in equal volume. Stiff dough, such as piecrust, is partially leavened by steam.

C. Carbon dioxide:

Carbon dioxide may be produced in flour mixture either by a biological process (i.e. yeast breaking down sugar) or a purely chemical reaction (i.e. from carbonate). Hoseney (1986) reported that most of the sources of carbon dioxide are sodium and ammonium bicarbonates.

c1. Baking soda:

It is The most popular leavening agent because 1) it has a relatively low cost, 2) it is nontoxic, 3) it is easy to handle, 4) it gives a relatively tasteless end product, and 5) the commercial product is of high purity (Hoseney, 1986).

Sodium bicarbonate is quite soluble in water and dissolves rapidly when the dough or batter is mixed. That of course, raises the pH of the batter or dough to the point where no carbon dioxide is released. To obtain significant amounts of gas, the dough or batter must contain an acid. (Hoseney, 1986). Kordylas (1991) reported that many ingredients used in baking are sources of acid, e.g. vinegar, lemon juice, sour cream, yogurt, butter milk, chocolate, honey, molasses (also brown sugar), fruits. When baking soda is mixed with an acid found in the recipe, it releases the carbon dioxide gas:

$$Na\,HCO_3 + H^+ \longrightarrow Na^+ + H_2O + CO_2$$

(Soda) (acid) (Sodium) (water) (gas)

$$\text{eg. } Na\,HCO_3 + HCl \longrightarrow NaCl^+ + H_2O + CO_2 \uparrow$$

The amount of acid needed to react with a given quantity of baking soda depends upon the degree of acidity of the acid compound. Proportions used in household preparations are half a teaspoonful of baking soda to a cup of sour milk. Milk may be soured by the addition of one tablespoon of lemon juice or vinegar, to one cup of ordinary milk. CO_2 can also be obtained by mixing half a teaspoonful of baking soda with one cup of molasses (Kordylas, 1991).

Baking soda or sodium bicarbonate (alkali), exerts a weakening effect on the flour proteins (gluten) and helps to promote spreading. Baking soda can be added alone or as component of baking powder.

The problem with baking soda is that, it releases the gas all at once, if the batter sits around for a while before getting into the oven, or if the batter is beaten too much, the leavening will be lost and the baked products will get flat. Therefore the batter must be baked immediately.

Too much soda will result in salty taste, this because of more acid addition, if the acid is not enough to react with the soda, the gas won't be released, plus the cookie will have a bitter soapy taste (Meyer, 1960). Kulp (1994) reported that recently potassium bicarbonate has become commercially available as a substitute for sodium bicarbonate, it is functionally equivalent but lowers the sodium content of the finished product.

Sodium carbonate could also be used as a source of carbon dioxide but is not used. Its major disadvantage is its high alkalinity, which increases the danger of getting a pocket of high pH that might be detrimental to the product. (Hoseney, 1986)

c2. Ammonium bicarbonate :

It can only be used in products that are to be baked to a low moisture content. When heated, it breaks up to give three gases as

$$NH_4HCO_3 \longrightarrow NH_3\uparrow + H_2O + CO_2\uparrow$$

shown below:

It is used fairly widely in dry cookies and in some snack crackers types of products. It does have the advantage that it leaves no residual salt after it reacts. Residual salts could affect the flavor or the dough rheology or both (Hoseney, 1986).

c3. Baking powder:

Baking powder is a combination of one or more acid salts with baking soda. When baking powder is mixed in a batter with the wet ingredients, the dry acid and the baking soda can then react together and release carbon dioxide (Meyer, 1960). By law, a baking powder must yield not less than 12% available carbon dioxide.(Hoseney, 1986)

There are different types of baking powders, depending on the type of acid they include:

c3.1. Tartrate baking powders:

Tartarate baking powders contain both cream of tartar (potassium acid tartrate) and tartaric acid. Hoseney (1986) reported that cream of tartar was obtained as a by- product from wine production. These create gas quickly when combined with baking soda in the presence of liquid, at room temperature, therefore batter must be cooked quickly or it will go flat. It is relatively expensive.

c3.2. Phosphate baking powders:

Phosphate baking powders contain either calcium phosphate or sodium acid pyrophosphate (SAPPS)(source of sodium pyrophosphate). They work a little slower than the tartrate baking powders, but most of the gas is still created outside of the oven and therefore can be lost (Meyer, 1960). Calcium acid phosphate is more commonly used as acid phosphate salt for baking powders available on the retail market, where sodium acid pyrophosphate is used by food manufactures (Bennion, 1980). The phosphate and tartrate baking powders react rapidly at room temperature to release the gas, which means that the batter has to be cooked quickly after the liquid ingredients have been added (Meyer, 1960). SAPPs are used widely in canned biscuits and in cake doughnuts, the major problem with SAPPs is the "aftertaste" that they leave in the mouth and teeth (Hoseney, 1986).

c3.3. S.A.S. baking powder:

SAS baking powder has sodium aluminum sulphate (alum) as the acid. SAS baking react slowly at room temperature and release more of the gas when heated, it is better for products that will sit a while before being cooked. Hoseney (1986) reported that the major problems with SAS are its weakening effect upon crumb texture and its slightly astringent taste.

Bennion (1980) and Meyer (1960), reported that too much baking powder can cause the batter to be bitter tasting, also can cause the batter to rise rapidly and then collapse. Too little baking powder, cause insufficient expansion and resulted in a compact product, therefore an optimum amount of baking powder is desirable for any baked product.

A general recommendation has been made that substantially less S.A.S.-phosphate than tartrate or phosphate baking powders be used in flour mixture.

Most baking powder used today is doubled- acting which means it reacts to liquid and heat and happens in two stages:

- **The first reaction :**

It takes place when the baking powder is added to the batter it is moistened. One of the acid salts reacts with the baking soda and produces carbon dioxide gas.

- **The second reaction :**

It takes place when the batter is placed in the oven the gas cells expands causing the batter to rise.

Because of the two stages, baking of the batter can be delayed without it losing its leavening power.

When using baking powder or baking soda in a recipe, they should be sifted with the other dry ingredients before adding to the batter to ensure uniformity (Bennion, 1980).

To keep the baking powder in good state during storage, this done by:

a. Adding a mixture of corn starch or other standard so as to:

a.1) Starches keep the product dry and free- flowing.

a.2) Starches keep the bicarbonate and acid dry, therefore they are separated from each other, and will not react during storage.

a.3) Starches helps bulk up the powder for easier measuring and standardization.

a. The containers should always be kept tightly covered to avoid the absorption of moisture that causes the acid and alkali constituents to react prematurely with loss of some carbon dioxide (Kordylass, 1999; Meyer, 1960; and Bennion, 1980).

According to Federal Low, all types of baking powder must contain at least 12% of available CO_2 gas. Those powder manufactured for some use generally contain 14%, and some powders for commercial use have 17% available gas (Bennion, 1980).

2.4.1.1.7. Salt:

According to Kordylas (1999), and Stevenson and Miller (1960), salt is used to improve the flavor.

2.4.1.1.8. Flavor:

Flavor can be defined as the combined sensation resulting from the ingestion of both volatile and nonvolatile compounds and is composed of a taste portion perceived in the oral cavity, and an aroma or odor portion detected in the nasal area (Amerina *et al*, 1965). During baking, aroma is an important factor governing food acceptability. When eaten, both aroma and taste are major contributors to overall food acceptability. From a physical standpoint, added flavoring agents can be described as being solid, semisolids or liquids which, in turn, dictate storage conditions as well as how and when and they are added to a product. Also, from a chemical standpoint, these flavoring materials can be composed of a single, several or many components. Most flavorings can contain solvents such as water, ethanol, propylene glycol, or glycerine if they are in the liquid or semiliquid forms, or various carbohydrates such as, starch or gums, if the material is in the powdered form (Maga, 1994).

Vanilla (3- methoxy-4-hydroxybenzaldehyde) is one of the most pleasant universally accepted flavors. Many cookie formulations used vanilla in some form as the only added flavorant or as a base flavor to which other flavors are added. Some cookie formulations call for a product called vanilla sugar. Usually as a topping to be applied to cookie after baking (Maga, 1994).

2.4.1.2. Mixing batters and dough:

Bennion (1980) stated that, generally the objective of mixing dough and batters include uniform distribution of ingredients, minimum loss of the leavening agent, optimum blending to produce characteristic textures in various products and optimum development of gluten for various products.

To get a definite structure from mixing of batters and dough, many factors affect this stage:

a. Temperature of the ingredients:

This affects textures, tenderness, and keeping quality of baked products. Method of mixing is usually given for ingredients that are at room temperature (75°F), unless methods are changed. Fat directly from the refrigerator does not cream well, nor can it be evenly distributed throughout a product. Conversely, fat is melted or become very soft and oily and has a tendency to separate from the batter during baking. The temperature of ingredients to which the fat is added will also change it's plasticity. When cold egg whites are whipped, they produce a relatively small volume, which means that the lightness desired in the finished product is not attained. Gluten of the flour takes up water rapidly at temperatures higher than 75°F thus producing tough strands with less mixing.

b. Kind, quality, and proportions of ingredients:

These factors affect not only the finished product, but also some mixing procedures. Baking powders, for example, contain different salts, each of which has a specific effect upon the rate the gluten absorbs water. The combination of sulfate-phosphate powders takes up the water rapidly and this cause dehydration of gluten. The net result is that batters in which these powders are used are less easily over mixed than those that contain other powders.

The effects that variations in the composition of ingredients have upon the finished product should be considered when substitutions in recipes are made. All- purpose flour is used in smaller amounts than cake flour, and mixing should be decreased because all-purpose flour absorbs more water and has more and stronger gluten than cake flours have; or if honey is used as a substitute for sugar, it should be remembered that it contains liquid and therefore the liquid content of the recipe should be decreased and a lower temperature used in baking to prevent off flours from over heated honey.

The proportion of ingredients influences method of mixing, amount of mixing which is optimum, baking time, and keeping qualities of the finished product.

Sugar and fat in large quantities cause a delay in the development of gluten and therefore products contain large amounts of fat and sugar must be mixed longer than product with lesser amounts to obtain sufficient gluten strands for structure.

c. Order, method, and amount of mixing:

Order and method of combining ingredients are particularly important in making all baked products. The flake of biscuits and piecrust is the result of both the method of combining fat with other ingredients and the kneading.

The amount of mixing of batters and dough effects flavour as well as texture. A long mixing period allows for a more through blending of ingredients as well as more complete dissolving of sugar and other solutes than does a short mixing period. The amount of gluten development is directly related to the mixing after the flour is added. Since gluten structure is so closely related to texture and eating quality, this cannot be over looked. Over stirring results in tunnels, peaks, small crust, and poor browning product. Sugar crust, concave tops, and a coarse texture may be the result of under stirring.

Many times a small error in measuring can be compensated for by adjusting the mixing procedure.

d. Size and shape of mixing equipment:

Large or shallow mixing bowls used for small amounts of batters may be the cause of over stirring. Thus both size and shape of the bowl should be considered. If batters are mixed with a spoon, size and shape of the spoon are influential. A large slotted wooden spoon will be more efficient than a small spoon. Wooden spoons are usually more efficient than metal spoons because the rough surface of wood has more pull than does the smooth surface of metal, and if stirring is more efficient the stirring time will be reduced (Stevenson & Miller, 1960).

According to Fellows and Hampton (1992), they classify the mixers according to the type of product that they are used for, i.e. either solids or liquids. A common solids mixer operates with a planetary action and can be fitted with a hook or with pastry or dough "K- beater" for dry powders. Liquid mixers include a balloon- whisk attachment for batters or propeller- type mixers for thin liquid such as sugar solutions.

2.4.1.2.1. Methods for mixing batters and dough:

Some basic methods for mixing batters and doughs in preparing biscuits and cookies.

a. The pastry method:

Bennion (1980) & Stevenson and Miller (1960) reported that in the pastry method, the dry ingredients are sifted together. Fat is blended with the dry ingredients and liquid is added at the last. This method is used mainly for pastry and biscuit products. The techniques of handling the dough after the addition of liquid, differ between pastry and biscuits. Biscuits are generally mixed more thoroughly and may then be dropped as for "drop biscuits" or lightly kneaded and rolled and cut into the desired shapes (i.e. as pie crust and flaky biscuits).

b. The conventional cake method:

The conventional cake method is used for mixing most cookies.

The fat and part of or all the sugar is creamed together. The beaten eggs are added to this mixture and thoroughly mixed. The dry ingredients are thoroughly mixed by sifting and then are added alternately with the liquid to the creamed mixture. Variations can be made from this by separating the egg and adding the beaten while at the end, or by making amargreen with part of the sugar and folding it at the end of mixing (Bennion, 1980; & Stevenson and Miller , 1960).

b1. Spong cake methods:

According to Bennion (1980), this method is used in making cookies of the spong type.

Mixing procedures for any type of spong goods are similar. Better volume of foam is obtained and whipping is easier if ingredients are at room temperature than if they are cold. Egg whites should be beaten in a bowl large enough to hold the complete cake batter. The acid and salt are added to the egg whites as soon as they are foamy. One- fourth of the sugar may be mixed with the flour to separate the particles thus making incorporation of flour easier. With an electric mixer it might be well to begin adding sugar as soon as acid and salt are added, but it will be easier when hand beated, if the sugar is added after, soft peaks are formed. The meringue should be stiff but not dry and will be stiffer than the egg foam without sugar.

The dough for rolled biscuits should be a soft, rather than a stiff, dry dough and many rolled- cookie recipes have very little or no liquid. Because large volume is not desired in rolled cookies, the mixtures contain little or no leavening agent other than air incorporated in the creamed fat- sugar mixture.

According to Elkhalifa (1998), he used Hobart N-50 mixer with flat beater to mix the biscuits ingredients, he also used 10, 20, 30% sorghum flour instead of wheat flour, also L- cysteine hydrochloride was added to the blends according to the percent of the sorghum flour (15ppm for each 5% sorghum).

Gallagher, (1984) reported that the amount of water which flour will absorb to form satisfactory dough can be shown to depend on protein content and the proportion of damaged starch in the flour.

Geer and Stewart (1959) measured the water absorption of flours from 23 samples of two wheat varieties, he found the water up take to be 0.44 and 2.00g per gram of native and damaged starch, respectively.

Biscuit manufacturing requires flours with low water absorption since biscuits are baked down to a standard moisture content of 2-3% (Gallagher, 1984).

2.4.1.3. Kneading and forming Of Biscuits:

Kneading is a process of stretching and folding dough. In doing so the gluten fibers are stretched and the consistency of the dough becomes smooth. Kneading is most usually done by hand, but if a large quantity is being produced it can be a stirring task and a powered kneader may be preferred (Fellows and Hampton, 1992).

According to Stevenson and Miller (1960), Kneading is a folding and turning process in which the dough is worked by hands. Biscuits require only 10 to 20 folds to obtain a satisfactory product with flaky layers.

Kneading lightly, using ten to thirty strokes (depending on the amount of stirring used to mix the dough), produces biscuit of fine texture that sheets when broken rises to larger volume than unkneaded biscuits. Also kneading gives better external appearance e.g. biscuit with smooth top crusts. Biscuit dough that is patted or rolled with no preliminary kneading yields biscuits that are very tender and have crisp crusts but are coarse in texture, small in volume, and have slightly rough crust. Over kneading produces a compact, toughened product (Bennion, 1980).

After kneading, the dough has to be formed into the desired shape (Fellow and Hampton, 1992). Either dropped from a spoon or rolled and cut, for the dropped biscuits, the dough is not kneaded (Stevenson and Miller, 1960).

Drop biscuits are irregular in shape, and are tender and slightly coarse in texture, and has crisp crusts (Bennion, 1980). Crisp and tender dropped biscuits may be used as topping for desserts, meat pies, or short cakes bases. This dough may also be steamed for dumplings (Stevenson & Miller, 1960).

Biscuits dough are rolled out and cut using either a knife or a shaped biscuits cutter (Fellows and Hampton, 1992). Elkhalifa (1998), sheeted the dough from wheat and sorghum composite flour to a thickness of 3.5mm with the help of an aluminum plate, the sheeted dough was cut into round shape using 45mm diameter cutters.

2.4.1.4. Baking Of Biscuits:

Baking is heating or cooking by the hot air, and also by oven floor and trays. Moisture at the surface of the food is evaporated by the hot air, and this lead to a dry crust in products such as bread and many biscuits (Kordylas, 1991; and Fellows & Hampton, 1992). The cooking temperature for most ovens range from 120 to 260°C (250-500°F) (Kordylas, 1991).

After kneading biscuits should be baked on sheets made from a metal that transmits heat rapidly and evenly. Therefore the size, shape and material from which the baking pan is made affect the quality of the finished baked products (Stevenson, Miller, 1960).

Bennion (1980), found that baking sheets rather than cake pans are more efficient for baking most cookies as there are no high sidewalls to interfere with the circulation of heat. Cookies baked in pans with high side may cook well but brown little or non-on top. Bar cookies are usually baked in cake pans with sides.

Stevenson & Miller (1960) reported that, tin or aluminum is better suited to baking muffins and biscuits than are iron or glass. Also round pans give more browning than pans with square corners. The product may be browner at these corners than on the crust of the area, the size of the baking pan should be suited to the amount of batter and the shape of the product. To improve the volume, pans should be oiled only on the bottoms. According to Bennion (1980), baking sheets requires greasing for dropped biscuits but not for rolled biscuits or icebox cookies. Rolled cookies spread little in baking so that space is needed (1 or 1.5 inches) between them, if crusty biscuits are desired. Icebox cookies spread some what more and dropped cookies must have space to spread.

Temperature and time of baking also affect the quality of finished baked products (Stevenson & Miller, 1960). Oven temperatures recommended for baking flour mixtures depend upon the native of the ingredients used in preparing the mixture, the size and the shape of the unit of dough. When a flour mixture contains large proportions of sugar, the baking temperature must be low enough to prevent too much browning and burning. Oven temperature used for baking all flours mixtures should be such that the outer layer of dough does not congeal or coagulate before optimum leavening has been achieved. If that occurs, expansion becomes insufficient, with flatness and heaviness produced in the product. The top may crack open if gas continues to be produced at a rate high enough to develop sufficient pressure to break the surface at its weakest point. The rate of heat penetration is normally related to the temperature of the oven and the size and shape of the dough units. Small masses of dough require comparatively short periods of time to heat to the center. They are, therefore, cooked quickly at high oven temperature. Larger units, however, should be baked at lower temperature to provide sufficient time for heat penetration to the center (Kordlas, 1991). The optimum baking temperatures depend on the type of pan used and the results desired at various times or with different products might include; complete cooking without browning, which requires a low temperature; rapid expansion of steam, which requires a high temperature. If the temperature is too high and a hard crust forms on the surface before the gases have completely expanded, pressure of the expanding gas may break the crust and cracks will be formed.

In some cases the unclosed center of the dough may flow out through the cracks (Stevenson & Miller 1960).

The kind of material from which the pan is made also affects the cooking time and the palatability of the product. Cakes baked in dark and dull pans bake faster than those baked in bright pans or in glass dishes. The faster baking pans give products with larger volumes and better crumb quality, but have slightly inferior appearance with regard to the shape of the top. 425-450°F (218-232°C) for 10-15 minutes is the best temperature and time for baking biscuits (Kordylas, 1991).

Fellows & Hampton (1991); and Stevenson & Miller (1960) stated that, since biscuits are relatively small they are quickly baked so that a high temperature is used (400-425°F), for 10 to 12 minutes. Large size will require longer times and, often, lower temperature than the small biscuits. Bennion (1980) reported that a hot oven (426 to 450°F) for about 15 minutes is satisfactory for baking biscuits. According to Elkhalifa (1998), biscuits made from wheat flour or wheat and sorghum composite flours are baked in an electric oven at 205°C for 8.5 minutes.

2.4.1.4.1. Changes that occur during the baking of flour mixtures:

1) The production of steam or water vapor from the water or liquid used in the mixtures; the production of carbon dioxide from the baking soda source; and the expansion of all the leavening gases, including air incorporated during beating of eggs, sifting of flour and mixing (Kordylas, 1991).

2) The coagulation or congealing of protein substances such as gluten and egg, in the mixture with heat (Kordylas, 1991). The gluten and egg proteins coagulate, which causes a loss of water and a hardening that results in a fixation of the structure (Stevenson & Miller, 1960).

3) The gelatinization of starch in the flour. Starch attracts water when it is in storage, it retains 10 percent moisture, when it is mixed with cold water, and it forms a suspension, which is not sticky. If the cold water is heated, the starch granules or units begin to absorb water and

to swell when the temperature reaches about 20 to 30°C (68- 86°F). When the heating is continued, the suspension thickness (gelatinization) increased and this is recognized by a change in the appearance of the heated suspension. It becomes translucent or semi transparent, because of other substances present in it. The complete gelatinization of starch needs the presence of a sufficient amount of water and a good supply of heat with sufficient time for heating. The higher the temperature at which the heating is done, the faster gelatinization takes place, and the lower the temperature the longer the time needed to achieve gelatinization (Kordylass, 1991).

FAO (1995) reported that the plasticity of sorghum flour mostly arises from the gelatinization of starch when the dough is prepared in hot or boiling water. The stickiness of the cooked flour is a function of the starch gelatinization. Dough with cold water has poor adhesiveness and is difficult to roll thin. Thus heat modification of the starch when the dough is prepared with hot water determines its rolling properties. Heat treatment of starch in a limited a mount of water leads to swelling of the granules with very little loss of soluble material and partial gelatinization of the starch.

Gelatinization of starch that is not in thermodynamic equilibrium. There is, therefore, a progressive reassociation of the starch molecules upon aging. This recrystallization is referred to as retrogradation, and may reduce the digestibility of starch (FAO, 1998).

Rooney & Serna-Saldivar (1991) reported that the initial gelatinization temperature for sorghum is 68.5°C and the final is 75.0°C, and for pearl millet is 61.1 and 68.7°C for initial and final temperature respectively.

4) The melting of fat (Kordylass, 1991).

5) The loss of water from the product. This is highest on the surface blends to form crust (Kordylass, 1991).

6) The formation of sugar solution with any undissolved sugar and its reaction with other compounds (gluten) to brown the crust (Kordylass, 1991).

2.4.1.5. Packaging and storage:

Packaging serves two purposes protection from spoilage and physical damage. The most common form of packaging is that of paperboard carton with an inner liner containing the food. The inner liner will provide most of the protection while the outer carton provides protection from physical damage and also from potential tampering (Elamin, 2002).

In general, baked goods have a short shelf–life, but for products such as biscuits, this can be extended from a few days to several weeks, or months, if packaged correctly.

Many biscuits are characterized by their crispness, and as a result need low moisture content. In order to prevent the biscuits from becoming soggy, it is important that the packaging material prevents uptake of moisture from the surrounding air. In addition, biscuits that contain fat should be protected from light, air, and heat to prevent development of ‘OFF’ flavors due to rancidity (rancidity defined as deterioration of flavor and odor of fat or the fatty portions of foods, due to hydrolysis oxidation or to microbial action). Plastic films, glass jars, or metal tins are all acceptable packaging materials (Fellows & Hampton, 1992).

According to Sirokhman and Konoval (1991) packaging of high rich biscuits (>20% fat) with cardboard cartons, caused rapid deterioration of the product, but biscuits stored in foil laminates kept their original quality for a longer time than biscuits stored in the card board cartons and polyethylene packaging material.

Alkhalifa (1998) packed the biscuits from wheat and wheat sorghum composite flours in polyethylene bags and stored the bags in airtight tins.

CHAPTER THREE
MATERIALS AND METHODS

3.1. Materials:

- Australian wheat flour: from Sayga Flour Mills.
- Indian wheat flour: from Albdreen Milling Factory.
- Fakimustahi sorghum flour: from Food Research Center.
- Ghee (Hydrogenated vegetable oil): from Food Research Center.
- Alaseel (Hydrogenated vegetable oil), Cottonseed oil, Sesame oil, Groundnut oil, Sun flower oil: from the local market.
- Shortening (Hydrogenated vegetable oils) Skimmed milk, Glucose, and sodium bicarbonate, Ammonium bicarbonate: from a local Biscuit factory (Industrial grade).

3.2. Methods:

3.2.1. Chemical methods:

3.2.1.1. <u>Moisture determination:</u>

Moisture contents was determined by rapid moisture tester type MLJ-400 (BUHLER). Ten grams of flour were placed on pan, when the oven temperature reached 125°C. After 20 minutes, the reading of moisture percentage was directly obtained from scale reading.

3.2.1.2. <u>Ash determination:</u>

The ash content of the sample was determined according to (A.O.A.C. 1980, No. 13.006). 2 grams of the samples were weighed. The crucible containing the sample was placed in a muffle furnace at 650°C for 3 hours. Then the crucible was removed and cooled in a desiccator and weighed again. After that the ash was calculated as percentage on dry weight basis according to the equation:

$$\text{Ash content (\%)} \ \frac{\text{Weight of residue} \times 100}{\text{Weight of sample}} \times \frac{100}{(100 - M)}$$

Where:

M: Moisture content of the sample.

3.2.1.3. Crude Protein determination:

Protein content was determined using the standard micro-Kjeldahl method (A.O.A.C. 1980, No. 13.031). 0.2 grams of sample was weighed, into micro-Kieldahl flask, 0.4 gram of a mixed catalyst, cupric sulphate and sodium sulphate ($CuSo_4.5H_2O$ & Na_2SO_4) was added with 3.5 ml of concentrated sulphuric acid. The sample and contents were heated on an electrical heater for 2 hours (Digestion). The digested material was cooled and then placed in the distillation apparatus; 20 ml 0f 40% NaOH were added and mixture was heated and distilled until 50ml were collected in a 100ml conical flask, the ammonia evolved was received in 10ml of 2% boric acid. The trapped ammonia was titrated against 0.02N hydrochloric acid (HCL) using universal indicator (Bromo cresol green and methyl red in alcohol). The protein content percentage was calculated according to the following equation:

$$\% \text{ Protein content} = \frac{\text{HCl volume}(S-B)\times 0.02\times 14\times F\times 100\times 100}{W\times 1000(100-M)}$$

Where:

S : Sample HCL titration volume

B: Blank.

0.02: Normality of HCl.

1000: To convert from mg to g.

14.0: Each ml of HCl is equivalent to 14mg nitrogen.

F Factor (5.7 for wheat flour, and 6.25 for other grains).

W: Weight of sample in gm.

M : % of Moisture content.

3.2.1.4. Determination of gluten:

Percentage of gluten content was determined according to the ICC standard No 137 (1982). Ten g of flour were mixed with 5.2ml distilled water for 20 seconds in test chamber, the dough was washed with 2% NaCl for 10 min. then with distilled water in test chamber. The gluten ball was stretched to measure the length-using ruler, then weighed to get wet gluten, dried in a Glutrok 2020 Heater to give dry gluten. The dry gluten is then weighed.

Wet Gluten % = Weight of wet gluten × 10

Dry Gluten (%)= Weight of dry gluten × 10

3.2.1.5. Crude fat determination:

The crude oil of the sample was determined according to (A.O.A.C. 1980, No. 13.018). Using modified Soxhlet Method. Two grams of sample were weighed and placed in filter paper, then placed in an extraction thimble. The thimble was placed in an extractor, Extraction was carried out for 8 hours with hexane, after that the apparatus was carefully dismantled and the solvent was evaporated to dryness in an air- oven at 105C for two hours. The flask with extracted hexane was cooled and weighed. The crude fat percentage was calculated on dry basis as follows:

$$\text{Fat content (\%)} = \frac{\text{Weight of residue} \times 100}{\text{Weight of sample}} \times \frac{100}{(100 - M)}$$

Where:

M: Moisture content of the sample.

3.2.1.6. Total Carbohydrates:

The carbohydrates were calculated by difference. The sum of moisture, fat, protein and ash contents was subtracted from 100 to obtain the total carbohydrates by difference (Pearson, 1976).

3.2.1.7. Total Energy (calorific value):

Energy was calculated as described by Sukkar (1985) using the Atwater factors:

1g of carbohydrates provides 4 K calories, 1g of protein provides 4 K calories and 1g fat provides 9 K calories.

C. (g) X 4 = K Cal. of carbohydrates.

P.(g) X 4= K Cal. of protein.

F.(g) X 9 = K Cal. of fat.

3.2.1.8. Fat Acidity determination:

Fat Acidity is determined according to the (A.O.A.C. 1980, No. 13.068) Method:

40g of flour were mixed with 100ml Toluene using magnetic stirrer for 4 minutes. Mixture was filtered with filter paper. 25ml of the mixture mixed with 25ml phenolphthalein indicator, and titrated with KOH. The fatty acid was calculated according to the following equation:

$$\text{Fat Acidity (mg KOH/100g flour)} = \frac{(T.V - B) \times 2 \times 10 \times 100}{100 - M}$$

Where:

B: Blank = 0.3 T. V.: Sample Titer Volume.

M: % of Moisture content.

10: concentration of flour in 25ml of the mixture.

3.2.1.9. Free Fatty Acids (FFA):

Free Fatty Acids were determined according to (A.O.A.C. 1980, No. 26.060).

Reagents:

1- Equal volume of 96% ethanol and diethyl ether were mixed, and neutralized shortly before used with 0.1 NaOH using phenolphthalein as indicator.
2- Sodium hydroxide: 0.1N aqueous solution, accurately standardized.
3- Phenolphthalein indicator: 1% solution in 96% ethanol.

Procedure:

Ten gram of oil samples were dissolved in 50ml of the solvent, then titrated while swirling with 0.1N NaOH solution using phenolphthalein as indicator.

The result was calculated as follows:

FFA (%): $\frac{VNM}{W}$

Where**:**

V: Volume (in ml) of NaOH.

N: Normality of NaOH.

M: Molecular weight of fatty acid (282 as oleic acid).

W: Weight (g) of sample.

3.3. Rheological properties of dough:

The rheological properties of the dough prepared from blends of wheat and sorghum flour in the ratio of 20:80, 40:60, 60:40, 80:20% were determined using the Brabender Farinograph and the Extensograph methods of AACC (1983).

3.3.1. Farinograph characteristic:

3.3.1.1 <u>The titeration curve:</u>

Titeration curve was used for the assessment of the water – absorption for each flour sample.

A sample of 300g flour was weighed and transferred into a clean mixer. The farinograph was switched on 63rpm for one minute, then the distilled water was added from special burette (at deviations from the 500 units consistency, correspond to water – absorption can be calculated from the deviation 20 minutes deviation correspond to 0.5% water, whenever consistency was higher than 500F.U. more water was needed and vice-versa). When the consistency was constant, the instrument was switched off and the water drawn from the burette indicates water absorption of the flour (water used for preparing the dough).

3.3.1.2. **The standard curve :**

The measuring mixer was thoroughly cleaned. A sample of 300g was weighed, then introduced into the mixer, farinograph was switched on such as above. The water quantity, which is determined by the titration curve was fed at once. When an appreciable drop on the curve was noticed, the instrument was run for further 12 minutes, then shut off.

The significant readings taken from a farinograph are:

1- The water absorption: the ability of the flour to absorb water and prescribes the quantity of water, which has to be added to the flour during the production.
2- Arrival time: the difference between zero and the point at which the top of the curve first intersect the 500F.U.line.
3- Departure time: the time from zero to the point where the top of the curve leaves the 500 F.U. line.

4- Dough stability: the difference between the time where curve first intercept (Arrival time) and leaves (the departure time) the 500 F.U. consistency line.

5- The softening of the dough: the difference of the dough strength between the moment dough weakening begins and after 12 minutes dough kneading in F.U.

3.3.2. Extensigraph characteristics:

A dough sample was prepared from wheat flour, water and salt with farinograph described before. Two pieces of 150g from the dough were separated. The dough pieces were shaped to a ball, then the two pieces were put in a dough holder then put into fermentation cabinet. After 45 minutes both dough pieces were tested one by one. For this purpose, the dough holder with the dough was put onto a balance system. A hook was pulled through the dough piece at a constant speed which was thus stretched untill it breaks. By means of the balance system, the load acting onto the dough during this procedure was measured and recorded. The resulting diagram- the Extensogram – showed the force which the dough opposes to the stretching force as a function of the stretching time, i.e. the stretching length.

Then the dough was put back again into fermentation cabinet for another resting time. The dough pieces were tested again after 90 and 135minutes.

The most common measurements made on load-extension charts or extensogram is:

1- Resistance to extension: height of diagram after 5 cm of diagram length.

2- Extensibility: length of curve in cm.

3- Energy: area covered by the curve, measured by the planimeter.

3.4. Preparation of biscuits:

Biscuits were prepared according to the modified method reported by Alkhalifa (1998). Biscuit formulation is shown in the table below:

Ingredients	Quantity (g)
Flour	100
Sugar powder	30
Shortening	20
Skim milk powder	2

Sodium chloride	1
Sodium bicarbonate	0.3
Ammonium bicarbonate	1.5
Glucose	2
Water	25
L-cysteine	0.015

Procedure:

200g of flour were weighed. Sugar powder, shortening, skim milk powder and glucose was creamed in Hobart N-50 mixer with a flat beater for 8 min. Salt, ammonium bicarbonate, Sodium bicarbonate and Cysteine were dissolved separately in part of the required water and added to the cream. Mixing was done for 3 min till homogenous cream formed. Finally, flour sieved thrice was added and mixed for 1 min. The dough was sheeted to a thickness of 0.235mm with the help of two ruler placed at two sides of the dough. The sheeted dough was cut into round shape using 4.985mm-diameter cutter. The cut dough was transferred to an aluminum tray. The biscuits were baked in electric oven maintained at 200°C for 11 min. The baked biscuits were cooled for about 20 min, packed in plastic bags and stored in room temperature for further analysis. Steps of processing was shown in diagram (1).

3.4.1. Method A:

Different types of biscuits were prepared using the cotton seed oil, Sesame oil, Ground nut oil, Sunflower oil, Shortening, Ghee, and Hydrogenated Vegetable oil. 10 Judges were asked to evaluate the appearance, taste, flavor, texture, and over all quality according to the ranking test described by Ihekoronye and Ngoddy (1985). The test sheet for sensory evaluation was shown in diagram (2).

3.4.2. Method B:

Biscuits were made from sorghum and wheat composite flours, they were mixed in the ratio 0/100, 10/90, 20/80, 30/70, 40/60, 50/50, 60/40, 70/30, 80/20, 90/10, 100/0 %. The test sheet for sensory evaluation was shown in diagram (3).

3.5. Physical characteristics of biscuits:

Biscuits were evaluated for thickness (cm), Diameter (cm), and spread ratio.Spread ratio were calculated using the following equation:

$$\text{Spread ratio} = \frac{\text{Diameter}}{\text{Thickness}}$$

Six biscuits were used for the evaluation, the average was noted.

3.6. Sensory evaluation of biscuits:

Evaluation of biscuits made from wheat and sorghum composite flour for various sensory characteristics was carried out. Ten judges were asked to evaluate the biscuit samples, before (Zero time) and after (three months) storage. Diagram (3) represent the sheet for panel test.

3.7. Analysis of biscuits:

The biscuits samples were analysed before (time zero) and after storage (after three months).

Each percentage of biscuits were milled using morter and pestle hound, the sample were stored in deep freezer until used.

3.7.1. Chemical methods:

3.7.1.1. <u>Moisture determination:</u>

2.0 gram of the sample is weighed in a dry bottomed dish, the sample is dried in an oven at 105C until the weight at interval of ½ hour, remain constant.

The loss in weight is taken as moisture content. The percentage of moisture content is then calculated from the following equation (Yashajahu& Clifton, 1971):

$$\text{Moisture} = \frac{\text{Weight lost} \times 100}{\text{Weight of sample}}$$

3.7.1.2 Ash determination:

2.0 grams of sample were weighed into a dish and the organic matter is burned off by ignition in muffle furnace at 600C to constant weight. The dish containing the residue is cooled in a desicator and the amount of the total ash is determined by weight. The percentage of ash content calculated from the following equation (Yashajahu & Clifton, 1971):

$$\% \text{ Ash } = \frac{\text{Weight of ash(g)} \times 100 \times 100}{\text{Weight of sample(g)} \times (100 - \text{M})}$$

Where

M : Moisture content

3.7.1.4. Protein determination:

Proteins content was determined using the standard micro-Kjeldahl method (A.O.A.C. 1980, No. 13.031), as mentioned in (3.2.1.3).

3.7.1.3. Crude fat determination:

The crude oil of the sample was determined according to (A.O.A.C. 1980, No. 13.018), as mentioned in (3.2.1.4).

3.7.1.5. Total Carbohydrates:

The carbohydrates were calculated by difference as mentioned in method (3.2.1.6) above.

3.7.1.6. Total Energy (calorific value):

Energy was calculated as described by Sukkar (1985) using the Atwater factors, mentioned in the method (3.2.1.7) above.

3.7.1.7. Fat acidity determination:

Fatty Acids were determined according to the (A.O.A.C, 1980, No. 13.068) Method, mentioned before in (3.2.1.8).

3.7.1.8. Free Fatty Acid (FFA):

25.0 g of biscuit sample is treated with 100 ml. Of hexane for the extraction of fat. The fat solution is filtered through a paper containing unhydrous sulphate. The filtrate is collected in 100 ml. Volumetric flask. 10 ml. of the filtrate are evaporated on steam bath. It is then dried in an oven at 100°C for 3 hours, cooled in desiccator and weighed (W) (This is to determined the fat content). To 10 ml. of the filtrate, 10 ml. of neutralized ethanol is added. The mixture is titrated with 0.01N NaOH solution using phenolphthalein as indicator. The free fatty acid is calculated as oleic acid percentage from the following equation (FAO, 1986):

$$\text{F.F.A. (as oleic acid in the fat) \%} = \frac{V \times N \times 28.2}{W}$$

V: Volume of NaOH.

N : Normality of NaOH.

W : Weight of fat.

282 : equivalent wt. of oleic acid.

3.8. Statistical analysis:

Replicates of each sample were analyzed using statistical analysis system. The analysis of variance was performed to examine the significant effect in all parameters measured. Duncan multiple range test was used to separate the means.

Diagram (1). Flow sheet for biscuits preparation

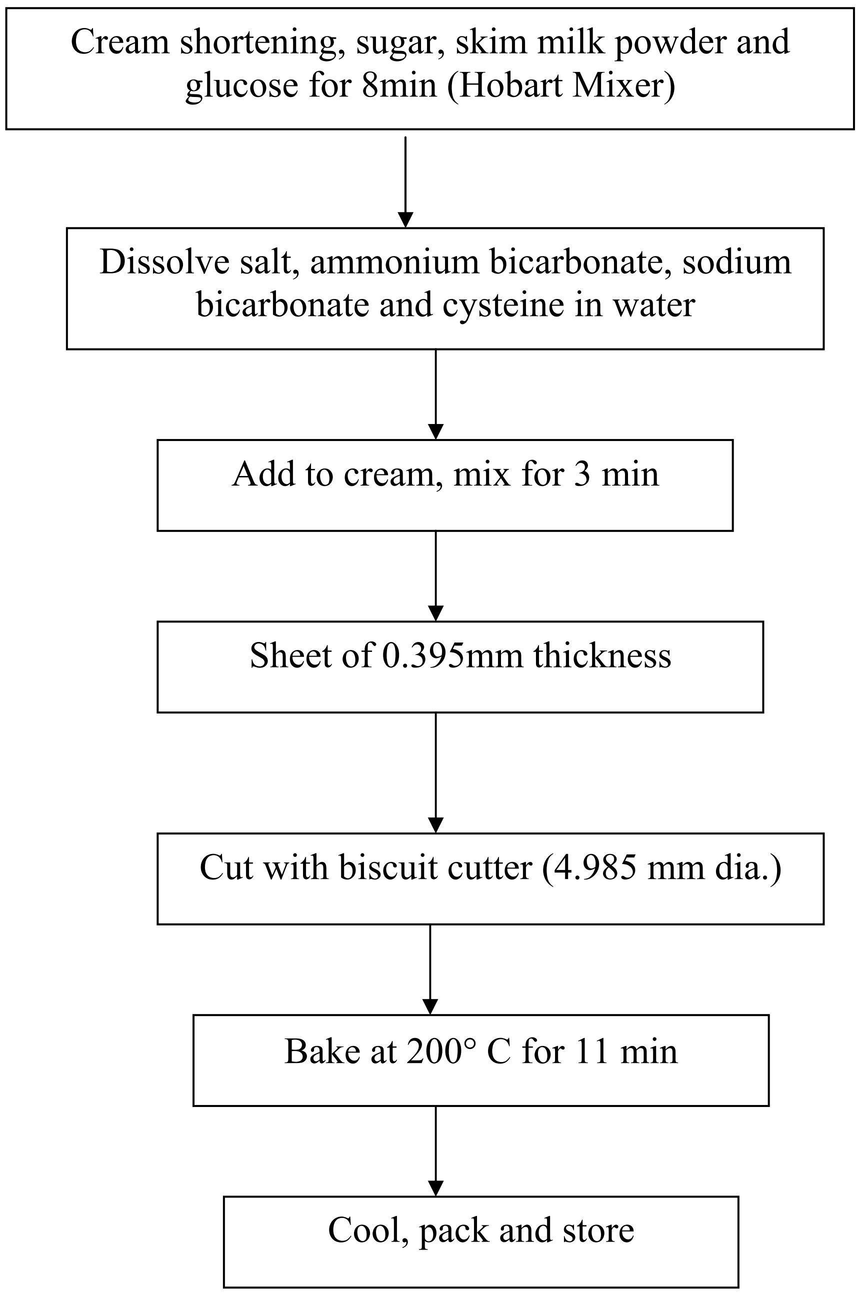

Diagram (2)

PANEL TEST FOR BISCUIT SAMPLES (Ranking)

Please examine the following samples of biscuits presented in front of you, and give ranks to attributes shown on the form sheet, taking (1) as Best, and (4) as least in quality. (Do not repeat the score)

No. of sample	General feature	Flavor	Taste	Texture	Preference
A					
B					
C					
D					

Diagram (3)

PANEL TEST FOR BISCUIT SAMPLES (Hedonic)

Please examine the following samples of biscuits presented in front of you, and give values to attributes shown below, using Table (2) to help you.

10-8: Excellent. 6–7.9: Very good. 4–5.9: Good.

2–3.9: Fair. 1–2.9: Poor

Table (1)

Sample No.	Color (10)	Odor (10)	Surface feel (10)	Taste (10)	Mouth feel (10)	Texture (10)	Total Score (60)
A							
B							
C							
D							
E							
F							
G							
H							
I							
J							
K							

Table (2)

<table>
<tr><th>Quality Description</th><th>Color</th><th>Odor</th><th>Surface feel</th><th>Taste</th><th>Mouth feel</th><th>Texture</th></tr>
<tr><td rowspan="2">Desirable</td><td>Golden Brown.</td><td>Desirable.</td><td rowspan="2">Smooth.</td><td>Pleasant</td><td rowspan="2">Easy break down.</td><td rowspan="2">crispy</td></tr>
<tr><td>Uniformity.</td><td>Normal.</td><td>Normal</td></tr>
<tr><td rowspan="3">Undesirable</td><td>Brownish.</td><td rowspan="3">Off flavor</td><td rowspan="3">Rough</td><td rowspan="3">Off Taste</td><td>Residual Taste.</td><td>Hard</td></tr>
<tr><td>Whitish.</td><td rowspan="2">Formation of dough lump in mouth</td><td>Brittle</td></tr>
<tr><td>Non Uniform</td><td>Grittiness</td></tr>
</table>

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1. Chemical composition of wheat and sorghum flours:

The chemical composition of two wheat flours, Australian (72 to 75% extraction rate), Indian (82% extraction rate), and sorghum flour Fakimustahi (85% extraction rate) is shown in table (1). The results are expressed on dry matter basis per 100gm of material.

4.1.1. Moisture content :

The moisture content of Australian wheat flour was (13.45%), Indian wheat flour was (10.67%), and Fakimustahi sorghum flour was (7.43%) as presented in table (1.a).

4.1.2. Ash Content:

Fakimustahi gave higher value of ash content 1.41%, while Indian and Australian gave 0.790% and 0. 518% ash content respectively, as shown in table (1.a). The ash content of Indian and Australian were lower than the range of 1.2% -1.8% and 1.4% for whole wheat flour, reported by Egan *et al* (1981) and Alias and Linden (1991) respectively, and lower than hard red winter reported by Pomeranze and Dikman (1983). The results obtained were in agreement with the range of 0.31% to 0.62% for Australian wheat flour(69% extraction) reported by Pareds– Lopez *et al* (1987). The ash content of Fakimustahi sorghum flour was in the range of 1.35% to 1.83%, reported by Neucere and Sumrell (1980), but lower than the range of 1.7 to 1.72%, reported by ELTinay *et al* (1979), this value was higher than the ash content of Sudanese sorghum cultivars, 1.32% and 1.39% for Hageen, and Dabar respectively, reported by Hamad (1994). Fakimustahi gave similar result of ash at 100% extraction rate as reported by Mohammed (2000).

4.1.3. Protein content: -

Table (1.a) shows the protein content of wheat and sorghum flours. Results showed that Fakimustahi sorghum flour contains 15.47% protein content, higher than Australian flour, 10.97%, and Indian flour 10.30% (with significant difference at level ($P>0.05$). Protein content of wheat is highly influenced by the environmental conditions, grain yield, available nitrogen and the variety genotype (George, 1973). The protein content of Australian and Indian wheat flour is comparable to the range of 8% to 11%, and 8.1 to 15.5% as found by Schruben (1979) and Kent– Jones and Amos (1967), Yamazaki and Donelson (1983) respectively, but lower than the range of 11% - 14% reported by Badi et al (1978). The value of Indian wheat flour is within the range of 8.5% to 10.5% for soft wheat flour reported by Zeleny (1971), unlike the Australian wheat flour, which is higher than the range reported the Zeleny (1971) and within the range of 8-13.8% reported by Kent and Evers (1994).. The protein content of Fakimustahi sorghum flour was within the range of 7.3-15.6% reported by Hulse, et al (1980), this value was higher than the range of 8.8- 11.6%, reported by Yousif and Magboul (1972), also higher than the Sudanese varieties reported by Budair (1977), Eggum (1983), Hamad (1994) and Arbab (1997).

4.1.4. Gluten content:

Table (1.b) shows the results of wet, dry, and length of gluten as 36.03%, 14.45%, 12.55cm for Australian wheat flour, and 27.20%, 9.43%, 10.00cm for Indian wheat flour, respectively. The two wheat flours had a higher gluten and protein content, addition of L-cystein reducing the disulphide bonds, and more preferable in the process of biscuits.

In comparing the two wheat flours, the Indian, wet, dry, and length of gluten was lower than Australian one, for these reasons, the variety of Indian wheat flour with L-cystein was used in method (a).

4.4.5. Fat content:

The fat content for Australian and Indian wheat flour were 1.73% and 2.85% respectively, within the range reported by Ahmed (1995). Indian wheat flour was lower and Australian wheat flour was higher than the value reported by Alias and Liden (1991). While the fat content for

Fakimustahi sorghum flour was 3.01% lower than range reported by Inamdar et al (1984), Budair (1977), Hamad (1994), and Arbab (1995). The three samples showed significant difference at ($P>0.05$).

Table (1.b). Gluten content of Australian and Indian wheat flours

Varieties	**Gluten**		
	Wet	Dry	Length
Australian (72-75% ext.)	36.03±1.95[a]	14.45±1.48[a]	12.55±1.10[a]
Indian (82% ext.)	27.20±0.95[b]	9.43±0.32[b]	10.00±0.00[b]
Lsd 0.05	3.48	2.03	1.93

Means in the same column with the same letters are not significantly different at level P>0.05 according to CRD.

4.1.6. Carbohydrates:

The calculated carbohydrate (by difference) for Indian wheat flour was (75.390) higher than Australian wheat flour (73.332%) and Fakimustahi sorghum flour (72.680%), as shown in table (1.a). Fakimustahi showed the same value as reported by Hulse et al (1980), NRC/NAS (1982), USDA/HNIS (1989).

4.1.7. Total energy content:

Energy for Fakimustahi was higher (379.690 Kcal/100g) than Indian (368.410 Kcal/100g) and Australian (352.778 Kcal/100g). The energy for Fakimustahi sorghum flour was higher than 329Kcal/100g reported by Hulse, *et al* (1980), NRC/NAS (1982), USDA/HNIS (1989), and Serna- Saldivar and Rooney (1991), as shown in table (1.a), this result was higher than the results of wheat flours, because energy was calculated by using Atwater factor (4.0 for protein, 4.0 for carbohydrate and 9.0 for oil), and Fakimustahi contained the higher value of oil content than wheat flours.

4.1.8. Fat Acidity content:

Indian wheat flour showed higher value (59.70mgKOH/100g) of fat acidity than Australian (25.96mgKOH/100g) and Fakimustahi (25.92mgKOH/100g), (table 1.a), Australian and Fakimustahi showed insignificant difference at ($P>0.05$), the higher value of fat acidity maybe due to bad storage.

4.2. Free fatty acids of oils and fats:

The free fatty acid of sesame oil, sunflower oil, ground nut oil, cotton seed oil, ghee, Alaseel (Soyabeen and Palm oil) and shortening were 0.874%, 0.885%, 0.099%, 0.042%, 0.470%, 0.062%, and 0.112% respectively as shown in table (2).

Free fatty acids arise from the hydrolysis of fats (glycerides):

$$C_3H_5(OOCR)_3 + 3HOH \text{ ------}\rightarrow C_3H_5(OH)_3 + 3RCOOH$$

Triglyceride + water -------→ Glycerol + F.F.A.

The free fatty acids of sesame oil and sunflower oil showed higher value with insignificant difference ($P>0.05$), while cotton seed oil showed lower value with insignificant difference ($P>0.05$) from the free fatty acids of groundnut oil and Alaseel. The percentage of free fatty acids of shortening gained the intermediate free fatty acid ranking, and insignificant difference ($P>0.05$) from the free fatty acids of Alaseel and groundnut oil.

4.3. Rheological characteristics:

The rheological properties of Wheat flours and sorghum blends were shown in Table (3).

4.3.1. Farinogram characteristics:

The farinograph characteristics of Australian and Indian wheat flours with Fakimustahi sorghum flour are presented in table (3.a).

The water absorption of wheat flour for Australian and Indian was 59.9% and 63.1% respectively, and the dough development time was 2.7 minutes and 1.9 minutes respectively. Stability of 17.2 minutes and 14.1 minutes respectively, a weakening of 50.0 B.U. and 70.0 B.U. respectively, were observed. All these values indicated relatively strong characteristics of wheat flour.

Table (2). Free fatty acid of oils/ fats (sesame, sun flower, groundnut, cotton seed oil, ghee, Alaseel and shortening hydrogenated vegetable oil).

Fats/ oils	Free fatty acid (%)
Sesame oil	0.874 ± 0.05^{a}
Sunflower oil	0.885 ± 0.00^{a}
Groundnut oil	$0.099\pm0.01^{c\ d}$
Cotton seed oil	0.042 ± 0.00^{d}
Ghee	0.470 ± 0.04^{b}
Hydrogenated vegetable oil :	
Alaseel	$0.062\pm0.01^{c\ d}$
Shortening	0.112 ± 0.00^{c}
Lsd 0.05	0.055

Means in the same column with the same letters are not significantly different at level (P> 0.05) according to Lsd.

The data showed a decrease in water absorption with the addition of 20%, 40%, and 60% sorghum flour, but at 40% and 60% sorghum using Indian wheat flour gave the same water absorption. Further increase in the level from 0% to 60% lowered the dough development from 2.7 minutes to 1.6 minutes (for Australian wheat flour) and from 1.9 minutes to 1.0 minute (for Indian wheat flour).

With the addition of sorghum from 20% to 60%, the stability decreased from 13.8 to 9.0 minutes, and from 8.6 to 4.1 minutes using Australian and Indian wheat flours respectively.

Softening increased with all types of blends indicating weakening of dough.

Comparing the Australian to Indian wheat flour (control), the water absorption for Australian wheat flour is lower than Indian wheat flour, this may be due to the lower level of extraction rate and ash for Australian wheat flour.

4.3.2. Extensogram characteristics:

The extensogram characteristics of wheat flour, and wheat and sorghum flour blends are presented in table (3.b).

The energy of wheat flour at 45 min., 90 min., 135 min., for Australian wheat flour was 121cm^2, 140cm^2, 147cm^2, respectively.

The energy for Indian wheat flour was 55 cm^2, 68 cm^2, and 69cm^2 respectively.

The consistency (resistance) at 45 min., 90 min., and 135min., for Australian wheat flour was 495 B.U., 630 B.U., 670 B.U., while the resistance for Indian wheat flour was 310 B.U., 458 B.U., and 519 B.U. respectively.

The extensibility at 45 min., 90 min., 135 min., for Australian wheat flour was 176 cm, 167 cm, 162 cm, and for Indian wheat flour was 118 cm, 107 cm, and 94 cm respectively.

The ratio of resistance at maximum to extension (Rm./Ex) at 45 min, 90 min., and 135 min., for Australian wheat flour was 2.8, 3.7, 4.1 and for Indian wheat flour was 2.6, 4.3, 5.5 respectively. As the time increased the energy, resistance, and ratio increased, while the extensibility decreased.

As the time increased the energy increased except at 90 min. to 135 min. interval of time and 20%, 40%, and 60% sorghum blends using Indian wheat flour and at 60% sorghum using Australian wheat flour. The data showed a decrease in the energy with the addition of sorghum except at 60% sorghum, using Indian wheat flour, at 135 min. The energy at 45min. and 90 min., using Indian wheat flour with 60% sorghum blends, showed the same results.

The resistance of wheat flour increased as the time increased from 45 min. to 135 min. except at 60% sorghum blends, the resistance decreased from 375 B.U. to 373 B.U , and from 285 B.U. to 280 B.U. using Australian and Indian wheat flours respectively. The resistance decreased with 20%, 40% and 60% blends, except with 60% sorghum blends resistance increased from 310 B.U to 375, from

380 B.U. to 392 B.U, and from 315B.U to 373 B.U. at 45 min., 90 min., and 135 min. using Australian wheat flour respectively.

The extensibility increased with increasing the time from 45 min. to 135 min. except at 135 min using Indian wheat flour with 60% sorghum blends, and decreased with increasing the sorghum.

As the time increased from 45 min. to 135 min., the ratio of resistance to extensibility (Rm./Ex) increased except at 60% sorghum flour blends, using Australia wheat flour where the ratio decreased from 5.0 to 4.1. The ratios increased with the sorghum increase from 0% to 60% sorghum flour blends, except at 135 min. while they showed the same results, and at 90 min. and 135 min. the ratio decreased from 4.3 to 3.6 and from 5.5 to 3.4 respectively using Indian wheat flour.

Generally as the percentage of sorghum increased, the energy, resistance and extensibility decreased, showing softer dough, this is due to the shortening of gluten as the percentage of sorghum increased, this also indicates that Indian wheat flour is softer than Australian wheat flour.

4.4. Physical quality:

Table (4) showed the effect of different oils and fats (sesame oil, sunflower oil, groundnut oil, cotton seed oil, ghee, alaseel, and shortening on the diameter, thickness and spread ratio of biscuits made with Indian wheat flour.

4.4.1. Diameter:

Biscuits made with ghee showed the highest Diameter, 5.200 mm, and biscuits made with sunflower oil showed lowest Diameter, 4.834mm. Diameter of biscuits made with alaseel and shortening showed the same results 5.168mm, higher than 4.849mm, 4.949mm, and 4.895mm for biscuits made with sesame oil, groundnut oil, and cotton seed oil respectively.

4.4.2. Thickness:

Biscuits with ghee showed the lowest thickness (0.887mm) and biscuits made with groundnut oil showed the highest one (1.033mm). Biscuits made with alaseel and shortening showed the same results (0.896mm), while the thickness of biscuits made with sesame oil, sunflower oil, and cotton seed oil were 0.961mm, 0.973mm, and 0.914mm respectively.

4.4.3. Spread ratio:

The values of biscuits spread ratio were shown in table (4) and figure (1). The spread ratio of biscuits made with ghee gained the higher value (5.862), because of their higher diameter, and lower thickness, as spread ratio means the ratio between diameter and thickness. Biscuits made with alaseel and shortening, gained the same spread ratio (5.770), because they gained the same diameter and thickness. Biscuits made with groundnut oil showed the lower spread ratio 4.791, because of their higher thickness. The spread ratio of biscuits made with sesame oil, sunflower oil, and cottonseed oil was 5.046, 4.968, and 5.356 respectively. These results agree with the earlier findings that shortening has a function on spread ratio (Kulp, 1994) and hard fats give better results on spread ratio than oils such as peanut oil, sesame oil, cotton seed oil etc (Mustafa *et al*, 1977).

Table (4). Effect of different oil/fat on the spread ratio of biscuits

Biscuits	**Width (mm)**	**Thickness (mm)**	**Spread Ratio (Wid./Thi.)***
Sesame oil	4.849	0.961	5.046
Sunflower oil	4.834	0.973	4.968
Groundnut oil	4.949	1.033	4.791
Cotton seed oil	4.895	0.914	5.356
Ghee	5.200	0.887	5.862
Hydrogenated vegetable oil :			
Alaseel	5.168	0.896	5.770
Shortening	5.168	0.896	5.770

* Wid. : Width. Thi. : Thickness.

4.5. Organoleptic quality:-

The organoleptic evaluation of biscuits prepared with Indian wheat flour using different types of oils and fats were shown in table (5).

Table (5.a) showed the organoleptic score of biscuits made with groundnut, sesame, sun flour and cottonseed oils. Biscuits made with cottonseed gained the lower score in general features (20), flavor (25), taste (25) and preference (25) showing significant difference from the other types of biscuits at ($P < 0.05$). Biscuits made with ground nut oil showed the higher score in general feature (52), flavor (43), taste (44), texture (47) and preference (45), showing significant difference ($P < 0.05$) from the other types of biscuits made with sesame and sunflower at the evaluation of the general feature, but insignificant different ($P < 0.05$) with the other types of biscuits in flavor, taste, texture and preference evaluation.

Biscuits made with cottonseed oil gained the lower score this indicates better quality in general feature, flavor, taste and preference, therefore biscuits from cottonseed oil goes for further organoleptic test.

Table (5.b) showed the organoleptic evaluation of biscuits prepared from Indian wheat flour using ghee, cottonseed oil, alaseel and shortening.

The score for biscuits made with shortening was 19, 23, 23, 18, and 19 in evaluation of general feature, flavor, taste, texture and preference, respectively, significantly lower than the other types of biscuits. Biscuits made with cottonseed oil gained significantly higher score as 58, 55, 55, 60, and 60 for evaluation of general feature, flavor, taste, texture, and preference respectively.

There are insignificant differences (P<0.05) between the biscuits made with ghee and biscuits made with alaseel at all types of evaluation, but biscuits made with alaseel showed the lower score than the biscuits made with ghee, therefor alaseel biscuits gained the better quality as the shortening biscuits.

4.6. The effect of fats on chemical composition of biscuits:

Table (6) shows the effect of fats (shortening and alassel) on chemical composition of biscuits made with Indian wheat flours and Fakimustahi sorghum flour ranged from 0% to 100% with increment of 20%, before and after 3 months storage (composite flours 1) and Australian wheat flours and Fakimustahi sorghum flour ranged from 0% to 100% with increment of 20%, before and after 3 months storage (composite flours 2).

4.6.1. Biscuits from composite flours 1:

4.6.1.1. Moisture content:

The moisture content of biscuits, made with Indian wheat and Fakimustahi sorghum flours, firstly using shortening and then alaseel fats, before and after storage are shown in table (6.a).

Before and after storage, the moisture content of biscuits made from Indian (0% sorghum flour) using shortening or alaseel gained the higher value. The values of moisture contents were comparable to the range of 1% to 6% reported by Kent and Evers (1994).

As the percentage of sorghum increased the moisture content decreased, this may be due to the percentage of moisture content of sorghum flour which is lower than the percentage moisture content of wheat flours as shown in table (1.a).

Percentage of moisture content of biscuits after storage increased with significant difference (P>0.05) except at 100% sorghum using shortening, this may be due to the environment. Generally the moisture content of biscuits using shortening was higher than the percentage of moisture using alassel.

4.6.1.2. Ash content:

Table (6.a) shows the ash content of biscuits made with shortening and alaseel before and after storage. Although analysis of variance (P>0.05) between all blends of biscuits using shortening and alaseel showed insignificant difference before and after storage, but numerically as the percentage of sorghum increased the percentage of ash content increased, this because the percentage of ash content of sorghum flour was higher than the percentage of ash content of Indian flour as shown in table (1.a).

4.6.1.3. Protein content:

The protein content of biscuits made with shortening and alaseel before and after storage is shown in table (6.a). The percentage of protein content of biscuits using shortening and alaseel are the same. The values of which were significantly higher than obtained by Holland *et al* (1988) who reported 6.7% for semi-sweet biscuits. The percentage of protein increased as the percentage of sorghum increased, but with insignificant difference (P>0.05), this is due to the higher level of protein content in the sorghum flour, as shown in table (1.a). There are insignificant differences (P>0.05) in the percentage of protein content for biscuits before and after storage.

4.6.1.4. Fat content:

The fat content of biscuits made with shortening and alaseel using range of sorghum before and after storage was shown in table (6.a). The values were higher than the fat contents of biscuits obtained by Holland *et al* (1991) who reported 16.6% for semi-sweet biscuits. Generally the fat content of biscuits increased as the percentage of sorghum increased, but analysis of variance showed insignificant difference ($P>0.05$) between the blends before storage, this is due to the higher level of sorghum fat as shown in the results of chemical composition of sorghum in table (1.a). After storage there is a slightly decrease in the fat content with insignificant difference ($P > 0.05$).

4.6.1.5. Carbohydrates content:

The results of carbohydrates content (by difference) of biscuits made with shortening and alaseel before and after storage using shortening and alaseel was shown in table (6.a). Biscuits made with 20% sorghum flour gained the higher value. All the values were lower than 74.8% reported by Holland *et al* (1991).

4.6.1.7. Total Energy:

Table (6.a) showed the energy contents of processed biscuits made with shortening, alaseel, using sorghum percent, before and after three months storage.

The calculated results obtained were lower than the value 1925 Kcal/100g obtained by Holland *et al* (1991). Generally as the percentage of sorghum increased, the calculated energy increased. The value of energy content decreased after storage except at 100% sorghum using shortening and alaseel, this may be due to the value of fat content, protein and carbohydrates.

4.6.1.7. Fat acidity content:

The acidity of biscuits made from Indian and sorghum flours, shortening and alaseel, was shown in table (6.a), fig. (2 & 3). Biscuits made from 100% sorghum flour gained the lower fat acidity than the other biscuits sorghum flour blends. Although there are insignificant difference ($P>0.05$) between all the fat acidity of biscuits before and after storage, but as the percentage of sorghum increased the value of fat acidity decreased, this is due to the low fat acidity of sorghum flour as shown in (table.1).

After storage, the fat acidity of biscuits increased at low level, this may be due to the increasing in the moisture content after storage.

Numerically fat acidity for biscuits made with shortening fat was higher than alaseel fat, with insignificant difference ($P>0.05$), because alaseel (Soyabeen oil and Palm oil) had a preservative factor (E 320 and E 321).

4.6.1.8. Free fatty acids content:

The free fatty acids for biscuits before and after storage made with shortening and alaseel using sorghum flours, was shown in table (6.a) and fig. (4& 5).

The free fatty acids of biscuits made from 20% sorghum flour using shortening and alaseel showed higher value, addition of sorghum decrease the free fatty acids with insignificant difference ($P>0.05$), this may be due to the decrease in the moisture content (table 1.a). After

storage the free fatty acids increased, this does not agree with Klare (1964) who said that during three months storage the free fatty acids dropped, this is due to the high concentration of the free fatty acids which accelerates the backward reaction to form di-or tri-glycerides. There are insignificant difference ($P>0.05$) between the free fatty acids of biscuits made with shortening and alaseel, but the free fatty acids of biscuits made with alaseel were lower than shortening, this due to the antioxidant factor (E 320 and E 321).

4.6.2. Biscuits from composite flours 2:

Table (6.b) shows the effect of fats (shortening and alaseel) on chemical composition of biscuits made with Australian wheat flour and Fakimustahi sorghum flour at 0%, 20%, 40% 60% 80% and 100% level, before and after three-months storage.

4.6.2.1. Moisture content:

Table (6.b) showed the values of moisture content of biscuits made with shortening and alaseel. The values obtained in this study are within the range of 1% to 6% reported by Kent and Evers (1994). Increasing the percentage of sorghum affected the moisture content of biscuits. As the percentage of sorghum increased the moisture content of biscuits decreased (with significant difference $P>0.05$). Generally after storage the moisture of biscuits increased, this may be due to the environmental factor.

4.6.2.2. Ash content:

As shown in table (6.b) the ash content of wheat flour biscuits made with shortening was 0.505%, and 0.506% before and after storage respectively, but using alaseel, the ash content of wheat flour biscuits was 0.503% before and after storage. As the percentage of sorghum flour increased the percentage of ash increased (with insignificant difference at P>0.05), this is due to the high percentage of sorghum ash content as shown in table (1.a). After storage, biscuits made with 0% (control) and 20% sorghum blends using alaseel showed the same results as before storage, but generally the percentage of ash content were decreased after storage (with insignificant different P>0.05).

4.6.2.3. Protein contents:

Table (6.b) represented the protein content of wheat flour biscuits made with shortening and alaseel were 8.494% and 8.482% before and after storage respectively, the values of which were significantly higher than what was obtained by Holland *et al* (1991) who reported 6.7% for semi sweet biscuits, and within the range of 8.75% to 9.2% before storage and 8.72% to 9.20% after storage as reported by Elamin (2002).

As the percentage of sorghum increased, the percentage of protein increased with insignificant difference (P>0.05). This is due to the higher level of protein in Fakimustahi sorghum flour as shown in Table (1.a). After storage the percentage of protein content decreased, except at 100% sorghum, with insignificant difference (P>0.05).

4.6.2.4. Fat content:

Table (6.b) shows the values of oil content of wheat flour biscuits made with shortening as 16.249%, and 16.240% before and after storage respectively. Using alaseel fat, the fat content of biscuits made with wheat flour before and after storage was 16.106% and 16.105% respectively. The value of fat content of biscuits made with shortening using 0% (control) and 20% sorghum flour, and from alaseel using 0% up to 40% sorghum flour were significantly lower than the fats content of biscuits obtained by Holland *et al* (1991) who reported 16.6% for semi sweet biscuits (without using sorghum flour). Generally as the percentage of sorghum increased the percentage of fat content of biscuits increased, this is due to the fat level of sorghum flour as shown in Table (1.a). Generally, at any level of sorghum, the fat content decreased after storage, but with insignificant difference ($P>0.05$).

The oil content of biscuits made with shortening was higher than the oil content of biscuits made with alaseel.

4.6.2.5. Carbohydrates content:

Table (6.b) shows the carbohydrate content of biscuits (by difference), using shortening and alaseel. The values of carbohydrates were lower than 74.8%, reported by Holland *et al* (1991). As the percentage of sorghum increased, the percentage of carbohydrates decreased, this is due to the lower percentage of sorghum carbohydrates as shown in Table (1.a).

Generally, the percentage of carbohydrates after storage decreased, because of the change in the values of moisture, ash, protein, and fat contents of biscuits.

The carbohydrates content for biscuits made from alaseel was higher than the carbohydrates of biscuits made from shortening.

4.6.2.6. Total energy content:

The energy content of biscuits was shown in table (6.b) using shortening and alaseel.

These values of energy were lower than 1925 Kcal/100g reported by Holland *et al* (1991). As the percentage of sorghum increased, the percentage of biscuit energy increased, this is due to the higher value of sorghum flour (Fakimustahi) energy as shown in Table (1.a). Energy contents of biscuits decreased after storage, this is because the value of energy significantly depends on the values of protein, fat, and carbohydrates.

4.6.2.7. Fat acidity:

The fat acidity of biscuits was shown in table (6.b) and figure (6 & 7), made with shortening and alaseel fat.

The fat acidity decreased as the percentage of sorghum increased, this is due to the level of sorghum flour (Fakimustahi) fat acidity, table (1.a), but results of fat acidity show insignificant difference at ($P>0.05$).

Fat acidity of biscuits made with shortening was higher than the fat acidity of biscuits made with alaseel. This is due to the antioxidant found in alaseel fat.

Generally, the value of fat acidity increased with low increment after storage for all biscuits with sorghum blends, but analysis of variance ($P>0.05$) showed insignificant difference, increasing fat acidity may be due to the increasing in the moisture content after storage.

4.6.2.8. Free fatty acids:

The percentage of free fatty acids for biscuits made with composite flour was shown in table (6.b) and figure (8 & 9). The free fatty acids for biscuits made with wheat flour (0% sorghum) using shortening was 1.625%, 1.789%, before and after storage, respectively, while for alaseel was 1.473%, and 1.482% before and after storage respectively.

The results of free fatty acids content before storage comparable to that of 1.1% to 1.7% reported by Elamin (2002). As the percentage of sorghum increased the percentage of free fatty acids decreased, this may be due to the decreasing of the moisture content of biscuits before storage, decreasing in the value of free fatty acids showed insignificant difference at ($P>0.05$). After storage only the results of free fatty acids of biscuits made with 40%, 60% and 80% using alaseel were within the range of 0.5% to 1.4% reported by Elamin (2002) and the free fatty acids of other types of biscuits blends were higher than the range reported by Elamin (2002). Free fatty acids arise from the hydrolysis of neutral fat (glycerides), and the relative high moisture content lead to the increase in the free fatty acids, but the increase in the value of free fatty acids was insignificant at ($P>0.05$).

The free fatty acid for biscuits made with shortening was higher than the free fatty acid of biscuits made with alaseel, this is due to the antioxidant found in alaseel.

4.7. Physical quality of biscuits made with composite flours:

Table (7) shows the effect of two types of fats, shortening and alaseel on diameter, thickness and spread ratio of biscuits made from Indian (composite flours 1), and Australian (composite flours 2) wheat flours and sorghum flour ranged from 0% to 100% with 10% increment and

4.7.1. Biscuits from composite flours 1:

Table (7.a) shows the results of diameter, thickness and spread rati of biscuits made with alaseel and shortening using Indian wheat flour with Fakimustahi sorghum flour blends.

4.7.1.1. Diameter:

The diameter of biscuits made from wheat flour with shortening and alaseel gained the same value of 5.168mm, insignificantly difference (P>0.05) from biscuits made with sorghum range from 10% to 40% using shortening. Using shortening the diameter of biscuits made with 10% to 30% sorghum blends showed the same results, continuous addition of sorghum, increased the diameter of biscuits, this may be due to the decrease in the quality of protein thus reducing the gluten strength. Biscuits made from alaseel with 90% sorghum flour gained the higher diameter, insignificantly different from biscuits made with 80% sorghum flour. Only the diameter of biscuits made from 10% to 40% sorghum blends using shortening was higher than the diameter of biscuits using alaseel fat.

4.7.1.2. Thickness:

The thickness of biscuits made from wheat flour with alaseel and shortening showed the same thickness of 0.896mm, as shown in table (7.a).

After 20% sorghum blends the thickness of biscuits increased as the percentage of sorghum increased, increasing the percentage of sorghum decreased the strength of gluten, i.e. dough became softer, except at 100% of sorghum using alaseel fat. Biscuits made with 10% to 60% sorghum flour blends using shortening, showed higher thickness than using alaseel, and the thickness of biscuits made with shortening and alaseel fats using 20% sorghum blends showed insignificance different at ($P>0.05$).

4.7.1.3. Spread ratio:

Cookie spread ratio is the test characterizing the cookie baking properties depending on the value of the biscuit diameter and thickness.

The spread ratio of biscuits made with Indian wheat flour using shortening and alaseel fats gained similar result 5.770, as shown in table (7.a), and figure (10).

Addition of sorghum flour affect the spread ratio of biscuits, using shortening or alaseel fats, as the percentage of sorghum increased from 0% (control) to 20%, the spread ratio increased, after that the spread ratio decreased.

Generally, the spread ratio of biscuits with alaseel was higher than the spread ratio of biscuits with shortening, this is due to the lower level of thickness.

4.7.2. Biscuits from composite flours 2:

Table (7.b) showed the diameter, thickness and spread ratio of biscuits made from Australian wheat flour, and Fakimustahi sorghum flour from 0% to 100% with 10% increment.

4.7.2.1. Diameter:

The result of biscuits diameter made from wheat flour (control) using shortening was 5.233mm insignificantly difference (P>0.05) with biscuits made with sorghum ranged from 10% to 30%, and significantly higher than the diameter of biscuits made with alaseel 5.072mm (significantly difference (P>0.05) with the other types of biscuits), as shown in table (7.b).

As the percentage of sorghum increased, the diameter of biscuits increased, while statistically increasing the percentage of sorghum from 60% to 100% showed insignificant difference at (P>0.05) using either shortening or alaseel fats. Generally the diameter of biscuits made with shortening were significantly higher than the diameter of biscuits made with alaseel fat.

4.7.2.2. Thickness:

From table (7.b) the thickness of biscuits made with Australian wheat flour using shortening was higher than alaseel, 1.065mm and 0.859 respectively.

The thickness of biscuits made with 60% and 70% sorghum blends using shortening gained the same value, insignificantly different (P>0.05) with the thickness of biscuits made with 50% sorghum blends, also biscuits made with 80%, 90% and 100% sorghum blends, using alaseel gained the same thickness, show insignificant difference (P>0.05) compared with the thickness of biscuits made with 60% and 70% sorghum blends. Generally as the percentage of sorghum increased the value of thickness increased. The thickness of shortening biscuits made with 10%, 20%, 80%, 90% and 100% sorghum flour blends were higher than the thickness of alaseel fat biscuits.

4.7.2.3. Spread ratio:

The spread ratio for biscuit made from wheat flour and shortening was 4.914, lower than the spread ratio of biscuits made from wheat flour and alaseel fat, 5.905 insignificantly different (P>0.05) compared with biscuits made with 10% and 20% sorghum flour, as shown in table (7.b) and figure (11).

Addition of sorghum flour affects the spread ratio of biscuits. Using shortening fat, addition of sorghum flour from 10% to 30% decreased the spread ratio of biscuits (insignificant different (P>0.05)). Further increase in the percentage of sorghum flour to 50% increased the spread ratio but with insignificant difference (P>0.05), but increasing the percentage of sorghum flour to 70%, spread ratio showed a significant higher spread ratio, while increasing the level of sorghum flour to 100%, decreased the spread ratio of biscuits.

Generally the spread ratio of biscuits made with shortening was higher than the biscuits made with alaseel after addition of 40% sorghum flour.

4.8. Organoleptic quality of biscuits:

Table (8) shows the effect of Indian and Australian wheat flours, Fakimustahi sorghum flour, Shortening and Alaseel on sensory evaluation of biscuits, before and after three months of storage.

4.8.1. Biscuits from composite flours 1 with shortening:

Table (8.a) & Plate (1) shows the effect of Indian wheat flour and shortening on sensory evaluation (color, odor, surface, fat, taste, mouth feel, texture and total score) of biscuits made from Indian flour with Fakimustahi sorghum flour ranged from 0% to 100% with 10% increment before and after three months of storage.

4.8.1.1. <u>Color:</u>

The score of color of biscuits before and after storage was shown in table (8.a).

Before storage the color significantly changed with increasing the percentage of sorghum according to the panelist. Increasing the percentage of sorghum from 10% to 40% changed the color from excellent golden brown (at 0% sorghum flour) to desirable uniformity color, more addition to 60% changed the color to excellent golden brown, increasing the percentage of sorghum to 90% declined the color from very good to good (brownish color) at 100% sorghum flour, the deterioration in the color after 60% may be due to the color of sorghum flour.

Although biscuits made with 10%, 20%, 30%, and 40% sorghum blends gained the higher score after storage than before storage, they gained the same very good desirable color. Biscuits made with 70% sorghum blends showed the same color score before and after storage. Generally the storage does not affect the color.

4.8.1.2. Odor

The score of odor of biscuits before and after storage was shown in table (8.a).

Before storage biscuits made with 20% sorghum showed the higher score of odor but insignificantly different from the biscuits made with wheat flour 0%, 10%, 30%, 40%, 50%, 80% and 100% sorghum flour. The score of odor of all biscuits blends ranged between 6.0 to 7.0, this range indicates the very good odor. Generally the addition of sorghum did not affect the odor of biscuits.

After storage the score of odor of biscuits made with 10% sorghum flour showed the higher score (8.3) and biscuits made with 40% and 100% sorghum flour blends gained the lower score (6.4), and showing insignificant difference ($P>0.05$) with the other types of biscuits except biscuits made with 10% sorghum flour blends. Storage of biscuits did not affect the odor except at 10% sorghum blends, the odor changed from very good odor (before storage) to excellent odor (after storage).

4.8.1.3. Surface feel:

Table (8.a) shows the score of surface feel of biscuits before and after three months storage.

Before storage biscuits made with 10% sorghum blends gained the higher score (8.2) showing insignificant different ($P>0.05$) with biscuits made with sorghum flour ranged from 20% to 60%. While biscuits made with 100% sorghum flour gained the lower score (6.9), showing insignificant difference ($P>0.05$) with biscuits made from sorghum flour ranged from 40%, to 90% and 0%. Biscuits made with

0% and 70% sorghum flour blend, 20% and 30% sorghum flour blends, and from 80% and 90% sorghum flour blends, gained similar scores of surface feel. Generally the addition of sorghum decreased the score of surface feel after 60%. Biscuits made with 10%, 20%, 30% sorghum flour blend gained excellent smooth surface feel than the other types of the biscuits, and they gained very good attributes.

After storage the score of surface feel of biscuits made with 10% sorghum flour gained a higher score (7.5), while biscuits made with 100% sorghum flour gained a lower score (6.4) the same as before storage. Analysis of variance to the biscuits surface feel at ($P>0.05$) showed insignificant difference between all biscuits made with sorghum flour blends. The range of score of surface feel for all biscuits blends showing very good surface feel. Storage of biscuits affected the surface feel at 10% and 20%, 30% sorghum blends, the surface feel change from excellent to very good attributes.

4.8.1.4. Taste:

Before storage the taste of biscuits made with 20% sorghum flour gained the highest score (8.1) but insignificant difference ($P>0.05$) with all the other types of biscuits except biscuits made with 90% sorghum flour blends. Biscuits made with 90% sorghum flour gained the lowest score (6.0), as shown in table (8.a).

Biscuits made with 10%, 20% showed excellent attribute i.e. pleasant taste, while the other biscuits made from sorghum flour blends showed very good attributes. The addition of sorghum decreased the score of taste after 20% sorghum. After storage biscuits made with 30% sorghum flour showed the highest score (7.4) and biscuits made from 100% sorghum flour gained the lowest score (3.3).

Biscuits made with sorghum flour ranged from 0% to 70% gained very good taste while the biscuits made from 80% and 90% gained the good taste, and biscuits made with 100% sorghum flour gained fair results and this showed the off taste.

Generally storage of biscuits decrease the score of taste.

4.8.1.5. Mouth feel:

Before storage the mouth feel score ranged from 6.4 (at 90% sorghum flour) to 7.7 (at 20% sorghum flour), All the types of biscuits showed insignificant difference (P>0.05), as shown in table (8.a). All the types of biscuits showed very good mouth feel attributes. But after storage the score of biscuits ranged from 4.9 (at 100% sorghum flour) to 7.2 (at 0%, 30% and 60% sorghum flour). Biscuits made with 0% sorghum flour to 80% sorghum flour showed insignificant difference (P>0.05) between them. All biscuits show the very good attributes and were easier to break down except biscuits made with 50%, 90% and 100% sorghum blends they showed good mouth feel but with after taste. Generally storage of biscuits did not affect the feeling of the mouth much.

4.8.1.6. Texture:

Biscuits made with 20% sorghum flour before storage gained the highest texture score (8.3) while biscuits made with 90% sorghum flour gained the lowest score (6.0) as shown in table (8.a). Biscuits made with sorghum flour ranged from 30% to 80% and 100% blends showed insignificant difference at (P>0.05) between them. While biscuits made with 0% (control), 90% and 100% show insignificant different (P>0.05) between them. The texture of biscuits made with 10%, 20%, 30%, and 80% sorghum flour gained excellent attributes (crispy texture), the other biscuits gained the very good attributes (less crispy texture). After storage biscuits made with 40% sorghum flour gained the highest score (7.9) and biscuits made with 50% sorghum flour gained the lowest score (5.5) as shown in table (8.a).

Biscuits made with 10%, 20%, 30%, 40%, 60%, 80%, 90%, and 100% sorghum flour showed insignificant difference (P>0.05) with biscuits made with wheat flour (0% sorghum flour). All the biscuits show very good attributes (crispy texture), except biscuits made with 50% sorghum flour blends, which showed good attributes (hard texture). Generally storage of biscuits did not affect the texture of biscuits so much.

4.8.1.7. Total score:

Before storage biscuits made with Indian wheat flour and shortening using 20% sorghum flour gained the highest total score (47.4) and biscuits made with 90% sorghum blends gained the lowest score (39.2) as shown in table (8.a) and figure (12). There was an insignificance different (P>0.05) between biscuits made with 0% to 60% and 80% sorghum flour blends. The range of sorghum flour from 50% to 100% and 0% sorghum flour blends showed insignificant different (P>0.05) in total score. The decrease in the total score after 20% sorghum flour explained the effect of addition of sorghum in the sensory evaluation of biscuits, but the range of total score (47.1–39.2)

indicates the very good attributes. After storage the total score of biscuits made with 10% sorghum flour gained the highest score (44.4) while the biscuits made with 100% sorghum flour gained the lowest score (36.7) as shown in table (8.a) and figure (12). The total score of biscuits made with 60% and 70% sorghum showed the same total score (40.7). The range of sorghum flour from 0% to 70% showed insignificant difference (P>0.05) in the total score, also the range from 60% to 100% sorghum flour showed insignificant difference (P>0.05) in the total score. Although there is a little decrease in the total score value after storage, but the range of total score (44.4 – 36.7) shows the very good attributes, the same as before storage.

4.8.2. Biscuits from composite flours 1 with Alaseel fat:

Table (8.b) & Plate (2) shows the effect of Indian wheat flour and alaseel on sensory evaluation (color, odor, surface feel, taste, mouth feel, texture, and total score) of biscuits made with Indian wheat and sorghum (Fakimustahi) composite flours before and after three months storage.

4.8.2.1. <u>Color:</u>

Before storage, biscuits made with 10% sorghum flour gained the highest score (8.1) with excellent criteria, while the biscuits made with 50% sorghum flour gained the lowest score (5.5), showing good attributes as biscuits made from 60% sorghum flour, and the other types of biscuits showed very good attributes, as shown in table (8.b).

Generally increasing the percentage of sorghum, decreased the score of color.

After three months storage biscuits made with 0% sorghum flour gained the highest score (8.8), while biscuits made with 80% and 90% sorghum flour gained the lower score (5.8). There are insignificant difference at (P>0.05) in color between the biscuits made with 0%, 10%, 30%, 40%, 60%, and 100% sorghum flour, they gained an excellent golden brown color. The color of biscuits made with 20%, 50%, and 70% sorghum flour showed very good criteria, while biscuits made with 80% and 90% sorghum flour gained good color criteria.

4.8.2.2. Odor:

As shown in table (8.b), before storage, the odor score of biscuits made with 60% sorghum flour gained the highest score (7.9), while biscuits made with 0% sorghum flour gained the lowest score (5.8). Analysis of variance of biscuits made with 10%, 30, 50, 60, 70, and 100% sorghum flour blends showed insignificant difference at (P>0.05), but significantly higher than the score of biscuits made with wheat flour (0% sorghum flour), with very good odor. Generally the addition of sorghum enhanced the odor of biscuits (get better).

After storage, as shown in table (8.b), biscuits made with 40% sorghum flour gained the highest value (7.8), while biscuits made with 60% sorghum flour gained the lowest value (5.2). Biscuits made with sorghum flour ranged from 0%, to 80%, and 100% showed insignificant difference at (P>0.05). All the types of biscuits made with wheat and sorghum flour blends showed very good odor attributes except at 60% sorghum flour blends, biscuits gained good odor attribute. Generally storage did not affect the odor of biscuits.

4.8.2.3. Surface feel:

Table (8.b) showed the score of surface feel of biscuits made of wheat (Indian) and sorghum (Fakimustahi) composite flours before and after storage.

The score of surface feel (before storage) for biscuits made with 20% sorghum flour gained the higher score (8.0), insignificantly difference (P>0.05) with biscuits made with 0%, 10%, and 40% sorghum flour. While biscuits made with 70% sorghum flour gained the lower score (6.0), insignificantly difference (P>0.05) compared with biscuits made with 50% to 100% sorghum flour.

The surface feels of biscuit made with 20% sorghum blends showed excellent smooth surface feel. While all the others biscuit blends showed very good smooth surface feel. But after storage the surface feel of biscuits made from wheat flour (0% sorghum flour) showed the higher value (8.4) showing insignificance different (P> 0.05) with biscuits made from 10% to 70% sorghum flour. Biscuits made form 90% sorghum flour gained the lower score (6.2), showing insignificant difference (P>0.05) with biscuits made from 100% sorghum flour.

Biscuits made with 0% (control), 30%, and 40% sorghum flour blends showed the smooth surface feel (more acceptable than before storage). The other types of biscuits showed the same attributes as before storage (very good attributes in surface feel).

4.8.2.4. Taste:

The results of biscuit made from wheat and sorghum composite flours taste before and after storage are shown in table (8.b).

The highest taste score was obtained by biscuits made with 60% sorghum blends (8.3), showing insignificant difference (P>0.05) with biscuits made with 10% to 40%, and 70% sorghum flour. The lowest score was obtained by biscuits made with 80% and 90% sorghum flour blends (6.4), showing insignificant difference (P>0.05) with all biscuits type made from sorghum flour except biscuits made with 60%. All the types of sorghum biscuits showed a very good taste, except at 60% sorghum flour blend showed excellent desirable biscuits taste.

After storage**,** the taste for biscuits made with 60% gained a higher score (7.9), the same as before storage, showing insignificant difference (P>0.05) with biscuits made from 0% to 70% sorghum flour, with very good taste. Addition of 80% sorghum flour to wheat flour changed the score to 5.3 (a lower score the same as before storage), showing insignificant difference (P>0.05) with biscuits made from 90% and 100% sorghum flour, and taste changed to good taste.

4.8.2.4. <u>Mouth feel:</u>

Table (8.b) showed the score of mouth feel of biscuits made from wheat and sorghum composite flours before and after storage.

Biscuits made with 30% sorghum flour showed the highest score (7.6), while biscuits made with 80% showed the lowest score (6.3). All the biscuits ranged as very good on mouth feel, i.e. biscuits are easier to break down, although there were small variation in score between the percentage of biscuits in mouth feel, but statistically increasing the percentage of sorghum did not affect the mouth feel.

After storage, the score of mouth feel for biscuits made, according to the panelist, with 10% have the highest score (8.2), forming insignificant difference (P>0.05) with biscuits made with 20% and 30% sorghum flour. Biscuits made with 60% and 70%

sorghum flour ranked as the lowest one (5.5), forming insignificant difference (P>0.05) with biscuits made from 40% to 100% and 0% sorghum flour.

Biscuits made with 10% sorghum flour blends were judged as excellent i.e. easier to break down. While biscuits made with 0%, 20%, 30%, 40%, and 90% sorghum flour, judged as very good a bit lower than biscuits made from 10% sorghum flour. The other biscuits had after taste in the mouth.

4.8.2.6. Texture:

The texture of biscuits from Indian wheat flour and Fakimustahi sorghum flour, using alaseel oil, before and after storage are presented in table (8.b).

The texture of biscuits made with 40% sorghum flour gained a higher score (7.5), and biscuits made from 100% sorghum flour gained the lowest one (5.5).

All the biscuits made with sorghum ranged from 0% to 100% showed insignificant difference at (P>0.05). The texture of biscuits were very good, i.e. crispy texture, except at 100% sorghum flour blends criteria changed to good, showing hard texture, i.e. the texture of biscuits was not affected so much by incorporation of the sorghum. After storage, biscuits made with 20% gained the higher value (7.8), insignificantly difference (P>0.05) with biscuits made with 40%, and 50% sorghum flour. Biscuits made from 80% sorghum flour gained a lower value (5.3) forming insignificant difference (P>0.05) with all biscuits types except biscuits made from 20% sorghum flour.

The texture of biscuits made with 0%, 10%, 70%, 80%, and 100% sorghum flour gained good attributes i.e. hard texture while the other biscuits types gained a very good attributes i.e. crispy texture.

Generally the score of texture was decreased after storage, this may be due to the decrease in the protein content after storage.

4.8.2.7. <u>Total score:</u>

The total score for biscuits made from Indian and Fakimustahi composite flours using alaseel fat was shown in table (8.b), and figure (13), before and after storage.

Before storage the total score of biscuits made from 10% sorghum gained a higher score (45.0), showing insignificant difference (P>0.05) with biscuits made from 20% to 70% sorghum flour. Biscuits made from 100% sorghum flour gained a lower score (38.6) showing insignificant difference (P>0.05) with biscuits made with 0%, and 30% to 90% sorghum flour. The range of overall quality from 45.0 to 38.6 indicates the very good attributes

Generally the very low decrease in the value of total score means that the incorporation of sorghum did not affect the biscuits so much.

But after storage the total score of biscuits made with 20% and 40% sorghum flour showed a higher score (44.7), forming insignificant difference (P>0.05) with biscuits made from 0% to 70% sorghum flour. While biscuits made with 80% sorghum flour showed a lower score (36.7) forming insignificant difference (P>0.05) with biscuits made from 60% to 100% sorghum flour.

The lower variation in score after storage did not affect the very good sign criteria of biscuits.

4.8.3. Biscuits from composite flours 2 with shortening:

The sensory evaluation of biscuits made with Australian wheat and Fakimustahi sorghum composite flours in the range of 0% to 100% sorghum flour with increment of 10%, using shortening fat, before and after 3 months storage was shown in table (8.c) & Plate (3).

4.8.3.1. Color:

The score of biscuits color was showed in table (8.c), before storage the color of biscuits made with Australian wheat flour, and 30% sorghum flour gained a higher score (8.0), and biscuits made from 0%, 50%, 60%, 80%, and 100% gained the same and the lower score (7.0),

Biscuits made with wheat flour, and wheat flour with sorghum blends showed insignificant difference at ($P>0.05$) showing the very good sign i.e. uniformity in color except at 30% sorghum flour blend which showed excellent golden brown color, indicating that increasing the percentage of sorghum flour did not affect the color. This agreed with Alkhalifa (1998), who reported that "The color of biscuits were not affected by the incorporation of sorghum from 10% to 30%".

After storage the score of color of biscuits made with 10% sorghum flour gained the higher score (8.8), insignificantly difference ($P>0.05$) with biscuits made from 30% sorghum flour. While biscuits made from 70% sorghum flour gained a lower score (4.3), significantly difference ($P>0.05$) from the other types of biscuits. The color of biscuits made with 10% and 30% sorghum flour show the excellent sign i.e. the golden brown color, although there was a low decrease in color score after storage but they showed the same uniformity in color criteria, i.e. storage did not affect the color of biscuits.

4.8.3.2. Odor:

Table (8.c) showed the odor of biscuits made with wheat and sorghum composite flours, before and after storage.

Increasing the percentage of sorghum flour by 10% to 40% sorghum flour increased the score of odor from 7.4 to 7.7, but increasing the level of sorghum flour to 100%, lowered the score to 7.0 showing normal odor with insignificant difference at ($P > 0.05$), before storage. But after storage the representative data showed low variation with insignificant difference ($P > 0.05$), and the biscuits made with 60% sorghum blends show the same score before and after storage. The behavior of odor after storage did not changed, they show a very good attributes i.e. normal odor.

4.8.3.3. Surface feel:

The score of surface feel of biscuits made with wheat and sorghum composite flours, before and after three months storage was shown in table (8.c).

Before storage, biscuits made with 20% sorghum flour gained a higher score (8.4) forming insignificant difference ($P > 0.05$) compared with biscuits made from 10% to 50% sorghum flour. Biscuits made with 80% sorghum flour gained a lower score (5.8).

Biscuits made with 20%, 30%, 50%, sorghum flour gained an excellent degree, i.e. smooth in surface feel, after that the score of surface feel decreased, this appear on biscuits made with 80% sorghum flour, here the surface feel changed to good degree. This may be due to the increase in the biscuits moisture content.

But after storage the surface feel score of biscuits made from 10% sorghum flour showed a higher result (7.6), showing insignificant difference (p>0.05) compared with biscuits made with 0% to 30% and 60% sorghum flour. But biscuits made from 80% sorghum flour showed a lower score (6.3), showing insignificant difference (P>0.05) compared with biscuits made from 0% and 40% to 100% sorghum flour.

All biscuit blends showed very good degree, i.e. smooth in surface feel after storage.

4.8.3.4. <u>Taste:</u>

Table (8.c) shows the taste score of biscuits made from wheat and sorghum composite flours. Before storage, biscuits made with 50% sorghum flour gained a higher score (7.8), insignificantly difference (P>0.05) with biscuits made with 0% to 90% sorghum flour, showing very good attributes, i.e. normal taste. While biscuits made with 100% gained a lower score (5.3), significantly difference (P>0.05) with the types of biscuits, showing good attributes.

Generally increasing the percentage of sorghum to 100% sorghum flour, decreases the acceptance of biscuits.

But after storage the taste of biscuits made with 20% gained a higher score (7.8), and biscuits made with 80% gained the lower score (6.3) all of the scores of biscuits taste shows insignificant difference (P>0.05), showing the very good taste.

Generally the score of taste of all types of biscuits after storage was close to taste score before storage.

4.8.3.5. Mouth feel:

Before storage the score of mouth feel of biscuits made with wheat and sorghum composite flours before and after storage was shown in table (8.c). Biscuits made with 0% sorghum flour (100% wheat flour) gained a higher score (7.8), showing insignificant difference (P>0.05) with biscuits made with 10% to 80% sorghum flour, while biscuits made with 90% gained a lower score (6.2) forming insignificant difference (P>0.05) with biscuits made with 100% sorghum flour. Addition of sorghum flour after 80% decreased the score of mouth feel of biscuits.

Biscuits made with wheat flour (control), wheat flour and sorghum flour blends showed very good attribute in mouth feel, i.e. easier to break down. After storage, biscuits made with 30% and 50% sorghum flour showed a higher score (7.6), insignificantly difference (P>0.05) with biscuits made with 0% to 80%. Biscuits made with 90% and 100% gained a lower score of (6.5) and (6.8) respectively. There was a lower decrease in the mouth feel score after storage but all the types of biscuits showed a very good attributes, the same as before storage.

4.8.3.6. Texture:

Before storage the score of texture of biscuits made with wheat and sorghum composite flours before and after storage was shown in table (8.c). Biscuits made with 0% and 60% sorghum flour gained a higher score (8.1), and biscuits made with 80% sorghum flour gained a lower score (7.2).

Analysis of variance showed insignificant difference at (P>0.05) for all biscuits made with wheat flour, and biscuits from wheat and sorghum composite flours. The texture of biscuits made with 60% sorghum flour gave the (100% wheat flour). The other types of biscuits from sorghum blends gave a very good crispy texture.

After storage biscuits made with 70% sorghum flour gained a higher score (7.7), showing insignificant difference (P>0.05) with biscuits made with 0% to 50% sorghum flour, and biscuits made with 100% sorghum flour gained a lower score (5.8). All types of biscuits were very good crispy in texture except biscuit made with 100% sorghum flour which showed good attributes but with hard texture.

4.8.3.7. Total Score:

Before storage table (8.c) and figure (14) shows the total score of biscuits made with Australian wheat and Fakimustahi sorghum composite flours before and after storage. Biscuits made with 20% sorghum flour gained a higher total score (46.3), showing insignificant difference (P>0.05) with biscuits made with 0% to 70%, and 90% sorghum flour, and biscuits made with 100% sorghum flour gained a lower score (40.2), showing insignificant difference (P>0.05) with biscuits made with 80%.

Generally Addition of sorghum flour decreased the overall quality of biscuits but with low variation. The overall quality score ranged from 46.3 to 40.2 indicating the very good biscuit quality. But after storage the total score of biscuits made with 30% sorghum flour gained a higher score (45.8), showing insignificant difference with biscuits made with 0% to 40% sorghum flour. While biscuits made with 80% and 100% sorghum flour gained a lower total score

(39.6) with insignificant difference (P>0.05) with biscuits made with 60% to 100% sorghum flour.

The overall quality of biscuits made from wheat flour, wheat flour with sorghum flour blends, decreased after storage but with low variation. The criteria of very good quality did not change after storage.

4.8.4. Biscuits composite flours 2 with Alaseel fat:

The sensory evaluation of biscuits made with Australian wheat flour and sorghum flour in the range of 0% to 100% sorghum flour with increment of 10% (composite flours 2), using alaseel fat, before and after 3 months storage was shown in table (8.d) & Plate (4).

4.8.4.1. Color:

Table (8.d) shows the color of biscuits made with wheat and sorghum composite flours before and after storage.

Before storage, biscuits made from 0% sorghum flour (100% wheat flour) gained a higher score (9.0), insignificantly difference (P>0.05) with biscuits made with 10% (8.6) and 60% (8.2) sorghum flour. While biscuits made with 70% (7.1) gained a lower score, insignificantly difference (p>0.05) with biscuits made with 20% to 50% sorghum flour, and from 80% to 100% sorghum flour. Addition of sorghum flour from 0% to 40% decreased the color score of biscuits from 9.0 to 7.6, and the excellent golden brown color changed to very good color. While addition of sorghum flour from 70% to 100% increased the score of biscuit color from 7.1 to 8.1, and changed the color of biscuits again to excellent golden brown color.

The variation in the color scores due to the untrained panalists.

The score of biscuits made with 10% sorghum flour gained a higher value (8.3) after storage, showed significant difference (P>0.05) compared with the biscuits made with 20%, 30%, and 60%

sorghum flour. Biscuits made with 80% and 100% sorghum flour gained a lower score (6.2) showed significant difference (P>0.05) compared with the biscuits made with 40% to 100% sorghum flour. Biscuits made from 0%, 10%, 30% sorghum flour gained an excellent golden color. The other types of biscuits made with sorghum flour blends showed very good uniformity color. Generally the score of color decreased after storage.

4.8.4.2. Odor:

Table (8.d) shows the odor of biscuits made with wheat and sorghum composite flours before and after storage.

Before storage, biscuits made from 10% sorghum flour gained a higher score (8.1), and biscuits made with 50% gained a lower score (7.3), Although, statistically there are insignificant differences (P>0.05) between all types of biscuits, but increasing the percentage of sorghum above 20%, the odor changed from excellent to very good odor.

Biscuits made from 10% sorghum flour gained a higher score (7.7), and biscuits made with 80% gained a lower score (6.9) after storage.

All the odor scores of biscuits decreased after storage except at 30%, and 40% sorghum flour blends, they gained the same score as before storage. All the odor scores of biscuits made insignificant difference (P>0.05), and showing a very good normal odor as before storage.

4.8.4.3. Surface feel:

The score of biscuits surface feel made from wheat and sorghum composite flours before and after storage was shown in table (8.d).

Before storage the surface feel score for biscuits made with 0% (100% wheat flour) sorghum flour gained a higher value (8.5), insignificantly difference (P>0.05) compared with biscuits made from 10% and 20% sorghum flour. While biscuits made from 80% sorghum flour gained a lower surface feel score (7.1), insignificantly difference (P>0.05) compared with biscuits made from 30% to 100% sorghum flour.

Generally as the percentage of sorghum increased, the score of biscuits surface feel decreased. Addition of sorghum flour after 20% changed the criteria of surface feel from excellent smooth surface feel to very good biscuit surface feel.

After storage the score of biscuits surface feel with 0% and 30% gained a higher score, insignificant difference (P>0.05) compared with biscuits made with 10% sorghum flour. While biscuits made with 100% sorghum flour gained a lower score (6.2), insignificantly difference compared with biscuits made with 40% sorghum flour, and from 70 %to 100% sorghum flour.

All the scores of biscuits decreased after storage, except for biscuits made with 30%, which had the same score as biscuits from wheat flour (control), and showing an excellent smooth surface feel, unlike the other types of biscuits they showed a very good biscuits surface feel.

4.8.4.4. Taste:

The scores of biscuit taste made from wheat and sorghum composite flours before and after storage was shown in table (8.d).

Before storage, the taste score for biscuits made with 10% sorghum flour gained a higher value (8.2), insignificantly difference ($P>0.05$) compared with biscuits made from 20% to 70% sorghum flour. While biscuits made from 100% sorghum flour gained a lower surface feel score (6.4), insignificantly difference ($P>0.05$) compared with biscuits made from 50% to 90% sorghum flour, and 0% sorghum flour.

Generally increasing the sorghum after 70% sorghum flour decreased the score of biscuit taste. The pleasant taste was affected by the increasing of sorghum flour in the blends. After 30% sorghum flour blends the taste of biscuits changed from excellent pleasant taste to very good taste.

After storage, a higher taste score (7.4) was gained by biscuits made with 20% sorghum flour, forming insignificant difference ($P>0.05$) with biscuits made with sorghum flour from 0% to 80%, increasing the percentage of sorghum after that lowers the score of taste but with low variation.

Generally all types of biscuits showed a very good biscuits taste.

4.8.4.5. Mouth feel:

The scores of biscuit mouth feel made from wheat and sorghum composite flours before and after storage was shown in table (8.d).

Before storage, the mouth feel score for biscuits made with 10% sorghum flour gained the higher value (7.9), insignificantly difference ($P>0.05$) compared with biscuits made from 0% to 70%

sorghum flour. While biscuits made from 100% sorghum flour gained a lower surface feel score (5.4), insignificantly difference (P>0.05) compared with biscuits made from 80% and 90% sorghum flour.

Biscuits made with sorghum flour from 0% to 70% gained very good surface feel biscuits criteria i.e. biscuits were easier to break, increasing the percentage of sorghum flour leads to after taste in the mouth.

After storage biscuits made with 20% sorghum flour appeared to have a higher score (7.6), insignificantly different (P>0.05) compared with biscuits made with sorghum flour ranged from 0% to 40%. Biscuits made from 70% sorghum flour showed a lower value (6.1)

The scores of biscuit mouth feel showed a low variation after storage, but all types of biscuits were very good break down.

4.8.4.6. <u>Texture:</u>

Table (8.d) shows the texture of biscuits made with wheat and sorghum composite flours before and after storage.

Before storage, biscuits made from 20% sorghum flour gained a higher score (8.3), and biscuits made with 60% gained a lower score (6.9).

Statistically, the texture of all types of biscuits showed insignificant difference at (P>0.05). Biscuits made with 20% to 50% sorghum blends gained an excellent crispy texture, while increasing the percentage of sorghum the texture changed to very good crispy texture.

Biscuits made with 20% sorghum flour gained a higher score (7.4) after storage, the same as before storage, and insignificantly difference (P>0.05) compared with biscuits made with sorghum flour ranged from 0% to 70% sorghum flour.

Storing the biscuits at room temperature affected the texture of biscuits. The texture of biscuits after 70% sorghum flour changed the biscuit texture from very good to good criteria but with hard texture.

4.8.4.7. Total score:

Table (8.d) and figure (15) showed the overall quality of biscuits made with wheat and sorghum composite flours and alaseel fat, before and after storage.

Biscuits made with 10% sorghum blends gained higher score (48.3), insignificantly difference (P>0.05) compared with biscuits made with sorghum flour ranged from 0% to 30% sorghum flour. While biscuits made with 80% sorghum flour gained lower score (41.2), insignificantly different (P>0.05) compared with biscuits made with sorghum flour ranged from 70% to 100% sorghum flour.

Although the overall quality of the biscuits was reduced by the addition of more than 50% sorghum flour, and the presence of 10% and 20% sorghum flour improved the quality, but all types of biscuits gained a very good quality.

After storage, biscuits made from 30% sorghum flour gained a higher total score value (44.9), insignificantly different (P>0.05) compared with biscuits made with sorghum flour ranged from 0% to 40% sorghum flour. While biscuits made from 100% sorghum flour gained a lower total score (37.3), insignificantly different (P>0.05) compared with biscuits made with sorghum flour ranged from 70% to 90% sorghum flour.

Generally the overall quality of all types of biscuits was reduced after storage, but still the score was within the range of very good quality the same as before storage.

Plate (1). Biscuits made from Indian and Fakimustahi composite flours using shortening. (0%, 10%,…,90%,100% : % of sorghum flour).

Plate (2). Biscuits made from Indian and Fakimustahi composite flours using alaseel. (0%, 10%,…,90%,100% : % of sorghum flour).

Plate (3). Biscuits made from Australian and Fakimustahi composite flours using shortening. (0%, 10%,…,90%,100% : % of sorghum flour).

Plate (4). Biscuits made from Australian and Fakimustahi composite flours using alaseel. (0%, 10%,…,90%,100% : % of sorghum flour).

CHAPTER FIVE

CONCLUSIONS

1. 100% sorghum flour biscuits could be used as a replacement (alternative) to wheat flour biscuits for those who suffer from coeliac disease.
2. Indian wheat flour with 10% and 20% sorghum flour using shortening, and with 10% to 70% sorghum flour using alaseel showed biscuits with higher spread ratio than the biscuits made from wheat flour. Australian wheat flour with sorghum flour ranged from 10% to 100% and 10% using shortening and alaseel respectively gave higher spread ratio than the biscuits made from wheat flour.
3. Using shortening or alaseel with Indian wheat flour and with sorghum flour ranged from 10% to 80% gave more acceptable biscuits.
4. Australian wheat flour mixed with 10% to 90% sorghum flour using shortening and with 10% to 30% using alaseel gave acceptable biscuits.

Shortening and alaseel are better fats for biscuits making. .5

6. Low level increment of free fatty acids content and fat acidity resulted during the shelf life of biscuits for three months.
7. L-cystein was added to the Australian and Indian wheat flour because they were medium in hardness.
8. Indian wheat flour was better for making biscuits since it is softer than Australian wheat flour.

RECOMMENDATIONS

1. The Indian and Australian wheat flours under studies showed that the Indian is more suitable than Australian wheat flour in making biscuits.
2. L- cystein is required to soften Australian wheat flour for making good biscuits.
3. Fakimustahi sorghum flour with high protein content can be used in making biscuits preferably in poor areas.
4. Emulsifiers could be used to improve the quality of biscuits made from composite flours (sorghum & wheat).
5. Further studies are needed to improve the quality of 100% sorghum flour biscuits.

REFERENCES

AACC (1983): American Association of Cereal Chemists.

Abboud, A.M.; Rubenthacer,G.L.; and Hoseney, R.C. (1985). Effect of fat and sugar in sugar-snap cookies and evaluation of tests to measure cookies flour quality. *Cereal Chem. 62: 124. AACC, Inc.*

Ahmed, E.E. (1993). Fammine foods in eastern region of the Sudan. MSc. Thesis, University of Khartoum, Sudan.

Ahmed, S.E.(1995). Proximate Composition and Flour Quality of Wheat Cultivars Grown in Sudan. M.Sc. Thesis. University of Khartoum.

Aisien, A.O. (1982). Enzymic modification of sorghum endosperm during seedling growth and malting. *J. Sci. Food Agric., 33, 754-759.*

Aisien, A.O. and Palmer, G.H. (1983). The sorghum embryo in relation to the hydrolysis of the endosperm during germination and seedling growth. Ibid, 34, 113-121.

Al kalifa, A.O. (1998): Effect of cooking on the digestibility of sorghum kafrinis and its improvement. Ph.D. Thesis. Department of Food Science and Technology, Faculty of Agric. Sudan.

Ali, H. I.; and Horland , B. F. (1991): Effects of fiber and phytate in sorghum in weaning rates: A pilot study. *Cereal Chem. 68: 234-238.*

Ali, M.F. (1987). Wheat research and production in the Sudan. Technical Bulletin No. 5. Agricultural Reach. Corporation. Wad medani-Sudan.

Alias , C.; and G. Linden (1991): Food Biochemistry. New York, Ellis Horwood Ltd., 222PP.

Amerina, M. A. Pangborn, R. M. and Roessler, E.B. (1965). Principal of Sensory Evaluation of Food. Academic Press, NY. Cited from Minor Ingredients in Cookies, Maga, J. In: Cookie Chemistry and Technology, Kulp, K., (1994) chap. 9, pp: 179-209. The American Institute of Baking. Manhattan, Kansas.

Anon, (1993). Agricultural Situation and Out look. Vol. Ix. No.I. Department of Agricultural Economic and Statistics Planning and Agricultural Economics.

Anon, M.C.; Rubilo, A.; Leon,A. E. (1996). Use of triticale flours in cookies: quality factor, *Cereal Chem. 73(6): 779-784.*

Anon. (1987). Wheat Fact. In official Publications of the National Association of Wheat Grower 10:7-10.

AOAC (1980): Association of Official Agriculture Chemists. Official methods of analysis

Arbab, M.E. and El Tinay, A.H.(1997). Effect of Cooking and Treatment with Sodium Bisulphite and Ascorbic Acid on In vitro Protein Digestibility of Two Sorghum Cultivars. *Food Chem., 29, 339-344.*

Baba, K.S. (1995). Influence of reducing agents emulsifiers on the quality of cream crackers. M.Sc. Thesis, University of Mysore, Mysore, India.

Bachknudsen, K.F. and Munck, L. (1985). Dietary fiber contents and composition of sorghum based food. *J. Cereal Sci. 3: 153-164*.

Badi, S. M. (1973). Chemical characterization of sorghum & Millet grain and their use in baked products. M.Sc. Thesis. Dept. of Grain Science and Industry. Kansas University.

Badi, S.M. and Monawar, L.Y (1987). Sudanese sorghum and Millet directly, A pamphlet of Food Research Centre (FRC), Shambat, Sudan.

Badi, S.M.; Elfaki, H.A. and Perten, H. (1978). Evaluation of Sudanese wheat varieties. Sudan, *J. Food Science and Technology. 10:5-11.*

Baltsavias (a), A.; Jurgens, A. and Vanviliet, T. (1999). Large deformation properties of short doughs: Effect of sucrose in relation to mixing time. *J. Cereal Science. Academic Press. (29)1/2: 43-48.*

Baltsavias (b), A. Jurgens, A. and Vanviliet, T. (1999). Fracture properties of short Drought Biscuits. Effect of composition. *J. Cereal Science. Academic Press. 29(3): 235-244.*

Barber, S. (1972). Milled rice and changes during aging. Page 215 in: Rice: Chemistry and Tech D.F. Houston, ed. Am. Assoc. Cereal Chem., st. Paul, MN.

Barlow, K.K., Simmonds, D.H. and Kenrick, K.G. (1973). The Localization of water- soluble proteins in the wheat endosperm as revealed by fluorescent antibody techniques. Experientia 29: 229.

Belavady, B. and Gopalan, C. (1965). Production of black tongue in dogs by feeding diets containing Jowar (Sorghum Vulgare), Lancet, 2, 1220-1221.

Bennion, M. (1980). Introductory Foods. Brigham young University, Macmillan publishing co. 7th (ed.) USA.

Betschart, A.A. (1982). "World Food and nutrition problems". *Cereal Food World. 27: 562.*

Bode, C.E. (1954). Research at the soft wheat quality laboratory. Part 1. Trans. Am. Assoc. *Cereal Chem. 12:108.*

Brune, M. Rossander-Hulten, Hallberg, L. Erlandsson. M, Sandberg A.S (1992). Iron absorption from bread. Inhibiting. Effect of cereal fiber, phytate and insoitol phosphates with different number of phosphates groups. *Journal of Nutritional. 122: 442-449.*

Budair, A. Abdel, R. (1977). Chemical studies on some sorghum grains and their products. M.Sc. (Agric.). Thesis. University of Khartoum. Sudan.

Bullard, R.W.; Garrison, M.V.; Kilburn, S.R. and York, J.O. (1980). Laboratory comparisons of polyphenols and their repellent characterization in bird-resistant sorghum grains. *J. Agric. Food Chem. 28: 1006.*

Champau, S.R. and Carter, L.P. (1976). Crop production. Principle and Practices, W. H. Freeman and company, San Francisco. United State of America. 247-249.

Chaven, J.K. and Kadam, S.S. (1989). Nutritional improvement of cereals by fermentation. *CRC critical Reviews in Food science and Technology. 28(5): 349.*

Chiroma, Z.B. (1990). Sorghum milling at Zaki flour Mills. In: Industrial Utilization of Sorghum in Nigeria (ICRISAT). Zoria, Nigeria, 16-17.

Chung, O.K. and Pomeranz, Y. (1985). Functional and nutritional characteristics of cereal proteins. P 169-231. In: Digestibility and amino acid availability in cereal and oils seeds. Fin by, J.W. and Hopkins, D.T. (eds), American Association of Cereal Chemists, Inc.; st. Paul, MN, USA.

Collier, J.W. (1963). Caryopsis development in several grain sorghum varieties and hybrids. *Crop Sci. 3: 419-422*.

Cosgrove, D.J. (1966). Chemistry and biochemistry of inositol polyphosphates. Reviews in pure applied chemistry 16: 209.

Culwick, G.M. (1951). Diet in the Gezira irrigated area, Sudan, Sudan survey depth. No. 304.

Curley, L.P. and Hoseney, R.C. (1984). Effect of corn sweetness on cookie quality. *Cereal Chemistry, Inc. 61: 274.*

D'appolonia, B.L. and Young's, V.L. (1978). Effect of bran and high protein concentrate from oats on dough properties and bread quality, *Cereal Chem. 55: 736-740.*

Davies, N.T. and Nightingale, R. (1975). The effects of phytate on intestinal absorption and secretion of Zinc and whole body retention of zinc, copper, iron and manganese in rats. *British Journal of Nutrition. 34: 243-258.*

De Boland, A.R.; Garner, G. and O'Dell, B.L. (1975). Identification and properties of "Phytate" in cereal grains and oil seed products. *J. Agricultural and Food Chemistry. 23: 1180.*

Deatherage, W. L., MacMasters, MajelM., and Rist, C. E. (1955). Trans. Am Assoc. Cereal Chemists. 13:31. Cited from Cereal Science Today, 13(10): 382-292. The function of starch in dough, by Medcalf, D. G. and Gilles, K. A. (1968).

Defrancisco, A.; varriano, Marston, E. and Hoseney, R.C. (1982). Hardness of pear millet and grain sorghum. *J. Cereal Chem. 59:5.*

Desikachar, H.S.R. (1981). Pearling and Milling studies on sorghum. In: Processing of the International Symposium of Sorghum Grain Quality. ICRISAT, centre, Patan-cheru, India. P 194-199.

Deyoe, C.W. and Shellenberger, J.A. (1965). Amino Acid protein in sorghum grain. *J. Agric Food Chem.* 13: 446-450.

Doherty, C.; Faubion, J.M. and Rooney, L.W. (1982). Semi automated determination of phytate in sorghum and sorghum products. *Cereal Chem. 59(5): 373-378.*

Doherty, C.; Rooney, L.W. and Faubian, J.M. (1981). Phytin content of sorghum and sorghum product. In: Processing of International Symposium of Sorghum Grain Quality ICRISAT, Centure, Patan chenu, India. 329-333.

Dyer, T.A. and Novellie, L.(1966). Kaffir corn melting and brewing studies. XVI. The distribution and activity of alpha and beta amylases in germination kaffir corn. *J.Sci. Food Agric. 17, 449-454.*

Earp, C.F. Doherty, C.A. and Rooney, L.W.(1983). Fluorescence microscopy of the pericarp, aleurone layer and endosperm cell walls of three sorghum cultivars. *Cereal Chem. 60: 408.*

Egan, H.; Kirk, R. and Sawyer, (1981).Person's Chemical Analysis of Food. 8th edition. Longman Scientific and Technical. London.

Eggum, B.O.; Back Knudsen, K.E.; Munch, L.; Axtell, J.O. and Mukuru, S.Z. (1981). Milling and Nutritional value of sorghum in Tanzania. In: Proceedings of the International Symposium an Sorghum Grain Quality, ICRISAT, Center, Patan-cheau, India, pp. 211-226.

Eggum, H. (1983). Sorghum, 2nd. ed Longman. Scientific and techinical. Harlow, Essex, England.

Eh, E. (1999). Biscuit-making potential of millet/ Pigean pea flour blends. *Plant Food Hum Nut, 54(1): 21-7.*

Elamin, Y. K. (2002). Chemical changes of biscuits ingredients during storage. M.Sc.Department of Chemistry, Faculty of Science, Sudan.

Eliasson, A.C. and Larsson, K. (1993). Cereal in Bread Making. New York, Marcel Dekkar, Inc., 376 pp.

Elkhalifa, A.O.(1993).Effect of fermentation and germination on the protein fractions, Tannin content and invitro protein Digestibility of low and high Tannin cultivars of sorghum. M.Sc. Thesis, University of Khartoum, Sudan.

Elkhalifa, A.O. (1998). Effect of cooking on the digestibility of sorghum kafirins and its improvement. Phd. University of Khartoum, Sudan.

Elnour, N.A. (1997).Biochemical characterization of sorghum storage protein (Kafirins). Ph.D. (Agric.) Thesis. University of Khartoum, Sudan.

ElTinay, A.H.; Abdelgadir, A.M. and El Hadia, M. (1979). Sorghum fermented Kisra bread- Nutritive value of Kisra. *J. Sci. Food Agric. 30: 859-863.*

FAO, (1970).Wheat in Human Nutrition. Food and Agric. Organization of the United Nations, No 23, Rome. Italy.

FAO, (1981). “Improvement of nutritional quality of food crops” Food and Agricultural Organization of the United Nations. Plant Production and Protection Papers. 34, Rome, Italy.

FAO, (1986). Food and Nutrition Paper, 14/8, Manuals of Food Quality Control, Food Analysis, 8 quality, Adultration and test of identify, UN, Rome.

FAO, (1991).FAO year book, Food and Agriculture Organization of the United Nations, Rome Italy. vol. 4, No. 25.

FAO, (1992). Maize in human nutrition “Food and Agric. Organization of the United Nations”, Rome Italy. No. 25.

FAO, (1995). Sorghum and Millet in human nutrition. FAO, food and nutrition series No. 27. Rome, Italy. P: 55-60.

FAO, (1997). Human nutrition in the developing World. Rome Italy, No. 29, p 255-303.

FAO, (1998). Utilization of tropical foods.Cereals 47/1, Food and Agricultural Organization of the United Nation , Rome,

FAO, (1999). Fermented cereals. A global perspective services bulletin, Food and Agriculture Organization. Rome.,United Nation. No. 138.

FAO, (2000). FAO Production. United Nations. Vol. 54.

Faridi, H., and Finley, J. W. (1989). Improved wheat for baking. Critical Review in Foods Science and Nutrition 28(2), 175.Cited from Functionality of Ingredients in Cookie System., Kulp, K (1994). In: Cookie Chemistry and Technology, Kulp, K., chap. 10, pp: 211-275. The American Institute of Baking. Manhattan, Kansas.

Fellows, P. and Hampton, A. (1992). Small-scale food processing-A guide for appropriate equipment intermediate technology publication (103-105 South amptan Raw, London, WCIB UHH, UK.

Freeman, J.E.; Kramer, N.W. and Watson, S.A. (1968). Gelatinization of starch from corn (*Zea mays L.*) and (*Sorghum bicolar L. Monech*). Effect of genetic and environmental factors. Crop. Sci. 8, 409-413.

Froning, G. W. (1994). Eggs and Eggs Substitutes. In: Cookie Chemistry and Technology, Kulp, K., chap. 8, pp: 167-177. The American Institute of Baking. Manhattan, Kansas.

Gallagher, E.J. (1984). Cereal production. Royal Society Dean, Faculty of Agriculture, University Lollege, Dublin.

Geer, E.N. and Stewart, B.A. (1959). The water absorption of wheat flour, relative effect of protein and starch. *J. Sci. Food Agr. 10, 248-252*.

George, E.L. (1973). Wheat production and utilization. pp. 108-118. The AVI Publishing Company INC Westport Connecticut.

Glennie, L.W. (1983).Polyphenol changer in sorghum grain during malting. *J. Agric. Food Chem. 36: 1295.*

Gopinath, L. (2002). Food allergy and intolerance.The news letter of the International Food Information Service (IFIS). Food Science and Technology Abstact.

Gorden, D. (1991). Defining dietary fiber. *Cereal Chem. 44(2), 74*.

Greenaway, T.W. (1969). The sprouted wheat problem the search for solution. *J. Cereal Science Today. 14: 390-395*.

Gregory, M.; Glenn, R. and Saunders, M. (1990).Physical and structural properties of wheat endosperm associated with grain texture. *J. Cereal Chem. 67: 176-182.*

Grosh, G.M. and Milner, M. (1959).Water penetration and internal cracking in tempered wheat grain. *J. Cereal Chem.. 36: 260-263.*

Haard, N. F. and G. Chism, Eds (1996). Characteristics of edible plant tissues. Food chemistry. New York, Marcel, Dekker, Inc. pp. 943-1011.

Haldore, H.; Norman, E.B. and Anderson, R.G. (1982). Wheat in the Third World Weslerleur Press Bounder Colorado.

Hamad, H. A. (1994). A study of the hardness phenomenon in sorghum grains and its effect on the nutritional quality of composite flour bread and insect infestation. M.Sc. Thesis, University of Khartoum, Sudan.

Haris, H.B.; Cummins, D.G. and Burnd, R.E. (1970). Tannin content and digestibility of sorghum grain as influenced by bagging. *Agron. J. 62: 633.*

Harper, F. (1983). Priciples of Arabe crop Production, Introduction to crop production, chap.(1), Granada Publishing linited. London, Toronto, Sydeny, Newyork.

Harrel, C.G. (1959). Manufacture of prepared mixes In: The chemistry and technology of cereals as food and feed. West part, CONN, Avi. Publishing company, Inc P: 226-230, Chap. 2.

Holland, B.; Unwin, D. and buss, D.H. (1988). Cereals and products. Third supplement to the composition of foods. Royal Society of chemistry, London.

Hoseney, R. C. (1986). Principles of cereal science and technology. Department of grain Science and Industry. American Association of Cereal Chemists, Inc. USA, Kansas.

Hoseney, R.C., Finney, K.E.; Pomeranze, Y. and Shorgen, M.D. (1969). Functional (bread) making biochemical properties of wheat flour component. III characterization of gluten protein fraction obtained by ultra centrifugation. *J. Cereal Chem. 46:126-131.*

Hoseney, R.C.; Davis, A.B. and Harbers, L.H. (1974).Pericarp and endosperm structure of sorghum grain by scanning electron microscopy. *Cereal Chem. 51:552-558.*

Hoseney, R.C.; Finney, K.F.; Pomeranz, Y. and Shogen, M.D. (1971). Functional (bread making) and biochemical properties of wheat flour components VIII. *Cereal Chemistry, 48: 91*.

Hulse, J. H.; Lating, E. M. and Pearsoin, O.E. (1980). Sorghum and millet. Their composition and nutritive value. International Development Research Center, Ottawa, Canada .

ICC (1983). International Association of Cereal Chemistry.

Idow, A. (1989). Bread from composite flours. In: Industrial utilization of sorghum summary proceeding of symposium on the current status and potential of industrial uses of sorghum in Nigeria, Dec. 1989. Kano, Nigeria, Western Africa. Sorghum: Improvement program (WASIP), ICRISAT.

Ihekoronye, A.I. and Ngoddy, P.O. (1985).Integrated Food and Technology for the Tropics. Mac Millan Publisher, London.

Inamdar, D.G.; Desai, B.B. and Sangle, P.B. (1984). Proximate composition and protein fractions of some promising sorghum cultivar. J. Maharashtra. Agri, Univ. 9(3): 263-265.

Ishag, H. M.; and Ageep, O.A. (1991). The physiology of grain yield in wheat in an irrigated tropical environment. 27: 71-77.

Jambunathan, R. and Subramanian, V. (1988). Grain quality and utilization of sorghum and pearl millet. In: Biotechnology in tropical crop improvement. Proceedings of the International Biotechnology Workshop, Patancheru, ICRISAt, India, p: 133-139.

Jenkins, D.J.A.; Wolever, T.M.S. and Venketeshwer Rao, A. (1993). Effect on blood lipids of very high in takes of fiber in diets low in saturated fat and cholesterol. N. Engl. J. Med. 329: 21.

Jones, R. W. and Beck with, A. C. (1970). Proximate composition and protein of three grain sorghum hybrids and their dry-mill fractions. *J. Agric. Food Chem. 18: 33-36.*

Kasarda, D.D., Nimmo, C.C., and Kohler, G.O. (1978). Proteins and amino acid composition of wheat fractions. In: Wheat Chemistry and Technology, 2nd ed., Y, Pomeranzed., pp.227-299, St. Paul, MN: AACC. Cited from Functionality of Ingredients in Cookie System, Kulp, K (1994). In: Cookie Chemistry and Technology, Kulp, K., chap. 10, pp:211-275. The American Institute of Baking. Manhattan, Kansas.

Kent, N.L. and Evers, A.D. (1994). Technology of cereals. 4th (ed.). Pergman Elsevier science. The Boulevard, Longford Lane, Kidlington, Oxford, UK.

Kent, N.L. (1983). Technology of cereals. An introduction for student of food science and agriculture. 3rd (ed.) Pergman Press ltd.

Kent-Jones, D.W. and Amos, A.J. (1967). *Modern Cereal Chemistry*, 4th edition, Northern Pub. Co. Ltd. Liverpool.

Khatir, A.M. (1990).Chemical and rheological characterization of traditionally extracted millet starch. M.Sc. Thesis. University of Khartoum, Sudan.

Kirleis, A.W. and Crossy, K.D. (1981). Sorghum hardness comparison method for its evaluation. In: Processing of the International Symposium of Sorghum Grain Quality. ICRISAT, Centre, Pantan-Cheau, India. P. 231-241.

Kissell, L.T.; Marshal, B.D. and Yamazaki, W.T. (1973). Effect of variability in sugar granulation on the evaluation of flour cookie quality. *Cereal Chem., Inc. 50: 225*

Klare, S. M. (1964). Fatty acids, Part three, 2nd, Interscience Publisher, a Division of John Wiley & Sons, cited from: Elamin, Y.K. (2002). Chemical changes of biscuits ingredients during storage. M.Sc. University of Khartoum. Sudan.

Klopfenstein, C.F. and Hoseney, R.C. (1995). Nutritional properties of sorghum and millets. Pages 125-168. In: Handbook of sorghum and Millets chemistry and technology. David, A.V. Dendy-Oxford, United Kingdom.

Kordylas, J.M. (1991). Processing and preservation of tropical and subtropical foods. Macmillan Education Ltd. Hounmills, Basing Stoke. British.

Kulp, K. (1994). Cookie Chemistry and Technology. The American Institute of Baking. Manhattan, Kansas.

Lathan, M.C. (1997). Human Nutrition in the Developing World. FAO, 29: Ithaca "New York" USA, Rome.

Lee F. A. (1975). Basic Food Chemistry, AVI Publishing Co., Westport, CT pp 87-114.

Lehrfeld, J. (1989). High performance liquid chromatography analysis of phytic acid on a pH stable mono-porous. *Cereal Chemistry 66(6): 510-515.*

Lorenz, K. (1983). Tannins and phytate contents in proso millets (*Panicum miliaceum*). *Cereal Chemistry 60(6): 424-426.*

Mac Ritchie, F. (1980). Physical aspects of some problems in wheat research. Advances in Cereal Science and Technology. 3:271. (Y. Pomeranzed.); American Association of cereal Chemists. St. Paul. Mn.

Maga, J. (1994). In: Minor Ingredients in Cookies. In: Cookie Chemistry and Technology, Kulp, K., chap. 9, pp: 179-209. The American Institute of Baking. Manhattan, Kansas.

Maga, J. A (1982). Phytate : It's chemistry, occurrence, food interaction nutritional significance and method of analysis. *J. Agric. and Food Chemi. 30(1): 1-9.*

Mahamoud, A.M. and Awad, E.A. (1975). Sorghum. Introduction. First agricultural conference. Ministry of Agric. and Food and Neutral Resources, Sudan.

Mahoney, A. W. (1982). Mineral contents of selected cereals and baked products. *Cereal Chemists. 27(4):147.*

Manley, D. J. B. 1983. Technology of Biscuits, Crackers and Cookies, Ellis Horwood, Ltd., Chickesters U. K. pp. 446. Cited from Functionality of Ingredients in Cookie System., Kulp, K (1994). In: Cookie Chemistry and Technology, Kulp, K., chap. 10, pp: 211-275. The American Institute of Baking. Manhattan, Kansas.

Marlett, J.A; Cheung, T.F. (1997).Database and quick methods of assessing typical dietary fiber intakes using data for 228 commonly consumed foods. *J. Am. Diet. Assoc. 1148-97:1139.*

Martin, F.W. (1984). Hand book of Tropical Food Crops. CDC Press, Boca Rotan, 8.Fl.

Matthews, R. H.; and Drawson, E. H. (1963). Performance of fats and oils in pastry and biscuits. *Cereal Chemists, Inc. 40:291.*

Matz, S. A., (1968). Cookie and Cracker Technology, AVI Publishing CO., INC, Westport, Connecticut.

Mazhar, H. (1993). Characterization of the alcohol extractable proteins (kafirins) of *sorghum bicolor* (L.) Moench. Ph.d. Thesis, University of Mysore, Mysore, India.

Mc Cance, R.A.; and Widobwson; E.M. (1935). Phytin in human nutrition. *Biochemistry Journal 298:2694.*

Mc Cluggage, M. E. (1973). Factors influencing the pearling test for kernel hardness in wheat. Cereal Chem. 20:686.

Medcalf, D.G., and Gilles, K.A. (1968) *Cereal Chem. 42: 558.* Cited from *Cereal Science Today*. 13:10 pp 382-392. The Function of Starch in Dough, by Medcalf, D.G. and Gilles, K.A. (1968).

Meyer, L.H. (1960).Food chemistry. Lillon Education Publishing, Inc, West part, Ct.

Miller, D. F. (1958). Composition of cereal grain and forages. NAS/ NRC. Pub. No. 585, Washington, D.C.

Mohammed, A.O. (2000). The role of sorghum flour starches (amylase, amylopectin) in composite bread quality. University of Khartoum. H.Sc. Sudan.

Mohammed, A.S. (1992). Production and utilization of wheat in the Sudan. M.Sc. Thesis. University of Khartoum.

Morison, W.R., Miligan, T.P., and Azudin, M.N. (1984). A relationship between the amylose and lipid contents of starches from diploid cereals. *J. Cereal Sci. 2:257.*

Morris P. Jacobs, (1958). The chemical Analysis of Food & Food Production, 3rd edition, D. Van Nostrand Co., Inc., Princeton, New Jersey.

Munck, L.; Bachkundsen, K.E., and Axtell, J.D. (1981). Milling processes and products as related to kernel morphology. In: Processing of the International Symposium of Sorghum Grain Quality. ICRISAT, Centre Patan-cheru, India, p:200-209.

Murty, D.S. and Rooney, L.W. (1981). Color of sorghum food products. In: Processing of the International Symposium of Sorghum Grain Quality. ICRISAT, Centre Patancherue, India, p: 323-333.

Mustafa, A. I. (1973). Production of bread composite flour. *Sudan Journal of Food and Technology. Vol5. P41.*

Mustafa, A.I. (1978). Sorghum milling- A comparative study. *J. Fd. Sci. Technol. 10:77-82.*

Mustafa, A. I.; Mahgoub, S.; and Abdo, S. (1971). Ginger biscuits from Dura (Sorghum Vulgare). *Sudan Journal of Food and Technology. 3: (30-31).*

Neucere, N.J. and Sumrell, G. (1980). Chemical composition of different varieties of grain sorghum. *J. Agric. Food Chem. 28: 19-21.*

Ngddy, P.O. and Ihekoronye, A.I. (1985). Integrated Food Science and Technology for the Tropics. Nigeria, Macmillan Publishers.

Nishibori, S. and Kawakishi, S. (1992). Effect of various sugars on the quality of baked cookies. *Cereal Chem. Inc: 69: 160-163.*

NRC/NAC, (1982). United States-Candian tables of feed composition, third revision. National Academy Press, Washington, D. C.

Obiana, W.A. (1990). Dry milling sorghum. In: Industrial utilization of sorghum in Nigeria. Summary proceeding of symposium of the current status and potential of industrial uses of sorghum Nigeria 4-6 Dec. Kano, Nigeria, ICRISAT, India. p 13.

Oltaunji, O.; Adesing, A.A. and Koleoso, O.A. (1989). Use of sorghum as composite flour in Baking. In: industrial utilization of sorghum in Nigeria. Summary proceeding of symposium of the current status and potential of industrial uses of sorghum Nigeria 4-6 Dec. Kano, Nigeria, ICRISAT, India. p 13.

Orewa, G.O., and Iloh, A. (1989). Current status of composite flour technology and prospects with particular reference to the production of biscuits in Nigeria. In: Industrial utilization of sorghum in Nigeria. India- ICRISAT.

Orth, R. A. and Bunshuk, W. (1972). A comperative study of the proteins of wheat of diverse baking qualities. *J. Cereal Chem. 41:268-275.*

Pareds-Lopez Barba. Rosa, A.P.; and Gonzalez-cost auedau. J. (1987). Physiochemical and functional properties of Mexican wheat flour for break making. *J. Cereal Food World. 32: 602-608.*

Paul, A.A. and Southgate, D.A.T. (1978). MC Canc Widdow son's. The composition of food. 4^{th} ed. HMSO, London.

Pearson, D. (1976). The chemical analysis of food, 7^{th} (ed.). Churchill, Livingstone.

Peplinski, A.J; Paulsen, M.R., Bouzaher, A. (1992)."Physical, chemical and dry milling properties of corn of varying density and breakage susceptibility" *Cereal Chem. 69(4): 397-400.*

Perten, H. (1977). UNDP/FAO sorghum processing project in Sudan. In: Proceeding of symposium on sorghum and millets for human food. Tropical Products Institute, London.

Pickett, R.C. (1967). Inheritance and improvement of protein quality and content in sorghum vulgare, 1^{st}. ed .Purdue University, USA.

Pomeranz, Y. and Chunge, O.K. (1978). Interactions of lipids with protein and carbohydrate in bread making. *J. Am. Oil Chem. Soc. 55: 285.*

Pomeranz, Y. and Dikman, F. (1983): Minerals and protein content in hard red winter wheat flour. *J. cereal Chem. 60:80-82.*

Pomeranz, Y. and Bechtel, D.B. (1978). Structure of cereal grains as related to end–use properties. *Post-harvest Biology and Biotechnology* H.O. Hultin and M. Milner, eds. Westport, CN, Food and Nutrition Press, inc., PP. 244-266.

Pratt, D.B., (1971). In Wheat Chem. and Tech. Pomeranz, 4. (ed.). PP. 201-225 Am. Associ of cereal chem. st. Paul Minnisota.

Priyolkar, V.S. (1989). Use of sorghum flour in biscuits and waffer production: the Nasco Experience. In: Industrial Utilization of Sorghum, Summary Proceeding Symposium on the Current Status and Potential of Industrial Uses of Sorghum in Nigeria, Dec. (1989) Kano, Nigeria, West Africa sorghum improvement program (WASIP), ICRISAT.

Radhakrishnan ,M. R., and Sivaprasad, J. (1980). Tannin contents varieties of sorghum and their role of in Fe-bioavailability. *J.of Agric. and Food Chemistry 28:55.*

Reddy, N.R. and M.D Pierson (1994). "Reduction" in plant foods by fermentation" Food Research International 27:281.

Reddy, N.R.; Pierson, M.D.; Sathe, S.K. and Salunkhe, D.K. (1989). Phytates in cereals and legumes. Boca Raton, FL, CRC. Press.

Reichert, R.D.; Youngs, C.G. and Oamah, B. D. (1981). Measurement of grain hardness and dehulling quality with multi sample, Tangential abrasive dehulling device of the international. In: Processing of the International Symposium of Sorghum Grain Quality. ICRISAT, center, Patan-cheau, India. P: 186-193.

Rooney, L.W. and Clark, L.W. (1968). The chemistry and processing of sorghum grain, *Cereal Science Today 13: 259*.

Rooney, L.W. and Serna- Saldivar, S.O. (1991). Sorghum. Hand book of cereal and technology. K.J. Lorenz and K. Kulp. Ed. Marcel Dekker. New York.

Rooney, L.W. and Sullins, R.D. (1977). The structure of sorghum and relation to processing and nutritional value. In: Proceedings of symposium on sorghum and millets for Human food , Tropical Products Institute. London. UK.

Rooney, L.W. (1973). A review of the physical properties composition. In: Industrial uses of cereal. (Y. pomeranzed). American Association of Cereal Chemists, st. Paul, Minnesota. PP. 316-342.

Rooney, L.W. and Kirlies, A.W. (1980). Trip report of Mali and Upper Volta. INRSORM.L/25pp.

Rooney, L.W. and serna–Saldivar, S.O. (1991). Sorghum. In: Handbook of cereal science and technology, K.J. Lorenz & K. Kulp, eds. page 233-270. New York. Marcel Dekker.

Salunkhe, D.K, Chavan, J.K., and Kadam, S.S. (1990). Dietary Tannins: Consequences and Remedies. Boca Raton, FL, CRC press.

Sanders, E.H. (1955). Development morphology of the grain sorghum. *Cereal Chem. 32:12-25.*

Schanot, M.A. (1981a). Sweeteners. Technical Bulletin, Vol, III, No.3. American Institute of Baking. Manhattan, Kansas, March.

Schanot, M.A. (1981*b*). Sweeteners: Functionality in cookies and crackers. Technical Bulletin Vol.III, No. 4. American Institute of Baking, Manhattan, Kansas.

Schanot, M.A. (1981). Sweeteners: Functionality in cookies and crackers. American Institute of Baking Research Technical Bulletin. 3(4), Manhattan KS.

Scheuring, J.F.; Sidible, S.; Rooney, L.W. and Earp, C.F. (1983). Sorghum pericarp thickness and its relation to decortications in wooden mortar and pestle. *Cereal Chem. 60(1): 86-89.*

Schmidt, J.W. (1973). In wheat production and utilization. George. I (ed.) pp.8-30, AVI publishing company INK.

Schruben, L.W. (1979).Principal of wheat protein pricing. In: wheat protein conference, Agrc. Res. Manual ARMg, Sci. & Ed. Admin, U.S.D.A

Selvendran R.R. (1984). The plant cell wall as a source of dietary fiber Chemistry and structure. *American Journal of Chemical Nutrition. 39: 320-327.*

Simwemba, C.G., Hoseny, R.C., Varriano Marstan, E., and Zelenznak, K.(1984). Certain vitamins and phytic acid content of pearl millets. Pennisetum American cern (l) leek. *Journal of Agric., and Food Chemistry. 32(1): 31-34.*

Singh, R. Axtell, J.D. (1973). High lysine mutant gene (h1) The improve protein quality and biological value of grain sorghum. *Crop Sci. 13: 535-539.*

Sirokhman, L.V. and Konoval chuk, A.V. (1991). Influence of packing material on storability of biscuits. Food Sci. of technology: No. 24(44-47), Food Sci. of Tech. (abstract) 24-1992.

Smith, W. H. (1972). Biscuit, Crackers and Cookies, Vols, 1, 2, 3, Magazines for Industry, Inc., New York, N.Y. Cited from Functionality of Ingredients in Cookie System., Kulp, K (1994). In: In: Cookie Chemistry and Technology, Kulp, K., chap. 10, pp: 211-275. The American Institute of Baking. Manhattan, Kansas.

Southgate, D.A.T. (1993): Cereals and cereal products. In: Human nutrion and dietetics. Garrow, J.S. and James, W.P.T. 9th (ed). Longman Singapore.

Spies, R.D. and Hoseney, R.C. (1982). Effect of sugars on starch gelatinization. *Cereal Chem. Inc: 59: 128*

Stauffer, C.E. (1998). Fats and oils in bakery products. *Cereal Chemists. Inc. 43(3): 120-130.*

Stevenson, G.T. and Miller, C. (1960). Introduction to foods and nutrition. John Wiley of Sons, Inc. New York. London. Sydney.

Sukkar, M.Y. (1985). Human Nutrition for Medical Studies and Applied Health Science. 1th (ed.). Thaca, Press 13 South Work Street. London.

Sullins, RD., Rooney, L.W. and Riggs, J.K. (1971). Physical changes in the Kernel during reconstitution of sorghum grain. *J. cereal Chem. 48: 567-575.*

Tothill, J.O. (1952). “Agric. in the Sudan.” London Oxford Univ. Press. P: 319-220.

Tran, T.L.; DeMan, J.M. and Rasper, V.F. (1981). Measurement of corn hardness. *J. Can. Inst. Food Sci. Tech. 14:42.*

UNECA (1985): United Nations Economic Commission for Africa. Technical compendium on composite flour, Addis Ababa, Ethyopia. P: 11-68.

USDA/HNIS, (1989). Composition of Foods: Cereal grains and pasta. U. S. Dep. Agric. Handb. 8-20 U.S. Govt. Printing Office, Washington, D.C.

Vogel, S., and Graham, M. (1979). Sorghum and millet. Food production and use. Report of workshops 4-7 July1978, Narrobi, Kenya. Ottawa, Canada: IDRC. PP. 64.

Wade, P. (1988). Biscuits, Cookies and Crackers, Vol., I. The Principles of the Craft. Elsevier Applied Science. London and New York pp. 176. Cited from Functionality of Ingredients in Cookie System., Kulp, K (1994). In: Cookie Chemistry and Technology, Kulp, K., chap. 10, pp: 211-275. The American Institute of Baking. Manhattan, Kansas.

Wall, J.S., and Blessin, C. W. (1970). Composition of sorghum plant and grain. In Sorghum Production and utilization. pp. 144-145, 118-120. Published by the AVI Publishing Company, Inc, West Port Connecticut.

Walton, P.D. (1988). Principals and practices of plants. Prentice Hall, division of Simon A schuster, Englewood Chiffs, New Jersey. USA.

Whistler, R.C. and Passchal, E.F. (1967). Starch chemistry and technology, Industrial aspect, Academic Press, NewYork and London. Vol.2.

Whistler, R.L., and smart, L.L (1953). Starch poly saccharide chemistry .229-275. Academic press, New York.

Wolf; W., Weddon, D. Loewe, R., Lorenz, K. (1979). Natural levels of nutrient in commercially milled wheat flours III. Mineral Analysis. *Cereal Chem. 57(1):65-69.*

Wood, P.J., Braaten, J.T., Scott, F.W, Riedel, K.D., Wolynetz, M.S. and Collin, M.W. (1994). Effect of dose and modification of Varian's properties of oat germ gum on plasma glucose and insulin following an oral glucose load . Brit. *J.Nutr.72:731.*

Woodheed, S.; Padgham, D.E, and Bernays, E.A. (1980). Insect feeding on different Sorghum cultivars in relation to cyanide and phenolic acid content. Ann. Appl. Biol. 95:151.

Yamazaki, W.T., and Donelson, J.R. (1983). Kernel hardness of some U.S. wheats. *Cereal Chemistry. 60(5): 344-350*

Yamazaki, W.T., Willimas. P.C.; Ranum, P.M. and Kulp, K. (1979).Natural levels of nutrients in commercially milled wheat flours. I. Description of samples and proximate analysis cereal. *Cereal Chem. 57(1). 54-58.*

Yashajahu, P. and Clifton, E.M. (1971). Food Analysis Theory, Practice, The AVI Publishing Co., Inc. Cited from: Chemical changes of biscuits ingredients during storage, Elamin, Y.K. (2002). M.Sc. Thesis. University of Khartoum, Sudan.

Yousif, Y.B. and Magboul, B.I. (1972). Nutritive value of Sudan food stuff. Part (1): Sorghum valgure Dura. Sudan. *J. of Food Sci. and Technology. 4:39-45.*

Zeleny, L. (1971). In wheat chem. and tech. Pomeranze Y. (ed) 2nd edition. Am. Associ. of Cereal Chem. St. Paul Minnisota. PP: 19-140.

Zoran, B. (1982). On the effect of composition and structure of maize (Kernel) endosperm, on the process of double enzyme hydolysis maize research institute. PP: 184-185.

Zuber, M.S. (1965). In starch: chemistry and technology, R.L Whistler and E. F. Paschall. Eds.; vol. I, p. 43. Academic Press: New York. Cited from: *Cereal Science Today*. 13:10 pp: 382-392. The Function of Starch in Dough, by Medcalf, D. G. and Gilles, K. A. 1968.

Table (1.a). Chemical composition of Australian & Indian wheat flours and Fakimustahi sorghum flour

	Moisture (%)	Ash (%)	Protein (%)	**Fat (%)**	**Carbohydrates** * (%)	Energy* (Kcal/100g)	(M
flour:							
alian xt.)	13.45±0.05[a]	0.518±0.01[c]	10.97±0.09[b]	1.73±0.03 [c]	73.332	352.778	
	10.67±0.15 [b]	0.79±0.05[b]	10.30±0.14[c]	2.85±0.03 [b]	75.390	368.410	
lour							
hi	7.43 ± 0.15 [c]	1.41±0.03[a]	15.47±0.27[a]	3.01±0.09 [a]	72.680	379.690	
	0.253	0.179	0.368	0.109	*	*	

Means in the same column with the same letters are not significantly different at level P > 0.05 according to CRD.

* : Without mean separation.

Table (3) Dough rheological properties of Australian and Indian wheat flours

Table (3.a) Farinogram reading:

Flour Blends*	**Water absorption (%)**	**Dough development time (min)**	*Dough Stal (min)*
Australian (72-75% Ext.):			
Control W.F.	59.9	2.7	17.2
80% W. F. + 20% sorg.	55.6	2.3	13.8
60% W. F.+ 40% sorg.	51.1	2.2	9.3
40% W. F+ 60% sorg.	48.6	1.6	9.0
Indian (82% Ext.):			
Control W.F.	63.1	1.9	14.1
80% W. F.+ 20% sorg.	57.0	1.4	8.6
60% W. F. + 40% sorg.	43.2	1.2	5.4
40% W. F. + 60% sorg.	43.2	1.0	4.1

* W.F. : Wheat flour, Sorg.: Sorghum flour.

Table (3.b) Extensogram reading :

r Blends *	Energy (cm^2)			Resistance (cm)			Extensibility (cm)			
	45 min	90 min	135 min	45 min	90 min	135 min	45 min	90 min	135 min	45 min
/.F. (72-75%Ext.):										
-	121	140	157	495	630	670	176	167	162	2.8
- 20% sorg.	62	71	77	357	420	493	130	126	119	2.7
40% sorg.	55	57	58	310	380	315	114	104	104	2.7
60% sorg.	41	52	50	375	392	373	75	91	90	5.0
(82% Ext.):										
-	55	68	69	310	458	519	118	107	94	2.6
20% sorg.	47	38	36	300	358	310	96	96	86	3.1
40% sorg.	29	31	21	292	315	300	90	83	80	3.2
60% sorg.	28	28	25	285	290	280	86	80	81	3.3

heat flour, Sorg. : Sorghum flour. Rm. : Maximum resistance. Ex. : Extensibility.

Table (5). Organoleptic evaluation of biscuits from Indian wheat flour using different types of oils and fats.

Table (5.a)

Type of oils	General Feature	Flavor	Taste	Tex
Ground nut	52^{a}	43^{a}	44^{a}	4
Sesame	46^{b}	43^{a}	42^{a}	3
Sunflower	32^{b}	39^{a}	39^{a}	3
Cotton seed oil	20^{c}	25^{b}	25^{b}	2

Table (5.b)

Type of fats and oil	General Feature	Flavor	Taste	Tex
Ghee	32^{a}	40^{a}	42^{a}	3
Cotton Seed	58^{b}	55^{b}	55^{b}	6
Alaseel	41^{a}	32^{a}	29^{a}	3
Shortening	19^{c}	23^{c}	23^{c}	1

Any two sum of ranks having different superscript letter in the same column differ significantly ($P \leq 0.05$).

Lower score means better quality.

Table (6). Effect of Fats (Shortening & Alaseel) on Chemical composition of biscuits made from wheat and sorghum composite flours before and after storage

Table (6.a). Biscuits from Indian Wheat flour

Treatments	**Moisture** (%)		Ash (%)		**Protein** (%)		Fat (%)		Carbohyd-rates* (%)		
	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St	A. St	
<u>Shortening:</u>											
Control Wheat flour	4.445^{b}	4.500^{a}	0.802^{a}	0.803^{a}	8.517^{a}	8.521^{a}	18.990^{a}	18.988^{a}	67.246	67.188	47[illegible]
20% sorg. 80% W.F.	4.195^{f}	4.404^{c}	0.905^{a}	0.889^{a}	9.163^{a}	8.844^{a}	17.199^{a}	17.197^{a}	68.538	68.666	46[illegible]
40% sorg. 60% W.F.	3.996^{I}	4.202^{f}	1.042^{a}	1.044^{a}	9.418^{a}	9.408^{a}	17.448^{a}	17.441^{a}	68.096	67.905	46[illegible]
60% sorg. 40% W.F.	3.897^{k}	4.046^{h}	1.162^{a}	1.164^{a}	9.652^{a}	9.636^{a}	18.151^{a}	18.150^{a}	67.138	67.022	47[illegible]
80% sorg. 20% W.F.	3.800^{n}	4.000^{i}	1.282^{a}	1.285^{a}	9.945^{a}	9.935^{a}	18.729^{a}	18.726^{a}	66.244	66.054	47[illegible]
100% sorg. 0% W.F.	3.505^{q}	3.516^{q}	1.399^{a}	1.382^{a}	9.673^{a}	9.704^{a}	18.401^{a}	18.736^{a}	67.022	66.662	47[illegible]

Means in the same column with the same letters are not significantly different at level (P > 0.05) according to DMRT.
B. St :Before storage. A. St. : After storage. Sorg. :Sorghum flour. W.F. :Wheat flour. * : Without mean separation

Continue table (6.a)

Moistur (%)		Ash (%)		Protein (%)		Fat (%)		Carbohyd-rates* (%)		Energy* (Kcal/100g)		Fat acidity (Mg KOH/10	
B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St	A. St	B. St.	A. St.	B. St.	A.
4.398^{c}	4.450^{b}	0.785^{a}	0.785^{a}	8.517^{a}	8.521^{a}	17.939^{a}	17.903^{a}	68.361	68.341	463.148	468.575	7.950^{a}	7.9
4.295^{e}	4.367^{d}	0.923^{a}	0.924^{a}	9.163^{a}	8.844^{a}	16.804^{a}	16.801^{a}	68.815	69.091	465.005	462.841	6.966^{a}	7.1
3.880^{L}	4.080^{g}	1.040^{a}	1.026^{a}	9.418^{a}	9.408^{a}	16.937^{a}	16.896^{a}	68.725	68.590	467.747	464.056	6.173^{a}	6.7
3.855^{m}	3.915^{j}	1.162^{a}	1.162^{a}	9.652^{a}	9.636^{a}	17.563^{a}	17.564^{a}	67.768	67.723	468.041	467.512	4.022^{a}	5.1
3.666^{o}	3.601^{p}	1.280^{a}	1.279^{a}	9.945^{a}	9.935^{a}	17.565^{a}	17.564^{a}	67.544	67.621	468.443	468.300	3.876^{a}	4.0
3.499^{q}	3.406^{r}	1.364^{a}	1.363^{a}	9.673^{a}	9.704^{a}	17.579^{a}	17.574^{a}	67.885	67.953	470.551	468.794	2.832^{a}	2.8
0.017		-		-		-		*		*		-	

Means in the same column with the same letters are not significantly different at level ($P > 0.05$) according to DMRT.

B. St :Before storage. A. St : After storage. Sorg. :Sorghum flour. W.F.:Wheat flour. *: Without mean separation

Table (6.b). Biscuits from Australian Wheat flour:

Moisture (%)		Ash (%)		Protein (%)		Fat (%)		Carbohyd-rates* (%)		Energy* (Kcal/100g)		Fat acidity (MgKOH/100	
B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St.	A. St.	B. St.	A. St.	B. St.	A. S
$.195^{b}$	4.399^{a}	0.505^{a}	0.506^{a}	8.494^{a}	8.482^{a}	16.249^{h}	16.240^{h}	70.557	70.373	462.445	461.445	3.897^{a}	3.90
$.176^{f}$	3.843^{b}	0.696^{a}	0.686^{a}	8.797^{a}	8.782^{a}	16.248^{f}	16.242^{h}	70.083	69.903	461.752	461.278	3.896^{a}	3.90

.886^{h}	4.040^{e}	0.857^{a}	0.851^{a}	9.403^{a}	9.392^{a}	16.764^{f}	16.687^{f}	69.130	69.030	465.008	463.871	3.882^{a}	3.88
.723^{k}	3.806^{I}	1.066^{a}	1.057^{a}	9.633^{a}	9.612^{a}	17.321^{e}	17.289^{e}	68.270	68.236	467.501	466.993	3.739^{a}	3.73
.599^{m}	3.572^{n}	1.228^{a}	1.227^{a}	9.924^{a}	9.921^{a}	18.401^{b}	18.393^{b}	66.845	66.887	471.030	472.769	3.734^{a}	3.73
.505^{pq}	3.516^{op}	1.399^{a}	1.382^{a}	9.673^{a}	9.704^{a}	18.401^{b}	18.401^{b}	67.023	66.661	472.389	473.570	3.593^{a}	3.59

Means in the same column with the same letters are not significantly different at level ($P > 0.05$) according to DMRT.

B. St :Before storage. A. St : After storage. Sorg. :Sorghum flour. W.F. :Wheat flour. * : Without mean separation

Continue Table (6.b)

Moisture (%)		Ash (%)		Protein (%)		Fat (%)		Carbohyd-rates* (%)		Energy* (Kcal/100g)		Fat acidity (MgKOH/100g)	
B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St.	A. St.	B. St.	A. St.	B. St.	A. St
3.898^{g}	3.947^{f}	0.503^{a}	0.503^{a}	8.494^{a}	8.482^{a}	16.106^{a}	16.105^{a}	70.999	70.963	462.925	462.725	3.469^{a}	3.569
3.745^{j}	3.799^{I}	0.693^{a}	0.693^{a}	8.797^{a}	8.782^{a}	16.277^{a}	16.275^{a}	70.488	70.451	463.633	463.407	3.325^{a}	3.326
3.685^{I}	3.689^{I}	0.865^{a}	0.805^{a}	9.403^{a}	9.392^{a}	16.572^{a}	16.572^{a}	69.525	69.532	464.860	464.844	3.252^{a}	3.252
$.506^{pq}$	3.525^{d}	1.085^{a}	1.037^{a}	9.633^{a}	9.612^{a}	16.731^{a}	16.729^{a}	69.097	69.097	465.487	465.397	3.252^{a}	3.179
3.413^{s}	3.481^{r}	1.285^{a}	1.226^{a}	9.924^{a}	9.921^{a}	18.282^{a}	18.289^{a}	67.156	67.113	472.858	472.787	2.968^{a}	2.969
3.499^{q}	3.406^{s}	1.364^{a}	1.363^{a}	9.673^{a}	9.704^{a}	17.579^{a}	17.574^{a}	67.885	67.953	468.443	468.794	2.832^{a}	2.899
0.017		-		-		0.074		*		*		-	

Means in the same column with the same letters are not significantly different at level ($P > 0.05$) according to DMRT.

B. St :Before storage. A. St : After storage. Sorg.: Sorghum flour. W.F.: Wheat flour. * : Without mean separation.

Table (7). Effect of two types of fats (Shortening and Alaseel) on spread ratio of biscuits made from Wheat & sorghum composite flours

Table (7.a). Indian wheat flour:

Blends	Diameter (mm)		Thickness (mm)	
	Sh.	Al.	Sh.	Al.
Control (Wheat flour)	5.168^{g}	5.168^{g}	0.896^{f}	0.896^{f}
10% sorg. 90% W.F.	5.163^{gh}	5.061^{j}	0.874^{g}	0.830^{j}
20% sorg. 80% W.F.	5.163^{gh}	5.119^{i}	0.807^{k}	0.811^{k}
30% sorg. 70% W.F.	5.163^{gh}	5.148^{h}	0.908^{e}	0.846^{i}
40% sorg. 60% W.F.	5.164^{g}	5.155^{gh}	0.910^{e}	0.857^{h}
50% sorg. 50% W.F.	5.201^{f}	5.245^{e}	0.918^{de}	0.878^{g}

Means in the same column with the same letters are not significantly different at level ($P > 0.05$) according to DMRT.

Sh.: Shortening. Al. Alaseel. Sorg.: Sorghum flour. W.F.: Wheat flour. Wid. : Width. Th.: Thickness.

Continue Table (7.a)

Blends	Diameter (mm)		Thickness (mm)		
	Sh.	Al.	Sh.	Al.	
60% sorg. 40% W.F.	5.202^{f}	5.247^{e}	0.917^{de}	0.892^{f}	5.
70% sorg. 30% W.F.	5.245^{e}	5.466^{c}	0.925^{d}	0.928^{d}	5.

80% sorg. 20% W.F.	5.373^{d}	5.546^{a}	0.944^{c}	0.991^{a}	5.
90% sorg. 10% W. F.	5.476^{c}	5.548^{a}	0.947^{c}	0.991^{a}	5.
100% sorg. 0% W.F.	5.528^{b}	5.373^{d}	0.977^{b}	0.953^{c}	5.
LSD 0.05	0.010		0.014		

Means in the same column with the same letters are not significantly different at level (P > 0.05) according to DMRT.

Sorg. : Sorghum flour. W.F. : Wheat flour. Sh. : Shortening fat. Al. : Alaseel fat. Wid. : Width. Th.: Thickness.

Table (7.b) Australian wheat flour:

Blends	Diameter (mm)		Thickness (mm)	
	Sh.	Al.	Sh.	Al.
Control (Wheat flour)	5.233^{h}	5.072^{j}	1.065^{a}	0.859^{k}
10% sorg. 90% W.F.	5.249^{gh}	5.166^{I}	0.924^{gh}	0.858^{k}
20% sorg. 80% W.F.	5.250^{gh}	5.243^{h}	0.926^{f-h}	0.890^{j}
30% sorg. 60% W.F.	5.251^{gh}	5.324^{e}	0.927^{f-h}	0.931^{f}
40% sorg. 60% W.F.	5.265^{g}	5.335^{de}	0.929^{fg}	0.942^{e}
50% sorg. 50% W.F.	5.296^{f}	5.351^{cd}	0.918^{I}	0.952^{d}

Means in the same column with the same letters are not significantly different at level ($P > 0.05$) according to DMRT.

Sh.: Shortening. Al. Alaseel. Sorg.: Sorghum flour. W.F.: Wheat flour.

Wid. : Width. Th.: Thickness.

ontinue Table (7.b)

Blends	Diameter (mm)		Thickness (mm)	
	Sh.	Al.	Sh.	Al.
60% sorg. 40% W.F.	5.519^{a}	5.359^{bc}	0.923^{hi}	0.954^{d}
70% sorg. 30% W.F.	5.520^{a}	5.378^{b}	0.923^{hi}	0.957^{d}
80% sorg. 20% W.F.	5.528^{a}	5.376^{b}	0.970^{c}	0.953^{d}
90% sorg. 10% W. F.	5.529^{a}	5.375^{b}	0.971^{c}	0.953^{d}
100% sorg. 0% W.F.	5.528^{a}	5.374^{b}	0.977^{b}	0.953^{d}
LSD 0.05	0.017		0.0056	

Means in the same column with the same letters are not significantly different at level ($P > 0.05$) according to DMRT.

Sorg. : Sorghum flour. W.F. : Wheat flour. Sh. : Shortening fat. Al. : Alaseel fat.

Table (8) Effect of wheat flours and fats on sensory evaluation of biscuits made from wheat and sorghum composite flours before and after three months storage.

Table (8.a). Indian wheat flour & Shortening:

nds	Color		Odor		Surface feel		Taste		Mouth feel		Texture		Total s
	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St	A. St	B. St.	A. St.	B. St.
flour)	8.7^{a}	7.6^{abc}	6.9^{abc}	7.0^{b}	7.1^{bc}	7.0^{a}	7.3^{a}	6.6^{ab}	7.1^{a}	7.2^{a}	6.4^{de}	6.8^{ab}	43.5 $(\pm 4.03)^{abc}$
rg. .F.	7.9^{abc}	8.1^{ab}	7.2^{ab}	8.3^{a}	8.2^{a}	7.5^{a}	8.0^{a}	7.3^{a}	7.5^{a}	6.1^{abc}	8.3^{ab}	7.1^{ab}	47.1 $(\pm 5.99)^{a}$
rg. .F.	7.5^{bcd}	8.0^{abc}	7.6^{a}	7.0^{b}	8.0^{ab}	7.0^{a}	8.1^{a}	7.0^{ab}	7.7^{a}	6.4^{abc}	8.5^{a}	7.2^{ab}	47.4 $(\pm 7.62)^{a}$
rg. .F.	6.4^{ef}	6.9^{bcd}	7.3^{ab}	6.9^{b}	8.0^{ab}	7.4^{a}	7.0^{ab}	7.4^{a}	7.7^{a}	7.2^{a}	8.0^{abc}	7.2^{ab}	44.3 $(\pm 5.27)^{ab}$
rg. .F.	6.9^{cde}	7.4^{a-d}	7.4^{ab}	6.4^{b}	7.4^{abc}	7.2^{a}	7.3^{a}	6.9^{ab}	7.5^{a}	6.8^{ab}	7.6^{abc}	7.9^{a}	44.1 $(\pm 3.73)^{ab}$
rg. .F.	8.2^{ab}	7.9^{abc}	6.5^{abc}	7.1^{b}	7.6^{abc}	7.9^{a}	7.0^{ab}	7.3^{a}	7.1^{a}	5.8^{abc}	7.3^{bcd}	5.5^{c}	43.7 $(\pm 2.16)^{abc}$

Means in the same column with the same letters are not significantly different at level (P > 0.05) according to DMRT.
Values of total score are means (±SD).
B. St. : Before storage. A. St. : After storage. Sorg. : Sorghum flour. W.F. : Wheat flour.
Scale : 8 - 10 : Excellent . 6 – 7.9: V. Good. 4 – 5.9: Good. 2 –3.9: Fair. 1 – 2.9: Poor.
Scale for Total score: 48-60: Excellent. 36-47.9: V. Good. 24-35.9: Good. 12-23.9: Fair. 1-11.9: Poor.

Continue Table (8.a)

nds	Color		Odor		Surface feel		Taste		Mouth feel		Texture		Tot
	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St.	A. St.	B. St.	A. St.	B. St.	A. St.	B. St.
org. W.F.	8.6^{a}	6.3^{de}	6.3^{bc}	6.7^{b}	7.7^{abc}	6.9^{a}	7.3^{a}	6.8^{ab}	6.7^{a}	7.2^{a}	6.9^{cde}	6.8^{ab}	43.5 (±4.33)
org. W.F.	7.0^{cde}	7.0^{bcd}	6.0^{c}	7.2^{b}	7.1^{bc}	7.2^{a}	7.5^{a}	7.1^{a}	7.2^{a}	6.2^{abc}	7.2^{bcd}	6.3^{bc}	42.0 (±3.13)
org. W.F.	6.8^{de}	5.4^{e}	6.4^{abc}	7.0^{b}	7.0^{c}	6.5^{a}	7.2^{a}	5.2^{c}	7.6^{a}	6.9^{ab}	8.0^{abc}	7.1^{ab}	43.0 (±3.62)
org. W.F.	7.8^{a-d}	6.8^{cd}	6.0^{c}	6.6^{b}	7.0^{c}	7.0^{a}	6.0^{b}	5.7^{bc}	6.4^{a}	5.5^{bc}	6.0^{e}	7.3^{ab}	39.2 (±3.49)
sorg. .F.	5.8^{f}	8.5^{a}	6.7^{abc}	6.4^{b}	6.9^{c}	6.4^{a}	7.0^{ab}	3.3^{d}	7.1^{a}	4.9^{c}	7.4^{a-d}	6.9^{ab}	40.9 (±3.07)
0.05	0.945	1.064	1.034	0.904	0.852	-	1.037	1.191	-	1.411	1.036	1.136	3.579

Means in the same column with the same letters are not significantly different at level (P > 0.05) according to DMRT.

Values of total score are means (±SD).

B. St. : Before storage. A. St. : After storage. Sorg. : Sorghum flour. W.F. : Wheat flour.

Scale : 8 - 10 : Excellent . 6 – 7.9 : V. Good. 4 – 5.9: Good. 2 –3.9: Fair. 1 – 2.9: Poor.

Scale for Total score: 48-60: Excellent. 36-47.9: V. Good. 24-35.9: Good. 12-23.9: Fair. 1-11.9: Poor.

Table (8.b) Indian wheat flour & Alaseel fat:

Blends	Color		Odor		Surface feel		Taste		Mouth feel		
	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St.	A. St.	B
Control (Wheat flour)	6.3^{cd}	8.8^{ab}	5.8^{e}	7.3^{ab}	7.0^{a-d}	8.4^{a}	6.7^{b}	6.7^{ab}	6.8^{a}	6.0^{bcd}	6
10% sorg. 90% W.F.	8.1^{a}	8.2^{ab}	7.3^{ab}	7.0^{ab}	7.7^{ab}	7.8^{abc}	7.5^{ab}	7.0^{ab}	7.4^{a}	8.2^{a}	7
20% sorg. 80% W.F.	7.9^{ab}	7.5^{bc}	6.4^{b-e}	7.4^{ab}	8.0^{a}	7.4^{abc}	7.3^{ab}	7.3^{a}	7.0^{a}	7.3^{ab}	6
30% sorg. 60% W.F.	7.3^{abc}	8.4^{ab}	7.0^{a-d}	7.2^{ab}	6.8^{bcd}	8.0^{ab}	7.1^{ab}	7.4^{a}	7.6^{a}	7.3^{ab}	7
40% sorg. 60% W.F.	7.8^{ab}	8.1^{ab}	6.1^{cde}	7.8^{ab}	7.2^{abc}	8.0^{ab}	6.8^{b}	7.3^{a}	7.2^{a}	6.7^{bcd}	7
50% sorg. 50% W.F.	5.5^{d}	6.5^{cd}	7.2^{abc}	7.7^{a}	6.8^{bcd}	7.9^{abc}	7.4^{ab}	7.8^{a}	7.2^{a}	5.9^{cd}	7

Means in the same column with the same letters are not significantly different at level (P > 0.05) according to DMRT.

Values of total score are means (±SD).

B. St. : Before storage. A. St. : After storage. Sorg. : Sorghum flour. W.F. : Wheat flour.

Scale : 8 - 10 : Excellent . 6 – 7.9 : V. Good. 4 – 5.9: Good. 2 –3.9: Fair. 1 – 2.9: Poor.

Scale for Total score: 48-60: Excellent. 36-47.9: V. Good. 24-35.9: Good. 12-23.9: Fair. 1-11.9: Poor.

Continue table (8.b).

ds	Color		Odor		Surface feel		Taste		Mouth feel		Texture		Tota
	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St.	A. St	B.St.	A.St.	B. St.	A. St.	B. St.
g. F.	5.9^{d}	8.2^{ab}	7.9^{a}	5.2^{c}	6.5^{cd}	7.8^{ab}	8.3^{a}	7.9^{a}	7.4^{a}	5.5^{d}	7.1^{a}	6.2^{b}	43.1 $(\pm5.74)^{ab}$

rg. F.	7.8^{ab}	7.4^{bc}	7.4^{ab}	6.8^{ab}	6.0^{d}	7.9^{abc}	7.5^{ab}	7.7^{a}	6.6^{a}	5.5^{d}	6.7^{a}	5.4^{b}	41.9 $(\pm4.11)^{ab}$
g. F.	7.6^{abc}	5.8^{d}	6.0^{de}	6.9^{ab}	6.2^{cd}	7.2^{bc}	6.4^{b}	5.3^{c}	6.3^{a}	5.9^{cd}	6.3^{a}	5.3^{b}	38.8 $(\pm5.20)^{b}$
g. F.	6.6^{bcd}	5.8^{d}	6.4^{b-e}	6.3^{b}	6.6^{bcd}	6.2^{d}	6.4^{b}	6.0^{bc}	7.0^{a}	6.9^{cd}	6.5^{a}	6.1^{b}	39.5 $(\pm4.20)^{b}$
org. .	7.4^{abc}	8.0^{ab}	6.8^{a-e}	6.9^{ab}	6.2^{cd}	6.9^{cd}	6.6^{b}	5.8^{bc}	7.0^{a}	5.7^{cd}	5.5^{a}	5.8^{b}	38.6 $(\pm4.01)^{b}$
:	1.182	0.997	1.026	1.058	1.022	0.915	1.121	1.160	-	1.188	-	1.168	4.142

Means in the same column with the same letters are not significantly different at level ($P > 0.05$) according to DMRT.

Values of total score are means (±SD).

B. St. : Before storage. A. St. : After storage. Sorg. : Sorghum flour. W.F. : Wheat flour.

Scale :- 8 - 10 : Excellent.. 6 – 7.9: V. Good. 4 – 5.9: Good. 2 –3.9: Fair. 1 – 2.9: Poor.

Scale for Total score: 48-60: Excellent. 36-47.9: V. Good. 24-35.9: Good. 12-23.9: Fair. 1-11.9: Poor.

Table (8.c) Australian wheat flour & Shortening fat:

Blends	Color		Odor		Surface feel		Taste		Mouth feel		
	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St	A. St	B.
Control (Wheat	7.0^{a}	7.2^{bc}	7.2^{a}	7.4^{a}	6.9^{c}	7.1^{abc}	7.5^{ab}	7.1^{a}	7.8^{a}	7.2^{ab}	8.
10% sorg. 90% W.F.	7.4^{a}	8.8^{a}	7.4^{a}	7.3^{a}	7.9^{ab}	7.6^{a}	7.4^{ab}	7.2^{a}	7.7^{a}	7.3^{ab}	7.
20% sorg. 80% W.F.	7.9^{a}	7.3^{bc}	7.5^{a}	7.6^{a}	8.4^{a}	7.4^{ab}	7.4^{ab}	7.8^{a}	7.4^{a}	7.3^{ab}	7.
30% sorg. 70% W.F.	8.0^{a}	8.2^{ab}	7.1^{a}	7.7^{a}	8.0^{a}	7.6^{a}	7.3^{ab}	7.3^{a}	7.6^{a}	7.6^{a}	7.
40% sorg. 60% W.F.	7.5^{a}	7.2^{bc}	7.7^{a}	7.3^{a}	7.3^{bc}	6.6^{bc}	7.5^{ab}	7.2^{a}	7.3^{a}	7.4^{ab}	7.
50% sorg. 50% W.F.	7.0^{a}	6.4^{c}	7.4^{a}	7.0^{a}	8.3^{a}	6.6^{bc}	7.8^{a}	7.7^{a}	7.7^{a}	7.6^{a}	7.

Means in the same column with the same letters are not significantly different at level (P > 0.05) according to DMRT.

Values of total score are means (±SD).

B. St. : Before storage. A. St. : After storage. Sorg. : Sorghum flour. W.F. : Wheat flour.

Scale :- 8 - 10 : Excellent . 6 – 7.9 : V. Good. 4 – 5.9: Good. 2 –3.9: Fair. 1 – 2.9: Poor.

Scale for Total score: 48-60: Excellent. 36-47.9: V. Good. 24-35.9: Good. 12-23.9: Fair. 1-11.9: Poor.

Continue table (8.c)

ls	Color		Odor		Surface feel		Taste		Mouth feel		Texture		Tot
	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St	A. St	B. St.	A. St.	B. St.
g. F.	7.0^{a}	7.1^{bc}	7.3^{a}	7.3^{a}	6.9^{c}	7.4^{ab}	7.0^{a}	7.1^{a}	7.3^{a}	6.1^{a}	8.1^{a}	6.1^{cd}	43.6 $(\pm4.68)^{a}$

g. F.	7.7^{a}	4.3^{d}	7.1^{a}	7.4^{a}	7.1^{bc}	6.4^{c}	7.7^{a}	6.7^{a}	7.6^{a}	7.2^{ab}	7.3^{a}	7.7^{a}	44.5 (±3.78)^{a}
g. F.	7.0^{a}	6.7^{c}	6.8^{a}	6.9^{a}	5.8^{d}	6.3^{c}	6.5^{b}	6.3^{a}	7.3^{a}	7.0^{ab}	7.2^{a}	6.4^{bcd}	40.6 (±3.69)^{b}
g. F.	7.8^{a}	6.8^{c}	7.4^{a}	7.1^{a}	8.5^{a}	6.5^{bc}	7.0^{ab}	6.9^{a}	6.2^{b}	6.5^{bc}	7.4^{a}	7.1^{abc}	44.3 (±2.98)^{a}
rg. .	7.0^{a}	6.2^{c}	7.0^{a}	6.7^{a}	6.9^{c}	6.7^{abc}	5.3^{c}	7.3^{a}	6.7^{b}	6.8^{abc}	7.3^{a}	5.8^{d}	40.2 (±5.03)^{b}
05	-	1.105	-	-	0.841	0.857	0.947	-	0.946	0.804	-	0.928	2.787

Means in the same column with the same letters are not significantly different at level ($P > 0.05$) according to DMRT.

Values of total score are means (±SD).

B. St. : Before storage. A. St. : After storage. Sorg. : Sorghum flour. W.F. : Wheat flour.

Scale :- 8 - 10 : Excellent . 6 – 7.9 : V. Good. 4 – 5.9: Good. 2 –3.9: Fair. 1 – 2.9: Poor.

Scale for Total score: 48-60: Excellent. 36-47.9: V. Good. 24-35.9: Good. 12-23.9: Fair. 1-11.9: Poor.

Table (8.d). Australian wheat flour & Alaseel fat:

	Color		Odor		Surface feel		Taste		Mouth feel		Texture		
	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St.	A. St.	B. St.	A. St.	B. S
r)	9.0^{a}	8.2^{a}	8.0^{a}	7.2^{a}	8.5^{a}	8.1^{a}	7.1^{bcd}	7.3^{a}	7.4^{a}	7.1^{abc}	7.3^{a}	6.6^{ab}	47.9 (± 3.9
	8.6^{ab}	8.3^{a}	8.1^{a}	7.7^{a}	8.3^{a}	7.4^{ab}	8.2^{a}	7.3^{a}	7.9^{a}	7.0^{abc}	7.2^{a}	7.0^{a}	48. (±4.3
	7.8^{bcd}	7.3^{ab}	8.0^{a}	7.4^{a}	8.2^{ab}	7.3^{bc}	8.0^{ab}	7.4^{a}	7.7^{a}	7.6^{a}	8.3^{a}	7.4^{a}	48. (±4.1
	7.7^{bcd}	8.0^{a}	7.5^{a}	7.5^{a}	7.4^{c}	8.1^{a}	7.5^{abc}	7.1^{ab}	7.5^{a}	7.1^{abc}	8.0^{a}	7.1^{a}	45. (±4.03

7.6^{cd}	6.5^{b}	7.6^{a}	7.6^{a}	7.3^{c}	6.8^{b-e}	7.8^{ab}	6.8^{ab}	6.9^{ab}	7.3^{ab}	8.2^{a}	7.0^{a}	45.4 (±3.8
8.0^{bcd}	6.4^{b}	7.3^{a}	7.1^{a}	7.5^{bc}	7.1^{bcd}	7.1^{bcd}	7.3^{a}	7.1^{a}	6.5^{bc}	8.0^{a}	6.5^{ab}	45.0 (±3.3

Means in the same column with the same letters are not significantly different at level (P > 0.05) according to DMRT.

Values of total score are means (±SD).

B. St.: Before storage. A. St. : After storage. Sorg.: Sorghum flour. W.F. : Wheat flour.

Scale :- 8 - 10 : Excellent . 6 – 7.9: V. Good. 4 – 5.9: Good. 2 –3.9: Fair. 1 – 2.9: Poor.

Scale for Total score: 48-60: Excellent. 36-47.9: V. Good. 24-35.9: Good. 12-23.9: Fair. 1-11.9: Poor.

Continue table (8.d)

Color		Odor		Surface feel		Taste		Mouth feel		Texture		T
B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St.	A. St	B. St.	A. St.	B. St.	A. St.	B. St.
8.2^{abc}	7.3^{ab}	7.6^{a}	7.3^{a}	7.4^{c}	7.0^{bcd}	7.3^{a-d}	6.8^{ab}	7.3^{a}	6.5^{bc}	6.9^{a}	6.3^{ab}	44.7 (±4.08)
7.1^{d}	6.3^{b}	7.8^{a}	7.4^{a}	7.2^{c}	6.5^{de}	7.3^{a-d}	6.5^{ab}	6.8^{abc}	6.1^{c}	7.7^{a}	6.6^{ab}	43.9 (±4.72)
7.3^{d}	6.2^{b}	7.4^{a}	6.9^{a}	7.1^{c}	6.4^{cde}	6.5^{d}	6.5^{ab}	5.8^{cd}	6.5^{bc}	7.1^{a}	5.7^{bc}	41.2 (±3.88
7.4^{cd}	6.4^{b}	7.9^{a}	7.2^{a}	7.3^{c}	6.6^{cde}	6.8^{cd}	6.1^{b}	5.9^{bcd}	6.7^{abc}	7.5^{a}	6.3^{ab}	42.8 (±4.32)
8.1^{cd}	6.2^{b}	7.9^{a}	7.3^{a}	7.3^{c}	6.2^{e}	6.4^{d}	6.4^{ab}	5.4^{d}	6.3^{bc}	7.2^{a}	4.9^{c}	42.3 (±5.25)
0.902	0.987	-	-	0.733	0.679	0.864	-	0.961	0.933	-	0.989	2.857

Means in the same column with the same letters are not significantly different at level (P > 0.05) according to DMRT.

Values of total score are means (±SD).

B. St.: Before storage. A. St. : After storage. Sorg.: Sorghum flour. W.F. : Wheat flour.

Scale :- 8 - 10 : Excellent . 6 – 7.9: V. Good. 4 – 5.9: Good. 2 –3.9: Fair. 1 – 2.9: Poor.

Scale for Total score: 48-60: Excellent. 36-47.9: V. Good. 24-35.9: Good. 12-23.9: Fair. 1-11.9: Poor.