Introduction

Cereal grains store energy in the form of starch. The amount of starch contained in a cereal grain varies in general between 60% – 75% of grain weight. Thus most of food that humans consume is in the form of starch, an excellent source of energy. In addition to its nutritive value, starch is important because of its effect upon the physical properties of many of our foods (Hoseney, 1986).

Starch is a natural, cheap, available, renewable, and biodegradable polymer produced by many plants as a source of stored energy. it is the second most abundant biomass material in nature, it is found in plant leaves, stems, roots, bulbs, nuts, stalks, crop seeds, and staple crops such as rice, corn, wheat, cassava, and potato. The most common use of starch in our daily life is as food ingredient. It is the most common source of glucose in the body. It has found wide use in the food, textiles, cosmetics, plastics, adhesives, paper, and pharmaceutical industries. In the food industry, starch has a wide range of applications ranging from being a thickener, gelling agent, to being a stabilizer for making snacks, meat products, fruit juices (Manek, *et al.*, 2005).

Pure starch is white, tasteless and odorless that is insoluble in cold water or alcohol. It consists of two types of molecules: the linear and helical amylose and the branched amylopectin.

Depending on the plant, starch contains 20% to 25% amylose and 75% to 80% amylopectin (Frazier *et al.*, 1997), its granules may be classifiedas oval, oblong, spherical, polygonal, irregular or lens- -shaped. Starch properties depend on the physical and chemical characteristics such as mean granule size, granule size distribution, amylose/amylopectin ratio and mineral content (Singh*et al.*, 2003).

In Sudan starch is used in industries by Arab Sudanese Company for Starch and Glucose using both Sorghum and maize, but it couldn't continue because of many reasons such as shortage in raw materials.

Lentil contains high level of proteins, including the essential amino acids isoleucine and lysine and is essential source of inexpensive proteins in many parts of the world for those who adhere to vegetarian diet. Lentils also contain dietary fiber, vitamin B1and minerals. Lentils are the one of the best vegetable sources of iron and useful for preventing iron deficiency (Murphy *et al.,* 2000).

Starch can be produced by wet milling sorghum though the procedures typically require long time periods to complete because of the steeping process needed to loosen up the kernel requires 24-96 hours (Wang *et al.,* 2000). Starch properties are therefore an important factor to determine the grain quality. Rice starch is usually digested quite rapidly, compared with other starch foods such as noodles, sweet potato etc. (Sidhu, 1989). Cooking and eating characteristics are mainly determined by the properties of the starch that makes up to 90% of milled rice. Gelatinization temperature, amylose content and gel consistency are the important starch properties that influence cooking and eating properties. Starch constitutes the main component of the cassava root (Ceballos *et al.,* 2006) and thus plays an important role in the use of cassava as a food and industrial crop. Cassava starch has been studied and characterized for its different properties such as granule structure, pasting properties and functional properties such as swelling power and solubility (Zaidul *et al.,* 2007; Gomes *et al.,* 2005; Charles *et al.*, 2004). Many important physicochemical, thermal, and rheological properties of starch are influenced by the ratio of amylose and amylopectin. Amylose content strongly affects starch gelatinization and retrogradation (Russel 1987, Fredriksson *et al.,* 1998), paste viscosity (Reddy *et al.,* 1994, Yanagisawa *et al.,* 2006), gelation (Biliaderis and Zawistowski 1990, Miles *et al.,* 1985), and R-amylase digestibility (Skrabanja *et al.,* 1999). The fine structure of amylopectin (chain-length distribution) also was found to influence starch gelatinization and retrogradation properties (Shi and Seib 1992, Jane *et al.,* 1999).

Strong dough with an extensive gluten network is suitable for bread- making (Pomeranz, 1971), while Gaines (1990) stated that weak dough without an extensive gluten network is best for cakes, so glutens are designated as strong and weak glutens.

Rheological properties of dough and gluten during mixing are affected greatly by the flour composition (low or high protein content), processing parameters (mixing time, energy, temperature) and ingredient (water, salt, yeast, fats and emulsifiers) Sliwinski *et al.,* (2004_b) . Bread baking quality is dependent not only on protein quantity but also on its quality. Therefore many extensive works were performed on gluten protein and the real ability of crude gluten as an indicator of flour strength for baking products. Technological quality of wheat is strongly related to the storage proteins (gliadin and glutenin) and characteristics of both of these proteins must be considered when attempting to explain the quality variation observed among different wheat Anjum and Walker (2000). The limit for the addition of the cassava/maize/rice to wheat flour for bread and small baked products is at least 50 – 80% wheat flour. The percentage depends on the baking quality of the imported wheat flour concerned.

Most of the trails with composite flours have been carried out in this continent because of Africans continually growing population. Reports are available from Senegal, Niger and Sudan (Anon, 2000).

A more economical blend, producing acceptable bread, is 50%, 10% and 40% wheat, rice and cassava respectively. Rice starch used at 25% with 75%wheat flour yielded acceptable bread (Bean and Nishita, 1985). Lehman *et al.,* (1994) reported that the factors affecting variation in cookie spread are summarized as follows: flour with low protein content and low protein quality, uses of fluid shortening, small particle size of sugar, high percentage of sugar syrup in formula, high level of leaving, single stage versus. multistage mixing, high percentage of moisture added to formula, low initial or slowly rising heat during baking and low fat-high sugar ratio.

The objectives of this study are as follows:

1. To extract and characterize starch from five plant sources (Wheat, sorghum, millet, rice and cassava).
2. To makebread and biscuits from composite flour.
3. To study the effect of starches on dough rheological properties for making bread and biscuit.
4. To see acceptability of products.

Chapter Two

Literature review

2.1. Importance of wheat

Wheat is considered good source of protein, minerals, B-group vitamins and dietary fiber i.e. an excellent health-building food. Thus, it hasbecome the principal cereal, being more widely used for the making of bread than any other cereal because of the quality and quantity of itscharacteristic protein called gluten. Gluten makes bread dough stick together and gives it the ability to retain gas.

Wheat has several medicinalvirtues; starch and gluten in wheat provide heat and energy; the inner bran coats, phosphates and other mineral salts; the outer bran, themuch-needed roughage the indigestible portion that helps easy movement of bowels; the germ, vitamins B and E; and protein of wheat helpsbuild and repair muscular tissue. The wheat germ, which is removed in the process of refining, is also rich in essential vitamin E, the lack ofwhich can lead to heart disease. The loss of vitamins and minerals in the refined wheat flour has led to widespread prevalence of constipationand other digestive disturbances and nutritional disorders.

The whole wheat, which includes bran and wheat germ, therefore, providesprotection against diseases such as constipation, ischemic, heart disease, disease of the colon called diverticulum, appendicitis, obesity anddiabetes(Kumar1*et al.*,2011).(Appendix 1)

2.2. Importance of sorghum

Sorghum is the world’s fifth most important cereal, in terms of both production and area planted. Roughly 90% of the world’s sorghum area lies in thedeveloping countries mainly in Africa and Asia.Sorghum is widely grown both for food and as a feed grain (Rooney and Awika ,2005).

Starch is the major component of grain sorghum, constituting 70% of dry grain weight (Hoseney *et al.*, 1981). Some sorghum grains have a layer of highly pigmented cells beneath the pericarp. This layer has been referred to as testa, seed coat, sub coat, under coat or nuceller layer. Pigmentation of testa is generally attributed to the presence of polyphenols (Tannins).(Rooney and Serna-Saldivar 1991). The majority of the carbohydrate in sorghum is starch, while soluble sugar, pentosans, cellulose, and hemicellulose are low. Regular endosperm sorghum types contain 23 to 30% amylose, but waxy varieties contain less than 5% amylose. Sorghum is a good source of fiber, mainly the insoluble (86.2%) fiber. The insoluble dietary fiber of sorghum may decrease transit time and prevent gastrointestinal problems. (Appendix 1)

2.3. Importance of Millet

Millet is a general category for several species of small grained cereal crops; it is the world's seventh most important cereal grain. 95% of the world's millet area lies in the developing countries mainly in Africa and Asia, millet is produced almost entirely for food.Pearl millet kernels are generally tears shaped and weigh about 8.9 g/1000 kernel, seed size varies widely among different cultivars of millet and within different locations within a single head (Hoseney *et al.*,1982).

The structure of mature kernels of pearl millet is similar to the structure of sorghum but with several differences. (Abdelrahman *et al.,* 1982, 1984).PericarpComposed of three layers, epicarp, mesocarp and endocarp (Sullins and Rooney (1975). Thick pericarp cultivars don't have starch granules in mesocarp (Rooney and McDonough 1987).

Monawar (1983) showed a value of 69.4%starch content. The starch ranges between 62.8% to 70.2% of pearl millet (Subramanian *et al.*, 1986). Abdalla (1996) examined starch content for three pearl millet genotypes and the result was 61.0%, 67.3% and 66.2%.

The germ of pearl millet is a much larger percentage of the total kernel than is the germ of sorghum (17.4% in millet and 9.8% in sorghum). This difference explains in part the lower starch and the higher protein and oil contents of millet as compared to sorghum. Starch represents about 56 to 65% of the kernel and is about 20 to 22% amylose; free sugars range from 2.6 to 2.8% of the grain(Kent, 1978).(Appendix 2)

2.4.Importance of rice

Rice is the seed of the monocot plant of the genus Oryza and of the grass family Poaceae (formally Graminae) which includes twenty wild species and two cultivated ones, Oryzasativa (Asian rice) and Oryzaglaberrima (African rice). Oryzasativa is the most commonly grown species throughout the world today.

Rice has been considered the best staple food among all cereals and is the staple food for over 3 billion people, constituting over half of the world's population (Cantral and Reeves, 2002). Rice is the most important grain with regard to human nutrition and caloric intake, providing more than one fifth of the calories consumed worldwide by the human species (Smith, 1998). It has higher digestibility, biological value andprotein efficiency ratio owning to presence of higher concentration of lysine.

Brown andmilled rices contains about 75-85% and 90% carbohydrates, respectively. Starch properties aretherefore an important factor to determine the grainquality (Yousaf, 1992).The rice grain consists of 75-80 % starch, 12 % water and only 7 % protein with a full complement of amino acids. (Appendix 2)

2.5. Importance of Cassava

Cassava (ManihotesculentaCrantz) is an important vegetable crop that isgrown throughout the tropics and sub-tropics, where it contributes a considerableproportion of the total caloric intake and ranks fourth after rice, wheat and corn on food energy production basis as a source of complex carbohydrates (Moorthy andMathew 1998; and Belei *et al.,*2006).

It is a staple food for more than half of the West African population (Anonymous 1992), Steinkraus (1983) and Oduro *et al.,* (2000),and can be processed into various products that are useful as human andanimal food, including gari (farina) and many other West Africantraditional dishes (Beeching *et al*.,1994, Oboh and Akindahunsi, 2003, and Obilie *et al.,*2004).

However, cassava and its products are low in protein,deficient in essential amino acids and therefore, have poor protein quality, with protein content between 3.6 and 4.4% on dry weight (Oboh and Akindahunsi, 2003).

The main industrial use of cassava is in the manufacture of starch and alcohol (Amutha and Gunasekaran, 2001). Cassava is often considered an inferior food because the storage root is low in protein, essential minerals and vitamins. However, in many cassava-growing areas, its used as food helps to alleviate problem of hunger and carbohydrate intake deficiency and thus its importance in terms of food security in these areas cannot be overemphasized.(Appendix 3)

2.6. Importance of lentil

Legumes play an important role in the diet of most of the people of the world and are second only to the cereals as a source of human and animal food (Singh*et al.,* 2004a). They are excellent source of carbohydrates (50–60%) and an inexpensive source of proteins (20–24%).

In Sudan lentil is incorporated into many dishes e.g. tamia, soap and stew. A survey in the urban area of Khartoum (1982 – 1983) showed that lentils were the main substitute for faba beans and the percapita consumption was 0.41 kg/ month (Ali *et al.,* 1984).

Dry lentils seeds are a good source of high quality protein,vitamins, and a balanced range of minerals. They are also anexcellent source of complex carbohydrates and dietary fibers (Adsule *et al.,*1989). Lentil seeds, which are highly accepted in most parts of theworld, provideone of the best meansof fightingmalnutrition among people in developing countries (Savage,1988).

A variety of lentils exist with colors that range from yellow tored-orange to green, brown and black. Lentils are divided into twomain types based on difference between the seed coat and cotyledoncolor. Green lentils (Macrosperma) have a green to brownseed coat with yellow cotyledons. Red lentils (Microsperma) havea pale grey to dark seed coat with red cotyledons. Like mostlegumes, lentil seeds contain about two-thirds carbohydrates,24–30% protein and are also a good source of B-complex vitamins, such as folate, thiamine, niacin and riboflavin, with a good balance of minerals (Jood*et al.,* 1998; Longnecker*et al*., 2002). Lentil seeds provide an excellent source of dietary fiber and complex carbohydrates (Sotomayor *et al.,* 1999).

2.6.1. Nutritional value of lentil

Lentil contains a high concentration of proteins, carbohydrates and dietary fiber and makes an important contribution to human diet in many countries. Lentil is a nutritional food legume, cultivated for its seeds and mostly eaten as a dhal (lentil seeds that are decorticated and split). The primary product is the seed, which has a relatively higher content of protein and calories compared to other legumes.

Lentil is a protein caloric crop, its protein content amounting to 22 – 35%. Lentil protein deficient in the amino acids methionine and cysteine is an excellent supplement to cereal grain diets because of its good protein carbohydrate content (Oplinger *et al.,* 1990). About 90% of lentil protein is found in the cotyledons with albumins and globulins being the major fractions. Digestibility coefficient for lentil is relatively high and ranged from 78 – 93%, while biological values range from 32 – 58% (Hulse, 1990).

2.7. Starch Definition

Starch is a large polysaccharide, of considerable industrial importance particularly to the food and is mainly compose of amylose and amylopectin (Englyst and Hudson, 1997).

2.7.1. Scientific definition of starch

A carbohydrate that is the chief form of stored energy in plants, especially wheat, corn, rice, and potatoes. Starch is a mixture of two different polysaccharides built out of glucose units, and forms a white, tasteless powder when purified. It is an important source of nutrition and is also used to make adhesives, paper, and textiles (Roger *et al.*, 1999;Roger andColonna,1996)

2.8. Starch Supplement

All plantseeds and tubers contain starch which is predominantly present as amylose and amylopectin. Plants use starch as a way to store excess glucose, and thus also use starch as food during mitochondrial oxidative phosphorylation. Animals do not store excess glucose as starch; they store them as glycogen. (Cura and Krisman, 1990)

2.9. Sources of starch

Starch is the main reserve carbohydrate in the plant kingdom, is also one of its most widely distributed substances. It occurs in seeds and fruits, in tubers and pithy stems and in leaves, although in the last instance its presence is only transitory, the starches present in, or obtained from, cereals, tubers and roots are of sufficient interest to warrant detailed consideration. These include the cereal starches of corn, wheat, rice etc… and the non-cereal starches finding application to various degrees in baking, such as tapioca starch, potato starch, arrowroot starch, etc. these starches, while similar in their over-all characteristics, differs nevertheless in many essential properties which govern their suitability for certain specialized applications (Pyler,1973).

2.10. Classification of starch

Starch can be classified into two types:

1. Native starch
2. Modified starch

2.10.1. Native starch:

Native starches are produced through the separation of naturally occurring starch from either grain or root crop, such as cassava, maize and sweet potato, and can be used directly in producing certain foods, such as noodles. The raw starches produced still retain the original structure and characteristics and are called (native starches). Native starch is the basic starch product that is marketed in the dry powder form under different grades for food, and as pharmacological, human and industrial raw material.

Native starch has different functional properties depending on the crop source and specific types of starch are preferred for certain applications. Native starch can be considered as primary source that can be processed into a range of starch products. Native starches have limited usage, mainly in the food industry, because they lack certain desired functional properties. The native starch granules hydrate easily, when heated in water they swell and gelatinize, the viscosity increase to a peak value, followed by a rapid decrease, yielding weak-boiled, stringy and cohesive pastes of poor stability and poor tolerance to shear pressure, as commonly employed in modern food processing (Internet, 2011 http//www.Cassavvbiz.org/postharvest/starch03.htm).

2.10.2. Modified starch:

Modified starch is native starch that has been changed in its physical or chemical properties. Starch is often modified to change or improve its cooking characteristics, gelling tendency, flow behavior, freeze-thaw stability, and for other reasons (BeMiller 1997).Modification may involve altering the form of the granule or changing the shape and composition of the constituent amylose and amylopectin molecules. Modifications are therefore carried out on the native starch to confer it with properties needed for specific uses. When starch is modified chemically or physically the properties of the native starch is altered. Various modifications give the starch properties that make it useful in many industries such as food, pharmacological, textile, petroleum and paper pulp industries.

Modified starch is important to provide the following properties, thickening, gelatinization, adhesiveness and film-formation, improve water retention, enhance palatability and remove or add opacity, the reasons why native starch is modified are to modify cooking characteristics (gelatinization), to reduce retrogradation, to reduce paste, tendency to gelatinize, to increase paste, stability when cooled or frozen, to increase transparency of pastes and gels, to improve texture of pastes and gels, to improve adhesiveness between different surfaces, such as in paer applications.

Modification can be as simple as sterilizing products required for the pharmaceutical industry or highly complex chemical processes to confer properties totally different from the native starch. A simple modification process is represented by washing, air classification, centrifugation and pre-gelatinization. (IENICA, 2003).

2.11. Uses of starch

There are many potential uses of starch such as unmodified starch which can be used in paper, mining and building industries, also it can be modified and converted to starch derivatives, isosugar, high fructose syrup and ethanol. Starch also can be used in Pharmaceutical applications such as, disintegrating agent, binder, film forming material, microspheres, colon targeting of drugs and nanoparticles (IENICA, 2003, Chen L *et al.*, 2007)

2.11.1. Uses of starch as food

It is used in making foods for cattle, pigs, poultry and humans, in jellies and gum, food thickener, yogurts and puddings, bakery fillings for cream and fruits pies and doughnuts, dry mixes for cakes and muffins, brownies and cookies. There are specialty starches used to help create reduced fat and non-fat products. Dextrose is also made from starch. Other special food starches improve the flavor, texture, shelf life and processing of a variety of baked products and also improved baked goods rich in fiber(Internet ,2014 http://bodyecology.com/articles/millet-nutrition-benefites-uses).

2.11.2. Other uses of starch

Starch is used to make foam for packaging, making sizing for textile, preparing laundry starch, syrup, substitute for talcum powder and other beauty and health product, processed to produce dextrin- a gummy substance used primarily in making adhesive. Industrial alcohol, nitro starch and the glucose from which can be fermented to biofuel ethanol (Internet, 2014 http://science1.knoji.com/the-essentials-and-many-uses-of-starch).

2.12. Wheat starch

Wheat starch makes up to 80% of wheat meal and has a great impact on the functionality of wheat products. Wheat starch can be divided into the larger, lenticular-shaped A-starch granules and the smaller, spherical B-starch granules. A-starch granules have been studied the most extensively. They make up 90% of the weight but less than 20% of the number of starch granules in wheat. They form a separate phase from the gluten phase in dough, and their swelling behavior strongly affects product characteristics. The smaller B-starch granules are embedded in the gluten matrix, and changes in the properties of the B-starch granules are often mistaken for changes in the protein matrix Anne and Karin, (1990). Wheat has two types of starch granules: large (25-40 um) lenticular and small (5-10um) spherical ones. The lenticular granules are formed during the first 15 days after pollination. The small granules, representing about 88% of the total of granules, appear 10-30 days after pollination (Belderok *et al*., 2000).

Normal wheat starch typically contains 20–30% amylose and 70–80% amylopectin (Konik-Rose *et al*., 2007).

2.13. Sorghum starch

Granules of grain sorghum starch are almost indistinguishable from those of corn. The upper limit of diameter is about 35 microns. Sorghum starch appears to have more large granules than are closely similar to those of ordinary sorghum starch, but usually the maximum diameter is a few microns greater for the waxy starch granules. Their reddish brown coloration with iodine distinguishes the waxy starch granules (Matez, 1959). Moreover sorghum starch granule is round and the size of the granule is 25nm (Lineback, 1984). On average, sorghum starch granules are slightly larger 15µ compared to 10µ for corn (Wall and Blessin, 1969).

Sorghum starch plays an important role in both the productionof food products and the fermentation of sorghum to produce products such as fuel ethanol. During fermentation, it is the starch that is broken down into sugars, later to be converted into ethanol. Starch content has been positively correlated to ethanol yields in sorghum (Zhan *et al.,* 2003). Sorghum starch plays an important role in the production of many sorghum-based food products, including bread (Schober *et al.,* 2005).

For better application of sorghum starch in foods, feeds, and industrial utilization, the study of physicochemical properties of sorghum starch is needed. Often the characterization of starches requires a purified starch. Currently, there is no specific method forisolating sorghum starch. Starch can be produced by wet milling sorghum, though the procedures typically require long time periods to complete because of the steeping process needed to loosen upthe kernel requires 24-96 hours (Wang *et al.,* 2000).

2.14. Millet starch

Starch is the main carbohydrate component of pearl millet grain and is smooth with a gel viscosity (Burton *et al.,* 1972). The starch granules are both spherical and polygonal and range in diameter from 8 to 12 μ.The starch of pearl millet appears smaller, but similar to maize and sorghum starch (Watson, 1974).

Starch content of pearl millet has been shown to vary between 59.35 to 69.49% (Uprrety and Austin, 1972). Freeman and Bocan (1973) reported that the range from 58.8 to 64.49%. Monawar (1983) reported 69.40%, while Subramanian et al, 1986 reported that the contents ranged from 62.8 to 70.2%.

The amylose content of pearl millet starch ranged from 17 to 29%. Badi *et al.,* (1976a) reported 17%. Badi *et al.,* (1987) reported 20 to 22%, while Subramanian *et al.,* (1986) found that the amylose content ranged from 24 to 29%.

Hadimani *et al.,* (1995) reviewed the non-starchy polysaccharides of pearl millet and concluded that they form 18 to 22% of total pearl millet carbohydrates, out of which 1.2 to 1.6% water soluble, 10.4 to 12.3% water insoluble (alkaline soluble), 5.8 to 6.8% cellulose and 1.2 to 2.2% lignin.

Starch content of pearl millet in general is found to range between 50.4 to 69.5% as reported by Uprety and Austin (1972).Freeman and Bocan (1973) reported values in the range between 58.8 to 64.5%, whereas Monawar (1983) reported a value of 69.4%, and Subramanian *et al.,* (1986) found that the starch content ranged between 62.8 to 70.2%. Almeida-Dominques*et al.,* (1993) reported a value of 70.8% for whole pearl millet. Abdalla (1996) reported values of 61.0%, 67.3% and 66.2% for three pearl millet genotypes.

2.15. Rice starch

Rice (Oryzasativa L.), a major cereal crop, is the staple food source for half of the world population. Rice is an excellent source of energy, in the form of starch, and it gives the benefit of providing proteins with a higher nutritional quality than those of other cereal grains (Moldenhauer*et al.,* 1998). It contains up to 75% starch depending on the variety. This means that plant is one of the main sources of starch worldwide. Rice starch has very small granules. It's white color and natural taste makes it particularly advantageous for the starch processing industry. Rice starch is thus used to make coated or chewable tablets with soft or hard coatings, for example, as it achieves a particularly smooth surface. Rice starch is also highly significant in the food and cosmetics industry.

Rice starch is used as an additive in various food and industrialproducts. With the inherent merits of small and uniformsize distribution of rice starch and its white color andclean odor, deserts and bakery products are some of the favorable applications among processed foods (BeMiller, 1984). The smallgranular size of the starch imparts it soft texture, high waterretention and low syneresis, suggesting the possibility inusing rice starch as fat substitute (Labell,1991).

Starch properties are therefore an important factor to determine the grain quality. Rice starch is usually digested quite rapidly, compared with other starch foods such as noodles, sweet potato etc. Sidhu, (1989). Cooking and eating characteristics are mainly determined by the properties of the starch that makes up 90% of milled rice. Gelatinization temperature, amylose content and gel consistency are the important starch properties that influence cooking and eating properties.

2.16. Cassava starch

Cassava starch is produced primarily by the wet milling of fresh cassava roots but in some countries such as Thailand it is produced from dry cassava chips. Starch is the main constituent of cassava. About 25% starch may be obtained from mature good quality tubers, about 60% starch may be obtained from dry cassava chips and about 10% dry pulp may be obtained per 100 kg of cassava roots. Cassava starch has many remarkable characteristics including high paste viscosity, high paste charity and high freeze-thaw stability, which are advantageous to many industries, (internet, 2011 http//www.Cassavvbiz.org/postharvest/starch03.htm).

In recent years, cassava has received more attention asa root crop not only for its resistance to abiotic stresses(Chavez *et al.,* 2005; Baguma, 2004) but also its highproductivity with considerable starch yield (up to 30% ofthe fresh root or 80% of root dry matter) and purity(Ceballos *et al.,* 2006; Benesi, 2005).Starchconstitutes the main component of the cassava root(Ceballos *et al.,* 2006) and thus plays an important role inthe use of cassava as a food and industrial crop. Cassavastarch has been studied and characterized for itsdifferent properties such as granule structure, pastingproperties and functional properties such as swellingpower and solubility (Zaidul *et al.,* 2007; Gomes *et al.,*2005; Charles *et al.,* 2004).

Studies have shown thatcassava starch granules are truncated with variousshapes and sizes ranging from 2 - 40 micron(Tukomane *et al.,*2007). The starch has pasting properties typical of othertuber and root starches with low amounts of proteins,lipids and fiber (Charles *et al.,* 2004).

Other industries that require cassava with novel starchesinclude the production of glucose syrups and in the emerging construction and mining industry wherecassava starch is required because of its good viscosityproperties. In addition, the food and dietetics industryrequire improved starches ideal for delivering healthbenefits to people since starch forms a major part of thenutritional components among most communities. Starches with a low glycemicindex are also important in health (Baguma, 2004).

2.16.1. Advantages of cassava starch

Cassava has many advantages for starch production

- High level of purity.
- Excellent thickening characteristics.
- A neutral (bland) paste.
- Desirable textural characteristics.
- A relatively cheap source of raw material containing a high concentration of Starch (dry matter basis) that can equal or surpass the properties offered by other starches.
- Easy to extract.
- Preferred in adhesive production as the adhesive are more viscous, work more
- Smoothly and provide stable glues of neutral pH
- Has clear paste

2.17. Chemical composition of cereal starch

Starch is composed essentially of glucose. Although it may contain a number of minor constituents, these occur at such low levels that it can be debated whether they are trace constituents of the starch or contaminants not completely removed during the extraction process. Even though these minor constituents are found in small amounts in the starch, they can affect the starch properties.

Cereal starches contain low level of fats. The lipids associated with starch are generally polar lipids, which require polar solvents such as methanol-water for their extraction. Generally, the level of lipids in cereal starch is between 0.5 and 1.0%. Non cereal starches contain essentially no lipid. Besides low levels of other minerals, starches contain phosphorous and nitrogen. In the cereals, most of the phosphorous is in the form of phospholipids. Phosphorous in potato starch is clearly esterified to glucose, but this is apparently not true with the cereal starches.

All starches also contain low level of nitrogen (<0.05%) part of this is from the lipids and the reminder may be proteinaceous, perhaps remnants of enzymes involved in starch synthesis. Starch is basically polymers of α–D-glucose, chemically at least two types of polymers are distinguishable, amylose is essentially linear polymer and amylopectin which is highly branched Hoseney, (1986).

2.17.1. Amylose

Amylose is generally assumed to be a linear polymer α-D- glucose linked α-1, 4. The molecular weight is around 250,000 (1,500 anhydro-glucose units) but varies quite widely, not only between species of plants but also within a species. and depends upon the plants stage of maturity. Although the polymer is generally assumed to be linear, this appears to be true for only part of the amylose; the reminder appears to be lightly branched.

When amylose leached from starch by heating slightly above the starches gelatinization temperature, the amylose solubilized is essentially linear. As the leaching temperature is increased, amylose of higher molecular weight and more branching is obtained. Both enzymatic studies and studies of viscosity have indicated that this is long-chain branching, with the slide chains containing hundreds of glucose residues. The branch points are α . 1, 6 bonds, the same as those found in amylopectin. The branches on amylose are so long and so few that in many ways the molecule acts as an unbranched entity. The long, linear nature of amylose gives it some unique properties, for example, its ability to form complexes with iodine, organic alcohols or acids. Such complexes are called Clathrates or helical inclusion compounds.

Amylose can be precipitated from a solution of starch (solubilized with potassium hydroxide or dimethylsulfoxide) by the addition of n – butyl alcohol. The alcohol and the amylose form an insoluble complex. The nature of which is similar to that formed by iodine with amylose. The well-known blue color given by iodine and starch is thought to be due to polyiodine ions in the central core of the amylose helix. The long linear nature of amylose is also responsible for its tendency to associate with itself and precipitate from solution. Hoseney, (1986).

2.17.2. Amylopectin

Like amylose, amylopectin is composed of α-D- glucose linked primarily by α-1-4 bonds. Amylopectin is branched to a much greater extent than is amylose, with 4-5% being α-1-6 bonds. This level of branching means that on the average, the unit chain in amylopectin is only 20 – 25 glucose units long. Amylopectin has a molecular weight of about 10^8. It is truly a huge molecules, one of the largest found in the nature, with 595, 238 glucose residues (10^8/168,168 is the molecular weight of an anhydro – glucose unit) or 29, 762 chains with an average degree of polymerization of 20.

Amylopectin is thought to be randomly branched. The molecule has three types of chains: A – chains, composed of glucose linked α – 1, 4, B – chains, composed of glucose linked α – 1, 4 and α – 1, 6, and C – chains, made up of glucose with α – 1, 4, and α – 1, 6 linkages plus a reducing group. Thus, A – chains don't carry branches and B – chains do, the C- chain is branched and also has the only reducing group in the molecules.

The structure of amylopectin is best examined by a series of enzyme that partially degrade the molecule. One such enzyme is β- amylase, which attacks at the nonreducing end of starch chain and breaks every other α – 1,4 bond, it thus reduces a linear chain to maltose (two glucose molecules linked α -1,4). B amylase cannotpass a branch point on the starch chain. Thus, it will leave residues of two or three glucose residues, depending upon weather the original chain had an even or odd number of glucose residues outside the branch point.

Amylopectin is degraded about 55% by β amylase. The products are maltose and large residue, the β – limit dextrin still has a very large molecular weight (10^4**).** Two other enzymes that have been helpful in determining the structure of amylopectin are the debranching enzymes pillulanase and isoamylase, Both hydrolyze the α – 1, 6, bonds but not α – 1, 4. Bonds. Thus, treating amylopectin with either of these enzymes breaks all the α – 1, 6, bonds (branches) and leaves relatively short linear chains. By determining the reducing power per unit weight, the average chain length can be calculated. Amylopectin has an average chain length of about 25 (Hoseney, 1986)

2.17.3. Amylose and amylopectin

Many important physicochemical, thermal, and rheological properties of starch are influenced by the ratio of amylose and amylopectin, the two major polymers in the starch granule, and by the structure of amylopectin. Amylose content strongly affects starch gelatinizationand retrogradation (Russel 1987, Fredriksson*et al.,* 1998), paste viscosity (Reddy*et al.,* 1994, Yanagisawa*et al.,* 2006), gelation (Biliaderisand Zawistowski1990, Miles*et al.,* 1985), and R-amylase digestibility (Skrabanja *et al.,* 1999). The fine structure of amylopectin (chain-length distribution) also was found to influence starch gelatinization and retrogradation properties (Shi and Seib 1992, Jane*et al.,* 1999).

The encapsulating ability of starch dependson the amylopectin and amylose contents in thematrix. The higher the amylopectin content in the gelatinized starch, the greater is the encapsulatingability. The highly branched nature ofamylopectin reduces the mobility of the starchchains and interferes with their tendency to becomealigned for close packing. As a result,amylopectin provides a relatively larger volumefor the active agent to be accommodated insidethe polymer matrix than does amyloseRobert *et al.,* (1988).

The structure of the amylopectin molecule, in particular, appears to influence viscoelastic properties of rice. Juliano *et al.,* (1987) studied three high-amylose rices that contained similar amounts of amylose but differs in gel consistency, a measurement used to differentiate high-amylose rices. They found that the rices that produced hard gels (the firmer, less sticky cooked rice) had more long-chain linear portions in the amylopectin molecule than the softer gel rices. The long chain amylopectin also apparently increases iodine-binding capacity. Amylopectin structure also differed between apparent low- and high-amylose rices (Takeda *et al.,*1987).

Amylopectin is branched to a much greater extent than amylose. So much that, on the average, the unit chain in amylopectin is only 20-25 glucose molecules long. Amylopectin has a molecular weight of about 108. The ratio of amylose to amylopectin is relatively constant, at about 23. Amylopectin is a much larger glucose polymer (DP 105–106) in which α-(1, 4) - linked glucose polymers are connected by 5–6% α-(1, 6)-linkagesHoseney, (1986).(Appendix 4)

2.18. Molecular characterization of starch granules

Many investigators tried to explain that peculiar behavior of starch granules in terms of structural intricacies, which are not yet well understood. According to the size of individual granules, starches may be grouped into four classes following large-above 25 µm, medium from 10-25 µm, small from 5-10 µm, and very small below 5 µm (Lindeboom *et al.,* 2004).

In some cases, bimodal size distribution (predominantly small and large granules) is observed. Most of cereal starches show bimodal size, oat, buck wheat, rice and millet represent the class of small starch. Considering their morphology, starch granules may be classified as oval, oblong, spherical, polygonal, and irregular or lens shaped.

The size distribution of granules in a specimen may be the main factor responsible for properties of starch in bulk (aggregation clustering) that influence its behavior during transportation and storage which in turn may affect the quality of the product. Bergthaker, (2004) reported that the granules of wheat starch represent bimodal type and the result showed by watson (1970), Badi *et al.*, 1976) found that starch of pearl millet appear smaller, but similar to Maize and sorghum starch and the diameter of pearl millet starch ranged from 8 – 12 microns.

2.19. Size and shape of starch granules

The size of starch granules, which is generally expressed in microns (1µ = 0.001mm) and signifies the length of their longest axis, varies from about 2 µ to 150µ. Among the more common types, potato starch granules are among the largest, ranging up to 100µ, while those of rice starch are among the smallest, their range being 3µ to 8µ. Granules size within the same type of starch may be either fairly uniform or show a relatively wide spread. Thus, potato starch granules may vary in size from 15µ to 100µ giving a ratio of about 1 to 7, while the range for rice starch granules is from 3µ to 6 µ, or a ratio of 1 to 2. Some starches, such as wheat, consist partly of relatively large and partly of relatively small granules, with few granules of intermediate size.

The average granule size is of some practical significance since it has been observed that some starch properties, such as ease of gelatinization or dispersibility, are to some degree correlated with the granule size of a given starch type. Thus, it is a long-known fact that the larger granules of any particular starch gelatinize more easily than do the smaller granules.

The shape of starch granules, as revealed by microscopic examination, appears to be largely determined by the environmental conditions under which they have grown.

The wheat starch granules are rather thin and fairly round in form. Rice starch is the smallest of the cereal starches, and also generally the most uniform in size Pyler (1973).

2.20. Starch gelatinization

All starch granules swell when heated in the presence of water. This process requires the prior loss of at least some of the ordered structures within the native granule, and is often regarded as the final stage in the process of gelatinization. Despite the central importance of the swelling process in many technological applications of starches, there is limited understanding of the factors that control its rate and extent. The botanical/genetic origin of starches is recognized to be an important determinant of granule swelling properties Martine and Michael, (2006)

One of the important distinguishing characteristics of different starches is their swelling behavior during gelatinization. The starch granule is completely insoluble in water at room temperature or below. When an aqueous starch suspension is heated, nothing happens until a critical temperature is reached, usually at about 140 F (60 C°) at which the energy level is sufficiently high to dissociate the weaker bonding in the more accessible and amorphous intercellular areas of the granules. At this point some of the granules swell tangentially and progressively and lose some of their opacity and their Maltese or polarization crosses. The granules within any given starch species do not begin to swell at the same temperature but rather over a range of about 18 F (10 C°).Pyler (1973).

The factors that influence the gelatinization include granule size and shape, amylose content, degree of crystallinity in the amylopectin fraction, chain length in amylopectin and possibly placement and content of starch granule-associated protein and lipid (Juliano*et al.*, 1965, 1987, Manginat and Juliano, 1980, Hamaker and Griffin, 1990, Tester and Morrison, 1990).

Leach (1965) found that gelatinization start in the region of the granules where the associative forces were weakest (amorphous region). The strength of the associative bonds in this region varied among the different granules belonging to the same botanical type. That was why gelatinization took place over a range of temperature rather than a single temperature. It was also observed that larger granules lose their structure at lower temperature than smaller granules.

Gelatinization temperature of pearl millet starch (1% suspension) was found to range from 51C◦ to 69C◦. Gelatinization temperature of the rice grain is recognized as one of the most important determinants of cooking quality (Bao*et al.,* 2004). The birefringence end point temperature (BEPT) of sorghum starch is ranged between 68C◦ to 70C◦, which is higher than for maize starch (Leach *et al.,* 1959), while (Badi, 1973) showed that sorghum and millet starches (1% suspension) gelatinization temperature ranged from 63C◦ to 74C◦ and 51C◦ to 69C◦ respectively by using Kolfer hot microscope.

According to Ubwa *et al.,* (2011), gelatinization temperatures of white sorghum, 74-82C°; and brown sorghum, 74-82C°. Morales-Sanchez *et al.,* (2009) carried out wet method for measuring starch gelatinization temperature using electrical conductivity and found the gelatinization temperatures for potato, 55-66; wheat, 52-66.; corn, 66.2-77.; and rice, 66-82C°.

Starch gelatinization is associated with the disruption ofgranular structure causing starch molecules to dissolve inwater and, as such, is one of the starch's most importantand unique properties Lineback (1986). Many food products containpartially cooked starch granules that contribute to theirfunctional and structural properties. Therefore, it is importantto understand the time and temperature dependence of starch structural changes in water to characterize the gelatinization processes, especially how the granular structurechanges and how amylose and amylopectin polymersbehave at different water temperatures.

2.21. Swelling and retrogradation of the starch

The granules start swelling irreversibly over small temperature range, when starch heated with water. Continued heating lead to further swelling of granules, accompanied by a substantial increase in viscosity. Along with partial leaching of the paste upon cooling, however, the molecules tend to come close and associate with each other means of hydrogen bonding among the numerous hydroxyl groups and the paste viscosity again increases (Bhattacharya 1995).

Kulp (1979) reported that by heating starch in water above certain temperature, the starch granules begin to swell and increase in size according to the temperature and time. This takes place for wheat starch between 52C◦ to 62C◦, for sorghum starch 68C◦ to 75C◦ and waxy sorghum 67.5C◦ to 74.0C◦.The major factor that controls swelling is the strength and nature of hydrogen bonding network within the granule (Hoseney *et al.,* 1978). Starch granules are not water soluble, but easily hydrated in aqueous solution, swelling about 10% in volume. When an aqueous suspension of granules is heated, additional swelling occurs over a range of about 10C◦ (Annon 1998).

Starch retrogradation is a process that occurs when the molecules composing gelatinized starch begin to re-associate, leading to a more ordered structure, which may develop into crystalline form (Atwell *et al.,* 1988). Upon further heating (pasting or cooking), swelling continues and amylose with portion of amylopectin leach from the granules producing a viscous suspension. Cooling of this suspension leads to the formation of gel. With further time, realignment of the linear chains of amylose and the short chains of amylopectin can occur in the process known as retrogradation. In food products based on starch gels, this can lead to liquid being expressed from the gel in the phenomenon known as syneresis, which is generally an undesirable occurrence. Retrogradation is most rapid with amylose and much slower and more incomplete with amylopectin due to the short chain length of its branches (Annon 1998).

Upon continuous heating, granules tend to swellto greater extents, and the crystallites melt, resulting in increasedmolecular motion that eventually leads to completeseparation of amylose and amylopectin Keetals *et al.,* (1996), Levin and Slade (1990).The temperature at which granules lose their birefringence is referred toas the gelatinization temperature; this temperature dependsin part on the botanical source of starch Lineback (1986). Tester and Morrison(1990) reported that starch granular swelling is primarily a property of amylopectin because waxy starch swelledmuch more than normal starch did.

In food products, starch granules are subjected to differentthermal conditions and other unit operations thatresult in granules with differing stages of partial and fullgelatinization; these collectively influence the product's physicochemical properties.

2.22. Functional properties

Afunctional property isany nonnutritional property of a food or food additive that affects it utilization Rhee, (1985). Functionality of food protein is defined as those physical and chemical properties, which affect the behavior of protein in food system during processing storage, preparation and consumption (Fennema, 1996). Many factors influence the functional properties of proteins. Including moisture, temperature, pH, concentration, reaction time, enzymes, chemical additives, mechanical processing, ionic strength, and amount, sequence rate, and time of the additives (Johnson, 1970).

2.22.1. Water absorption capacity (WAC)

Among various physiochemical properties of protein, hydration is important in foods systems because it's related to other functional properties, such as solubility, emulsification, wettability, cohesion and adhesion, dispersibility, viscosity and gelation (Hansen, 1978). Water absorption capacity was defied as the ability of material to hold water against gravity (Chou and Morr, 1979). Water absorption capacity of isolate concentrate may be affected by conformational and environmental factors (pH and temperature).

Riganakos and kontominas (1994) reported that when soybean protein heat-treated, its hydration capacity decreased, because denaturation of soybean protein allows exposure of hydrophobic groups previously buried inside the protein. A higher heat treatment promotes the formation of gel matrix capable of retaining water in its structure, thereby increasing water absorption. Primary protein – water interaction occur at polar amino acid sites on protein molecules so that protein are capable of binding large quantities of water because of their ability to form hydrogen bonds between water molecules and polar groups (carboxyl, sulfhydryl) of poly peptide chains (Jones and Tung, 1993; Alkahlani*etal.*, 1997).

Starch granules are insoluble in cold water. When starch is heated in water, granules absorb water and swell. The absorptionof water by amorphous regions within the granulesdestabilizes their crystalline structure, resulting in theloss of birefringence, which is one definition of gelatinization Donovan (1979), Biliaderis (1990), Parker and Ring, (2001)**.**

2.22.2. Fat absorption capacity (FAC)

Kinsella (1976) reported that fat absorption of food products is an important functional property that improves mouth feel and flavor. The mechanism of fat absorption is mostly attributable to physical entrapment of oil and bulk density. The role-played by surface hydrophobicity and total hydrophobicity cannot be overlooked (Nakai, 1983).

Bhatty (1993) reported fat absorption capacity of flour, bran, and short of hull-less barley as 1.4 ml/g, 2.7ml/g and 3.4 ml/g respectively, and reported oil absorption capacity of barley flour (13 ml/g) slightly higher than that of wheat flour (1.2 ml/g).

2.23. pH of starch

Chemists and scientists use pH as a standardized measure of the acidity of various liquid solutions. The pH scale is a universal tool that helps people understand whether a solution is acidic or basic, and these characteristics are generally displayed numerically on a scale from 1 to 13. Substances exist at the ends of this scale are usually either highly corrosive or caustic. Hydrochloric acid, for instance, has a pH of 1, and lye usually hits close to 13. Most organisms have a certain pH range in which they do the best, and amylase is no different. When things go either lower or higher, the enzyme often can't keep up with the changed environment and starts to break down (Internet 2014http://www.wisegeek.org/what-are-the-effects-of-ph-onamylase.htm).

The pH affects the magnitude of the change on molecules which in turn alters attractive and repulsive interaction. By lowering the pH to 4 carboxyl groups are converted toward no ionized forms thus reducing water-binding capacity of protein.

The pH of pearl millet starch ranged from 4.8 to 5.0 (Khatir, 1990 and Sokarb, 1994). The pH of traditionally extracted starch was found to be 3.3 (Khatir, 1990).

2.24. Gelation

Gelation may be defined as protein aggregation in which polymer-polymer and polymer solvent interaction as well as attractive and repulsive forces are so balanced that a tertiary network of matrix is formed. Such a matrix is capable of immobilizing or trapping large amount of water (Schmidt, 1981). Factors that affect gelation properties include protein concentration, protein components in a complex food system, non-protein components, pH, ionic and reducing agents and heat treatment conditions (Schmidt, 1981).

Gelation involves the formation of a continuous network that exhibits order. Higher protein concentration may enhance the rate at which such a network is formed (Deshpande *et al.,* 1982).

Differences in gelling ability of different food stuffs could be due to differences in protein and to the nature of proteins (Sathe *et al.,* 1982).

2.25. Dispersibility

Ease of dispersibility is important in food formulations. The dispersibility of a mixture in water indicates its reconstitutability, the higher dispersibility the better reconstitutability (Kulkarni *et al.,* 1991). Temperature, ionic composition, pH and degree of agitation of solvent are major factors affecting dispersibility (Kinsella, 1976).

2.26. Wettability

Wettability properties depend on the affinity of the protein to water and other polar solvent (Abdel kareem and Brennan, 1974). Ease of wettability is important in food formulations. Wettability of protein is affected by surface polarity, topography, texture, area and by the size and microstructure of the protein particles, but not necessary by the amount of native structure (Hagerdal and lofqvist, 1978).

Wettability may be a convenient parameter providing information on surface properties of starch gels ‘surface. The wettability of a solid surface can be determined by a relatively simple method, measuring the so-called contact angle (Adamson, 1990). The study of starch gels ‘wettability and their surface free energy may be useful for food science and pharmacology fields. In food technology, a better understanding of the surface properties of gels can be useful in developing new food products and food components. In pharmacology, wettability can help to explain the drug delivery systems and mucosa adhesion (Bialopiotrowicz, 2003).

Furthermore, an intense search for new renewable sources to produce edible and biodegradable materials is observed. Edible and biodegradable natural polymer films offer alternative packaging with lower environmental coasts. The main renewable and natural biopolymer films are obtained from polysaccharides, lipids and proteins. Furthermore, starch is considered one of the most promising raw materials for developing biodegradable plastic to reduce the environmental impact of plastic wastes, especially from packaging (SinhaRay and Bousmina, 2005).

2.27. Bulk density

Bulk density depends on interrelated factors including intensity of attractive interpretable forces,, particle size and number of contact points (Peleg and Bagley, 1983). Higher bulk density is desirable since it helps to reduce the paste thickness, which is an important factor in convalescent and child feeding (Padmashree *et al.*, 1987).

2.28. Viscosity of starch

The viscosity of starch systems often decreases markedly asa result of stirring during I hr. holding at 95°C (Hoseney 1986).This decrease in viscosity often is referred to as shear thinning.Starches vary in their amount of shear thinning and, generally,those with greater shear thinning are more soluble (Zobel 1984).Lorenz and Hinze (1976) reported that holding the temperature of the starch paste at 92°C for 30 min reduced the viscosity ofmillet starches and increased those of wheat and rye.

2.29. Falling number of starch

The graph of cereal-amylose activity versus falling number indicated inversely proportional curvilinear relationship, during which at lower activity values, falling number tend to be at its maximum values, then drastically reduced within a limited activity, thereafter the proportional gradual decrease in falling number paroled an increase in activity occurs. Idris (2001) found that the falling number of starch of pearl millet is 62 seconds.

2.30. Wet milling process

Industrial wet milling of sorghum grain for starch production was developed during the Second World War as an alternative to maize starch production. Also sorghum can be milled for oil, germ and livestock feed (Watson 1970).Weller *et al.,* (1980) reported that the development of the laboratory wet milling process required precision in the release of starch granules from protein matrix and in the separation of starch from protein.

Steeping corn has not changed over the past 100 years as preparation for wet milling. Moreover the process enables the recovery of the starch of about 90%. Reducing steeping time from 48hrs may reduce processing cost, but creates serious problem in processing and product quality (Steinke and Johnson 1991).

2.31. Protein fractionation

Protein is considered the most important nutrient for humans and animals, as manifested by the origin of its name, from the Greek proteios for primary. The protein content of wheat grains may vary between 10% - 18% of the total dry matter. Wheat proteins are classified according to their extractability and solubility in various solvents. Classification is based on the classic work of T.D. Osborne at the turn of the last century. In his procedure, sequential extraction of ground wheat grain results in the following protein fractions: Albumins, which are soluble in water; Globulins, which are insoluble in pure water, but soluble in dilute NaClsolutions, and insoluble at high NaCl concentrations, Gliadins, which are soluble in 70% ethyl alcohol and Glutenins, which are soluble in dilute acid or sodium hydroxide solutions.

Albumins are the smallest wheat proteins, followed in size by globulins. The separation of albumins and globulins turned out to be not as clear as initially suggested by Osborne. Gliadins and glutenins are complicated high-molecular weight proteins.

Most of physiologically active proteins (enzymes) in wheat grains are found in the albumin and globulin groups. In cereals, the albumins and globulins are concentrated in the seed coats, the aleurone cells and the germ, with a somewhat lower concentration in the mealy endosperm. The albumin and globulin fraction cover about 25% of the total grain proteins (Belderok *et al.*, 2000).

Gliadins and glutenins are storage proteins and cover about 75% of the total protein content. The wheat plant stores proteins in this form for future use by the seedling. Gliadins and glutenins are mainly located in the mealy endosperm and are not found in the seed coat layers nor in the germ. Storage proteins in wheat are unique because they are technologically active. They have no enzyme activity, but they have a function in the formation of dough as they retain gas, producing spongy baked products (Belderok *et al*., 2000).

Protein **c**ontent and composition varies due to genotype, and water availability, temperature, soil fertility and environmental conditions during grain development. The protein content of sorghum is usually 11-13% but sometimes higher values are reported (David, 1995).

Prolamins (kafirins) constitute the major protein fractions in sorghum, followed by glutelins. Lack of gluten is characteristic of protein composition, and traditionally, the bread which cannot be baked from sorghum and millet is only cake bread.

The protein content of pearl millet ranges from 8 to 19%, and there is better amino acid balance than in sorghum. Pearl millet is low in lysine, tryptophan, threonine and the sulfur-containing amino acids. Finger, teff, and kodo millets have similar amounts of lysine to pearl millet.

Fractions of protein in millets are as follows: albumins and globulins from 22 to 28%, prolamin and prolamin-like 22 to 35%, and glutelin and glutelin-like 28 to 32% of total N. The prolamin fraction in pearl millet is smaller than sorghum.

Rice protein which accounts for 7–8 % (DB) in the milled rice kernel is classified into four types: alkali-soluble glutelins (80 %), water-soluble albumins (9–11 %), salt-soluble globulins (7–15 %) and alcohol-soluble prolamins (2–4 %) (Landers and Hamaker, 1994). Among those, albumin and globulin existing in the aleurone layer are usually removed during milling. But heterogeneous large molecules of glutelins exist inside the rice endosperm in the forms of protein bodies (Cagampang *et al.,* 1966, Juliano and Boulter, 1976). These spherically shaped protein bodies bind strongly to the compound starch granules with strong disulfide bonds and/or hydrophobic bonds [Bechtel, and Pomeranz, 1978, Tanaka *et al.,* 1978).

2.32. Gluten content

The gluten content is an important parameter in assessing the quality of wheat flour (Grabski *et al.,* 1979; Kulkarni *et al.,* 1987). The flour quality is mainly affected by the nature of the gluten and its various components. The term 'gluten' refers to the proteins, because they play a key role in determining the unique baking quality of wheat by conferring water absorption capacity, cohesiveness, viscosity and elasticity on dough. The gluten, roughly comprising 78 to 85% of total wheat endosperm protein, is a very large complex composed mainly of polymeric (multiple polypeptide chains) and monomeric (single chain polypeptides) proteins known as glutenins and gliadins, respectively (Wieser and Kieffer(2001).

Woychick (2009) reported that gluten form as glutenin molecules cross- link to form a sub- microscopic network attached to gliadin, which contributes viscosity (thickness) and extensibility to the mix. If this dough is leavened with yeast, sugar fermentation produces bubbles of carbon dioxide which, trapped by the gluten network, cause the dough to rise. Baking coagulates the gluten, which along with starch stabilizes the shape of the final product.

Strong dough with an extensive gluten network is suitable for bread- making (Pomeranz, 1971), while Gaines (1990) stated that weak dough without an extensive gluten network is best for cakes, so glutens are designated as strong and weak glutens, and then wheat classified as hard and soft wheat.

Edward *et al.,*(2003) and Tosi*et al.,* (2005) reported that more refining (of gluten) leads to chewier products such as pizza and bagels, while less refining yields tender baked goods such as pastry products. Generally, bread flours are high in gluten (hard wheat), pastry flours have a lower gluten content. Kneading promotes the formation of gluten strands and cross- links, creating baked product that is a chewier in proportion to the length of kneading.

Gluten index is an important test for gluten quality and there is a positive relationship between glutenin quantity and gluten index percentage (the percentage of wet gluten remaining on the sieve after centrifugation) but there is a negative co- relation with gliadin quantity Perten (1995).

2.33. Falling Number

Falling Number test measures the α-amylase activity. Falling Number test is applicable for flour (Hagberg, 1960). α-amylase is an inherent enzyme of wheat which converts starch into simple sugars (Bloksma and Bushuk, 1988). Falling Number value is critical for final product because there is direct relationship between α- amylase activity and finished product attributes e.g. bread crumb quality and loaf volume (Perten, 1964). α-amylase is an inherent enzyme of wheat which converts in to simple sugars (Bloksmaand Bushuk, 1988).

Falling Number value of greater than 250 is generally acceptable for bread making. Adequate α-amylase activity in flour results high volume bread with firm and soft texture (Muller*et al.*, 1973). Excessive α-amylase activity (low FN) results in the formation of darkened loaf crust as a result of sugar caramalization and sticky crumb structure which causes problems during slicing (Gooding and Davies, 1997). Millers prefer to avoid wheat with excessive α-amylase activity (low FN) (Muller*et al.*, 1973). High α-amylase activity reduces the water holding capacity of the flour and weakens the bread crumb (Pyler, 1988).

Crandall (1996) reported that the lower the alpha- amylase activity of the flour, the higher the falling number reading, and vice versa. Average bread flours have falling number values within the range of 250 to 290 seconds.

Badi *et al.*, (1978) observed that the falling number of Sudanese wheat was abnormally high, indicating the low alpha- amylase activity in the wheat. Ahmed (1995) reported that the falling number of some Sudanese wheat was found to be in the range of 397- 482 seconds for whole flour. Perten (1996) stated that the falling number below 150 seconds produces sticky bread- crumb, while that between 200-300 seconds produces bread with good crumb and above 300 seconds reduces the loaf volume and dries the bread crumb.

Marchylo *et al.*, (1976) stated that the alpha- amylase of wheat affects the quality wheat for bread.

Ludwig, *et al.*, (2009) reported that Amylases have two important effects on the volume of wheat based bakery items. During the dough phase, amylases partly degrade the damaged starch to fermentable sugars. These, in turn, will be converted into alcohol and carbon dioxide by the yeast and ultimately contribute to the leavening of the dough. The main effect of the alphaamylases, however, takes place during the baking process when the gas bubbles in the dough expand because of the temperature increase (oven spring). This thermal expansion is counteracted by the increasing viscosity of the starch which is simultaneously absorbing water, swelling and partially gelatinizing. Selective use of amylases can decrease the viscosity of the starch enabling greater expansion of the gas bubble at the start of the baking process. Amylases also have an effect on the browning of the crust (bloom). Dextrins and sugars formed during the enzymatic degradation of starch give rise to the formation of a brown colour during baking and the typical bread flavour develops as a result of the reaction between these ingredients and other dough components.

2.34. Dough Rheology

Rheological properties of dough are important to baker for two reasons, first, they determine the behavior of dough pieces during mechanical handling, such as dividing, rounding and molding. Second, they affect the quality of the finished loaf of bread.

The rheological properties of the dough are determined by farinograph, mixograph, extensograph etc (Austein and Ram, 1971).Farinograph is the most widely used to understand rheological behavior during dough mixing (Anonymous, 1990, and Pomeranz,and Meloan, 1994). Farinograph is a recording dough mixer that measures torque needed for mixing dough at a constant speed and temperature. The resistance offered is integrated with time and traced on kymograph chart in form of curve. This curve is used to evaluate various rheological parameters such as dough development time, dough strength, dough stability etc Anonymous, (1990). Farinograph is the most frequently used equipment for empirical rheological measurements (Razmi-Rad *et al.,* 2007).

The water absorption capacity is the most important physical parameter affecting the farinogram, and is a function of the wheat flour protein content and quality (Finney *et al.,* 1987). The absorption is the amount of water required to counter the farinograph curve on the 500-Brabender Unit line for dough (Shuey, 1984). The flour with higher water absorption gives more favorable end products because it improves the texture and grain of the bread (Simon, 1987). DAppolonia (1976) reported that farinograph curve characteristics for any given wheat cultivar changes from location to location.The weather and soil conditions affect the protein content and wheat quality and indirectly the shape of the farinographic curve.

Rheological testing plays an important role in maintaining consistent flour quality. There are two primary categories of physical testing of doughs, the torque- or viscosity- measuring instruments like the farinograph and mixograph and the elasticity- measuring instrument like the alveograph. The farinograph is the one of the most commonly used instrument. This high speed mixture measures the resistance of the dough against constant mechanical shear. It measures the rate of flour hydration, dough development time, (peak time), flour mixing tolerance and flour strength (Kimberlee, 2006).

Rheological properties of dough and gluten during mixing are affected greatly by the flour composition (low or high protein content), processing parameters (mixing time, energy, temperature) and ingredient (water, salt, yeast, fats and emulsifiers) Sliwinski *et al.,* (2004_b)

Extensibility of dough must be maintained long enough under baking conditions to permit sufficient oven rise as reported by Bloksma (1990a) and Bloksma and Bushuk (1988). Extensibility is enhanced by the presence of many un-branched, long-chain glutenin molecules as reported by Bloksma (1990a). Kieffer (2003) mentioned that the resistance is positively related to baked volume. The full bread making potential of the dough is attained only at the optimum point of dough development as stated by Faubion and Hoseney (1990). Beyond the point of optimum mixing, resistance to extension no longer increased and the dough starts to breakdown as reported by Spies (1990). Bloksma (1990b) mentioned that a long dough development time of flour is considered an indication of good baking performance.

2.35. Bakery products

Bakery products are important read-to eat processed foods. Breads, sweet-dough products, biscuits, cookies, crackers and cakes are common bakery products that are widely consumed throughout the world. Bakery products are no longer considered fancy or luxury teatime snacks, but have become essential and significant components of the dietary profile of the population (Chavan and Kadam, 1993).

However, nutritional quality of these products could be low because of the inferior nutritional composition of wheat grain per second. The basic ingredient of bakery snacks of the wheat proteins are characterized by low lysine, methionine and threonine content. Due to that fact, in many developed countries, bakery products very often are enriched with protein, fat and sugar improvers. The demand for ready-to eat processed foods with better shelf life, satisfying taste, texture and with high nutritional quality seem to be the most important item that can satisfy consumers. The major bio-components of wheat flour in combination with other ingredients such as protein (animal and vegetable), lipids, sugars, emulsifiers as well as processing conditions strongly determine biscuit quality.

Bread baking quality is dependent not only on protein quantity but also on its quality. Therefore many extensive works were performed on gluten protein and the real ability of crude gluten as an indicator of flour strength for baking products. Technological quality of wheat is strongly related to the storage proteins (gliadin and glutenin) and characteristics of both of these proteins must be considered when attempting to explain the quality variation observed among different wheat Anjum and Walker (2000).

Starch is another important bio-component of cereal products and its gelatinization induces major structural changes during baking. It was found that the swollen and partially solubilized starch granules act commonly with wheat proteins as essential structural elements of baking products (Baszczak *et al.,* 2000 and Fornal, 1998). However, short dough has been identified as a suspension of solid particles in a liquid phase consisting of an emulsion of lipids in a concentrated sugar solution. Baltsavias *et al.,* (1999) showed that irrespective of composition, starch gelatinization was slight, presumably due to the limited water content coupled with the low baking temperature. These authors concluded that biscuits comprised a glassy matrix and their properties were mainly determined by the air and fat volume fraction as well as size of inhomogeneity.

The effect of additives such as lactic acid, fat and sodium chloride on dough development and bread making properties were examined (Chevallier *et al.,* 2000), Manohar and Rao (1999) and Maache *et al.,* 1998). Increasing level of fat has a positive effect on dough development and bread volume. Addition of emulsifier i.e. glycerol monostearate, lecithinlower the elastic recovery value, resulted in a reduction in consistency and hardness. Highly cohesive structure and a crisp texture also characterized biscuits with a high level of sugar. Addition of sugar to the dough formula decreased its viscosity and relaxation time, it promoted biscuits length and reduced their thickness and weight as for the quantity of water (Maache *et al.,* 1998).

2.36. Composite flour

Composite flour may be considered a combination of wheat and non-wheat flour for the production of leavened bread, other baked products and pastas, or wholly non-wheat flour prepared from mixture of flours from cereals, root tubers, legumes raw materials, to be used for traditional or novel products (Dendy, 1992). Composite flour is an important from an economic point of view where by this technique expensive wheat imports are reduced.

Composite flours are quite different from the ready-mixed flours familiar to millers and bakers. Whereas, ready mixed flours contain all the non-perishable constituents of the recipe for a certain baked product, composite flours are only a mixture of different vegetable flours rich in starch or protein, with or without wheat flour, for certain groups of bakery products. This gives rise to the following definition: “Composite flours are a mixture of flours from tubers rich in starch (e.g. cassava, yam, sweet potato) and/or protein rich flours (e.g. soy, peanut) and/or cereals (e.g. maize, rice, millet and buckwheat), with or without wheat flour Chatelanat (1973).

The composite flours containing wheat flour usually consisted of 70% wheat flour, 25% maize/cassava starch and 5% soy flour. But there were tests in which the composite flour contained no wheat flour at all for example 70% cassava flour or starch and 30% peanut and/ or soy flour.

As a rule, the composite flour containing wheat consisted of 70 – 80% wheat flour and 20 – 30% soy flour. In cases where no wheat was included, a mixture of 100% sorghum/millet flour or 50% cassava starch, 20% milk powder and 30% soy flour was used.

The use of composite flours used with or without gives rise to technical problems in the production of baked goods. From the bakers point of view the most important components of wheat flour is the proteins of the gluten that plays a decisive role in dough formation, gas retention and the structure of the crumb. If flour mixtures containing little or no wheat are used, certain tricks have to be employed to achieve a properly leavened product at the end Bugusu *et al.,* (2001).

The limit for the addition of the cassava/maize/rice to wheat flour for bread and small baked products is at least 50 – 80% wheat flour. The percentage depends on the baking quality of the imported wheat flour concerned. In the case of biscuits it is possible to replace wheat flour completely.

Most of the trails with composite flours have been carried out in this continent because of Africans continually growing population. Reports are available from Senegal, Niger and Sudan (Anon, 2000).

When bakery products are made from composite flour; their overall quality (odor and flavor, chewing properties, appearance, shelf life) should be as similar as possible to those of products made from wheat, to achieve this, the wheat flour contained in the composite flour must be suitably treated. The familiar flour improvers potassium bromate and ascorbic acid have proved very satisfactory for this purpose. The amount added must be adjusted to the quality of the wheat flour. As a rule it is between 20 and 50ppm.

2.37. Starch in bread

The major role of starch in bread making as in other food system is to act as water sink and thus set the system, that is to say when starch is heated in water, it changes from a water insoluble material to a partially soluble and vary hydrophilic substance. As a result much of free water in starch water mixture becomes bound as the temperature increased.

Starch acts as temperature triggered water sink in food system, the properties associated with the distribution of amylose and amylopectin within a granule are required for starch to function successfully in bread making (Hoseney *et al.,* 1978). In baking of bread, according to Sandstedt (1961) the function of starch is as follows: Diluting the gluten to a desirable consistency, Furnish a surface suitable for strong bond with gluten, Furnish sugar through amylose action and Provide flexibility during heating and starch takes water from the gluten to cause a firm set during complete gelatinization. Thus the properties of starch are extremely important to the baker.

2.37.1. High starch bread

Flour milled from local crops is used with imported wheat supply to save some of the foreign currency. This arrangement is particularly appropriate for developing countries which do not grow wheat. Satisfactory bread can be made from such composite flour, a blend of wheat flour with flour of either cereals such as maize, sorghum, millet or rice, or with flour from roots crops such as cassava (Kent and Evers, 1994). The flour of the non-wheat component acts as a diluent, impairing the quality of the bread to an extent depending on the degree of substitution of the wheat flour.

A higher level of substitution is possible with strong wheat flour than with a weak one. Possible levels of substitution, as percentage by weight of the composite flour are 15 to 20% for sorghum flour and millet flour, 20 to 25% for maize is possible by the use of bread improvers or by modifying the bread making process. A blend of 70% of wheat flour, 27% of rice flour and 3% of soy flour made acceptable bread provided that surfactant-type dough improver were used. A more economical blend, producing acceptable bread, is 50%, 10% and 40% wheat, rice and cassava respectively. Rice starch used at 25% with 75%wheat flour yielded acceptable bread (Bean and Nishita, 1985).

Bread of acceptable quality is being made in Senegal and Sudan from a blend of 70% imported wheat flour of 72% extraction rate and 30% of flour milled locally from white sorghum of 72 to 75% extraction rate, and also can be made at an even higher rate of substitution (Kent and Evers, 1994).

2.38. Bread quality

Bread quality is usually judged by:

2.38.1. Loaf volume

Soulaka and Morrison (1985) reported that loaf volumes obtained from reconstituted flours were larger, and the crumb softer as the gelatinization temperature of the starch fraction increased, however, Hoseney *et al.*, (1971) did not find a relation between the gelatinization temperatures of starches from various plants and their baking quality.

Cauvain and Chamberlain (1988) stated that, loaf volume increase is attributed to improved gas retention and to extending the period of dough expansion during the baking stage.

Perten (1995) stated that quality factors such as loaf volume and water absorption are related to gluten quality and quantity, higher gluten quantity values generally give a greater bread volume. Basically, strong flours must be used for making good bread. If weak flour is used, loaves of small volume are produced.

2.38.2. Crumb texture

Dough is a complex system, and many problems associated with the poor textural quality of a final product can result from a deficiency in one or more of the following characteristics: gas generation, gas retention, and setting of the structure in the expanded state.

The texture may be too soft, sometimes gummy. This retention of moisture in the crumb results from the production of too many dextrins from the starch and the loss of gluten structure (Mathewson, 2000).

Kaldy and Rubenthaler (1987) reported that a fine uniform crumb texture that is tender and moist is one of the main criteria for good bread quality. Generally, flour with high protein content or strong gluten or both, produces a coarse or heavy crumb texture.

2.38.3. Aroma

Aroma is important factor governing food acceptability. The aroma of bread results from the interactions of reducing sugars and amino compounds, accompanied by the formation of aldehydes. Also aroma is affected by the products of alcoholic and in some cases, lactic acid formation (Kent, 1983, Lyla, 2002). Matz (1968) mentioned that yeast consumes sugars and produces carbon dioxide and alcohol, the former reaction is responsible for raising the dough, while alcohol is partly responsible for the aroma of the baked product.

2.38.4. Color

Golden brown color of the crust is one of the most obvious traits of a baked product. This color results from polymerization reactions known as Millard browning and caramelization. Millard browning occurs when amine groups of amino acid combine with carbonyl groups of reducing sugar molecules. It is temperature and pH dependent, with higher pH increasing the reaction rate. The reactions continuous and colored pigment known as melanoidins is eventually formed. Caramelization involves only the sugar in the system, and although it is fostered by condition of high temperature and lower moisture than Millard browning, it likely contributes to the appearance as well.

Mathewson (2000) reported that, amylases and proteases can contribute to Millard reaction which required a reducing sugar and amino group, by making these compounds available.

2.39. Ingredients mixing and baking

A large number of optional ingredients such as hydrocolloids, skim milk, fat, acids, emulsifiers and gluten are included in bread formulation to improve its nutritional, shelf-life and organoleptic properties. Salt gives flavor to bread and also acts as a dough strengthener (Hoseney 1986). Fat acts as a plasticizer, gives softness, improves volume and has anti-stalling properties when added to a bread formula.

Brooker (1996) reported that during baking fat crystals melt and thereby makes it possible for the crystal-liquid interface to be incorporated into the surface of the bubble as it expands. This transfer of interfacial material from crystals to bubble surfaceexplains how the addition of shortening to dough allows bubbles to expand during baking without rupturing, thus producing high volume of bread with fine crumb structure. Acetic and lactic acids are used in bread formulation to improve the shelf-life of bread. Treatment of flour with acetic acid has been suggested as an alternative to potassium bromate and ascorbic acid in bread making (Seguchi *et al.,* 1997).

Dough mixing duration has a significant effect on rheological and baking properties. Under mixed dough will have unhydrated starch and protein which cannot interact in the dough during fermentation (Hoseney 1986). On the other hand over mixing leads to the formation of wet, sticky dough which poses problems during handling. The quality of bread dough depends on mixing conditions such as mixer type, rotation speed, mixing time and water content.

2.39.1. Additives

Additives are commonly used in baking industry to improve the quality of bakery products and the machinability of the dough. Common additives used are oxidants such as potassium bromate, ascorbic acid and azodicarboamide, enzymes such as α-amylase, protease and lipoxygenase and surfactants/emulsifiers such as glycerol monostearte (GMS) and diacetyl tartaric esters of monoglycerides (DATEM).

The use of these additives in bakery products is increasing all over the world because of the advantage they offer, such as improved volume, texture, crumb, shelf-life and slicing characteristics of bread. Several reports are available on the influence of additives on the quality of dough and bread (Aust and Doerry 1992, Maninder and Bains 1976). The advantages of additives are greater when either the desired quality flour is not available or bakery products are made from composite flour.

2.39.2. Bread improvers

Bread improvers encompass a large group of dough additives that serve to alter the handling properties of the dough or the sensory properties of bread or both, its designs are constantly changing to meet the rapid advance in food ingredient technology and demand for higher quality bakery products.

There are many types of commercial bread improvers manufactured for a variety of applications, whether it is for pan bread, pizza bases, or fermented dough. Each bread improver type is specially tailored to enable the desired characteristic of dough or bread type to be achieved. The usage of bread improver can vary widely, often reflecting the level quality or type of the improving ingredients that it contains.

Bread improvers provided better gas retention, resulting in lower yeast requirements, shorter proof time and larger finished product volume. It also improved tolerance to variations in the quality of flour and other ingredients, and gave drier dough that can be mechanically processed more easily and have greater resistance to abuse.

2.40. Biscuits ingredients

Soft wheat flour with about 9-9.5% protein is normally used in biscuit making (NCFM, 2003). If strong flours are being used, more shortening and sugar must be added to obtain an acceptable texture.

Sweeteners are very important to the cookie formula. Lorenz (1994) reported that the types of dry sugars, sucrose, dextrose, lactose and brown sugars, and liquid sugar, such as corn syrup high fructose, invert syrup, molasses and honey were used in cookies manufacturing. Wade (1988) reported that the addition of sugar to the biscuits dough has the effect of reducing the amount of water required in the dough. As the sucrose content increases, it acts as hardening agent, making cookies more crisp and firm. However, when in a solution it tends to act as softening agent when used at moderate levels, helping to hold water in the finished products.

Fats, such as butter, shortening or oils are essential ingredients in baking Philips, (2003). Lorenz, (1994) reported that shortening four primary functions in cookies, lubrication, aeration, eating quality and spreading. The principle classes of fats and oils used in cookies production are butter, shortening and margarine.

The addition of fat has the effect of reducing the amount of water required to make dough with a workable consistency and making the product more tender. A use of hydrogenated vegetable oil cream is satisfactory (Philips, 2003).

In baked goods milk and milk derivatives are used for color improvement, water absorption and spread control properties, and flavor.

Addition of ammonium bicarbonate enhances the spread as well as opens the structure to provide some lift, and the addition of sodium bicarbonate makes a rapid increase width and also affects the thickness. Also ammonium bicarbonate is frequently used in cookies dough, particularly the moist types such as rotary cookies, to increase the volume.

2.40.1. Biscuit making process

Lehman *et al.*, (1994) reported that the factors affecting variation in cookie spread are summarized as follows: firstly, causes of increased cookie spread, flour with low protein content and low protein quality, uses of fluid shortening, small particle size of sugar, high percentage of sugar syrup in formula, high level of leaving, single stage vs. multistage mixing, high percentage of moisture added to formula, low initial or slowly rising heat during baking and low fat-high sugar ratio.

Second possible causes of decreased cookie spread were: flour with high protein, chlorinated flour, use of plasticized shortening, large particle size sugar, high fat-low sugar ratio, use of multistage mixing-creaming method, low percentage of water added, high initial oven heat during baking and high amount of water absorption ingredients.

There are two ways to shape the dough, roll and cut or drop. The rolling and kneading results with flakiness biscuits, not sticky, and has sufficiently developed gluten. After rolling, the biscuit dough is cut into shape, 2-3 inches in diameter and the pieces are placed in a greased baking sheet.

The dropping method drops the dough in an irregular shape into grease baking sheet by highly floured fingertips as the dough is more sticky. The shaped dough then put in a well-preheated oven 250 C° Philip (2003).

Whitely (1971) noticed that to make biscuit palatable, baking is essential, and is achieved by transferring heat from a heat source to the biscuit. Wade (1988) recommended those two properties of the product which are, its color and moisture generally judges the completion of baking process content.

Chapter Three
Materials and Methods

3.1. Materials:

Sorghum (Tabat) and Millet (Ashana) were brought from Agricultural Research Corporation (Sinnar Research station), season 2010 – 2011. Wheat (Imam) is brought from Agricultural Research Corporation (Wad Madani Research station), season 2010 – 2011.Lentil (Abu Gibbaa) is brought from Agricultural Research Corporation (Alhodaiba Research station), season 2010 – 2011. Sudanese Rice was purchased from Kosti Local Market season 2011 – 2012. Cassava was purchased from Khartoum Local Market season 2011 – 2012.

3.1.1. Chemicals and reagents:

Some chemicals and reagents were purchased from local Market (Sodium metabisulfite, cysteine) other chemicals and reagents were purchased from outside the Country (Potasium iodide, Resublimed iodine and amylose standard) the rest of chemicals and reagents were obtained from Food Research Centre (FRC).

3.2. Methods:

3.2.1. Preparation of starch:

Wheat, Sorghum, Millet, Rice and Cassava were cleaned from impurities and foreign matter and prepared for extraction of starch by using Wet Milling process.

3.2.1.1. Wet milling process:

Method of Steinke and Johnson (1991) was used for wet milling process. Two hundred grams from each sample of Wheat, Sorghum, Millet, Rice and Cassava were weighed and soaked in a distilled water with 0.3% of sulfur dioxide (by adding Sodium meta bisulfite), for about 48 hours for all samples except for Cassava which was soaked for 72 hours, and its distilled water was changed daily for three days, then the soaked samples were stored in a refrigerator (4 C^o) to prevent germination and keep down fermentation.

The steeped grains were taken out of the steeping water and washed several times with tap water and then with distilled water, then ground in water using a blender for one minute. The blended grains sieved through 180 microns sieve (Tyler standard screen scale, opening in inches. 0097 meshes to the inch 60 U.S.A series equivalent OH1044060 U.S.A).The slurry was kept a side in a clean container and the material remaining over the sieve was blended again.

The process of blending and sieving was repeated several times until most of endosperm was reduced. The slurry was centrifuged for 10 minutes at 2000 rpm (Dentrfu-oversize, serial No. A080-5, Shanghai food package, Machinery Branch Corp. China). The supernatant liquid was discarded and protein layer on the top of the starch was removed out with stainless steel spatula.

The starch and protein were spread on a wide trays and left until dried by air, then dispersed in distilled water and mixed with hand, then sieved through 150 micron sieve(Tyler standard screen scale, opening in inches. 0058 meshes to the inch 100 U.S.A series equivalent OH1044060 U.S.A).

Again the starch and protein were centrifuged and the protein layer was removed as before. Centrifugation step and protein removal were repeated to get white starch. The starch was taken out and directly air- dried. The collected clean, white and granulated starch of each sample was kept in a clean and dry container and ready for analysis (flow chart 1, 2).

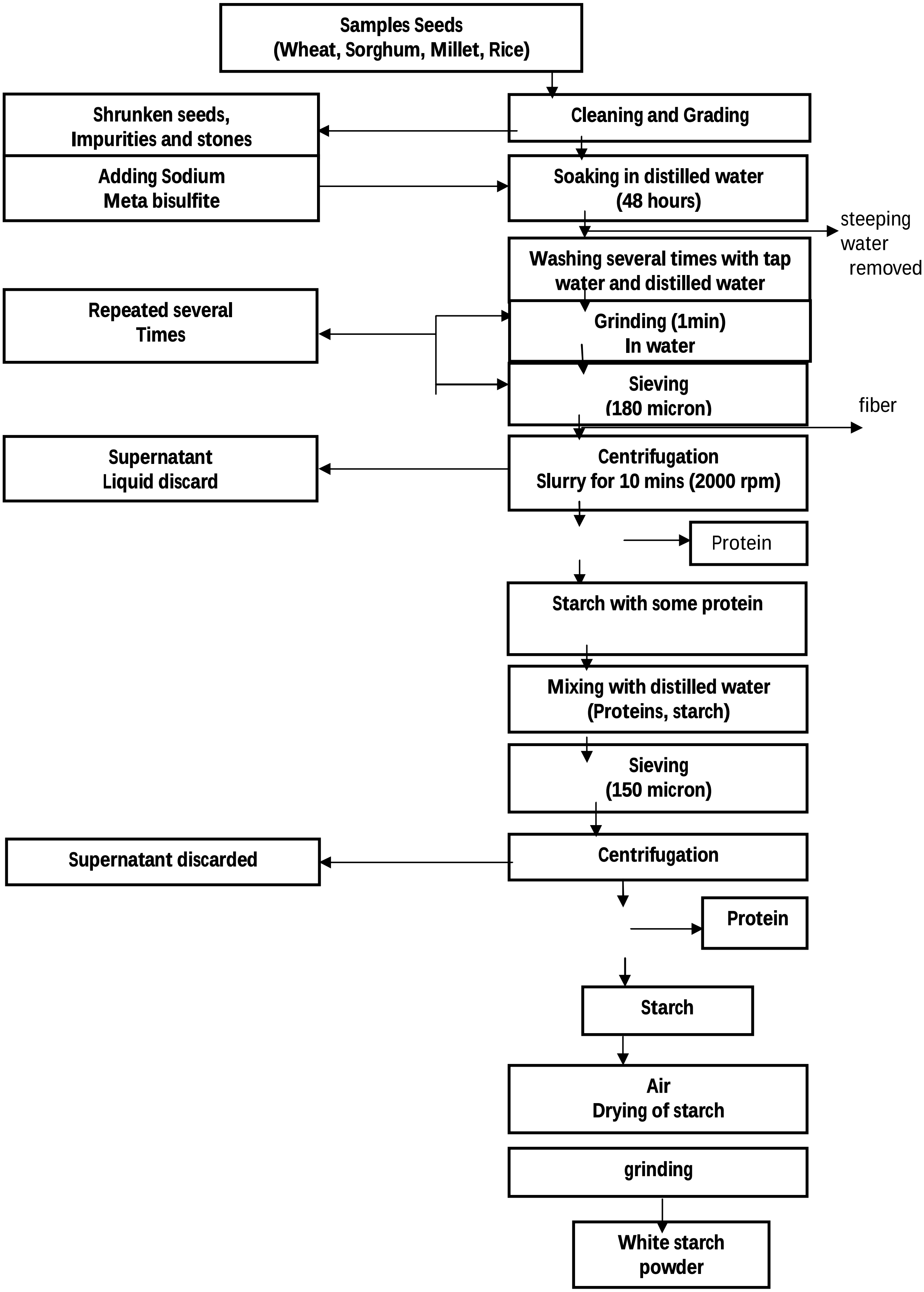


Chart.1. Flow Chart Showing Preparation of Cereal Starches

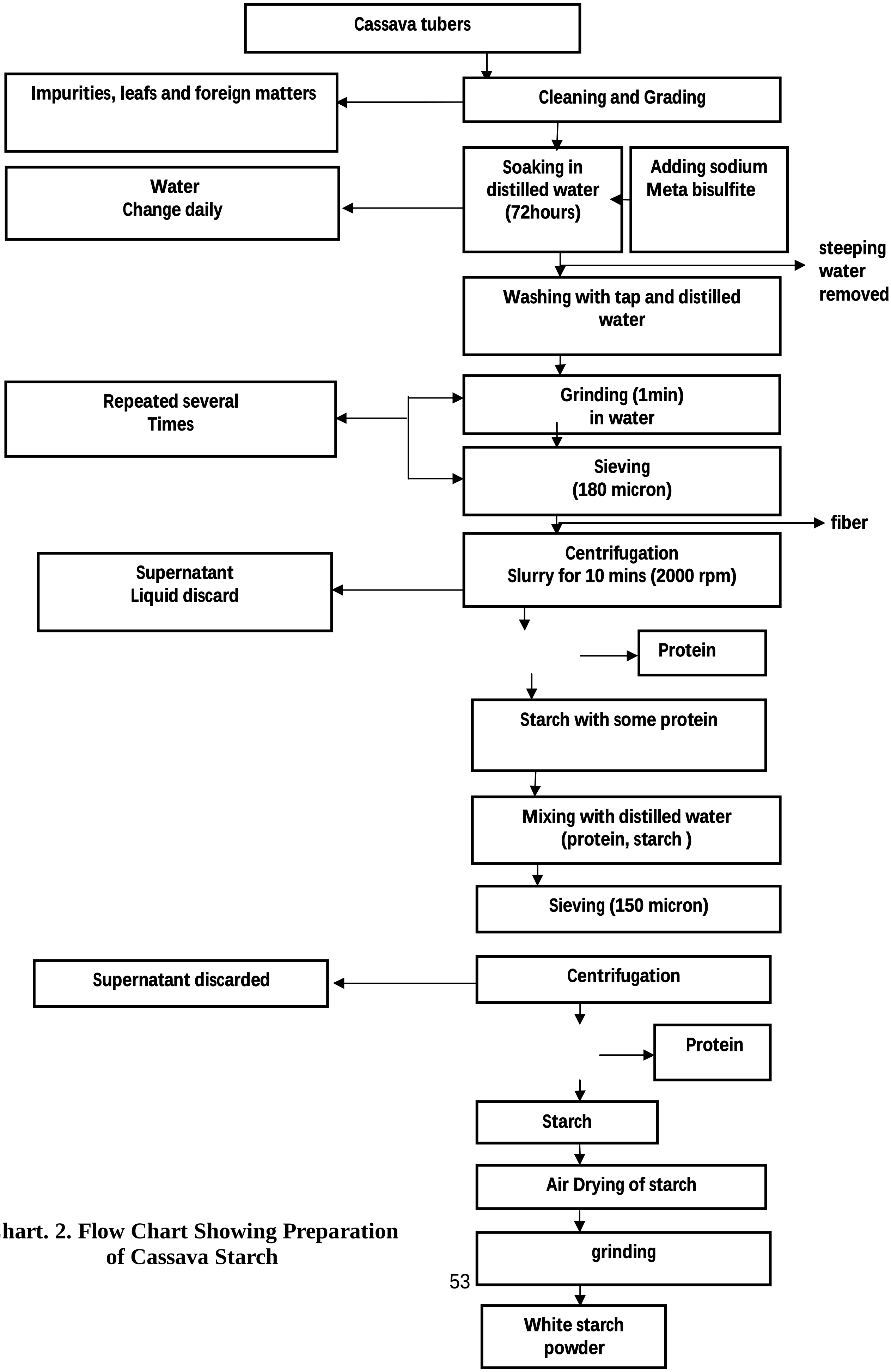


Chart. 2. Flow Chart Showing Preparation of Cassava Starch

3.2.1.2. Preparation of wheat flour:

Wheat was cleaned manually using 2.8 micron sieve for removing of impurities. Some of sample was ground in a falling number mill to obtain whole wheat flour (100% extraction rate). The other sample of wheat was tempered for 17 hours to obtain 14.5% grain moisture, and then milled in a Chinese flour mill with the capacity of 5tons/day (GFY-5) (plate 1). The flour was adjusted to 72% extraction rate by sifting using 180 micron sieve. The sample was well mixed and placed in air-tight plastic container, then stored under appropriate conditions (Deep freezer).

3.2.1.3. Preparation of lentil flour:

Lentil (Abu Gibbaa) was decorticated using Stone Mill at Omdurman Local Market. The decorticated seeds were ground into flour using an efficient universal pulverizer, (GF 300, serial number 69578, and powder fineness 90 – 120 mesh – Shanghai).

3.2.1.4. Preparation of Composite Flour Blends:

The starch of each sample of wheat, sorghum, millet, rice and cassava was added to wheat flour with three different percentages 5%, 10% and 15% for bread making, 5% of lentil flour was added to each of the three blends in order to compensate for the loss of protein content expected from starch addition. For biscuits, the starches of five samples were blended with three different percentages 10%, 15% and 20%. 10% of lentil flour is added to each of the three blends for the same purpose.

3.3. Analytical Methods:

Analytical methods were carried out for each starch sample of wheat, sorghum, millet, rice and cassava. Also for wheat flour with extraction rate of 72% and 100%, for lentil flour and their blends.

3.3.1. Moisture content:

The Moisture content was determined according to the method of A.A.C.C (2000) by using Buhler Rapid Moisture Tester (Model ML 11000).The Buhler drying temperature was 130 C^{o} and the time taken was 10 minutes.

3.3.2. Ash content:

The ash content of the sample was measured according to the A.O.A.C method (2000) using the muffle furnace (Carbolite Company). 2gms of sample were weighed into porcelain crucible and placed in a temperature controlled furnace at 600c^{o} complete for ashing; the crucible with ash was transferred directly to a dessicator, cooled, weighed and calculated as percent of original weight of sample.

$$\text{Ash content (\%)} = \frac{(wt_1 - wt_2) \times 100}{\text{Sample weight}}$$

Where:

wt_1 = weight of crucible with ash

wt_2 = weight of empty crucible

3.3.3. Crude protein:

Protein was determined according to A. O. A. C. method (2000) by micro Kjeldahl technique. 0.2g of sample was weighed accurately into micro- kjeldahl flask, 0.4g catalyst mixture and 3.5 ml of concentrated sulphuric acid were added, the sample content was heated on an electric heater for 2hr and cooled, then the contents were placed into the distillation apparatus. 20mls of 40% NaOH were added, the ammonia evolved was received in 10mls of 2% boric acid solution. The trapped ammonia was titrated against HCl (0.02 N) using universal indicator (methyl red + bromo cresol green), the total nitrogen and protein were calculated using the following formula:

$$N\% = \frac{\text{Volume of HCL X N X 14 X 100}}{\text{Weight of sample X 1000}}$$

P% = N% X 5.7 (for wheat flour)

P% = N% X 6.25 (for other samples)

Where:

N% = Crude nitrogen

P% = Crude protein

N = Normality of HCl

14 = equivalent weight of nitrogen

3.3.4. Fat content:

Total fat was determined according to the A.O.A.C method (2000).2gm of sample were extracted with petroleum ether BP 60 – 80C^{o} for 8 hr. in soxhlet apparatus. The fat content was calculated according to the following equation:

$$\text{Fat \%} = \frac{\text{Dry extract weight (g) x100 x100}}{\text{Wt of sample (100 - \% moisture)}}$$

3.3.5. Carbohydrate content:

The total carbohydrates were calculated by difference. The sum of moisture, fat, protein and ash contents was subtracted from 100 as it was described by West *et al.*, (1988).

3.3.6. Mineral content:

Mineral contents were determined according to Pearson (1970).Two grams of samples put into a weighed porcelain crucible, the crucible was placed in a muffle furnace at 550 C^{0} for 3 hours, each crucible was cooled in the desiccator and weighed. The ash obtained was treated with 10 ml concentrated hydrochloric acid (50% Hcl) with addition of 5ml of nitric acid (33%), then placed on water bath for one hour, 10 ml of Hcl was added and placed on water bath again for 15 minutes, after that transferred to 100 ml – volumetric flask filled to mark with distilled water, then well shaked.

After sample preparation, the element concentration was determined. Sodium (Na) and Potassium (K) were determined by flame photometer. Calcium (Ca) and iron (Fe) were determined by the atomic absorption spectrum. Phosphorus (P) was determined by the spectrophotometer (VV – visible spectrophotometer – wave length 440).

3.3.7. Protein fractionation:

Flour protein fractionation was carried out using the method described by Mendle and Osborne (1924).Albumins (water soluble proteins), Globulins (salt – soluble proteins), Gliadins (alcohol – soluble proteins), Glutamines (Alkali – soluble proteins) and Residual proteins (non – protein nitrogen) were determined as follows:

A sample of two grams of (wheat flour, lentil flour and their blends with different percentages of starch) were taken and treated with 30 ml distilled water. The mixture was shaken for 30 minutes, using a mechanical shaker, then centrifuge at 3000 rpm for 20 minutes to separate the insoluble parts. The supernatant was defined as Albumins.The insoluble parts obtained after extraction of Albumins, were re-extracted as described above using 30 ml (1.0N) Nacl aliquot. The supernatant was defined as globulins.The insoluble parts obtained after extraction of globulins, were re-extracted as described with 70 % ethanol, the procedure goes such as above. The supernatant was defined as gliadins.The insoluble parts obtained after extraction of Gliadins, were re-extracted by using 30 ml of 0.2% NaOH solution.. The supernatant was defined as Glutenins. Usually, supernatant was made up to 100 ml by using volumetric flask. The residues remaining after those successive extractions with the four solvents were defined as insoluble residues (non – protein nitrogen).The extracted proteins and the non – protein nitrogen, were determined by the micro – Kjeldahl method. Percent protein extracted was calculated with reference to the total amount of protein in the flour sample extracted as follows:

$$\text{Soluble protein \%} = \frac{T \times N \times TV \times 14 \times 5.7}{1000 \times a \times b}$$

$$\text{Percent solubility} = \frac{\text{Soluble protein}}{\text{Total protein}} \times 100$$

Where:

T = Titer reading (ml/HCL).

N = Normality of HCL (0.02N).

TV = Total volume of the aliquot extracted (100 ml).

a = Number of (ml) of aliquot taken for digestion (10 ml).

b = Number of (g) of flour sample extracted (2.0g).

14 = each (ml) of HCL is equivalent to 14 mg.

100 = 100 g of flour sample.

3.3.8. Analysis for starch

3.3.8.1. Acidity

Total acidity

The titeratable acidity was conveniently determined according to the AOAC (2000) method.20 ml of distilled water was added to the sample (2g) and then 10 ml of the mix was pipetted, phenolphthalein solution was added and titrated with

0.1N NaoH solution. The total acidity was calculated according to the following formula:

$$\text{Total acidity (mg citric acid/100g)} = \frac{\text{TX N X dilution Xequivalent weight X100}}{\text{Weight of sample X volume X1000}}$$

Where:

T = Burette titer.

N = Normality of NaoH

Dilution = Dilution factor (100 ml).

Equivalent weight = Equivalent weight of citric acid (64).

Weight of sample =2g

Volume = 100 ml.

3.3.8.2. pH value

pH was determined in 2% aqueous solution at room temperature using a pH meter (Hanna pH 211, Instruments microprocessor pH meter, serial number 805465 Woonsocket –RI – USA, made in Romania).

3.3.8.3. Falling number

Three grams of starch were weighed and put into falling number tube; 25 ml of distilled water were added, then shake and put into the falling number apparatus.

3.3.8.4. Color

Half kg of starch sample was taken for color test using Chroma meter – CR - 400/410 instrument. The instrument is attached directly to starch sample and the reading was appeared directly in the screen. The high reading value means whiter color of starch.

Instrument specifications

- Name: Chroma meter measuring head.
- Model: CR – 400/410 head.
- Measurement time: 1 second.

- Minimum measurement interval 3 seconds.

- Operating temperature 0 – 40 C° relative humidity 85% with no condensation.

3.3.8.5. Estimation of amylose content of starches

A rapid colorimetric method described by Williams *et al.,* (1975) was used for estimating the amylose content of starches.

Reagents.

(A) Stock iodine solution:

Potassium iodide (20g) was weighed into 100 ml beaker together with 2g resublimed iodine. The reagents were dissolved in minimum water and carefully diluted to 100 ml volumetric flask.

(B)Iodine reagent:

Ten ml of stock A was pipette into volumetric flask and diluted to 100 ml with distilled water.

Procedure

0.02 g for each of five starch samples were weighed into 100 ml beaker. Exactly10 ml of 0.5N KOH solution (28.05 per liter) was added and the starch was dispersed with stirring rod or magnetic stirring bar for 5 minutes or until fully dispersed. The dispersed samples were transferred to a 100 ml volumetric flask and diluted to the mark with distilled water with careful rinsing of the beaker. An Aliquot of the test starch solution (10 ml) was pipette into 50 ml volumetric flask and 5 ml of 0.1N Hcl (8.17 ml AR Conc. Hcl per liter) was added followed by 0.5 ml of iodine reagent B. The volume was diluted to 50 ml and the absorbance of blue color was measured at 625 nm after 5 minutes.

Calibration of the colorimetric test:

Increment of amylose from 2 to 12 mg was platted against absorbance at 625 nm wavelength. (fig.1)

3.3.8.6. Functional properties

3.3.8.6.1. Viscosity

Viscosity for 1% aqueous solution of sample was determined by the method of Quinn and Beuchat (1975) using HAAK eviscotester 6 plus,(Type 387 0100, Serial number 387200612206 – Thermo electron corporation (Karlsruhe) – GmbH – Germany (made in EECIP20), spindle No. 2 and speed 60 rpm at room temperature (25 C°) and viscosity was expressed as centipoises (cps). Viscosity was also measured for hot slurries after heating them at 70 C° for 15 minutes, using heater (Scott science – UK, model GHP, serial number 1127).

3.3.8.6.2. Water retention capacity

The water retention capacity (WRC) for starches was measured by the method of Lin *et al.,* (1974) with modification described by Quin and Beuchat (1975). 10% H2O suspension (3g/30ml) was stirred in a 50ml centrifuge tube using glass rod for 2 minutes. After 30 minutes equilibrium, the tube was centrifuge for 20 minutes at 4400 rpm (Centrifuge 5430/5430 Reppendorf, Humburg, Germany). The freed water was carefully decanted into a graduated cylinder and the volume was recorded. The WRC was expressed as milliliters of water retained by 100g of sample.

3.3.8.6.3. Bulk density

The bulk density was determined by the method of Wang and Kinsella (1976). 10 g sample of material was placed in a graduated cylinder (25ml) and packed by gently tapping the cylinder on the bench top (10 times) from a reasonable height (5-8cm). The final volume of sample was recorded and the bulk density is expressed as gram sample per milliliters volume occupied.

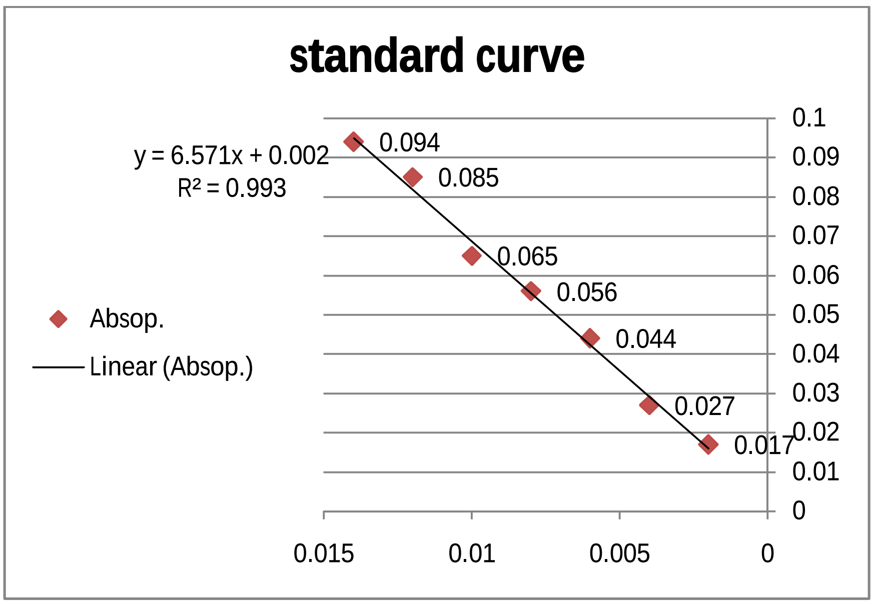


Fig.1. Standard curve of amylose

3.3.8.6.4. Fat absorption capacity

The fat absorption capacity (FAC) of the samples were measured by a modified method of Lin *etal.,* (1974). 4g material was treated with 20 ml of refined edible oil (specific gravity 1.52) in a 50ml centrifuge tube. The suspension was stirred with a glass rod for 5 minutes and the contents were allowed to equilibrate for farther 25 minutes. The suspension was then centrifuged at 4400 rpm for 20 minutes (Centrifuge 5430/5430 R eppendorf, Humburg, Germany) and the volume of the fat was measured. The FAC was expressed as milliliters of fat – absorbed by 100g of sample.

3.3.8.7. Least gelation concentration

Least gelation concentration of the sample was measured according to Coffman and Garcia (1977) with slight modification. Appropriate sample suspensions of (2, 4, 6, 8 and 10%) were prepared in 10ml of distilled water. The test tubes containing these suspensions were then heated for one hour in a boiling water bath (APP No5b, Gallenkamp, cat. No 250, made in England) followed by rapid cooling under running cold tap water. The test tubes were farther cooled for 2hours at (4C^{o}). The least gelling concentration was determined as that concentration did not fall down or slip when the test tube was inverted.

3.3.8.8. Gelatinization temperature

The gelatinization temperature was measured according to Abdalla *et al.,* (2009). One gram of the sample was weighed into 100 ml beaker. Hundred milliliters of distilled water were added (1% aqueous solution) and placed on heater. After gelatinization the temperature was measured using thermometer.

3.3.8.9. Dispersibility

The dispersibility was measured according to the method of Kulkarni *etal.,* (1991). Three grams of samples were dispersed in distilled water in a 50 ml stoppered measuring cylinder. Then distilled water was added to reach a volume of

30 ml, the mixture was stirred vigorously and allowed to settle for three hours, the volume of settled particles was subtracted 30 and divided by 30 and multiplied by 100 and reported as percentages dispersibility.

3.3.8.10. Wettability

The wettability was estimated according to the method of Regenstein and Regenstein (1984). Two grams of the samples were weighed in a sieve and transferred to a beaker containing 80 ml water. The behavior of the powder was observed on the water surface immediately after adding the sample. After 30 minutes observation, the material was stirred on the magnetic stirrer sufficiently fast to form a vortex which reached the bottom of the beaker and the stirring continued for one minute after which the grade describing wettability was recorded as excellent, good, fair, and poor according to the time and behavior of the dispersion (Appendix 5).

3.3.8.11. Shapes of starch granules

Starch sample (0.1gm) was weighed into 100ml beaker. 10 ml of distilled water were added. A drop of the solution was put on a slide of electronic microscope with magnify (10/0.25 160/017).

3.3.9. Rheological characteristics of dough:

3.3.9.1 Gluten Content:

The gluten content was determined according to the standard ICC method (1982) and by the use of gluten washing machine (using Glutamatic type 2200). Ten grams of sample were mixed with 5ml distilled water to obtain dough and the dough was washed with 2% sodium chloride solution. The gluten was centrifuged, weighed and the weighed quantity was multiplied by 10 to give wet gluten percentage.

3.3.9.2 Alpha amylase activity:

The alpha amylase activity was determined according to the falling Number Method of Perten (1996). The corrected weight of sample based on 14% moisture was weighed and transferred into viscometer tubes (using Apparatus of falling Number type 1800). 25ml distilled water was added. Then shacked strongly and the flour adhering to the sides of the viscometer tubes was scraped down into the suspension. The viscometer tubes together with viscometer stirrers were placed in the boiling water bath. After 59 seconds, the stirrers were lifted to the upper position, released and sinked under its own weight through the uniform gelatinized suspension. The time in seconds for the stirrers to fall through the suspension was recorded as the falling number in seconds.

3.3.9.3 Farinograph of dough:

The rheological properties of the dough prepared from wheat flour and wheat flour blends were measured using the Brabenderfarinograph method (Brabender OHG, Kulturte, 51-55, D-4055, Duisburg, Germany) according to the method of AACC (2000).

The titration curve

Brabenderfarinograph was operated as described in AACC method (2000). The titration curve was used for the assessment of the water absorption for each flour sample. A sample of 300gm was weighed and transferred to a cleaned mixture. The farinograph was switched on 63rpm, for one minute, then the distilled water was added from a especial burette (at deviation from the 500 units consistency, the correct water absorption can be calculated from the deviation, 20 units deviation correspond to 0.5% water, if the consistency is higher than 500 F.U. more water is needed and vice– versa. When the consistency is constant, the instrument was switched off and the water drown from the burette indicates water of the flour in percentage.

The standard curve:

The measuring mixer was thoroughly cleaned. A sample of 300 grams was weighed, then introduced in to 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. Fig. (2).

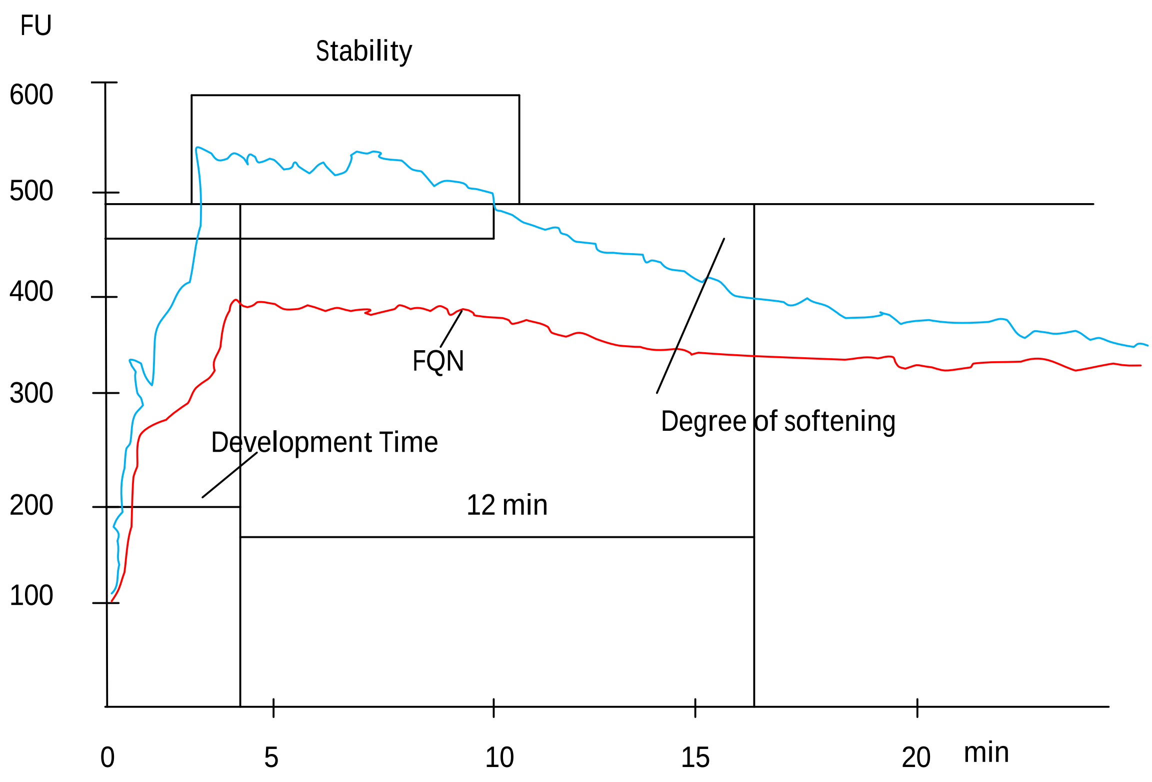


Fig. 2. Standard curve of a farinogram and its evaluation

3.3.9.4 Extensoghaph characteristics:

The dough extensibility was determined by using the Brabenderextensograph according to the standard method of the AACC No. 54 – 10 (2000). The extensograph records a force-time curve for a test piece of dough stretched until it breaks. Characteristics of force – time curves or extensographs are used to assess the general quality of flour and its response to improving agents.

Dough was prepared as described before in the Farinograph. The amount of water (at 30 C^o) was filled from the burette into an Erlenmeyer flask and 6 grams of salt (Sodium Chloride of recognized analytical quality) was dissolved. The salt solution was added quickly after one minute, premixing within 25 seconds as slow water addition influences the dough development time. The dough was mixed for one minute, and then the Farinograph stopped for 5 minute. After the completion of mixing, two pieces of 150±0.1 gram dough were scaled off and revolved in the extensoghaph rounder with automatic shut off after 20 revolutions. The dough was centered on shaping unit and rolled into cylindrical test piece, clamped in lightly greased dough holders, the test pieces on dough holders were stored in humidified chamber.

After rest period of 45 minutes from end of shaping, the cradle holding test sample was placed on the balance arm of the extensograph. A hook was pulled through the dough piece at a constant speed, which was thus stretched until the dough breaks. By means of the balance system, the load acting onto the dough during this procedure was measured and recorded.

The resulting diagram extensogram showed the force, which the dough opposed to the stretching force as a function of the stretching time i.e. the stretching length. The dough of the first test was removed from the holder and reshaped. As before, allowed next period of 45 minutes before stretching. The dough pieces were tested again after 90 and 135 minutes. The four most common measurements made on force-time charts, or extensograms Fig. (3) are as follows:

Resistance to extension

The resistance to extension is the height of extensogram at a constant deformation of the dough. The value is determined at the point where the curve start rising. The results are given inBUwith a precision of 5 BU.

Extensibility

The extensibility of the dough is a distance in mm from beginning of the stretching until the breaking of the test piece.

Energy

The energy measures the area under the curve in cm^2.The value (energy) describes the work applied for stretching the dough and is a measure for the flour quality.

Ratio

The ratio is the quotient of resistance and extensibility.

$$\text{Ratio} = \frac{\text{Resistance to extension (BU)}}{\text{Extensibility (mm)}}$$

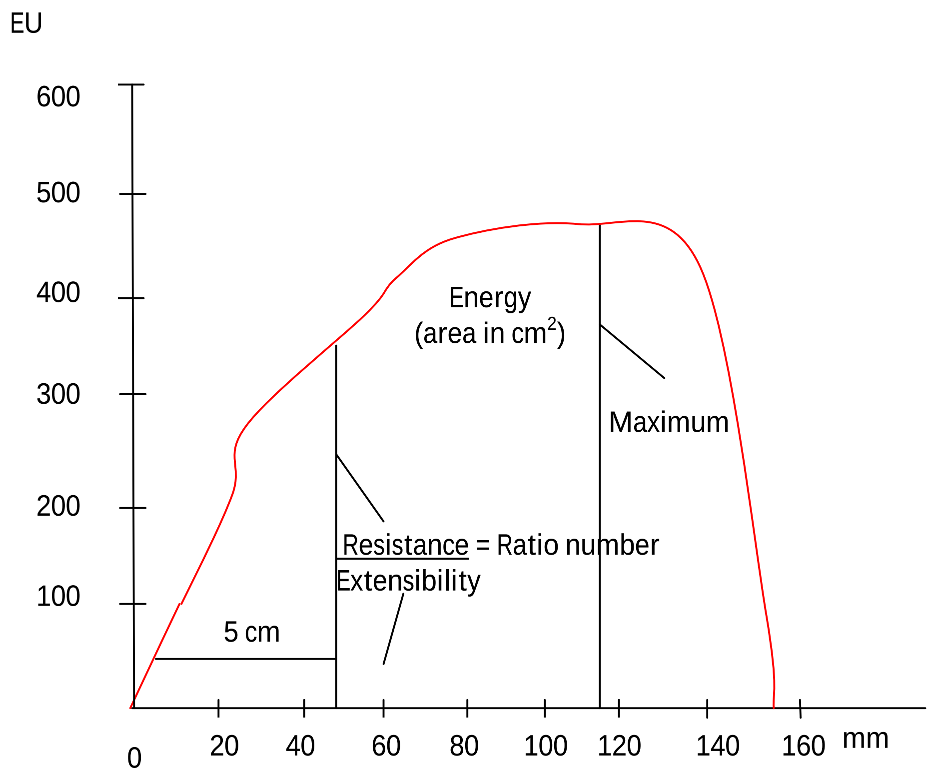


Fig. 3. Standard curve of an Extensogram

3.3.10. Amylograph of starches and wheat flour blends:

Gelatinization for starches and wheat flour blends was determined by using the brabender GmbH and Co. KG amylograph-E (Kulturstr. 51-55 D-47055 Duisburg, Type 800150, No- 080085, model 2008) according to the standard method of ICC-standard no 126/1, ISO 7973, AACC method no 22-10 (2000).

The standard methods for amylograph tests are based on sample moisture of 14% however, as the real sample moisture may slightly deviate from this value, the real sample moisture needs to be measured in order to determine the correct sample weight and amount of water for the test.

From the basis moisture and the real sample moisture the software automatically corrects the sample weight and the amount of water to be used for the test. The usual start temperature is 30℃ however, other start temperature can be selected from 20-60℃. The standard method prescribes a heating rate of 1.5℃/min; however other heating rates can be selected as well for special application.The burette fill with distilled water, the over flow pipe ensures a constant filling level of 450ml.

3.3.10.1.Sample preparation for starch gelatinization curve and test procedure:

The sample was weighed according to the sample weight indicated by the software (±0.1g) (80g on a 14% moisture basis) into a1000-ml Erlenmeyer flask.360 ml of distilled water from the burette was added, and then the Erlenmeyer flask was closed and shakes 50 times in 30s (the suspension must be perfectly homogenous and free from lumps).After that the suspension was filled into the measuring bowl of the amylograph, the Erlenmeyer flask was flushed with the residual water and added the necessary amount of this suspension into the measuring bowl. After that the test was starting by click the start button, the system tares automatically, the monitor reads tare upon completion of tarring.

There is request by the system to push the measuring head down into operating position. The temperature controller first heats up to the preset start temperature. As soon as this has been reached, the controller starts heating with the preset heating rate up to a final temperature of 93℃ which is held for 5min. During the test, the diagram is recorded and displayed on-line the monitor. After test start, the monitor shows a diagram with two x-axes and ay-axis occupied as follows:

- Upper x- axis temperature in ℃
- Lower x- axis test time in min
- Y-axis viscosity in AU (amylograph units)

When the test time has elapsed, data transmission from the amylograph is stopped automatically. The over test is 42+5 min holding time =47min. after completion of the test, the test is evaluated automatically by means of the software. The test including test conditions, diagram, and evaluation. As shown in Fig. (4)the following evaluation points are calculated:

- Beginning of gelatinization
- Gelatinization temperature
- Gelatinization maximum

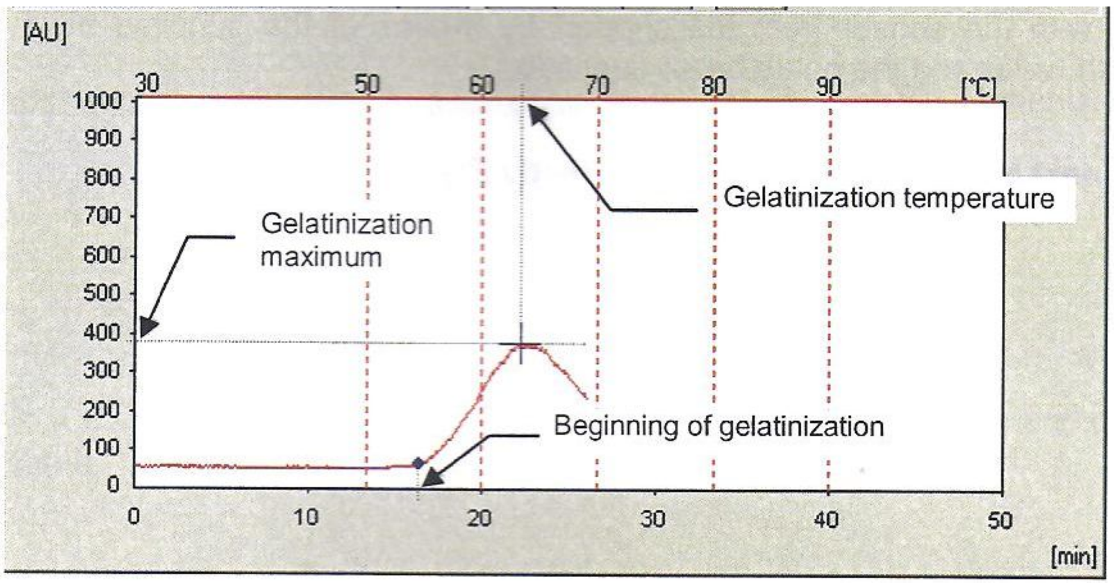


Fig. 4. Standard Curve of Amylograph

3.3.11. Processing of the bread samples

The bread-baking test for assessing the quality of wheat flour and blends were carried out according to the method of Badi *et al.,* (1978). Bread flour sample (100% wheat flour) and blends of wheat flour (5%, 10% and 15% starch) with 5% lentil flour were prepared into bread. The ingredients used in bread making were as follows:

Item	Quantity (g)
Flour	250
Yeast	2.5
Salt	1.5
Sugar	2.5
Improver (Banda) (Hemicellulose, Fungal alpha amylase , pentosanase, lipase, oxidase, glucose and ascorbic acid)	0.025

The amount of water used for the wheat flour and blends was added according to water absorption of the farinograph. All the ingredients were weighed and mixed to form dough in mono- universal laboratory dough mixer for 5 minutes at medium speed. The dough was allowed to rest for 10 minutes at room temperature (30 C°) then it was scaled to three portions of 120g each. The three dough portions were made into round balls and allowed to rest for another 15 minutes. Then molded up, put into pans, placed in the fermentation cabinet for final proof between 50 – 60 minutes. The fermented dough samples were baked in a Simon Rotary Test Oven at 220 – 250 C° with saturation of steam for 20 – 55 minutes. The loaves were then left to cool. The loaves were sliced with an electric knife, part of the slices were kept in polyethylene bags at room temperature for sensory evaluation in the same day.

3.3.11.1. Evaluation of bread quality

The bread made from wheat flour and different blends were cooled at room temperature (38±2C°) for an hour after baking and quality measures were made on triplicate loaves as follows:

3.3.11.1.1. Bread volume

The loaf volume expressed in cubic centimeters was determined by Seed Displacement Method according to pyler (1973). The loaf was placed in a container of a known volume into which small seeds (millet seeds) were run until the container is full. The volume of seeds displaced by the loaf is equal to the loaf volume.

3.3.11.1.2 Bread weight

The loaf weight of bread was taken in grams.

3.3.11.1.3. Bread specific volume

The bread specific volume of the loaf was calculated according to the AACC method (2000) by dividing the loaf volume by its weight (g).

3.3.11.1.4. Sensory evaluation of loaf bread

Loaf bread samples were assessed organoleptically according to procedure described by Ihekovonye and Ngoddy (1985). Sensory evaluation (color, odor, taste, crumb texture, crumb grain uniformity, and preference) was carried out by fifteen panelists. The evaluation depends on the range of 8 – 9 as excellent, 6 – 7 is very good, 4 – 5 is good, 2 – 3 is fair and 1 is poor.

3.3.12. Processing of biscuit samples

Biscuits were prepared according to Vatsala and HaridsRaO (1991) method. Control sample of wheat flour (biscuit flour) and blends of wheat flour were prepared (10%, 15%, and 20% starches) with 10% lentil flour. The formula used in biscuit processing was as follows:

Ingredients	Quantity (g)
Biscuit flour	100
Sugar powder	30
Shortening	30
Skim milk powder	2
Sodium chloride	1
Sodium bicarbonate	0.4
Ammonium bicarbonate	1.5
Glucose	2
Cysteine	0.02
Water	15 ml

The ingredients were weighed for 200 g of flour. Sugar powder, shortening, skim milk powder, and glucose were creamed in Hobart N – 50 mixer with a flat beater for three minutes at 61 rpm. Salt, ammonium bicarbonate and sodium bicarbonate and sodium bicarbonate were dissolved separately in part of required water and added to the cream. Mixing was continued for 8 minutes at 125 rpm to obtain a homogenous cream. Finally, flour was added and mixed for three minutes at 61 rpm, and then the dough was sheeted to a thickness of 3.5 mm with the help of an aluminum plate form and frame. The piece of dough was transferred to an aluminum tray. The biscuits were baked in an electric oven maintained at 205 C° for 8.5 minutes; the baked units were cooled and analyzed.

3.3.12.1. Evaluation of biscuit quality

3.3.12.1.1. Biscuit weight

Biscuits were weighed (5 biscuits) and the weights were recorded.

3.3.12.1.2. Biscuit spread ratio

Biscuits were evaluated for the spread ratio according to the following equation;

$$\text{Spread ratio} = \frac{\text{weight of the biscuit}}{\text{Thickness of the biscuit}}$$

3.3.12.1.3. Sensory evaluation of Biscuits

Evaluation of biscuits made from wheat flour and blends were carried out. Fifteen semi-trained assessors were provided coded samples and asked to evaluate the general appearance, color, after taste, texture and overall quality of the biscuits according to the scoring (Hedonic) scale of 5 points described by Ihekoronye and Ngoddy (1985). A key table was given to the panelists guided them to score accordingly.

3.3.13. Method of statistical analysis

The data were statistically analyzed by the Completely Randomized Designasdescribed by Montgomery ((2001) and the mean differences were tested by Duncan Multiple Range Test (DMRT).

Chapter Four

Results and Discussion

4.1. Chemical composition of starches:

The chemical compositions of cereal and cassava starches are shown in table (1).

4.1.1. Moisture content:

The moisture content of wheat, sorghum, millet, rice and cassava starches are found to be 8.30, 9.23, 8.44, 6.89 and 8.61% respectively as shown in table (1). Statistical analysis of the results showed significant ($P \leq 0.05$) differences among the five starches in their moisture content. Rice starch showed low moisturecontent compared to the other starches and the highest value was found in sorghum starch. Moisture content of wheat, millet and cassava starches is in agreement with values obtained by Idris (2001) who reported that the moisture content for pearl millet starch was 8.8% and Abdelnour (2001) who found 8.35%. Khatir (1990) reported 7% moisture content for yellow pearl millet and 8.7% for the green pearl millet and Sokarab (1994) reported 9.20 % for pearl millet. These values are higher than the value of 3.10, 3.14, 3.93, 3.60, 4.20 and 3.32% moisture content of traditionally extracted starch from Ashana and Dembi cultivar reported by Elkashan (2006).

The moisture content value of rice starch agreed with the values obtained by Ali (2008) who found that the moisture content of six starches extracted from corn were 6.15, 6.76, 6.36, 5.53, 7.18 and 7.19 respectively. Singh *et al.*, (2003) reported the values of moisture content of rice starch to range between 10.40and 12.77%.

Table (1): Chemical composition (%) of cereal and cassava starches

Source of starch	Moisture content	Ash content	Protein content	Fat content	Carbohydrates
Wheat	8.30 ± 0.11^{c}	0.17 ± 0.01^{d}	0.58 ± 0.01^{a}	0.85 ± 0.05^{ab}	90.11 ± 0.11^{b}
Sorghum	9.23 ± 0.22^{a}	0.27 ± 0.03^{a}	0.50 ± 0.02^{c}	0.92 ± 0.06^{a}	89.09 ± 0.28^{c}
Millet	8.44 ± 0.11^{bc}	0.24 ± 0.02^{b}	0.55 ± 0.03^{b}	0.83 ± 0.08^{ab}	89.93 ± 0.18^{b}
Rice	6.89 ± 0.03^{d}	0.20 ± 0.03^{c}	0.31 ± 0.02^{e}	0.77 ± 0.03^{b}	91.84 ± 0.10^{a}
Cassava	8.61 ± 0.01^{b}	0.07 ± 0.01^{e}	0.45 ± 0.01^{d}	0.65 ± 0.05^{c}	90.22 ± 0.03^{b}
$Lsd_{0.05}$	0.2153*	0.0005753*	0.0005733*	0.9965*	0.2989*
SE±	0.06831	0.0001826	0.000183	0.03162	0.09487

Values are mean ± SD.

Any two mean value(s) having same superscript(s) in a column are not significantly different($P\leq0.05$).

NS = not significant

* = significant

** = highly significant

The moisture content value of sorghum starch is higher than the values reported by Idris (2001) who found values 8.35 and 8.05% and lower than values reported by Sokarab (1994) who found 10.4% for sorghum starch.These values were in good agreement with that reported by Abdalla*et al.,* (2009) as 7.67 and 8.87%.

4.1.2. Ash content:

The ash content of wheat, sorghum, millet, rice and cassava starches was 0.17, 0.27, 0.24, 0.20 and 0.07% respectively, as indicated in table (1). These results were in a good agreement with the values reported by Abdalla*et al.*, (2009), Singh *et al.,* (2003), Sokarab (1994) and Khatir (1990) who found that the ash content of starch was 0.20 – 0.24%, 0.17 – 0.20%, 0.05- 0.22% and 0.40 – 0.50% respectively. Moreover, these values were lower than the values of 0.55, 0.53, 0.43% and 0.63, 0.56, 0.45% respectively for traditional starch from Ashana and Dembi as reported by Elkashan (2006). Also the values of ash content are in good agreement with values reported by Idris (2001), Ali (2008) and Abdelnour (2001) who reported the values as 0.20 - 0.30%, 0.12 - 0.22% and 0.25% respectively.Statistical analysis for ash content for five starches showed significant ($P \leq 0.05$)
differences.

4.1.3. Protein content:

The protein content of the five starches (wheat, sorghum, millet, rice) and cassava was 0.58, 0.50, 0.55, 0.31 and 0.45% respectivelyas shown in table (1). The results obtained were close to those values reported by Steinke and Johnson (1991) who found 0.56%. Ali (2008) found that the values ranged from 0.18 to 0.24%. These values were lower than the results reported by Abdelnour (2001), Idris (2001) and Abdalla*et al.,* (2009) who gave 1.14, 1.14 to 1.63 and 1.70%

respectively. Norris and Rooney (1970) found the values of protein content of starch ranged from 0.80 to 1.90%.

These values are lower than values obtained by Elkashan (2006) who found the values ranged from 2.87 to 3.37%. Singh *et al.,* (2003) found the protein content of rice starch ranged from 0.41 to 0.42%.

Statistical analysis of the results showed significant ($P \leq 0.05$) differences among the five starches. The decrease in protein content of the starch may be due to the better steeping and proper separation of the starch.

4.1.4. Fat content:

The fat content of wheat, sorghum, millet, rice and cassava starches was shown in table (1), the values are 0.85, 0.92, 0.83, 0.77 and 0.65% respectively. The values of wheat, sorghum, millet and rice starches are higher than the values reported by Abdalla*et al.,* (2009)as 0.55 to 0.59% andthe value of cassava starch is lower than the value reported by Sokarab (1994) as 0.68%. However, slightly lower values of fat content were reported for traditionally extracted starch by Khatir (1990) and Elkashan (2006) who reported the values ranged between 0.20 to 0.30% and 0.34 to 0.54% respectively. Singh *et al.,* (2003) reported that fat content of starch ranged between 0.10 to 0.70%.Analysis of variance showed significant ($P \leq 0.05$) differences among the five starches in their fat contents.

4.1.5. Carbohydrates:

The results of carbohydrates content of wheat, sorghum, millet, rice and cassava starches are shown in table (1) as 90.11, 89.09, 89.93, 91.84 and 90.22% respectively. Statistical analysis showed significant ($P \leq 0.05$) differences between starches in their carbohydrates content. The highest value of carbohydrates was observed in rice starch (91.84%) followed by cassava starch (90.22%) and the lowest value was in sorghum starch (89.09%). The results obtained were in agreement with what has been reported by Abdalla*et al.,* (2009) who reported the range between 88.67 to 89.88% and Elkashan (2006) whoreported the range as between 91.71to 92.76%.

4.1.6. Minerals content

Minerals content of five starches (wheat, sorghum, millet, rice and cassava) were presented in table (2).

4.1.6.1. Sodium (Na)

Sodium content of five starches (wheat, sorghum, millet, rice and cassava) was 5.40, 5.53, 4.50, 3.27, and 3.10 mg/100g respectively. The highest value of sodium content was observed in sorghum starch, while the lowest value was in cassava starch. Statistical analysis showed significant ($P \leq 0.05$) differences between the five starches in their sodium content. These values were in a good agreement with the range mentioned by Hoseney *et al.,* (1978) who reported 2 to 5 mg/100gm and Huang *et al.,* (2012) reported that the values of sodium content for rice, wheat, cassava and sorghum ranged from 2 to 14 mg/100gm.

These results were higher than the results obtained by Abdalla *et al.,* (2009) and Abdalla *et al.,* (1998) who reported 0.88 to 1.31 mg/100gm and 1.30 mg/100gm respectively, for millet starch. Elkashan (2006) reported the values of sodium content for millet starch to range from 1.49 to 1.71mg/100gm.

4.1.6.2. Potassium (K)

Potassium content of five starches (wheat, sorghum, millet, rice and cassava) was 51.67, 40.33, 38.33, 23.33 and 39.33 mg/100gm respectively. Statistical analysis showed significant ($P \leq 0.05$) difference between the starches in their potassium content. Compared to the other starches, wheat starch gave the highest value and rice starch gave the lowest value in potassium content. These values were lower than the values obtained by Molina *et al.*, (2011) who reported the values to range between 115 to 363 mg/100gm for rice, wheat, cassava and sorghum.

Table (2): Minerals content of cereal and cassava starches

Source of starch	Na (mg/100g)	K (mg/100g)	Ca (mg/100g)	P (mg/100g)	Fe μ/g
Wheat	5.40 ± 0.10^{a}	51.67 ± 2.52^{a}	6.07 ± 0.06^{a}	16.33 ± 1.53^{ab}	240.00 ± 10.00^{a}
Sorghum	5.53 ± 0.35^{a}	40.33 ± 2.08^{b}	6.40 ± 0.10^{a}	15.33 ± 1.53^{ab}	233.30 ± 15.28^{a}
Millet	4.50 ± 0.36^{b}	38.33 ± 3.51^{b}	6.43 ± 0.05^{a}	18.00 ± 1.00^{a}	243.30 ± 15.28^{a}
Rice	3.27 ± 0.25^{c}	23.33 ± 1.53^{c}	4.40 ± 0.03^{b}	14.67 ± 1.53^{bc}	220.00 ± 20.00^{a}
Cassava	3.10 ± 0.26^{c}	39.33 ± 1.53^{b}	4.07 ± 0.04^{b}	12.33 ± 1.53^{c}	190.00 ± 10.00^{b}
$Lsd_{0.05}$	0.5113*	4.279**	0.581*	2.616*	26.57**
SE±	0.1623	1.358	0.1844	0.8301	8.433

Values are mean ± SD.

Any two mean value(s) having same superscript(s) in a column are not significantly different ($P \leq 0.05$).

NS = not significant

* = significant

** = highly significant

Elkashan (2006) found that the range is between 1.20 to 1.52 mg/100gm and 1.25 to 1.60 mg/100gm for millet starch. Abdalla *et al.,* (1998) and Abdalla *et al.,* (2009) reported the range is between 7 to 10 mg/100gm and 1.60 mg/100gm, respectively, for millet starch.

4.1.6.3. Calcium (Ca)

Calcium content of wheat, sorghum, millet, rice and cassava stanches was 6.07, 6.40, 6.43, 4.40 and 4.07 mg/ 100 gm respectively. There is significant ($P \leq 0.05$)difference among the five starches in their calcium content. The low value of calcium content was observed in cassava starch, while the high value was in millet starch. These results are close to values obtained by Abdalla *et al.,* (2009) who reported the range as between 5.0 to 8.33mg/100gm. Elkashan (2006) found the range to be between 5.00 and 10.83 mg/100gm for millet starch. These values are lower than values obtained by Smith (1998) who reported a range from 16 to 29 mg/100gm for rice, wheat, cassava and sorghum. Hoseney *et al.,* (1978) showed values from 110 to 120 mg/100gm for millet.

4.1.6.4. Phosphorus (P)

Table (2) showed the phosphorus content of wheat, sorghum, millet, rice and cassava starches values obtained as 16.33, 15.33, 18.00, 14.67 and 12.33mg/100gm respectively.Statistical analysis of the results showed significant ($P \leq 0.05$) differences among the five starches in their phosphorus content. Cassava starch gave the lowest value of phosphorus content, while the highest value was in millet starch. These values were higher than the values obtained by Abdalla *et al.,* (2009) who found the range between 7.27 to 8.00 mg/100gm. Elkashan (2006) found the range between 30.67 to 33.67 mg/100gm for millet starch. Hoseney *et al.,* (1978) indicated the range from 63 to 135 mg/100gm for millet starch. Ling *et al.,* (2001) found the higher values of phosphorus content for rice, wheat, cassava and sorghum to range from 27 to 288 mg/100gm.

4.1.6.5. Iron (Fe)

Ironcontent of wheat, sorghum, millet, rice and cassava starches was 240.00, 233.30, 243.30, 220.00 and 190.00µ/gm respectively. Statistical analysis showed highly significant ($P \leq 0.05$)differences in their iron content. Cassava starch gave the lowest value of iron content, while millet starch gave the highest value. These results are in good agreement with the results reported by Elkashan (2006) who reported the values to range between 230 and 240 µ/gm. Abdalla *et al.,* (2009) found the values ranged from 153.33 to 190.00 µ/gm. Huang *et al.,* (2012) found the values of iron content for rice, cassava, wheat and sorghum ranged from 0.27 to 4.31 mg/100gm.

In general mineral concentration is affected by many factors, which include type and variety, field location, milling methods and analytical methods (Betschart, 1988).The greater concentration of minerals was in the covering layers and the germs than in the endosperm portion for most of cereal grains, thus the reduced mineral content in the starches can be attributed to removal of both outer layer and germ during extraction procedures.

4.1.7. Acidity of starches

4.1.7.1. pH of starches

The pH of wheat, sorghum, millet, rice and cassava starches are presented in table (3). The values are 5.90, 6.43, 5.83, 5.35 and 5.73 respectively. Statistical analysis of the results showed significant ($P \leq 0.05$)differences among the different starches. The highest value of pH was observed in sorghum starch, while the lowest was in rice starch. The results agreed with those reported by Abdalla *et al.,* (2009), Khatir (1990) and Sokarab (1994) 6.6, 3.3 to 3.4 and 4.8 to 5.2

respectively, for millet starch. Leach (1965) found the values ranged from 5 to 7. Elkashan (2006)reported the values in the range from 3.2 to3.4 for millet starch. Singh *et al.*, (2003) found the pH of rice starch ranged from 5.30 to 6.90. pH is an

Table (3): pH-value, total acidity (mg/100g) and falling number (sec) of cereal and cassava starches

Source of starch	pH-value	Total acidity	Falling number
Wheat	5.90 ± 0.00^{b}	0.03 ± 0.00^{b}	61.67 ± 0.58^{c}
Sorghum	6.43 ± 0.02^{a}	0.05 ± 0.00^{a}	180.30 ± 4.04^{b}
Millet	5.83 ± 0.02^{c}	0.05 ± 0.00^{a}	64.00 ± 2.65^{c}
Rice	5.35 ± 0.01^{e}	0.05 ± 0.00^{a}	62.00 ± 0.00^{c}
Cassava	5.73 ± 0.06^{d}	0.03 ± 0.00^{b}	186.00 ± 3.00^{a}
$Lsd_{0.05}$	0.05753*	0.0005753*	4.65**
SE±	0.1826	0.0001826	1.476

Values are mean ± SD.

Any two mean value(s) having same superscript(s) in a column are not significantly different ($P \leq 0.05$).

NS = not significant

* = significant

** = highly significant

important property in the starch industrial applications, being used generally to indicate the acidic or alkaline properties of the liquid media.

4.1.7.2. Total acidity

The total acidity of wheat, sorghum, millet, rice and cassava starches were found to be 0.03, 0.05, 0.05, 0.05 and 0.03mg/100gm respectively as shown in table (3). There is significant ($P \leq 0.05$)difference between the starches in their total acidity.These results were supported by Abdalla *et al.,* (2009) who found total acidity of starch of millet 0.09mg/100gm. Elkashan (2006) found the total acidity for millet starch ranged from 0.18 to 0.27 mg/100gm

4.1.8. Falling number

The falling number of the five starches ranged between 61.67 and 186 seconds as shown in table (3). Analysis of variance indicated that there are highly significant ($P \leq 0.05$)differences among the five starches. The highest mean falling number value (186 seconds) was for cassava starch followed by sorghum starch (180.30 second), they are significantly greater than the values of all other starches. The lowest value of falling number was in wheat starch (61.67 second).

These results are comparable with Idris (2001) and Elkashan (2006) who reported 62 to 76 seconds for sorghum and millet starches and 62 seconds falling number for pearl millet. Abdalla *et al.,* (2009) reported 116 and 268 seconds for millet starch. Ali (2008) found the range from 274 to 347 seconds for corn starch.

4.2. Functional properties of starches

The functional properties of cereal and cassava starches are shown in table (4).

4.2.1. Water retention capacity (WRC)

The Water retention capacity (WRC) of wheat, sorghum, millet, rice and cassava starches was found to be 55.56, 44.44, 66.67, 122.20 and 66.67ml/100gm respectively as shown in table (4). Rice starch gave the highest value among the other starches (122.20 ml/100gm), while the lowest value was observed in sorghum starch (44.44 ml/100gm).

Statistical analysis of the results showed highly significant ($P \leq 0.05$) differences between the starch samples. These results are lower than the results obtained by Abdalla *et al.*, (2009) and Akubor and Obiegbuna (1999) who reported the range between 160 and 172 ml/100gm for millet starch. Elkashan (2006) reported the values between 206 to 224ml/100 gm for millet starch. Hassan (2007) found the water retention capacity for bread flour, biscuit flour, pigeon pea protein isolate and decorticated pigeon pea flour ranged from 130 to 190 ml/100 gm. Mizubuti *et al.,* (2000) reported the values of water retention capacity ranged from 107 to 120 ml/100 gm.

4.2.2. Fat absorption capacity (FAC)

The Fat absorption capacity (FAC) of wheat, sorghum, millet, rice and cassava starches was found to be 50.00, 75.00, 75.00, 95.83 and 7500.ml/100gm respectively,as shown in table (4).

Statistical analysis showed highly significant ($P \leq 0.05$)differences between the five starches. Rice starchgave the highest value of fat absorption capacity (95.83ml/100gm), while wheat starch gave the lowest value (50.00 ml/100gm). Abdalla (2003), Oshodi *et al.,* (1999), and Akubor and Obiegbuna (1999) reported the values of pearl millet flour and products varied from 27 to 55 ml/100gm. The results were supported by Abdalla *et al.,* (2009) who found the ranges 91 and107 ml/100gm for millet starch. Elkashan (2006) found the range from 164 to 175 ml/100gm for millet starch. Hassan (2007) reported the value ranged from 55 to

105 ml/100gm for bread flour, biscuit flour, pigeon pea protein isolate and decorticated pigeon pea flour.

Table (4): Functional properties of cereal and cassava starches

Source of starch	Water retention capacity (ml/100g)	Fat absorption capacity (ml/100g)	Bulk density (g/ml)	Dispersibility (%)	Gelatinization temperature (°C)
Wheat	55.56 ± 19.25^{b}	50.00 ± 0.00^{c}	0.67 ± 0.00^{a}	83.33 ± 0.00^{a}	68.33 ± 1.53^{b}
Sorghum	44.44 ± 19.25^{b}	75.00 ± 0.00^{b}	0.59 ± 0.00^{c}	83.33 ± 0.00^{a}	68.67 ± 1.53^{b}
Millet	66.67 ± 0.00^{b}	75.00 ± 0.00^{b}	0.50 ± 0.00^{e}	76.67 ± 0.00^{b}	75.00 ± 0.00^{a}
Rice	122.20 ± 19.24^{a}	95.83 ± 7.22^{a}	0.56 ± 0.00^{d}	70.00 ± 0.00^{c}	70.00 ± 0.00^{b}
Cassava	66.67 ± 0.00^{b}	75.00 ± 0.00^{b}	0.63 ± 0.00^{b}	83.33 ± 0.00^{a}	64.67 ± 0.58^{c}
$Lsd_{0.05}$	27.12**	5.872**	0.0005753*	0.00058*	1.819*
SE±	8.607	1.863	0.0001826	0.000183	0.5774

Values are mean±SD.

Any mean value(s) having same superscript(s) in a column are not significantly different ($P\leq0.05$).
NS = not significant

* = significant

** = highly significant

The values obtained in the study are considered to be lower than the other values; this could be probably due to elimination of fiber and reduction of protein during isolation of the starch.

4.2.3. Bulk density

Table (4) showed the bulk density of five starches wheat, sorghum, millet, rice and cassava with values of 0.67, 0.59, 0.50, 0.56 and 0.63g/ml respectively. Statistical analysis of the resultsshowed significant ($P \leq 0.05$) differences among the five starches. The highest valueof bulk density was observed in wheatstarch (0.67g/ml), while the lowest value was found in millet starch (0.50 g/ml).

The results were supported by Akubor and Obiegbuna (1999) and Abdalla *et al.*, (2009) who obtained 1.00, 0.63g/ml bulk density for millet flour and starch respectively.These results are comparablewith the results obtained by Elkashan (2006) who found the range between 0.46 and 0.53 g/ml for millet starch. Patindol and Wang (2009) reported the bulk density of rice starch to range from 0.41 to 0.56 g/ml.

Venktesh and Prakash (1993) reported that higher moisture content in addition to the higher and greater regulatory in shape of the starch granules, resulting in dense packing of the starch particles. High bulk density is the desirable characteristic when powdered food materials of high nutrients content are to be packed in a limited space or area; also it helps to reduce the paste thickness which is an important factor in convalescent and child feeding (Padmashree *et al.*, (1987).

4.2.4. Dispersibility

As indicated in table (4), wheat, sorghum, millet, rice and cassava starches showed dispersibility values of 83.33, 83.33, 76.67, 70.00 and 83.33% respectively. Statistical analysis showed significant ($P\leq0.05$)differences between starches in their dispersibility. Rice starch showed the lowest dispersibility (70.00%) which is significantly lower compared to other starches. This is similar to whatas reported by Abdalla *et al.,* (2009) 83.30% for millet starch from Ashana and Dembi cultivars. Elkashan (2006) reported the values to range between 63.30% and 79.90% for millet starch. Singh *et al.,* (2003) found the dispersibility of rice starch ranged from 75.10 to 82.12%. Akanbi *et al.,* (2009) obtained dispersibility of bread fruit starch 40.67%. The higher the dispersibility the better the flour reconstitutes in water (Kulkarni *et al.,* 1991).

4.2.5. Gelatinization temperature

Table (4) showed the gelatinization temperature of five starches wheat, sorghum, millet, rice and cassava with values of 68.33, 68.67, 75.00, 70.00 and 64.67 C° respectively. Millet starch showed significantly higher gelatinization temperature of 75.00 C°, while cassava showed significantly lower gelatinization temperature (64.67 C°).

Statistical analysis showed significant ($P\leq0.05$)differences between starches intheir gelatinization temperature. These results are close to results obtained by Leach *et al.,* (1959) who found sorghum starch gelatinization temperature to range from 68 to 70 C°. This is in good agreement with what was reported by Beleia *et al.,* (1980) who found that the initial gelatinization temperature of pearl millet starch varied from 63 to 68 C° and end point from 68 to 70 C°. Badi (1973) obtained gelatinization temperature for sorghum and millet starch from 63 to 74 C° and 51 to 69 C° respectively. Abdalla *et al.,* (2009) found the gelatinization temperature of millet starch 60.70 and 61.40 C°. Elkashan (2006) reported the range from 69.20 to 70.00 C°. Gelatinization temperature of pearl millet starch was found to range from 51 to 69 C° (Kulp, 1972). Ubwa *et al.,* (2011) found the gelatinization temperature of white and brown sorghum starch ranged from 74 to 82 C°. Morales-Sanchez *et al.,* (2009) obtained the gelatinization temperature of wheat starch to range from 52 to 66 C° and rice starch 66 to 82 C°.

4.2.6. Wettability

The wettability of wheat, sorghum, millet, rice and cassava starches was good since it wet slightly when it comes in contact with water, and after 30 minutes the samples were completely wet and sank to the bottom. Sufficiently fast stirring for one minute dispersed the samples (Appendix5). Osman (2004) reported that the wettability of the chick pea flour gave the grade of good. The results support the results obtained by Abdalla *et al.,* (2009) and Elkashan (2006) who found the wettability grade of millet starch was good and excellent respectively, since it wets as soon as it come in contact with water and after 30 minutes the samples were completely dispersed.

4.2.7. Gelation concentration

The least gelation concentration of wheat, sorghum, millet, rice and cassava starches was shown in table (5). Sorghum and cassava starches gave a very strong gel at concentration of 10% (w/v) while wheat, millet and rice starches gave strong gel at the same level of concentration. Wheat, millet and rice starches formed a weak gel at 8%, a very weak gel at 6% and no gel was obtained at 2% and 4%. Sorghum and cassava starches formed strong gel at 8%, a weak gel at 6%, a very weak gel at 4% and no gel was obtained at 2%. This finding is supported by the results obtained by Sulieman (2007) who found a weak gel at 6%, strong gel at 8%, very strong gel at 10% and no gel at 2 and 4%. This is similar to what is reported by Abdalla *et al.,* (2009) who found a very strong gel at concentration of 10% (w/v), strong gel at 8%, weak gel at 6% and 4% and no gel at 2%. Elkashan (2006) found a weak gel at 2%, strong gel at 4% and a very strong gel at 6, 8 and 10%.

Variation among the five starches might be linked to the relative ratio ofdifferent constituents ofprotein, carbohydrates and lipids as suggested bySathe*et al.*,(1982). Singh and Singh (1991) reported that the lower least gelation concentration may be due to the starch and starch protein interactions. Oshodi*etal.*, (1999)

Table (5): Least Gelation Concentration of Cereal and Cassava Starches

Sample	Concentration (g starch/100ml water)				
	2%	4%	6%	8%	10%
Wheat starch	−	−	±	+	++
Sorghum starch	−	±	+	++	+++
Millet starch	−	−	±	+	++
Rice starch	−	−	±	+	++
Cassava starch	−	±	+	++	+++

Where:

− No gel

± Very weak gel

+ Weak gel

++ Strong gel

+++ Very strong gel

reported that the least gelation concentration of pearl millet flour was 12% (w/v). Osman (2004) reported that chick pea protein has higher content of starch which induces gelation due to starch-starch and/or starch-protein interaction.

4.2.8. Viscosity

Thecold paste viscosity (at room temperature) and hotpaste viscosity(hot slurries) of wheat, sorghum, millet, rice and cassava starches were shown in table (6). Coldpaste viscosity was found to be106.70, 152.00, 112.70, 143.30 and108.00 cps respectively.

Statistical analysis revealed highly significant ($P \leq 0.05$)differences among the five starches in their cold and hotpaste viscosity. Upon heating at (70 C°) the viscosity increased to 121.30, 157.00, 155.00, 148.30 and 149.40 cps for wheat, sorghum, millet, rice and cassava starches respectively. Sorghum starch gave the highest value in cold and hotpaste viscosity, while wheat starch gave the lowest value. These results are comparable with the results obtained by Elkashan (2006) who reported that the values ranged between 98.90 to 178.30 cps for coldpaste viscosity and 162 to 180.70 cps for hotpaste viscosity. Abdalla*et al.*, (2009)reported that the valve was 93.30 for coldpaste viscosity and 130, 131cps for hotpaste viscosity.

Circle *et al.*, (1964) stated that at a given concentration, heated dispersions gain greater viscosity than unheated dispersions. The viscosity can be used to test the thickening potentiality of food materials to be used in fluid food and beverages as reported by Kinsella (1979). Important factors that influence paste viscosity are: the degree to which the granules swells (indicated by swelling potential), the dispersibility of the swollen granules and the amount exudates in the intergranular spaces (Hamaker and Griffin, 1993).

Table (6): Cold and hotpasteviscosity (cps) of cereal and cassava starches

Source of starch	Cold paste viscosity	Hot pasteviscosity
Wheat	106.70 ± 5.77^{b}	121.30 ± 1.15^{c}
Sorghum	152.00 ± 5.00^{a}	157.00 ± 4.00^{a}
Millet	112.70 ± 3.79^{b}	155.00 ± 4.36^{a}
Rice	143.30 ± 3.21^{a}	148.30 ± 1.15^{b}
Cassava	108.00 ± 7.21^{b}	149.40 ± 1.55^{b}
$Lsd_{0.05}$	9.453**	5.151**
SE±	3.0	1.635

Values are mean±SD.

Any two mean value(s) having same superscript(s) in a column are not significantly different ($P\leq0.05$).

NS = not significant

* = significant

** = highly significant

4.2.9. Amylose and Amylopectin contents of extracted starch:

The starch amylose and amylopectin is shown in table (7). Wheat, sorghum, millet, rice and cassava starches contain 30.94, 28.66, 22.60, 22.88and 23.59%amyloserespectively. Also contain 69.06, 71.34, 77.40, 77.12 and 76.41% amylopectin respectively. Statistical analysis confirms that the five types of starches are significantly ($P \leq 0.05$) different in their amylose and amylopectin contents. The high value of amylose content was found in wheat starch, while the low value was in millet starch. Millet Starch had high value of amylopectin, whereas wheat Starch had low value of amylopectin. These results of amylose content are in good agreement with the results obtained by Idris (2001), Elkashan (2006), Beleia *et al.,* (1980), Badi *et al.*, (1976) and Subramanian *et al.,* (1986) who reported values between 28.2 to 30.0% for sorghum starch and 17 to 30.0 % for millet starch.

Idris (2001) reported the value of amylose content for millet starch to be 20% and amylopectin 80%. These values are comparable with whistler and Smart (1953) who reported that the majority of starches pass nearly identical ratio of amylose to amylopectin and the most prevalent composition is 22 to 26% amylose and 74 to 78 % amylopectin. Ali (2008) reported that the value of amylose ranged from 13.62 to 30.49% and amylopectin ranged from 69.51 to 86.39% for starch extracted from six maize hybrids. Elkashan (2006) reported values of amylose content ranged from 17.00 to 30.00% for three classes of Jir from Ashana and Dembi cultivars.

These results are similar to the results obtained by Rooney and Serna-Saldivar (1991) who found values of amylose content for sorghum and millet varieties to range from 16.00 to 28.20%. About 70 to 80% of the sorghum starch is amylopectin and the remaining 20 to 30% is amylose (Deatherage *et al.,* 1955). DakuBu and Bruce (1979) obtained values of amylose content for cassava starch to range from 13 to 20%. Panlasigui *et al.,* (1991) found the values of amylose

Table (7). Amylose and amylopectin contents of the extracted starch

Source of starch	Amylose %	Amylopectin %
Wheat	30.94^{a} ±0.19	69.06^{e} ±0.19
Sorghum	28.66^{b} ±0.11	71.34^{d} ±0.11
Millet	22.60^{e} ±0.23	77.40^{a} ±0.23
Rice	22.88^{d} ±0.04	77.12^{b} ±0.04
Cassava	23.59^{c} ±0.08	76.41^{c} ±0.08
$Lsd_{0.05}$	0.2698^{*}	0.2698^{*}
SE±	0.08563	0.08563

Values are mean ± SD.

Mean(s) bearing same superscript(s) are not significantly different ($P \leq 0.05$).

content for rice starch ranged from 26.70 to27.00. The values of amylose content of wheat starch from different varieties ranged from 23.4 to 27.6% obtained by Medcalf and Gilles (1965). Nuwamanya *et al.,* (2010) reported the values of amylose content for cassava starch ranged from 23.01 to 26.98%.

Sestili *et al.,* (2010) obtained the amylose content for wheat starch to range from 24.50 to 32.40%. Corcuera *et al.,* (2007) found the amylose content for wheat starch ranged from31.5 to 42.5%. Amylose content of wheat starch extracted from different wheat varieties ranged from 20 to 30% was reported by Hallstrom *et al.,* (2011).

The lower the amylose content, the better is the starch for industrial use, particularly in the food industry as a thickener. When however starch contains high percentage of amylose, it may be modified by oxidation to give it physical properties like the clarity of its paste, the viscosity of its paste, the tendency of its paste to retrograde and the temperature of complete paste formation depend upon the fraction of the amylose percent (Radley, 1968).

4.2.10. Color

The color of the starches was shown in figure (5). From these results it was observed that cassava starch have the highest value of reading (95.71%) followed by wheat starch (92.09%). The lower reading was observed in millet (80.98%) and sorghum (84.80%) starches. (High reading means whiter color). The lower reading of millet and sorghum may be due to the pigments in the pericarp.

Starch made from certain white-seeded cultivars can be off-white because of non-carotenoid pigment in the endosperm (Watson *et al.,* 1955). If the pigments could be removed, the color and appearance of the isolated starch would improve. The discoloration of starch may be due to the presence of pigments in the pericarp that are leached into the endosperm weathering in the field or during steeping for wet milling (Norris, 1971). However, sorghum starch has been reported to have an

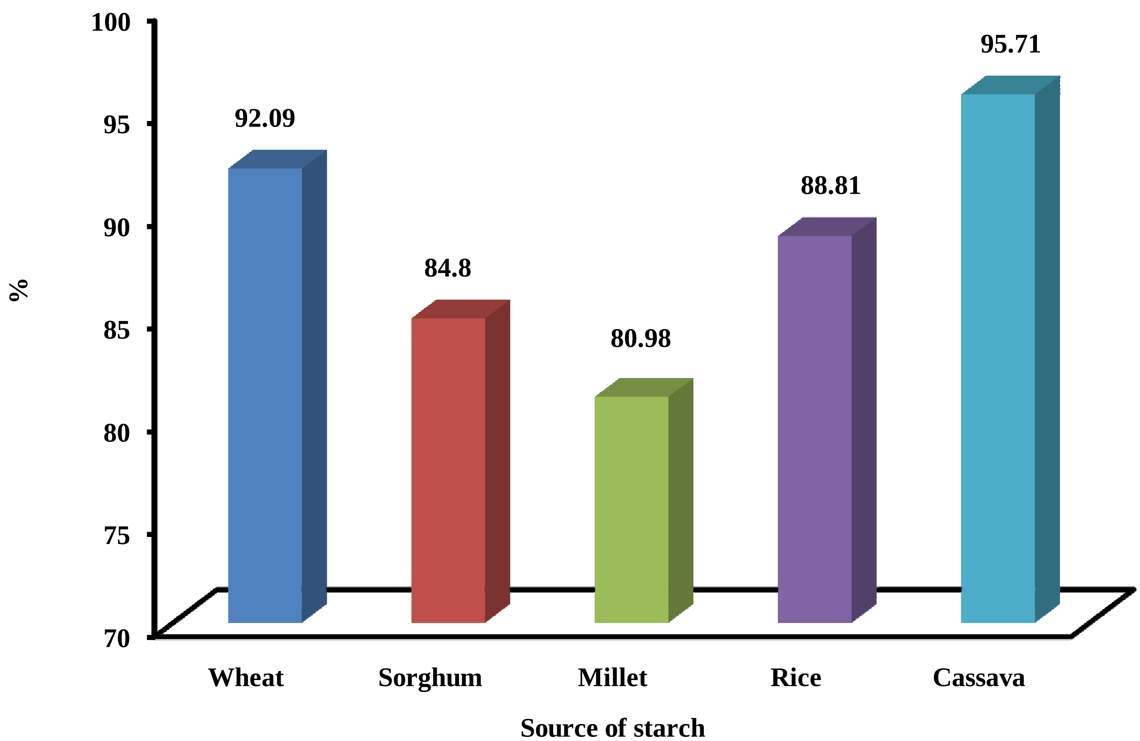


Fig. 5. Color of cereal and cassava starches

off-color, whereas corn starch is white or light yellow and bright in appearance (Watson and Hirata, 1955). Color of the finished sorghum starches was related tothe intensity of the pigments in the pericarp and in the leaves of sorghum plant. The results were justified by the results obtained by Idris (2001) who found that as the number of decortication of millet and sorghum increases, the dark color of the starch decreases to white color, indicating removal of layers containing the pigments during decortication.

4.2.11. Starch granules

Starch granules of five starches were shown in plates from 1to 5. From these results, it could be observed that wheat starch granules gave the biggest size, while rice starch granules gave the smallest size. These results are in good agreement with the results obtained by Itiola and Odeku (2005) who found that the rice starch had the least particle size and wheat exhibited the largest particle size.

On the other hand sorghum starch granules gave the biggest size comparing with millet and cassavastarches.This variation in size and shape of starch granules may be due to their biological origin (Svegmark and Hermansson, 1993).The millet starch granules had irregular shapes, which varied from oval, round to bean-shaped (Bangoura *et al.,* 2012).The starch granules of three proso millets presented as mostly polygonal and rarely elliptical in shape with round edges and some pores at the surface.

Heterowaxy sorghum starch appeared to have granule shape and size similar to normal and waxy sorghum starches. Granules of the three starches were polygonal or spherical in shape, and some granules had dents at the surface (Sang *et al.,* 2008). Cassava starch granule is large and mostly round with a flat surface (Moorthy, 1999).

Starch granules in storage tissues can vary in shape, size and composition. The shape and size of the granules depends on the source, which allows one to identify the botanical source of the starch by microscopic examination (Preiss, 2004).

4.3.Chemical compositionof wheat flour extraction rate (100 and 72%) and lentil flour

The Chemical composition of wheat flour extraction rate (100 and 72%) and lentil flour is shown in table (8).

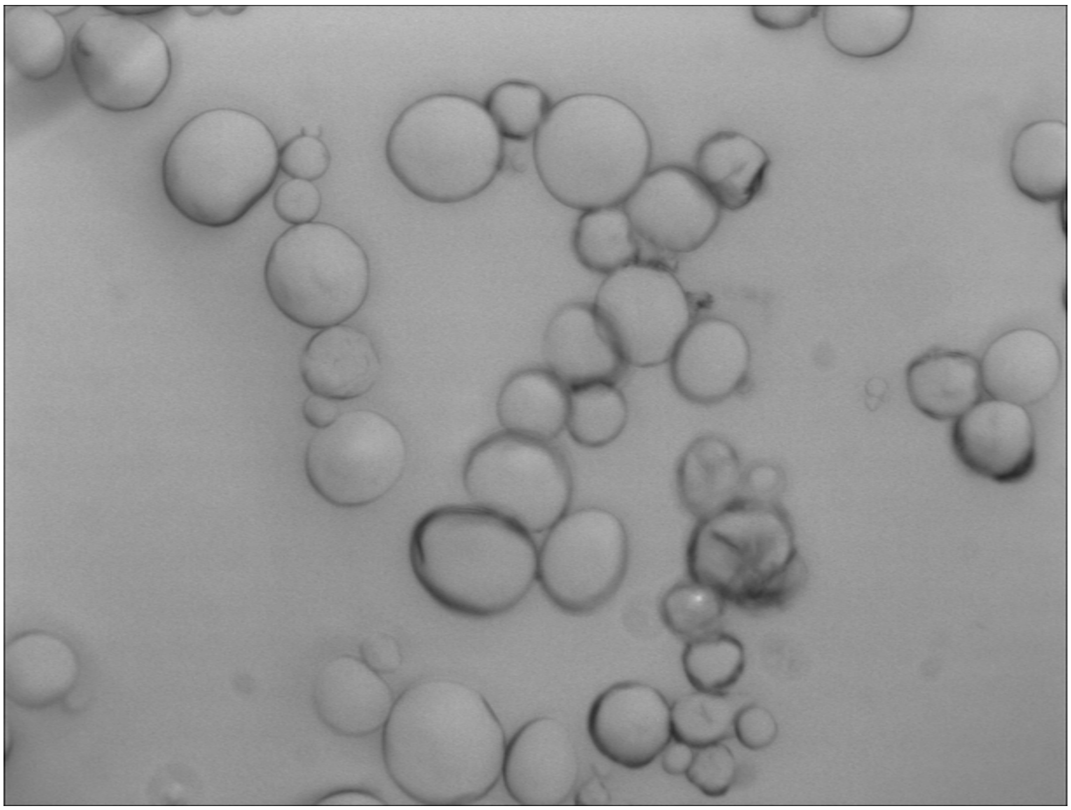
4.3.1. Moisture content

The moisture content of the whole wheat flour (100% extraction rate) and wheat flour (72% extraction rate) were found to be 8.73 and 11.81% respectively. These results were in a good agreement with the results obtained by Ahmed (2005), Mohamed (2000), Badi *et al.,* (1976) and Pareds – Lopez (1978) who found the values ranging between 7.00 to 7.90, 7.65 to 7.90, 10.00 to 11.00 and 11.20 % respectively. The moisture content of lentil is 7.97%. The value of moisture content of lentil flour agreed with values obtained by Sulieman (2007) who reported the range from 6.40 to 10.40% and similar to that reported by Muehlbauer *et al.,* (1985). Statistical analysis showed significant ($P \leq 0.05$) differences among the three samples.

4.3.2. Ash content

Ash content of wheat flour (100% extraction rate) and wheat flour (72% extraction rate) were found to be 1.66 and 1.00% respectively. These results are Comparable with results obtained by Ahmed (2005) and Mohamed (2000) who found the ranges were between 1.44 to 1.60 and 1.20 to 1.84% respectively. Abdalla (2002) found ash content as 1.50% .The ash content of lentil flour was found to be 3.53%.

The result of ash content of lentil flour agreed with what was reported by Sulieman (2007) who found the ash content ranged between 2.70 to 3.80% and similar to that reported by Adsule *et al.,* (1989) and Muehlbauer *et al.,*(1985). Analysis of variance showed significant ($P \leq 0.05$) differences among the samples.



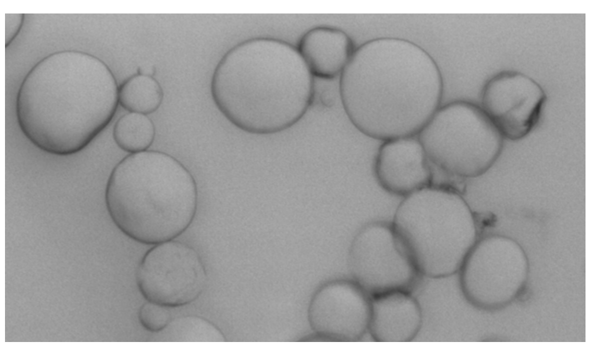
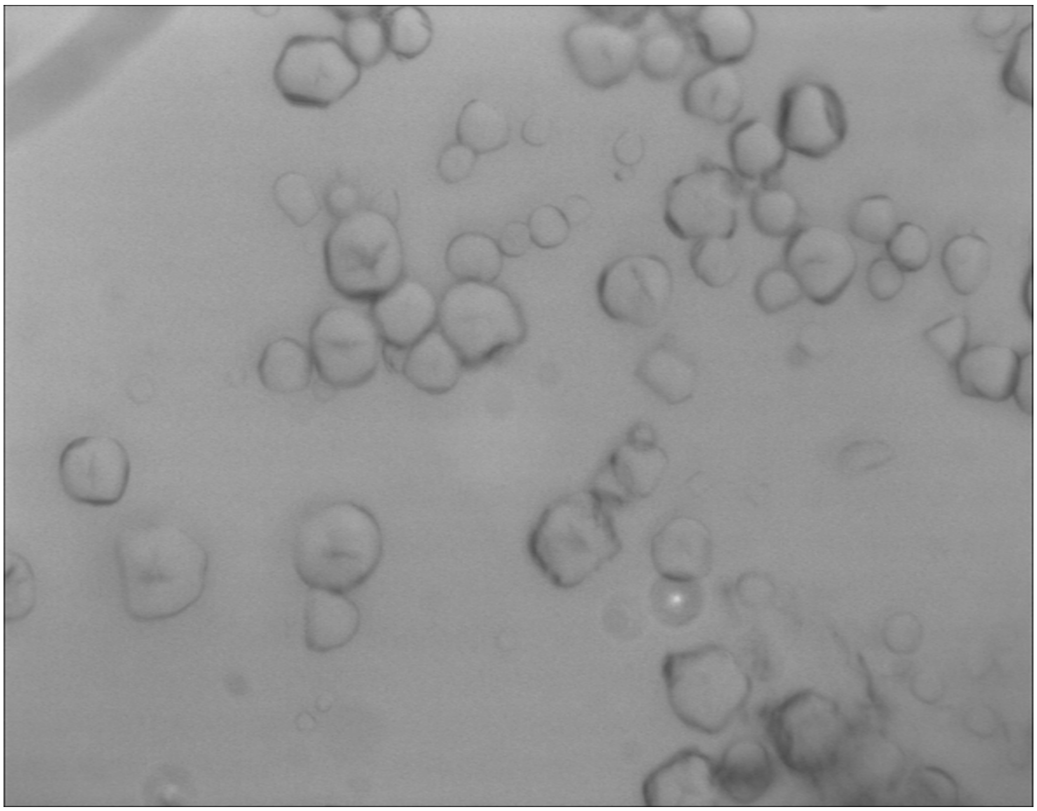


Plate .1. Wheat starch granules



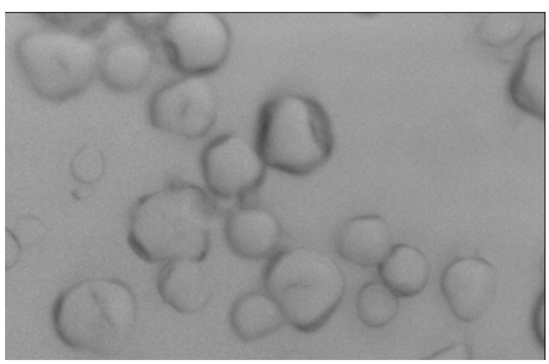
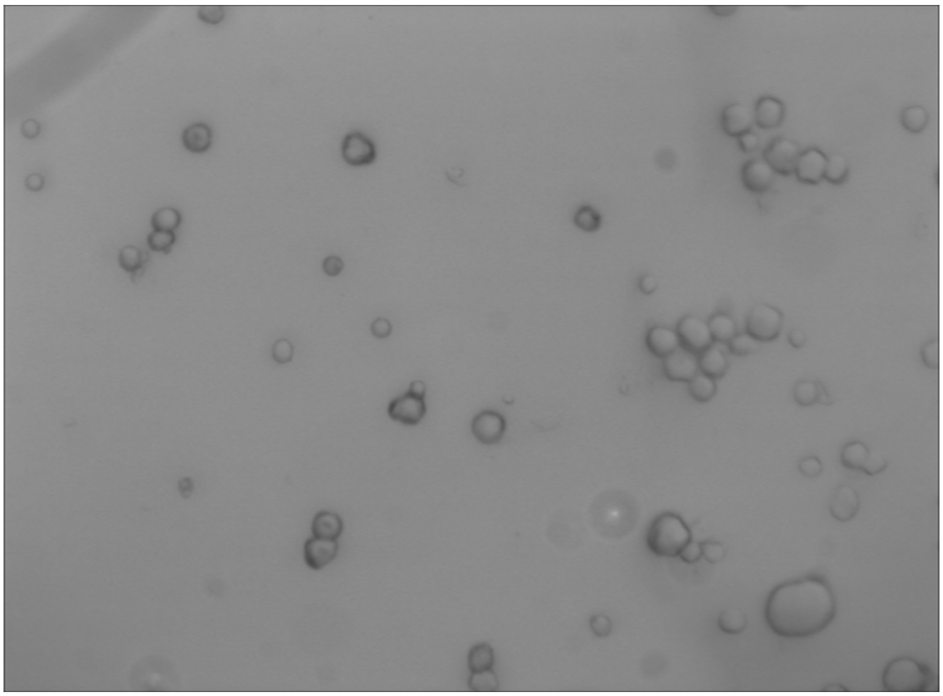


Plate. 2. Sorghum starch granules



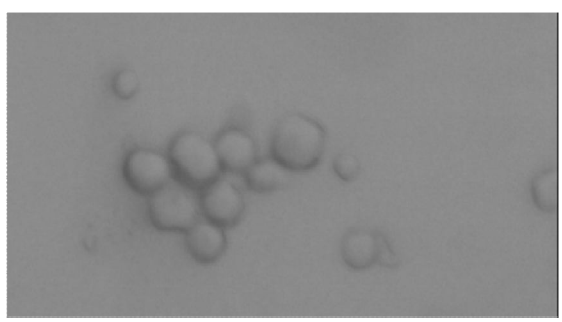
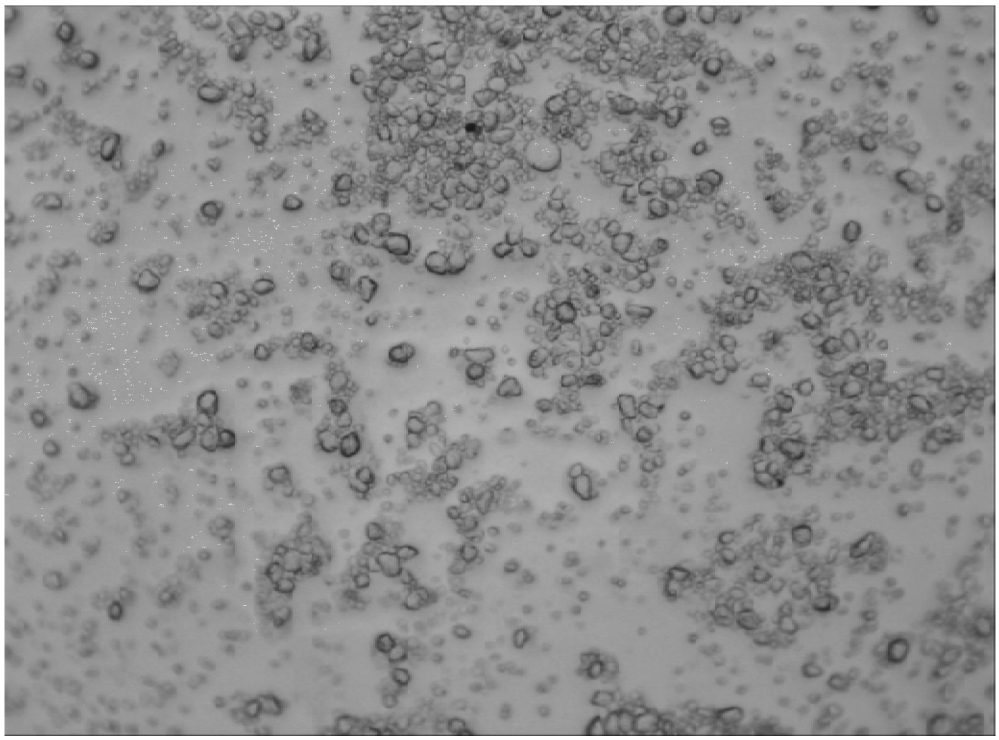


Plate. 3. Millet starch granules



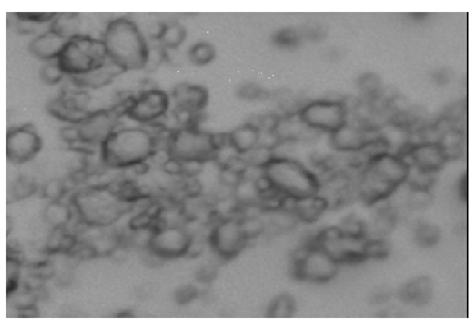
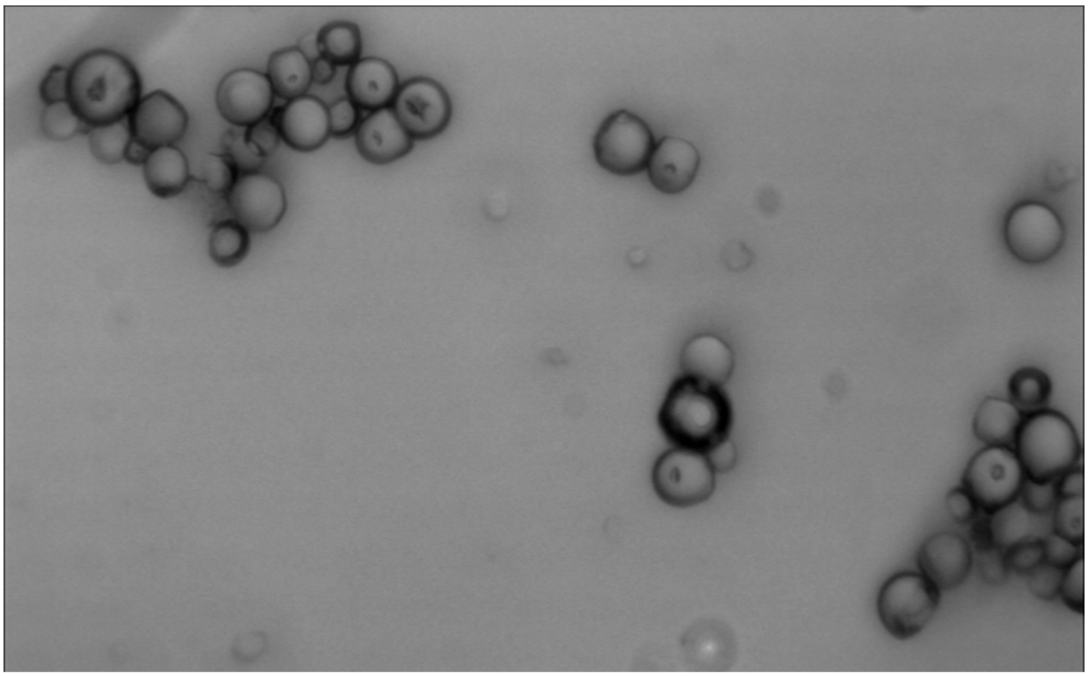


Plate. 4. Rice starch granules



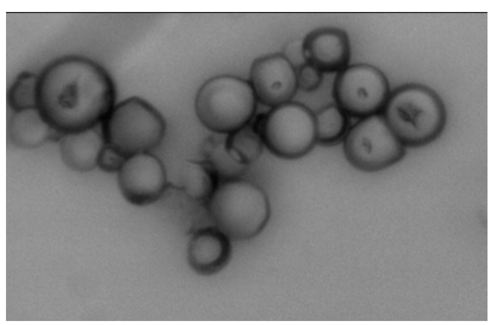


Plate. 5. Cassava starch granules

4.3.3. Protein content

The protein content of 100% extraction rate and 72% extraction rate wheat flours were found to be 14.87 and 13.87% respectively. These results are justified by results obtained by Ahmed(2013), Ahmed (2005), Yasar (2002), Abdalla (2002) and Mohamed (2000) who reported the protein content as 11.73, 10.44 to 14.97, 7.84 to 14.11 and 12.10% respectively. The protein content of lentil flour was found to be 29.60%. Adsule*et al.,* (1989) reported that the protein content of lentil ranged between 22.00 to 33.60%. Duke (1981) reported one hundred grams of decorticated lentil seeds contained 25.80 grams of protein. Sulieman (2007) found the protein content of lentil flour grown in Sudan ranged between 32.30 to 35.60% and Abd Elhady (2005) found that the protein content of lentil was26.00%.

Statistical analysis showed significant ($P \leq 0.05$)differencesbetween the three different flour samples. The protein content of wheat is very highly influenced by environmental conditions, grain yield and available nitrogen as well as the variety genotypes reported by George (1973).

4.3.4. Fat content

Fat content of 100% extraction rate and 72% extraction rate wheat flour were found to be 2.30 and 1.82% respectively as shown in table (7). These results are in a good agreement with what was reported by Morrison (1978), El Agib (2002) and Quisenberry and Reitz (1967) who found that the fat content of wheat flour was 2.90, 1.80 to 2.00 and 1.20 to 2.00% respectively. Fat content of lentil flour was found to be 1.07%. This result is lower than that reported by Duck (1981) and Hulse (1990). Decorticated lentil seeds contain 1.83g fat/100gm decorticated seeds (Hulse, 1990). Sulieman (2007) found that the fat content of lentil ranged from 1.95 to 2.40%. Hundred grams of dried lentil seeds contain 0.6g

Table (8): Chemical composition (%) of wheat flour (extraction rate 100% and 72%) and lentil flour

Samples	Moisture content	Ash content	Crude protein	Fat content	Carbohydrates
Wheat flour (100%)	8.73 ± 0.12^{b}	1.66 ± 0.00^{b}	14.87 ± 0.06^{b}	2.30 ± 0.11^{a}	72.44 ± 0.13^{a}
Wheat flour (72%)	11.81 ± 0.06^{a}	1.00 ± 0.00^{c}	13.87 ± 0.12^{c}	1.82 ± 0.19^{b}	71.50 ± 0.28^{b}
Lentil flour	7.97 ± 0.03^{c}	3.53 ± 0.03^{a}	29.60 ± 0.14^{a}	1.07 ± 0.10^{c}	57.84 ± 0.04^{c}
$Lsd_{0.05}$	0.1548^{*}	0.0006318^{*}	0.2189^{*}	0.2754^{*}	0.3574^{**}
SE±	0.04472	0.0001826	0.06325	0.07958	0.1033

Means are mean±SD.

Mean value(s) having different superscript(s) in a column are significantly different ($P\leq0.05$).

fat (Adsule *et al.*, 1989). Statistical analysis showed significant ($P \leq 0.05$) differences between the results of wheat flour extraction rate 100%, 72% and lentil flour.

4.3.5. Carbohydrates

Carbohydrates content of the whole wheat flour (100% extraction rate) and white wheat flour (72% extraction rate) were found to be 72.44 and 71.50% respectively. The results were supported by Ahmed (2013) who reported the range between 70.30 to 72.78%. Ahmed (2005) found that the carbohydrate of wheat flour (100% and 72% extraction rate) of Debaira, Elnielain and Sasaraib ranged from 71.70 to 74.64%. El Agib (2002), Abdalla (2002) and Mohamed (2000) reported that the carbohydrates of Sudanese wheat cultivars were ranged between 72.20 to 80.60%. The carbohydrate of lentil flour was found to be 57.84%. One hundred grams of dried lentil seeds contain 65.00 grams total carbohydrate (Adsule *et al.*, 1989). Hulse, (1990) reported that one hundred grams of decorticated lentil seeds contain 58.90 grams of total carbohydrate. Sulieman (2007)found the carbohydrate content of lentil ranged from 47.04 to 52.63%.

Statistical analysis showed highly significant ($P \leq 0.05$) differences between the results of different flours.

4.3.6. Mineral content

Table (9) showed the mineral content of wheat flour extraction rate 72% and lentil flour. Wheat flour extraction rate 72% was found to contain 63.33mg/100g Sodium (Na), 483.33 mg/100gm potassium (K), 67.00 mg/100gm calcium (Ca), 106.67 mg/100gm phosphorous (P) and 2773.33 μ/g iron (Fe). The values obtained in this study are higher than that obtained by Lorenz *et al.,* (1986) and Hassan (2007) for hard and soft wheat.

Betschart (1988) found that many factors influence mineral concentration which include; type and variety of wheat, field location, milling methods, and analytical methods. Lentil flour mineral content were 51.67mg/100 g sodium (Na), 303.33 mg/100 g potassium (K), 40.68 mg/100g calcium (Ca), 120.00mg/100 g phosphorus (P) and 1733.33 μ/g iron (Fe) respectively. From the results it could be observed that the wheat flour contains higher level of sodium (Na), potassium (K), calcium (Ca) and iron (Fe) compared to lentil flour which contains high level of phosphorous.

Statistical analysis showed significant ($P \leq 0.05$) difference between the two types in their calcium and phosphorus. On the other hand showed highlysignificant ($P \leq 0.05$)differences in their Sodium, potassium and iron content.

4.4. Falling number of wheat flour and wheat flour containing starches blends:-

The falling number values of wheat flour extraction rate 100% and 72% are shown in table (10), whereas tables (11), (12) and (13) showed the falling numbervalues of wheat flour containing 5%, 10%, 15% starch with 5% lentil flour.The falling number values of wheat flour extraction rate 100% and 72% was found to be 618.67 and 734.67 seconds,respectively. Statistical analysisshowed highlysignificant ($P \leq 0.05$)differences between the two extraction rates.Addition of wheat, sorghum, millet, rice and cassava starches increased the values of the falling number. Addition of wheat starch in wheat flour increased the value of falling number from 734.67 seconds in control to 838.30, 1011.00 and 1079.00 seconds for 5, 10 and 15% wheat starch blends. Addition of sorghum starch increased the value to 833.70, 1053.00 and 1076.00 seconds for 5, 10 and 15% sorghum starch blends. Addition of millet starch increases the value to 981.30, 987.70 and 1052.00

seconds for 5, 10 and 15% millet starch blends. Addition of rice starch increases the value to 808.00, 1020.00 and 891.30 seconds for 5, 10 and 15% rice starchblends. Addition of cassava starch resulted in increasing to 784.00, 847.00 and 825.70seconds for 5, 10 and 15% cassava starch blends. Statistical analysis

Table (9): Minerals content of wheat flour extraction rate (72%) and lentil flour

Type of flour	Na (mg/100g)	K (mg/100g)	Ca (mg/100g)	P (mg/100g)	Fe (μ/g)
Wheat flour (72%)	63.33±15.28[a]	483.33±76.38[a]	67.00±1.00[a]	106.67±11.55[b]	2773.33±94.52[a]
Lentil flour	51.67±1.53[b]	303.33±25.17[b]	40.68±3.06[b]	120.00±10.00[b]	1733.33±152.75[b]
$Lsd_{0.05}$	10.6653**	160.5753**	15.2579*	12.0694*	990.2989**
SE±	2.915	0.40.1325	2.6718	1.3162	152.7653

Values are mean ± SD.

Any mean value(s) having same superscript(s) in a column are not significantly different(P≤0.05).

NS = not significant

* = significant

** = highly significant

showed highly significant ($P \leq 0.05$) differences between all the ratios of starches. Form the results obtained above, it could be observed that the values of falling number for different blends of starch were relatively high (low alpha- amylase) and all of the blends were higher than the falling number of wheat flour, that may be attributed to the increase of level of starch in the blends.

These results were found to be in agreement with the data reported by Hassan (2007) and Badi *et al.,* (1978) who observed that the falling number of Sudanese wheat was abnormally high, indicating the low alpha- amylase activity in the wheat.

Perten (1996) stated that the falling number below 150 seconds produces sticky bread- crumb, while that between 200 -300 seconds produces bread with good crumb and above 300 seconds reduces theloaf volume and dries the bread

crumb. The above results were relatively high with the data reported by Ahmed (1995) who reported that the falling number of some Sudanese wheat flour was found to be in the range of 396 – 482 seconds for whole flour. Lukour and Mcvett (1991) reported that the falling numberof hard red springwheat cultivars ranged between 203 and 332 seconds. Kaldy and Rubenthaler (1987) found that the falling number of soft white winter and spring wheats ranged between 380 to 451seconds and 111to 479 seconds respectively.

Ahmed (2005) found that the falling number values of white flour of three Sudanese wheat cultivars ranged from 516 to 639 seconds for extraction rate 72%. Ahmed (2013) reported falling number values ranged between 415-583 seconds.

Alpha- amylase may be added to wheat flour to achieve any desired level of enzyme activity. The optimum level of enzyme activity is ultimately governed by the end use of the flour and the type of processing involved in the end use, as mentioned by Mailhot and Patton (1988).

Table (10): Falling number (sec.) and gluten content (%)of wheat flour extraction rates (100% and 72%)

Wheat Flour	Falling number (sec)	Gluten values	
		Wet gluten (%)	Gluten index(%)
Wheat flour (100%)	618.67 ± 8.02^{b}	34.18 ± 0.05^{b}	82.00 ± 1.00^{b}
Wheat flour (72%)	734.67 ± 8.50^{a}	35.10 ± 0.10^{a}	91.67 ± 0.58^{a}
$Lsd_{0.05}$	96.2514^{**}	0.8275^{*}	8.6733^{*}
SE±	17.8256	0.0413	1.0189

Values are mean±SD.

Any mean value(s) having same superscript(s) in a column are not significantly different(P≤0.05).

NS = not significant

* = significant

** = highly significant

Table (11): Falling number (sec) and gluten content (%) of wheat flour containing 5% of starch wheat, sorghum, millet, rice and cassava with5% lentil Flour

Source of starch	Falling number(sec)	Gluten values	
		Wet gluten (%)	Gluten index (%)
wheat starch	838.30±3.51^{b}	33.13±0.12^{a}	78.33±0.58^{d}
sorghum starch	833.70±5.69^{b}	32.37±0.12^{bc}	91.33±1.53^{b}
millet starch	981.30±5.51^{a}	31.70±0.17^{d}	94.00±1.00^{a}
rice starch	808.00±5.57^{c}	32.53±0.15^{b}	87.67±0.58^{c}
cassava starch	784.00±4.00^{d}	32.17±0.06^{c}	87.67±1.15^{c}
$Lsd_{0.05}$	8.987**	0.2372*	1.879**
SE±	2.852	0.07528	0.5964

Values are mean ± SD.

Any mean value(s) having same superscript(s) in a column are not significantly different ($P \leq 0.05$).

NS = not significant

* = significant

** = highly significant

Table (12): Falling number (sec) and gluten content (%) of wheat flour containing 10%ofstarch of wheat, sorghum, millet, rice and cassava with 5% lentil Flour

Source of starch	Falling number (sec)	Gluten values	
		Wet gluten (%)	Gluten index (%)
wheat starch	1011.00±9.50^{b}	30.53±0.15^{a}	82.67±0.58^{d}
sorghum starch	1053.00±7.02^{a}	28.60±0.10^{a}	90.67±0.58^{b}
millet starch	987.70±6.11^{c}	27.47±0.15^{a}	96.33±0.58^{a}
rice starch	1020.00±4.00^{b}	28.07±0.21^{a}	85.00±1.00^{c}
cassava starch	847.00±4.36^{d}	29.70±0.10^{a}	85.67±1.15^{c}
$Lsd_{0.05}$	11.85**	0.2698*	1.486*
SE±	3.759	0.08563	0.4715

Values are mean±SD.

Any mean value(s) having same superscript(s) in a column are not significantly different ($P \le 0.05$).

NS = not significant

* = significant

** = highly significant

Table (13): Falling number (sec) and gluten content (%) of wheat flour containing 15% ofstarch of wheat, sorghum, millet, rice and cassava with 5% lentil Flour

Source of starch	Falling number(sec)	Gluten values	
		Wet gluten (%)	Gluten index (%)
wheat starch	1079.00 ± 6.11^{a}	26.57 ± 0.12^{c}	86.33 ± 1.53^{c}
sorghum starch	1076.00 ± 4.58^{a}	27.07 ± 0.15^{b}	89.67 ± 1.53^{bc}
millet starch	1052.00 ± 5.86^{b}	27.27 ± 0.12^{b}	94.67 ± 3.79^{a}
rice starch	891.30 ± 4.16^{c}	27.63 ± 0.06^{a}	71.00 ± 1.00^{d}
cassava starch	825.70 ± 4.51^{d}	27.20 ± 0.10^{b}	90.33 ± 1.15^{b}
$Lsd_{0.05}$	9.288**	0.2074*	3.758**
SE±	2.948	0.06583	1.193

Values are mean±SD.

Any mean value(s) having same superscript(s) in a column are not significantly different ($P \leq 0.05$).

NS = not significant

* = significant

** = highly significant

4.5. Gluten quantity and quality of wheat flour and wheat flour containing starches blends with 5% lentil flour:-

Wet gluten and gluten index values of wheat flour extraction rate 100% and 72% were shown in table (10), whereas tables (11), (12) and (13) showed the wet gluten and gluten index of wheat flour blends. Wet gluten of wheat flour extraction rate 100% and 72% was 34.18, 35.10% respectively. Gluten index percentage of wheat flour extraction rate 100% and 72% were 82.00 and 91.67% respectively. Analysis of variance showed significant ($P \leq 0.05$)differences between the two extraction rate in wet gluten and gluten index percentages. These results agreed with results obtained by Mohammed (2000), Ahmed (2005) and Hassan (2007). Ahmed (2013) reported values ranged from 26.33 to 34.40%. Addition of starch in wheat flour resulted in significant decrease in wet gluten. The value of wet gluten decreased from 35.10% for control wheat flour to 33.13, 30.53 and 26.57% for 5, 10 and 15% wheat starch blends respectively. In sorghum starch blends decreased to 32.37, 28.60 and 27.07% for 5, 10 and 15% respectively. For millet starch blends decreased to 31.70, 27.47 and 27.27% for 5, 10 and 15% respectively. Also in rice and cassava starch blends decreased to 32.53 and 32.17%, 28.07 and 29.70% and 27.63 and 27.20% for 5, 10 and 15% respectively.

Statistical analysis of the results showed significant ($P \leq 0.05$)difference between blends in their wet gluten. The high value of wet gluten was observed in 5% wheat starch blend, while the low value was in 15% wheat starch blend.

These results are comparable with results reported by Hassan (2007), Ahmed (2005) and Mohammed (2000) who reported values ranged from 22.50 - 32.45 , 26.25- 29.81 and 26.20- 31.90% respectively. The results were in good agreement with those obtained by Kulkarni *et al.,* (1987) who reported that the percentage of wet gluten ranged from 25.90 to 42.00% for winter wheat and from 31.00 – 41.90 for spring wheat. Ahmed (2013) obtained values from 30.87 to 33.13% wet gluten for wheat flour blends. Addition of wheat, sorghum, rice and cassava starches in wheat flour resulted in a significant decrease in gluten index.

The value of gluten index decreased from 91.67% in control wheat flour to the values ranged from 78.33- 91.33% for 5% starches blends, 82.67- 90.67% for 10% starches blends and 71.00-90.33% for 15% starches blends.

Addition of 5% and 10% millet starch resulted in increasing the gluten index to 94.00 and 96.33% respectively followed by decrease in gluten index to 94.67% for 15% millet starch blend.

Analysis of variance showed highly significant ($P \leq 0.05$)difference in the ratio of 5% and 15% starches blends in their gluten index, on the other hand showed significant difference in the ratio of 10% starches blends in their gluten index.

It was observed that higher values of gluten index were obtained from the blends of millet starch when compared with other starches.

These values agreed with the results obtained by Ahmed (2013) who reported the values of gluten index ranged from 74.33 – 96.33% for wheat flour and values from 85.00 to 94.00% for differentwheat flour blends. Hassan (2007) showed that the gluten index values ranged from 80.29 to 80.73% for wheat flour and values from 60.19 to 76.69% for different wheat flour blends. Ahmed (2005) and Mohammed (2000) reported values ranged from 63.05 to 92.21% and 69.96 to 82.21% for gluten index for Sudanese wheat cultivars respectively. The decreasing level of wet gluten was attributed to the dilution effect of starch in wheat flour and the high gluten index of millet starch blends may be attributed to the protein content of millet starch when compared to other starches.

4.6. Rheological properties:-

4.6.1. Farinogram characteristics of doughs:-

4.6.1.1. Farinograms of doughs prepared from wheat flour and composite flour blends:-

The farinograph behavior of doughs made from wheat flour and the various composite flour blends is presented in tables (14), (15) and (16) and shown in figures (6) to (21). Water absorption value for control wheat flour was 59.70%, this value decreased to 57.50, 59.50 and 58.10% for 5% wheat, sorghum and cassava starches blends respectively and increased to 60.20% for 5% rice starch blend. Water absorption value for 5% millet starch blend was same as wheat flour 59.70%. The value of water absorption of wheat flour decreased to 57.50, 56.90, 55.80 and 58.10% for 10% wheat, sorghum, millet and cassava starches blends and decreased to 55.70, 57.00, 58.10 and 58.40% for 15% wheat, sorghum, millet, cassava starches blends respectively.

The flour water absorption for control wheat flour increased to 61.50 and 63.80% for 10% and 15% rice starch blend respectively.The results were supported by the results obtained by Hassan (2007) who found that the water absorption value for bread wheat flour increased from 65.30% to 65.90% when supplemented with 5% decorticated pigeon pea flour and to 65.70% when supplemented with10% and 15% decorticated pigeon pea. Decreasing of water absorption values in blends could be attributed to the lower water absorption capacity and decreasing levels of protein content caused by starch. Also these results agreed with the results obtained by Sulieman (2005) who supplemented wheat flour with chick pea flour and similar trends of water absorption increase were observed. Mustafa *et al.,* (1986) reported similar results. Ahmed (2013) found that water absorption values increased with the addition of improver from 60.80, 57.50 and 53.40 to 61.70, 58.50 and 56.10 for Canadian, Australian and Sudanese wheat flours respectively.

Dough development time for wheat flour (control) was 4.00 minutes. The blends gave values ranged from 4.00 to 4.70 minutes for 5% starches, 1.70 to 3.70 minutes for 10% starches and 1.20 to 3.70minutes for 15% starches. However, dough development time for wheat flour increased to 4.30, 4.70 and 4.20 for 5% wheat, millet and rice starches blends respectively, and decreased in 10% and15% starches blends. 5% sorghum starch blend and 5% cassava starch blend gave the same results of dough development time similar to control.

Addition of high percentages of starch (10%and 15%) resulted in low values of dough development time. This followed the general trends reported by Anaka and Tipples (1979) who reported that dough development time increased in flours with high protein content.

The dough stability time of wheat flour (control) value was 5.60 minutes tended to decrease with addition of 5%, 10%and 15% starches to the ranges between 4.90 to 5.20minutes for 5% starch blend, 4.80 to 5.10minutes for 10% starch blend and 4.20 to 5.50 minutes for 15% starch blend respectively. The dough stability time of 10% millet starch blend was the same as the control wheat flour. The lowest dough stability time was observed in 15% sorghum, rice and cassava starches blends, while the highest value was in wheat flour (control) and 10% millet starch blend.The same result was obtained by Hassan (2007) who found that the dough stability decreased with increasing level of decorticated pigeon pea flour in blends. The degree of softening for control wheat flour was 91.00 F.U. The lowest degree of softening value was 63.00 F.U. was observed in 5% wheat starch blend, while the highest degree of softening was 111.00 F.U. was observed in 15% rice starch blend. This value 91.00 F.U. (control wheat flour) was decreased to 63.00, 90.00 and 70.00 F.U. for 5% wheat, rice and cassava starches blends and to 85.00, 69.00, 82.00, 86.00 and 65.00 F.U. for 10% wheat, sorghum,

Table (14): Farinograms Characteristics of wheat flour containing 5%ofstarchofwheat, sorghum, millet, rice and cassava with 5% lentil flour.

Source of starch in wheat Flour blends	Farinograph readings				
	Water absorption %	Dough development time (min.)	Dough stability (min.)	Degree of softening (F.U.)	Farinograph quality number
Wheat flour (control)	59.7	4.0	5.6	91	66
wheat starch	57.5	4.3	5.2	63	70
Sorghum starch	59.5	4.0	5.0	91	62
Millet starch	59.7	4.7	4.9	91	61
Rice starch	60.2	4.2	4.9	90	60
Cassava starch	58.1	4.0	5.1	70	67

Table (15): Farinograms Characteristics of wheat flour containing 10%of starch of wheat, sorghum, millet, rice and cassava with 5% lentil flour.

Source of starch in wheat Flour blends	Farinograph readings				
	Water absorption%	Dough development time (min.)	Dough stability(min.)	Degree of softening(F.U.)	Farinograph quality number
Wheat flour (control)	59.7	4.0	5.6	91	66
wheat starch	57.5	3.5	5.0	85	60
Sorghum starch	56.9	1.7	4.9	69	58
Millet starch	55.8	3.5	5.6	82	71
Rice starch	61.5	3.7	4.8	86	64
Cassava starch	58.1	1.7	5.1	65	63

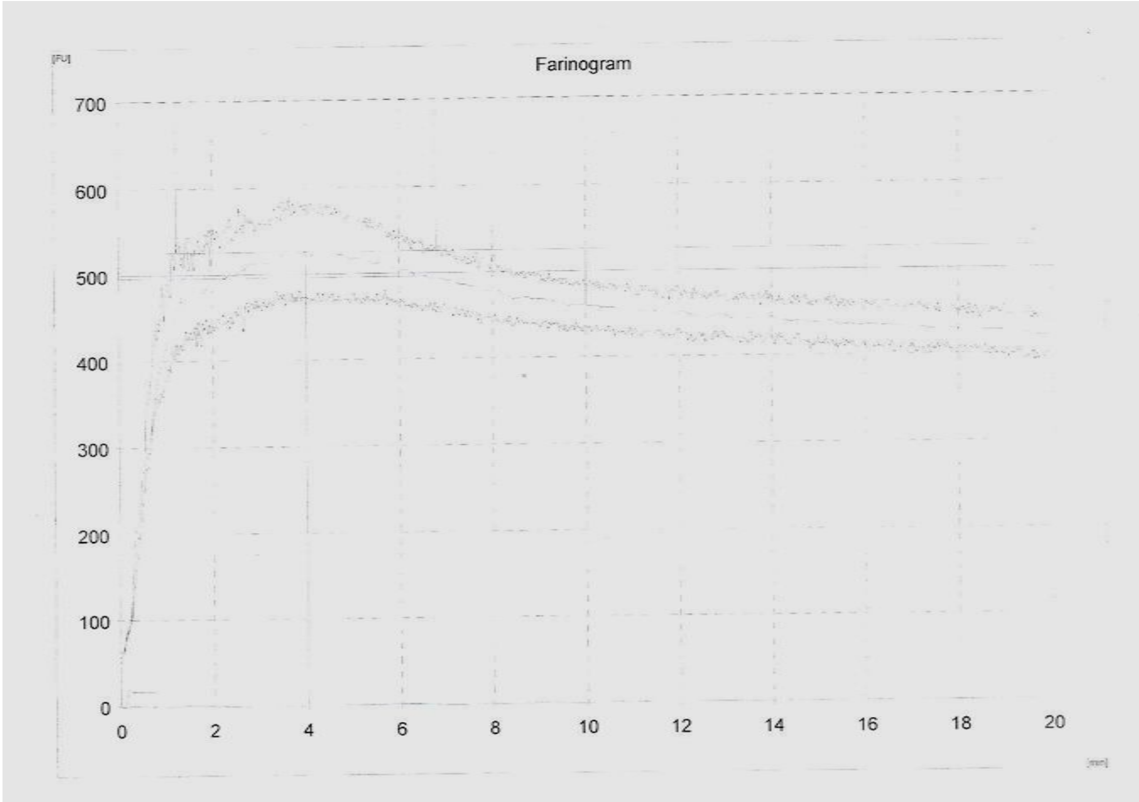


Fig.6.Farinogram of Wheat Flour (Imam)

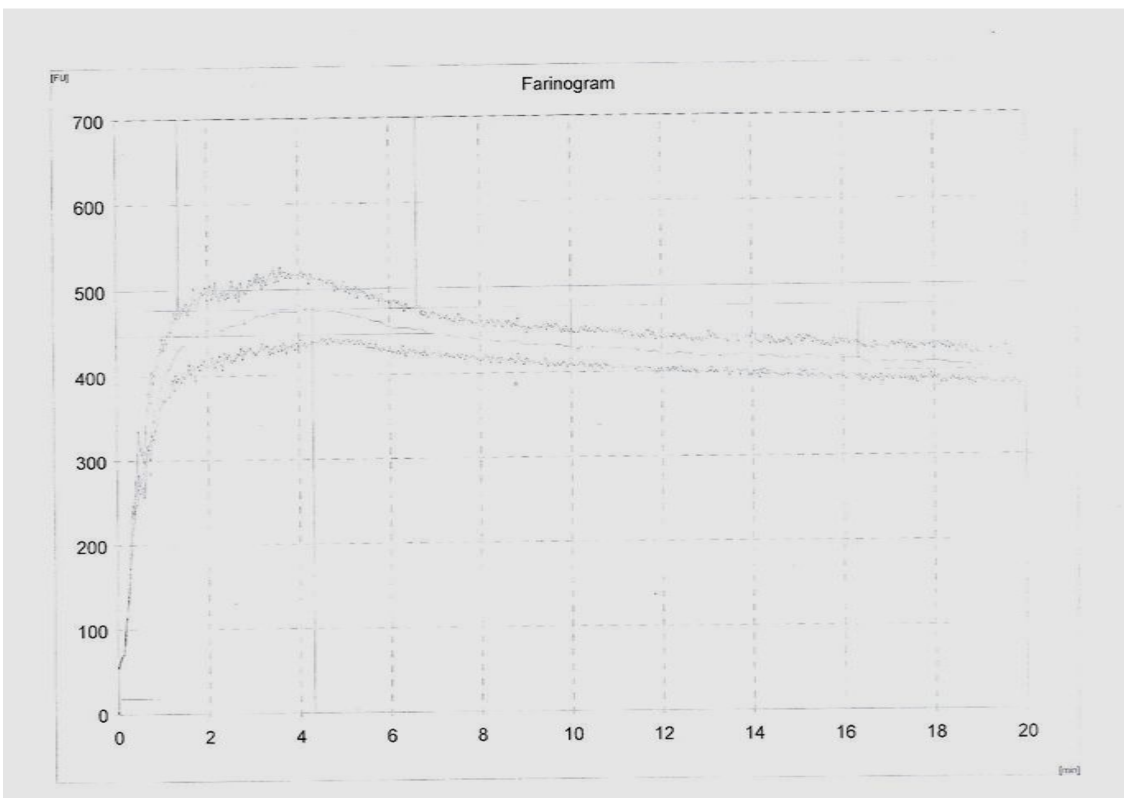


Fig.7.Farinogram of wheat flour containing5% Wheat starch

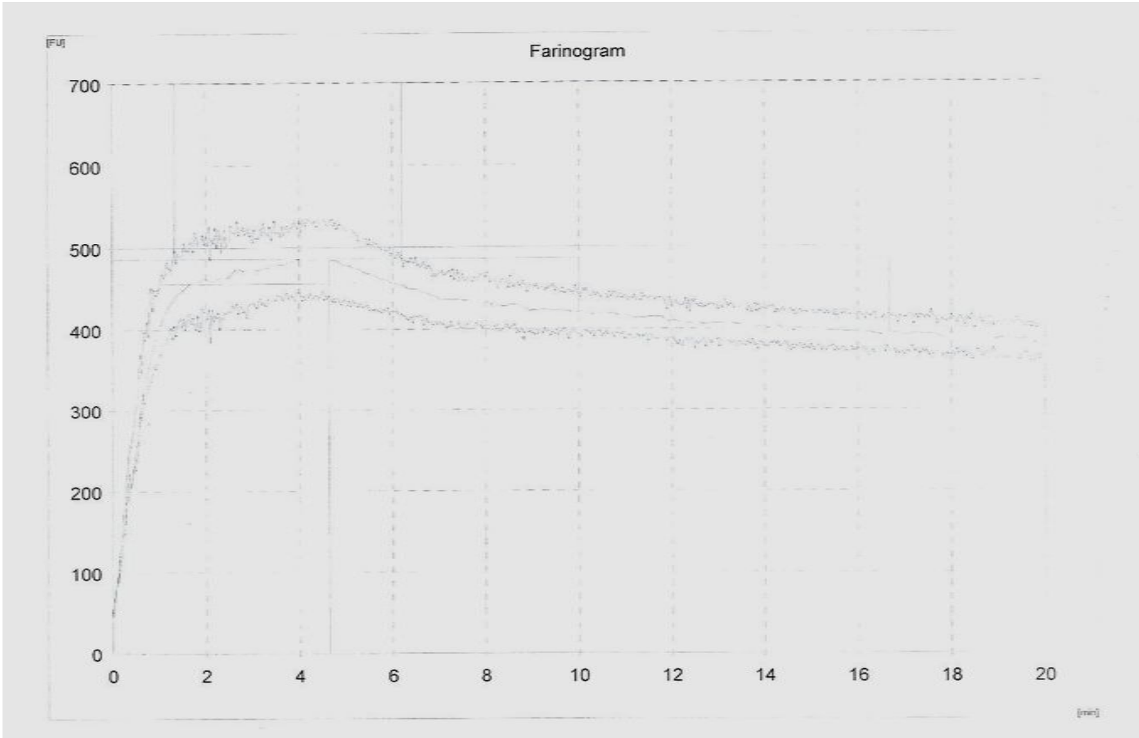


Fig.8.Farinogram of wheat flour containing5% Sorghum starch

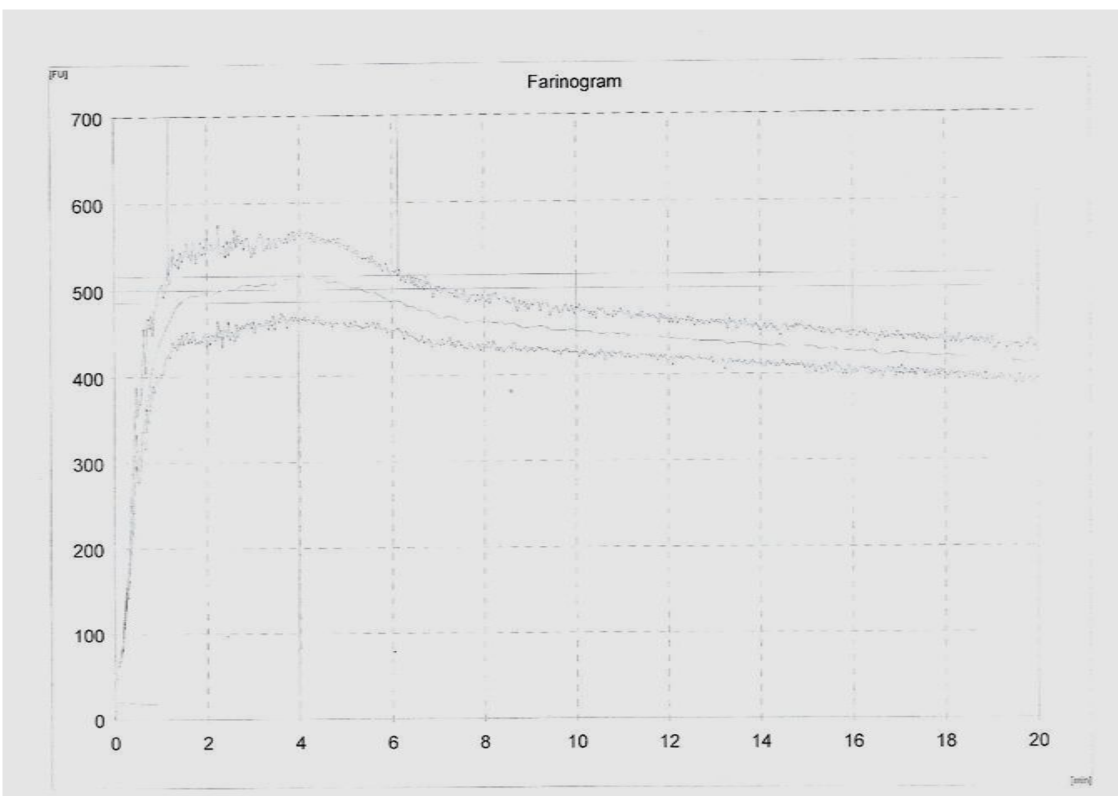


Fig.9.Farinogram of wheat flour containing5% millet starch

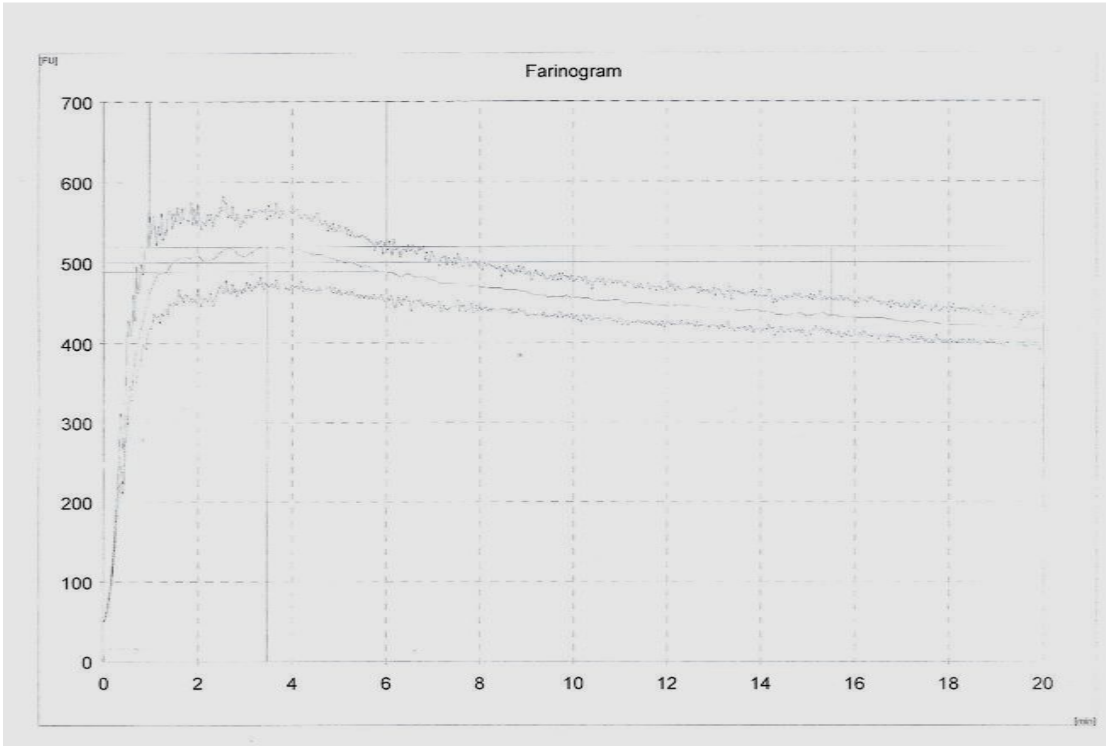


Fig.10.Farinogram of wheat flour containing 5% Rice starch

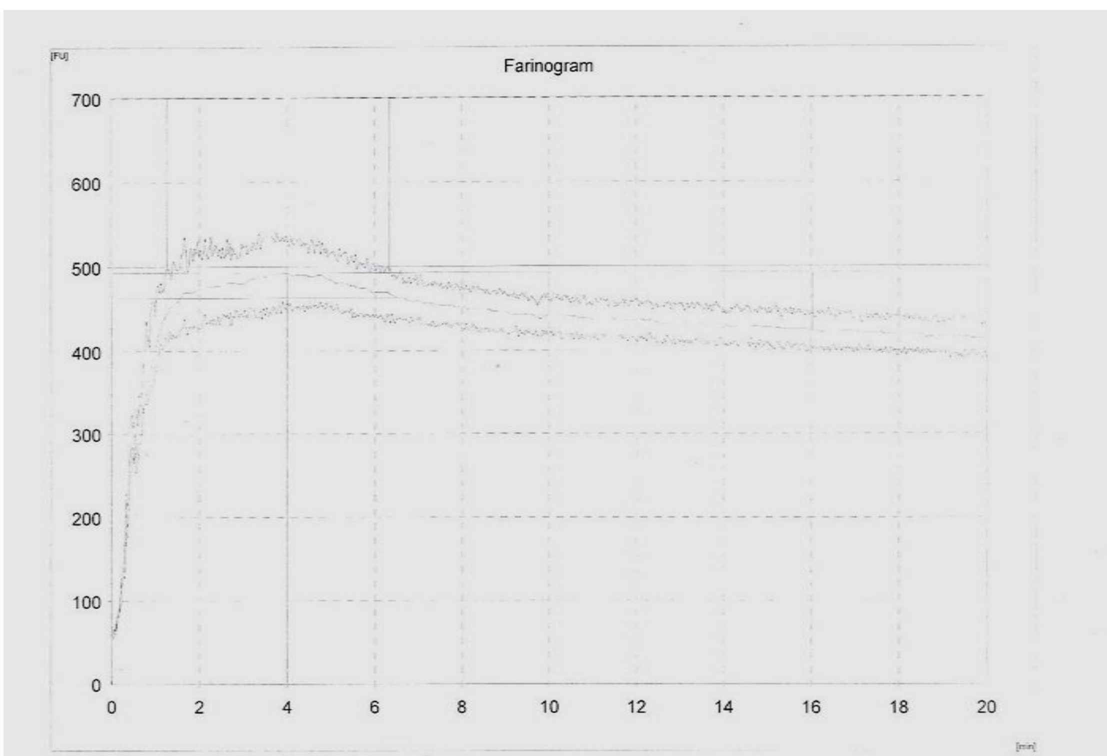


Fig.11.Farinogram of wheat flour containing 5% cassava starch

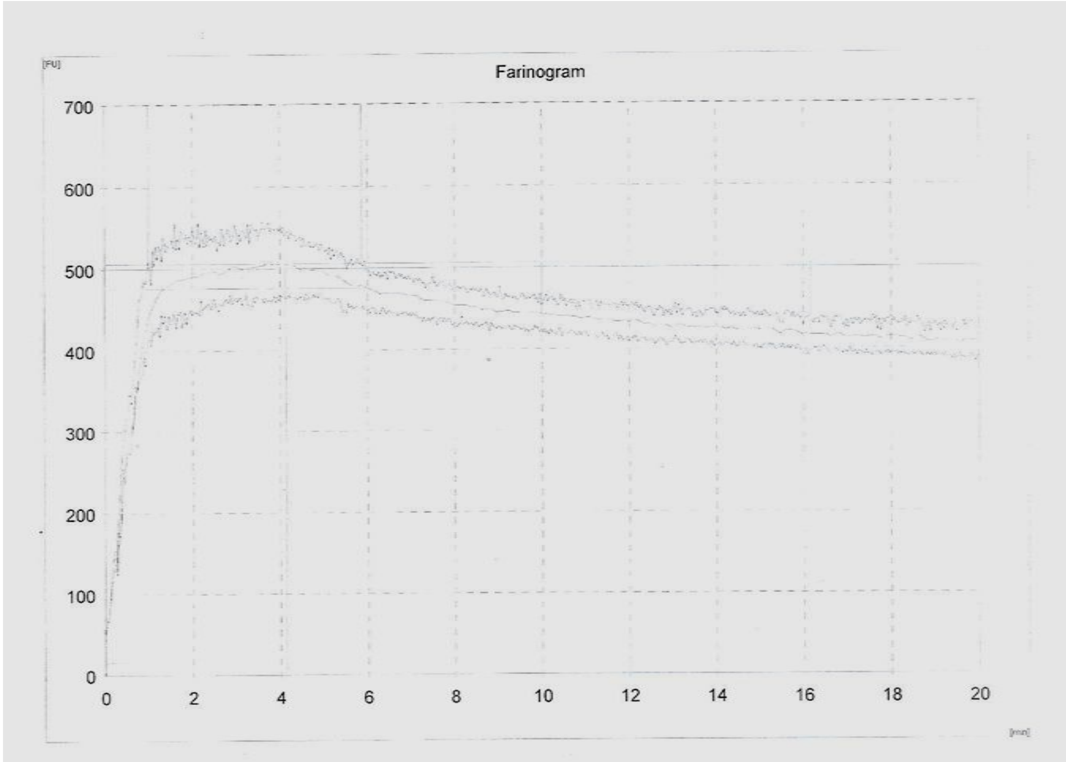


Fig.12.Farinogram of wheat flour containing10% wheat starch

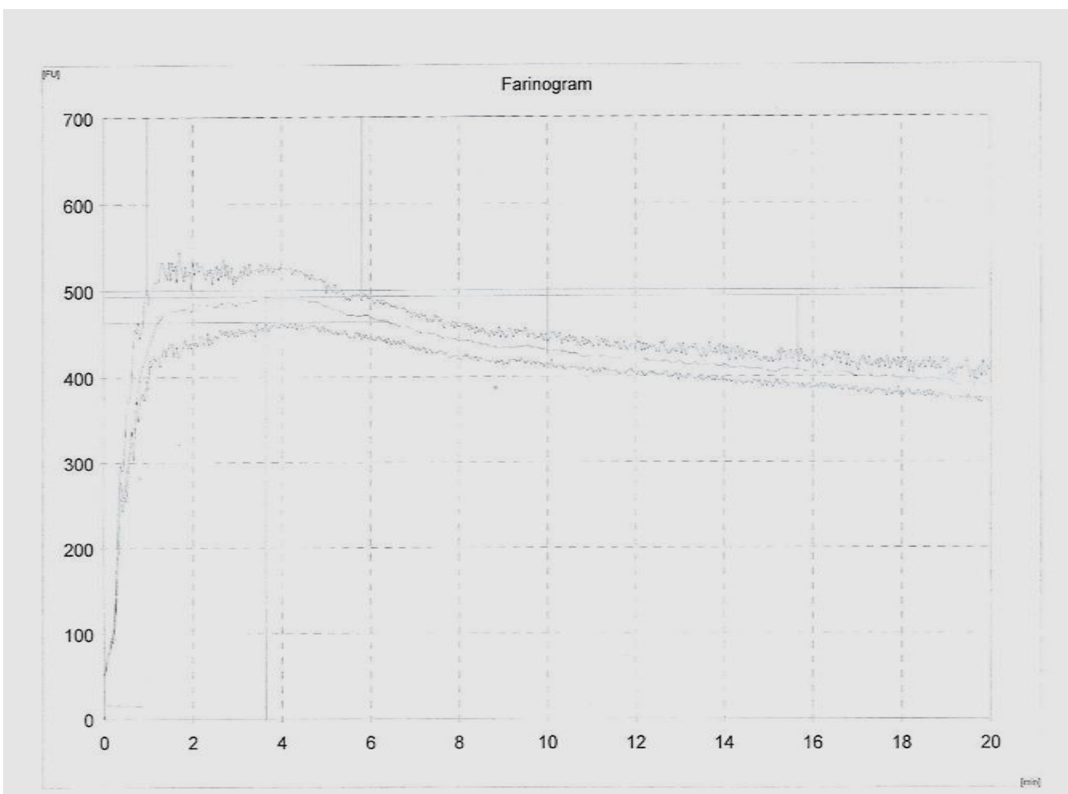


Fig.13.Farinogram of wheat flour containing10% sorghum starch

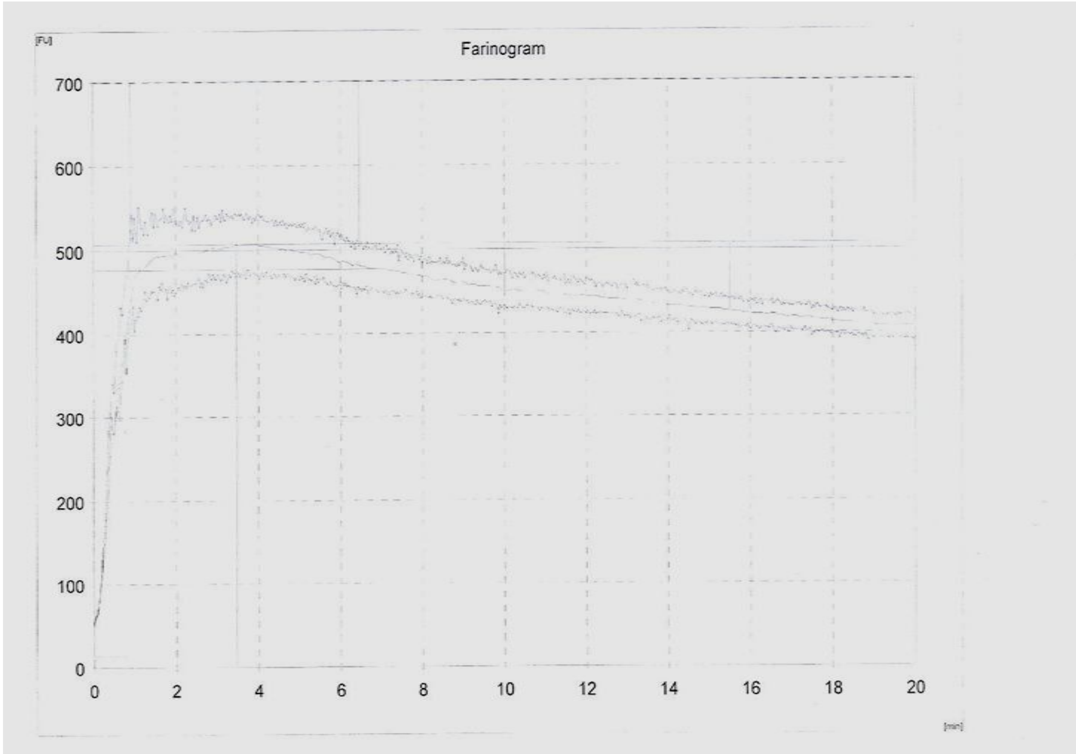


Fig.14.Farinogram of wheat flour containing10% millet starch

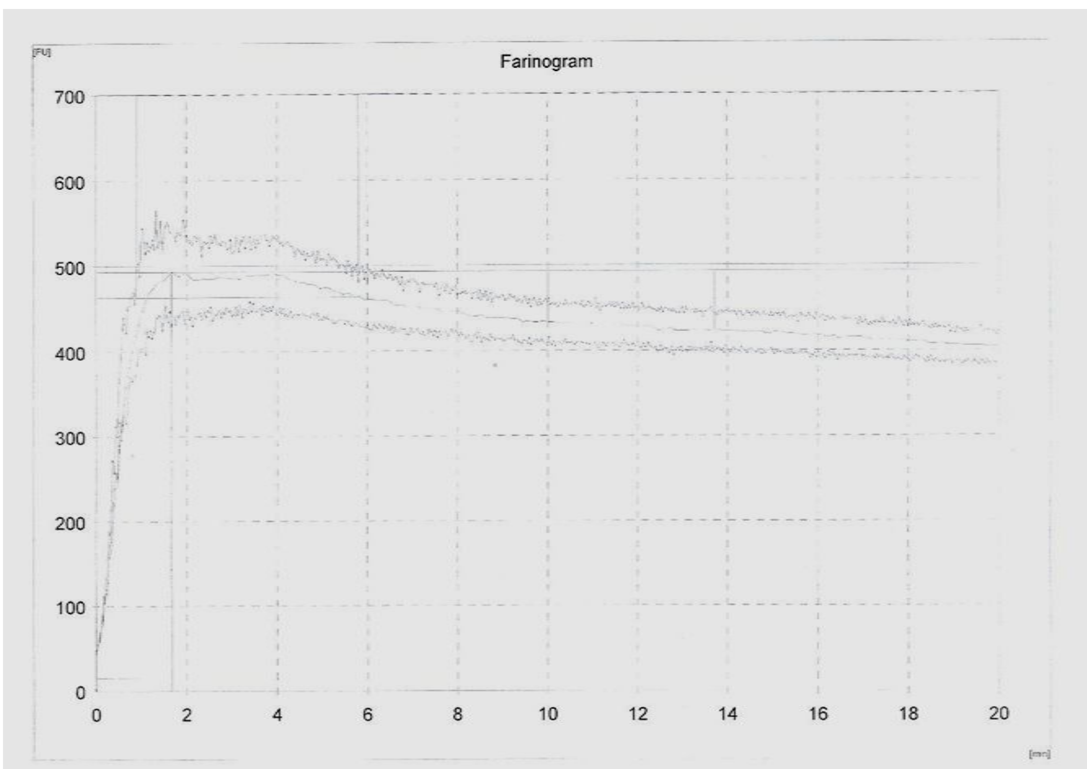


Fig.15.Farinogram of wheat flour containing10% Rice starch

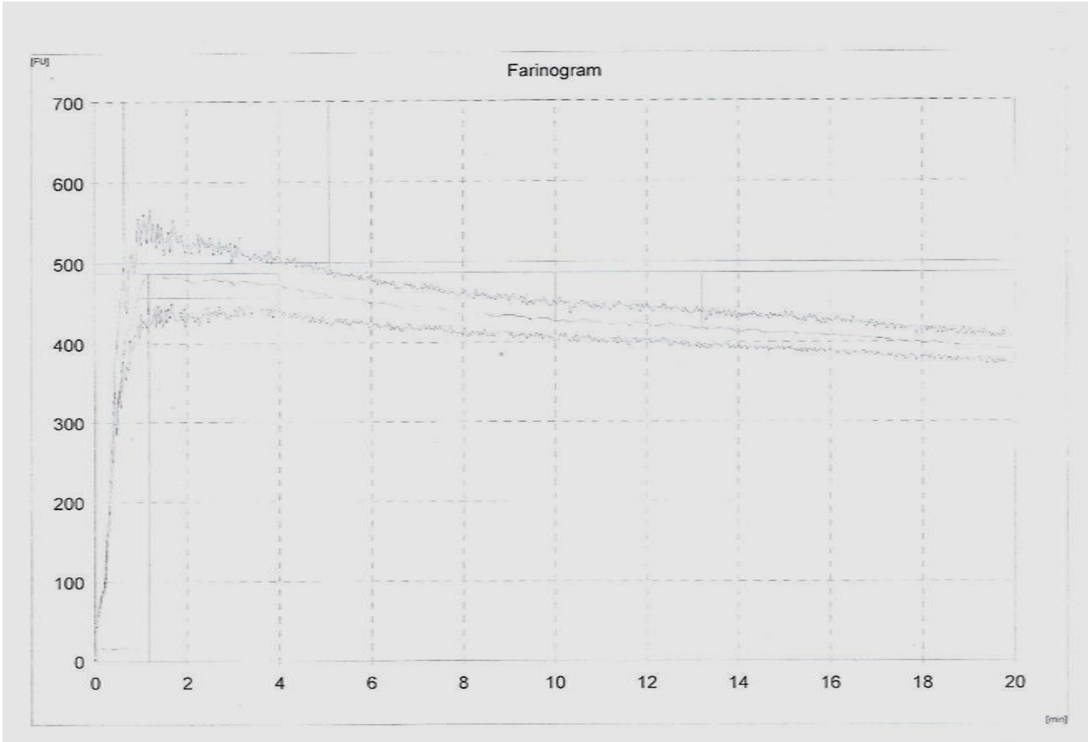


Fig.16.Farinogram of wheat flour containing10% cassava starch

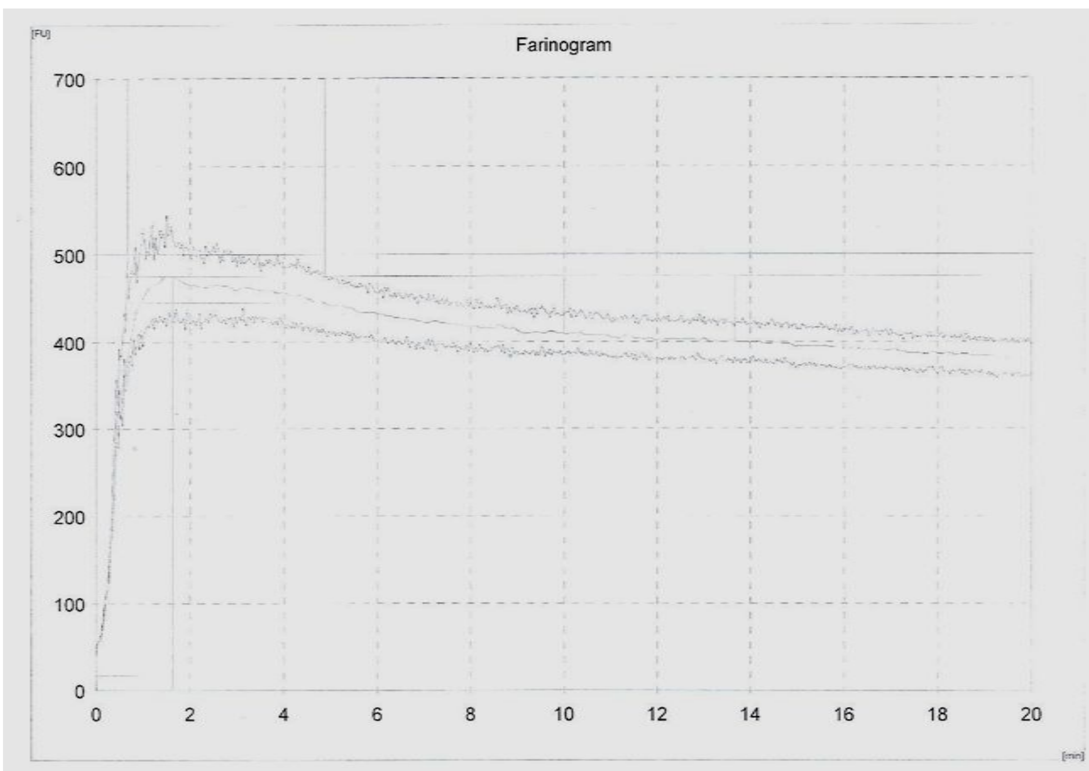


Fig.17.Farinogram of wheat flour containing15% wheat starch

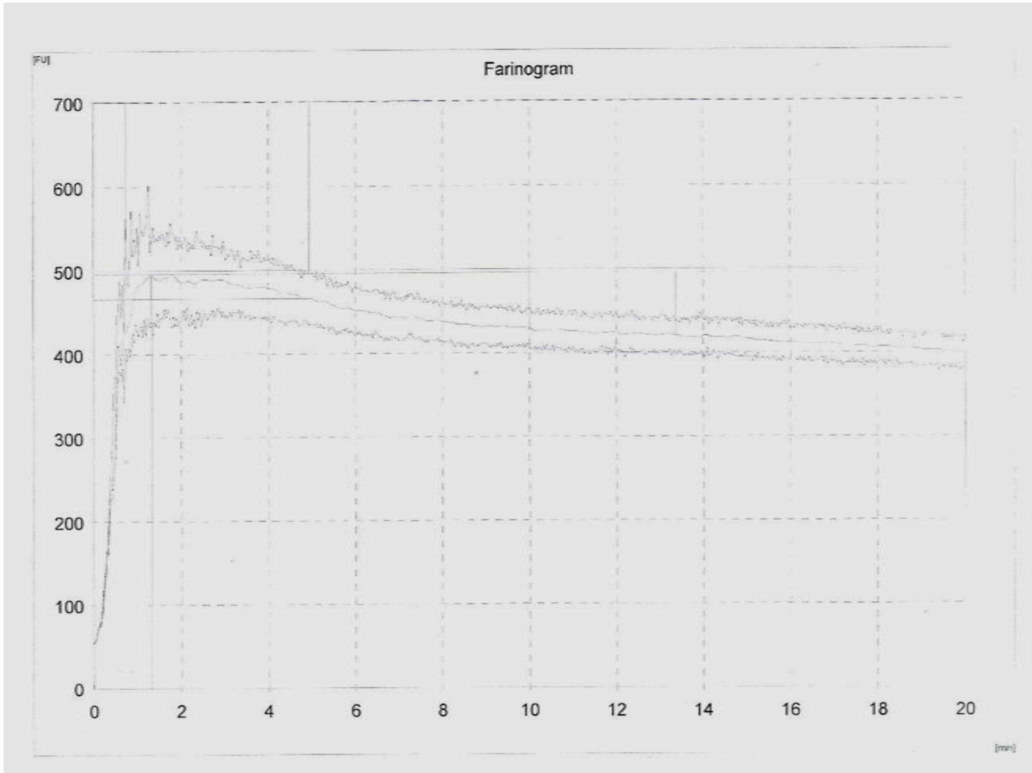


Fig.18.Farinogram of wheat flour containing15% sorghum starch

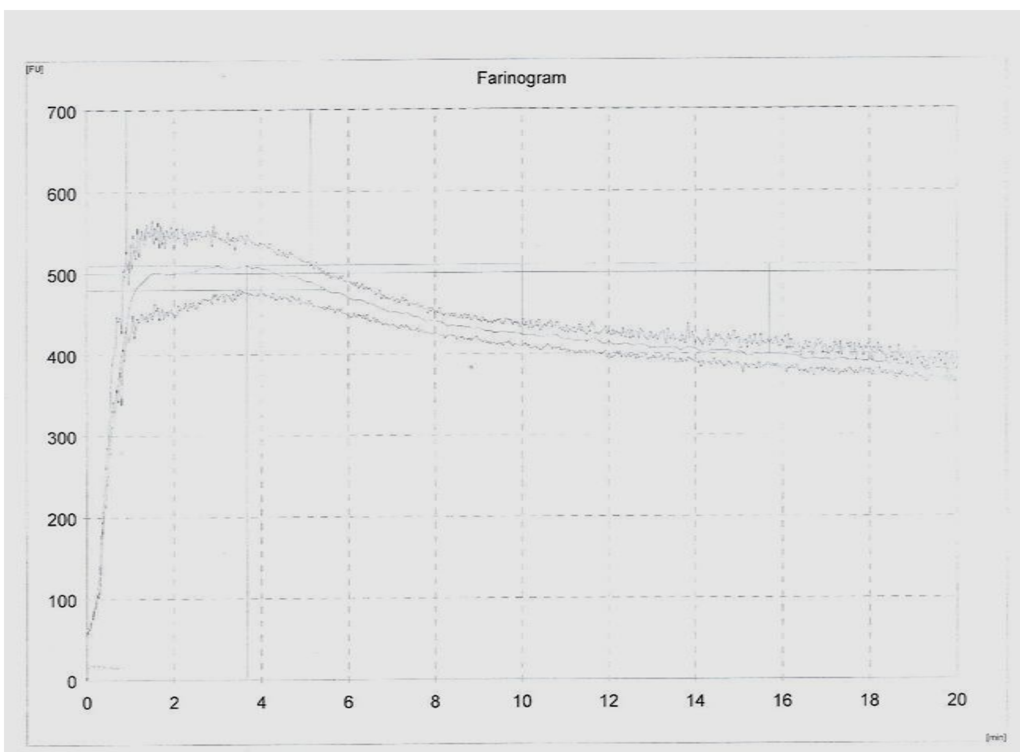


Fig.19.Farinogram of wheat flour containing15% millet starch

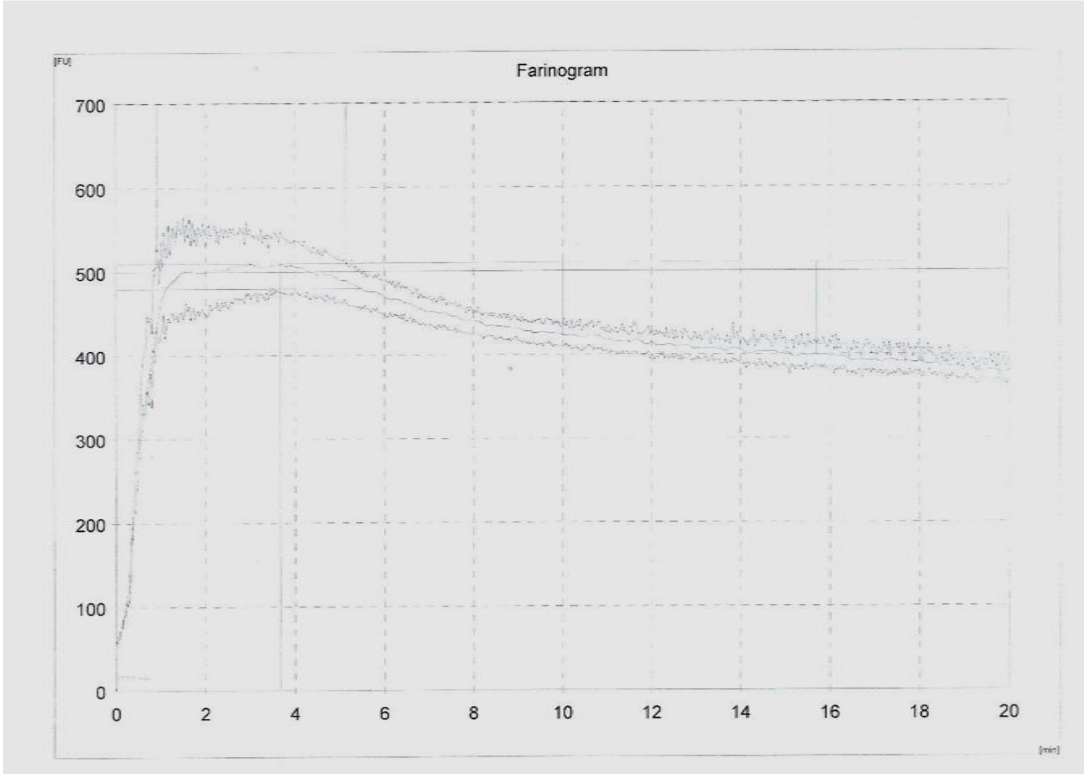


Fig.20.Farinogram of wheat flour containing15% Rice starch

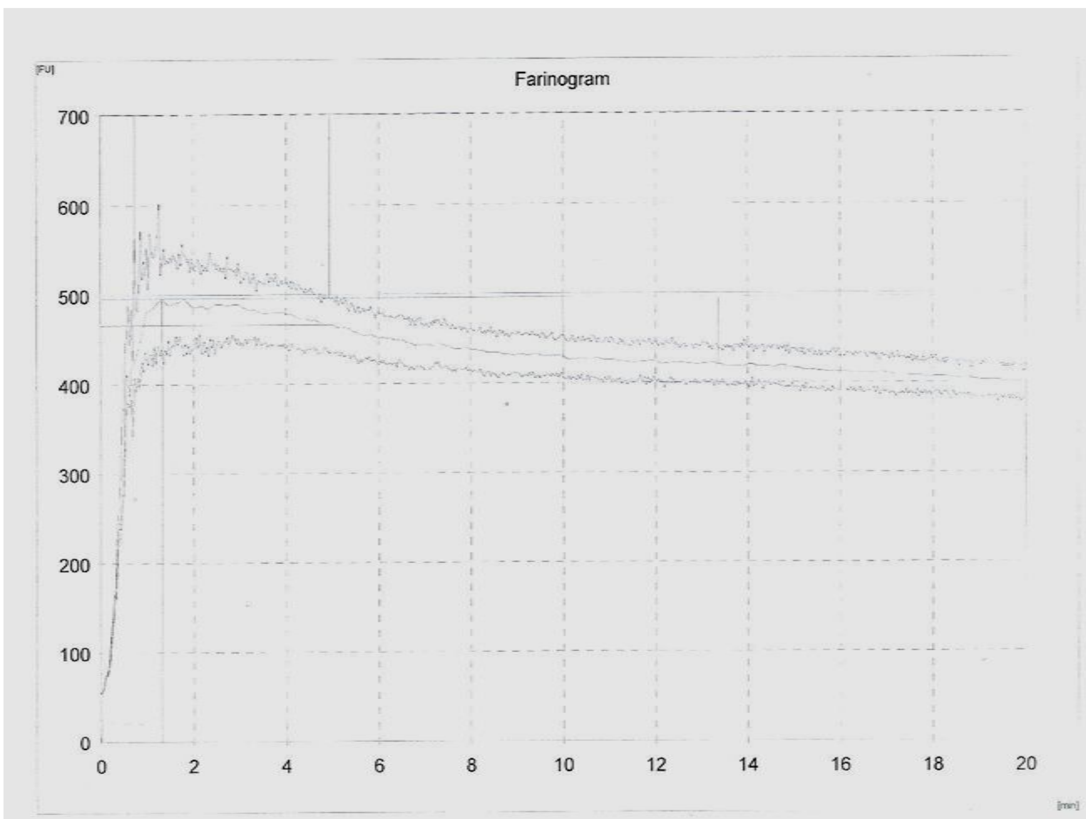


Fig.21.Farinogram of wheat flour containing15% Cassava starch

millet, rice and cassava starches blends and to 71.00, 75.00, 70.00 and 76.00 F.U. for 15% wheat, sorghum, millet and cassava starches blends respectively. 5% sorghum and 5% millet starch blends gave the same value of degree of softening of the control wheat flour. The farinograph quality number values decreased gradually from 66.00 minutes for wheat flour (control) to 62.00, 61.00 and 60.00 minutes for 5% sorghum, millet and rice starches blends and to 60.00, 58.00, 64.00 and 63.00 minutes for 10% wheat, sorghum, rice and cassava starches blends and to 63.00, 49.00, 51.00, 55.00 and 50.00 minutes for 15% wheat, sorghum, millet, rice and cassava starches blends respectively. Also this value increased to 70.00, 67.00 and 71.00 minutes for 5% wheat and cassava starches blends and 10% millet starch blend respectively.

These results were in agreement with the results obtained by Hassan (2007) who reported that the farinograph quality number values decreased gradually from 101.00 minutes for bread wheat flour to 53.00 for the substitution of 25% decorticated pigeon pea flour, moreover he found that the degree of softening for doughs increased with addition of decorticated pigeon pea flour and pigeon pea protein isolate to the ranges between 14.00 to 28.00 F.U. and 38.00 to 115.00 F.U. respectively. Mohammed (2000) reported that the water absorption for Sudanese cultivars ranged from 57.50% to 61.00%; also he found that dough development time, dough stability and degree of softening were 3.00 to 5.00 minutes, 1.00to 3.50 minutes and 40.00 to 70.00 F.U. respectively. Hamada *et al.,* (1982) reported that water absorption ranged from 59.00% to 65.70% for spring wheat; also he found that the dough development time and dough stability of spring wheat ranged from 3.00 to 7.00 minutes and from 3.00 to 28.00 minutes respectively. The results were supported by result obtained by Ahmed (2013) who found dough development time ranged from 2.00 to 6.50 minutes, dough stability time from 1.50 to 10.40 minutes and degree of softening from 13.00 to 129.00 F. U. Kulkarni *et al.,* (1987) reported that the flour protein content was of significantly high positive correlation with the dough development time and water absorption. It has significantly negative correlation with dough breakdown. He and Hoseney (1992) reported that protein content was positively correlated with Farinograph mixing time, mixing tolerance and water absorption. Anaka and Tipples (1979) reported that high water absorption gives more stability curve and long development time. Hamada *et al.,* (1982) and Bietz (1986) showed that the mixing strength is correlated with dough stability and the dough stability also showed an increase with increase in gluten content. Meredith (1967) reported that the dough development time ranged between 3.00 and 6.00 minutes.

4.7. Extensograms characteristics of the doughs prepared from wheat flour and composite flour blends:-

The extensogram characteristics of the doughs prepared from wheat flour (control) and wheat flour in different blends with starch and lentil flour is shown in table (17), (18), (19) and figures (22) to (37). The extensogram measures the extensibility (E) (mm), the energy (cm^2), the resistance (BU) and the resistance to extension (R/E) (BU) i. e. ratio, of the doughs from wheat and different composite flours. The stretching properties of the dough, in particular the resistance to stretching and extensibility characterize the flour quality and consequently, the baking and the processing properties of corresponding dough. Control wheat flour gave energy about 115, 116 and 106 cm^2after 45, 90 and 135 minutes respectively. Also gave resistance to extension about 395, 445 and 431 BU after 45, 90 and 135 minutes respectively.

Extensibility of wheat flour was 160, 148 and 142 mm after 45, 90 and 135 minutes respectively. The maximum (BU) was 510, 571 and 538 (BU) after 45, 90 and 135 minutes respectively. The values of the energy of the dough (dough strength) for control wheat flour were decreased with the addition of starch to the range from 77 to 93 cm^2 after 45 minutes, 73 to 93 cm^2after90 minutes and to the range from 74 to 93 after 135 minutes respectively for 5% starches blends. For 10% starches blends it decreased to the range between 62 to 101 cm^2 after 45 minutes, 4 to 89 cm^2 after 90 minutes and from 64 to 93 after 135 minutes respectively. Also it decreased to the range from 54 to 104 cm^2 after 45 minutes, from 51 to 89 cm^2 after 90 minutes and from 46 to 95 cm^2 after 135 minutes respectively for 15% starches blends.

The dough extensibility (mm) was decreased to the range between 139 to 157 mm after 45 minutes, 126 to 140 (mm) after 90 minutes and 120 to 135 (mm) after 135 minutes respectively for 5% starches blends. For 10% starches blends decreased to the range between 115 to 134 mm after 45 minutes, 4 to 123 mm after 90 minutes and 92 to 130 mm after 135 minutes respectively. On the other hand dough extensibility decreased to the range between111to 129 mm after 45 minutes, 100 to 130 mm after 90 minutes and 88 to 128 mm after 135 minute respectively for 15% starches blends.

From the results obtained, the energy of the dough (dough strength) and the dough extensibility were decreased with increasing of level of starch in wheat flour blends. The dough resistance to extension was decreased from 395 BU for control wheat flour to the range between 308 to 386 BU for 5% wheat, sorghum, millet and rice starches blends after 45 minutes. After 90 minutes it decreased to the range from 445 BU to 426 for wheat, sorghum, millet, rice and cassava starches blends. Dough resistance to extension decreased from 431 BU to the range from370 to 386 BU for sorghum, millet and rice starches blends after 135 minutes. The dough resistance to extension was increased to 409 and 487 BU for 5% cassava starch blend after 45 and 135 minutes respectively. Dough resistance to extension was increased to 444 BU after 135 minutes for 5% wheat starch blend.

Table (17) Extensograms characteristics of wheat flour containing 5% ofstarch of wheat, sorghum, millet, rice and cassava with 5% lentil flour

Source of starch in wheat Flour blends	Energy (cm^2)			Resistance to extension (BU)			Extensibility (mm)			Maximum Resistance (BU)		
	45 **min**	90 **min**	135 **min**	45 **min**	90 **min**	135 **min**	45 **min**	90 **min**	135 **min**	45 **min**	90 **min**	135 **min**
Wheat flour (control)	115	116	106	395	445	431	160	148	142	510	571	538
wheat starch	93	85	83	386	426	444	143	126	120	441	470	483
sorghum starch	85	79	83	308	353	386	157	137	133	365	396	430
millet starch	84	82	83	325	348	379	150	139	135	371	401	427
rice starch	77	73	74	328	351	370	143	131	128	343	368	388
cassava starch	93	93	93	409	408	487	139	140	123	455	458	528

Table (18) Extensograms characteristics of wheat flour containing 10% ofstarch of wheat, sorghum, millet, rice and cassava with 5% lentil flour

Source of starch in wheat Flour blends	Energy (cm^2)			Resistance to extension (BU)			Extensibility (mm)			Maximum Resistance (BU)		
	45 min	90 min	135 min	45 min	90 min	135 min	45 min	90 min	135 min	45 min	90 min	135 min
Wheat flour (control)	115	116	106	395	445	431	160	148	142	510	571	538
wheat starch	86	81	87	398	467	524	132	113	112	431	495	547
sorghum starch	93	89	82	421	514	546	134	115	104	457	537	559
millet starch	101	4	93	561	321	737	115	4	92	583	1147	744
rice starch	62	63	64	307	330	302	127	122	130	307	330	315
cassava starch	77	88	86	392	458	510	124	123	112	410	485	542

Table (19) Extensograms characteristics of wheat flour containing 15% ofstarchof wheat, sorghum, millet, rice and cassava with 5% lentil flour

Source of starch in wheat Flour blends	Energy (cm^2)			Resistance to extension (BU)			Extensibility (mm)			Maximum Resistance (BU)		
	45 min	90 min	135 min	45 min	90 min	135 min	45 min	90 min	135 min	45 min	90 min	135 min
Wheat flour (control)	115	116	106	395	445	431	160	148	142	510	571	538
wheat starch	75	86	95	446	508	554	111	113	113	450	521	583
sorghum starch	83	83	84	446	518	565	119	107	102	461	534	584
millet starch	104	89	80	578	610	648	119	100	88	590	625	651
rice starch	54	51	46	270	260	243	129	130	128	271	261	244
cassava starch	85	86	84	436	488	522	123	114	106	449	513	545

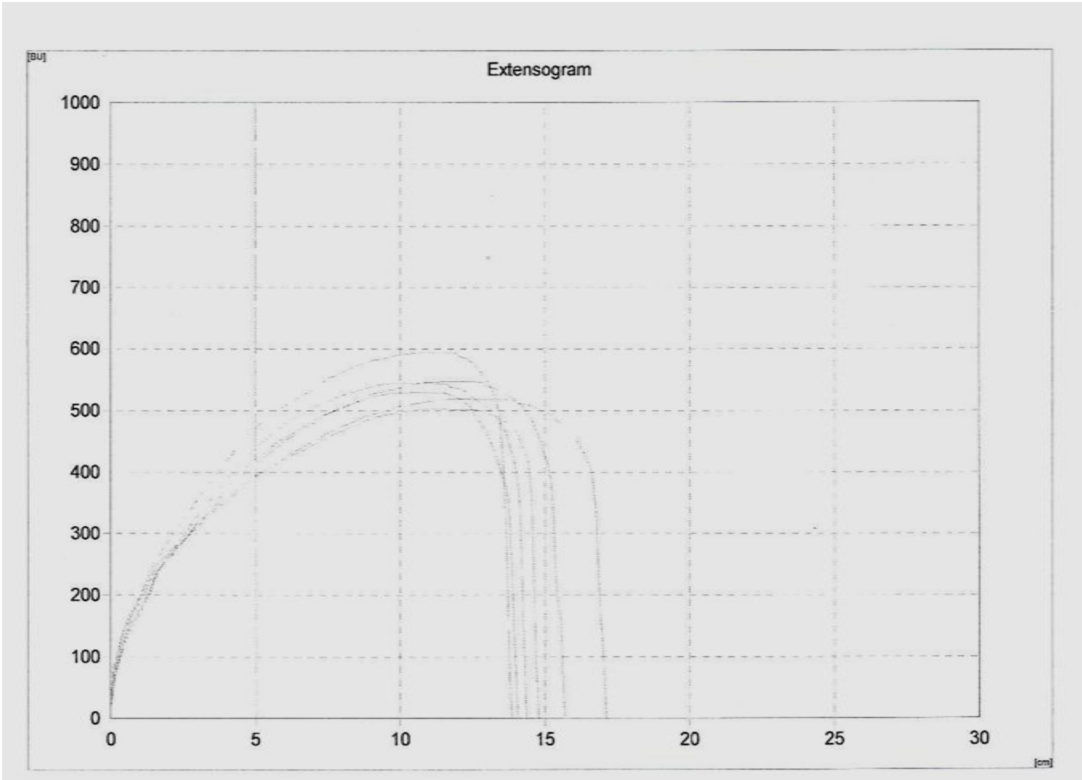


Fig.22.Extensograms Characteristics of Wheat Flour (Imam)

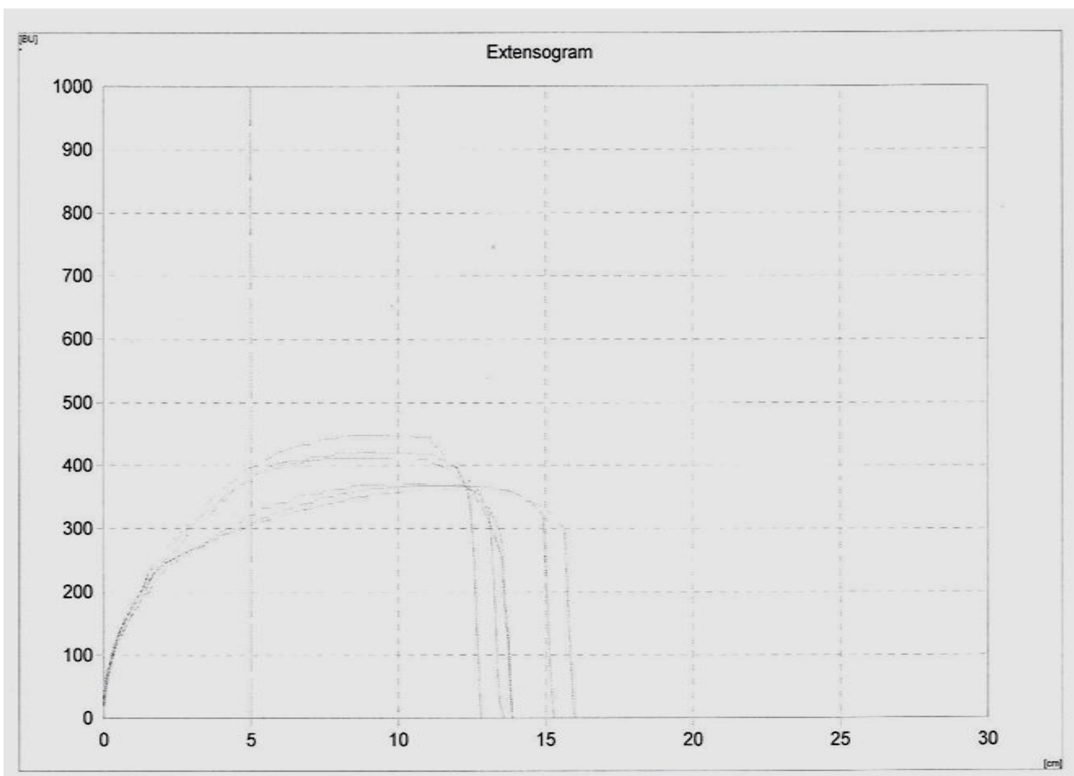


Fig.23.Extensograms Characteristics of wheat flour containing5% wheat starch

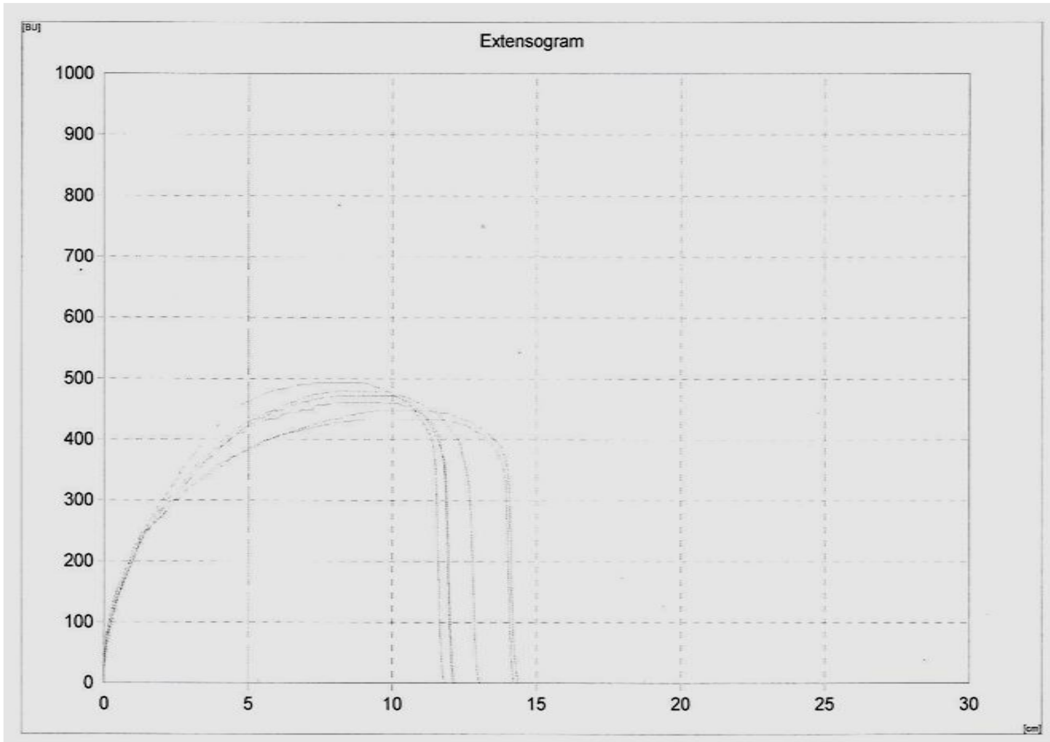


Fig.24.Extensograms Characteristics of wheat flour containing5% Sorghum Starch

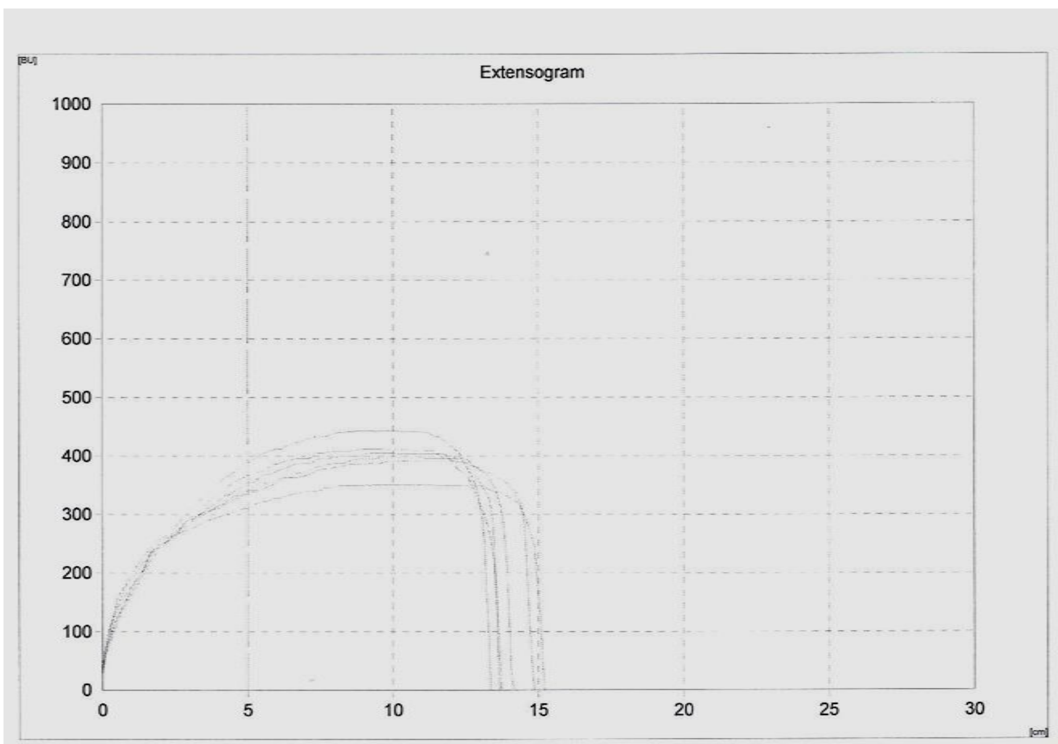


Fig.25.Extensograms Characteristics of wheat flour containing 5% millet starch

Fig.26..Extensograms Characteristics of wheat flour containing5% rice starch

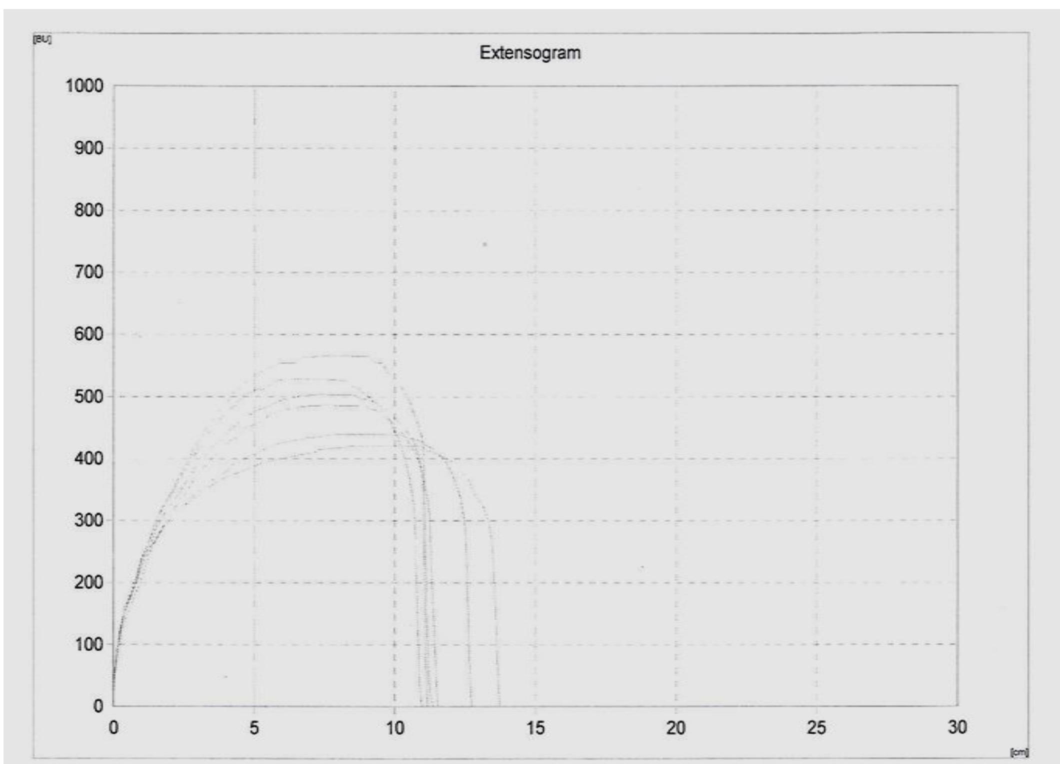


Fig.27.Extensograms Characteristics of wheat flour containing5% cassava starch

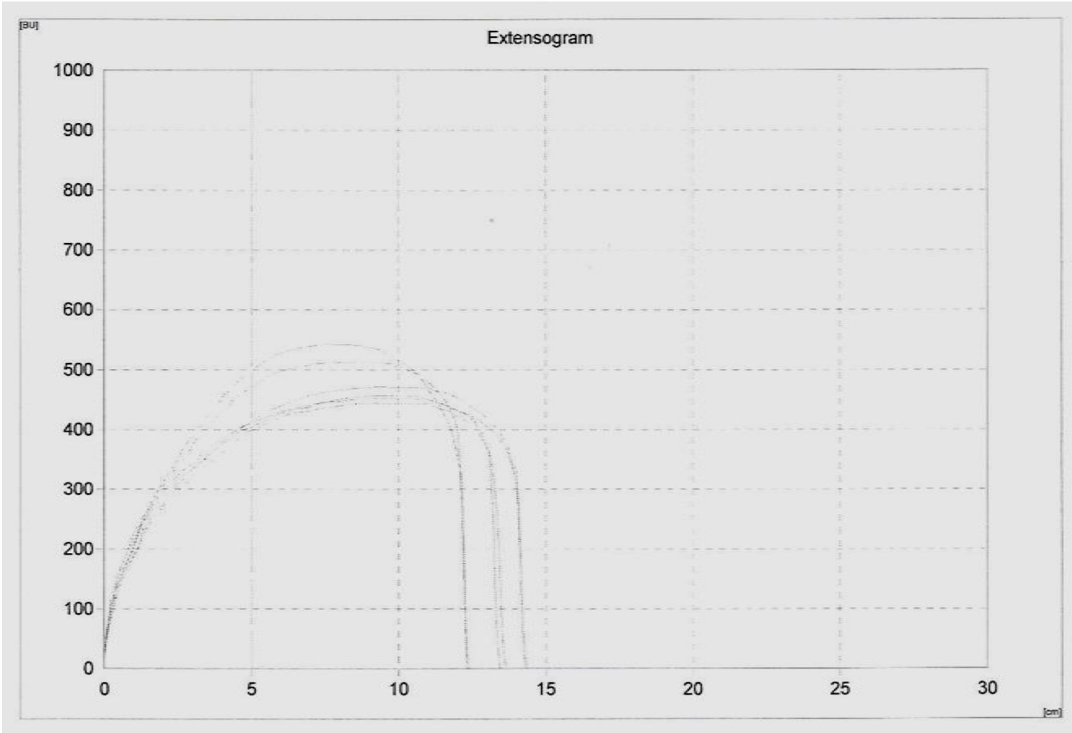


Fig.28.Extensograms Characteristics of wheat flour containing10% wheat starch

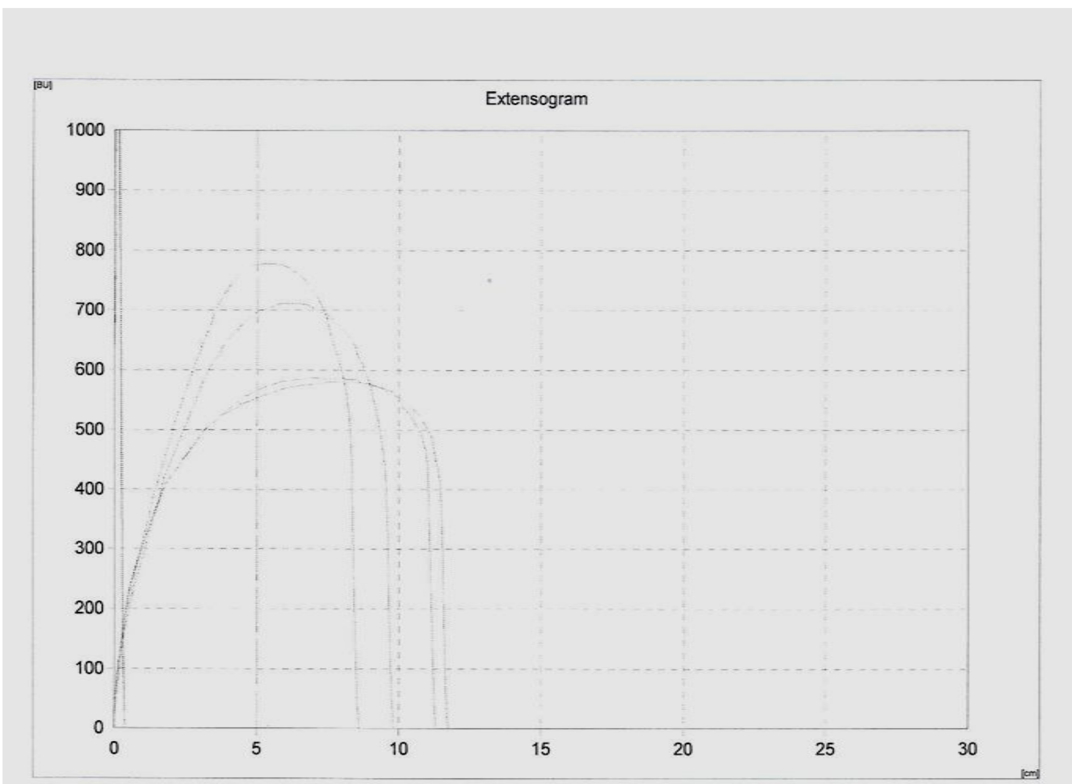


Fig.29.Extensograms Characteristics of wheat flour containing10% sorghum starch

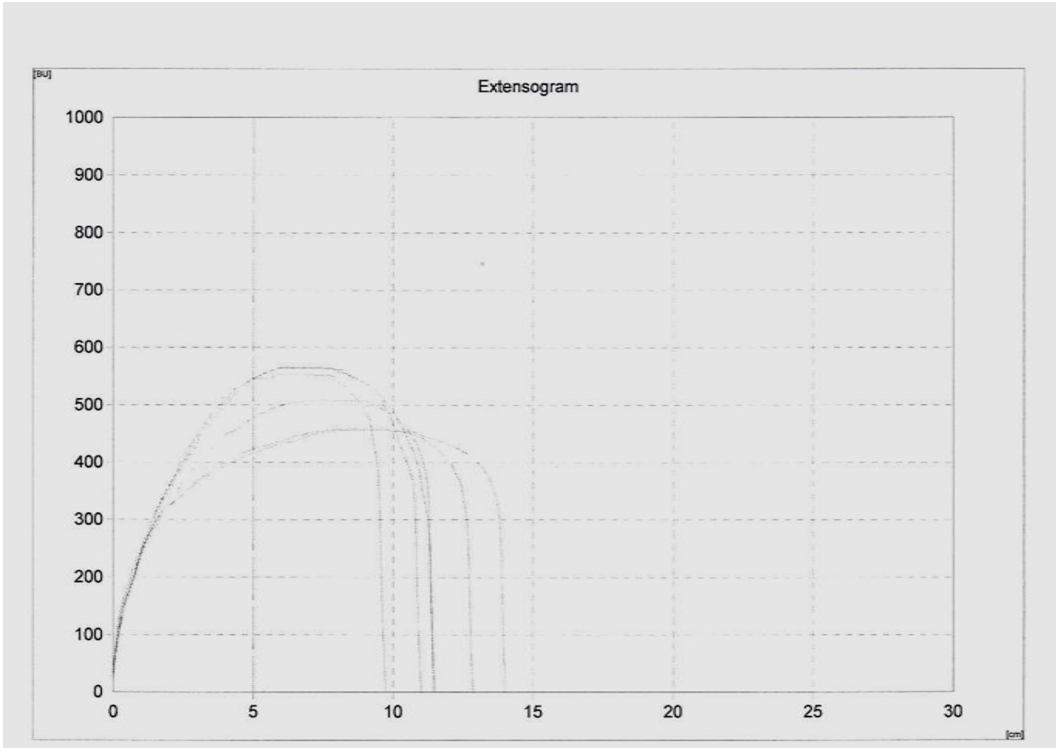


Fig.30.Extensograms Characteristics of wheat flour containing10% millet starch

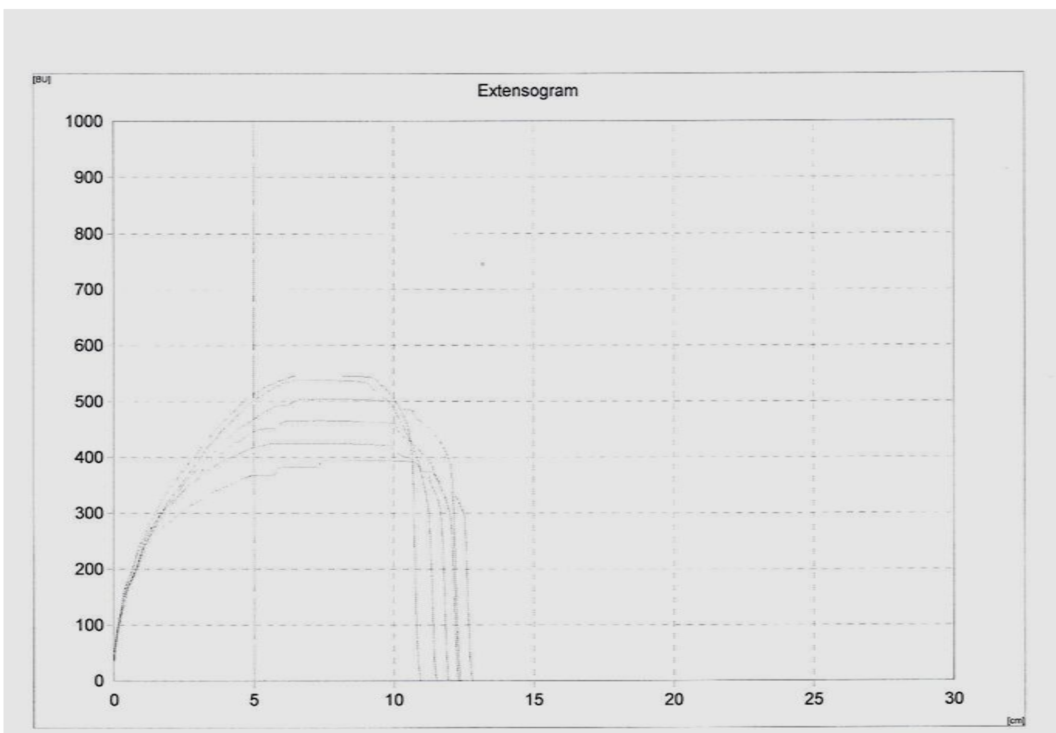


Fig.31.Extensograms Characteristics of wheat flour containing10% rice Starch

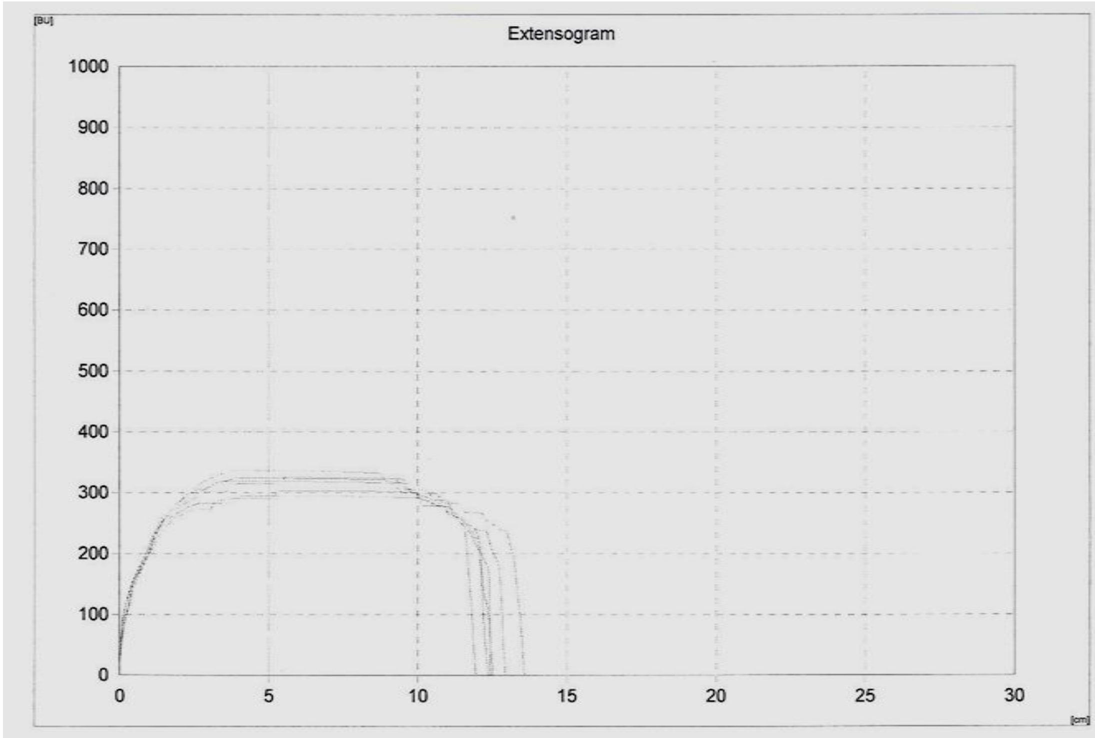


Fig.32.Extensograms Characteristics of wheat flour containing10% cassava starch

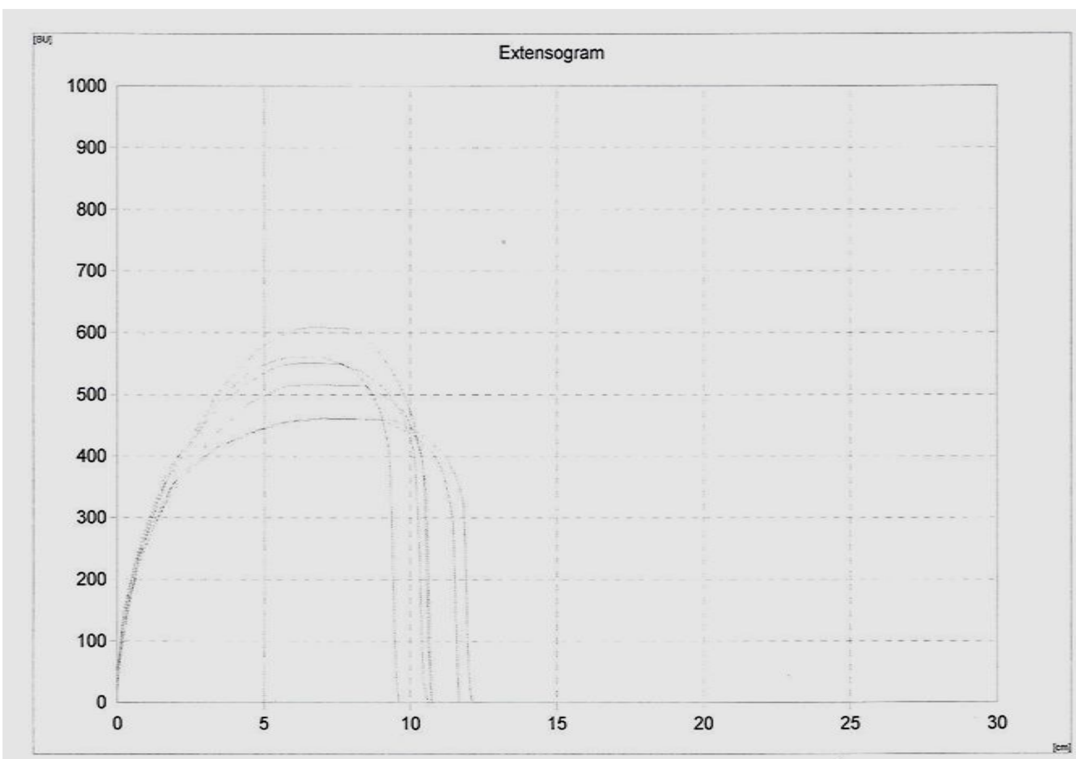


Fig.33.Extensograms Characteristics of wheat flour containing15% wheatStarch

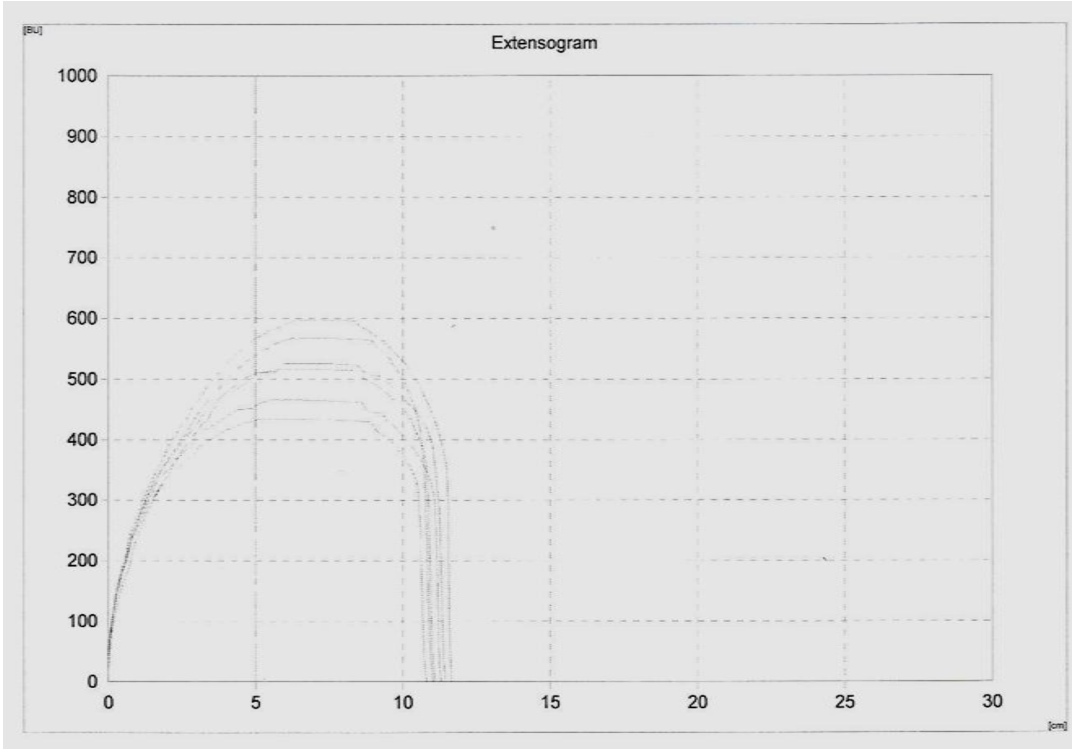


Fig.34.Extensograms Characteristics of wheat flour containing15% sorghum starch

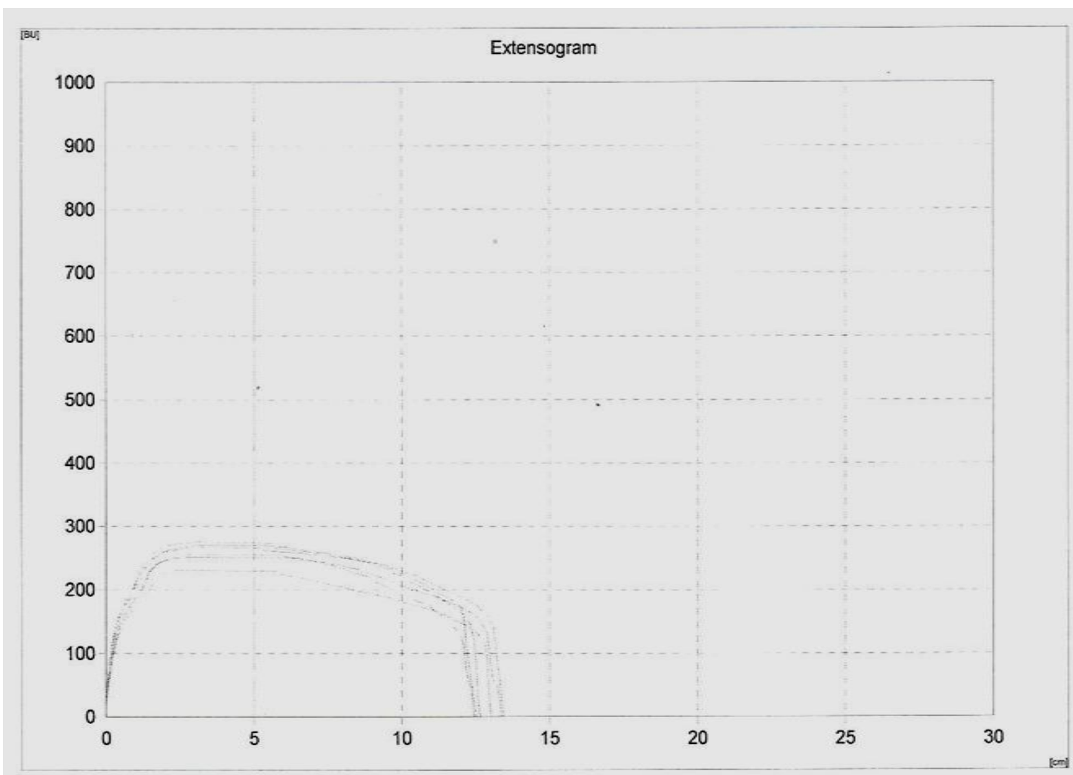


Fig.35.Extensograms Characteristics of wheat flour containing15% millet starch

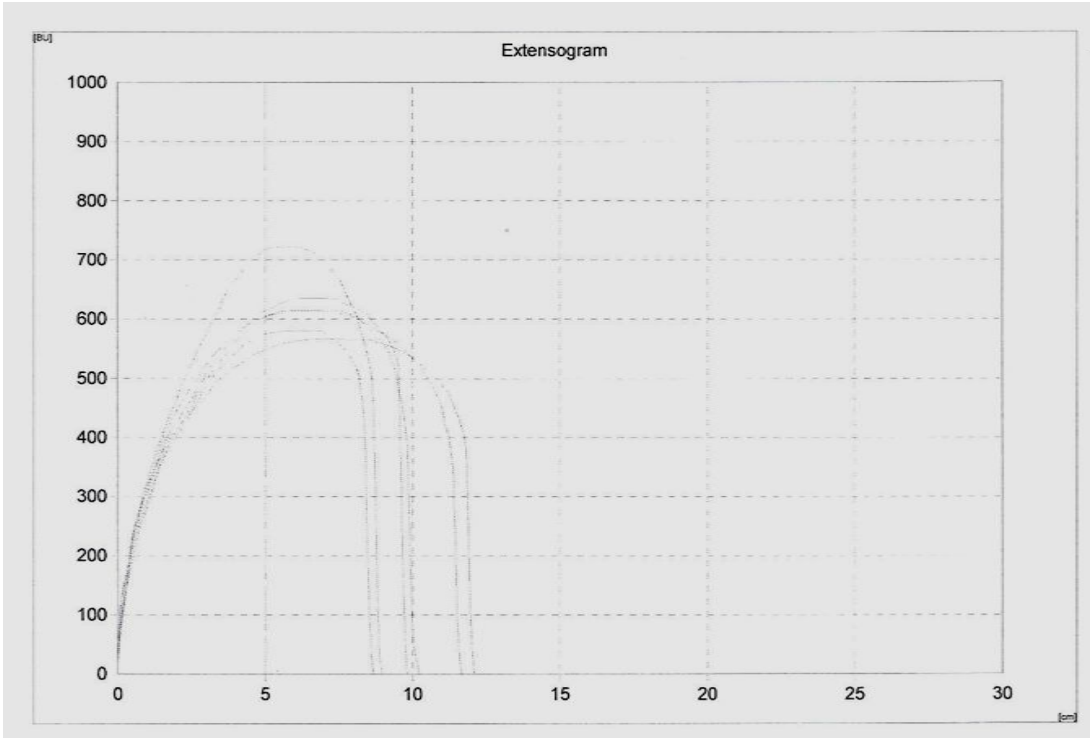


Fig.36.Extensograms Characteristics of wheat flour containing15% rice starch

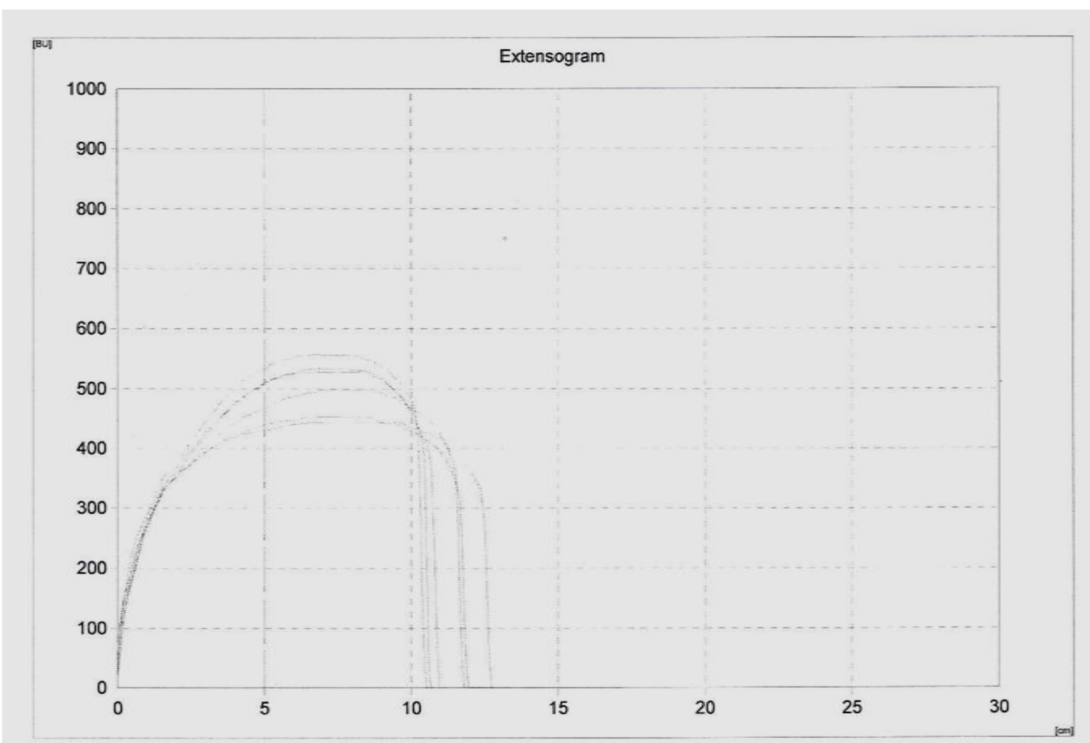


Fig.37.Extensograms Characteristics of wheat flour containing15% cassava starch

Also it increased to the range from 398 to561 BU for 10% wheat, sorghum and millet starches blends after 45 minutes. Increasing to the range between 458 to 514 BU for 10%wheat, sorghum and cassava starches blends after 90 minutes. The dough resistance to extension increased to the range from 510 to 737 BU for 10% wheat, sorghum, millet and cassava starches blends after 135 minutes. Dough resistance to extension was increased to the range from 436 to 578 BU after 45 minutes, 488 to 610 BU after 90 minutes and to the range from 522 to 648 BU after 135 minutes for the blends of wheat, sorghum, millet and cassava starches respectively. The maximum dough resistance decreased from 510, 571 and 538 BU to the ranges from 343 to 455 BU, 368 to 470 BU and to the range from 388 to 528 BU for 5% wheat, sorghum, millet, rice and cassava starches blends after 45, 90 and 135 minutes respectively.

The maximum dough resistance increased from 538 BU for control wheat flour to the range from 542 to 744 for 10% wheat, sorghum, millet and cassava starches blends after 135 minutes. It is also increased to 583 and 1147 BU after 45 and 90 minutes for 10% millet starch blend respectively.

The maximum dough resistance decreased to 307, 330 and 315 BU after 45, 90 and 135 minutes respectively for 10% rice starch blend. Also it decreased to the range between 410 to 537 BU after 45 and 90 minutes for 10% wheat, sorghum and cassava starches blends. Maximum dough resistance increased to the range between 545 to 651 BU for 15% wheat, sorghum, millet and cassava starches blends after 135 minutes respectively.

Maximum dough resistance increased to 590 and 625 BU after 45 and 90 minutes respectively for 15% millet starch blend. On the other hand it decreased to the range of between 449 to 534 BU after 45 and 90 minutes for 15% wheat, sorghum and cassava starches blends respectively. It was decreased to 271, 261and 244 BU for 15% rice starch blendafter 45, 90 and 135 minutes.

From these results it could be observed that dough energy and extensibility decreased with increasing level of starch in blends, dough resistance to extension decreased at low level (5%) and then increased with increasing level of starch and maximum resistance increased with increased level of starch when the time increased to 135 minutes.

The dough resistance (maximum dough) (BU) was decreased for 5% starches blends, increased for 10% wheat, sorghum, millet and cassava starches blends after 135 minutes and for 15% wheat, sorghum, millet and cassava starches blends respectively.

Energy, resistance to extension, extensibility and maximum dough resistance decreased in all blends of rice starch

In general these agreed with the findings of Jone (1991). The results were justified by results obtained by Hassan (2007) who reported that the energy of the dough (dough strength), the dough extensibility and dough resistance to extension were decreased with increasing by replacement of the two types of wheat flour for bread and biscuit. It was clear that increasing of percentages of starch in wheat flour blends increased the dough resistance to extension.

4.8. Amylograph properties of cereal and cassava starches:

Amylogram of the five starches is presented in table (20) and shown in figure (38) to (42). Pasting temperature for wheat, sorghum, millet and cassava starches was 65.10, 73.40, 72.10 and 63.80 C° respectively. Rice starch had the highest pasting temperature 76.60 C° (beginning of gelatinization) compared to other starches.The low pasting temperature was observed in cassava starch. Gelatinization temperature ranged from 73.80 to 115.00 C°. The highest value of gelatinization temperature was observed in rice starch, while the lowest value was in cassava starch. Viscosities of wheat, sorghum, millet, rice and cassava starches in amylograph unit (Gelatinization maximum) was 3011, 3631, 2733, 1349 and 4643 AU respectively.

Cassava starch showed the highest viscosity; while rice starch showed the lowest viscosity and wheat, sorghum and millet starches were in between. From these results it could be concluded that rice starch had the highest pasting temperature, Gelatinization temperature and lower viscosity in amylograph unit. I found these results agreed with the results obtained by Badi *et al.,* (1976) who found the pasting temperature for sorghum starch from two varieties ranged from 78.00 to 78.50 C° and the pasting temperature for millet starch was 72.00 C°. Also he found that the gelatinization temperature for sorghum starch ranged from 63.00 – 74.00 C°and for millet starch 51.00 – 69.00 C°.

Badi *et al.,* (1976) obtained viscosities for sorghum and millet starch ranged between 560 to 635 BU. Also found that amylograms of millet flour gave drastically lower peak viscosity than similar amylograms of sorghum flour. The low peak viscosity of millet flour compared with normal peak viscosity of millet starch isolated form the same flour suggested that millet flour contained an active amylase system. When starch granules are heated in aqueous suspensions, they swell and soluble leach from the granules into the surrounding aqueous phase to produce a viscous paste. That is the most important practical property of starch. A common belief is that the increased viscosity of a cooked starch paste results from the granules imbibing increasing amounts of free water as they swell thus making contact among them more likely (collison 1968, Schoch, 1965). Reports have also stated that the increase in viscosity is a measure of the work required to move the granules past each other as they continue to swell.

4.8.1. Effect of starches on amylograph properties of wheat flour:

Amylograph of wheat flour and wheat flour blends is shown in table (21) and presented in figures (43) to (58). Pasting temperature of wheat flour (beginning

Table (20): Amylograph readings of cereals and cassava starches

Source of starch	Beginning of Gelatinization (C°)	Gelatinization temperature (C°)	Gelatinization maximum (AU) (viscosity in AU)
Wheat starch	**65.1**	**92.9**	**3011**
Sorghum starch	**73.4**	**79.6**	**3631**
Millet starch	**72.1**	**83.1**	**2733**
Rice starch	**76.6**	**115**	**1349**
Cassava starch	**63.8**	**73.8**	**4643**

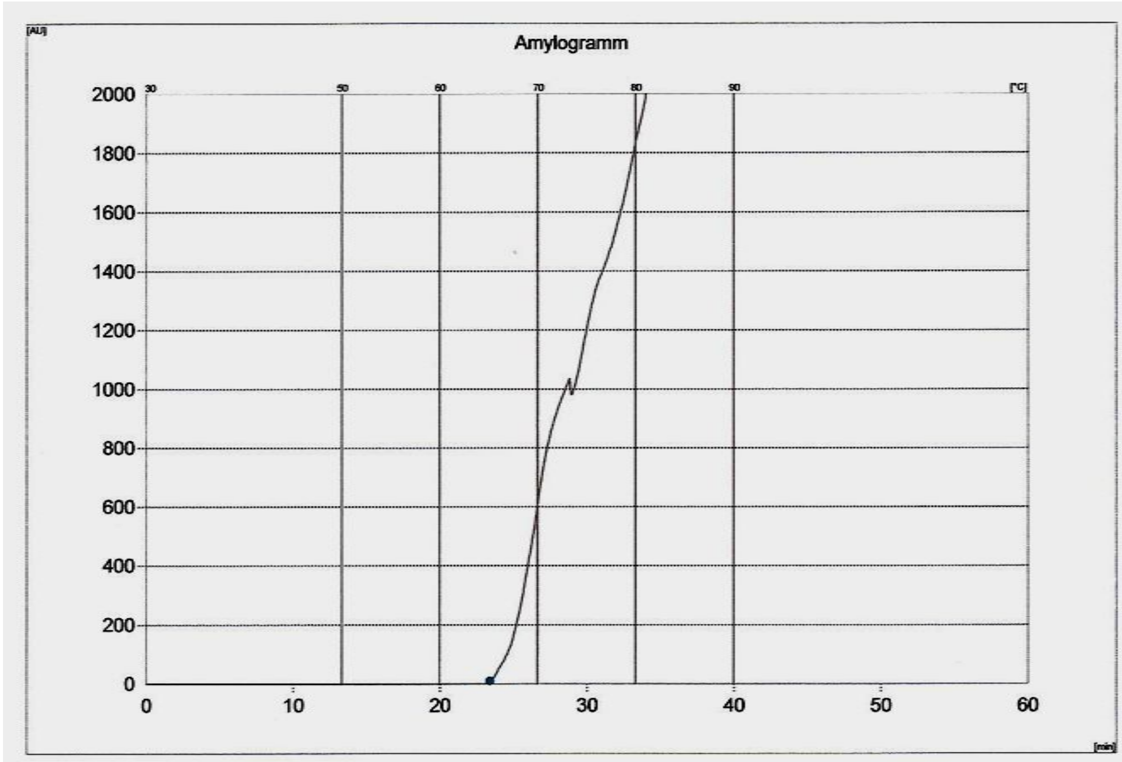


Fig.38.Amylograph of wheat starch

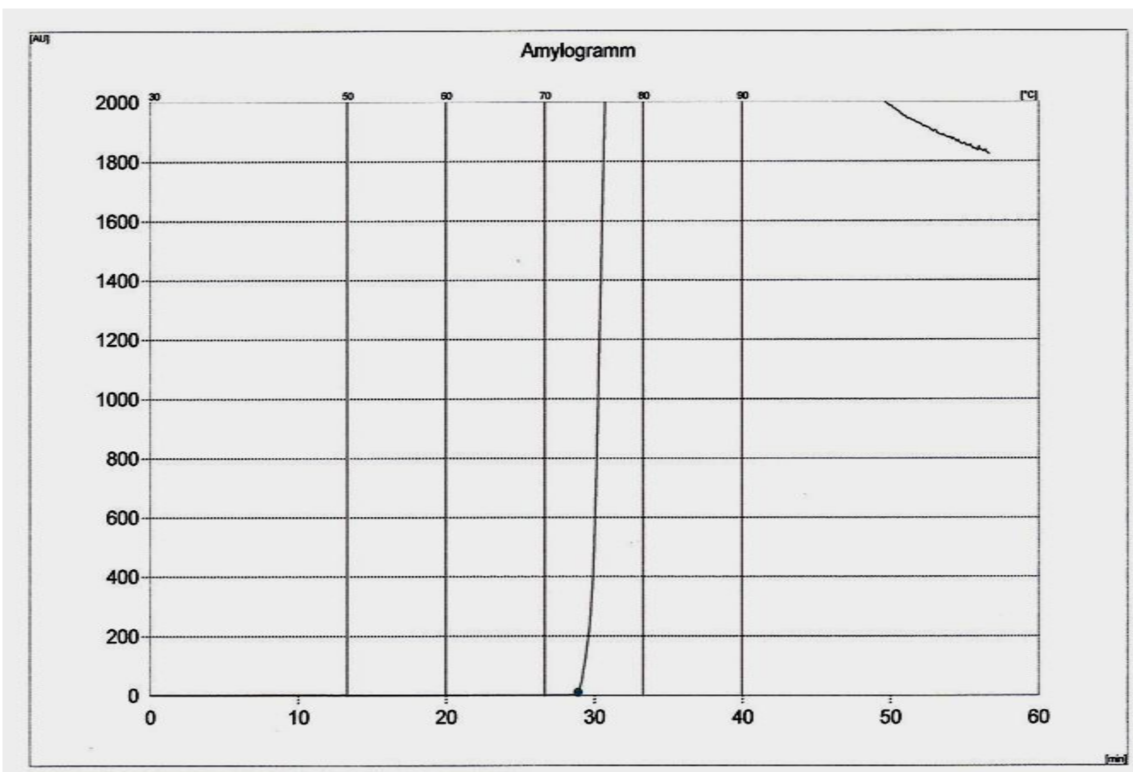


Fig.39.Amylograph of sorghum starch

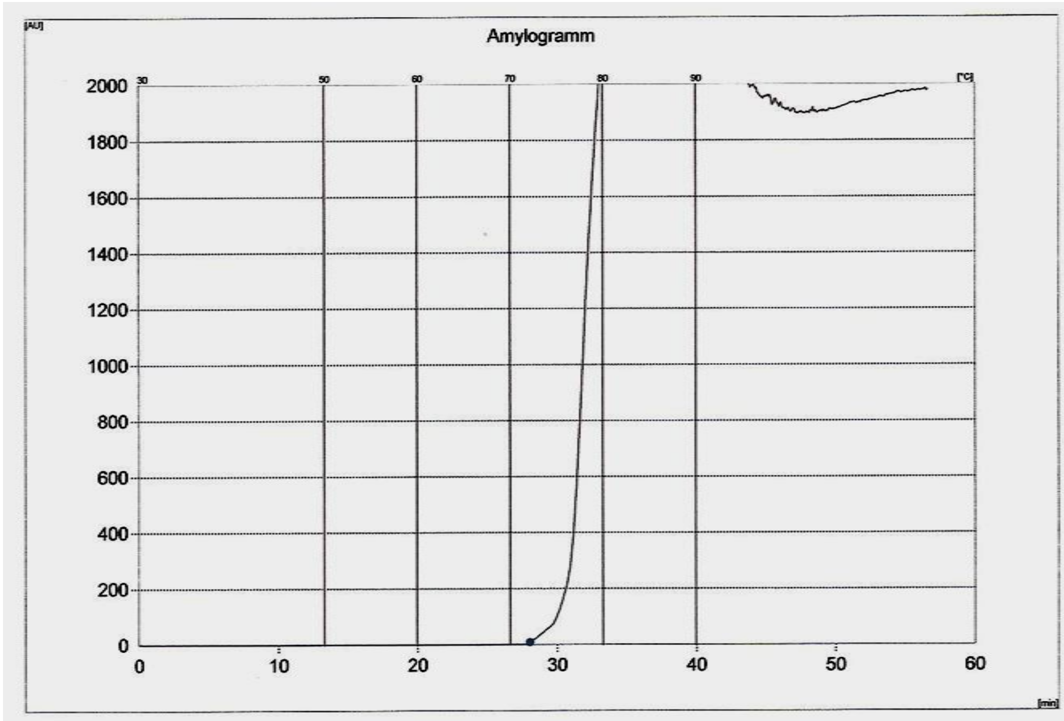


Fig.40.Amylograph of millet starch

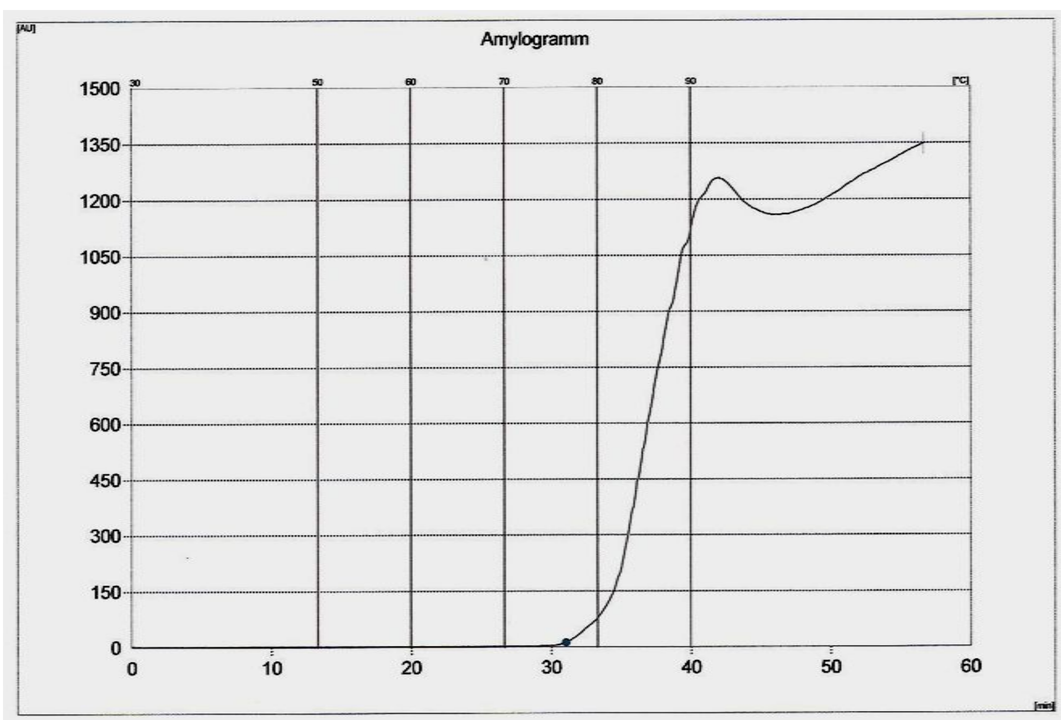


Fig.41.Amylograph of rice starch

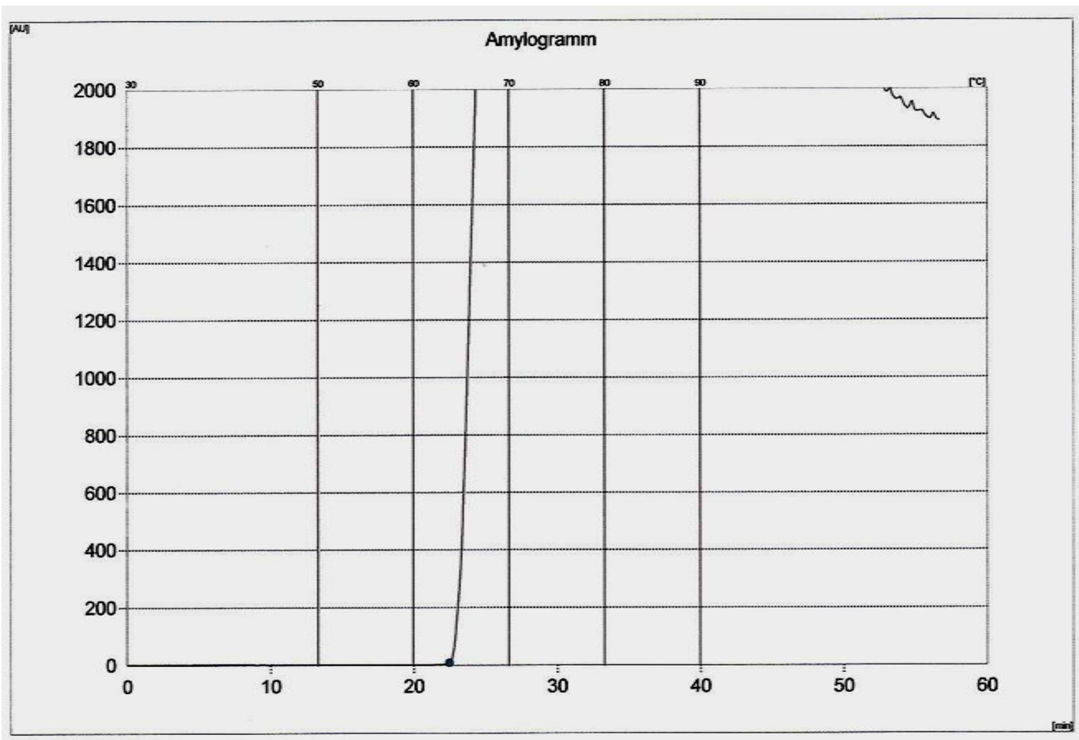


Fig.42.Amylograph of cassava starch

of gelatinization) was 63.90 C°, gelatinization temperature was 91.30 C° and gelatinization maximum (viscosity in Amylograph unit) was1625 AU.

Addition of different starches with different percentages 5, 10 and 15% resulted in increasing of pasting temperature to the range from 64.10to 64.80 C° for 5% starches blends (wheat, sorghum, millet, rice and cassava), 64.10 to 64.60 C° for 10% starches blends and to the range from 64.00 to64.90C° for 15% sorghum, millet, rice and cassava starches blends respectively. Pasting temperature was decreased to 63.80 C° in 15% wheat starch blend. Gelatinization temperature was decreased to the range between 90.40 to 90.90C° for 5% wheat, sorghum, millet, rice and cassava starches blends respectively and to the range from 89.40 to 90.40 for 10% wheat, sorghum, millet and cassava starches blends respectively and to the range from 88.80 to 91.10C° for 15% starches blends (wheat, sorghum, millet, rice and cassava). Gelatinization temperature of 10% rice starch blend was as the same of the control wheat flour 91.30 C°. Viscosity of wheat flour increased with the addition of 5%, 10% and 15% wheat, sorghum, millet and cassava starches to the range between 1644 to 1774 AU for 5% starches blends, between 1678 to1848 AU for10% starches blends and between 1755 to 1962 AU for 15% starches blends respectively.

Gelatinization maximum (viscosity) decreased to 1611, 1551and 1604 AU for 5%, 10% and 15% rice starch blends respectively. Generally it could be concluded that pasting temperature of wheat flour increase with the addition of different starches percentages and gelatinization maximum (viscosity). Gelatinization temperature decreased in all percentages of starch blending except for 10% rice starch blend. Viscosity value in Amylograph unit of rice starch blends with different percentages was lower than wheat flour.

These results were comparable with the results obtained by Ghiasi *et al.*, (1982) who found that several factors are involved in controlling viscosity clearly, soluble starch increases the viscosity and the viscosity increases as a function of the soluble - starch concentration. During starch gelatinization, starch granule volume also increased, i.e. the granule swell as more water is bound. Thus as more water becomes bound, the concentration of soluble starch in the remaining free water increases, sharply increasing viscosities. Dappolonia *et al.,* (1982) found that the amylograph peak viscosity for different wheat flour blends with various amount of barley malt ranged from 130 to3400 BU. Chung and Ponte (1992) found that the storage time of bread had no significant effect on the amylograph readings of bread crumb instead of changes in bread formula in terms of shorting and additives contributes significantly to the amylogram readings of bread crumb. An inverse relationship between crumb compressibility and crumb amylograph viscosities was found and was attributed to the formula changes.

The pasting behavior is apparently linked to the swelling and solublization properties (Akingbala and Rooney, 1987). It is in particular the gelatinization maximum which gives information on the gelatinization and degradation of the starch contained in the flour. This maximum is influenced by the enzyme activity of the flour. In case of sprouted grain, this enzyme activity is high i.e. the Flour has high alpha amylase content, resulting in a very low maximum. In this case, the baked product would have a rather poor quality (moist, gummy dough with streaks). The same is true for the opposite case i.e. a low enzyme activity with a very high maximum would not give a satisfactory baking result. In order to obtain good baking result for wheat flour, the maximum gelatinization should have at least 350 AU and the gelatinization temperature should be at least 77.00 C°. For whole meal wheat flour 400AU and 80.00 C° are recommended (AACC 2000).

Yaseen andShouk(2011) found that replacing wheat flour using corn starch at different levels increased all measured parameters of dough rheological

.

Table (21): Amylograph evaluation of wheat flour and wheat flour containing 5, 10, and 15% different starches with 5% lentil flour

Source of starch in wheat Flour blends	Beginning of Gelatinization (C°)	Max. Gelatinization Temperature (C°)	Gelatinization maximum (AU) (Viscosity in AU)
Wheat flour	63.90	91.30	1625
5% wheat starch	64.10	90.40	1687
5% sorghum starch	64.80	90.90	1678
5% millet starch	64.40	90.40	1774
5% rice starch	64.30	90.60	1611
5% cassava starch	64.10	90.40	1644
10% wheat starch	64.60	90.00	1848
10% sorghum starch	64.50	90.10	1815
10% millet starch	64.60	90.40	1732
10% rice starch	64.50	91.30	1551
10% cassava starch	64.10	89.40	1678
15% wheat starch	63.80	90.90	1800
15% sorghum starch	64.90	88.80	1962
15% millet starch	64.80	90.30	1856
15% rice starch	64.00	91.10	1604
15% cassava starch	64.40	89.60	1755

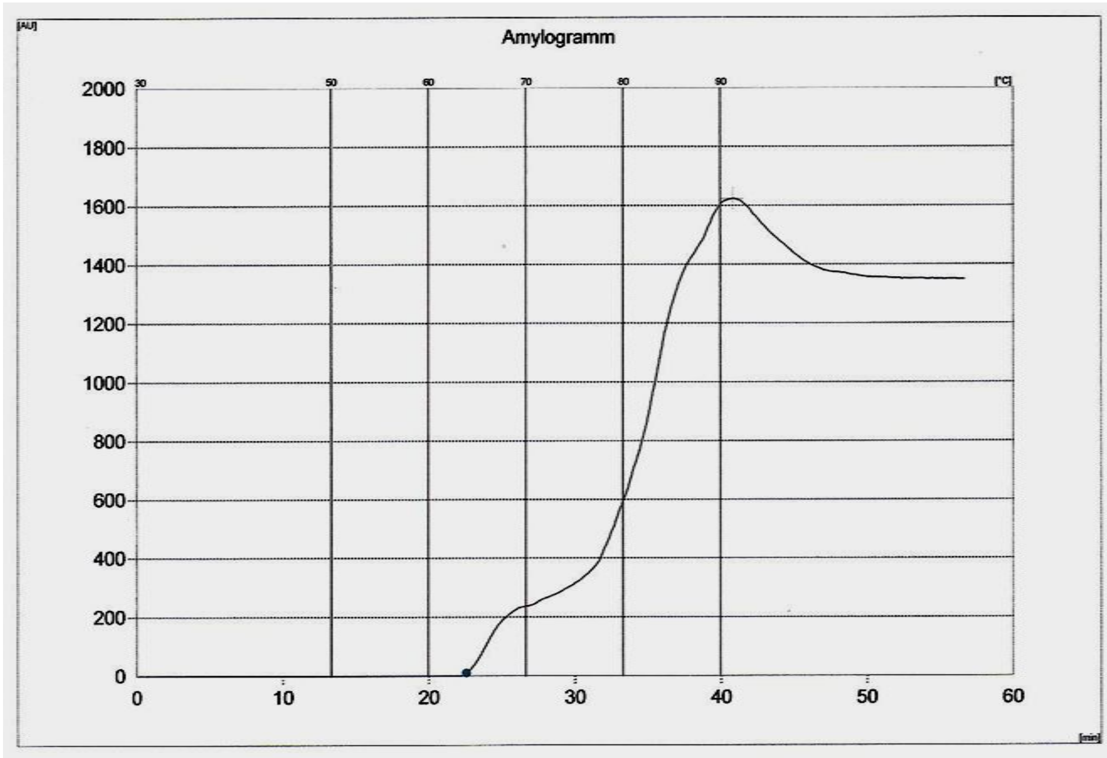


Fig.43.Amylograph of wheat flour

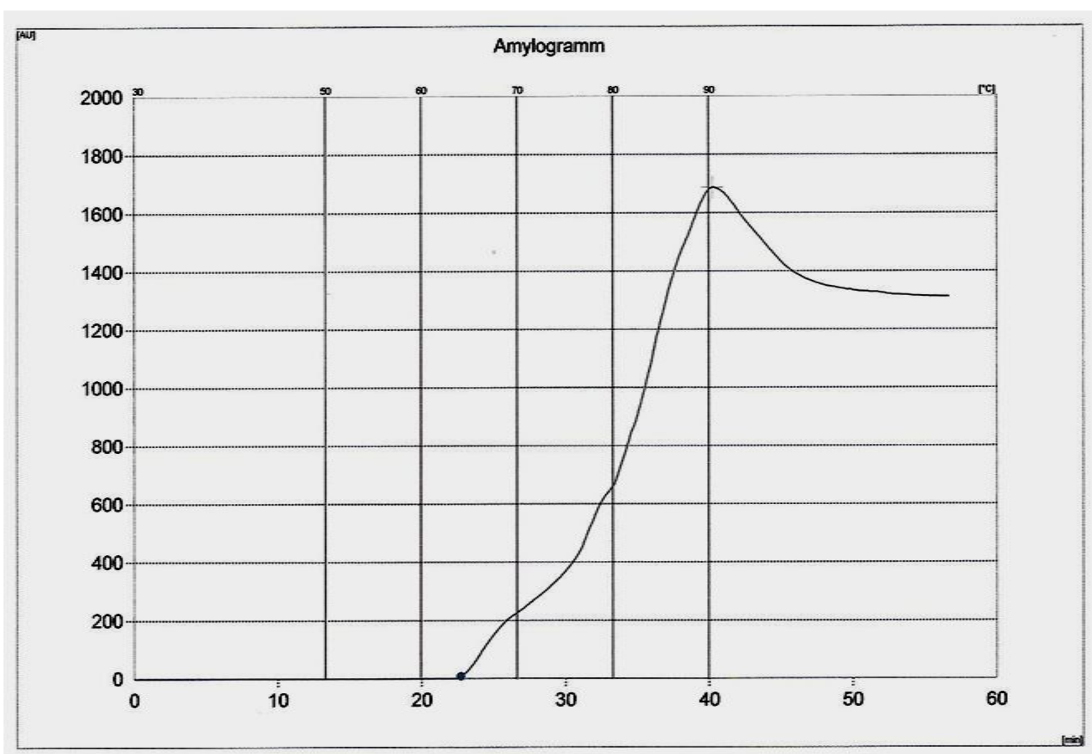


Fig.44.Amylograph of 5% wheat starch

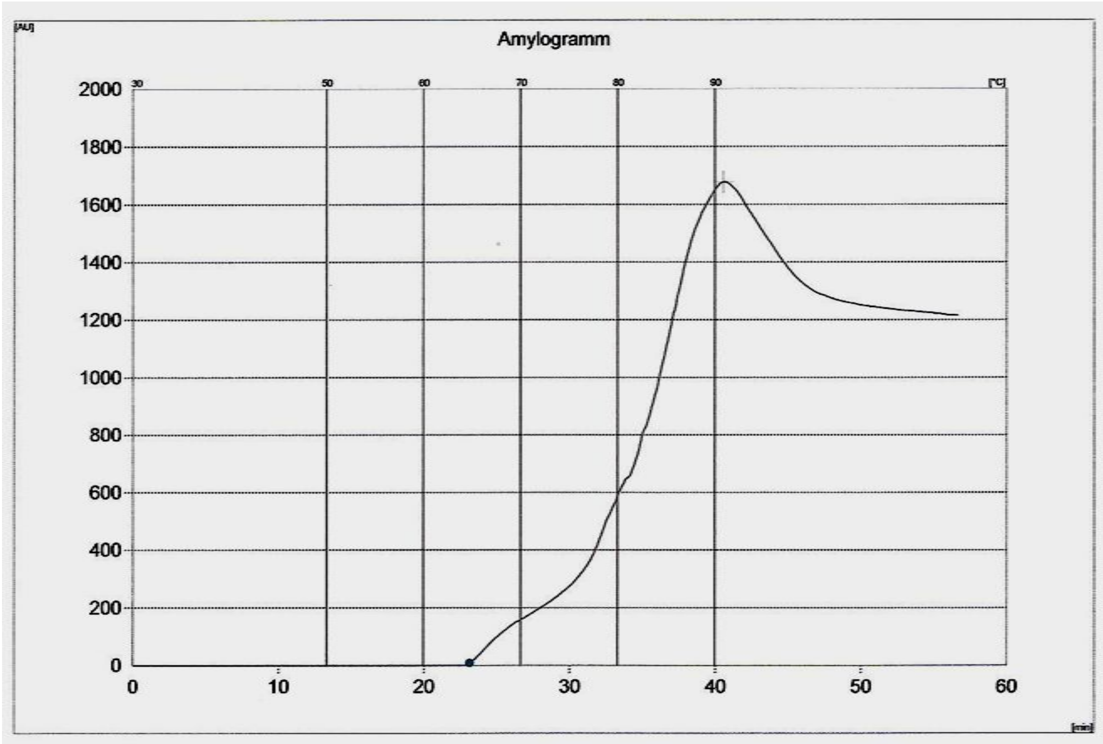


Fig.45.Amylograph of 5% sorghum starch

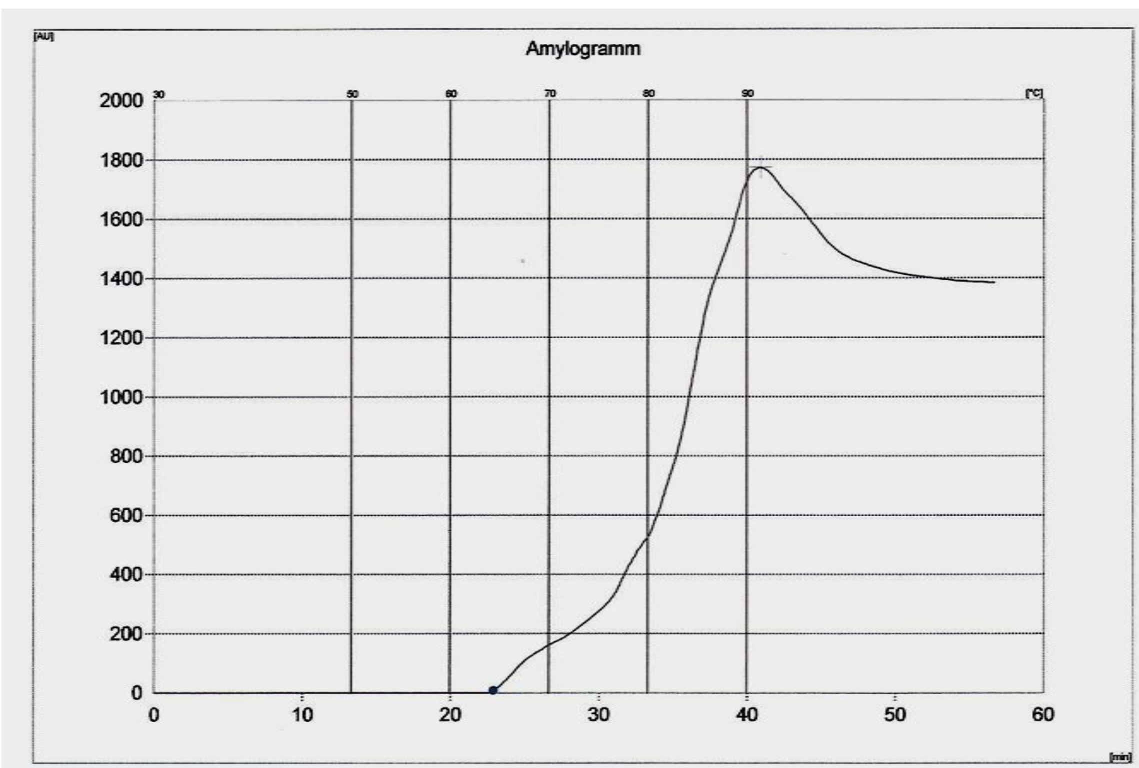


Fig.46.Amylograph of 5% millet starch

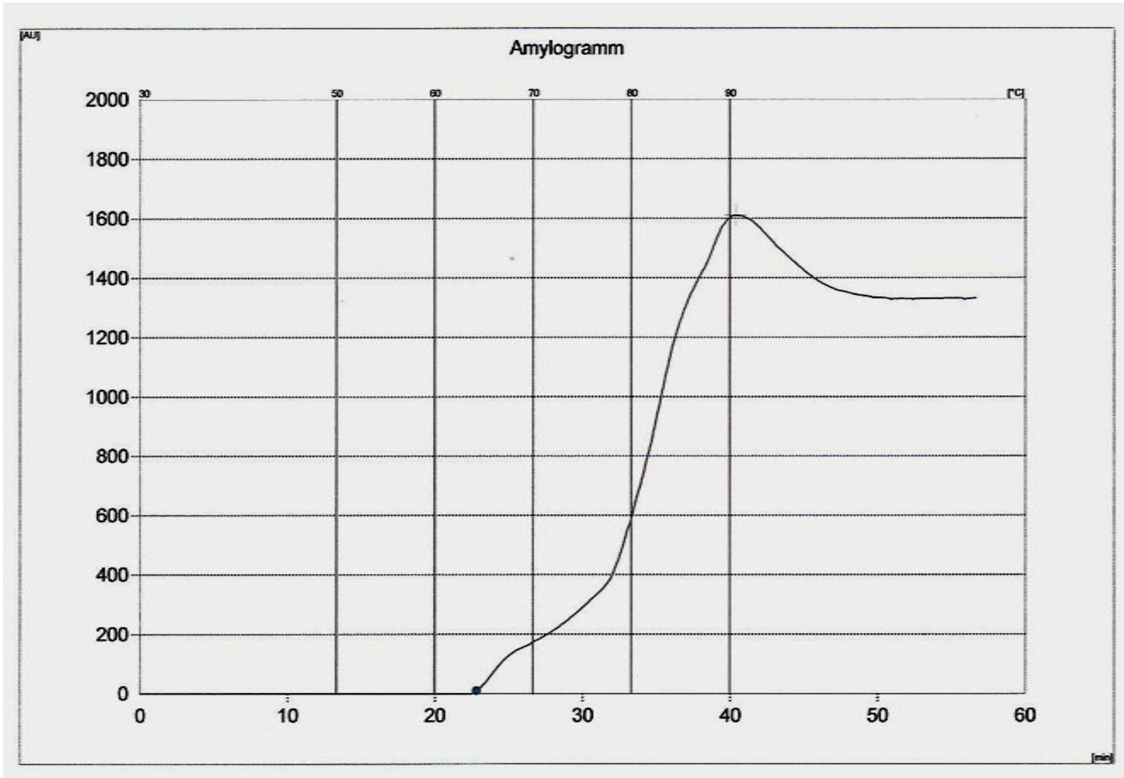


Fig.47.Amylograph of 5% rice starch

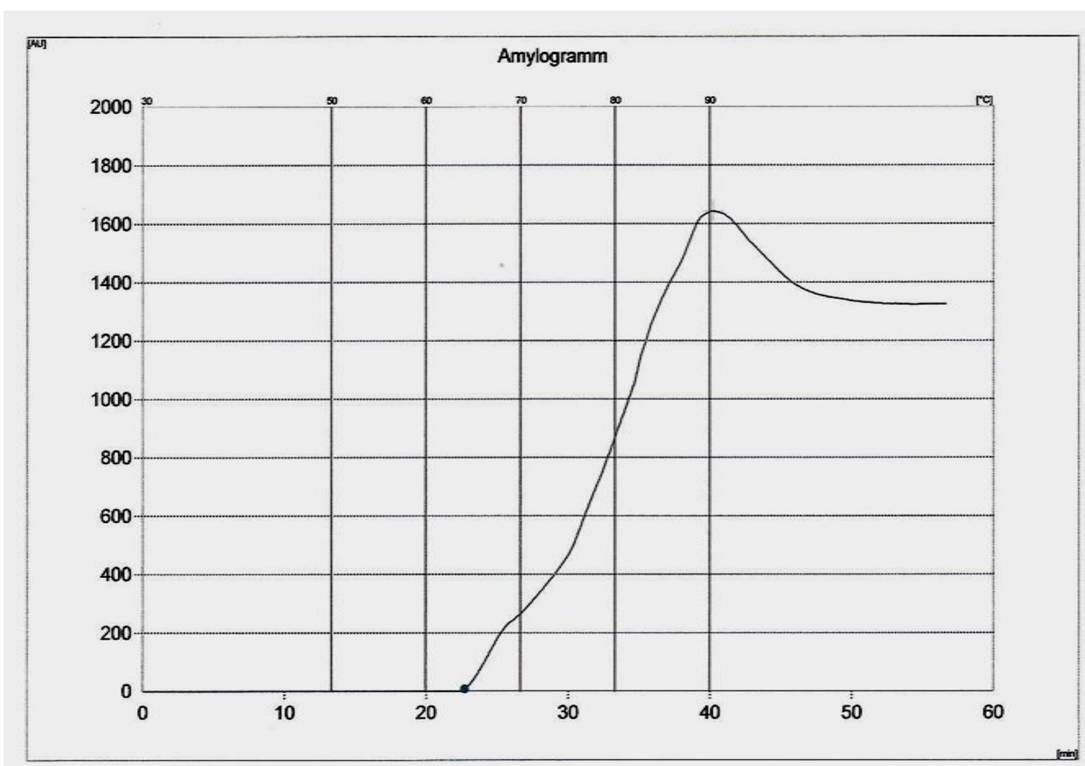


Fig.48.Amylograph of 5% cassava starch

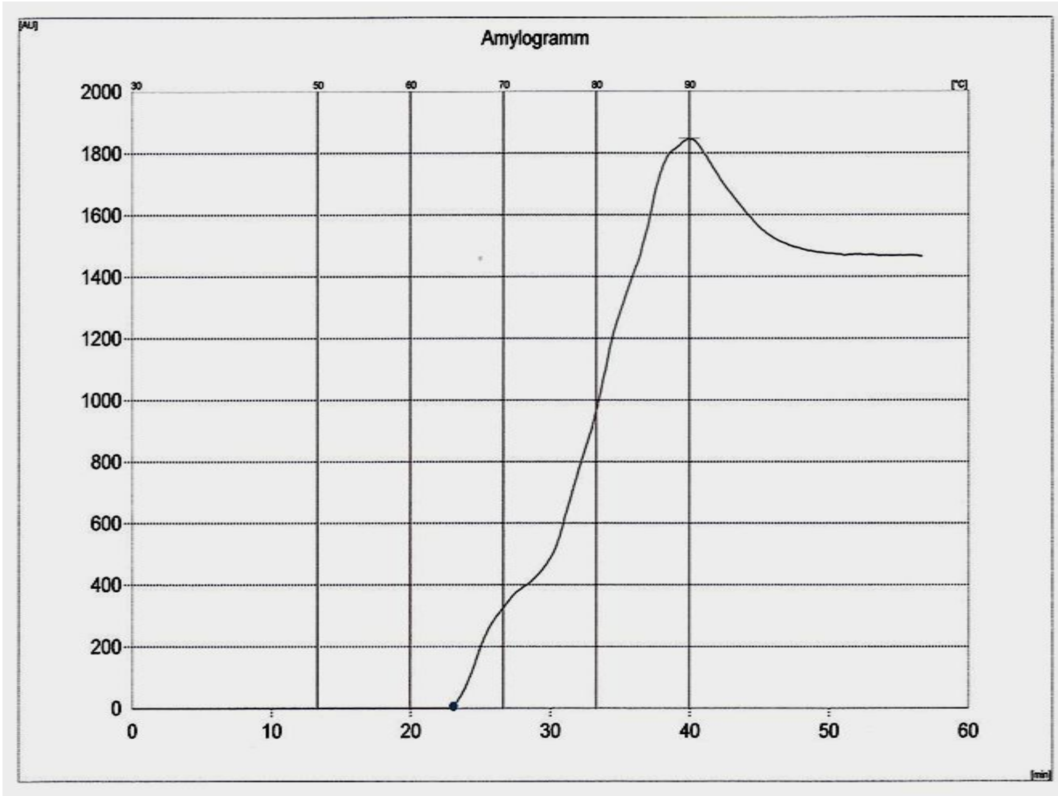


Fig.49.Amylograph of 10% wheat starch

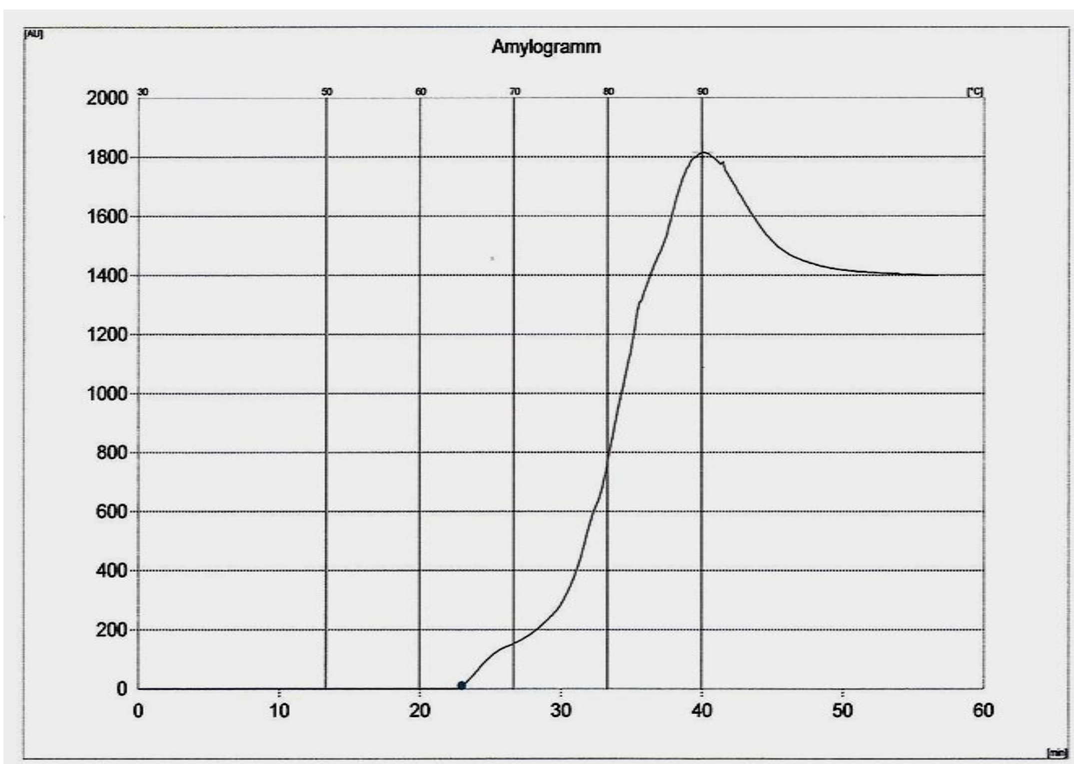


Fig.50.Amylograph of 10% sorghum starch

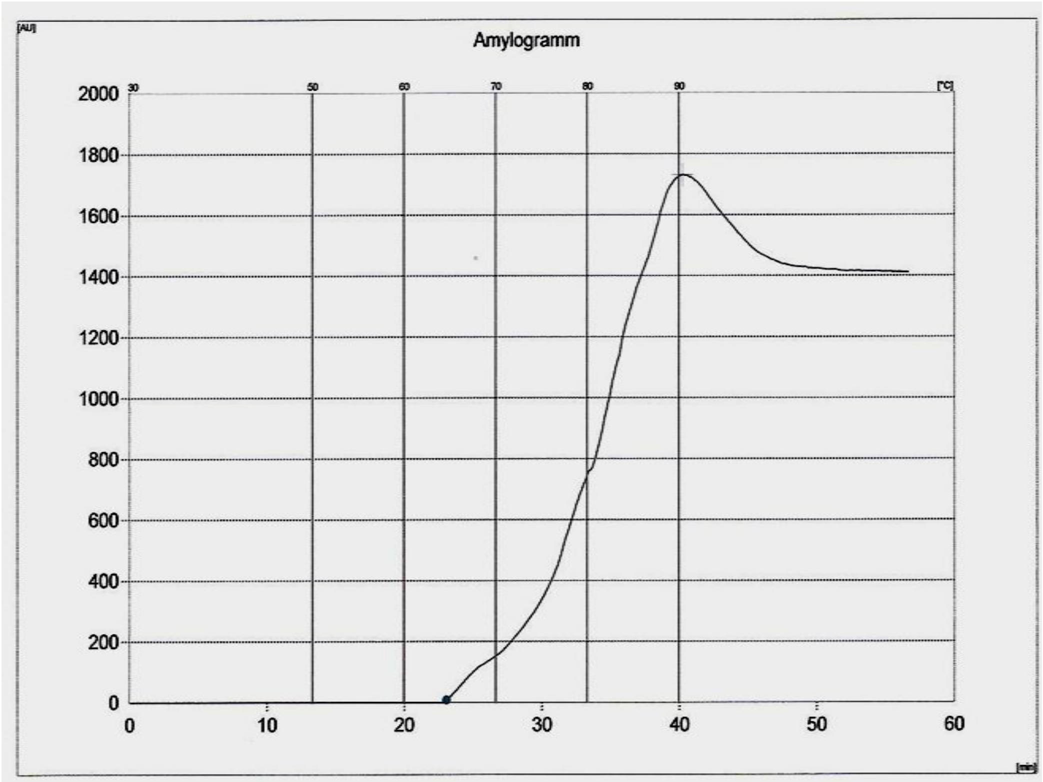


Fig.51.Amylograph of 10% millet starch

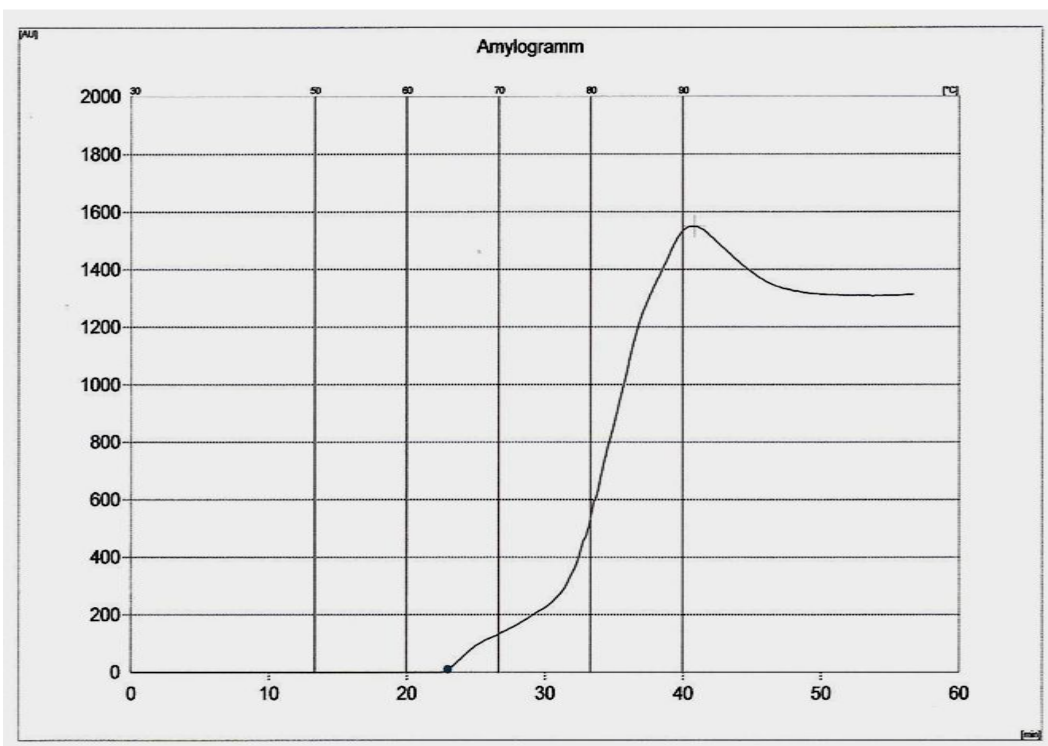


Fig.52.Amylograph of 10% rice starch

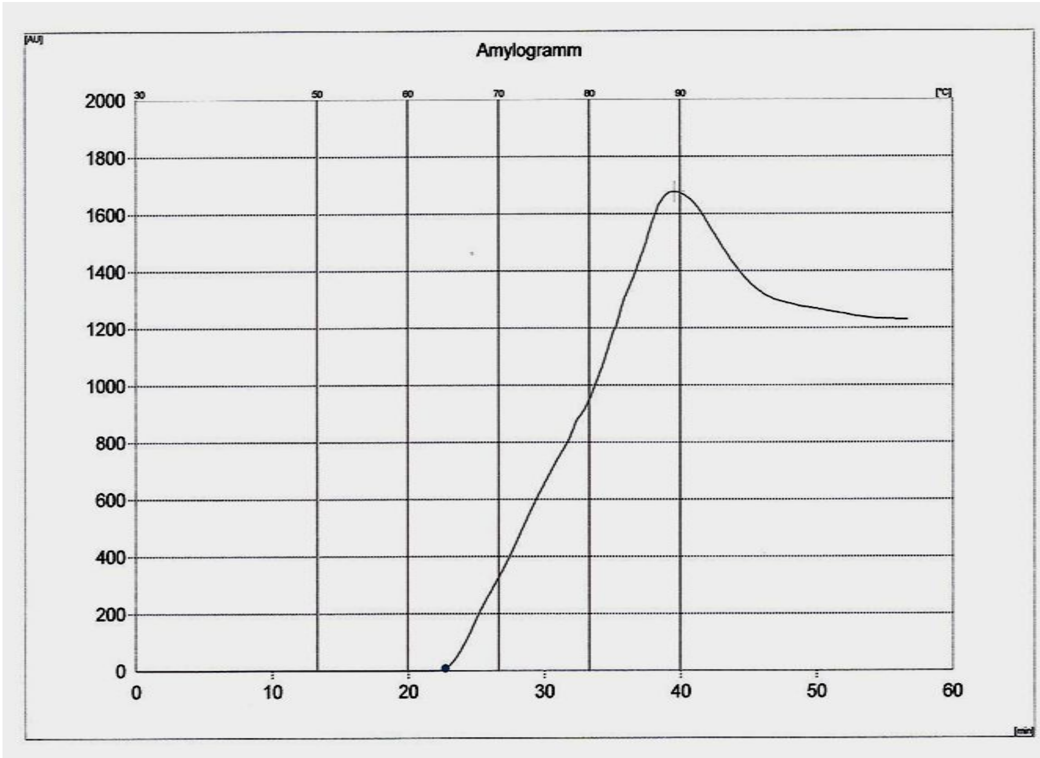


Fig.53.Amylograph of 10% cassava starch

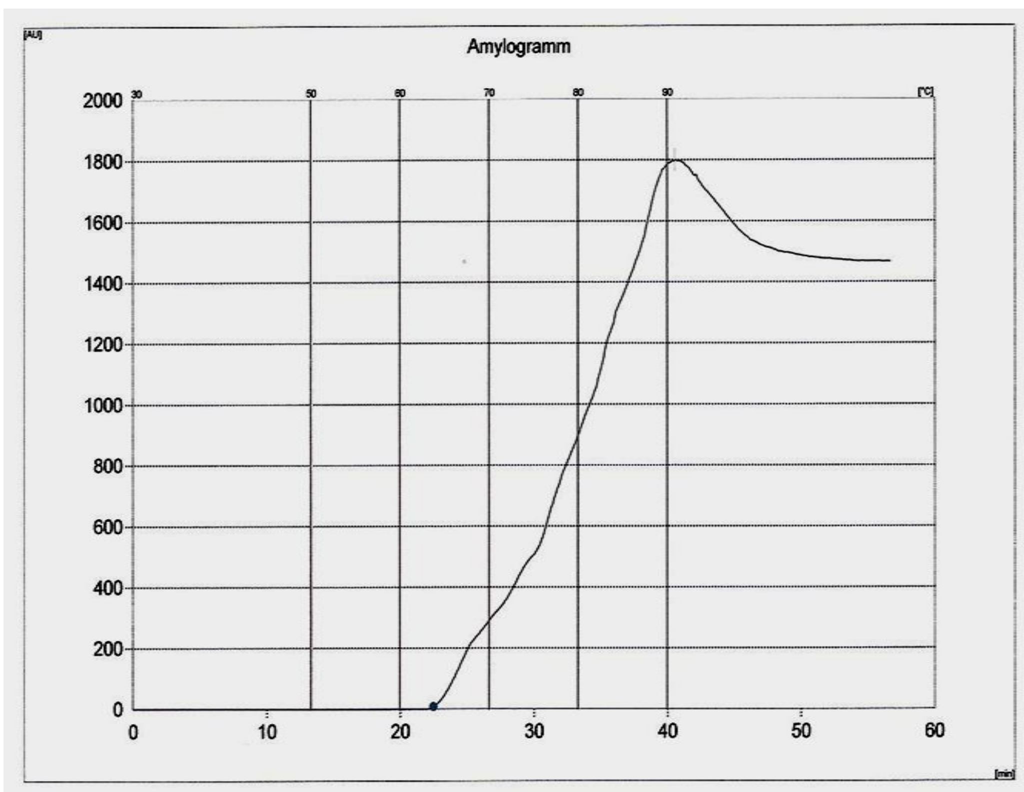


Fig.54.Amylograph of 15 % wheat starch

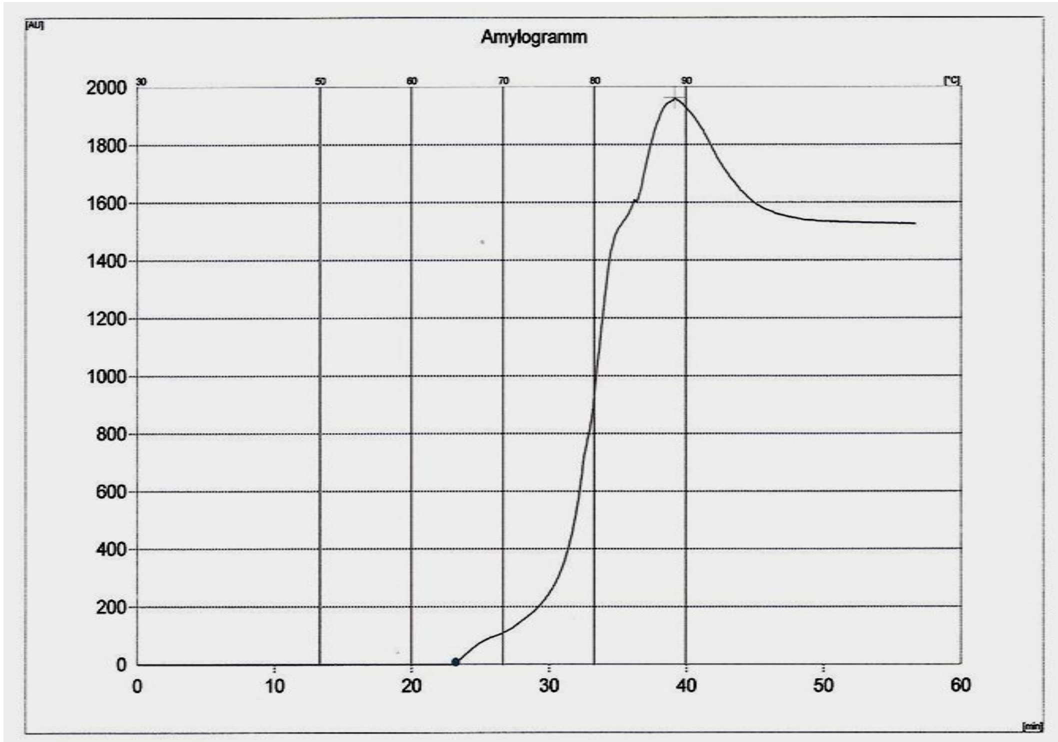


Fig.55.Amylograph of 15 % sorghum starch

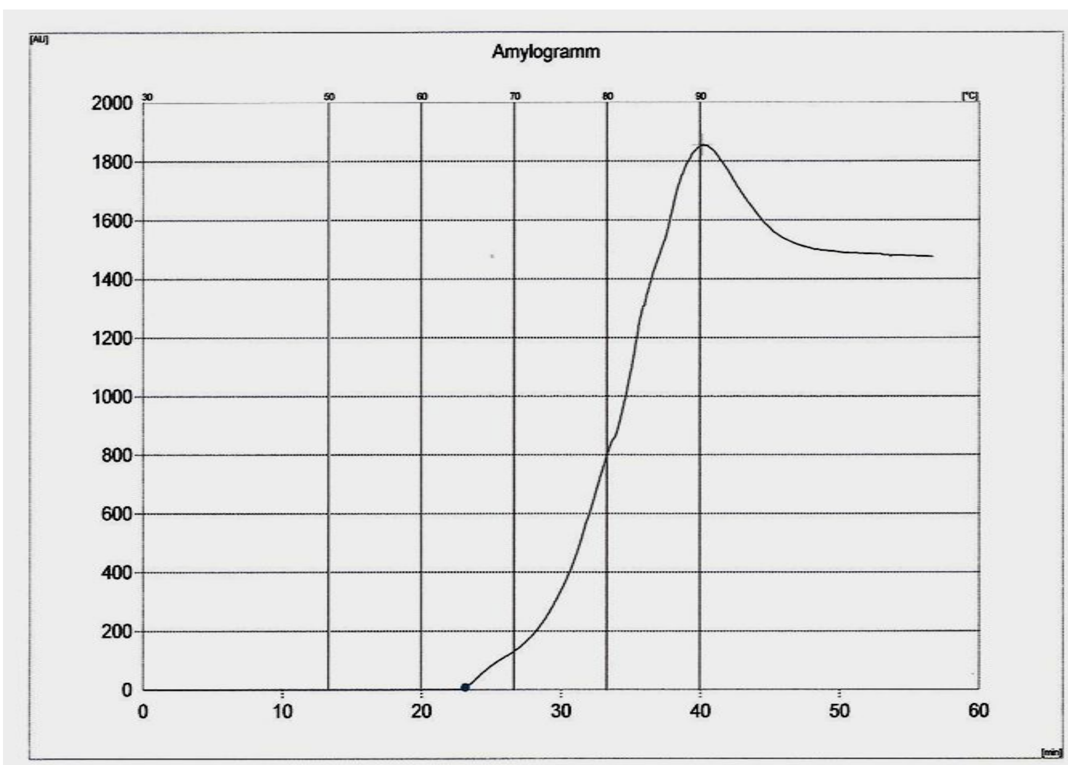


Fig.56.Amylograph of 15% millet starch

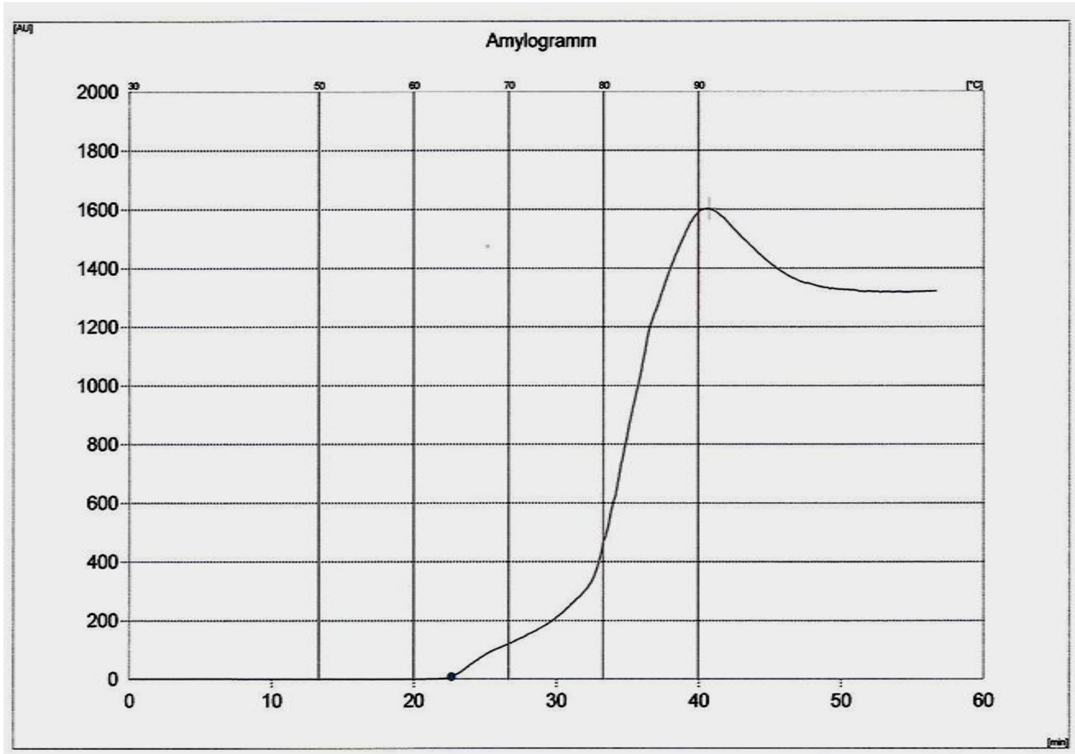


Fig.57.Amylograph of 15% rice starch

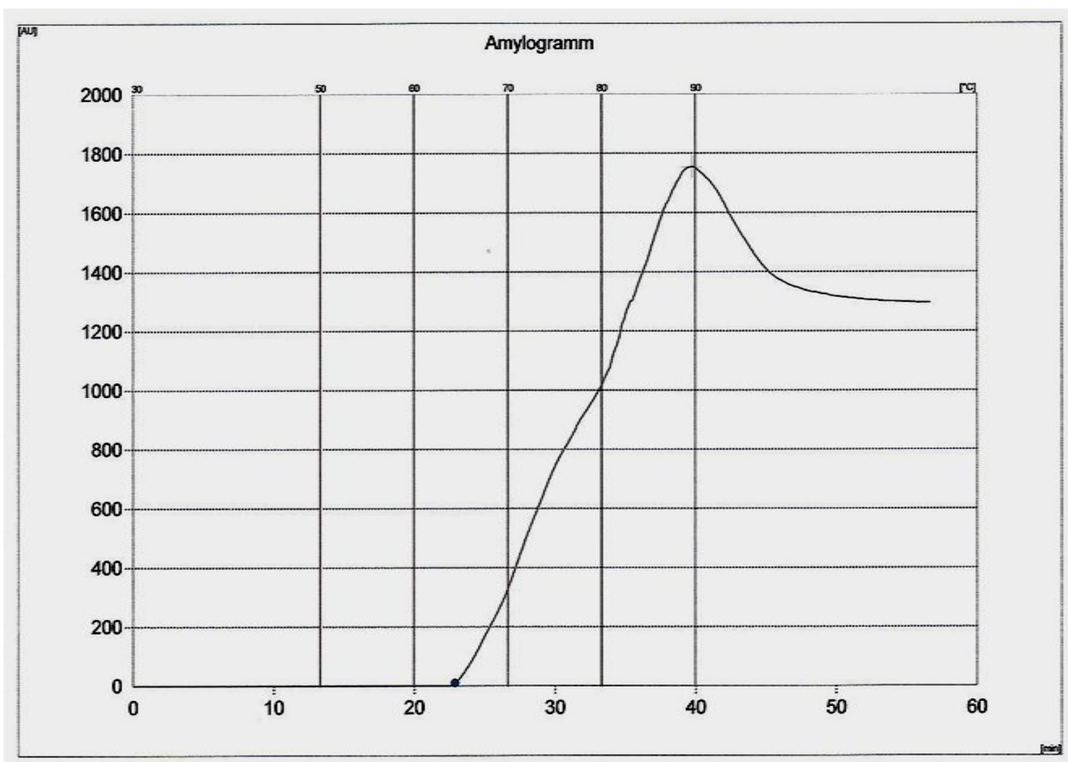


Fig.58.Amylograph of 15% cassava starch

evaluated by visco amylograph.

Shuey (1975) reported that higher amylograph values indicate less amylase activity and conversely lower amylogram values indicate higher activity, extremely low values or high activity will cause slackening of the dough, especially during fermentation. The amount of slackening depends on the starch damage of the flour.

Gelatinization temperature of wheat starch 54.00 – 62.00 C° is lower than that of corn starch 60.00 to 71.00 C° as reported by Colonna and Mercier (1985). Since corn starch granules are more rigid than wheat starch granules, it requires more heat energy to achieve complete swellings.

4.9. Effect of starch and lentil on chemical composition of wheat flour

Tables from 22 to 24 showed the effect of starch (5%, 10% and 15% of wheat, sorghum, millet, rice and cassava) with 5% of lentil flour on chemical composition of wheat flour. From the results there was significant ($P \leq 0.05$) difference in the moisture and ash contents of the blends, however, there was no significant ($P \leq 0.05$) difference in protein, fat and carbohydrates contents of the blends. No significant ($P \leq 0.05$)differences were observed in protein, fat and carbohydrates contents. The protein content increased with the addition of lentil flour in blends compared to control wheat flour. The values of ash ranged from 1.18 to 1.22% for 5, 10 and 15 % starches blends compared to control wheat flour (1.00%). The protein content of wheat flour was found to be 13.87%. This value increased to the range of 15.17 to 15.33% in the blends due to addition of lentil flour.

Value of fat content of wheat flour (1.82%) increased to the range of 1.90 to 2.01%. The (control) wheat flour had carbohydrate content 71.50%. This value was significantly decreased to 68%. From these results it could be concluded that addition of lentil flour increased the fat, protein contents and decreased carbohydrates content. These results of protein, fat contents and carbohydrates content obtained were similar to those reported by Sueliman (2005) and Hassan (2007).

4.10. Effect of starch and lentil flour on protein fraction of wheat flour

Table (25) showed protein fraction of wheat flour and lentil flour. Table (26) showed the effect of addition of lentil flour and starch on protein fraction of wheat flour. Albumins content (water soluble proteins) ofwheatflourandlentilflour were 13.14 and 61.68% respectively. Globulins (salt soluble proteins) were 4.91 and 29.68%,Gliadins (alcohol solubleproteins) were 3 6.15 and 1.32 and Glutennins (alkali soluble proteins) were44.33 and 2.95% for wheat flour and lentil flour respectively. The residual proteins (non- protein nitrogen) were 4.14 and 7.59% respectively. Statistical analysis of the results showed highly significant ($P \leq 0.05$) difference between the two flours in their Albumin, Globulin, Gliadin, Glutenin and significant ($P \leq 0.05$) differences in their residuals protein. The result of wheat flour protein fraction was in good agreement with the results obtained by Ahmed (2013) who reported that the range is between 12.45 to 14.21% for Albumin, 4.96 to 6.03% for Globulin, 33.00 to 39.72 for Gliadins, 40.31 to 43.30 for Glutenins and 3.65 to 5.04% for residual proteins. The results of lentil flour protein fraction `was very closed to the results reported by Sulieman *et al.,* (2008) who reported the range is between 56.26 to 64.00% for Albumin, 26.28 to 29.50% for Globulin, 1.43 to 1.96% for Gliadins (prolamins) , 2.10 to 3.50% for Glutenins and 7.10 to 8.78% for residuals protein. Addition of lentil flour and starch resulted in increasing of Albumin and Globulin, and decreasing in Gliadin and Glutenin. Albumin increased from 13.14% to 16.23%, Globulin increased from 4.91% to the range of 5.43 to 6.39. Gliadins decreased from 36.15 to 34.34%, 32.54% and30.73% for 5, 10 and 15% starches blends respectively. Glutenin decreased from 44.33 to 42.11, 39.89 and 37.68% respectively for 5, 10 and 15% starches blends.

Table (22): Chemical composition (%) of wheat flour containing 5% of starchof wheat, sorghum, millet, rice and cassava with 5% lentil flour

Source of starch in wheat Flour blends	Moisture content	Ash content	Protein content	Fat content	Carbohydrates
wheat starch	$12.63±0.06^{ab}$	$1.18±0.01^{c}$	$15.32±0.12^{a}$	$1.91±0.19^{a}$	$68.95±0.28^{a}$
sorghum starch	$12.67±0.06^{a}$	$1.19±0.00^{a}$	$15.32±0.12^{a}$	$1.92±0.19^{a}$	$68.90±0.27^{a}$
millet starch	$12.64±0.06^{ab}$	$1.19±0.01^{b}$	$15.32±0.12^{a}$	$1.91±0.19^{a}$	$68.94±0.28^{a}$
rice starch	$12.55±0.06^{b}$	$1.19±0.01^{b}$	$15.33±0.12^{a}$	$1.91±0.19^{a}$	$69.02±0.27^{a}$
cassava starch	$12.64±0.06^{ab}$	$1.18±0.00^{d}$	$15.33±0.12^{a}$	$1.90±0.19^{a}$	$68.95±0.27^{a}$
$Lsd_{0.05}$	0.09965^{*}	0.0005753^{*}	0.2228^{ns}	0.3404^{ns}	0.5015^{ns}
SE±	0.03162	0.0001826	0.07071	0.108	0.1592

Values are mean±SD.

Any two mean value(s) sharing same superscript(s) in a column are not significantly different (P≤0.05).

Table (23): Chemical composition (%) of wheat flour containing 10% of starchof wheat, sorghum, millet, rice and cassava with 5% lentil flour

Source of starch in wheat Flour blends	Moisture content	Ash content	Protein content	Fat content	Carbohydrates
wheat starch	13.04 ± 0.06^{a}	1.19 ± 0.01^{c}	15.26 ± 0.12^{a}	1.96 ± 0.19^{a}	68.55 ± 0.29^{a}
sorghum starch	13.13 ± 0.06^{a}	1.20 ± 0.00^{a}	15.27 ± 0.13^{a}	1.96 ± 0.18^{a}	68.43 ± 0.26^{a}
millet starch	13.06 ± 0.06^{a}	1.20 ± 0.00^{a}	15.26 ± 0.13^{a}	1.95 ± 0.18^{a}	68.53 ± 0.27^{a}
rice starch	12.90 ± 0.06^{b}	1.20 ± 0.01^{b}	15.30 ± 0.12^{a}	1.95 ± 0.18^{a}	68.66 ± 0.26^{a}
cassava starch	13.07 ± 0.06^{a}	1.18 ± 0.01^{d}	15.28 ± 0.12^{a}	1.94 ± 0.18^{a}	68.53 ± 0.27^{a}
$Lsd_{0.05}$	0.09965^{*}	0.0005753^{*}	0.2228^{ns}	0.3355^{ns}	0.4915^{ns}
SE±	0.03162	0.0001826	0.07071	0.1065	0.1560

Values are mean±SD.

Any two mean value(s) sharing same superscript(s) in a column are not significantly different ($P\leq0.05$).

Table (24): Chemical composition (%) of wheat flour containing15% ofstarch of wheat, sorghum, millet, rice and cassava with 5% lentil flour

Source of starch in wheat Flour blends	Moisture content	Ash content	Protein content	Fat content	Carbohydrates
wheat starch	13.46±0.06[b]	1.20±0.01[d]	15.17±0.12[a]	2.00±0.19[a]	68.17±0.29[a]
sorghum starch	13.60±0.07[a]	1.22±0.01[a]	15.20±0.12[a]	2.01±0.18[a]	67.98±0.24[a]
millet starch	13.48±0.05[b]	1.21±0.01[b]	15.18±0.13[a]	2.00±0.18[a]	68.00±0.26[a]
rice starch	13.25±0.06[c]	1.21±0.01[c]	15.25±0.13[a]	1.99±0.18[a]	68.31±0.27[a]
cassava starch	13.50±0.06[ab]	1.18±0.01[e]	15.21±0.13[a]	1.97±0.19[a]	68.13±0.27[a]
$Lsd_{0.05}$	0.09965*	0.0005753*	0.2228[ns]	0.3355[ns]	0.4848[ns]
SE±	0.03162	0.0001826	0.07071	0.1065	0.1538

Values are mean±SD.

Any two mean value(s) sharing same superscript(s) in a column are not significantly different (P≤0.05).

Statistical analysis showed significant ($P \leq 0.05$) differences between the blends intheir protein fraction. The residual protein decreased to the range from 0.93 to 1.25% for 5% starches blends from 4.14% for control wheat flour. On the other hand the residual proteins increased to the range from 4.94 to 9.94% for 10% and 15% starchesblends. This finding is supported by the results obtained by Sulieman (2007), Ali (2009), Fageer and El Tinay (2004), Arbab and El Tinay (1997) and Yousif and ElTinay (2000). Feillet (1980) reported that Albumins and Globulins account for 5 to 20% of the total proteins. Bushuk (1974) reported that Glutenins

comprises about 35 to 45% of wheat flour proteins. Mohamed (2000) stated that the protein fraction of four Sudanese wheat cultivars Debaira, Condor, Elneelain and Sasaraib ranged between 12.21 to 12.70% for Albumins, 4.61 to 5.20 for Globulins, 35.30 to 36.90 for Gliaddins and 2.45 to 2.63 for residuals. From these results it could be observed that, addition of lentil flour resulted in increasing of Albumin and Globulin because those are the main storage proteins in lentil (being the major fraction of lentil) as reported by Adsule *et al.,* (1989), on the other hand the decrease in Gliadin and Glutenin fraction is due to the addition of starch which break down their bond. These findings were supported by results obtained byCheftel *et al.,* (1985) reported that Gliadin has a good extensibility but lack elasticity, and Glutenin has better elasticity and low extensibility. Ahmed (2013)found that Glutenin percentage increased with the addition of improvers and Albumins, Globulins, Gliadins and residual proteins were decreased. Sulieman (2007) found that cooking of lentil decreased significantly the albumins from the range 56.26 - 64.00% to 30.19 – 39.87%, Globulins from the range 26.28 – 29.50% to 22.77 – 29.22%, Prolaminns from the range 1.43 – 1.96% to 1.00 – 1.64% and increase Glutenins from the range2.10 - 3.50% to 20.70 – 27.65%. Also Yaghoub

Table (25): Protein fraction (%) of wheat and lentil flours

Flour type	Albumin	Globulin	Gliadin	Glutenin	Residuals
Wheat flour (Imam)	13.143±0.58^{b}	4.910±0.33^{b}	36.150±0.00^{a}	44.327±0.43^{a}	4.143±0.01^{b}
Lentil flour	61.683±0.60^{a}	29.683±0.46^{a}	1.323±0.02^{b}	2.950±0.18^{b}	7.590±0.18^{a}
$Lsd_{0.05}$	34.526**	17.034**	28.756**	30.524**	1.8256*
SE±	12.5431	6.8509	9.7162	10.648	0.0793

Values are mean±SD.

Any two mean value(s) sharing same superscript(s) in a column are not significantly different ($P \leq 0.05$).

Table (26): Effect of different percentages 5, 10 and 15% of starches and 5% lentil flour on protein fraction (%) of wheat flour

Flour type	Albumin	Globulin	Gliadin	Glutenin	Residuals
Wheat flour	13.143±0.58^{b}	4.910±0.33^{c}	36.150±0.00^{a}	44.330±0.43^{a}	4.143±0.01^{e}
5% wheat starch	16.230±0.58^{a}	6.393±0.35^{a}	34.340±0.00^{b}	42.110±0.41^{b}	0.927±0.10^{g}
5% sorghum starch	16.230±0.58^{a}	6.393±0.35^{a}	34.340±0.00^{b}	42.110±0.41^{b}	0.927±0.10^{g}
5% millet starch	16.230±0.58^{a}	6.073±0.33^{a}	34.340±0.00^{b}	42.110±0.41^{b}	1.247±0.09^{f}
5% rice starch	16.230±0.58^{a}	6.393±0.35^{a}	34.340±0.00^{b}	42.110±0.41^{b}	0.927±0.10^{g}
5% cassava starch	16.230±0.58^{a}	6.393±0.35^{a}	34.340±0.00^{b}	42.110±0.41^{b}	0.927±0.10^{g}
10% wheat starch	16.230±0.58^{a}	6.393±0.35^{a}	32.540±0.00^{c}	39.893±0.38^{c}	4.943±0.08^{d}
10% sorghum starch	16.230±0.58^{a}	6.393±0.35^{a}	32.540±0.00^{c}	39.893±0.38^{c}	4.943±0.08^{d}
10% millet starch	16.230±0.58^{a}	5.753±0.32^{ab}	32.540±0.00^{c}	39.893±0.38^{c}	5.583±0.07^{c}
10% rice starch	16.230±0.58^{a}	6.393±0.35^{a}	32.540±0.00^{c}	39.893±0.38^{c}	4.943±0.08^{d}
10% cassava starch	16.230±0.58^{a}	6.393±0.35^{a}	32.540±0.00^{c}	39.893±0.38^{c}	4.943±0.08^{d}
15% wheat starch	16.230±0.58^{a}	6.393±0.35^{a}	30.730±0.00^{d}	37.680±0.36^{d}	8.967±0.06^{b}
15% sorghum starch	16.230±0.58^{a}	6.393±0.35^{a}	30.730±0.00^{d}	37.680±0.36^{d}	8.967±0.06^{b}
15% millet starch	16.230±0.58^{a}	5.433±0.30^{bc}	30.730±0.00^{d}	37.680±0.36^{d}	9.927±0.06^{a}
15% rice starch	16.230±0.58^{a}	6.393±0.35^{a}	30.730±0.00^{d}	37.680±0.36^{d}	8.967±0.06^{b}
15% cassava starch	16.230±0.58^{a}	6.393±0.35^{a}	30.730±0.00^{d}	37.680±0.36^{d}	8.967±0.06^{b}
$Lsd_{0.05}$	0.9569*	0.5737*	0.0005259*	0.6463*	0.1288*
SE±	0.3322	0.1991	0.0001826	0.2244	0.04472

Values are mean±SD.

Any two mean value(s) sharing same superscript(s) in a column are not significantly different (P≤0.05).

(2003) obtained that cooking of Karkade seeds decreased Albumin and that loss attributed to high susceptibility of Albumin to heat treatment.

Ali *et al.,* (2009) found that the Globulin fraction of pearl millet increased significantly as the level of Soybean protein supplement increased and was found to be 53.20, 63.10 and 69.80% when supplemented with 5, 10 and 15% Soybean protein respectively. Also he found that Albumin and Glutenin increased when supplemented with 5, 10 and 15% Soybean protein but prolamin (Gliadin) decreased.

4.11. Baking test

Three percentages of five types of starch from different sources (5, 10 and 15%), (wheat, sorghum, millet, rice and cassava) with 5% lentil flour were used for baking test.

4.11.1. Specific loaf volume of wheat flour and wheat flour blends:-

Baking characteristics of wheat flour and wheat flour blends were shown in table (27) to (29) and plates (6) to (8). From the results obtained, the loaf volume decreased significantly from 366.67, 380.00 and 435.00cc for control wheat flour bread to the range from 335.00 to 348.33cc for 5% starches blends bread. And decreased to the range from 300.00 to 336.67cc for 10% starches blends bread and to the range from 328.33 to 388.30cc for 15% starches blends bread respectively.

15% sorghum starch blend bread gave the highest volume of loaf bread, whereas 10% rice starch blend bread gave the lowest value compared to the other blends of starch bread. For 5% starches blends bread, the highest value of loaf volume was observed in 5% rice starch blend bread, while the lowest value was in 5% millet starch blend bread. 10% starches blends bread the highest loaf volume was observed in 10% wheat starch blend bread, while the lowest value was observed in 10% rice starch blend bread and for 15% starches blends bread the highest value of loaf volume was observed in 15% sorghum starch blend bread, while the lowest volume was in 15% rice starch blend bread.

Bread specific volume (cm^3/g) values of 10% starches blends bread ranged from 2.83 to 3.10 (cm^3/g).10% wheat starch blend bread gave the highest value, while 10% cassava starch blend bread gave the lowest value of specific volume. Bread specific volume (cm^3/g) values of 15% starches blends bread ranged from 3.10 to 3.64 (cm^3/g)**.** The highest value of specific volume was observed in 15 % sorghum starch blend bread, while the lowest value was in15% rice starch blend bread. These values were significantly lower than the specific volume of control wheat flour bread (3.49, 4.05 cm^3/g).

From these results, it can be concluded that the bread specific volume decreased with increasing level of starch percentage in blends, and 15% sorghum starch blend bread gave the highest value of bread specific volume compared to other starches blends percentages, whereas 10% cassava starch blend bread gave the lowest value.

Statistical analysis showed significant ($P \leq 0.05$) differences between wheat flour and wheat flour blends in their bread specific volume. These findings agreed with the results obtained by Mustafa *et al.,* (1986) who found that beyond 10% replacement of wheat flour by cowpea flour, the specific volume of the bread decreased. Mustafa (1976) also obtained similar results with 5% soy flour in bread. Dilution of gluten with the addition of non-wheat flours to wheat flour has been reported to be associated with loaf volume depression effect of composite floursDeruiter, 1978, Chavan and Kadam (1993). Hassan (2007) reported that the use of decorticated pigeon pea flour beyond 10% has a negative effect on the loaf bread specific volume and incorporation of pigonpea protein isolate shows significant increase and higher volumes of loaf bread specific volume. Youssef and Bushuk

(1986) mentioned that theproportion of non-wheat flour depends on the inherent

Table (27): Loaf bread specific volume of wheat flour with 5% starch and 5% lentil flour

Flour blends	Bread volume (cc)^3	Bread weight (g)	Bread specific volume (cc/g)
100% wheat flour (control)	366.67±18.93^a	104.93±1.12^c	3.49±0.16^a
5% wheat starch + 5% lentil flour	345.00±0.00^b	106.47±0.31^{ab}	3.24±0.01^b
5% sorghum starch + 5% lentil flour	340.00±5.00^b	105.93±0.32^{bc}	3.21±0.04^b
5% millet starch + 5% lentil flour	335.00±5.00^b	107.27±0.35^a	3.12±0.06^b
5% rice starch + 5% lentil	348.33±12.58^{ab}	105.47±0.57^{bc}	3.30±0.13^b
5% cassava starch + 5% lentil flour	336.67±10.41^b	105.40±0.44^{bc}	3.20±0.11^b
$Lsd_{0.05}$	18.87*	1.046*	0.1779*
SE±	6.124	0.3396	0.05774

Value are mean±SD.

Mean values having different superscripts in a column are significantly different (P≤0.05).

Table (28): Loaf bread specific volume of wheat flour with10% starch and 5% lentil flour

Flour blends	Bread volume (cc)^{3}	Bread weight (g)	Bread specific volume (cc/g)
100% wheat flour (control)	380.000±13.23^{a}	108.93±0.42^{a}	3.49±0.13^{a}
10% wheat starch + 5% lentil flour	336.67±36.17^{b}	108.77±1.17^{a}	3.10±0.36^{b}
10% sorghum starch + 5% lentil flour	328.33±7.64^{bc}	106.50±0.66^{c}	3.08±0.09^{b}
10% millet starch + 5% lentil flour	318.33±7.64^{bc}	108.60±0.80^{ab}	2.93±0.08^{b}
10% rice starch + 5% lentil flour	300.00±10.00^{c}	105.20±0.52^{d}	2.85±0.11^{b}
10% cassava starch + 5% lentil flour	303.33±11.55^{bc}	107.37±0.31^{bc}	2.83±0.11^{b}
Lsd$_{0.05}$	31.10**	1.254*	0.3132*
SE±	10.09	0.407	0.1017

Value are mean±SD.

Mean values having different superscripts in a column are significantly different (P≤0.05).

Table (29): Loaf bread specific volume of wheat flour with15% starch and 5% lentil flour

Flour blends	Bread volume $(cc)^3$	Bread weight (g)	Bread specific volume (cc/g)
100% wheat flour (control)	435.00 ± 5.00^{a}	107.40 ± 0.85^{b}	4.05 ± 0.04^{a}
15% wheat starch + 5% lentil flour	363.30 ± 15.28^{c}	106.00 ± 0.60^{c}	3.43 ± 0.13^{c}
15% sorghum starch + 5% lentil flour	388.30 ± 2.89^{b}	106.60 ± 0.40^{bc}	3.64 ± 0.04^{b}
15% millet starch + 5% lentil flour	351.70 ± 10.41^{cd}	109.10 ± 0.15^{a}	3.22 ± 0.09^{d}
15% rice starch + 5% lentil flour	328.33 ± 2.89^{e}	106.0 ± 0.76^{c}	3.10 ± 0.05^{d}
15% cassava starch + 5% lentil flour	343.33 ± 11.55^{de}	109.20 ± 0.59^{a}	3.15 ± 0.11^{d}
$Lsd_{0.05}$	16.51^{**}	1.078^{**}	0.1488^{*}
SE±	5.358	0.3498	0.0483

Value are mean±SD.

Mean values having different superscripts in a column are significantly different ($P \leq 0.05$).

Plate.6. photograph showing the breads of 5% starch

Where :

A : wheat flour bread (control)

B : 5% wheat starch + 5% lentil flour+ 90% wheat flour bread

C : 5% sorghum starch + 5% lentil flour+ 90% wheat flour bread

D : 5% millet starch + 5% lentil flour+ 90% wheat flour bread

E : 5% rice starch bread + 5% lentil flour+ 90% wheat flour bread

F : 5% cassava starch + 5% lentil flour+ 90% wheat flour bread

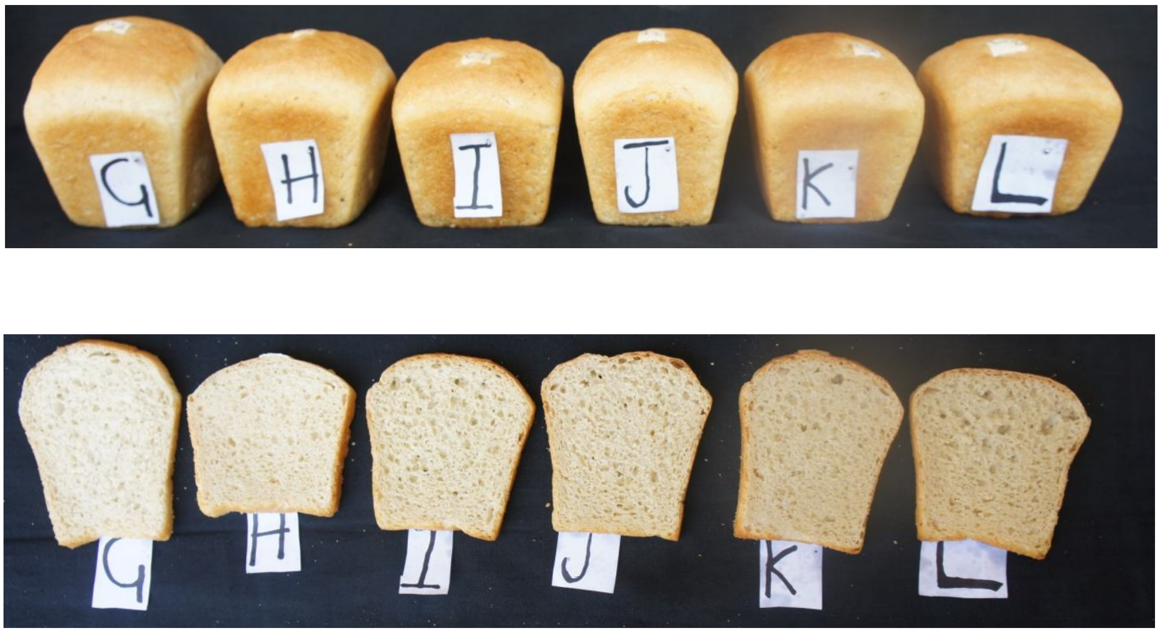


Plate.7. photograph showing the breads of 10% starch

Where :

G : wheat flour bread (control)

H : 10% wheat starch + 5% lentil flour+ 85% wheat flour bread

I : 10% sorghum starch + 5% lentil flour+ 85% wheat flour bread

J : 10% millet starch + 5% lentil flour+ 85% wheat flour bread

K : 10% rice starch + 5% lentil flour+ 85% wheat flour bread

L : 10% cassava starch + 5% lentil flour+ 85% wheat flour bread

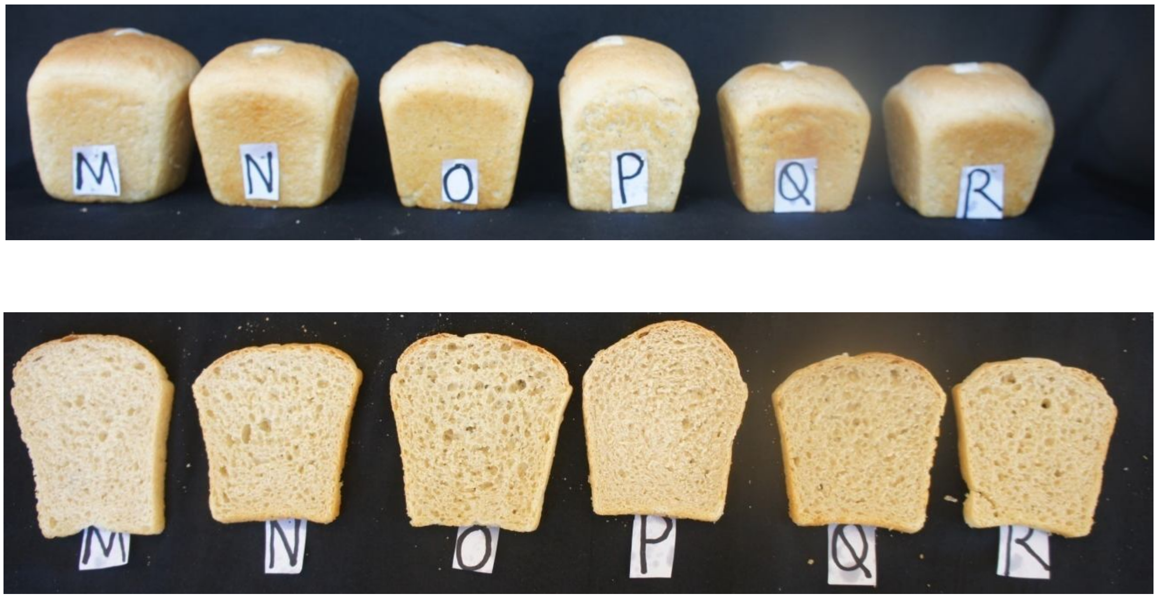


Plate.8. photograph showing the breads of 15% starch

Where :

M : wheat flour bread (control)

N : 15% wheat starch + 5% lentil flour+ 80% wheat flour bread

O : 15% sorghum starch + 5% lentil flour +80% wheat flour bread

P : 15% millet starch + 5% lentil flour+ 80% wheat flour bread

Q : 15% rice starch + 5% lentil flour+80% wheat flour bread

R : 15% cassava starch + 5% lentil flour+80% wheat flour bread strength of the wheat flour. These findings are supported by results reported by Mohamed (2000) and Ahmed (2005).These results were confirmed by data reported by Ahmed (1995) who showed that the bread specific volume of Sudanese wheat cultivars ranged between 3.25 to 3.95(cm^3/g). Ahmed (2005) found similar results that the bread specific volume decreased with increasing level of wheat bran in the blends. Mohamed (2000), Siddiq (1999) and Sid Ahmed (2003) reported that the bread specific volume ranged between 3.66 to 4.05 cm^3/g, 2.50, and 2.20(cm^3/g) respectively. High values of bread volume were reported by Hestangen and Frolish (1983) and Lukour (1990) 355 to 376(cm^3/g) and 376 (cm^3/g)respectively for Canadian wheat flour bread. Ahmed (2013) obtained bread specific volume for Sudanese wheat flour 2.89 (cm^3/g)without improverand 3.49 (cm^3/g) with improver. In general, theflours from stronger wheat cultivars can carry a higher percentage of the non-wheat products.

4.11.2. Organoleptic evaluation of loaf bread containing different levels of starches:

Tables from (30) to (32) showed the sensory evaluation of bread from wheat flour and wheat flour blends. The control wheat flour (Imam) was found to be very good in color, odor, taste, crumb texture, crumb grain uniformity and preference. Wheat flour bread with 5% and 15% wheat starch were found to be very good in color, odor, taste, crumb texture, crumb grain uniformity and preference. Wheat flour bread with 10% wheat starch was found to be good in color, odor, taste, crumb texture, crumb grain uniformity and preference. This means that addition of wheat starch was having positive effect on quality attributes of sensory evaluation.

Bread with 5% and 10% of sorghum starch was found to be excellent in color and very good in odor, taste, crumb texture, crumb grain uniformity and preference by panelists. Wheat flour blends with 15% sorghum starch was found to be very good in color, odor, taste, crumb texture, crumb grain uniformity and preference. This means that sorghum starch was having positive effect on color, odor, taste, crumb texture, crumb grain uniformity and preference.

Bread with 5% millet starch was found to be very good in color, odor, taste, crumb texture, crumb grain uniformity and preference. Wheat flour bread with 10% millet starch was found to be excellent in color, odor, taste, crumb texture, and very good in crumb grain uniformity and preference. Bread with 15% millet starch was found to be very good in color, odor, taste, crumb texture, preference and good in crumb grain uniformity. This means that addition of millet starch was having positive effect and it is better than control in quality attribute of sensory evaluation and overall quality. Bread with 5% rice starch was found to be very good in color, odor, taste, crumb texture, crumb grain uniformity andgood in preference. Wheat flour bread with 10% and 15% rice starch were found to be very good in color, odor, taste, crumb texture, crumb grain uniformity and preference. Also addition of rice starch has a good effect on quality attributes of sensory evaluation. Bread with 5% cassava starch was found to be good in color, odor, taste, crumb texture, crumb grain uniformity and preference. Bread with 10% cassava starch was found to be very good in color, odor, taste, crumb texture, crumb grain uniformity and preference. Wheat flour bread with 15% cassava starch was found to be very good in color, taste, crumb texture, crumb grain uniformity and good in odor and preference. In general, alsoadditionofcassava starch has positive effect on quality attributes of sensory evaluation similar to other starches.

Statistical analysis showed significant ($P \leq 0.05$) difference between 5% starches bread blends in their color, odor, crumb texture and preference. Also there is no significant difference between these blends in their taste and crumb grain uniformity

Analysis of variance showed significant ($P \leq 0.05$) difference between10% starches blends bread intheir quality attributes of sensory evaluation. Onthe

Table (30): Acceptability of bread from wheat flour containing 5% starch with 5% lentil flour

Source of starch in wheat Flour blends	Quality attributes					
	Color	Odor	Taste	Crumb texture	Crumb grains uniformity	Preference
	Scores					
wheat flour bread (control)	5.93 ± 1.53^{bc}	5.67 ± 1.59^{ab}	5.60 ± 1.40^{a}	5.47 ± 1.41^{ab}	5.60 ± 1.30^{a}	5.80 ± 1.08^{ab}
wheat starch bread	6.40 ± 2.56^{abc}	6.67 ± 1.88^{a}	6.00 ± 2.10^{a}	6.47 ± 1.85^{ab}	6.13 ± 1.73^{a}	6.33 ± 1.95^{a}
sorghum starch bread	7.80 ± 0.86^{a}	6.47 ± 1.73^{a}	6.00 ± 1.96^{a}	6.13 ± 2.13^{ab}	6.27 ± 1.98^{a}	6.47 ± 1.85^{a}
millet starch bread	5.27 ± 2.09^{c}	5.67 ± 2.09^{ab}	5.93 ± 2.22^{a}	5.07 ± 2.31^{b}	5.73 ± 2.09^{a}	5.47 ± 1.68^{ab}
rice starch bread	7.00 ± 1.83^{ab}	5.50 ± 1.51^{ab}	5.75 ± 1.95^{a}	6.63 ± 1.54^{a}	5.88 ± 1.63^{a}	5.13 ± 1.31^{ab}
cassava starch bread	5.43 ± 2.10^{c}	5.00 ± 2.00^{b}	5.07 ± 2.09^{a}	5.07 ± 1.94^{b}	5.00 ± 2.08^{a}	4.91 ± 2.02^{b}
$Lsd_{0.05}$	1.38^{*}	1.311^{*}	1.431^{ns}	1.369^{*}	1.318^{ns}	1.217^{*}
SE±	0.4906	0.4661	0.509	0.487	0.4688	0.4327

Value are mean ± SD.

Any two scores having different superscripts in a column are significantly different ($P\leq0.05$).

Table (31): Acceptability of bread from wheat flour containing 10% starch with 5% lentil flour

Source of starch in wheat Flour blends	Quality attributes					
	Color	Odor	Taste	Crumb texture	Crumb grains uniformity	Preference
	Scores					
wheat flour bread (control)	6.47 ± 1.64^{a}	6.00 ± 1.73^{b}	5.40 ± 1.59^{c}	6.67 ± 1.29^{a}	6.47 ± 1.60^{a}	6.73 ± 1.43^{a}
wheat starch bread	4.93 ± 2.05^{b}	5.40 ± 2.38^{b}	5.20 ± 2.21^{c}	4.53 ± 1.92^{b}	4.67 ± 1.99^{b}	4.93 ± 1.73^{b}
sorghum starch bread	7.13 ± 2.00^{a}	6.73 ± 1.94^{ab}	6.73 ± 1.67^{ab}	7.00 ± 1.60^{a}	6.27 ± 2.43^{a}	6.60 ± 1.80^{a}
millet starch bread	7.13 ± 1.46^{a}	7.53 ± 0.74^{a}	7.33 ± 1.05^{a}	7.13 ± 1.19^{a}	6.93 ± 1.22^{a}	7.00 ± 1.07^{a}
rice starch bread	6.94 ± 1.44^{a}	5.50 ± 1.75^{b}	5.75 ± 1.84^{bc}	6.13 ± 1.36^{a}	6.81 ± 2.14^{a}	6.63 ± 1.63^{a}
cassava starch bread	6.64 ± 1.74^{a}	5.71 ± 1.77^{b}	5.50 ± 1.29^{bc}	5.93 ± 1.59^{a}	5.64 ± 2.02^{ab}	6.14 ± 1.70^{a}
$Lsd_{0.05}$	1.258^{*}	1.30^{*}	1.204^{*}	1.096^{*}	1.41^{*}	1.147^{*}
SE±	0.4474	0.4622	0.4279	0.3899	0.5013	0.4079

Value are mean ± SD.

Any two scores having different superscripts in a column are significantly different ($P\leq0.05$).

Table (32): Acceptability of bread from wheat flour containing 15% starch with 5% lentil flour

Source of starch in wheat Flour blends	Quality attributes					
	Color	Odor	Taste	Crumb texture	Crumb grains uniformity	Preference
	Scores					
wheat flour bread (control)	$6.33{\pm}2.29^{ab}$	$5.80{\pm}2.21^{ab}$	$6.07{\pm}2.25^{a}$	$6.13{\pm}2.33^{a}$	$6.20{\pm}2.27^{ab}$	$6.33{\pm}2.32^{ab}$
wheat starch bread	$6.53{\pm}2.00^{ab}$	$7.00{\pm}2.00^{a}$	$7.00{\pm}1.81^{a}$	$6.53{\pm}1.73^{a}$	$6.47{\pm}1.96^{a}$	$6.93{\pm}1.71^{a}$
sorghum starch bread	$5.93{\pm}1.62^{ab}$	$6.07{\pm}1.28^{ab}$	$6.00{\pm}1.41^{a}$	$6.00{\pm}1.20^{a}$	$6.07{\pm}1.03^{ab}$	$5.80{\pm}1.26^{ab}$
millet starch bread	$5.07{\pm}1.67^{b}$	$5.53{\pm}1.73^{ab}$	$5.93{\pm}1.71^{a}$	$5.47{\pm}1.30^{a}$	$4.87{\pm}1.25^{b}$	$5.67{\pm}1.72^{ab}$
rice starch bread	$6.81{\pm}1.83^{a}$	$6.63{\pm}1.89^{ab}$	$6.56{\pm}2.03^{a}$	$6.50{\pm}1.79^{a}$	$6.63{\pm}1.67^{a}$	$6.69{\pm}1.70^{a}$
cassava starch bread	$6.07{\pm}1.98^{ab}$	$5.14{\pm}2.07^{b}$	$6.42{\pm}2.03^{a}$	$6.00{\pm}1.88^{a}$	$5.57{\pm}2.06^{ab}$	$5.07{\pm}1.98^{b}$
$Lsd_{0.05}$	1.351^{*}	1.369^{*}	1.375^{ns}	1.266^{ns}	1.277^{*}	1.312^{*}
SE±	0.4806	0.4868	0.4889	0.45	0.4542	0.4666

Value are mean ± SD.

Any two scores having different superscripts in a column are significantly different ($P \leq 0.05$).

other hand statistical analysis showed no significant (P≤0.05) difference in taste and crumb texture of 15% starches blends bread, and significant (P≤0.05) difference in color, odor, crumb grain uniformity and preference of the same blends. These results are in good agreement with the results obtained by Ahmed (2013) who found that the improver have a positive effect on quality attributes of the sensory evaluation.

From these results, it could be observed that starch has positive effect on taste; odor, crumb texture and crumb grain uniformity and has negative effect on bread specific volume.

Suielman (2005) found that 10% level of chick pea odor was dominated in the loaf. Hassan (2007) found that the high level of protein (25%) in the blends gave the lowest quality attributes of sensory evaluation and overall quality.

Gur and Janette (1988) reported that the dark crumbs were related to the presence of high ash content. Michael *et al.,* (1989) observed a gritty texture when cereal brans were added to the formulation of baked goods.

Physiochemical properties of cassava starch are suitable for supplementation of wheat flour in bread-making without compromising its sensory attributes (Eduardo *et al.,* 2013). Sim (2001) reported that the intake of bread is often enhanced by taste. Color of bread crust is important sensory attribute, which can enhance acceptability. The local populating thinks that pale colored bread crust is indicative of improper baking. Besides it is assumed that the brown color is what imparts nutrients, especially iron on the product. Browning of bread crust is an origin of Millard reactions during baking in the presence of amino acids, reducing sugars, temperature, time of baking and moisture levels of the fermented dough (Dendy, 2013).

Eduardo *et al.,* (2013) obtained that food texture sometimes embraces appearance. Udofia *et al.,* (2013) found that high supplementation of non-wheat flour showed low scores on texture, also reduces elastic properties of wheat flour dough rendering the dough incapable of retaining the gas emanating from fermentation. Preference is often influenced by prejudices, religious principles, group conformance, status value and snobbery, in addition to the quality of the food. People have preferences, no matter how illogical they may appear. Therefore, the parameters are difficult parameters to determine in a new product development (Sim, 2001). According to Giami *et al.,* (2004) and Akobudu (2006), up to 20% substitution of cassava flour had no adverse sensory and organoleptic effect on bread, while more development was still being expected.

Eddy *et al.,* (2007) found that bread baked with 10% and 20% supplementation with cassava composite flour was not significantly different in most sensory attributes, acceptability and readiness to buy from the control.

4.12. Physical characteristics of biscuit containing different percentages of starch with 10% lentil flour.

The effect of different percentage of starch (10%, 15% and 20%) with 10% lentil flour on physical characteristics width (cm), thickness (cm) and spread ratio of wheat flour biscuit are shown in table (33) to (35) and plates (9) to (11). The width of the biscuit control was 5.87 cm. This value increased with the addition of 10% starches of wheat, sorghum, millet, rice and cassava to the range from 5.90 to 6.06 cm. The highest value of width was observed in 10% wheat starch blend biscuit, while the lowest value was in 10% millet starch blend biscuit. The thickness of control biscuit was 0.63 cm. This value increased to 0.71 and 0.68 cm in 10% sorghum and millet starches blends biscuits respectively. On the other hand this value decreased to 0.59, 0.61 and 0.58 cm in 10% wheat, rice and cassava starches blends biscuits respectively. The control biscuit had spread ratio 9.27, this value increased to 10.31, 9.88 and 10.83 for 10% wheat, rice and cassava starches blends biscuits respectively. The width of 15% starches blends biscuit ranged from 5.88 to 6.27cm. The highest value was observed in 15% wheat starch blend biscuit, whereas the lowest value was observed in 15% rice starch blend biscuit. These values were high compared to control biscuit. The thickness was decreased from 0.63cm to 0.55, 0.59, 0.57, 0.50 and 0.56 in 15% wheat, sorghum millet, rice and cassava starches blends biscuits respectively.

The spread ratio of the biscuit increased with the addition of 15% wheat, sorghum, millet, rice and cassava starches from 9.27 to 11.52, 10.54, 11.05, 11.79 and 10.95 respectively. The width of the biscuit increased to 6.35, 6.48, 6.29, 6.16 and 6.08 for 20% wheat, sorghum, millet, rice and cassava starches blends biscuits respectively.

Thickness of biscuits decreased to 0.47, 0.54, 0.52, 0.59 and 0.54 for 20% wheat, sorghum, millet, rice and cassava starches blends biscuits respectively. The spread ratio of the biscuits increased to the range from 10.41 to 13.70 for 20% starches blends. The highest spread ratio was observed in 20% wheat starch blend biscuit, while the lowest value was in 20% rice starch blend biscuit. From these results it could be observed that the width of the biscuit increased with increasing the level of starch in blends, while thickness decreased. The biscuit spread ratio increased with increasing the level of starch in blends of biscuits. Analysis of variance showed significant ($P \leq 0.05$) differences between the blend of biscuits in width, thickness and spread ratios.

These values are in good agreement with the results obtained by Hassan (2007); who found that width and spread ratios of biscuits increased with increasing the levelof decorticated pigeon pea flour. Lehman*et al.*, (1994) reported that causes of increased cookie spread ratio are low protein content with poor protein quality and low initial or slowly rising heat during baking. Tesn (1976) reported that fortifying with protein rich food additives can drastically reduce cookie spread and increase thickness.

These results are comparable with the results obtained by Eltoum (2004) who found that spread ratio increased with increasing the level of Gongolase and Guddaim in the blends. Also he reported that the values of spread ratios ranged from 8.08 to 10.61. Elshiekh (2004) reported the values of spread ratio

Table (33): Spread ratios of biscuit samples containing 10%Starch with 10% lentil flour

Source of starch in wheat Flour blends	Width (cm)	Thickness (cm)	Spread ratio (width/thick)
biscuit wheat flour (control)	5.87 ± 0.13^{b}	0.63 ± 0.06^{b}	9.27 ± 0.77^{cd}
wheat starch biscuit	6.06 ± 0.11^{ab}	0.59 ± 0.00^{bc}	10.31 ± 0.25^{ab}
sorghum starch biscuit	5.94 ± 0.22^{b}	0.71 ± 0.01^{a}	8.41 ± 0.42^{e}
millet starch biscuit	5.90 ± 0.12^{b}	0.68 ± 0.05^{a}	8.73 ± 0.77^{de}
rice starch biscuit	6.02 ± 0.22^{b}	0.61 ± 0.01^{bc}	9.88 ± 0.37^{bc}
cassava starch biscuit	6.24 ± 0.05^{a}	0.58 ± 0.04^{c}	10.83 ± 0.78^{a}
$Lsd_{0.05}$	0.198^{*}	0.04128^{*}	0.7854^{*}
SE±	0.06782	0.01414	0.2691

Value are mean ± SD.

Mean values having different superscripts in a column are significantly different ($P\leq0.05$).

Table (34): Spread ratios of biscuit samples containing 15%Starch with 10% lentil flour

Source of starch in wheat Flour blends	Width (cm)	Thickness (cm)	Spread ratio (width/thick)
biscuit wheat flour (control)	5.87 ± 0.18^{a}	0.63 ± 0.06^{a}	9.27 ± 1.22^{b}
wheat starch biscuit	6.27 ± 0.24^{a}	0.55 ± 0.07^{c}	11.52 ± 1.87^{ab}
sorghum starch biscuit	6.18 ± 0.27^{a}	0.59 ± 0.01^{ab}	10.54 ± 0.54^{ab}
millet starch biscuit	6.21 ± 0.06^{a}	0.57 ± 0.05^{bc}	11.05 ± 1.24^{ab}
rice starch biscuit	5.88 ± 0.11^{b}	0.50 ± 0.05^{c}	11.79 ± 0.91^{a}
cassava starch biscuit	6.12 ± 0.19^{ab}	0.56 ± 0.05^{bc}	10.95 ± 1.25^{ab}
$Lsd_{0.05}$	0.2477^{*}	0.0715^{*}	1.615^{*}
SE±	0.08485	0.02449	0.5534

Value are mean±SD.

Mean values having different superscripts in a column are significantly different ($P\leq0.05$).

Table (35): Spread ratios of biscuit samples containing 20%Starch with 10% lentil flour

Source of starch in wheat Flour blends	Width (cm)	Thickness (cm)	Spread ratio (width/thick)
biscuit wheat flour (control)	5.87 ± 0.18^{ab}	0.63 ± 0.06^{a}	9.27\\$\pm1.22^{b}$
wheat starch biscuit	6.35 ± 0.12^{ab}	0.47 ± 0.08^{c}	13.70 ± 2.44^{a}
sorghum starch biscuit	6.48 ± 0.37^{a}	0.54 ± 0.06^{bc}	12.12 ± 1.74^{ab}
millet starch biscuit	6.29 ± 0.26^{ab}	0.52 ± 0.05^{bc}	12.14 ± 1.56^{ab}
rice starch biscuit	6.16 ± 0.14^{b}	0.59 ± 0.01^{ab}	10.41 ± 0.34^{b}
cassava starch biscuit	6.08 ± 0.10^{b}	0.54 ± 0.12^{bc}	11.70 ± 3.07^{ab}
$Lsd_{0.05}$	0.283^{*}	0.0923^{*}	2.523^{*}
SE±	0.09695	0.03162	0.8645

Value are mean ± SD.

Mean values having different superscripts in a column are significantly different ($P\leq0.05$).

Plate.9. photograph showing the biscuits of 10% starch

Where:

A : wheat flour biscuit (control)

B : 10% wheat starch + 10% lentil flour+ 80% wheat flour biscuit

C : 10% sorghum starch + 10% lentil flour+ 80% wheat flour biscuit

D : 10% millet starch + 10% lentil flour+ 80% wheat flour biscuit

E : 10% rice starch + 10% lentil flour+ 80% wheat flour biscuit

F : 10 % cassava starch + 10% lentil flour+ 80% wheat flour biscuit

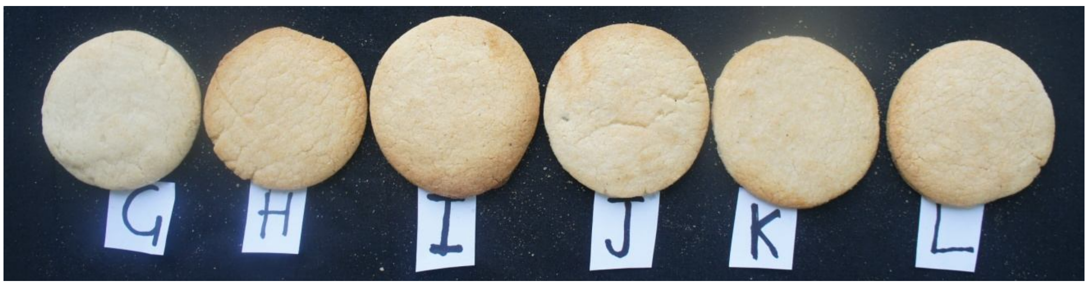


Plate.10. photograph showing the biscuits of 15% starch

Where:

G : wheat flour biscuit (control)

H : 15% wheat starch + 10% lentil flour+ 75% wheat flour biscuit

I : 15% sorghum starch + 10% lentil flour+75% wheat flour biscuit

J : 15% millet starch + 10% lentil flour+ 75% wheat flour biscuit

K : 15% rice starch + 10% lentil flour+ 75% wheat flour biscuit

L : 15 % cassava starch + 10% lentil flour+ 75% wheat flour biscuit

Plate.11. photograph showing the biscuits of 20 % starch

Where :

M : wheat flour biscuit (control)

N : 20% wheat starch + 10% lentil flour+70% wheat flour biscuit

O : 20% sorghum starch + 10% lentil flour+70% wheat flour biscuit

P : 20% millet starch + 10% lentil flour+70% wheat flour biscuit

Q : 20% rice starch + 10% lentil flour+70% wheat flour biscuit

R : 20 % cassava starch + 10% lentil flour+ 70% wheat flour biscuit

6.16. Kulp (1994) reported that fats with higher levels of solids tend to have the least effect onspread ratio, while fats with very low solids gave greater effect.

4.12.1. Sensory evaluation of biscuits containing different percentages of different starches and lentil flour:

Sensory evaluation of biscuits containing 10, 15 and 20% wheat, sorghum, millet, rice and cassava starches with 10% lentil flour are presented in tables (36), (37) and (38). No significant ($P \leq 0.05$) differences were observed in color, odor and texture of the blends prepared from 10% of wheat, sorghum, millet, rice and cassavastarches compared withcontrol biscuit. Addition of 10% of wheat, sorghum, rice and cassava starches in blends of biscuit resulted in decrease of color scores. On the other hand, addition of 10% millet starch resulted in increase of color scores from 4.07 to 4.40. Odor scores of biscuit decrease to 3.60, 3.40 in 10% wheat and sorghum starches blends respectively, and increase to 3.80, 3.80 and 4.00 in 10%, millet, rice and cassava starches blends respectively as compared to control biscuit (3.73).Also after taste scores decreased significantly from 3.87 (control) to 3.67 and 3.33 in 10% wheat and sorghum starches blends of biscuits respectively and increase to 4.20, 4.20 and 4.33 in 10% millet, rice and cassava starches blends of biscuits respectively. Texture scores of 10% starches blends decreased gradually from 4.20 (control) to 4.00, 3.8, 3.8, 3.8 and 3.60 in wheat, sorghum, millet, rice and cassava starches blends of biscuit respectively. Overall quality of 10% starches blends of biscuit showed no significant ($P \leq 0.05$)differences compared to control biscuit. Addition of 10% starches in blends of biscuit resulted in decrease of overall scores quality from 3.80 (control) to 3.63, 3.20, 3.70, 3.60 and 3.27 for wheat, sorghum, millet, rice and cassava starches blendsrespectively**.** From these results obtained, 10% millet starch blend biscuit was found to be very good in color (uniformity) odor (normal), after taste (normal) and overall quality compare to controlbiscuit. On the other hand 10% sorghum starch blend of biscuit showed low scores in odor, after taste and overall quality, while 10%

of rice and cassava starches blends of biscuit showed lower scores in color and texture respectively. Significant increase was observedin scores of color from 3.53 in control biscuit to 3.73, 4.40, 4.60 and 3.93 in 15% wheat, millet, rice and cassava starches blends of biscuitsrespectively. 15% sorghum starch blend biscuit showed low scores of color compared to control and other blends (3.4). Also there is significant decrease in odor scores from 4.00 in control to the range from 2.73 to 3.73 in 15% starches blends of biscuits. After taste showed significant decrease in scores from 4.00 in control biscuit to 3.53, 3.27 and3.80 in 15% wheat, sorghum and cassava starches blends of biscuit and significant increase to 4.20 in 15% millet and rice starches blends of biscuit. On the other hand, addition of 15% starches in biscuit blends was not significantly affecting the texture. Texture scores increased from 3.80 in control to the range from 4.00 to 4.47 in wheat, millet, rice and cassava starches blends of biscuit and decreased in to 3.73 in sorghum starch blends of biscuit. As overall quality 15% rice starch blend biscuit gave high scores about 4.13 that mean it is the best preferred by panelists. The scores of overall quality increased from 3.30 for control to the range from 3.40 to 4.13 in15% wheat, millet rice and cassava starches blends. 15% sorghum starch blend biscuit gave lower scores in color, odor, after taste, texture and overall quality. The high scores of quality attributes of sensory evaluation of 15% starch blends biscuit was observed in 15% rice starch blend biscuit. 15% rice starch blend biscuit was excellent in color (goldenbrown), very good in odor (normal) and after taste (normal), excellent in texture (crispy) and very good in overall quality. No significant ($P \leq 0.05$) differences were observed in color, odor, after taste and overall quality in all blends prepared with 20% starches blends compared with control biscuit. 20% wheat, rice and cassava starches blends of biscuit gave high scores in color comparedto control biscuit ranged between 4.20 to 4.33. 20% sorghum starch blend of biscuit gave the same scores of color of control (3.87). 20% millet starch blend of biscuit gave low scores in color compared to blends and control (3.73). 20%

Table (36): Acceptability of biscuit from wheat flour with 10% starch and 10% lentil flour

Source of starch in wheat Flour blends	Quality attributes				
	Color	Odor	Aftertaste	Texture	Overall quality
	Scores				
Wheat flour biscuit (control)	4.07 ± 1.16^{a}	3.73 ± 0.96^{a}	3.87 ± 0.92^{ab}	4.20 ± 0.86^{a}	3.80 ± 1.47^{a}
wheat starch biscuit	3.80 ± 1.15^{a}	3.60 ± 0.99^{a}	3.67 ± 1.05^{ab}	4.00 ± 0.85^{a}	3.63 ± 1.08^{a}
sorghum starch biscuit	3.80 ± 0.94^{a}	3.40 ± 1.06^{a}	3.33 ± 0.90^{b}	3.80 ± 1.15^{a}	3.20 ± 0.86^{a}
millet starch biscuit	4.40 ± 0.74^{a}	3.80 ± 0.77^{a}	4.20 ± 0.77^{a}	3.80 ± 1.15^{a}	3.70 ± 1.13^{a}
rice starch biscuit	3.60 ± 0.91^{a}	3.80 ± 0.94^{a}	4.20 ± 0.86^{a}	3.80 ± 1.21^{a}	3.60 ± 1.45^{a}
cassava starch biscuit	4.00 ± 1.20^{a}	4.00 ± 1.00^{a}	4.33 ± 0.90^{a}	3.60 ± 1.35^{a}	3.27 ± 1.75^{a}
$Lsd_{0.05}$	$0.7473^{n.s}$	$0.695^{n.s}$	0.6559^{*}	$0.805^{n.s}$	$0.9622^{n.s}$
SE±	0.2657	0.2471	0.2332	0.2862	0.3422

Value are mean±SD.

Any two scores having different superscripts in a column are significantly different ($P\leq0.05$).

Table (37): Acceptability of biscuit from wheat flour with 15% starch and 10% lentil flour

Source of starch in wheat Flour blends	Quality attributes				
	Color	Odor	Aftertaste	Texture	Overall quality
	Scores				
Wheat flour biscuit (control)	$3.53{\pm}1.30^{c}$	$4.00{\pm}1.00^{a}$	$4.00{\pm}0.93^{ab}$	$3.80{\pm}1.37^{a}$	$3.30{\pm}1.03^{ab}$
wheat starch biscuit	$3.73{\pm}1.03^{bc}$	$3.67{\pm}0.98^{a}$	$3.53{\pm}0.99^{ab}$	$4.00{\pm}0.85^{a}$	$3.40{\pm}1.06^{ab}$
sorghum starch biscuit	$3.40{\pm}1.06^{c}$	$2.73{\pm}1.03^{b}$	$3.27{\pm}1.28^{b}$	$3.73{\pm}1.33^{a}$	$2.93{\pm}1.16^{b}$
millet starch biscuit	$4.40{\pm}0.83^{ab}$	$3.47{\pm}0.92^{ab}$	$4.20{\pm}1.01^{a}$	$4.00{\pm}1.13^{a}$	$4.07{\pm}1.16^{a}$
rice starch biscuit	$4.60{\pm}0.51^{a}$	$3.73{\pm}1.03^{a}$	$4.20{\pm}0.68^{a}$	$4.47{\pm}0.74^{a}$	$4.13{\pm}1.25^{a}$
cassava starch biscuit	$3.93{\pm}1.16^{abc}$	$3.47{\pm}0.99^{ab}$	$3.80{\pm}1.08^{ab}$	$4.00{\pm}1.41^{a}$	$3.67{\pm}1.35^{ab}$
$Lsd_{0.05}$	0.7366^{*}	0.7203^{*}	0.7341^{*}	$0.8499^{n.s}$	0.9622^{*}
SE±	0.2619	0.2471	0.261	0.3022	0.3422

Value are mean ± SD.

Any two scores having different superscripts in a column are significantly different (P≤0.05).

Table (38): Acceptability of biscuit from wheat flour with 20% starch and 10% lentil flour

Source of starch in wheat Flour blends	Quality attributes				
	Color	Odor	Aftertaste	Texture	Overall quality
	Scores				
Wheat flour biscuit (control)	3.87 ± 1.13^{a}	3.73 ± 1.22^{a}	4.00 ± 1.00^{a}	3.67 ± 1.45^{b}	3.73 ± 1.03^{a}
wheat starch biscuit	4.20 ± 0.86^{a}	4.00 ± 0.85^{a}	3.87 ± 0.92^{a}	3.93 ± 1.22^{ab}	3.93 ± 0.96^{a}
sorghum starch biscuit	3.87 ± 0.92^{a}	3.73 ± 0.80^{a}	3.73 ± 0.70^{a}	4.06 ± 0.80^{ab}	3.67 ± 0.72^{a}
millet starch biscuit	3.73 ± 0.80^{a}	3.73 ± 1.10^{a}	3.40 ± 0.99^{a}	3.80 ± 1.08^{ab}	3.47 ± 1.06^{a}
rice starch biscuit	4.20 ± 0.77^{a}	3.60 ± 0.91^{a}	4.00 ± 0.85^{a}	4.20 ± 0.68^{ab}	3.80 ± 0.77^{a}
cassava starch biscuit	4.33 ± 0.62^{a}	3.60 ± 1.18^{a}	3.67 ± 1.72^{a}	4.60 ± 0.83^{a}	4.07 ± 1.22^{a}
$Lsd_{0.05}$	$0.6263^{n.s}$	$0.7434^{n.s}$	$0.7827^{n.s}$	0.7581^{*}	$0.71^{n.s}$
SE±	0.2227	0.2643	0.2783	0.2696	0.2525

Value are mean±SD.

Any two scores having different superscripts in a column are significantly different ($P \leq 0.05$).

sorghum and millet starches blends of biscuits gave similar scores ofodor of control (3.73). Lower score of odor was observed in 20% rice and cassava starches blends of biscuits (3.60). 20% wheat starch blend of biscuit gave high scores in odor (4.00) compared to control and blends. After taste scores decreased from 4.00 in control to the range between 3.40 to3.87 in 20% wheat, sorghum, millet and cassava starches blends of biscuits respectively. Similar value of scores of after taste of control biscuit was observed in 20% rice starch blend of biscuit. On the other hand texture scores increased significantly from 3.67 in control biscuit to 3.93, 4.06, 3.80, 4.20 and 4.60 respectively in 20% starches blends of biscuits. Scores of overall quality increased to 3.93, 3.80 and 4.07 in 20% wheat, rice and cassava starches blends of biscuits respectively and decreased to 3.67 and 3.47 in 20% sorghum and millet starches blends of biscuits respectively.

From these results, it could be observed that 20% cassava starch blend biscuit gave high scores in color (4.33) (uniformity), excellent in texture (crispy) and very good in overall quality. Good odor was observed in 20% wheat starch blend of biscuit and good after taste was in 20% rice starch blend of biscuit. From the results it could be observed that cookies made from the flour blend with starch was very good in their quality attributes of the sensory evaluation and within the acceptable range. Also panelists preferred biscuit with starch blends. 15% starches blends biscuit gave very good results of quality attributes of sensory evaluation compared to control and other blends. 15% rice starch blend biscuit was the best in all quality attributes of sensory evaluation and it is the best preference determined by panelists.

It was concluded that from all results obtained the addition of different starches with specific level in cookies can be carried out successfully without noticeable changes in desirable organoleptic properties of the end product, but better process method may needed to maintain quality. These products may be suitable for people suffering from celiac decreases because it contains low protein content. I found these results in good agreement with the results obtained by Hassan (2007) and Eltoum (2004). Whiteley (1971) reported that to improve texture, bite and appearance, it is necessary to achieve some forms of aeration for example mechanical, biological and chemical. Stauffer (1994) noticed that leavening of cookies produces two results, an increase in total volume of the cookies and an alteration of the spread ratio. Wade (1988) reported that the addition of sugar to the biscuit dough has the effect of reducing the amount of water required in the dough. As the sucrose content increases, it acts as a hardening agent, making cookies more crisp and firm.

However, when in a solution it tends to act as a softening agent when used at moderate levels, helping to hold water in the finished products. The addition of fats has the effect of reducing the amount of water required to make a dough with a workable consistency and making the product more tender (Phillips, 2003).

Stone and Sidel (1993) reported that sensory evaluation evokes measures, analyzes and interprets responses to products as perceived by senses of sight, smell, touch, taste and hearing. Taste is an important sensory attributes of any food (Sim, 2001). Aroma is an important parameter of food, good aroma from food excites the taste buds, making the system ready to accept the product. Poor aroma may cause outright rejection of food before they are tasted as reported by Lwe (2002) and Udofia *et al.*, (2013). Both acceptance and preference are primarily economic concept. Acceptance of food varies with standards of living and cultural background, whereas preference refers to selection when presented with choice Aleke and Germain (2000). According to Idowu *et al.,* (1996), the possibility of using starchy staples for some bakery products depends on the physical and chemical properties of the product.

Chapter Five

Conclusions and Recommendations

Conclusions:

- The five starches showed variations in moisture, ash, fat, protein, minerals contents and gelatinization temperature.
- The five starches have low acid, low falling number and white in color.
- Wheat, sorghum and cassava starches have the same values of dispersibility. while wheat starch have high bulk density.
- Wettability of five starches gave good grade and the least gelation concentration of starch gave a strong and very strong gel at 10 % concentration.
- Pasting temperature of the blends was high, while gelatinization temperature andgelatinization maximum were low compared with control.
- Addition of lentil flour increased the protein content, albumin and globulin fractions in wheat flour blends.
- Falling number increased as the result of adding starch to the blends.
- Gluten quantity and quality decreased.
- Characteristics of the dough of the blends decreased.
- 15% sorghum starch blend bread showed high specific volume, whilepanelists prefer 10% millet starch blend bread.
- Biscuits spread ratio increased with increasing the level of starch in blends
- Sensory evaluation showed that biscuits from the blends were very good specially 15% rice starch blend biscuit.

Recommendations:

- To recommend that cassava tubers, rice and wheat cultivars can be used for wet milling (starch production).
- The use of different starches for bread making has a positive effecton taste, odor, crumb texture and crumb grain uniformity.
- The best bread was produced by adding 15%sorghum starch and 5% lentil flour.
- 15% starches of wheat, sorghum and millet with 5% lentil flour are suitable for making bread.
- According to spread ratio 15% starches of wheat, sorghum and millet with 10% lentil flour are suitable for making biscuit.
- Further studies are recommended to be ondifferent Sudanese wheat cultivars flour.
- More research efforts should be directed to utilize the starches from different sources such as potatoes,different sorghumcultivars,corns, legumes, etc. as substitutes for the imported starch.
- Further studies are recommendedto be onaddition of other legumes for bread and biscuit making.

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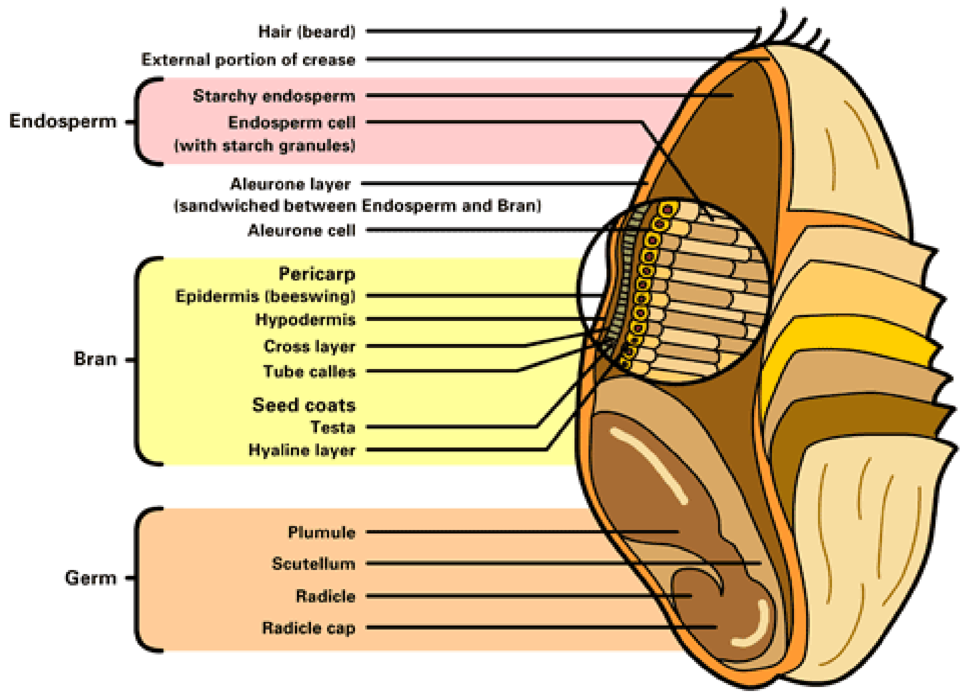
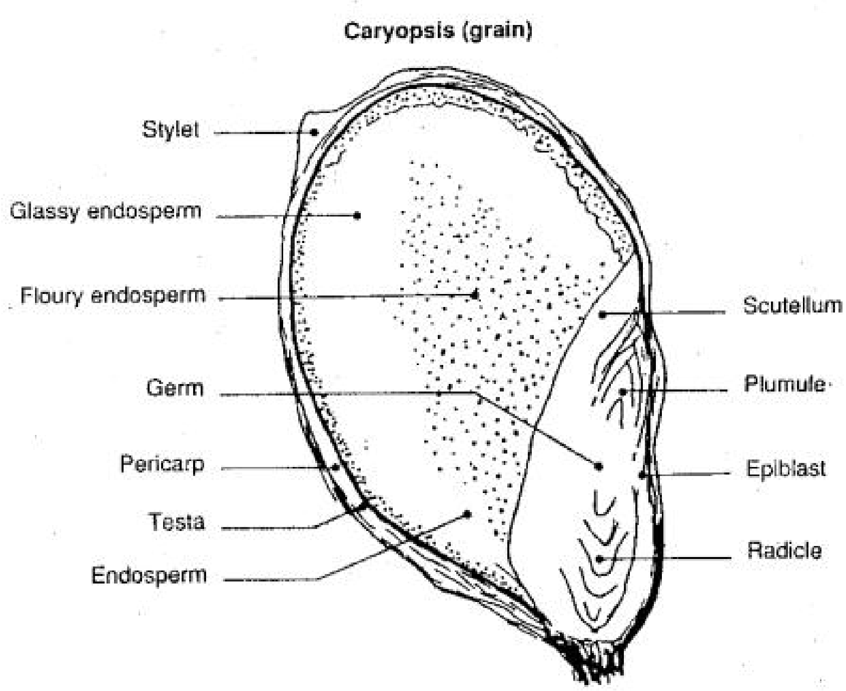
Appendix 1

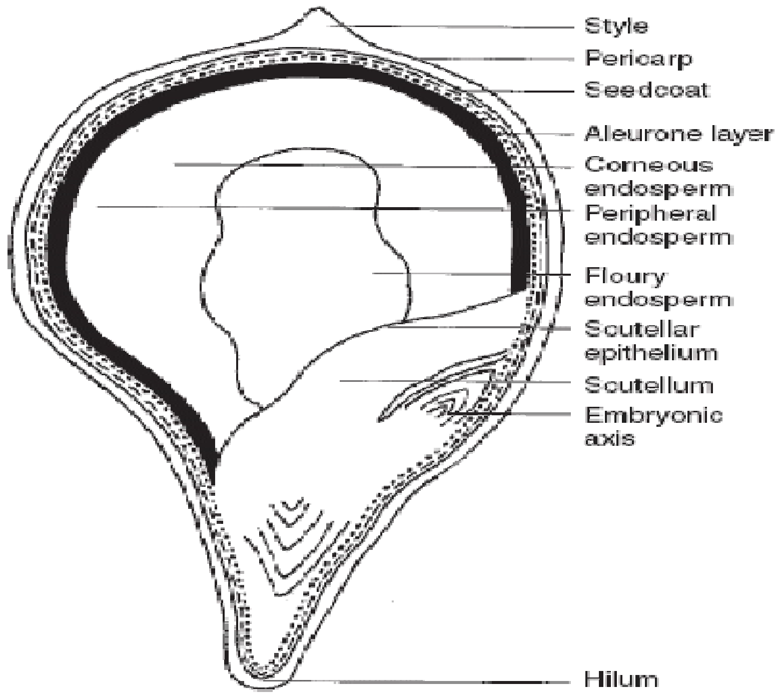


Structure of wheat grain

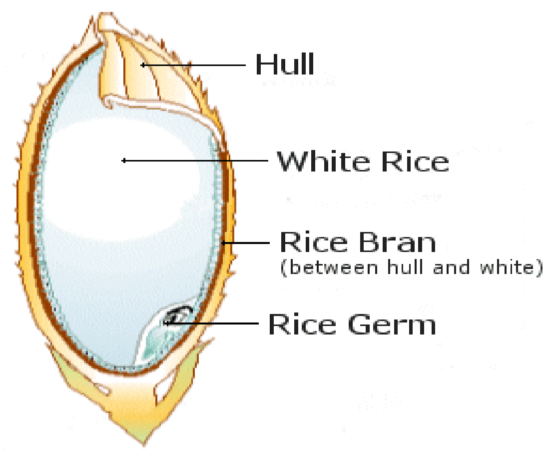


Structure of sorghum grain

Appendix 2



Structure of millet grain



Structure of a rice grain

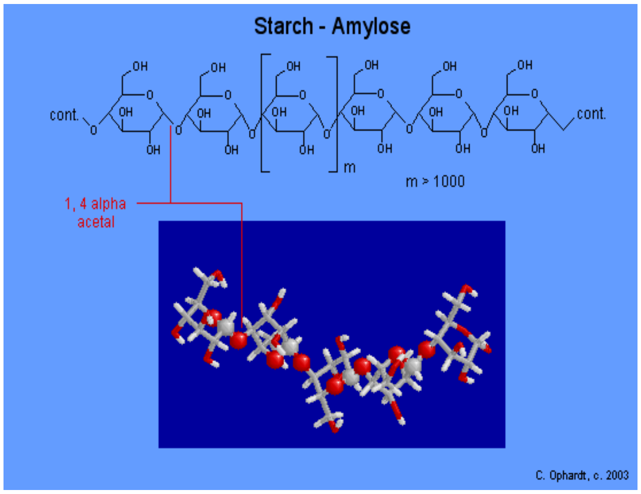
Appendix 3

Unprocessed cassava roots

A cross section of cassava roots

Cassava roots

Appendix 4



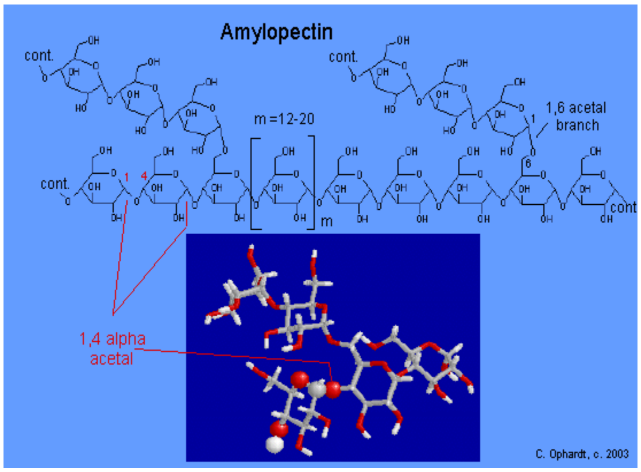


Fig. 6.Structure of the amylose and the amylopectin molecules

Appendix 5: Wettability grade according to respective characteristics

Characteristic of wet sample	Grade
Powder wet as soon as it contacts water, even with stirring after half an hour, the sample is completely dispersed.	Excellent
Powder only wets slightly when it comes into contact with water, After half an hour the sample is wet and powder had sunk to the bottom. Stirring disperse the sample.	Good
Powder wets very slightly on initial contact and tends to clump and remain at the surface. After half an hour the sample still at the surface although some of the sample has disperse. After stirring there are still a few clumps left	Fair
Powder hardly wets when it initially comes into contact with water. It also clumps. After half an hour the solution is slightly and most of the same is still in clumps at the surface. After stopping the stirring most of the sample still floats and clumps.	Poor

Appendix 6: Please exam biscuits samples present to you and give scores to attributes shown in table (2) to help you

Sample No.	Color	Odor	After taste	Texture	Overall quality

Table (2) key description of sensory evaluation of Biscuits samples

Color	Odor	After taste	Texture
Golden brown (5)	Desirable (5)	Pleasant (5)	Crispy (5)
Uniformity (4)	Normal (3 – 4)	Normal (3 – 4)	Hard (3 – 4)
Brownish (2 - 3)	Off flavor (1 - 2)	Off taste (1 - 2)	Brittle (1 - 2)

Where:

5. Excellent

4. Very good

3. good

2. Fair

1. Poor