FOOD RESEARCH INSTITUTE (C.S.I.R)

NUTRITIONAL STATUS AND PASTING PROPERTIES OF RECOMMENDED SORGHUM VARIETIES

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ABSTRACT

Seven sorghum *(Sorghum bicolor* (L) Moench) varieties -*Mankaraga, Kapaala, NSV1, NSV* 2, *Naga White, Kadaga* and *Local* 29 were characterized by their nutritional and anti-nutritional properties and their pasting characteristics. Proximate analysis showed *NSV* 1 as the variety with the highest protein and mineral content giving the indication that it may be suitable for infant food formulation. *Kapaala* and *Naga White* could also be useful for malting and brewing trials due to their relatively low protein content but high carbohydrate levels. Levels of tannins were relatively low for all the varieties except *Kadaga,* which had high tannin content.

The pasting temperatures were high for all the varieties (76.5°C -87.0°C). *Mankaraga* had the highest peak, hot paste and cold paste viscosities. *Naga White* also showed high paste stabilities and viscosities. As such they may be useful for the preparation of traditional thick porridge, *tuo. NSV* 2, *Local* 29 and *Kadaga* may also be processed into thin porridge, *koko* or other products such as *fula* and *basi.*

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1.0 INTRODUCTION

Sorghum *(Sorghum bicolor* (L) Moench) is a cereal plant, which can grow in both temperate and tropical zones. The plant is a physiological marvel and it is among the most photo-synthetically efficient plants having one of the highest dry matter accumulation rates. Sorghum thrives on many marginal sites and this makes it one of the toughest of all cereals in that it withstands high rainfall (water logging), and most importantly endures hot and dry conditions. It matures quickly and some varieties are known to mature in just a matter of seventy-five days and can provide three harvests a year (National Research Council of USA, 1996). These properties give the grain so much nutritional importance in arid and semi-arid regions particularly in Africa where lands can hardly support other food crops (National Research Council of USA, 1996).

In recent times, it has been found to be the dietary staple for an estimated five hundred million (500,000,000) people in more than thirty countries (National Research Council of USA, 1996). It is the fourth major cereal species of the world (FAO, 1984) and the third most important cereal cultivated in Ghana.

In Ghana, it is largely cultivated in the drier northern sector mainly in the Northern, Upper-East and Upper-West regions where the vegetation is savanna and in some parts of the coastal savanna. In these areas sorghum is used in traditional food preparations, which come in different forms.

Most of these products are bread, porridges, snack foods, alcoholic and non-alcoholic beverages (Vogel and Graham, 1979).

Sorghum is used basically as food in the arid regions of Africa due to its availability and nutritional status. However, the plant has a great deal of industrial potential, which is yet to be tapped and utilized in most parts of the world especially developing countries.

The increase in both its cultivation and consumption has attracted much scientific research in recent times. The establishment of bodies such as the International Crops Research Institute for the Semi -Arid Tropics, ICRISAT evidences this. This body seeks to improve semi-arid crops such as sorghum and safeguard their seeds. It also develops improved farming systems and finds ways of overcoming agricultural constraints. In Ghana the Savanna Agriculture Research institute has similar responsibility. Their research activities have led to the development and introduction of a number of sorghum varieties, which are usually referred to as improved varieties.

Though a number of products could be prepared from sorghum, the appearance, texture, taste, shelf life, digestibility and overall acceptability of the food are greatly affected by the variety of the sorghum. In the light of this, it is always very vital to screen both the traditional and improved varieties by way of physical and chemical characterization, to ascertain the grain quality and its suitability for certain specific purposes.

It is against this background that, this study seeks to investigate the properties of some recommended sorghum varieties. This could provide information that may be of significant help in determining the best possible uses to which these varieties could be put to and in addition the classification of these into different utilization categories. The objectives of this work are therefore:

- To characterize some selected improved varieties of sorghum
- To investigate the pasting properties of the selected sorghum varieties.

2.0 LITERATURE REVIEW

2.1. Sorghum

Sorghum is a cereal of remarkable genetic diversity. It is of much importance in human diets, particularly those of the semi-arid tropics. It more probable that early-cultivated sorghum forms were transferred from place to place as agricultural practices diversified.

The most attractive feature of sorghum is its capacity to survive and yield grain during continuous or intermittent drought stress (Hulse et al, 1980). It grows successfully on many soil types, tolerating medium to high pH (Ross and Webster, 1970). It is grown in a wide diversity of cropping patterns including mono cropping and inter-cropping with legumes (IDRC, 1977).

2.1.1. Sorghum Types

Sorghum has been broadly put into three groups namely:

- Subsistence types
- Commercial types
- Fuel and Utility types

2.1.1.1. Subsistence Types

Sorghum is a crucial grain to millions of people who coax out a living on often declining lands barely enough to sustain life. For them, it provides the dietary energy and nutrients that make the difference between health and hunger.

Subsistence types have over the years been selected by farmers to match local conditions and food preferences and have been remarkable for their diversity. In addition to remarkable qualities, they incorporate features like:

- Good seedling emergence and strong early shoot development
- Resistance to insects and moulds
- Tolerance to bird pests and striga

Apart from these qualities, they have features that affect appearance, texture, taste, preparation or shelf life of traditional foodstuffs. Subsistence sorghums are primarily used to prepare local foods. Vogel and Graham, (1979) gave a detailed description of the various methods of sorghum consumption in the world. The traditional sorghum products, mentioned include unleavened bread, leavened bread, thick porridge, thin porridge, stem cooked products, boiled sorghum, snack foods, alcoholic and non-alcoholic beverages.

The products are referred to by many different names depending on the locality and considerable variations exist in the exact techniques used to prepare each product (Vogel and Graham 1979).

2.1.1.2. Commercial Types

Beyond Africa where sorghum is grown mostly for subsistence, countries like the United States of America, Mexico and Argentina grow the crop in large quantities for commercial purposes. This has been possible through the use of sorghum hybrids. These hybrids have increased capacity to produce more and increased resistance to a wide range of conditions and diseases.

2.1.1.3. Specialty Types

Popping sorghums are found in parts of Africa and Asia and refer to sorghum that pops like corn. However, they have seldom received much scientific or entrepreneurial recognition. They make tasty foods. Popping boosts the flavour of sorghum and it is nutritionally desirable. Of 3,682 accessions tested, 36 have shown good popping qualities and most originated in India. The best types usually have small grains with a dense, "glassy" (corneous) endosperm that traps steam until the pressure builds to explosive levels.

Vegetable sorghum types are eaten like sweet corn. The whole seed head (panicle) is harvested while the grain is still soft. Like sweet corn, they have sugary endosperm containing 30% glycogen.

Vitamin A sorghums bear yellow grains. The colour comes from Xanthophyll and from the carotene pigments that are Vitamin A precursors. People eating them have a better - than - normal production of Vitamin A. Yellow sorghums are especially known in Nigeria. The carotene levels are typically only a fraction of those found normally in yellow maize.

Fuel and Utility types with woody stems have been found to put out surprising amounts of heat. An example is *Giza* 114, which is found in Egypt. These are used in place of fuel wood as a major source of energy for cooking in parts of Africa and Southeast Asia. Sweet sorghum in the United States of America, India and Brazil has also been used to produce alcohol to be used as fuel.

Other sorghum types include transplant sorghum which can be transplanted like rice, tannin free sorghum which have little or no tannin and quick cooking sorghums which have gelatinisation temperature of about 55oC (National Research Council of USA, 1996).

2.2. THE NUTRITIVE VALUE OF SORGHUM

In composition, sorghum is similar to maize. Compared with maize however, sorghum generally contains 1% less fat. Its complex carbohydrates have properties similar to those from maize. The protein content is quite variable ranging from 7% to 15%, averaging about 9%. However, for human nutrition, sorghum protein is "incomplete" and in addition its digestibility is low. It is deficient in critical amino acids, mostly lysine (National Research Council of USA, 1996).

2.2.1. Carbohydrates

This is the grain's major component with starch making up from 32% to 79% of its weight with the remaining being largely sugar. Chemically, the starch normally consists of 70% to 80% branched amylopectin (a non-gelling type) and 20% - 30% Amyloses (a gel forming type). Some sorghum starch however contain as much as 100% amylopectin, others 62% amylose. When boiled with water, the starch forms an opaque paste of medium viscosity and on cooking the paste sets to a rigid non-reversible gel. Gelatinisation temperatures range from 68°C to 75°C (National Research Council of USA, 1996).

2.2.2. Protein

Sorghum protein content is more variable as compared to maize. It can range from 7% to 15%. Lysine is the first limiting amino acid followed by threonine. The protein contains no gluten and a large proportion is prolamine; a cross-linked form that humans cannot easily digest. Prolamine is about 50% of the total protein in normal sorghum. This lowers the food value considerably (National Research Council of USA, 1996).

2.2.3. Fat

Generally, sorghum contains about 1% less fat than maize. Free lipids approximately amount to between 2% to 4% of the grain whilst bound lipids range from 0.1% - 0.5%. The fatty acids are highly unsaturated. Oleic and linoleic acids account for about 76% of the total fatty acids (National Research Council of USA, 1996).

2.2.4. Vitamins

Sorghum has higher levels of β-Vitamins, pantothenic acid, niacin, folate and biotin as compared to maize. Most of the β-Vitamins are located in the germ. The pigmented carotenoids in sorghum provide a source of β-carotene, which

can be converted to retinol (Vitamin A) in the human body (Blessing *et al*, 1958).

2.2.5. Minerals

The grain ash content ranges from about 1% to 2% and as in most cereals, Potassium and Phosphorus are the major ones. Calcium and Zinc levels are low. However sorghum has been reported to be a good source of more than twenty (20) micronutrients (National Research Council of USA, 1996).

2.3. ANTI NUTRITIONAL FACTORS

These factors refer to substances that naturally occur in the plant or are produced as a result of contamination. They generally affect effective digestion and absorption of nutrients. The toxins and nutritional inhibitors that have been reported fall into two categories.

i. Substances that naturally occur in the plant

These include polyphenols (often called tannins). Tannins impart to the grain an astringent taste and may cause discolouration in products derived from the grain. Others are the phytic acid and the phytates that have the property of forming insoluble or near insoluble compounds with mineral elements thereby making them unavailable for absorption (Gontzea and Sutzescu, 1968).

ii. Substances produced by microbial or other infections or contamination eg. Ergot and mycotoxins.

In addition to these, imbalance among naturally occuring amino acids in sorghum protein may produce undesirable physiological effects (Hulse et al, 1980).

2.4 THE SORGHUM GRAIN

2.4.1 Structure of the Grain.

The structure as shown in the figure below has been described by several workers including Rooney(1973), and York (1976).

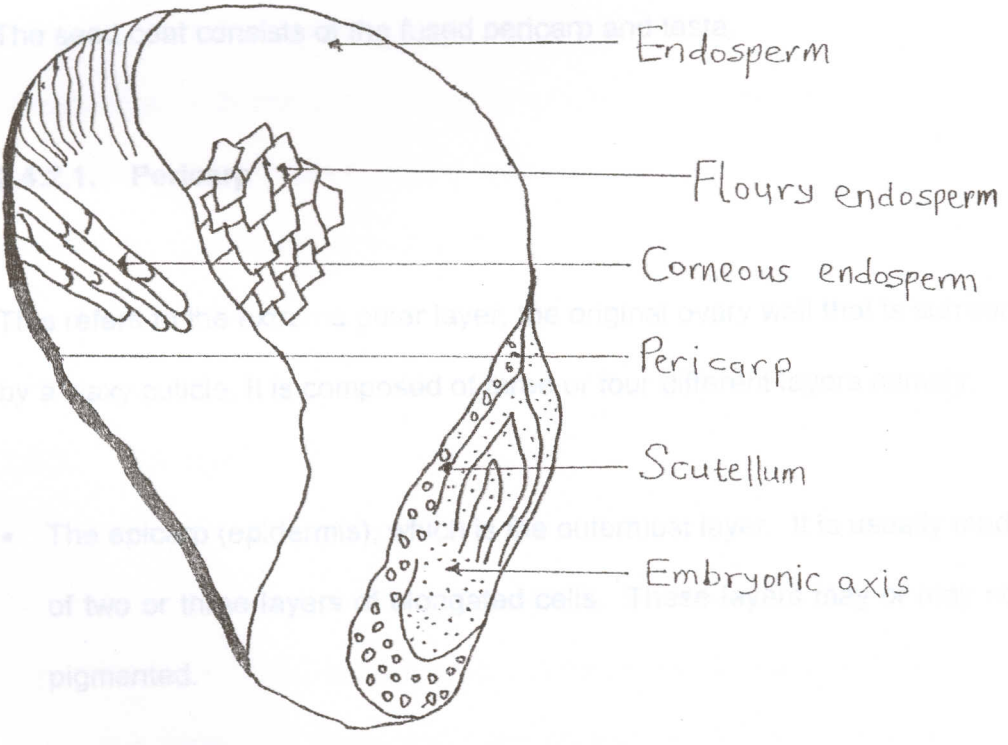

Fig: Cross section of the sorghum grain

The kernel is roughly spherical in shape and is composed of three main components:

- The seed coats (the outer covering).
- The embryo (germ).
- The endosperm (the storage tissue that provides food for the young plant, after germination).

The relative proportions vary but most sorghum kernels are made up of 6% seed coat (pericarp), 10% germ (embryo) and 84% endosperm.

2.4.2. Seed Coats

The seed coat consists of the fused pericarp and testa.

2.4.2.1. Pericarp

This refers to the extreme outer layer, the original ovary wall that is surrounded by a waxy cuticle. It is composed of three or four different layers namely:

- The epicarp (epidermis), which is the outermost layer. It is usually made up of two or three layers of elongated cells. These layers may or may not be pigmented.

- The hypoderm (which is not always differenciated from the epicarp)
- The mesocarp (the middle layer) and
- The endocarp (the inner layer)

The presence or absence of pigments in the epicarp is genetically controlled. If the kernel is enclosed in highly pigmented glumes, the pigments may migrate into the endosperm. The mesocarp cells are generally thin-walled and under polarized light may be seen to contain polygonal starch cells. The endocarp cells consist of cross and tube cells.

2.4.2.2. Testa

This component may also be known as "sub coat", "nucellus", "undercoat", "integument" or "seedcoat". Wall and Ross, (1970) stated that the testa is always present in the ovary as an inner integument with a definite structure. The testa is often thickest at the crown of the kernel and thinnest over the embryo. It may or may not be pigmented.

2.4.3. Embryo

The embryo is made up of a large scutellum, an embryonic axis, a plumule and a primary root. The scutellum is the flattened portion that serves as an absorptive organ. A cementing layer exists between the scutellum and the

endosperm. The embryo is relatively firmly embedded and difficult to remove by dry milling (Rooney, 1973).

2.4.4 Endosperm

This represents the largest portion of the kernel. It consists of an aleurone layer, corneous and floury zones. The aleurone (peripheral) layer is made up of cells containing a high proportion of protein. The corneous layer beneath the peripheral layer contains less protein and a higher proportion of starch than the peripheral. The corneous layer also called hard or horny endosperm is translucent in appearance. Inside the corneous layer is the floury or soft endosperm layer, which is lowest in protein. Sorghum can either be described as "floury" or corneous depending on the floury or corneous component within the kernel (Hulse et al, 1980).

2.5. MILLING

Like other important cereals such as rice and wheat, milling of sorghum is an important practice in a bid to improve its physical characteristics, food quality and consumer acceptability. Sorghum milling involves two main unit operations; namely, dehulling or pearling and milling. The dehulling operation aims at improving visual appearance by way of removing the colours and bitter rough bran and glumes (Desikachar, 1981). The actual milling breaks the grain up into desired particle sizes. The milling properties of the grain, and

consequently flour quality are affected by the structure and moisture of the grain as well as the milling equipment and grinding technique.

2.5.1. Traditional Milling

Traditionally, a wooden mortar and pestle are employed. Dehulling is done by pounding the grains in a mortar. Before the pounding, the grains are sprinkled with water to facilitate tempering. Winnowing then follows to separate the husk from the dehulled grains (Subramanian *et al*, 1988). The dehulled grains may be dried shortly before use or may be ground thereafter. Sieving is done to get the desired particle size.

2.5.2. Mechanical Milling

The entire traditional dehulling process is time consuming and laborious hence the introduction of mechanical mills. Mechanical dehulling gives more dehulled grain yield with uniformity than the traditional process. It is however important to note that the nature of the endosperm and type of equipment used gives different dehulled grain yield.

The dehullers (attrition type) usually consist of two metals or stone discs, one or both of which rotate in a horizontal or vertical plane. The attrition process can be modified by introducing a variety of impact or cutting surfaces such as

metal pins or blades into the surface of one or both of the rotors or the rotor and stator (Hulse et al, 1980).

Another major type of mechanical milling is the abrasion milling. It employs a rough surface such as carborundum or hard stone to rub off progressively, the various layers of the grain. The combination of the rotation of a horizontal abrasive surface and the static pressure within a body of grain, imparts a circulatory motion within the mass of the grain and subjects each individual kernel to abrasion for a period of time dependent upon the design of the abrasion unit and the rate of flow of grain (Reichert, 1977).

2.6. PASTING CHARACTERISTICS OF SORGHUM

Starch constitutes about 32% - 79% of the carbohydrate content of sorghum grain and because sorghum is traditionally used basically in the preparation of porridges, it is important to have knowledge of its pasting characteristics. Bhattacharya and Sowbhagya, (1979) and Smith, (1964) found out that when starch suspension is heated, it begins to swell, yielding a viscous paste, then it disintegrates on prolonged heating. It therefore produces a paste that is a mixture of swollen granules, granule fragments and dispersed starch molecules. If the temperature of the paste is subsequently decreased, the elements present in the paste start to associate or retrograde then increase in

viscosity. The significant changes in the viscosity during the whole pasting process are the characteristics of the particular type of starch.

Manful (1989), found out that there was a wide variation in their highest peak viscosities and nature of gel at set back giving the indication that, in the development of sorghum into flours, foods and other potential uses, there must be careful screening of the different varieties to enhance food value and quality.

The amylograph cooking characteristics of sorghum starches and flour has been tentatively related to food quality of sorghum (Waniska, 1976; Akingbala, 1980). The set back viscosity of sorghum starch and flour is high for sorghum with acceptable thick porridge making quality and is low for sorghums with acceptable unleavened bread making properties. Similar observations were recorded by (Desikachar and Chandrasekhara, 1981).

2.7. SORGHUM IN GHANA

In Ghana, sorghum is usually grown in the drier northern sector and in some few areas of the coastal savanna (Manful, 1989). It thrives best where there is distinct contrast between wet and dry seasons.

It is planted when the rains begin in May or June and after germination thinned to two or three per stand. Usually, it is inter-cropped with other food crops and matures within 140 to 190 days. Depending on the variety cultivated, it may be harvested between October and January. Yield is encouraging on well-drained soils ranging in pH from 5.5 to 8.5.

2.7.1. Varieties Cultivated

Locally grown sorghum has been classified into three races (C.R.I, 1974).

These are:

Caudatum race: This is termed the Gambaga type. It is characterized by large round grains, which protrude from tightly adpressed glumes. The pericarp and endosperm may be yellow. Some short strawed types cultivated mainly in the Upper regions belong to this race

Bacolor race: It is locally called Nanumba type. It is characterized by long papery glumes, which completely enclose the grain at maturity. It was first collected in the Lawra area (C.R.I, 1974).

Guinea race: It is locally known as the Belko type. It constitutes the most important race because it comprises most of the sorghum cultivated in Ghana. Typically it is tall and late maturing It has flattened grains exposed at maturity between long widely gaping glumes (C.R.I, 1974).

MOFA, (1992) estimates of cropped area for some major food crops in Ghana from 1990 -1992 revealed that, sorghum is the number three crop cultivated on a large scale, leaving behind other very important crops like rice, millet, cocoyam, yam and plantain, which play major roles in the diets of most Ghanaians. In other words, if the cropped area is anything to go by then apart from maize that has the highest cropped area, followed by cassava, sorghum is the next most important crop. It also revealed that sorghum is cultivated in five major regions namely, Northern, Upper-East, Upper-West, Volta and Brong-Ahafo regions.

The recorded figures show a 22% increase in the cropped area from 1990 to 1992 and a further increase of 17% from 1991 to 1992. During this period, the Northern region recorded the highest cropped area followed by the Upper-East region and then the Upper-West region confirming the fact that the crop does best in the savanna climate. Other regions that showed appreciable cropped area include the Volta and Brong-Ahafo regions. It is also interesting to note that, generally, there were increases in the cropped area with respect to the Northern and Upper-East regions over the three-year period. That of Upper-West region showed a decline.

2.7.2. Uses of Sorghum in Ghana

The use of sorghum in Ghana is basically as food, leaving its industrial potential largely untapped. Its food value is largely utilized in the traditional diets of the inhabitants of the northern sector of the country and the processing methods used are also indigenous. A survey carried out into the processing methods and utilization of sorghum and millet in May 1996 brought to light, the major products sorghum can be processed into and the areas or locations processing are done. They include *pito, koko, tuo - zafi,* and malt.

2.7.2.1. Methods of Processing

2.7.2.1.1. ***Koko*** (Porridge)

This product is widely taken for breakfast with flour products such as bread. The first step involves cleaning the grains to get rid of unwanted particles. Grains are then soaked for 8 to 24 hours (mostly overnight) and then water is drained. Spices such as ginger and pepper are added and then milled. Slurry is made from the flour obtained and it is sieved through cheesecloth and the filtrate kept overnight to develop sour taste.

After this the supernatant is decanted and boiled. The remaining slurry is stirred some fetched aside and the boiling water is added to the slurry with

constant stirring to give the desired consistency. Fresh water instead of the supernatant may be used. Good quality *koko* has cream or grey colour. It is also smooth, thick and starchy.

2.7.2.1.2 *Tuo-zaafi* (Thick Porridge)

Tuo-zaafi is a very thick porridge usually taken with sauce. It is traditionally prepared from sorghum flour obtained after dehulling and milling the grain. The flour is ground prior to preparing the *tuo*. It is often sifted to remove coarser particles and then a small amount of the flour is dispersed in cold water to from slurry.

This slurry is then poured into a vessel of boiling water. A thin porridge is obtained after 10 minutes cooking and a third is set aside in another container. The rest of the flour is added by handfuls to the porridge in the vessel, while constantly and vigorously stirring with a wooden spoon. The porridge then thickens and becomes firm, smooth and uniform. Some of the thin porridge that was set aside can be added if the mixture gets too thick. After about 20 minutes, the *tuo* is ready.

2.7.2.1.3 Malt

Although the procedure from soaking to the sprouting stage differs slightly, the principle underlying the process of brewing malt from sorghum is the same in

the localities where this activity is practiced. The grains are soaked overnight in water (or for 12hrs) after which water is drained. The grains are then spread evenly (about an inch thick) on a clear surface and kept moist for 48 hours after which the entangled sprouts are loosened.

The loosened sprouts are either heaped up or put in baskets and covered with polysacks or polythene sheets for 48 hours. The grains are further dried in the sun for 1 to 2 days depending on the intensity of light. The dried grains may then be collected and bagged and is usually sold to *pito* (an alcoholic beverage) brewers.

2.7.2.1.4 *Pito*

The process involves three stages namely, malting as described above, drying and fermentation. When the malt is thoroughly dry, the grains are milled and the mass transferred into a vessel of water with pounded okra leaf extract and allowed to settle. With the supernatant collected, the mash is boiled for about three hours with continuous stirring to form a thick paste. The boiled malt is added to the supernatant that was earlier collected and more extract added till the following day to develop sourness and also to cool. The supernatant is collected again into another vessel and more extract is added to the residue for more settling and decanting of supernatant.

The supernatant is boiled for 3 to12 hours depending on the heat intensity and light materials that float in the surface are skimmed off. The *pito* is cooled and yeast added overnight.

In order to obtain good quality *pito*, the mass must be well sieved, alcohol and sugar contents must be high and grains must have capacity to sprout.

3. PROXIMATE CHARACTERISATION

3.1. Materials and Methods

3.1.1. Materials

Seven cultivars of sorghum were received from the Savannah Agriculture Research Institute (S.A.R.I.) of the Council for Scientific and Industrial Research (C.S.I.R.), for the analysis.

3.1.2. Methods

3.1.2.1. Physical Quality Characteristics

This involved the use of rapid screening procedures to evaluate various qualitative and quantitative parameters to determine the end-use quality of sorghum grain. All tests were performed on whole, healthy grain from a representative sample; and three replicate tests were done on each sample. The objective of the grain-quality evaluation tests is to provide concise information on the quality of the materials under test, to determine the most relevant quality traits for end-use selection.

Physical characteristics analysed include grain colour, pericarp thickness, presence or absence of testa, endosperm colour, endosperm texture and 1000-kernel weight. All of these analyses were done on representative grain samples.

3.1.2.2. Grain Colour

A few clean kernels of sorghum were placed on a piece of white paper and the colour of the pericarp (outer coat of grain) was observed and recorded with such descriptors as: white, yellow, red, brown, buff, gray, or a combination of these colours, according to the IBPGR and ICRISA T (1993a, pp18 and 20) classification of kernel colour.

3.1.2.3. Pericarp Thickness

A few clean kernels of sorghum were placed on a piece of white paper and a razor blade was used to scrape the pericarp. The numerical scale below was then used to rate the thickness of the pericarp.

1 = Thin pericarp (scrapes come off in small fragments)

2 = medium pericarp

3 = Thick pericarp (scrapes come off in thin sheets)

3.1.2.4. Testa

To judge the absence or presence of a testa, a few clean grains were scraped to remove pericarp at the crown of the kernel and the layer covering the endosperm was observed to detect the presence of pigments.

(+) = Testa present (-) = Testa present

3.1.2.5. Endosperm Colour and Texture

A few of the kernels were cut longitudinally into two symmetrical halves and the colour of the endosperm was recorded as White or Yellow. Again the longitudinal cut of the kernel was observed with a hand lens and the relative proportions of the vitreous and floury endosperm was estimated using the scale below.

If vitreous and floury proportions were equal, the description 'intermediate' was recorded. For a more floury endosperm, 'chalky' was recorded and 'pearly' for a more vitreous endosperm.

3.1.2.6. 1 OOO-Kernel Weight

A Numigral seed counter (Durant Solid State 1800) was used to count a thousand grains of each of the varieties and their weights taken on an analytical balance.

3.1.3. Proximate Analysis

3.1.3.1. Fat

Extraction thimbles were half filled with samples and the accurate weights of samples (5-7g) were determined. The extraction was carried out in a Soxhlet extraction apparatus with 250ml of petroleum ether (b.p. 40°C -60°C) for 10 hours. The solvent was evaporated on a water bath, the extracted crude fat weighed, and proportion of fat in the samples determined (Pearson, 1970).

3.1.3.2. Ash

An accurately weighed 1 -2 g samples were weighed and placed into conditioned porcelain crucibles (method 942.05 of AOAC, 1990). The crucibles were placed in a preheated muffle furnace at 550°C. The ash content was expressed as a proportion of the original sample weight.

3.1.3.3. Protein

Protein determination was by AACC method 46 -10. 2g of finely mixed and ground sample was transferred into a digestion flask and 0.7g HgO, 15g powdered K_2SO_4 and 25 ml H_2SO_4 added. The flask was then placed in an inclined position and heated gently until frothing ceased. This was followed by brisk boiling until solution became clear and then for at least 30 minutes longer. 200ml water was added to cool the solution to below 25°C and then

25ml thiosulphate to precipitate mercury. A few zinc granules were added to prevent bumping. With the flask in a tilted position a layer of NaOH was added without agitation. Immediately after this the flask was connected to a digesting bulb on the condenser and with the tip of the condenser immersed in standard acid in receiver the flask was rotated to thoroughly mix contents. Heating followed till all ammonia had distilled. The excess standard acid in distillate was titrated with standard alkaline solution, using methyl red indicator.

Crude protein = N x 5.70

Nitrogen (N_2), % = [(B-S) x N x 0.01401 x 100] / W t. Of sample

B= ml alkaline back-titration of blank, S= ml alkaline back-titration of sample,

N= normality of alkaline.

3.1.3.4. Carbohydrates

The percent carbohydrate was obtained by finding the difference between 100 and the sum of the other constituents.

3.1.3.5. Phosphorus

Phosphorus was determined by the photometeric method number 965.12 of AOAC (1990). Samples (1 -2g) were ashed at 600°C for 4 hours or until white. The residue was dissolved in 40 ml HCl (1: 3 v/v: 3 parts de-ionized water) adding several drops of conc. HNO_3. The solution was brought to boil, cooled and diluted

to 200ml with de-ionized water. After filtration, aliquots containing 0.5mg to 1.5mg P were placed in 100ml volumetric flasks to which 20ml molybdovanadate reagent was added, and diluted to the mark. After allowing the solutions to stand for 10 minutes, the absorbance was read at 400nm against a 0.5mg standard set at 100% T. Phosphorus was determined from a standard curve of 0.5, 0.8, 1.0 and 1.5mg P standard solutions prepared from a working solution of 0.1 mg P / ml. The working solution was obtained from a 50ml stock solution (8.788g KH_2PO_4 in 1 L) diluted to 1 L. From the standard curve, % P = mg P in aliquot /g sample in aliquot x 10).

3.1.3.6. Calcium

About 4g sample was ashed and then dissolved in water. 20ml of this solution was pipetted into a 150ml beaker, 10ml hydrochloric acid solution added and topped with distilled water to produce 50ml. This was followed by the addition of 2 drops of methyl red indicator. The solution was then boiled for some few minutes. To the hot solution, 15ml of saturated ammonium oxalate solution and 5g of urea were added and boiled for another 10 minutes. Dilute ammonia was added drop-wise to the hot solution (70°C -80°C) with continuous stirring until the liquid was neutral or faintly alkaline (colour change from red to yellow). The solution was then left to stand overnight. On the next day, the solution was filtered using coarse filter paper (Whatman no.1) with the addition of small volume of water until chloride free. The precipitate was next dissolved with 30ml to 50ml of hot 2N

sulphuric acid and immediately titrated with standard N/50 potassium permanganate. The temperature of the solution was maintained at 60°C.

mg Ca / 100g sample was calculated thus:

Titre x 0.4 x 5 x 100/ Weight of sample

1 ml of N/50 $KMnO_4$ = 0.4 mg of calcium

3.1.3.7. Iron

20ml of digested sample solution was pipet ted into a 50ml volumetric flask, 40mg of crystalline ascorbic acid added and the neck of the flask rinsed with a small volume of water. About 10 minutes was allowed for complete reduction of the iron to the ferrous state. 10ml of ammonium acetate solution was next added and the pH of the solution tested with indicator paper to ensure a pH value of 4 to 5. 2ml of dipyridyl solution was added and the volume made up to the mark. 60 minutes was allowed for full development of colour at room temperature. The optical density was then measured at 500nm and for the setting of the colourimeter a blank solution was used.

In exactly the same way 0.5,1.0, 2.0, 5.0, 10.0ml of the standard solution was treated and measured and the resulting calibration curve was used for the determination of the iron in the sample solution.

mg iron/100g sample was calculated thus: mg/100g x 25/weight of sample

3.1.3.8. Moisture

Moisture was determined by the AOAC (1990) method number 934.01. Accurately weighed uniformly blended 1 -2g samples were introduced into pre weighed aluminum dishes (75mm diameter, 25mm deep) and dried in a vacuum oven at 70°C and 100 mmHg for a period of 9 to 12 hours. The moisture content was reported as loss in weight of samples after drying.

3.1.3.9. Tannin

The tannin contents of the varieties were determined using the procedure of Burns (1963), Maxon and Rooney, (1972) and Price et a/. (1978). 0.25g of milled sample was weighed into two Erlenmeyer flasks, and 10ml of 4% HCI in methanol was pipet ted into each flask. The flasks were then closed with parafilm and shaken for 20 minutes. The extracts were transferred into centrifuge tubes and centrifuged for 10 minutes at 4500rev. per minute. The supernatant aliquots were transferred into 25ml volumetric flasks. The residues were rinsed back from the centrifuge tubes into the original conical flasks using 5ml of 1% HCI in methanol. The shaking and centrifugation steps were the repeated. The combined extracts

were topped to the 25ml mark in the volumetric flasks. 1 ml of each extract was pipet ted into corresponding labelled test tubes. A set of catechin standard solutions were prepared by pipetting 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, and 1.0ml respectively of stock catechin solution into the tubes and made up to the 1 ml mark with the addition of methanol. After this, 5ml of freshly prepared vanillin-HCl reagent was slowly added to each of the standard solutions and the sample extracts. The absorbances of the standard solutions, sample extracts and sample blanks were taken with a spectrophotometer at 500nm exactly 20 minutes after adding the vanillin-HCl reagent to the samples.

A standard curve of absorbance (y) against catechin concentration (x) was prepared and the intercept and slope of the curve calculated. The blank absorbance reading was subtracted from the sample reading and the value was substituted into the regression equation in order to find the concentration of the extracts:

$y = a + bx$ where a = intercept, and b = slope of the graph.

The concentration in μg ml was converted into mg catechin / ml and the percent catechin eqivalents (% CE) were calculated as follows:

$\% CE = CC \times VM / VE \times wt$

Where CC = catechin concentration (ml/ml); VM = volume made up (mi) i.e. 25; VE = volume extract (ml) i.e. 1; and wt. = weight of sample.

3.1.4. Pasting Characteristics

This analysis was done using the Brabender Viskograph. Weighed samples of the different sorghum varieties were milled in a laboratory mill into fine particle sizes.

Using distilled water 8% slurry was made from the milled mass of the various samples and used for the running of the test.

The sample slurry was then transferred to the sample cup in the instrument and the sensing element placed in position. The instrument head was then lowered into the operating position; the thermo-regulator having previously been adjusted to 25°C.

The instrument was started, and temperature of the sample was increased at a rate of 1.5°C per minute. Heating was continued until the sample temperature reached 95°C, and the sample was maintained at this temperature for one hour while stirring and recording the viscosity continuously. The paste was then cooled to 50°C at a rate of 1.5°C per minute and held for one hour, at this temperature whilst stirring. Heating and cooling at the specified rate and temperature at the specified temperature are accomplished automatically by the instrument controls.

When the Brabender curves for the samples are plotted, they follow a specific pattern that contains five points of significant interest namely

- The peak viscosity, (P) irrespective of the temperature indicates the highest viscosity, which the user might encounter in the preparation of a usable paste.

- The viscosity of the paste when it reaches a temperature of 95°C, in relation to the peak viscosity, reflects the ease of cooking the starch.

- The viscosity after one hour at 95°C, (H) indicates the stability or breakdown of the paste.

- The viscosity of the cooked paste after cooling to 50°C, (C) is a measure of the setback produced by cooling.

- The final viscosity after stirring one hour at 50°C indicates the stability of the cooked paste as it might be used.

From the above direct measurements, the following important rheological indices were also computed:

- Breakdown, (BD) - P -H

- Setback, (SB) - C –P

- Total setback (SBt) - C- H
- Relative breakdown (BDr) - (P-H) / (C-H)
- Breakdown ratio - H/P
- Setback ratio - C/P
- Total setback ratio - C/H

RESULTS AND DISCUSSION

Table 1 shows some of the physical quality characteristics of the sorghum varieties. The seven cultivars of sorghum evaluated showed some variation for the selected parameters. The 1000-grain weight is a measure of grain size. The mean 1000-grain weight was 27.98g. Local 29 variety recorded the highest value of 32.70g indicating that out of the seven varieties, it had the largest grain. Kadaga and Mankaraga followed with 31.09g and 30.78g respectively. NSV 1 had the smallest grain size with a 1000-grain weight of 23.57g.

Pericarp colour is important because it influences the colour of any product made from that grain. For instance if the grain is to be milled and used for porridge meal such as *koko* and *tuo*, a white to light colour is generally preferred. In some parts of northern Ghana red coloured sorghum varieties are preferred in the brewing the local alcoholic beverage *pito*. Colour is therefore an important attribute of local food preparations such as *koko* and *tuo*. Four of the improved varieties were comparable to the white colour of the Local 29 variety. These are Mankaraga, NSV 1, Kapaala and Naga White. Even though they are all bicoloured, the white colour dominated making them nearer to the white Local 29. Kadaga and NSV 2 had dark colours of red and brown respectively. This means that these varieties would not be the most sought after ones in the preparation of foods like *koko* and *tuo* since a white to cream appearance is an important parameter with respect to consumer acceptability

of these foods. Pericarp thickness affects dehulling loss and milling yield. Grains with thin pericarps need a shorter dehulling time than thick pericarp grain. NSV 1 and Local 29 had pericarps of medium thickness. The pericarps of the remaining varieties were thin. This means Mankaraga, Kadaga, NSV 2, Naga White and Kapaala will have a relatively shorter dehulling time than NSV 1 and Local 29.

Of the varities evaluated, only NSV 2 and Naga White showed the presence of a testa. The testa closely adheres to the endosperm and for that matter affects the colour of milled products. The tannins in the testa also affect taste and digestibility.

The endosperm colour was white to translucent for all the varieties but endosperm texture showed differences. Endosperm colour, like testa affects the colour of milled products while endosperm texture affects hardness, hence the milling yield. NSV 2, Mankaraga, and Local 29 had about 80% of the endosperm being vitreous with 20% accounting for the floury inner part. NSV 1 and Kapaala showed an almost total vitreous endosperm texture.

Kadaga had a very floury endosperm of about 80% with only 20% being vitreous. Table 2 shows the proximate composition of the varieties. The nutritional statuses of all the varieties fall within the generally expected range for Sorghum (McCance and Widdowson, 1992). Local 29 and Kadaga had the highest ash contents of 1.6% with the others ranging between 1.35% and 1.5 %.

The mean fat content of the varieties was 3.97%. Kapaala and Kadaga had high values of 4.8% and 4.7% respectively with Naga White recording the least of 3.0%. Kadaga, Mankaraga, NSV 1 and NSV 2 showed higher protein content than Local 29 variety (9.6%). NSV 1 had the highest value of 12.1%. Naga White and Kapaala had lower values of 9.5% and 9.2% respectively.

The average carbohydrate content was 73.88%. Naga White had the highest carbohydrate content of 76.3% and Mankaraga had the least value of 72%. A high carbohydrate content generally indicates a better malting potential. Grains with such high carbohydrate content may be suitable for the brewing of pito and other malted products.

The minerals content of the cultivars (Table 3) were also within the levels stated by Hulse et al (1980) and McCance and Widdowson, (1992). For the major minerals (Calcium, Phosphorus and Iron), there was little variability between the varieties. However, Naga White had higher Calcium content of 11.8mg/100g. Kadaga, NSV 1 and NSV 2 had greater amounts of Phosphorus than the Local 29. The mean Iron content of the varieties was 1.96. Kadaga had the highest amount of 2.5 mg/100g.

In sorghum, tannins are predominantly found in the pericarp and pigmented testa layer. Therefore red sorghums and in particular brown sorghums, that have testa, are usually high tannin sorghums. Tannins in sorghum have agronomic advantages such as seed protection from mould attack, insects, birds

and pre-harvest germination. However they also have anti-nutritional effects. They bind to and precipitate proteins thereby reducing their availability to the body (Hahn *et al*, 1984). The tannin content of Kadaga was very high, i.e. 9.10mg catechin equivalent (CE) per gram of sample. The remaining varieties had tannin levels of less than 1.0mg CE/g of sample. This means that with the exception of Kadaga, the other recommended varieties have tolerable levels of the anti-nutritional factor tannin.

Tables 4 and 5 show the results of the pasting characteristics and some Brabender viscoamylographic indices of the seven varieties of sorghum investigated respectively. The peak viscosity, which indicates the highest viscosity that the user might encounter in the preparation of a usable paste ranged between 110 Brabender Units (BU) and 420BU. This is a measure of the ability of the starch to form a paste during cooking. The higher the value the thicker the paste would be. Mankaraga recorded the highest peak viscosity of 420BU followed by Naga White with a value of 375BU. Kapaala recorded the lowest peak viscosity of 110BU.

The breakdown viscosity is a measure of the stability of the paste after cooking for one hour at 95°C. The breakdown viscosity values ranged from 75BU for Kapaala to 240BU for Mankaraga. This means that Mankaraga had the most stable starch on cooking while Kapaala ahd the least. The indices of setback and total setback are considered as a measure of retrodegradation of starch (Bhattacharya and Sowbhagya, 1979). In addition, these two indices especially

total setback are closely related to their amylose content. A high setback or total setback value indicates a high amylose content. As indicated in table 4, Mankaraga had the highest total setback value and could therefore be expected to have a high amylose content while Kapaala is expected to have the lower amylose content.

Conclusion and Recommendation

Although work done so far is not very extensive and in depth to enable one draw very definite conclusions, the following general ones may be drawn from the above discussion.

NSV 1 is rich in protein, has high energy and good amounts of minerals. It may therefore be suitable for infant food formulation. Kapaala and Naga White have high carbohydrate levels and quite low protein levels. This makes them suitable for malting and brewing trials. Traditionally they may be useful for the brewing of *Pito,* an alcoholic beverage. The levels of tannins in all the varieties apart from Kadaga were within tolerable limits.

Mankaraga, due to its high paste stability and viscosity may be suitable for the preparation of traditional thick porridge, t*uo.* NSV1 and NSV2 have good peak viscosities and paste stabilities comparable to the local 29 variety. Kapaala and Kadaga based on their starch properties could be ideal for thin porridge, *koko.*
It is suggested that further work be done on the suitability of the new sorghum varieties for specific local staples like *tuo* and *koko*. This should include sensory evaluation so that each of the varieties can be precisely recommended for a specific use.

Table 1. Physical Quality Characteristics of Some Sorghum Varieties

Variety	Colour	Pericarp Thickness	Testa	Endosperm colour	Endosperm Texture	1000 grain wt./ g
Mankaraga	Yellow & White	Thin	Absent	White	Pearly	30.78
Kadaga	Red	Thin	Absent	White	Chalky	31.09
NSV 1	Yellow & Grey	Medium	Absent	White	Pearly	23.57
NSV 2	Grey & Brown	Thin	Present	White	Pearly	24.19
Local 29	White	Medium	Absent	White	Pearly	32.70
Naga White	White & Brown	Thin	Present	White	Chalky	27.50
Kapaala	Yellow	Thin	Absent	White	Pearly	26.05

Table 2. Proximate Composition of Some Sorghum Varieties.

Variety	% Moisture	% Ash	% Fat	% Protein	% Carbo-hydrate	Energy (Kcal/100g)
Local 29	10.2	1.6	4.4	9.6	74.2	423
Kadaga	9.8	1.6	4.7	11.5	72.4	378
Naga White	9.7	1.5	3.0	9.5	76.3	370
Kapaala	9.5	1.4	4.8	9.2	75.1	380
Mankaraga	11.6	1.5	4.1	10.8	72.0	368
NSV 1	8.8	1.3	3.6	12.1	74.2	378
NSV 2	11.3	1.4	3.2	11.1	73.0	365
Mean	10.12	1.47	3.97	10.54	73.88	380.28
LSD	0 .92	0.10	0.66	0 .85	1.41	18.21

Table 3: Mineral and Tannin contents of recommended some sorghum varieties

Variety	Calcium (mg/100g)	Phosphorus (mg/100g)	Iron (mg/100g)	Tannins (mg CE/g)
Local 29	11.7	61	2.0	0.30
Kadaga	9.5	78	2.5	9.10
Naga White	11.8	60	2.0	0.38
Kapaala	11.1	51	1.5	0.14
Mankaraga	11.5	60	2.0	0.59
NSV 1	10.1	75	2.0	0.62
NSV 2	11.0	67	1.7	0.45
Mean	10.59	64.5	1.96	1.65
LSD	0.80	8.72	0.29	3.04

Table 4. Pasting Characteristics of Some Sorghum Varieties.

Variety	Pasting Temperature (°C)	Peak Viscosity (BU) [P]	Viscosity at 95°C (BU) [V 95]	Hot Paste Viscosity (BU) [H]	Cold Paste Viscosity (BU) [C]
Local 29	86.1	360	60	160	320
Kadaga	76.5	140	40	40	115
Naga White	84.5	375	130	160	350
Kapaala	84.5	110	20	35	100
Mankaraga	85.0	420	100	180	400
NSV 1	87.0	360	45	142	335
NSV 2	82.5	330	90	130	300
Mean	83.72	299.28	69.28	121.00	274.28
LSD	3.22	113.16	36.00	54.72	109.43

Table 5. Brabender viscoamylographic indices of some Sorghum Varieties

Variety	Breakdown [P-H]	Setback [C-P]	Total Setback [C-H]	Relative Breakdown [P-H]/[C-H]	Breakdown Ratio [H/P]	Setback Ratio [C/P]	Total Setback Ratio [C/H]
Local 29	200	-40	160	1.25	0.44	0.89	2.00
Kadaga	100	-25	75	1.33	0.28	0.82	2.87
Naga White	215	-25	190	1.13	0.42	0.93	2.18
Kapaala	75	-10	65	1.15	0.32	0.91	2.85
Mankaraga	240	-20	220	1.09	0.43	0.95	2.22
NSV1	218	-25	193	1.13	0.41	0.93	2.34
NSV2	200	-30	170	1.17	0.39	0.91	2.31

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