PHYSICO-CHEMICAL PROPERTIES OF FOUR GHANAIAN SORGHUM (*Sorghum bicolor*) VARIETIES

A PROJECT REPORT SUBMITTED UNDER THE IFAD/FRI/ICRISAT SORGHUM IMPROVEMENT PROJECT

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September, 2001

SUMMARY

Some physico-chemical properties of four Ghanaian sorghum varieties (Kapaala, Kadaga, Mankaraga, Naga White) were studied. Separation of grains into small and large sizes, hardness of the grains, thousand kernel weight, water absorption, moisture content, crude protein content, germinative capacity, germinative energy and α- amylase activity were measured. Kadaga variety was found to be the best grain for pito production followed by Kapaala. Smaller grains must be steeped separately from large grains because they have different capacities for water absorption which affects the rate of germination. All varieties of sorghum used for the studies have relatively high levels of protein. They can therefore be used for infant food formulation as well as feed formulation for animals.

1.0 INTRODUCTION

Grain sorghum (*Sorghum bicolo*) is the staple food for more than seven hundred million people of the world (Sahnkhe et al, 1984). It forms a major source of calories and proteins to the poorest people of the arid and semi-arid tropics. In Ghana, sorghum is widely cultivated cereal in the northern parts of the country because it is used for the preparation of a staple diet called *tuo zafi* (popularly called TZ). It is also used for the production of a local sorghum brew called *pito*. Thus the cereal is commercially important and is playing a major role in the socio-economic development of the local people in the dry savannah areas of the northern Ghana. There is also a potential use of sorghum in the bakery industry and for the production of malt-based foods especially in the feeding of children as well as the by-products in animal production.

In spite of its potential uses, sorghum industry in Ghana has not been well developed. This is attributed to a number of reasons. Key among these is the low level of technologies used in the production and processing of the cereal. This has resulted in poor returns for sorghum farmers and non-optimal use of sorghum in Ghana. To address this problem a 3-year project on improving sorghum production was initiated in 1999 under the aegis of International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Mali with sponsorship from the International Fund for Agricultural Development (IFAD). This work is part of the search to address the problem of poverty in the Sahel by increasing the utilization of sorghum. It is aimed at finding out the best variety of sorghum grains cultivated in the northern regions of Ghana which can be used for brewing of *pito*. The objectives of this study were:

1. To evaluate some of the physical quantitative parameters of the sorghum varieties which are relevant to malting and brewing characteristics.
2. To evaluate some of the chemical characteristics as well as the respective enzyme activities of the different varieties.

2.0 The Sorghum Grain

Sorghums belong to the botanical genus sorghum of the grass family gramineae. They are of tropical origin and native to Africa and India. They are usually tall, robust plants with flat leaf blades and terminal panicles. There are two natural divisions of the genus sorghum grown as field crops. These are sorghum halepense and sorghum vulgare. Sorghum halepense (Johnson grass), is the division in which the plants are perennial with 20 chromosomes and creeping rhizomes. This is of little importance except for pasture and hay. The other division, sorghum vulgare, in which the plants are annual and have 10 chromosomes, include all the cultivated sorghums. These are divided agronomically into four general groups: (a) grain sorghum; (b) sorgos (sweet or saccharing sorghums); (c) brown corn; and (d) grass sorghums.

The grain sorghum plant is a coarse grass that may grow from two feet to more than 15 feet in height. Cultivated grain varieties are usually two to five feet tall. They have a rather large stiff stalk and a shallow root system. The stalks terminate in a loose to dense panicle of blossoms (called a "head") that mature into as many as two thousand seeds. A typical head of sorghum is nearly a foot long and will weigh about one pound.

Grain sorghums are primarily for grain and generally have larger seeds and produce seed more abundantly than the other sorghums. They constitute the third largest grain crop in the world (Kramer, 1959.) and are very important food crop in arid and semi-arid tropical areas (Sahnkne et al, 1984.). It provides the staple diet for low-income groups of India and Africa and accounts for about 50% of the total cereal production in Nigeria (Oke, 1977). Sorghum is one of the most widely cultivated cereals and important staple in northern Ghana. The total production of the crop has however not increased over the years as a result of low yields.

2.2 Cultivation conditions

Sorghums are widely adapted and are grown on all continents. The crop is however better adapted to semi-arid conditions than any other grain and generally will out-yield other cereals in areas with less than 30 inches annual rainfall. They require an average temperature of 65^{o}F or higher and a frost-free period of 120 days during cultivation. They are grown from sea level to elevations as high as 5,000 feet. Yield is encouraging on well drained soils ranging in pH between 5.5 to 8.5. The crop matures within 140-190 days depending on the variety cultivated. In Ghana, sorghum 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.

2.3 Nutritional Composition

Sorghum contains adequate quantities of nutrients such as protein, carbohydrates, fat and minerals to meet the daily requirements of humans (1). The protein quality of some genotypes appears to be comparatively better with respect to their amino acid composition. Lysine is the most limiting amino acid in sorghum. Starch accounts for about 56-75% of the total dry matter in sorghum. The physical characteristics of starch such as gelatinisation temperature, swelling power and solubility are variable. The sorghum grain contains 1.3 to 3.3% ash and minerals like phosphorus, potassium and magnesium in varying quantities. The tannin content (catechin equivalence) of brown sorghum grain range from 0.13 to 7.22% (5).

2.4 Uses of sorghum

About 75% of sorghum cultivated in the world is eaten by humans. In parts of India, Africa and China, it is the chief food grain. As a food, it is used to make bread, boiled with meals or cooked to porridge. It is also fermented into a drink. The stalks of sweet sorghum are eaten fresh or compressed into juice or syrup.

Grain sorghum finds only limited use as human food in the United States. The chief use for the grain is as feed for livestock with corn and barley as a feed grain. Sorghums are also a source of industrial raw materials. It is estimated that about 20 million bushels are used annually to produce alcohol and distilled spirits, and in the wet and dry mill industries. Such products as starch, dextrins, dextrose, syrups and edible oil as well as dry milled flours are readily available from grain sorghum.

In Ghana, sorghum is basically used as food leaving its industrial potential untapped. Its food value is largely utilized in the traditional diets of the inhabitants of the northern sector of the country. The processing methods used in these processing of sorghum are also indigenous. The major products sorghum can be processed into in Ghana include *pito* (a local brew), *koko* (thin porridge), *tuo* (thick porridge) and malt.

3.0 MATERIALS AND METHODS

Four sorghum varieties produced by Savannah Agricultural Research Institute (SARI) were used for the studies. These were Kapaala, Kadaga, Mankaraga and Naga White. The methods used in this study are described below.

3.1 Physical Parameters Determined

The physical parameters assessed were the hardness, the thousand kernel weight and the percent water absorption

3.1.1 Separation of the grains into two portions; small and large sizes

The grain sizes of all three of sorghum varieties were not uniform. It has been well established that grain size could decidedly affect some of the physico-chemical and the functional properties of sorghum, Duffour (1994). This is especially true for water absorption capacity. It has been established that the size of the sorghum grain could affect some of its physical properties, such as the amount of water it is able to absorb. Thus grains of the different varieties were first separated into large and small using sieves of mesh sizes 4 and 6 (Newark Wire Cloth Company, New York), respectively.

Fifty grains of each of the small and large samples of the four varieties were taken and the average sizes measured using a digimatic caliper. Measurement was taken across the longest section of each grain. The mean size was calculated and that represented the size of the group.

3.1.2 Hardness

Hardness was determined to assess how easily the respective varieties can be milled. Harder grains generally give a higher milling yield. Grain hardness also influences water absorption, which in turn has an effect on diastatic enzyme activity.

The grains were visually assessed by a panel of three and scored on a scale of 1 to 5 based on proportion of floury to vitreous endosperm; hardness scoring using this method is thus rather subjective.

3.1.3 Thousand Kernel Weight

The thousand kernel weight indicates the grain's density. The thousand kernel weight is, like the moisture content, an important factor by the assessment of the grain during purchase since it also delivers the average dry weight of thousand kernels minus the moisture content. Three sets of 100 kernels, manually counted, were obtained and weighed. The mean of the three weghings were determined and this was recorded.

3.1.4 Water Absorption

The percent water absorption of sorghum is the amount of water absorbed by a sample of sorghum grain in a given time. It gives an indication of the approximate depth of penetration of water into the kernel over that time. It gives an indication of the hardness of the endosperm. This is a useful factor to know when one wishes to condition grain before dehulling, milling and duration of steeping. Grains with lower percent water absorption require longer conditioning and steeping.

The percent water absorption was carried out on the two sizes of the grains from each variety. The water absorption characteristics of the varieties were determined by steeping triplicate samples, each 10 g, of the whole grains of each variety in water (1:5 w/v) at 28 °C for 1 to 9 h as well as for 24 h). At the end of the each steeping period, the grains were removed from the water, spread on a soft kitchen tissue paper and gently wiped and weighed. The tests were repeated with slightly warm water, at 37 °C, using a water bath.

3.2 Chemical Parameters Determined

The chemical parameters determined were the moisture content, crude protein content, the malting behaviour and diastatic power

3.2.1 Moisture Content

It is important to know the moisture content (m.c) of the grain because the m.c is an indication that the grains were well dried and most likely did not experience any fungal damage. Fungal damage is known to adversely affect the use of sorghum for making malt (Duffour, & Melotte, 1992). The m.c was determined according to AACC (AACC, 1983) air- oven method.

3.2.2 The Crude Protein Content

Protein is one of the most important nutrients in foods. The protein content of the grain can be affected by many different factors, e.g., inherent qualities of the grain itself or management of the crop and agronomic conditions. It is thus useful to be able to determine grain protein content in order to ascertain the grain's nutritional value, or to observe the effect of different treatments on its protein content. The crude protein amounts in the sorghum varieties were determined using the micro Kjeldahl method (AACC, 1983).

3.2.3 Germinative Capacity and Germinative Energy

Germination tests are fundamental to the whole success of the brewing process. Germination capacity is the percentage of all living grains in a given quantum. For the maltster, the germinative capacity of the grain is of a particular importance. In the malt house, the aim is to bring the grains to germinate. It is therefore very important that a high percentage of the grains have the capacity to germinate and that the germination is also even and regular. The germinative capacity is therefore an indication of the extent of viability of the grain for malting (germination) and therefore an important factor by grain purchase. The germinative energy is the percentage of grains in a given quantum, which after 3 days and after 5 days under normal ambient temperatures and very high relative humidity, germinate. It is an important factor at the point of time to malting and a test of the regularity of germination.

The germination capacities of both the small and large grains of each variety were determined using the method as described below;

Two lots of 200 grains of each sorghum variety were taken and steeped for two days in 200 ml hydrogen peroxide solution (7.5g/L) at 27^0C). The solution was strained off and 200 ml fresh hydrogen peroxide solution was added to the grains. The grains were then steeped for one additional day. The solution was removed and grains which had developed both root and acrospire growth were counted. Grains which developed either root or acrospire growth were also counted; so were grains which did not show either root or acrospire growth.

3.2.4 α- Amylase Activity

Only a preliminary study of the respective α- amylase activities of the malt of the four sorghum varieties was undertaken. The Biocon Ceralpha method was used in the investigation. Approximately 20 g of the malted sorghum grains was milled so as to pass through 0.5 mm screen. 0.5 g of the malt flour was accurately weighed into 100 mL volumetric flask. To this volumetric flask, a solution containing 1 % sodium chloride, 0.2 % calcium chloride and 0.02 % sodium azide was added. The enzyme was allowed to extract over a period of 1h at room temperature; with occasional mixing. An aliquot of the solution was filtered through a Whatman GF/A glass fibre filter paper. Approximately 0.1 mL aliquots of the α- amylase substrate solution was dispensed into test-tubes and the contents pre-incubated at 40 °C for 5 min. To each of the tubes containing the substrate solution, 0.1 mL of the pre-incubated sorghum malt was added and then incubated at 40 ° C for exactly 10 min. At the end of the 10 min, 1.5 mL of the stopping regent was added and stirred vigorously. The absorbance at 410 nm of the solutions and the reaction blank against distilled water were immediately read.

4.0 RESULTS AND DISCUSSION

4.1 Physical parameters

Table 1 (page 16) shows the average sizes (small and large) of the grains of the four sorghum varieties produced by SARI. It indicates that all the small grains of the four varieties are comparable and significantly different from the large grains.

Table 2 (page 17) shows the hardness of the grains of the sorghum varieties under study. It indicates that the hardness of the grains are as follows; Mankaraga < Naga White< Kapaala < Kadaga. This means that Kadaga is the hardest of the four varieties of grains under study and Mankaraga is the least hard variety.

Figure 1 (page 16) shows the thousand kernel weight of the four varieties of sorghum under study. It indicates that the Kadaga variety appears to be denser than the rest. The denser the grain, the more floury it is and this is known to indirectly influence the success of the malting of the grains.

Figures 2 – 7 (page 10) reveal that the sorghum varieties Mankaraga and Naga White absorb water much better than Kapaala and Kadaga. This is due to the fact that Kadaga and Kapaala are harder than Mankaraga and Naga white (Table 2).

Figures 10 and 11 (page 12) also reveal that the smaller the grain sizes the better the absorption rate and amount. These are in line with the findings of Duffour, 1994. Figures 12 –15 (page 13) indicate that a slightly warm water can significantly improve the water absorption rate and extent. Figures 8 and 9 (page 12) follows the principle of the smaller the grain size the more water it absorbs. It was observed however that Naga White deviated a bit from this principle. This could be attributed to a number of factors, one of which could be the fact the Naga White grains are comparatively softer than the other grains under study.

4.2 Chemical Properties

The moisture content of all the varieties fell between 9.49 to 9.98 %w.b. This is an indication that the grains were well dried.

Figure 18 (page 17) shows the total nitrogen and protein contents of the four varieties of sorghum produced by SARI. The protein content of all the varieties lie between 2 and 3 %. The relatively high protein contents of all the varieties (Fig. 18) indicate that all the varieties have the potential in the formulation of either good feed for animal (pigs and goats) or even for baby food formulations.

Figure 17 (page 15) shows the germinative energies of the four varieties of sorghum under study.

As shown in Fig. 17, the germinative energies of the two of the varieties, Kapaala and Mankaraga were too low for good malting. For brewing, the germination energy should be about 90 %. If the germination energy falls below 65 %, the grain is not viable enough to malt because diastatic enzymes are activated only during germination (Gomez *et al.*, 1997). A number of factors could account for the low germinative energy of Kapaala and Mankaraga. These include the very nature of the varieties, the drying and storage conditions.

Table 3 (page 16) gives the results of the α - amylase activity determinations. The table indicates that Mankaraga and Naga White have low α - amylase activity compared to Kadaga and Kapaala. The diastatic power is the joint ability of the enzymes α - amylase andβ -amylase to break down starch (Novellie, 1985). The α - amylase breaks down the starch chiefly into large fragments and is responsible for the thinning of the porridge. The β -amylase breaks down these large fragments into sugar and is mainly responsible for the saccharification of the mash. In most sorghum grains, the ratio of α : β -amylase varies from 2: 1 to 3:1 (Dryer & Novellie, 1966).

Fig. 2 Effect of variety on the amount of water absorbed by sorghum (Kapaala and Kadaga)

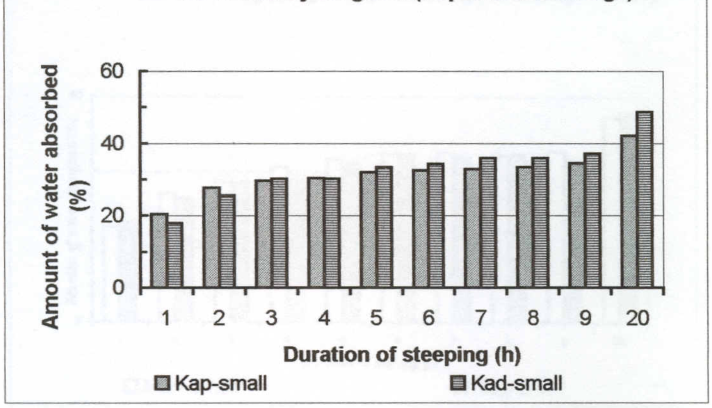


Fig. 3 Effect of variety on the amount of water absorbed by sorghum (Kapaala and Framida)

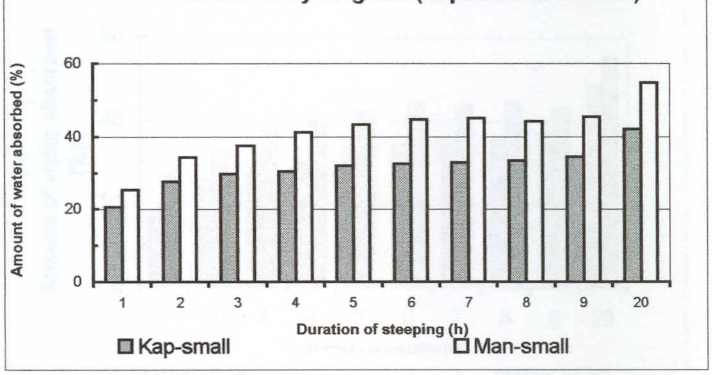


Fig. 4 Effect of variety on the amount of water absorbed by sorghum (Kadaga and Mankaraga)

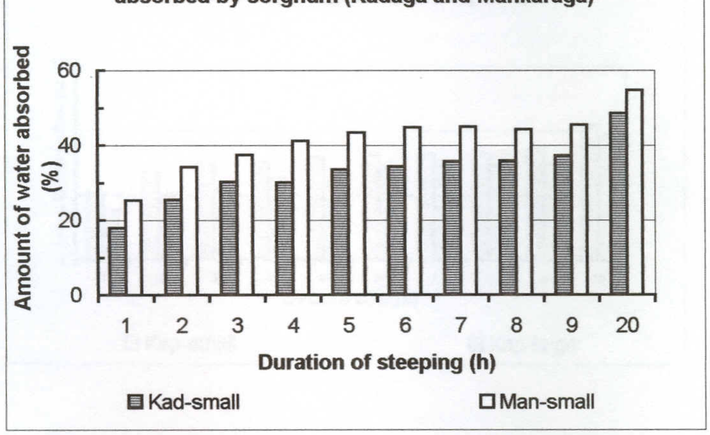


Fig. 5 Effect of variety on the amount of water absorbed by sorghum (Mankaraga and Naga-White)

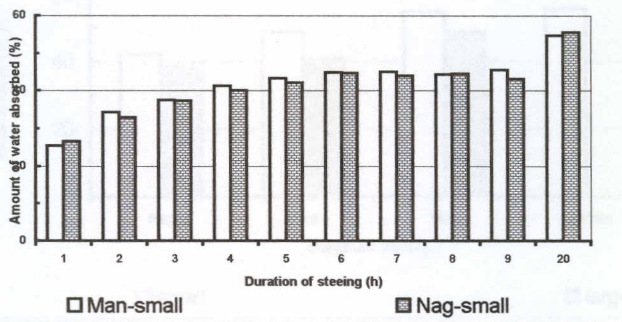


Fig. 6 Effect of variety on the amount of water absorbed by sorghum (Kadaga and Naga White)

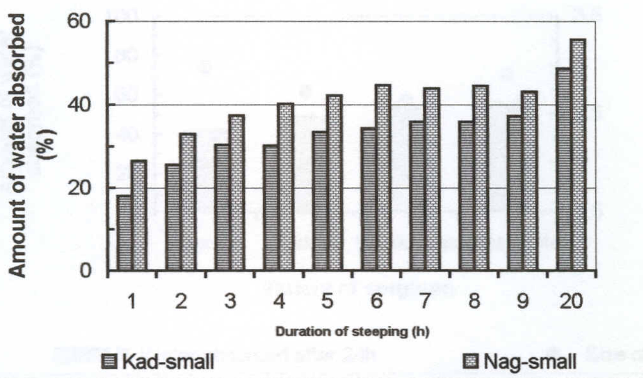
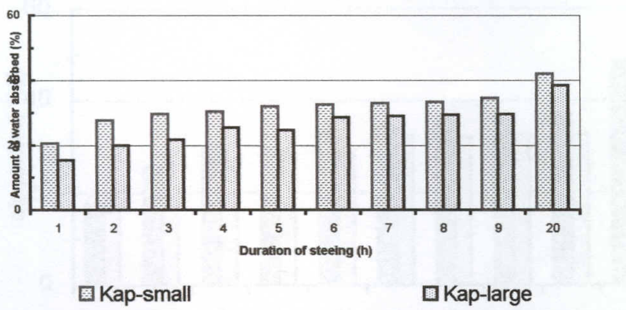


Fig. 7 Effect of size on the amount of water absorbed by sorghum (var. Kapaala)



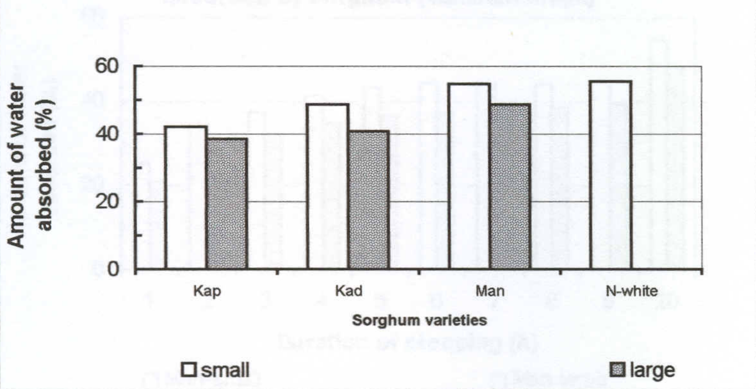


Fig. 8 Amount of water absorbed by four varieties of sorghum (small and large grains) after 24 h steeping

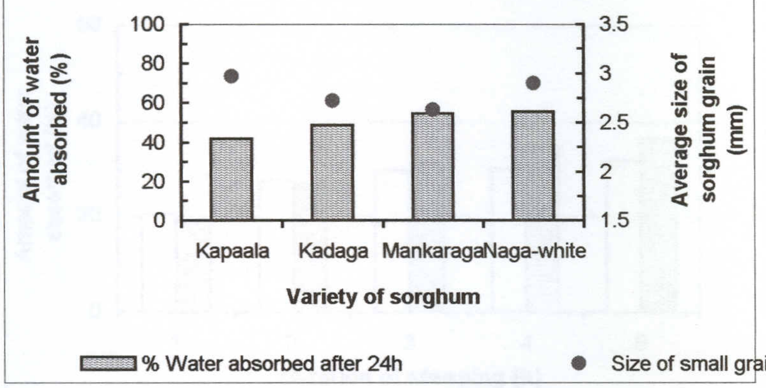


Fig. 9 Effect of size of sorghum grain on the amount of water absorbed after 24 h of steeping

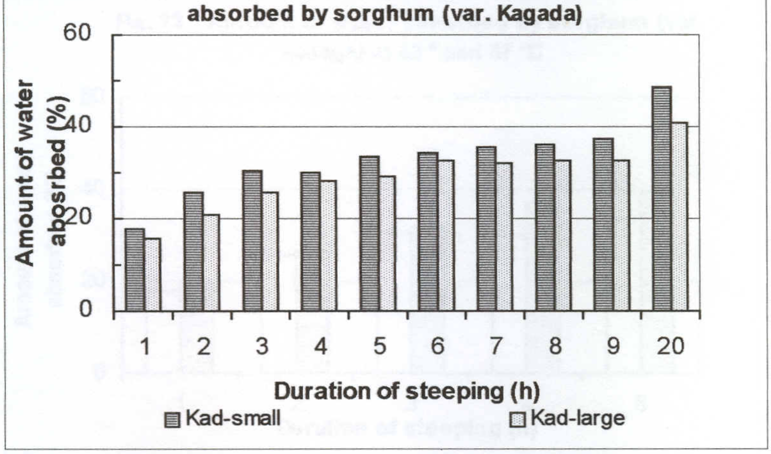


Fig. 10 Effect of size on the amount of water absorbed by sorghum (var. Kagada)

Fig. 11 Effect of size on the amount of water absorbed by sorghum (var.Mankaraga)

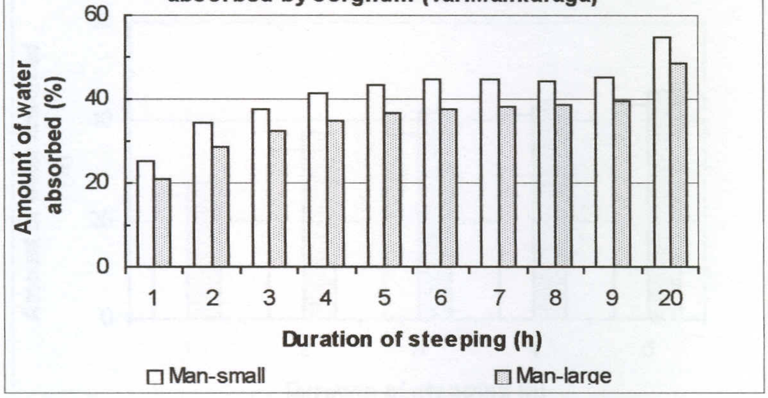


Fig. 12 Amount of water absorbed by sorghum (var. Kapaala) at 28 ° and 37 °C

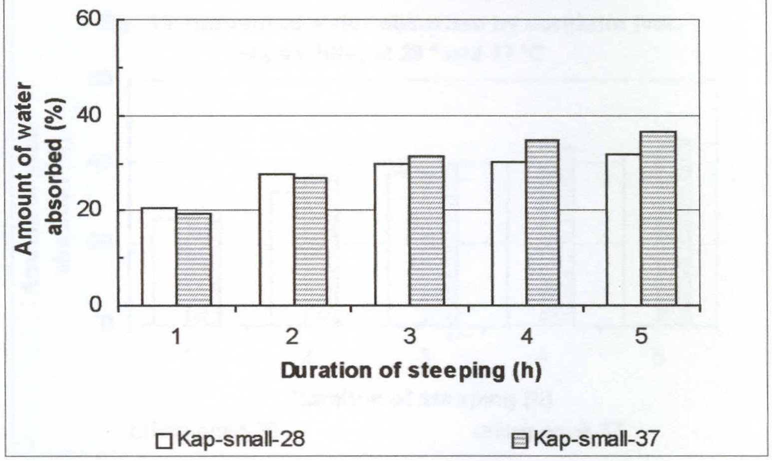


Fig. 13 Amount of water absorbed by sorghum (var. Kadaga) at 28 ° and 37 °C

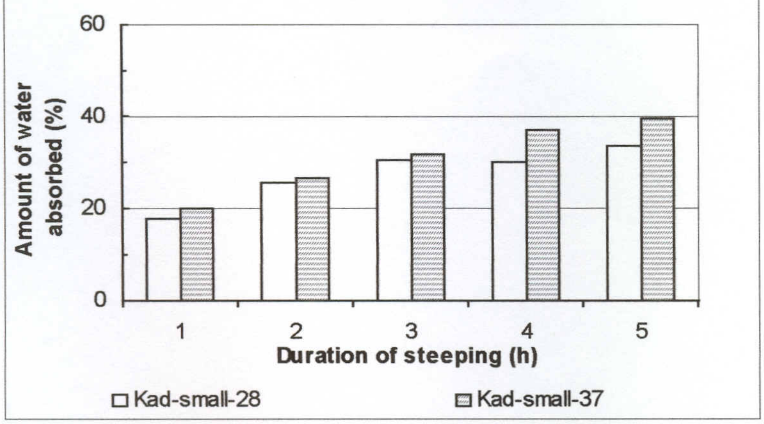


Fig. 14 Amount of water absorbed by sorghum (var. Mankaraga) at 28 ° and 37 ° C

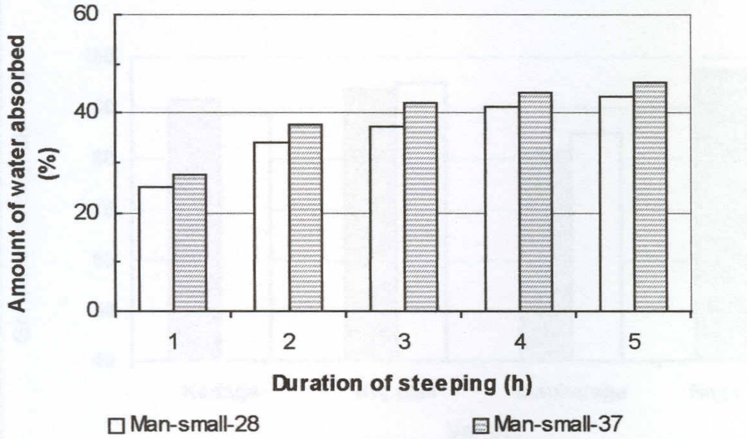


Fig. 15 Amount of water absorbed by sorghum (var. Naga white) at 28 ° and 37 °C

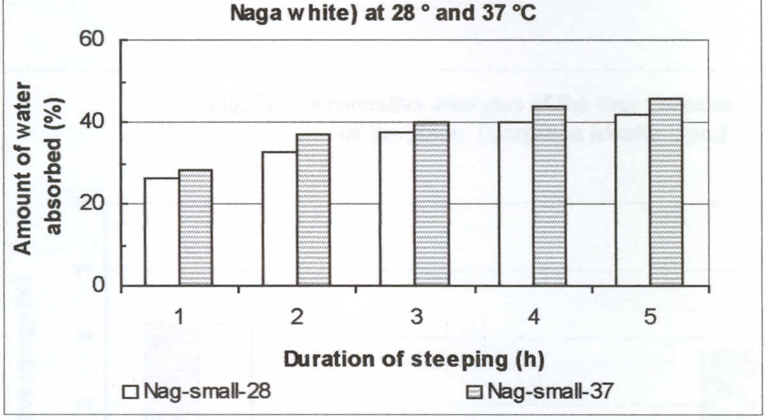


Fig. 16 Germinative capacities of four varieties of Sorghum (*Sorghum bicolor* spp.)

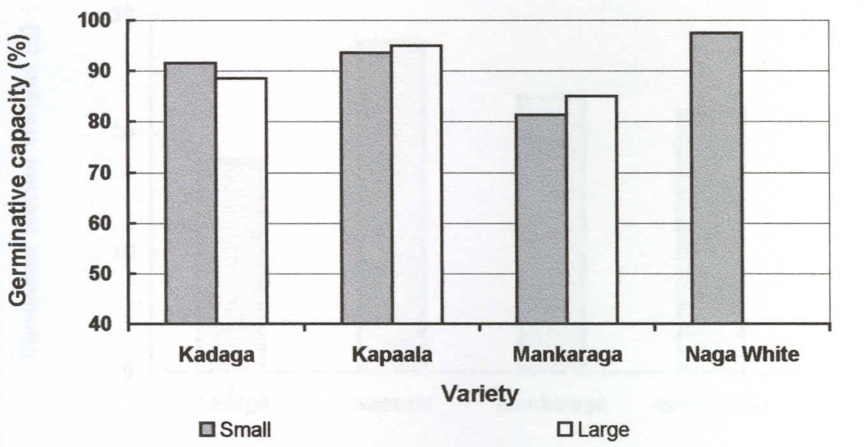


Fig. 17 Germinative energies of the four varieties of Sorghum (*Sorghum bicolor* spp.)

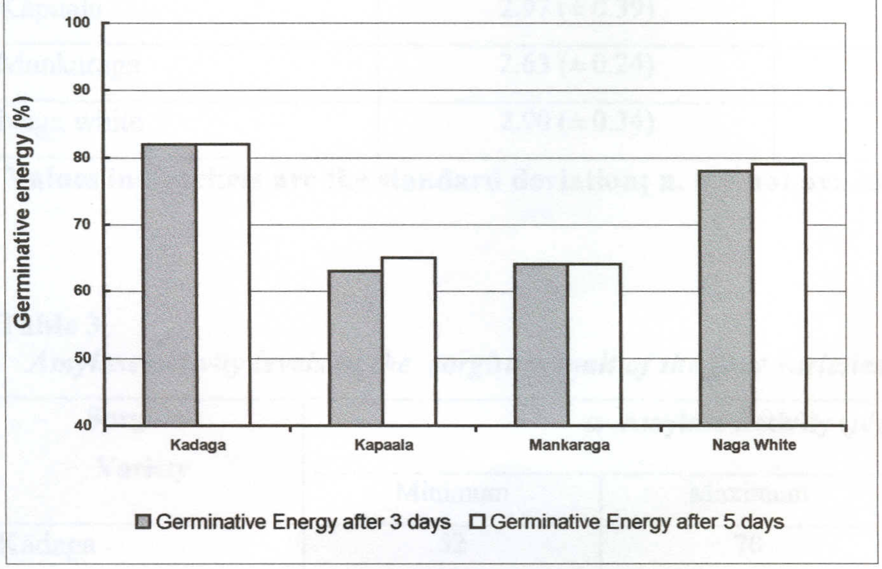


Fig. 1 Thousand Kernel Weight of the Four Varieties of Sorghum (Sorghum bicolor spp.)

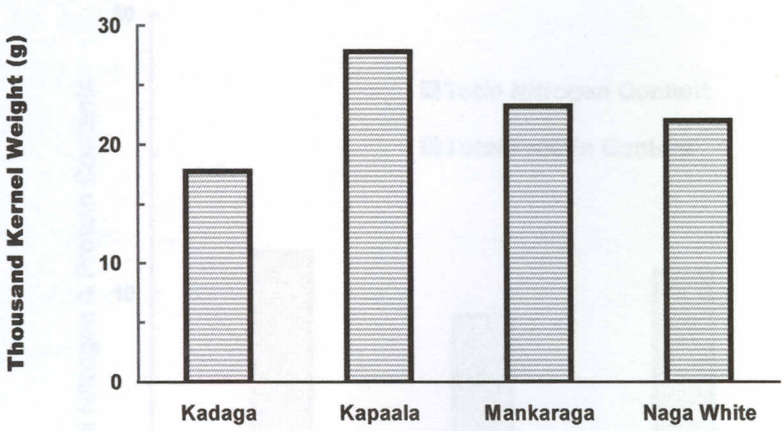


Table 1

Sizes of grains of four sorghum varieties (small and large) produced by SARI

Sorghum Variety	Mean sizes of small grains (mm)	Mean sizes of large grains (mm)
Kadaga	2.72 (± 0.49)	3.72 (± 0.31)
Kapaala	2.97 (± 0.39)	3.96 (± 0.20)
Mankaraga	2.63 (± 0.24)	3.98 (± 0.19)
Naga white	2.90 (± 0.34)	n.a

Values in brackets are the standard deviation; n. a = not available.

Table 3

Amylase activity levels in the sorghum malt of the four varieties produced by SARI

Sorghum Variety	α- Amylase Activity (μ/g)		
	Minimum	Maximum	Mean
Kadaga	52	70	61
Kapaala	68	72	70
Mankaraga	20	30	25
Naga white	24	32	28

Fig 18. Total Nitrogen and Protein Contents of the Four Varieties of Sorghum (Sorghum bicolor spp.)

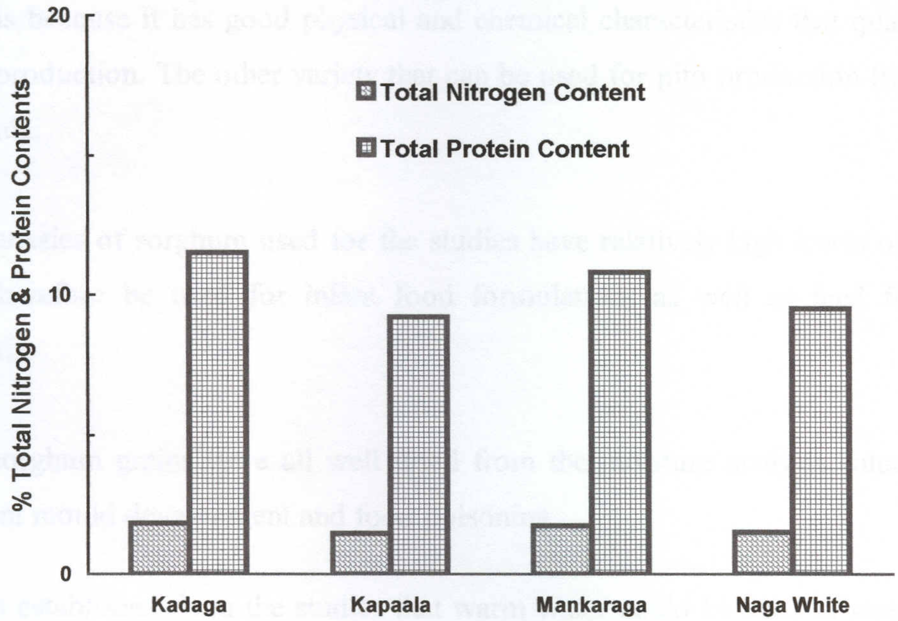


Table 2

Hardness of grains of four varieties.

Mankaraga < Naga White < Kapaala < Kadaga

5.0 CONCLUSSION

Kadaga variety was found to be the best grain of all varieties studied for pito production. This is because it has good physical and chemical characteristics that qualify a grain for malt production. The other variety that can be used for pito production from the study is Kapaala.

All varieties of sorghum used for the studies have relatively high levels of protein. They can therefore be used for infant food formulations as well as feed formulation for animals.

The sorghum grains were all well dried from the moisture analysis values. This would prevent mould development and food poisoning.

It was established from the studies that warm water could be used in steeping the grains to reduce the time of steeping. Also, smaller grains must be steeped separately from large grains since they have different levels for water absorption, which can affect germination of the grains.

REFERENCES

Kramer, N.W., 1959. *In* the Chemistry and Technology of Cereals as Food and Feed (Edt. By S. Matz), Avi Publishing Co., Westport, Conn. p. 120.

Hahn, R.R., 1966. Sorghum as a brewing adjunct, The brewers digest, pp. 70 – 74.

Adrain, J. and Sayerge, C., 1957. Composition of Senegal Millets and Sorghums, Brit. J. Nutrr. 11:99 – 105.

Oke, O.L., 1976. *In* Proceedings of a symposium on sorghum and millets for human food, Vienna, Dendy, D.A.V., 1977. Ed. Tropical Products Institute, London, England, p. 121.

Nutritional and Processing quality of sorghum, Edt, Sahnkhe, D.K., Chavan, J.K., Jadhav S.J. Oxford Publishing Co., New Delhi, pp. 1 – 5, 33 – 47.