Exploiting the Nutritional Profile and Consumer Behavior on Choice and Utilization of Selected Sorghum Varieties in Western Kenya

Mugalavai V.K.[1] Onkware A. O.[2]

[1]Department of Family and Consumer Sciences University of Eldoret Box 1125-30100 Eldoret Kenya

Abstract: ***In many arid and semi-arid tropics areas of the world especially in sub Saharan Africa sorghum is a staple food grain mainly due to its drought tolerance and its good yield of production. Therefore it has great potential to insure food security as well as curbing protein energy malnutrition and micronutrient deficiencies. Current research focused on variation in proximate composition and mineral content (calcium magnesium phosphorus copper iron manganese and zinc)as well as consumer views on utilization and value chains of seven sorghum cultivars from the western regions of Kenya. Results showed that there were significant differences among the sorghum cultivars in crude protein values. Mixed tannin (E117) and low tannin cultivars (E97-1) had higher amount of crude protein value of 8.54 and 8.07 respectively while crude protein values for high tannin cultivars (N68-1 and N57) were significantly lower than for no-and low-tannin varieties (P< 0.05). Mixed results were obtained for both fibre carbohydrates ash and fat content for all the sorghum varieties analyzed irrespective of the tannin content. Calcium and phosphorus values among the seven cultivars were not significantly different (P<0.05) while values for manganese zinc and magnesium were in trace amounts. Kensorg -a mixed tannin variety recorded highest amount of iron of 0.1039%/100g which was significantly higher (P<0.05) than other cultivars studied. Variation in mineral contents was attributed to soil characteristics difference in nutrient absorption and nutrient requirements. The differences in nutritional composition suggests that sorghum could be used to serve as alternative diet supplying adequate micronutrients protein (low-and-no tannin cultivars) and while high tannin varieties would be suitable for brewing industry. Sorghum is generally traded and consumed locally there exists symbolic and cultural significance in appreciating it and could go a long way in enabling rural smallholder household to be more food secure as they develop networks of trade.***

Keywords: Proximate Minerals Sorghum Value addition Cultural behaviour

1. Introduction

Malnutrition continues to be a major health problem in the developing world resulting from under nutrition that affects children especially the under-fives. Diets consumed in developing world are frequently deficient in macronutrients (protein carbohydrates and fats leading to protein–energy malnutrition) micronutrients (electrolytes minerals and vitamins leading to specific micronutrient deficiencies) or both [1]. There is a direct correlation between high food insecurity and malnutrition in Kenya. Food insecurity is reported the highest in arid and semi-arid zones [2]. Poverty is the underlying cause of malnutrition and most vulnerable populations survive on starchy staples such as sorghum maize wheat rice millet and cassava and legumes with little or no meat and dairy products [3]. However the nutritional quality of these staple foods is poor i.e. lysine amino acid is limited in most of the cereals consumed [1 3]. Therefore prevention of malnutrition of infants and under five children requires various approaches including broadening the diet to incorporate a wider range of foods increasing the utilization of conventional staples and boosting the nutritional quality of basic staples [2 4]. Cereals contribute over 60% of the world food production and along with pulses and oilseeds form a major bulk of dietary protein calories vitamins and minerals to the developing world in particular [3 5].Cereals are relatively poor sources of protein but have been reported to supply over 70% of dietary protein in developing countries [4]. With increasing reliance upon cereal grains to provide energy and proteins requirement of humans and animals in addition to the need for improving the overall nutritional quality of cereals efforts have been made by respective country governments to improve the amount and quality of regularly consumed cereal nutrients like sorghum [3 5 6].

Sorghum (*Sorghumbicolor* (L.) Moench) is considered as one of the most important food crops in the world following wheat rice maize and barley [6–8]. It is grown especially in the arid and semi-arid regions. The major sorghum production areas today include great plains of North America sub-Saharan Africa north eastern China and the Deccan plateau of central India Argentina Nigeria Egypt and Mexico [9]. In sub Saharan Africa sorghum is the basic staple food for many rural poor communities especially in drought prone areas characterized by shallow and heavy clay soils; thus it is a subsistence food crop for many food insecure people. Together with millet it forms a main source of protein and energy in the diet of large segments of the population of developing world [9 10]. Sorghum outperforms other cereals under various environmental stresses requires little input during growth and is thus generally more economical to produce [9 11].

A wide variety of traditional food products and recipes are based on sorghum. It is cooked like maize or rice brewed for beer production baked into flat breads or used for thin and thick porridge preparation [8 9 11 12]. Besides providing calories sorghum has actual nutritional value in principle due to its content of protein vitamins both fat-soluble (D E and K) and of B group (except for B12) as well as minerals such as iron phosphorus and zinc [3 7 9 13]. Its iron content is lower than millet but is higher than wheat maize and rice [14 15]. In composition sorghum grain compares favourably with some other cereals: it has a similar protein content to wheat but higher than maize and rice while the essential amino acid composition of sorghum is comparable to maize or wheat due to the limited content of threonine arginine and especially lysine [9 16]. Grain sorghum is rich in fibre apart from having a sufficient quantity of carbohydrates (72%) proteins (11.6%) and fat (1.9%) with starch being the main constituent of the grain. The high amount of fibre helps to eliminate LDL cholesterol level which upgrades the heart health and also prevents heart attacks atherosclerosis and strokes. Sorghum protein contains albumin globulin (15%) prolamin (26%) and glutelin (44%) [7].In particular sorghum's main storage proteins the kafirins are devoid of the essential amino acid lysine; thus the abundance of kafirins in a given sorghum variety has a direct negative impact on its nutritional value [3 9 17].Sorghum does not have gluten and hence is an ideal gluten free energy source for the people suffering from wheat or gluten allergies [3 7]. Despite all these nutritional potential of sorghum grains it has low nutritional value and inferior organoleptic qualities due to the presence of anti-nutritional factors-tannins and phytic acid which forms complexes with nutrients thus resulting into poor protein digestibility [3 6 9].

Sorghum production in western Kenya has been relatively stagnant over the years with the largest groups of producers being small-scale subsistence farmers with minimal access to production inputs and credit facilities [18].These factors have led to low profitability and less demand for the grain despite its potential benefits to health and nutrition [15 18]. While total food production of all cereals has risen considerably during the past 35 years farmers still continue to grow sorghum though to a certain minimum level which can be referred to as household food/fodder security level [11 15]. This study therefore sought to exploit the nutritional potential and consumer behaviour and utilization of sorghum varieties grown in western Kenya.

2. Materials and Methods

Study area

The study was conducted in Busia and Kakamega Counties of Western Kenya in the Sub-counties of Matayos and Koyonzo respectively which extends between 0° 30′N and 34°30′E. The Western Kenya region forms part of the extensive basin around Lake Victoria. It consists mainly of faulted plateaus marked by escarpments that descend gently from the Kenya Highlands to the lakeshore. Western Kenya receives an average monthly rainfall is 61 mm - 273 mm in January and May respectively while the mean range of temperature is 19.3-21.3 °C in July and February respectively (Climate-data.org 2019).

Sorghum varieties

Seven sorghum cultivars already characterized by their tannin levels namely C26-no tannin E97-1 and E95A-3-both low tannin Kensorg and E117-both mixed tannin and N68-1 and N57-both high tannin varieties were procured from farmers in Matayos Sub-County and Koyonzo Sub-county in Western Kenya.

Sample preparation

The sorghum seeds were cleaned and freed from foreign material and broken kernels. The clean seeds were placed in an electric drier to a moisture content of 12-13% then milled using a grinder as recommended by CTA 2007 into flour to pass through a 0.4 mm screen. The flour was stored in polyethylene bags at 24°C for further analysis. Unless otherwise stated all reagents used in this study are of lab-grade. 100 g of each variety of dried sorghum cereal was weighed into a digestion tube. About 5ml of the digestion mixture was added to the digestion tubes and the blanks for every batch of the reagents. These samples were then subjected to a temperature of 110 degrees for an hour removed and cooled. Thereafter 3 drops of hydrogen peroxide was added and heated at a temperature of 330 °C until a colourless solution was observed. The colourless solution was cooled and used in subsequent procedures done in triplicates.

Proximate analysis

The samples were analyzed to determine the Crude Protein (CP) Ether Extract (EE) Ash and Nitrogen Free Extract (NFE) according to AOAC (2000) while protein content (N × 6.25) was determined by a Dumas combustion method (Approved Method 46-30.01 AACC International 2010).

Determination of total minerals

The mineral element level was determined using Atomic Absorption method. Copper Magnesium Zinc Manganese Phosphorus Calcium and Iron were analyzed by dissolving the digested cereal sample. Then the sample standards of copper zinc and iron and blank digests for each mineral was aspirated in atomic absorption spectrophotometer (AAS) (Spectr-AA 200 Japan) at 324.7nm for Copper 248.3nm for iron and 213nm for Zinc which generated calibrated graphs with absorbencies. The calibrated graph of standard series generated was then used to determine the concentration of minerals in the vegetable samples. Copper iron and zinc concentration in the dried cereal sample was calculated as described by Okalebo et al. [19] in Equation 1 below:

Element (mg kg-1) = ……………………. (Equation 1)

Where;

a=element concentration in the solution (ppm)
b= mean values of micronutrient (Fe Zn K or Cu Mn Na) concentration in the blanks (ppm)
v= final volume of digestion (ml)
w=sample weight (g)
f= sample dilution factor (ppm).

Focus Group Discussions (FGD)

The FGD focused on food sovereignty food consumption patterns and priorities gender issues cultural and spiritual influences perception of sorghum food products and processing techniques of sorghum in value addition. Each FGD was composed of 8-12 participants excluding the interviewer. Both male and female participants were given equal chances of responding by the interviewer. A total of two focus group discussions were conducted in each of the study areas.

Statistical analysis

Each determination was carried out on three separate samples and analyzed in triplicate. Data was assessed by the Analysis of Variance (ANOVA). Duncan Multiple Range Test was used to separate means. Significance was accepted at $P \leq 0.05$. The FGD was transcribed and used to explain the consumer behaviour of the sorghum consuming households.

3. Results and Discussion

Proximate composition

Table 1 shows the results of the proximate composition of seven sorghum cultivars used for the study. Data are expressed on dry matter basis (per 100 gm material). The moisture content of the sorghum varieties was within the range of 12-13.24 %. These values are significantly higher than the range of 7.29-10% reported by Awadeelkareem et al [3] on sorghum varieties grown in the East African belt. Dicko et al [8] however reported moisture content values in the range of 8-12% for sorghum grains. High tannin varieties sorghum grain-N68-1 and N57 recorded the lowest amount of crude protein values of 4.28% and 4.90% respectively while mixed tannin sorghum – E117and E97-1 recorded the highest amount of protein value of 8.54% and 8.07% respectively. These varieties would be good for human food to boost nutrition security. The protein content of high tannin varieties was significantly lower than for no-and low-tannin varieties ($P< 0.05$) however the protein values recorded for all the sorghum varieties were within the range of 4.28-8.54 and this was similar to 3-18% reported by Kiprotich et al [20] on sorghum varieties grown in other arid and semi-arid agro-ecological zones in Kenya whereas Dickoet al [8] reported protein content in the range of 7-15% for sorghum cultivars.

Table 1: Proximate composition of sorghum cultivars (per 100g)

Variety	Moisture	Protein	Fibre	Fat	Carbohydrates	Ash
C26- No Tannin	13.24 ± 0.30^{A}	7.99 ± 0.85^{A}	3.30 ± 0.28^{CB}	2.80 ± 0.11^{C}	72.63 ± 0.02^{B}	1.41 ± 0.08^{BC}
E97-1- Low Tannin	13.27 ± 0.45^{A}	8.09 ± 0.78^{B}	3.84 ± 0.83^{CB}	3.41 ± 0.16^{D}	70.25 ± 0.05^{CB}	1.64 ± 0.02^{C}
E95A-3 Low Tannin	13.32 ± 0.45^{A}	5.56 ± 0.40^{B}	2.03 ± 0.91^{C}	3.08 ± 0.1^{B}	72.43 ± 0.05^{C}	1.48 ± 0.02^{BC}
Kensorg -Mixed Tannin	12.98 ± 0.45^{A}	5.53 ± 0.53^{A}	3.08 ± 0.96^{CB}	2.34 ± 0.27^{A}	72.45 ± 0.20^{F}	1.33 ± 0.06^{BC}
E117- Mixed Tannin	12.95 ± 0.13^{A}	8.54 ± 0.40^{A}	2.78 ± 1.03^{B}	3.28 ± 0.11^{A}	69.85 ± 0.04^{E}	1.50 ± 0.040^{BA}
N68-1 -High Tannin	13.13 ± 0.76^{A}	4.28 ± 0.46^{BC}	6.01 ± 0.66^{CB}	3.06 ± 0.14^{CB}	71.23 ± 0.03^{A}	1.75 ± 0.22^{BA}
N57 –HighTannin	13.14 ± 0.49^{A}	4.90 ± 0.34^{C}	2.74 ± 0.65^{A}	2.96 ± 0.04^{B}	74.21 ± 0.18^{D}	1.62 ± 0.14^{A}

Values are means (+SD) of 3 replicates per treatment.

Values with different superscript alphabetical letter(s) within the same column show significant differences ($P<0.05$) among proximate composition while values with same alphabetical letter(s) within the same column show no-significant differences among proximate composition ($P<0.05$).

The wide variety of sorghum proteins defines its utilization based on protein requirements of the industry for example the baking and brewing industry needs varieties with moderate proteins while animal and human feeds needs maximum proteins and sorghum offer a wide choice [20]. The low quantity of proteins in high tannin varieties can be attributed to the presence of tannins. Tannins are considered undesirable due to their ability to bind proteins thus reducing protein digestibility of sorghum [17] and binding with protein and inhibiting enzymes [17 21 22].Mixed results were obtained for both fibre and fat content for all the sorghum varieties analyzed irrespective of the tannin content. The fibre values for N57 E117 and E95A-3 were lower ($P< 0.05$) than values for N68-1 Kenmore E97-1 and C26 varieties. Contribution of polyphenols to the lignin fraction of dietary fibre is usually responsible for higher values of dietary fibre in the tannin varieties of sorghum cultivars [12].Fat content varied among the sorghum varieties ranging from 2.34% to 3.41% in Kensorg-mixed tannin and E97-1 a low tannin variety. These fat contents values were similar to the sorghum cultivars evaluated by Mabelebele et al [12] which ranged from 27 to 37 g/kg dry matter. The sorghum varieties recorded high carbohydrates content ranging from 69.85 to 74.21% in E117 and N57 respectively with N57 significantly higher ($P< 0.05$). The results obtained were in the range reported by Awadeelkareem et al [3] who recorded carbohydrates content of three local cultivars to be ranging between 72.44 and 77.28%.The ash value of Kensorg (1.33%) C26 (1.41%) and E95A-1 (1.48%) cultivars were lower ($P< 0.05$) than values for N68-1 cultivar (1.75%). These values were within the range of 1.28-1.78% reported by Awadeelkareem et al. [3] and 1.3-1.5% reported by Mabelebele et al [7 12]. The variations in proximate composition among the seven sorghum cultivars could be owing to differences in genotype and growing conditions such as geographical and seasonal variations climatic conditions and soil characteristics [12].

Mineral content

The mineral composition varied among the seven sorghum cultivars varieties (Table 2). Calcium and phosphorus values among the seven varieties were not significantly different ($P<0.05$) however the calcium content obtained in the current study was significantly lower than that reported by Shegro et al. [23] and Samia et al. [24].

Table 2: Mineral concentrations of grains of seven sorghum varieties (%/100g)

	Sorghum variety						
	C26 No Tannin	**E97-1 Low Tannin**	**E95A-3 Low Tannin**	**Kensorg Mixed Tannin**	**E117 Mixed Tannin**	**N68-1 High Tannin**	**N57 High Tannin**
Macro minerals							
Ca	0.0100^{A}	0.0100^{A}	0.0100^{A}	0.0100^{A}	0.0100^{A}	0.0100^{A}	0.0100^{A}
Zn	0.0200^{A}	0.0167 ± 0.0058^{A}	0.0100^{A}	0.0100^{A}	0.0123 ± 0.0153^{A}	0.0200^{A}	0.0100^{A}
P	0.0002^{C}	ND	0.0020^{A}	0.0010^{B}	0.0010^{B}	0.0010^{B}	ND
Mg	0.0233 ± 0.0058^{DC}	0.0233 ± 0.0058^{A}	0.0300^{BC}	0.0400^{BA}	0.0333 ± 0.0058^{DC}	0.0367 ± 0.0058^{D}	0.0200^{BA}
Trace minerals							
Cu	0.0017 ± 0.0006^{A}	0.0010^{A}	0.0013 ± 0.0006^{A}	0.0013 ± 0.0006^{A}	0.0010^{A}	0.0010^{A}	0.0017 ± 0.0006^{A}
Mn	0.0023 ± 0.0006^{C}	0.0030^{E}	0.0030^{B}	0.0006 ± 0.0001^{E}	0.0002^{B}	0.0070^{D}	0.0017 ± 0.0006^{A}
Fe	0.0275 ± 0.0035^{a}	0.0200^{a}	0.0200^{a}	0.08 ± 0.1039^{a}	0.0100^{a}	0.0167 ± 0.0058^{a}	0.023 ± 0.0111^{a}

Values are means (+SD) of 3 replicates per treatment.

Values with different alphabetical letter(s) within the same column show significant differences ($P<0.05$) among mineral composition while values with same alphabetical letter(s) within the same column show no-significant differences among mineral composition ($P<0.05$).

Calcium is an important mineral element used for human consumption especially for bone development and strength. Phosphorus is an essential mineral element in human nutrition and plays an important role in the structure and function of the human body. Zinc levels ranged from a high of 0.02%/100g in N68-1 line to a low of 0.01%/100g in Kensorg N57 and E95A-1 cultivar. Zinc plays an important role in human nutrition for growth and development as well as in the proper functioning of the immune system in the body. Magnesium levels ranged from 0.04%/100g in Kensorg – a mixed tannin variety to a low value of 0.02%/100g in N57 -high tannin sorghum cultivar. Copper values were found in trace amounts ranging from 0.001 % to 0.0017%. Values of manganese were also in trace amounts ranging from 0.0006% in Kensorg cultivar to 0.007% in N68-1.The concentrations of Cu and Mn in this study were relatively lower than values reported by Mabelebele et al. [12] and Shegro et al. [23]who reported values of 0.4-0.5 mg/100g and 9.5-20.67 $mgkg^{-1}$ for Cu and Mn respectively. The Fe content was significantly higher in Kensorg variety ($P<0.05$) than for other sorghum varieties. The lowest Fe concentration of 0.00%/100g and 0.0167%/100g found in E117 and N68-1 respectively. Variations in mineral concentrations may be accounted by several factors. This may include the genotype mineral concentration in the soil as well as translocation rates of the elements by the sorghum cultivars from the soil as well as environmental factors such as different cultivation or weather conditions (temperature and rainfall) obtained during the growth period of the plants. Variation could also be due to differences in the sorghum cultivars ability to absorb the nutrients from the soil as well as differences in their level of requirements for these mineral elements [23].

Sorghum varieties present in the area

Different varieties are grown in the two regions for example the local varieties (high tannin) and improved breed (low tannin). The most preferred varieties across the areas is the local varieties for consumption due to the typical taste and colour as culturally symbolically and cognitively ascribed and perceived by the households. Most participants preferred the ***nyataaakur*** (N68-1) a high tannin variety since it was passed on by the older generations and therefore perceived as bringing them closer to their ancestors. Local varieties are also perceived to have medicinal value especially in curing cases of diarrhoea and measles.

Sorghum value chain

Despite the preference for local varieties there is a positive shift of farming towards improved sorghum cultivars due to their higher yields and resistance towards pests and diseases. The farmers are able to decide which sorghum cultivars to use which enhances their food sovereignty. Early maturing varieties are also highly valued although the use of improved seed was low as the participant said they are relatively expensive. Participants said that they mainly cultivated sorghum on ancestral land handed down to them through generations and sometimes they leased land in the same region if they did not own sufficient land to have a greater yield. Access to land affected the cultivation of the sorghum cultivars. Both men and women participated in preparation of land for planting the sorghum seeds. Sometimes they hold spiritual rites like prayer and ceremonial cleansing before the commencement of the planting season. Participants said they use the improved varieties only when availed by the research organization but in the absence they would revert to the previously harvested seeds as improved cultivars are quite expensive for them to afford. Participants are also involved in collaboration with local and national governments as well as international organisations in ensuring that they get the best yields in sorghum cultivation.

After harvesting which is done by both men and women sorghum is traditionally decorticated by pounding the dried grain with a mortar and pestle (kinuu). A spiritual rite like prayers and offering of tithe in grain is also practiced as well as storing a portion of the harvest for the next planting season. Decortication is important to them as it removes the bitter taste [26] in the end products like porridge and ugali. Thereafter the grains are winnowed to remove the chaffs. Milling is done using an electric/diesel grinder (locally known as posho mill) to produce flour. Processing sorghum into food is done on small scale at the household level across the region and this is done mainly by women since men prefer to wait for the end product in form of food or beer as is the cultural gender norm. Sorghum is generally not a highly commercialized crop as it is grown more for food which limits its incentives for increased production. In these regions it is generally traded and consumed locally or sold to middlemen and small traders for wider distribution. This findings are similar to a report by Chemonics Inc. [27]. Middlemen generally buy bulk sorghum at local markets and transport it to wholesalers and wholesalers then sell directly to retailers millers or exporters. Sorghum is mainly processed into local brew as mention by most participants across the two regions.

Utilization of sorghum based food products

The most commonly consumed sorghum products are porridge ugali and local beer (busaa). All these were common across the two areas. The main sources were from farm production or from the local markets. Uji or thin porridge is made from pure or mixed flour from maize sorghum cassava and finger millet. It can be made of pure or mixed flour of the cereals and can either be fermented or unfermented. Milk legumes omena can be added asfortificants for those families who can afford. Porridge is consumed for breakfast although it is mainly a weaning product. Porridge is also given to nursing mothers to stimulate milk production according to views from the participants across the region. Ugali (stiff porridge)is the main staple food which is made of pure or mixed flour from either maize sorghum finger millet cassava mixed according to preference but with more sorghum. Ugali is consumed for lunch or supper and is served with vegetables but on rare occasions with chicken meat or omena (small dried fish) and this happens when they have a very important visitor in the homestead. These uses were like the uses reported by Dicko et al. and Muui [8 11 25]. Participants said that lunch meals are rarely prepared because the children are normally at school while the adult members of the family maybeaway from home engaged in other small businesses at the nearby markets. Consumption of sorghum-based products is on daily basis in almost all households. Busaa an alcoholic beverage is consumed during leisure or festivals. It is the only sorghum product for commercial across the regions. Busaa is brewed under the traditional liquor licensing act in urban areas while in the villages it is an illicit brew hence cannot be successfully industrialised and commercialised without addressing the legal and statutory issues affecting them [25]. Sorghum cereal is also used as a coping cereal during lean months by large size families. From the discussion it was realized that sorghum has a cultural preference aspect for example families with more than eight members consumed sorghum more frequently than smaller families in all areas. One participant from Matayos explained “if you have many children in the household and you put sorghum ugali on the plate it does not get finished as quickly and so the children will get satisfied”.

4. Conclusion

Results showed that the sorghum cultivars differ in their chemical composition and mineral profile. No- and-low tannin cultivars had superior protein quality compared to high tannin cultivars. Thus would serve as alternative diet supplying adequate protein while high tannin varieties would be suitable for brewing industry. Mineral composition was mainly influenced by genetic and environmental factors. Cultivars with high concentration of the most important mineral elements protein and carbohydrates are potential genetic sources for the future nutritional development of improved cultivars to curb malnutrition in Western Kenya. Sorghum remains a favourite staple cereal and is highly relied upon within the region and there is need to improve the quality characteristics for sustainable consumption since it is a climate friendly crop and more suitable for a food sovereign farming communities in western Kenya.

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Author Profile

Violet K. Mugalavai | PhD | University of Eldoret | Email: violet.mugalavai[at]gmail.com

Augustino Onkware |PhD |University of Eldoret |Email: aonkware[at]yahoo.com

Harriet Omutimba | MS | Pwani University |Email: hariet.scott[at]gmail.com

Oyalo Josiah |MS | University of Eldoret |Email: koyalo.josiah[at]gmail.com

Correspondence

Violet Mugalavai Department of Family and Consumer Sciences University of Eldoret Box 1125-30100 Eldoret Kenya. Email: violet.mugalavai[at]gmail.com