



Nutritional Analysis of Three Commonly Consumed Varieties of Sorghum (*Sorghum bicolor L.*) in Bauchi State, Nigeria

^{1*}MOHAMMED, ZS; ¹MABUDI, AH; ²MURTALA, Y; ¹JIBRIN, S; ¹SULAIMAN, S;
¹SALIHU, J

^{1*}Department of Biochemistry, Faculty of Science, Bauchi State University, Gadau, Bauchi. P.M.B, 065 Bauchi-Nigeria

²Department of Biochemistry, Faculty of Biomedical Sciences, Bayero University Kano, P.M.B 3011 Kano-Nigeria

*Corresponding Author Email: szinatmohammed@gmail.com, Tel: 08036953720

ABSTRACT: Three sorghum samples (yellow, red, and white sorghums) were analyzed for their proximate, vitamin (B1, B3, B6) and mineral element (Mg, Na, K, Ca, Fe, Zn, Cu and Mn) compositions. Vitamins and mineral compositions were determined using HPLC and AAS respectively. The results of the proximate analysis revealed that there was no significant difference ($p \leq 0.05$) in the ash, crude fibre, crude protein and carbohydrate content of the three samples. The difference in the moisture and fat content were significant ($p \leq 0.05$). The moisture content of white and red sorghum and white and yellow sorghums was significantly different ($p \leq 0.05$) while the difference in the moisture of red and yellow sorghums was not significant ($p \leq 0.05$). The fat content of white and red sorghum are significantly different ($p \leq 0.05$) while the difference between the fat content of white and yellow and red and yellow sorghums were not significant ($p \leq 0.05$). White sorghum has higher percentage of moisture and fat 11.90 ± 0.36 & 9.26 ± 1.81 respectively. Red sorghum has higher percentage of ash and protein 2.32 ± 0.68 & 6.08 ± 0.40 respectively. Yellow sorghum has higher percentage of fibre and carbohydrate 2.41 ± 1.44 & 73.53 ± 1.87 respectively. The HPLC vitamin analysis showed that sorghum has low vitamin B1 (thiamine), B3 (niacin), B6 (pyridoxine) content and did not meet the recommended dietary allowance of the world health organization, although red sorghum was richer in all the vitamins analyzed, followed by yellow sorghum and then white sorghum which has the lowest vitamin content. The AAS results for the mineral elements revealed that all the three sorghum varieties contains all the mineral elements analyzed except for white sorghum which does not show any trace of copper. Statistical analysis on the mineral elements of the three sorghum showed that there were no significant difference ($p \leq 0.05$) in all the mineral elements analysed with respect to each of the samples except for calcium that showed a significant difference ($p \leq 0.05$). The difference in the calcium content between white and red sorghum and red and yellow sorghum was significant ($p \leq 0.05$) while the difference was not significant ($p \leq 0.05$) between the white and yellow sorghum. It was also found that the three sorghum varieties are richer in potassium, zinc and sodium and low in the other mineral elements analyzed. The proximate analysis revealed that sorghum samples contain appreciable nutrient contents and vitamin analysis shows that red sorghum is nutritionally more valuable than the white and yellow sorghum.

DOI: <https://dx.doi.org/10.4314/jasem.v23i7.21>

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Dates: Received: 30 May 2019; Revised: 25 June 2019; Accepted 13 July 2019

Keywords: Mineral elements, Proximate Composition, Sorghum and Vitamins

Sorghum is a food crop that is widely produced and commonly consumed in northern Nigeria. Locally most varieties of sorghum are usually differentiated by their natural colours. In Nigeria, sorghum is consumed in different forms. Generally it is consumed as whole grain or processed in to powdered form (flour) from which different local traditional Nigerian meals are prepared. Sorghum has been rated globally as the fifth most important staple food crop after rice, wheat, maize and barley (FAO, 2016). Sorghum consumption in developing countries was projected to increase from 26 million to over 30 million tons from 1992 – 2005 (Leder, 2004) and the consumption rate has increased very much in recent years. Sorghum has different varieties and most of these varieties are been cultivated in the northern parts of Nigeria. The most commonly cultivated and consumed varieties are the

white, yellow and red sorghums yet this depends on the individual choice and location. The choice of the types of food consumed is closely associated with the locally available foods and with the biodiversity encountered, as both factors contribute mainly to the nutritive mineral values of the diets (Panafiel *et al.*, 2011) as well as the vitamin composition. It has been reported that sorghum contains bioactive compounds which has profound effect as anti-inflammatory, antioxidant, anti-colon cancer and in immune modulatory functions (Vanamala *et al.*, 2018). A recent study found that sorghum grain extracts possess strong enzymes (pancreatic lipase, α -amylase and α -glucosidase, and ACE) inhibitory and antioxidant activities and contains phenolics such as gallic, chlorogenic, caffeic, and ellagic and p-coumaric acids. The enzymes inhibitory activity and phenolic

*Corresponding Author Email: szinatmohammed@gmail.com, Tel: 08036953720

compounds levels were observed to have decreased with increase in temperature while the grains were roasted compared to the unroasted grains (Ironi *et al.*, 2019). Vitamins are essential nutrients necessary for performing chemical and physiological functions in humans. Due to the inability of the vitamins to be stored in the body, a continuous daily intake is required in the diet to maintain certain functions. B-complex vitamins consist of eight vitamins collectively known as water soluble vitamins including vitamin C (Henry and Chapman, 2002). B vitamins are widely distributed in foods, and they function mostly as coenzymes to aid the body in obtaining energy from food. Vitamins are supplied both by diet and by the gut microbiota (Said and Nexo, 2018). Vitamin deficiency occurs as a result of insufficiency of vitamin in the diet or as a result of certain disorder that prevent the intake or proper functioning of the vitamins. There is supportive evidence that water soluble vitamins can reduce risk of deficiency due to smoking and alcoholism and certain chronic diseases such as cardiovascular disease, cancer and Korsakov's syndrome (Forbes and Player, 2018). Toxicity of vitamins most often comes from high supplement consumption and not from natural food. Minerals are inorganic substances required by the body in small amounts for variety of different functions. The interactions between mineral elements in biological systems and their role in mediating the chemical and biological reactions fundamental to life are still being discovered (Marcovecchio, *et al.*, 2015). The body requires different amount of each mineral and just like vitamins, minerals helps the body grow, develop and maintain health status. The use of dietary supplements may not provide minerals in a soluble and metabolically available form (Fairweather-Tait, 1996). There has been a growing interest in investigating the chemical and micronutrient composition of sorghum due to their medicinal and health benefits. The aim of this study was to determine the proximate, mineral elements and some water soluble vitamin composition of three varieties of sorghum commonly consumed in Northern Nigeria.

MATERIALS AND METHODS

The following materials and reagents were used for this research work: Weighing balance, mortar and pestle, beakers (250ml), conical flask, incubator, pH meter, Whatman filter paper, micro pore filter, HPLC system, Buchner funnel, funnel, crucible, muffle furnace, dessicator, volumetric flask, AAS (AAS Brand/Model: BUCK Scientific/VGP 210), extraction flask, condenser, moisture analyser, Kjeldahl flask, H₂SO₄, NaOH, petroleum ether, sodium acetate,

takadaistase enzyme, HNO₃, HCl, Na₂SO₄, CuSO₄. Analytical Standards for B1 (Thymine Hydrochloride), B3 (nicotinamide) and B6 (pyridoxine hydrochloride) are all of grade from Sigma Aldrich.

Sample Collection and Preparation: Three different varieties of Sorghum grains (Red, Yellow and White sorghums) were collected from Azare central market. The samples were taken to the laboratory, Bauchi State University, Gadau, Department of Biological Sciences for authentication by a botanist. The samples were then dried at room temperature. The dried grains were grinded into powdered form and stored in the laboratory for the analysis.

HPLC Determination of B Vitamins (Water-Soluble) Vitamin B1, B3 and B6: Dried sorghum powder (2g) was placed in 25ml of H₂SO₄ (0.1 N) solution, incubated for 30min at 121^oC and adjusted to pH 4.5 with 2.5M sodium acetate, after which 50mg Takadiastase enzyme was added. The preparation was stored at 35^oC for 12 hours, filtered and filtrate was diluted with 50ml of pure water and filtered again through a micro pore filter (0.45 μm). Filtrate (20 μl) was injected into the HPLC system for quantification. Standard stock solutions for thiamine, niacin, and pyridoxine, were prepared as reported previously Ringling & Rychlik (2013). Chromatographic separation was achieved on a reversed phase- (RP) HPLC column (Agilent ZORBAX Eclipse Plus C18; 250 × 4.6mm i.d., 5 μm) through the isocratic delivery mobile phase (A/B 33/67; A: MeOH, B: 0.023 H₃PO₄, pH = 3.54) at a flow rate of 0.5 ml/min.

Analysis of Mineral Elements: About (5g) of dried sample was placed into the crucible, weighed and ashed. Ashed samples was heated with 5.0cm³ of HNO₃ at 400^o C followed by addition of 15cm³ 1:1 (vol:vol) HCl filtered and made up to 100 cm³ with deionised water. Mineral elements were determined using micro plasma atomic emission spectrophotometer (MP-AES). Reagent blank was used for zeroing while taking the readings of sample containing the respective minerals.

Crude Protein Determination: The ammonia steamed was distilled into 10ml 2% boric acid solution with 5 drops of methyl red indicator after digestion of the sample with catalyst using the Kjeldahl digestion flask. The distilled ammonia was then titrated with 0.01N HCl to pink colour.

$$\%CP = \frac{TV \times 0.00056 \times 6.25}{SW} \times 100$$

Where CP = crude protein; TV = titre value (ml) and SW = sample weight (g)

Determination of Crude Fat: Onto a defatted filter paper, 3g of moisture free sample (W₁) was wrapped, tied with a defatted string and weighed (w₂) and the fat was extracted using petroleum ether over heat for about three hours after which the samples were weighed.

$$\% \text{Fat} = \frac{(WFP + SBE) - (WFP + SAE)}{SW} \times 100$$

Where WFP =Weight of filter paper; SBE= sample before extraction; SAE = sample after extraction

Determination of Crude Fibre: Fat free sample (2g) was heated for 30mins with H₂SO₄, filtered and washed. The residue was then heated with 200cm³NaOH solution for 30 mins. It was filtered and washed with boiling 1.25% H₂SO₄, three 50cm³ portion of water and 25cm³ethanol. The residue was transferred to ashing dish (pre-weighed w₁), dried in an oven allowed to cool in a desiccator and weighed (W₂). Sample crucibles were placed in muffle furnace at 550°C for 30 min, Cooled and weighed again (W₃).

$$\% \text{CF} = \frac{(W_2 - W_1) - (W_3 - W_1)}{SW} \times 100$$

Where CF = crude fibre

Total Ash Content: An empty crucible was weighed (W₁), 5g of dried sample was placed into the crucible and weighed (W₂). The sample was placed in the muffle furnace at 550°C,ashedand weighed (W₃).% of ash = W₃ - W₁ / W₂ - W₁ x 100

Moisture Determination: Sample (3g) was weighed onto the plate present in the moisture analyser and the lid was closed. The result was recorded as average from triplicate values.

Calculation of Carbohydrate Content: Percentage of available carbohydrate was calculated by difference. Carbohydrate = 100 - (Moisture + Ash + Crude Fat + Crude Fiber + Crude Protein) %

Energy Calculation: The Atwater method of energy calculation uses factors to calculate energy from protein, fat and carbohydrate the energy was calculated using general Atwater factors = Energy (kcal) = (g protein×4)+(g carbohydrate ×4)+(g fat x 9) (Sally *et al.*, 1997).

Statistical Analysis: Statistical analysis of the data was done with SPSS (Version 20) using one way analysis

of variance (ANOVA) followed by post hoc least significant difference (LSD) test. Significant difference was accepted at p < 0.05 and results were expressed as mean ± Std Deviation.

RESULTS AND DISCUSSION

Proximate Composition: Table 1 shows the results of the proximate analysis of the samples investigated. For moisture content, red and yellow sorghum show no significant difference (p < 0.05) between them, while white sorghum significantly differ (p < 0.05) from both red and yellow sorghum. The mean moisture content value obtained for the three varieties of sorghum are similar to that reported by Jimoh and Abdullahi (2017); Adeyeye and Adewole (1992). For ash content, which is an indication of mineral content of a sample, all white, red and yellow sorghum are not significantly different (p<0.05) with respect to each other. The values for the ash content obtained from this research ranged from 1.67 – 2.32 % and this was found to be similar to results obtained from other study (Ponteri *et al.*, 2017). The ash content of the sample may be affected by the nature and amount of ion present on the soil from which plants draw their food (Akinsola, 1993). For crude fat, white sorghum is significantly different from red sorghum, and red sorghum is significantly different (p<0.05) from yellow, while yellow and white sorghum does not differ significantly (p<0.05). The crude fat content obtained in this study is in confirmation with the results obtained in previous study (Brhane *et al.*, 2016). There is no significant difference (p < 0.05) in crude fibre content of all the sorghum varieties. Also in the crude protein content, the red sorghum has the highest protein content with a mean value of 6.06±0.40 as reported while the white sorghum has a mean crude protein value of 4.82±2.39 and the mean crude protein of yellow sorghum was found to be 4.27±1.65 which has the least crude protein value. The result from this study was found to be within the same range of previously research (Jimoh and Abdullahi, 2017). The mean protein difference for all the samples was not significant (p < 0.05).The mean carbohydrate value of the three varieties of sorghum was found to be within the range of 70.55 – 73.53 % which is within range reported by Adeyeye and Adewole (1992). Carbohydrate constitutes the highest portion of all the nutritional constituents of sorghum and shows no significant difference (p < 0.05) among all the sorghum varieties. The estimated carbohydrate content in the sorghum was high and carbohydrates are known to produce energy required for the body because they are essential nutrient required for adequate diet (Emebu and Anyika, 2011) and supplies energy to cells such as brain, muscle and blood (Ejelonu *et al.*, 2011).

Table 1: Proximate Composition of the Three Varieties of Sorghum bicolor.

Samples	Moisture Content (%)	Ash (%)	Crude Fibre (%)	Crude Fat (%)	Crude Protein (%)	Carbohydrate (%)	Energy (kcal/g)
Sorghum (White)	11.9±0.34 ^b	2.01±0.45 ^b	1.45±0.18 ^c	9.26±1.81 ^d	4.82±2.39 ^c	70.55±3.57 ^f	384.86
Sorghum (Red)	10.23±0.40 ^a	2.32±0.68 ^b	2.39±1.75 ^c	6.72±1.08 ^a	6.06±0.40 ^c	72.28±1.53 ^f	388.15
Sorghum (Yellow)	10.80±0.17 ^a	1.67±0.38 ^b	2.41±1.44 ^c	8.31±0.23 ^d	4.27±1.65 ^c	73.53±1.87 ^f	380.03

Values are means ± standard deviation of three determinations, values on the same row with different superscripts are significantly different with respect to each other ($P \leq 0.05$). Carbohydrate is clearly predominant in all the sorghum tested, followed closely by moisture, fat, crude protein, fibre and ash. Sorghum (white) possessed the highest concentration of most nutrients tested.

Table 2: Result for the determination of water soluble vitamins composition of Sorghum bicolor (Vitamins B1 (thiamine), B3 (niacin), B6 (pyridoxine)). HPLC analysis of the vitamin content of the samples showed that the varieties of sorghum contains all the vitamins analysed and the values were found to be relatively low compared to the WHO (2004) recommended dietary allowance.

Samples	Sorghum			WHO RDA (mg/day)		
	(white) mg/g	(red) mg/g	(yellow) mg/g	0-9yrs	Adolescents 10-18yrs	Adults 19yrs- above
Vitamin B1	0.002	0.023	0.019	0.2-0.9,	1.1-1.2	1.1-1.5
Vitamin B3	0.009	0.017	0.017	2-12 (NE),	1-6 (NE),	14-17(NE)
Vitamin B6	0.001	0.004	0.003	0.1-1.0,	1.2-1.3,	1.3-2.0

NE, Niacin equivalent: 1mg NE = 60mg of tryptophan = 1mg = 1mg niacin. WHO RDA: World Health Organization Recommended Dietary Allowance (WHO, 2004)

Table 3: Result for the mineral elements analysis (using AAS) of the three varieties of sorghum (red, white, & yellow)

Mineral elements	Sorghum(white)	Sorghum(red)	Sorghum(yellow)
Magnesium(Mg) ppm	0.53±0.11 ^a	0.66±0.30 ^a	0.60±0.20 ^a
Sodium (Na) ppm	6.23±5.63 ^b	6.43±0.89 ^b	8.12±1.94 ^b
Potassium (K) ppm	53.0±26.15 ^c	87.0±14.17 ^c	61.0±9.53 ^{cs}
Calcium (Ca) ppm	0.61±0.25 ^d	1.00±0.16 ^a	0.61±0.09 ^d
Iron (Fe) ppm	0.33±0.11 ^a	0.33±0.11 ^a	0.33±0.00 ^a
Zinc (Zn) ppm	5.03±2.31 ^b	13.64±10.18 ^b	8.70±5.64 ^b
Copper (Cu) ppm	0.00±0.00 ^c	0.10±0.10 ^c	0.09±0.07 ^c
Manganese (Mn) ppm	0.25±0.33 ^a	0.79±0.59 ^a	0.68±0.08 ^a

Values are means ± standard deviation of three determinations, values on the same column with different superscripts are significantly different ($P \leq 0.05$). Ppm: parts per million

Vitamins: The result for HPLC analysis of water soluble vitamins (B₁, B₂ & B₃) is presented in table 2. Vitamins B₁ (thiamine), B₃ (niacin) and B₆ (pyridoxine) were found to be present in the three samples that were analysed although the vitamin content in the three food samples were found to be very low when compared to that reported by Adebisi *et al.* (2005). The vitamin content of sorghum is not up to the recommended dietary allowance (RDA) recommended by WHO (2004) with respect to the vitamins analysed. This research shows that red sorghum has the highest vitamin content in all the samples followed by yellow and finally white sorghum which has the least. This shows that red sorghum is nutritionally more valuable than the white and yellow sorghum as it has also been reported to contain some important flavonoids (Ironi *et al.*, 2019) which together with the vitamin content would increase the nutritional value. The vitamin B₃ (niacin) content was the highest (0.023) in the red sorghum. Niacin in cereals is found in free and bound forms and can be synthesized from tryptophan (Leder, 2004).

Mineral Element Analysis: Table 3 shows the result for analysis of mineral elements of the three varieties of sorghum (red, white & yellow). Among all the three samples analysed, red sorghum has the highest potassium content (87ppm), followed by yellow sorghum (61ppm) and the white sorghum having the least potassium content (53ppm). There was no significant difference ($p < 0.05$) in the potassium content of all the three samples analysed. This shows that sorghum has high potassium content and this shows that sorghum can serve as a valuable source of potassium, a macro and essential mineral to humans. The values obtained from this study were found to be higher than that reported by Leder (2004). The sodium content of all the three varieties of sorghum analysed was found to be highest in yellow (8.12±1.94) with red and white sorghum having about the content (6.43±0.89) and (6.23±5.63) respectively. Although there is no significant difference ($p < 0.05$) in the sodium content of the three sorghum samples analysed. The calcium content of the three varieties of sorghum analysed were found to be very low with red sorghum having the highest calcium content (1.00±0.16) and yellow and white sorghum having the

same calcium content (0.61 ± 0.09) and (0.61 ± 0.25) respectively. However there was a significant difference ($p < 0.05$) in the calcium content of all the three sorghum samples with respect to each other. Even though the calcium content is very low, it is still of advantage that sorghum has some calcium in it which will increase the nutritional value of this crop for human consumption. It has been reported that foods such as cereals are important food sources of calcium in developing countries (Miller *et al.*, 1989). The magnesium content of the samples were also found to be relatively low among all the three samples with red sorghum having the highest value (0.66 ± 0.30) and white sorghum having the lowest value (0.53 ± 0.11). The magnesium content of all the samples of sorghum analysed were not significantly different ($p < 0.05$) with respect to each other.

The Iron composition of all the samples were found to be low even though the three samples have the same values (0.33) and no significant difference between them. Iron is an essential nutrient for transport of oxygen and cellular generation of energy, its deficiency has been by estimated by WHO to affect over 2 billion people in the world especially in developing countries (de Benoist *et al.*, 2008). The red sorghum was found to have the highest zinc content (13.64 ± 10.18), with the zinc content of yellow and the white sorghum being (8.70 ± 5.64) and (5.03 ± 2.31) respectively. The difference in the zinc content of all the three samples was not significant ($p < 0.05$). The zinc content of food is very low even in foods that have been classified as zinc-rich foods, while unrefined cereals have high zinc content (Salguero *et al.*, 2000). The result from table 3 shows that white sorghum copper content was below detectable level (0.00) but the copper content of the red and yellow sorghum samples were found to be (0.10 ± 0.10) and (0.09 ± 0.07) respectively and it was very low. The difference between the red and yellow sorghum samples was not significant ($p < 0.05$). The manganese content of the three sorghum samples was not significantly different ($p < 0.05$) with respect to each other with red sorghum having the highest value (0.79 ± 0.59) and white sorghum having the least manganese content (0.25 ± 0.33). Approximately about 30-40% of dietary magnesium that is consumed is usually absorbed by the body (Rude, 2010). Finally, the result from this study has shown that red sorghum contains more nutritional composition when compared to the yellow and white sorghum varieties making the red sorghum a better choice for consumption with regards to its health benefits. Also flavonoids such as quercetin, luteolin and apigenin are common antioxidants associated with high health benefits have been found in red sorghum (Ironi *et al.*, 2019).

Conclusion: Proximate analysis revealed that red sorghum has the highest percentage of most of the nutrient tested followed by yellow and then white sorghum. The three sorghums (red, white and yellow) contained all the essential vitamins and mineral elements analysed, however, the quantity of these vitamins and mineral were low except for potassium which was found to be relatively high. With the quantity of macro and micro nutrients found to be present in sorghum, it can serve as important nutritious staple food which should be used to tackle and alleviate hunger and food insecurity in Nigeria.

Acknowledgement: The authors acknowledge the effort and contribution of the technical staff of the Department of Biochemistry, Bauchi State University, Gadau Bauchi State and that of Bayero University, Kano.

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