Nutritional, Calorie and Thermal Properties of Some Selected Food Grade Sorghum Grains from Maiduguri, Borno State, Nigeria

Canadian Journal of Agriculture and Crops
Vol. 5, No. 1, 41-51, 2020
e-ISSN: 2518-6655
Check for updates   check for updates

(Corresponding Author)

Kassum, Afobia Litini[1]
Danbaba, Naheminah[2]
Goni, Mala[3]
Mercy Ibrahim Kwari[4]
Fannah Mustapha Adam[5]
Hadiza Kubura Lawan[6]
Oderaa Amin Igwegbe[7]
Amina Idris Maijalo[8]

[1,3,4,5,6,7,8]*Department of Food Science and Technology, University of Maiduguri, Borno State, Nigeria.*
[1]*Email:* afodiasaleh@yahoo.com
[4]*Email:* messi2683@gmail.com
[5]*Email:* fannahmustapha@gmail.com
[6]*Email:* hadizakuburalawan@gmail.com
[7]*Email:* amajide1964@yahoo.com
[8]*Email:* aminaidrismaijalo@gmail.com
[2]*Department of Food Science and Technology, University of Maiduguri, Borno State, Nigeria; Food Technology and Value Addition Research Program, National Cereals Research Institute, Badeggi, Niger State, Nigeria.*
[2]*Email:* dnahemiah@gmail.com

ABSTRACT

Sorghum is an important crop in many countries of Africa and Asia and serves as a dietary sources of protein, calorie, minerals and vitamins for millions of people in this regions. The concentration of the different nutrients and thermal behavior varies among different cultivars of sorghum and therefore affect its nutritional contribution and selection for processing. In this study, we evaluate the proximate, calorie, mineral and thermal properties of 9 cultivars of sorghum varieties marketed in Maiduguri, Borno State, Nigeria. The results showed significant variation ($p<0.05$) in the moisture content 6.07-8.82%, ash, 1.41-2.17%, fat 3.15-5.12%, protein 10.30-14.10%, crude fiber 1.83-2.50% and total carbohydrate 71.57-78.07%. While calorie ranges between 379.02 -391.03 kcal/100g. The concentration of minerals ranged from 0.08-0.78, 079-9.38, 1.93-9.16, 0.62-0.70, 0.11-0.44 and 0.01-0.02 mg/100g in Zn, K, Ca, Mn, Fe, and Cu respectively. Specific heat capacity averaged 1.642 KjKg-1K-1 within a range of 1.602 to 1.677 KjKg-1K-1, while the thermal conductivity varied from 2.529 to 2.590 Wm−1K−1 with a mean value of 2.556 Wm−1K−1 and thermal diffusivity ranges from 8.41x10-6 ms−2 to 8.57x10-6 ms−2 with a mean value of 8.49x10-6 ms−2. The results showed that the value obtained were all within reported values and could assist in diet planning for a particular situation for those who solely depend on sorghum grain.

Keywords: *Sorghum, Nutrition, Calorie, Thermal properties, Maiduguri, Nigeria.*

DOI: 10.20448/803.5.1.41.51
Citation | Kassum, Afobia Litini; Danbaba, Naheminah; Goni, Mala; Mercy Ibrahim Kwari; Fannah Mustapha Adam; Hadiza Kubura Lawan; Oderaa Amin Igwegbe; Amina Idris Maijalo (2020). Nutritional, Calorie and Thermal Properties of Some Selected Food Grade Sorghum Grains from Maiduguri, Borno State, Nigeria. Canadian Journal of Agriculture and Crops, 5(1): 41-51.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
History: Received: 4 October 2019/ Revised: 7 November 2019/ Accepted: 12 December 2019/ Published: 23 January 2020
Publisher: Online Science Publishing

Highlights of this paper

- This paper examines the nutritional and thermal properties distinction among different cultivars of food grade sorghums used in Nigerian cuisine to help nutritional advising and development of appropriate processing technologies and techniques.
- The results showed that the value obtained were all within reported values and could assist in diet planning for a particular situation for those who solely depend on sorghum grain.

1. INTRODUCTION

Cereal grains are probably the most widely cultivated and consumed food crop together with legumes globally. In Nigeria, especially in the northern region, cereal production is a long time agricultural activity, providing livelihood for millions of smallholder farmers. While cereal grain consumption provides major sources of nutrients, including energy, protein and microelements in the diets of significant number of populations. The most common cereal grains cultivated and consumed in Nigeria include rice, maize, sorghum, millet, wheat and acha (fonio).

Sorghum (*Sorghum bicolor L.)*, also called guinea corn or great millet is considered as one of the most important food crop in the world, following wheat, rice, maize and barley [1]. In the semi-arid tropics of Africa and Asia, sorghum is a dual purpose crop providing about 35% of staple food consumed by humans and also provide feed for livestock and raw material beverage and syrup industries [2, 3]. Over last two decades, there has been huge improvement in the selection and breeding of different sorghum varieties to adopt to changing growing conditions and nutrient requirements. This development has provided farmers with wide range of varieties to select from. Some common varieties of sorghum cultivated in Nigeria includes *Samsorg 40*, *Samsung 41*, *Ex-kano*, *Ex-Katsina*, *Fara-fara*, *Kaura*, *Mere*, *Chakalari*, *Yafimoro*, *Tunbuna and Bulwalama*. While in Borno, the common cultivars are *Chakalari*, *Mire*, *Tunbuna*, *Bulwalana*, *Kaura*, *Fara-fara*, *Yafimoro*, *Ex-kano*, *and Ex-Katsina*.

But as in most crop varieties and cultivars, sorghum cultivars and varieties differ in their grain physical, chemical and processing characteristics. Abdulrahman and Omoniyi [4] reported that the nutritional composition of common cereals in terms of proximate composition is closely similar, yet each variety or cultivar has its special nutritional benefits terms of specific chemical composition, including protein, carbohydrate, fat, minerals and other physicochemical attributes. Whole grain sorghum is an important sources of B-group of vitamins and some minerals such as phosphorus, magnesium, calcium and iron [5] while the protein is similar to that of wheat and maize [6]. Therefore, evaluation of the range of chemical composition related to cultivars and varieties in a given location is essential in selecting grain for optimum utilization as food, feed or industrial raw material. The nutritional composition in terms of proximate composition analysis of any plant material consist of determining of the major group of chemical components, and include moisture content, crude protein, crude fat, fiber, ash and nitrogen-free extracts Simpkins and Williams [7]. Ihekoronye and Ngoddy [8] reported that sorghum contain typically, 68-80% carbohydrate, protein (10-15%), fat (3%), fibre (2%), ash (2%), food energy (394 calories at 11-12% moisture content. Distinction in quality among food crops indicates it market value and is also crucial in popularizing the utilization of the crop in local cuisine. It may also facilitate increased adoption of a cultivar, improve processors and consumer's acceptability and used in the design of appropriate machineries for grain processing [9].

Thermal properties of agricultural raw materials and products on the other hand are essentially the behavior of the material under varying heat treatments and are critical parameters considered in the design and development of processing and storage techniques and technologies and also a requirement for heat transfer calculation [10, 11]. But agricultural material unlike pure metals are complicated biologicals, they have complex biochemical compositions. Constituents majorly found in food materials includes water, protein, fat, carbohydrates, fiber and ash which is a measure of its mineral composition. Because of the importance of thermal properties utilization in the design of agro-processing and storage technologies and the need for easy assessment technique for thermal properties of food materials, Choi and Okos [12] developed a general mathematical models to predict the thermal properties of food products. The models were based on the principle that thermal properties of each main component of food can easily be related to its compositional weight fraction that are easily measured instead of comparing to volume fraction. Several workers [11-14] have used these models to predict the thermal properties of food materials in terms of their thermal conductivity, specific heat capacity, thermal diffusivity.

In our study, the nutritional composition in terms of proximate and mineral composition of common cultivars of sorghum cultivated and marketed in Maiduguri, Borno State, north-east Nigeria was evaluated and their thermal properties determined to provide basic information that will guide in the selection of cultivar for utilization as food and raw materials for industrial processing, help nutrition scientist in diet advising and processing engineers to develop appropriate processing technologies and techniques to enhance sorghum utilization and overall value-chain development.

2. MATERIALS AND METHODS

2.1. Plant Materials

The material used in this study were common sorghum marketed in Maiduguri. Samples were obtained from different open markets and Lake Chad Research Institute (LRI), Maiduguri. Market samples were taken to LRI for identification at the Crop Breeding Laboratory. The samples include *Chakalari* red, *Chakalari* white, *Mere*, *Kaura*, *Bulwalana*, CRS01, CRS02, Samsorg 40 and Samsorg 41. The samples were sorted and cleaned to obtain sound grains and were stored in polyethylene plastics until required for analysis.

2.2. Nutritional Composition Analysis

The standard chemical analysis techniques of AOAC [15] were adopted for nutritional evaluation in terms of proximate and mineral composition. The methods consist of technique for the analytical determinations of moisture, ash, crude fat (ether extract), crude protein and crude fiber. Crude fat (ether extracts) was determined by ether extraction based on the Soxlet extraction technique using the Soxtec System HT method (Tecator Soxtec System HT 1043 Extraction Unit, Tecator AB, Sweden), while protein by micro-Kjeldahl technique (Tecator Digestion System and Kjeltec Auto 1030 Analyzer (Tecator AB, Sweden) and 6.25 was used to convert nitrogen content to protein. The ash content was determined by incinerating 5g of sample flour (Carbolite Furnace England) to 550°C in a pre-weighed crucible. Nitrogen-free extract (carbohydrate), representing sugars and starches in food, was calculated by difference.

$$\text{Carbohydrate (\%)} = 100 - [\text{Moisture (\%)} + \text{Fat (\%)} + \text{Ash (\%)} + \text{Crude fiber (\%)} + \text{Protein (\%)}]$$

The Atwater general conversion factor system was used to calculate caloric value from the proximate composition data of protein, fat and carbohydrate, where the energy values of 17kJ/g (4.0kcal/g) for protein, 37kJ/g (9.0kcal/g) for fat and 17kJ/g (4.0kcal/g) for carbohydrates was used for conversion. The conversion factors for joules and calories are: 1 kJ = 0.239 kcal; and 1 kcal = 4.184 kJ [16].

$$\text{Calorie value (Kcal/g)} = (\%\ \text{Protein x } 4.0) + (\%\ \text{Fat x } 9.0) + (\%\ \text{Carbohydrate x } 4).$$

All equipment and chemical reagents used were of analytical grade and were obtained from the Central Services Laboratory, National Agency for Food and Drug Administration and Control (NAFDAC) Maiduguri, Borno State, where the proximate analysis was carried out.

For the mineral evaluation, three grams (0.3 g) of grounded sample of each of the sorghum grains was placed in a 50 ml beaker and was wet digested using 30 ml of HNO_3-$HClO_4$ acid solution (2:1 volume) on a hot digestion system, which were heated until the samples turn colorless and clear solution. After digestion was complete, the solution of each sample was transferred into a 50 ml calibrated sample bottle and the solution was diluted to the mark with distilled water. Ca, Mg, Fe, and Zn in cereal samples were determined by flame Atomic Absorption Spectrophotometer (VARIAN model AA240FS, USA), while Na and K were determined by flame photometer (PFP7, United States) using a working standard of 10 ppm for each of the species. The analysis was carried out at the Multi-User Science Research Laboratory, Ahmadu Bello University, Zaria.

2.3. Determination of Thermal Properties

Thermal properties of the sorghum samples in terms of specific heat capacity (C_p), thermal conductivity (k) and thermal diffusivity (T_d) were estimated as a function of proximate composition of each sample by applying the additivity principles [14, 17] in conjunction with temperature (-4°C≤ t ≤ 150°C) dependent mathematical models Equations 1-3 of the thermal properties of the individual food constituents.

$$C_p = 4.187X_{moisture} + 1.675X_{fat} + 0.837X_{ash} + 1.594X_{protein} + 1.424X_{carbohydrate} \quad (1)$$

$$k = 0.58X_{moisture} + 0.16X_{fat} + 0.135X_{ash} + 0.155X_{protein} + 0.25X_{carbohydrate} \quad (2)$$

$$T_d = 0.146 \times 10^{-6}X_{moisture} + 0.10 \times 10^{-6}X_{fat} + 0.075 \times 10^{-6}X_{protein} + 0.082 \times 10^{-6}X_{carbohydrate} \quad (3)$$

2.4. Statistical Analysis

Data generated were subjected to analysis of variance (ANOVA) at significant level of 0.05 using Statistical Tool for Agricultural Research (STAR) version 2.1 (International Rice Research Institute, IRRI, Manilla, Philippines) and significant means separated by Duncan's Multiple Range Test (DMRT) according to Gomez and Gomez [16].

3. RESULTS AND DISCUSSIONS

3.1. Proximate Composition of Sorghum Cultivars

The proximate composition (moisture, ash, crude protein, crude fiber, crude fat and carbohydrate) and some mineral content (Zn, K, Ca, Mn, Fe and Cu) were determined in the 9 sorghum cultivars and the results of each analysis are presented in Tables 1 and 2 for proximate and mineral composition respectively. The moisture content ranged from 6.07 to 8.42% with a mean value of 7.18% Table 1. Statistical analysis showed significant difference ($p<0.05$) among the sorghum samples. The highest moisture level was recorded in CRS 02 which was not significantly different ($p<0.05$) from *Samsorg* 40 and CRS 01. On the other hand, the lowest moisture content was recorded for *Bulwalana* (6.07%) which was not different statistically from *Samsorg* 41, and *Chakalari* white. The results were in agreement with the finding of Dicko, et al. [18] and Awadelkareem [19] who reported moisture content of between 6.49% and 12% in different cultivars of sorghum. Data on the moisture content of food materials is important to processors for a variety of reasons, for instance, it is an important factor in food quality, preservation and resistance to deterioration. Moisture content also is an important economic factor as grains are traded on weight basis, hence the grain quality will be affected by additional weight differences which in turn affects the storage ability of the food. Consequently, the low moisture content of the sorghums in this study indicates unsuitable conditions for spoilage organisms and agents to grow and multiply.

The mean ash content of the samples investigated was 1.81%, with *Chakalari* red scoring the highest ash content (2.17%) which was not significantly different from that of *Chakalari* white. Kaura had the least value

(1.41%) which makes it significantly different from all other samples. There was a significant difference ($p<0.05$) among the sorghum cultivars in terms of ash composition Table 1, but no significance was observed among *Samsorg* 40, *Samsorg* 41, CRS 02 and *Mere*. These results lie within the range of 1 to 4% reported by Abdulrahman and Omoniyi [4]; Awadelkareem [19] and Osman [20] among different sorghum and other cereal cultivars. Ash content of food materials is an index of mineral contents. The high ash content in *Chakalari* red and white in this study is an indication that these two sorghum varieties contain greater proportion of non-endosperm materials, since ash value is an indication of level of non-endosperm components [4, 21].

Table-1. Proximate composition of some common sorghum varieties marketed and consumed in Maiduguri, Nigeria.

Sorghum	Proximate composition (%)					
	Moisture	Ash	Protein	Fat	Fiber	CHO
Samsorg 40	8.10±0.10a	1.62±0.02c	14.10±0.10a	4.61±0.01b	1.83±0.03c	71.57±0.22e
Samsorg 41	6.51±0.01c	1.71±0.02c	13.53±0.15b	4.13±0.02c	2.14±0.12b	74.12±0.16b
CRS 01	8.21±0.01a	1.90±0.02b	14.10±0.01a	4.11±0.01c	2.31±0.03a	71.71±0.07e
CRS 02	8.42±0.02a	1.70±0.02c	13.43±0.21b	4.02±0.07c	2.11±0.02b	72.26±0.16d
Mere	6.82±0.02b	1.62±0.02c	13.10±0.10b	5.12±0.01a	2.12±0.02b	73.35±0.08c
Kaura	7.08±0.08b	2.07±0.06b	13.80±0.10a	3.19±0.02d	2.50±0.02a	73.83±0.10c
Bulwalana	6.07±0.6c	1.41±0.01d	11.50±0.10d	3.15±0.02d	1.91±0.02c	77.87±0.14a
Chakalari red	7.30±0.02b	2.17±0.06a	12.50±0.10c	3.50±0.01d	2.20±0.02b	74.52±0.17b
Chakalari white	6.14±0.06c	2.07±0.06a	10.30±0.10e	3.43±0.02d	1.89±0.01c	78.08±0.03a
Mean	7.18	1.81	12.93	3.92	2.11	74.15

Note: Values are means ± standard deviation (n = 3). Means followed by different letter in the column are significantly different ($p<0.05$) according to new Duncans Multiple Range Test (nDMRT), CHO = Carbohydrate.

The protein content of the sorghum samples ranged from 10.30% to 14.10% with a mean value of 12.93% Table 1. Statistical analysis indicated significant difference ($p<0.05$) among cultivars in terms of protein content. The highest score (14.10%) was recorded in *Samsorg* 40 and *CRS* 01 which are not significantly different ($p<0.05$) from *Kaura* which recorded 13.80%. *Chakalari* white on the other hand, scored the lowest protein content (10.30%). Our results are in agreement with the reported range of 6.46% to 16.80% by Abdulrahman and Omoniyi [4]; Osman [20] and Idris, et al. [22]. Cereal crops including sorghum contributes significantly to the protein and energy in the diet of millions of people in the semi-arid tropics, and raw materials for more in developing and developed countries. The protein content of 10.30 to 14.10% in the current study implies that these samples of sorghum are particularly useful in reducing the prevalence of protein related malnutrition. Abdulrahman and Omoniyi [4] reported among different cereals in Nigeria, a protein content of 12.39% (wheat), 11.03% (millet) and 10.49% (rice), indicating comparable protein from these sorghum samples in Maiduguri area. Mustapha and Magdi [23] also recorded a protein content of three sorghum samples varying between 14.51 and 14.80% which is slightly higher than the values recorded in this study. But according to Person [24] plant food materials providing more than 12.0% of its calorie value from protein are considered good sources of food protein. In this study, only *Bulwalana* and *Chakalari* white recorded protein level of less than 12%, indicating that all other sample can be considered a good sources of protein in human diet.

Crude fat content varied between 3.15% in *Bulwalana* and 5.12% in *Mere*, with a mean value of 3.92%. There was significant difference among the sorghum varieties in terms of crude fat content. *Mere* fat content (5.12%) was significantly ($p<0.05$) higher than all the other samples, but *Bulwalana* which recorded the least was not different from *Kaura*, *Chakalari* red and white Table 1. The mean crude fat content is within the reported value of 3.4 to 3.5% by Idris, et al. [22] and Gerrano, et al. [25] but *Mere* fat value (5.12%) was significantly higher than the reported range. There is generally low fat content in the sorghum samples. Low fat content is an indication of suitability for prolong storage with minimal quality deterioration through rancidity. However, fat content contributes significantly to the energy and essential fatty acids required for normal physical activities in adults and optimum neurological, immunological and functional development in children [26]. The fiber content ranges between 1.83% and 2.50% with a mean value of 2.11%. This slightly lower than 2.3 to 2.7% reported by Gerrano, et al. [25] from different cultivars of sorghum. Abdulrahman and Omoniyi [4] reported a mean fiber content of 1.86% in sorghum collected from local market in Abuja, Nigeria. This indicates that the fiber content of sorghum is lower than that of millet (3.19%) and maize (2.83%) reported by Abdulrahman and Omoniyi [4]. High fiber food materials are beneficial in nutrition, such as laxative effect on the bowl, increased fecal bulk and reduction in plasma cholesterol level [27]. Even though, the Protein Advisory Group (PAG) of the United Nations recommended an upper limit of 5% for crude fiber in foods intended for supplementation, Abdulrahman and Omoniyi [4] reported that a value less than 3.5% crude fiber is suitable for infant feeding, implying that all the sorghum varieties in this study are suitable for infant feeding. The carbohydrate content of the sorghum samples was averaged 74.15%, with highest scored in *Chakalari* white (78.08%) which is not significantly different ($p<0.05$) from *Bulwalana*, while the least value was recorded in *Samsorg* 40 (71.57%) which was not statistically different from *CRS* 01 Table 1. Like in most cereals, carbohydrate is the major component of sorghum samples analyzed. Ijabadeniyi and Adebolu [28] in a study of the effect of processing on nutritional quality of three maize varieties in Nigeria, reported a slightly lower mean carbohydrate (65.63-70.23%), while Mustapha and Magdi [23] reported 68.34 to 69.65% carbohydrates in some sorghum varieties. This indicate superior carbohydrate content of the samples from Maiduguri analyzed in this study. The principal component of cereal carbohydrate is starch, which make them absorb large quantity of water during processing. This makes them unsuitable for weaning food preparation as babies need to consume more to obtain the required nutrients. Though this problem is reduced significantly when the seeds are germinated or fortified with protein based products, but adds to the cost of food processing.

3.2. Calorie Values of Different Sorghum Cultivars

Sorghum is a staple food crop for millions of people living in Africa and Asia and semi-tropical countries and acts as an important source of energy, protein and minerals. Calorie value of the different cultivars are presented in Figure 1. From Figure 1, *CRS* 01 scored the least value (379.01 Kcal/100g) which was not statistically different ($p<0.05$) from that of *CRS* 02, *Kaura* and *Chakalari* red. *Mere* on the other hand scored the highest calorie value (391.03 Kcal/100g). Calorie value of 329.0% per 100g serving has been observed to be provided per day for normal adult activity by sorghum, indicating that the 379.01 to 391.03 Kcal/100g in this study is sufficiently higher. The slightly higher value in this study may be as a result of higher carbohydrate value observed.

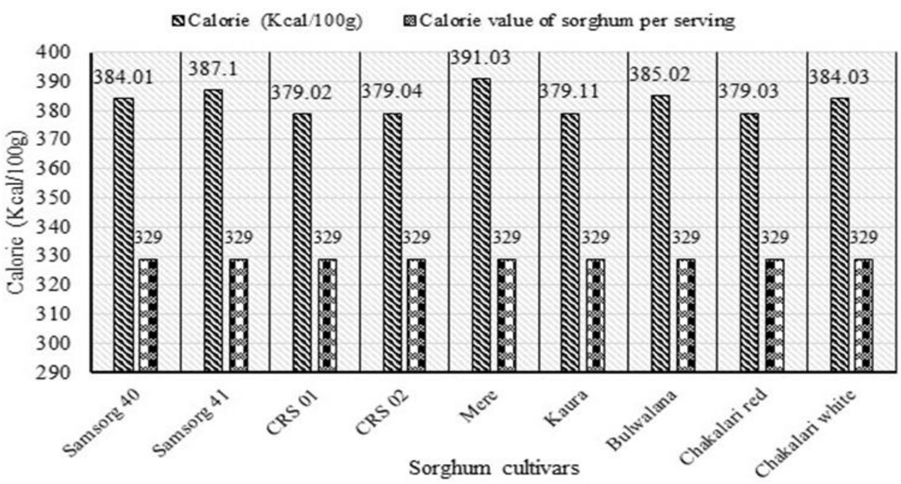

Figure-1. Calorie value of different sorghum cultivars compared with recommended value per serving.
Source: *Comparison figure of 329 was obtained from https://www.nutritionvalue.org>sorghum.

Data on the calorie value of food materials is essential for the problems protein-energy malnutrition, normal nutrition, undernutrition and obesity.

3.3. Mineral Composition of Sorghum Cultivars

One of the nutritional composition analyzed for sorghum in this study include their mineral composition as presented in Table 2. The results showed a significant variation among the cultivars in the concentration of Zinc which ranged between 0.16 to 0.80mg/100g. Highest Zn was recorded in CRS 02 with a non-significant ($p<0.05$) concentrations among Kaura, Chakalari red and white cultivars Table 2.

Table-2. Mineral content of some selected sorghum varieties marketed and consumed in Maiduguri, Nigeria.

Sample	**Mineral composition (mg/100g)**					
	Zn	**K**	**Ca**	**Mn**	**Fe**	**Cu**
Samsorg 40	0.16 ± 0.01^{e}	0.72 ± 0.03^{e}	5.09 ± 0.58^{d}	0.63 ± 0.03^{b}	0.28 ± 0.01^{a}	0.02 ± 0.01^{a}
Samsorg 41	0.28 ± 0.02^{b}	1.91 ± 0.02^{c}	6.08 ± 0.08^{c}	0.63 ± 0.01^{b}	0.16 ± 0.01^{c}	0.01 ± 0.00^{a}
CRS 01	0.37 ± 0.02^{c}	9.38 ± 0.07^{a}	7.57 ± 0.40^{b}	0.63 ± 0.01^{b}	0.12 ± 0.02^{d}	0.01 ± 0.00^{a}
CRS 02	0.80 ± 0.02^{f}	9.61 ± 0.02^{a}	1.93 ± 0.03^{f}	0.64 ± 0.01^{b}	0.11 ± 0.02^{d}	0.01 ± 0.00^{a}
Mere	0.25 ± 0.01^{d}	2.12 ± 0.04^{c}	3.68 ± 0.04^{e}	0.68 ± 0.03^{b}	0.11 ± 0.02^{d}	0.01 ± 0.00^{a}
Kaura	0.49 ± 0.02^{b}	1.21 ± 0.02^{d}	6.53 ± 0.02^{c}	0.70 ± 0.00^{a}	0.13 ± 0.02^{d}	0.01 ± 0.00^{a}
Bulwalana	0.73 ± 0.03^{a}	6.71 ± 0.02^{b}	3.58 ± 0.10^{e}	0.67 ± 0.01^{b}	0.13 ± 0.02^{d}	0.01 ± 0.00^{a}
Chakalari red	0.73 ± 0.03^{a}	1.70 ± 0.03^{d}	9.16 ± 0.05^{a}	0.65 ± 0.01^{b}	0.44 ± 0.02^{a}	0.02 ± 0.00^{a}
Charalari white	0.73 ± 0.02^{a}	1.43 ± 0.02^{d}	7.10 ± 0.10^{b}	0.62 ± 0.01^{b}	0.44 ± 0.01^{a}	0.02 ± 0.00^{a}
Mean	0.50 ± 0.25	3.87 ± 3.64	5.64 ± 2.27	0.65 ± 0.03	0.21 ± 0.14	0.013 ± 0.005

Note: Values are means ± standard deviation (n = 3). Means followed by different letter in the column are significantly different ($p<0.05$) according to new Duncan's Multiple Range Test (nDMRT).

Zn is a micro nutrient required for body weight gain and high in human, and also a component of proteinases and peptidases enzymes [29]. The K concentration ranges between 0.72 and 9.61mg/100g. Cultivars CRS 01and 02 were not significantly different ($p<0.05$) and had the highest concentration of K and the lowest was seen in Samsorg 40. K is a major cation in intracellular fluid which help to regulate the acid base, osmotic and water balance [30].

The mineral element Ca has been reported to play an important role in human nutrition for bone development and strength and also clothing of wounds [31]. In this study, the cultivars Ca concentration ranges from 1.93mg/100g in CRS 02 to 9.16 mg/100g in Chakalari red Table 2. Mn, Fe and Cu concentrations varies between 0.62 to 0.68, 0.11 to 0.44 and 0.01% to 0.02 mg/100g respectively. Statistical analysis indicated significant difference ($p<0.05$) among the sorghum cultivars in terms of their Zn, K, Ca, Mn and Fe contents, but no significant difference ($p<0.05$) was observed in copper concentration in the grains. This values are within the ranges reported by Abdulrahman and Omoniyi [4] for different classes of cereals (wheat, sorghum, millet, maize and rice) marketed in Gwagwalada market in Abuja, Nigeria. Nafisa [32] also reported similar results in some new sorghum varieties cultivated in Sudan, but less than the values reported by Jimoh and Abdullahi [6]. Several studies on the mineral concentration in different plant species and the contributing factors suggested that mineral concentration of seeds is dependent on the genetic makeup of the species, cultural practices especially fertilizer application during cultivation, soil type, weather conditions, growing season as well as cultivar [33-35]. One or more of these factors may therefore be the possible reason for the variation in mineral concentrations among the sorghum cultivars in this study.

3.4. Thermal Properties of Sorghum Cultivars

The thermal properties results of the different sorghum cultivars in terms of specific heat capacity (C_p), thermal conductivity (k) and thermal diffusivity (α) as estimated from predictive empirical models based on proximate composition mass fractions Equations 1, 2 and 3 respectively are presented in Table 3.

Table-3. Thermal properties* of some common sorghum marketed and consumed in Maiduguri, Nigeria.

Sorghum cultivars	Specific heat capacity C_p ($kJkg^{-1}K^{-1}$)	Thermal conductivity k ($Wm^{-1}K^{-1}$)	Thermal diffusivity α x 10^{-6} (ms^{-2})
Samsorg 40	1.674	2.573	8.57
Samsorg 41	1.627	2.529	8.46
CRS 01	1.674	2.579	8.55
CRS 02	1.677	2.590	8.56
Mere	1.638	2.536	8.50
Kaura	1.638	2.549	8.44
Bulwalana	1.611	2.546	8.45
Chakalari red	1.636	2.555	8.46
Chakalari white	1.602	2.542	8.41
Mean	1.642	2.556	8.49

Source: * Estimated as a function of proximate composition of each sample by applying the additivity principles Equations 1, 2 and 3.

The specific heat capacity of the sorghum cultivars was averaged at 1.642 $KjKg^{-1}K^{-1}$ within a range of 1.602 to 1.677 $KjKg^{-1}K^{-1}$, while the thermal conductivity varied from 2.529 to 2.590 $Wm^{-1}K^{-1}$ with a mean value of 2.556 $Wm-1K-1$ Table 3. The thermal diffusivity on the other hand was averaged 8.49 x 10^{-6} ms^{-2} for all the sorghum samples evaluated, with Chakalari white recording the least thermal diffusivity value of 8.41 x 10^{-6} ms^{-2} as compared to 8.57 x 10^{-6} ms^{-2} observed in Samsorg 40. Akeem, et al. [14] while analyzing the thermal properties of acha seeds reported C_p, k and α ranging from 1.68 to 2.97 $kJkg-1K-1$, 0.27 to 0.43 $Wm^{-1}K^{-1}$ and 0.86 x 10^{-7} to 1.17 x 10^{-7} ms^{-2} respectively. The results of this study are closely within the reported value for acha.

Choi and Okos [36] reported that the chemical composition of food materials affects its thermal properties. The variations in the thermal properties of the sorghum cultivars in this study therefore may be attributed to the differences in their compositions. Appropriate design of boiling system for grain processing is dependent on the thermal properties of the material [37]. Cp measures the amount of heat a material can absorb and is an essential design parameter for heat exchangers [13, 38]. The information provided in this study therefore will be useful in selecting heat transfer medium and processing conditions for industrial processing of sorghum. Thermal conductivity (k) is an essential property used in the determination of the rate of transmission of heat through foods during thermal processing and it is a measure of its ability to transmit heat [38]. Slightly uniform k was recorded among the sorghum cultivars in this study Table 3. This connotes that all the cultivars grains will have slightly uniform absorption and dissipation of heat during processing and storage. Thermal conductivity of food materials is dependent on the structure and chemical composition of the material and it increases with increasing water content for all food products at temperature above freezing [39]. The k values therefore could be used in the analysis of the heat transfer during the processing of the grains into different food products [40].

The thermal diffusivity (α) on the other hand, quantifies the materials ability to conduct heat relative to its ability to store heat [41]. Cooling is an important operation in food industry. Sorghum and related grains are pre-cooled before storage or transportation because heat moves from the surface to the environment. Therefore, values of α recorded in this study will be important in analyzing heat transfer phenomenon during grains handling.

4. CONCLUSION AND RECOMMENDATION

From the results of the investigation, proximate, calories, mineral composition and thermal properties analysis has been conducted; and the nine sample of sorghum varieties complied with the objective of this study and it was observed that chakalari red was found to contain highest ash which signifies the present of minerals element in it, chakalari white was highest in carbohydrate and fiber but low in protein. The protein content was found to be very high in Samsorg 40 and CRS 01. *Bulwalana* was the only variety that has poor nutrient value compared with the other varieties and also found to be low in moisture content; therefore, it is best for storage.

REFERENCES

[1] FAO, *Official agricultural statistic*, 18th ed. Canada: Food and Agricultural Organization, 2006.

[2] B. Mauder, "Sorghum: The global grain of the future." Retrieved from: http://www.sorghumgrowers.com/sorghum. [Accessed 16th July, 2019], 2006.

[3] J. M. Awika and L. W. Rooney, "Sorghum phytochemicals and their potential impact on human health," *Phytochemistry*, vol. 65, pp. 1199-1221, 2004.Available at: https://doi.org/10.1016/j.phytochem.2004.04.001.

[4] W. Abdulrahman and A. Omoniyi, "Proximate analysis and mineral compositions of different cereals available in gwagwalada market, FCT, Abuja, Nigeria," *Journal of Advances in Food Science & Technology*, vol. 3, pp. 50-55, 2016.

[5] FAO, *Sorghum and millets in human nutrition*. Rome Italy: Food and Nutrition Series FAO, 1995.

[6] W. L. O. Jimoh and M. S. Abdullahi, "Proximate analysis of selected sorghum cultivars," *Bayero Journal of Pure and Applied Sciences*, vol. 10, pp. 285 – 288, 2017.Available at: http://dx.doi.org.10.4314.bajopas.v10i.43.

[7] I. Simpkins and J. I. Williams, *The mammalian alimentary system' Advanced Biology*, 3rd ed. London: ELBS, 1990.

[8] A. I. Ihekoronye and P. O. Ngoddy, *Integrated food science and technology for tropics*. London: MacMillan Education Ltd, 1985.

[9] M. Nádvorníková, J. Banout, D. Herák, and V. Verner, "Evaluation of physical properties of rice used in tradition food science and nutritional Kyrgyz Cuisine," *Food Science and Nutrition*, vol. 10, pp. 1–10, 2018.Available at: https://doi.org/10.1002/fsn3.746

[10] M. A. Akintunde, "Modeling of thermal properties of food components," *Pacific Journal of Science and Technology*, vol. 9, pp. 629-639, 2008.

[11] R. Akinoso and A. Raji, "Physical properties of fruit, nut and kernel of oil palm," *International Agrophysics*, vol. 25, pp. 85-88, 2011.

[12] Y. Choi and M. R. Okos, "Effects of temperature and composition on thermal properties of foods," *Journal of Food Process and Applications*, vol. 1, pp. 93-101, 1986.

[13] R. Akinoso and N. E. El-alawa, "Some engineering and chemical properties of cooked locust bean seed (Parkia biglobosa)," *West Indian Journal of Engineering*, vol. 35, pp. 51–57, 2013.

[14] O. R. Akeem, O. N. Hajarat, E. A. Tawakalitu, O. R. Monsurat, and S. Maimuna, "Effect of cooking time on the physical, chemical and thermal properties of acha seeds," *International Journal of Food Studies*, vol. 6, pp. 178–191, 2017.Available at: http://www.doi.10.7455/ijfs/6.2.2017.a5.

[15] AOAC, *Association of official analytical chemists official methods of analysis*, 14th ed. Washington, DC, USA: Official Method, 1984.

[16] A. K. Gomez and A. A. Gomez, *Statistical procedure for agricultural research*, 2nd ed. New York: John Willey, 1983.

[17] N. Danbaba, "Effects of extrusion variables on the quality indices of rice-based extrudates," Ph.D Thesis Submitted to the School of Postgraduate Studies, University of Maiduguri, in Partial Fulfillment for the Award of the PhD Degree

in Food Processing Engineering, Department of Food Science and Technology, Faculty of Engineering, University of Maiduguri, 2017.

[18] M. H. Dicko, H. Gruppen, A. S. Traoré, W. J. van Berkel, and A. G. Voragen, "Evaluation of the effect of germination on phenolic compounds and antioxidant activities in sorghum varieties," *Journal of Agricultural and Food Chemistry*, vol. 53, pp. 2581-2588, 2005.Available at: https://doi.org/10.1021/jf0501847.

[19] A. M. Awadelkareem, "Characterization of tannin and nutritional value of sorghum (sorghum biocolor L. Monech) supplemented with soy," M. Sc. Thesis Faculty of Agriculture, University of Khartoum, 2008.

[20] H. A. Osman, "Proximate composition, antinutritional factors and protein fractions of sorghum (Sorghum bicolor (L) Moench)," M Sc. Thesis Faculty of Agriculture, U of K, 2005.

[21] A. Evers, "Ash determination - a useful standard or a flash in the pan. Retrieved from http://www.satake-europe.com. [Accessed October 20, 2012] " 2001.

[22] W. H. Idris, S. M. Abdel Rahaman, H. B. ElMaki, E. E. Babiker, and A. H. El Tinay, "Effect of malt pretreatment on HCl extractability of calcium, phosphorus and iron of sorghum (Sorghum biocolor) cultivars," *International Journal of Food Science & Technology*, vol. 42, pp. 194-199, 2007.Available at: https://doi.org/10.1111/j.1365-2621.2006.01207.x.

[23] A. A. G. Mustapha and A. O. Magdi, "Proximate composition and content of sugars, amino acids and anti nutritional factors of three sorghum varieties," Research Bulletin., No. 125, Agricultural Research Centre, King Sa'ad University2003.

[24] D. Person, *The chemical analysis of foods'. Egon, H.; Kerk, R.S. and Sawyer, R (Eds.)*, 7th ed. London, New York: Churchill Livingstone, 1976.

[25] A. Gerrano, M. Labuschagne, A. Van Biljon, and N. Shargie, "Quantification of mineral composition and total protein content in sorghum [Sorghum bicolor (L.) Moench] genotypes," *Cereal Research Communications*, vol. 44, pp. 272-285, 2016.Available at: https://doi.org/10.1556/0806.43.2015.046.

[26] A. A. Guthrie, *Introductory nutrition*, 7th ed.: Times Mirror/Mosby College Publisher, 1989.

[27] Z. S. C. Okoye, *Biochemical aspects of nutrition*. New Delhi. 147195: Prentice-Hall of India, 1992.

[28] A. Ijabadeniyi and T. Adebolu, "The effect of processing methods on the nutritional properties of ogi produced from three maize varieties," *Journal of Food, Agriculture and Environment*, vol. 3, pp. 108-109, 2005.

[29] C. A. Prince, H. E. Clark, and E. A. Funkhouse, *Functions of micronutrients in plants' micronutrients in agriculture*. Madison, Wisconsin, USA: Soil Science Society of America, 1972.

[30] E. M. A. Olatunji and B. M. Temitope, "Comparative study of mineral elements distribution in sorghum and millet from Minna and Bida, North Central Nigeria," *International Journal of Food Nutrition and Safety*, vol. 3, pp. 55-63, 2013.

[31] A. Shegro, N. G. Shargie, A. van Biljon, and M. T. Labuschagne, "Diversity in starch, protein and mineral composition of sorghum landrace accessions from Ethiopia," *Journal of Crop Science and Biotechnology*, vol. 15, pp. 275-280, 2012.Available at: https://doi.org/10.1007/s12892-012-0008-z.

[32] M. T. I. Nafisa, "Proximate composition and nutritional value of three sorghum (Sorghum bicolor (L) Moench) lines," University of Khartoum, A Dissertation Submitted to the University of Khartoum in partial Fulfillment of the Requirements for the Degree of M.Sc. in Food Science and Technology, , 2002.

[33] H. Gorz, F. A. Haskins, J. F. Pedersen, and W. Ross, "Combining ability effects for mineral elements in forage sorghum hbrids 1," *Crop Science*, vol. 27, pp. 216-219, 1987.Available at: https://doi.org/10.2135/cropsci1987.0011183x002700020017x.

[34] Z. Rengel, G. Batten, and D. D. Crowley, "Agronomic approaches for improving the micronutrient density in edible portions of field crops," *Field Crops Research*, vol. 60, pp. 27-40, 1999.Available at: https://doi.org/10.1016/s0378-4290(98)00131-2.

[35] S. M. Farahani, M. R. Chaichi, D. Mazaheri, R. T. Afshari, and G. H. Savaghebi, "Barley grain mineral analysis as affected by different fertilizer systems and drought stress," *Journal of Agricultural Science and Technology*, vol. 13, pp. 315-326, 2011.

[36] Y. Choi and M. R. Okos, *Food engineering and process applications. In M. L. Maguer & P. Jelen (Eds.), (Chap. Effects of temperature and composition on the thermal properties of foods* vol. 1. London: Elsevier, 1986.

[37] G. V. Barbosa-Canovas, P. Juliano, and M. Peleg, *Food engineering. Encyclopaedia of life support systems (EOLSS). In G. V. Barbosa-Canovas (Ed.), (Chap. Engineering properties of foods.* vol. 1. Oxford: EOLSS Publishers, 2006.

[38] R. P. Singh and D. R. Heldman, *Introduction to food engineering*, 3rd ed. London: Academic Press, 2001.

[39] H. Ishida, H. Suzuno, N. Sugiyama, S. Innami, T. Tadokoro, and A. Maekawa, "Nutritive evaluation on chemical components of leaves, stalks and stems of sweet potatoes (Ipomoea batatas poir)," *Food Chemistry*, vol. 68, pp. 359–367, 2000.Available at: https://doi.org/10.1016/s0308-8146(99)00206-x.

[40] R. Stroshine and D. Hamann, *Physical properties of agricultural materials and food products: Course manual.* West Lafayette Indiana: Purdue University Press, 1994.

[41] B. Seruga, S. Budžaki, Ž. Ugarčić-Hardi, and M. Seruga, "Effect of temperature and composition on thermal conductivity of "Mlinci" dough," *Czech Journal of Food Sciences*, vol. 23, pp. 152-158, 2005.Available at: https://doi.org/10.17221/3385-cjfs.