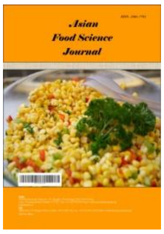

Asian Food Science Journal

21(8): 1-14, 2022; Article no.AFSJ.86764
ISSN: 2581-7752

Quality Evaluation of Gruels from Malted Sorghum-*Moringa oleifera* Flour Blends

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AFSJ/2022/v21i830441

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/86764

Original Research Article

Received 08 March 2022
Accepted 15 May 2022
Published 25 May 2022

ABSTRACT

Aim: In this study, moringa seed flour was subjected to treatments (boiling and roasting) and used to fortify sorghum flour (Kunun Zaki flour).
Study Design: The blend ratios of Kunun Zaki flour and Moringa seed flour were 100:0 (control), 95:5, 90:5, 85:15, and 80:20 which were subjected to standard methods for evaluation of physicochemical properties of the flours while flour samples were further processed into a gruel and subjected to sensory evaluation.
Result: The results of the proximate analysis indicated an increase in moisture, protein, fat, ash, and fibre from 9.06 – 9.34, 11.12 – 13.09, 3.64 – 5.74, 2.95 – 3.32, 7.65 – 8.24% respectively and decreased in carbohydrate (65.53 – 60.62%). The pH increased (3.90 – 4.37) while the titratable acidity decreased (0.87 – 0.68). All the phytochemicals (alkaloids, flavonoids, tannins, sterols, phenols, cyanides, and phytates) increased as the moringa seed flour was added. T The addition of moringa seed flour increased vitamins A, C, B1, B2, and B6. It also led to an increase in sodium and composite flour.

Keywords: Gruel; Kunun Zaki; Malted Sorghum; Moringa oleifera; flour;

1. INTRODUCTION

Gruel is a food consisting of some types of cereals such as oat, wheat or rye flour, rice boiled in water, or milk. It is a thinner version of porridge that may be more often drunk than eaten and may not need to be cooked. Historically, gruel has been a staple of the

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Western diet, especially for peasants. Gruel is often made from millet, hemp, barley, or, in hard times, chestnut flour or even the less bitter acorns of some oaks. Though its actual medical use is not proven, the importance of gruel as a form of sustenance has historically been considered for the sick and recently weaned children [1].

To meet the challenging food need of man, most especially those in the developing countries, various approaches to the use of underutilized local foods to supplement the daily staples such as millet, maize, corn, cassava, Sorghum, and so on has been advocated as a measure to tackle the root cause of malnutrition in developing countries. The introduction of an agreed approach toward providing adequate and sufficient nutrition is paramount [2]. To have a healthy population sufficiently satisfied with adequate nutrition hence, it is essential to exploit underutilized food resources [1].

Sorghum bicolour, commonly called sorghum and also known as great millet, *durra*, *jowari*, or *milo*, is a grass species cultivated for its grain, which is used as food for humans, animal feed, and ethanol production. Sorghum originated in northern Africa and is now cultivated widely in tropical and subtropical regions [3]. Sorghum is the world's fifth-most important cereal crop after rice, wheat, maize, and barley. *S. bicolour* is typically an annual crop, but some cultivars are perennial. It grows in clumps that may reach over 4m high. The grain is small, ranging from 2 to 4mm in diameter. Sweet sorghums are sorghum cultivars that are primarily grown for foliage, syrup production, and ethanol; they are taller than those grown for grain. Sorghum is an important crop for food and fodder in the semi-arid tropics of the world [4]. Sorghum is a staple food in African and Asian subcontinents. Most of the grain produced in these countries is utilised for human consumption. Though sorghum is known for its nutritional quality, the consumption of this cereal is decreasing due to the easy availability of rice and wheat through the public distribution system and easy methods of processing and cooking fine cereals (such as rice). Popular foods made in different parts of the world, especially in the Indian and African sub-continent include; Roti, Annam, SankatiKanji, Ogi, Agidi [4].

Moringa oleifera Lam. belongs to a single genus family *Moringaceae* which has fourteen species [5]. It is commonly called the ben oil tree and is locally known as *Zogeli* among the Hausa-speaking people of Nigeria [6]. It is grown and widely cultivated in the Northern part of Nigeria and many countries in tropical Africa [7]. Moringa seeds have a characteristic taste and could, therefore, serve as a gruel-tasting agent while at the same time improving the nutritional value of the gruels [8]. Due to the high nutritional value of moringa seeds, it is very important in the human diet as it can serve as a supplement to several food crops [9]. Malnutrition is a condition that results from eating diets in which nutrients are either not enough or are too much such that the diet causes health problems. It may involve calories, protein, carbohydrates, vitamins or minerals (Dorland, 2011). When the nutrients are not enough it is called undernutrition or undernourishment while too many nutrients in food are called overnutrition (Young, 2013).

The purpose of this research is malnutrition a problem affecting developing countries including Nigeria.

Sorghum alone can’t tackle malnutrition and hunger in the developing world. In response to the problem, this study investigated the supplementation of sorghum gruel with moringa seed flour which is rich in fat, protein, minerals and crude fiber and is readily available. Therefore, it could improve the protein and mineral content of the gruel which will help reduce malnutrition.

2. MATERIALS AND METHODS

2.1 Procurement of Materials

Sorghum and *Moringa oleifera* seeds used in this study were purchased from the Teaching and Research Farm of the College of Agronomy, University of Agriculture Makurdi. They were transferred to the dry processing laboratory of the Department of Food Science and Technology, the University of Agriculture for subsequent processing.

2.2 Preparation of Samples

2.2.1 Preparation of sorghum flour

The method described by [10] was used with slight modifications for the production of fermented sorghum sediment. As shown in Fig. 1.

2.2.2 Preparation of *Moringa oleifera* seed flour

The moringa seed flour was prepared by the method described by [11] with slight modifications as shown in Fig. 2.

2.2.3 Blend formulation of sorghum-moringa seed flours

Preliminary studies were conducted using ratio blends up to 50:50 sorghum flour to moringa seed flour. To ascertain the best blend formulation for this study. The blends of up to 50:50 sorghum flour to moringa flour were used to produce a gruel and sensory analyses were carried out based on acceptability, taste, aroma, and general acceptability on a 9-point descriptive scale.

The incorporation of moringa seed flour into sorghum flour beyond 20% (w/w) resulted in an undesirable taste of the gruel. Consequently, gruel was produced from blends of sorghum flour and moringa seed incorporated up to 20%. (Table 1).

2.2.4 Preparation of gruel from sorghum and moringa seed flour blends

The sorghum was prepared as described [10]. Each sample weighing 100g of both sorghum and moringa seed flours was reconstituted with 300ml of warm water (about 40°C) and stirred for the 60s.

2.3 Proximate Analysis of Sorghum-moringa Seed Flour Blends

The protein, moisture, fat, fibre, ash, carbohydrate, pH, Titratable Acidity(TTA) minerals, and vitamins were determined according to AOAC 2012 [12]

2.4 Determination of Phytochemicals in Sorghum-moringa Seed Flour Blends

The method described by [13] was adopted in the determination of **alkaloids**, The content of total phenolics was determined according to the Folin-Ciocalteu assay [14], Total flavonoids content was determined by a colorimetric assay developed by [15], Tannin content and Steroids content was determined with the method described by [16] Okeke and Elekwa (2003). The method of [17] was used for phytate determination and lastly This was determined according to the method described by [18].

Table 1. Blend formulation of sorghum-moringa seed flours

Samples	Sorghum flour (SF)	BMSF & RMSF
A (Control)	100	0
BB1	95	5
BC2	90	10
BD3	85	15
BE4	80	20
RB1	95	5
RC2	90	10
RD3	85	15
RE4	80	20

Key: A = Control =100%.
Boiled samples: BB1 = 95SF + 5BMSF; BC2 = 90SF + 10BMSF; BD3 = 85SF + 15BMSF; BE4 = 80SF + 20BMSF
Roasted samples: RB1 = 95SF + 5RMSF; RC2 = 90SF + 10RMSF; RD3 = 85SF + 15RMSF; RE4 = 80SF + 20RMSF

2.5 Statistical Analysis

The experiments were conducted in triplicates and data generated were analyzed using analysis of variance (ANOVA) and means separated by the Fishers' LSD test. The significant difference was accepted at a 5% level of probability ($p<0.05$) using the statistical package for social sciences (SPSS) version 23.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of Sorghum-moringa Seed Flour Blends

The proximate composition is shown in Table 2. The moisture content of the composite flour increased with the increased substitution of sorghum flour with moringa seed flour. There was no significant ($p>0.05$) difference between samples containing BM and RM at different blend ratios. Samples with RM and BM were also not significantly ($p>0.05$) different from each other. A similar increase was reported by [19]. Low moisture content below 10% implies that the flour can be stored if properly packaged [20]. The low moisture content is also an indication that drying was efficiently carried out on the samples. Samples with BM had higher moisture content than those with RM.

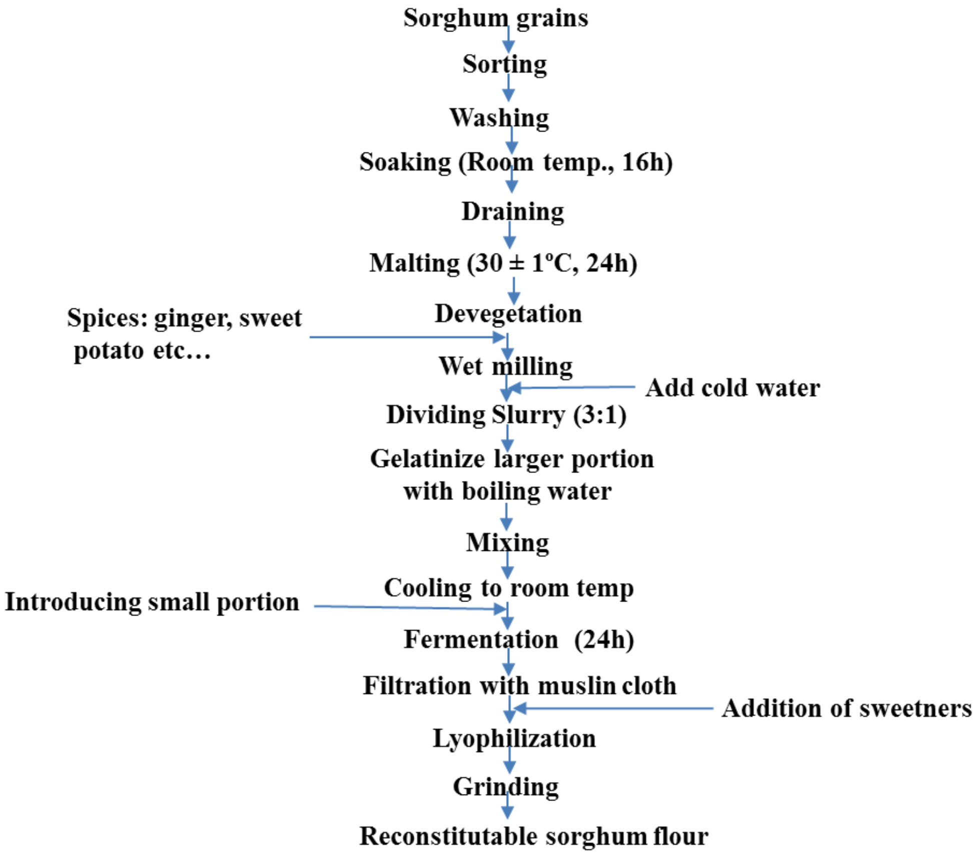

Fig. 1. Flow chart for the production of sorghum flour
Source: [10] modified

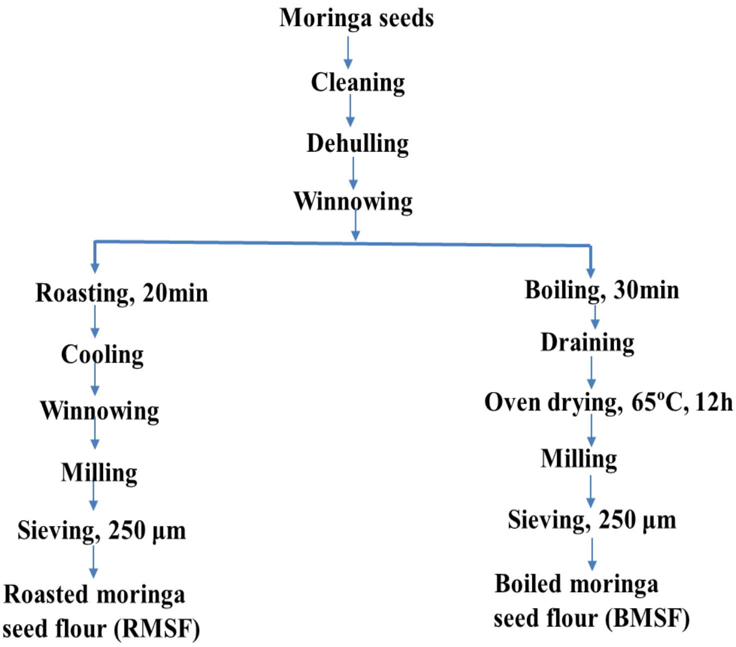

Fig. 2. Flow chart for the production of roasted and boiled moringa seed flours
Source: Adejumo [11] et al. (2012)

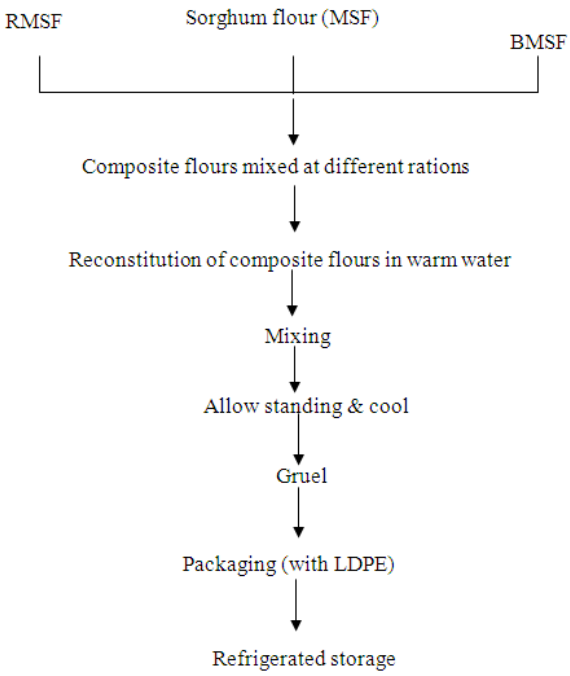

Fig. 3. Flow chart for the production of gruel from sorghum/moringa flour blends
Source: [10]
RMSF = Roasted moringa seed flour; BMSF = Boiled moringa seed flour

There was an increase in the protein content of all samples and there was no significant (p>0.05) difference between samples with BM and RM. The control had the least protein content. A similar increase was reported by Bolarinwa [21] and Olaitan [22] where there was an increase in protein with the increased addition of millet flour. The increase in protein is due to the increased addition of moringa seed flour which is rich in protein [23] Samples with RM had higher protein values than samples with BM. The protein content of moringa complemented the protein of sorghum flour thereby improving its nutritional quality and can also serve as a complementary food to relieve PEM (Protein-energy malnutrition) as experienced in children within Nigeria and Africa [22]. According to [23] *Moringa oleifera* is a nutrient-rich plant with the potential to combat malnutrition problems in Africa. Moringa seed flour was also reported by [6] to contain 28% crude protein while its cake flour contained 50% protein.

There was a significant (p<0.05) increase in the fat content. The control had the least fat content among all the samples. Comparing samples with BM and RM there was no significant (p>0.05) difference between the samples at the same blend ratios except at 10% moringa seed flour where the samples were significantly (p<0.05) different. A similar increase was reported by [19]. The increased fat content could be due to the increased addition of moringa seed flour. According to [23] low-fat content is recommended for complementary foods because fat contents can affect the shelf life of foods, this occurs due to deterioration which leads to oxidative deterioration, rancidification, and spoilage thus reducing the shelf life of food samples. Hence foods with high-fat content are more prone to spoilage. Samples fortified with RM were higher in fat than those with BM.

The ash content increased significantly (p<0.05) with the increased addition of moringa seed flour. The control had the least ash content among all samples. Samples with both BM and RM with the same blend ratios were not significantly (p>0.05) different from each other. An increase in ash was also reported by [19]. The increase in the ash could be due to inherent properties and nutrients in moringa seed flour [19] and due to the increased addition of moringa seed flour [6]. According to [24], the application of treatments such as roasting, fermentation, and boiling of moringa seeds improves its nutritional properties.

Table 2. Proximate composition of sorghum-moringa seed flour blends

Parameter		The blend ratio of sorghum-moringa seed flours				
(%)		**100:0**	**95:5**	**90:10**	**85:15**	**80:20**
Moisture	BMSF	$9.12^{ab} \pm 0.19$	$9.07^{b} \pm 0.01$	$9.16^{ab} \pm 0.03$	$9.26^{ab} \pm 0.05$	$9.34^{a} \pm 0.05$
	RMSF	$9.12^{a} \pm 0.19$	$9.06^{a} \pm 0.02$	$9.14^{a} \pm 0.04$	$9.22^{a} \pm 0.06$	$9.29^{a} \pm 0.09$
Protein	BMSF	$11.12^{b} \pm 0.73$	$11.44^{b} \pm 0.0$	$11.851^{b} \pm 0.02$	$11.99^{b} \pm 0.00$	$13.09^{a} \pm 0.03$
	RMSF	$11.12^{c} \pm 0.73$	$11.45^{c} \pm 0.12$	$12.00^{bc} \pm 0.06$	$12.74^{ab} \pm 0.17$	$13.11^{a} \pm 0.23$
Fat	BMSF	$3.64^{e} \pm 0.19$	$4.26^{d} \pm 0.01$	$4.73^{c} \pm 0.01$	$5.22^{b} \pm 0.00$	$5.69^{a} \pm 0.03$
	RMSF	$3.64^{e} \pm 0.19$	$4.27^{d} \pm 0.00$	$4.76^{c} \pm 0.01$	$5.24^{b} \pm 0.03$	$5.74^{a} \pm 0.02$
Ash	BMSF	$2.95^{d} \pm 0.06$	$3.08^{c} \pm 0.00$	$3.166^{bc} \pm 0.02$	$3.25^{ab} \pm 0.01$	$3.32^{a} \pm 0.04$
	RMSF	$2.95^{d} \pm 0.06$	$3.07^{c} \pm 0.01$	$3.16^{b} \pm 0.01$	$3.24^{b} \pm 0.01$	$3.32^{a} \pm 0.01$
Fibre	BMSF	$7.65^{a} \pm 1.34$	$7.37^{a} \pm 0.01$	$7.87^{a} \pm 0.01$	$8.06^{a} \pm 0.01$	$8.24^{a} \pm 0.00$
	RMSF	$7.65^{a} \pm 1.34$	$7.38^{a} \pm 0.00$	$7.91^{a} \pm 0.02$	$8.08^{a} \pm 0.01$	$8.26^{a} \pm 0.01$
Carbohydrate	BMSF	$65.53^{a} \pm 2.13$	$64.22^{ab} \pm 0.01$	$63.27^{ab} \pm 0.06$	$62.36^{bc} \pm 0.04$	$60.67^{c} \pm 0.04$
	RMSF	$65.53^{a} \pm 2.13$	$64.22^{a} \pm 0.10$	$63.25^{ab} \pm 0.16$	$61.48^{bc} \pm 0.85$	$60.62^{c} \pm 0.12$

BMSF, Boiled moringa seed flour; RMSF, Roasted moringa seed flour; Values are mean ± standard deviation of duplicate determination, Mean values across a row followed by different superscript letters are significantly different at (p<0.05)

Table 3. The pH and TTA values of sorghum-moringa seed flour blends

Parameter		The blend ratio of sorghum-moringa seed flours				
		100:0	**95:5**	**90:10**	**85:15**	**80:20**
pH	BMSF	$3.90^{e} \pm 0.01$	$4.02^{d} \pm 0.23$	$4.14^{c} \pm 0.01$	$4.25^{b} \pm 0.01$	$4.37^{a} \pm 0.01$
	RMSF	$3.90^{d} \pm 0.07$	$4.02^{d} \pm 0.01$	$4.14^{c} \pm 0.01$	$4.26^{b} \pm 0.12$	$4.37^{a} \pm 0.11$
TTA	BMSF	$0.87^{a} \pm 0.01$	$0.85^{b} \pm 0.01$	$0.79^{c} \pm 0.01$	$0.73^{d} \pm 0.01$	$0.68^{e} \pm 0.03$
	RMSF	$0.87^{e} \pm 0.11$	$0.84^{d} \pm 0.02$	$0.79^{c} \pm 0.01$	$0.74^{b} \pm 0.01$	$0.68^{a} \pm 0.01$

BMSF, Boiled moringa seed flour; RMSF, Roasted moringa seed flour; Values are mean ± standard deviation of duplicate determination. Mean values across a row followed by different superscript letters are significantly different at (p<0.05)

The fibre content increased with the increased addition of moringa seed flour. There was no significant ($p>0.05$) difference within samples with both BM and RM. There was also no significant ($p>0.05$) difference when samples were compared between samples with the same blend ratios. Samples with RM had higher fibre content than samples with BM A similar increase was also reported by [25] . The increase in fibre is due to the increased addition of Moringa seed flour which is high in fibre and thereby aids in digestion [25]. Fibre also helps intestinal motility and activities of probiotics, prevents rectal and colon cancer reduces blood sugar [26-28].

Carbohydrate content decreased with the addition of Moringa seed flour. The control had the highest carbohydrate content. There was a significant ($p<0.05$) difference within individual samples containing BM and RM but comparing samples containing BM and RM with the same blend ratios all samples were not significantly ($p>0.05$) different except samples with 15 % moringa seed flour which were significantly ($p<0.05$) different. A similar decrease was also observed by [25] and Abioye [29]. The decrease in carbohydrates can be attributed to the increased addition of Moringa seed flour [25, 29, 30] reported that the addition of a plant to cereal-based traditional foods results in carbohydrate content reduction. Samples with BM had higher values of carbohydrate than samples with RM.

3.2 pH and TTA of Sorghum-moringa Seed Flour Blends

The pH of the composite flour is shown in Table 3. There was an increase in the pH with a significant ($p<0.05$) difference observed within samples with BM and RM but they were not significantly ($p>0.05$) different when compared between samples with the same blend ratios. The control had the lowest pH value. A similar increase was also reported by [25]. The increase in the pH is due to the increased addition of moringa seed flour. According to [25] increased moringa seed flour incorporation decreases the acidity of the products and could therefore affect the storability of the product.

The TTA decreased with the increased addition of moringa seed flour. There was a significant ($p<0.05$) difference within individual samples with BM and RM but no significant ($p>0.05$) difference between samples with BM and RM with the same blend ratios. The control had the highest TTA value. [25] also reported a similar decrease in TTA. The increased incorporation of moringa seed flour reduced the acidity of the products [25]. The low TTA in these samples may be due to the departure of volatile acidity and organic compounds [31].

3.3 Phytochemical Properties of Sorghum-moringa Seed Flour Blends

The results are shown in Table 4. There was an increase in the alkaloid content of the composite flour. Samples with both BM and RM at 10 and 15% moringa seed flour were significantly ($p<0.05$) different while samples with 5 and 20% were not significantly ($p>0.05$) different from each other. A similar increase was recorded in work done by [32]. The increase in alkaloids is due to high concentrations of phytochemicals in moringa seed. The samples with RM had higher alkaloid values than those with BM while the control had the lowest value. Alkaloids are therapeutic and are used as medicinal agents because of their analgesic, antispasmodic and antibacterial properties [33].

The total phenols increased in composite flour and all samples with BM and RM were significantly ($p<0.05$) different from each other. The control had the least total phenol content while samples with RM had higher values than samples with BM. Phenolic compounds are potent water-soluble antioxidants and free radical scavengers that prevent oxidative cell damage and have strong anticancer activity [34].

Flavonoids also increased with the increased addition of moringa seed flour. All samples with BM and RM at the same blend ratios were significantly ($p<0.05$) different. The values in this work were lower than those reported by [35]. Flavonoid content was higher in samples with RM than in samples with BM and least in the control sample. The increase in flavonoid content is due to the increased addition of moringa seed flour indicating that it is a good source of natural antioxidants [36] which neutralize free radicals that can stimulate reactions that make the cells more vulnerable to cancer-causing chemicals, called carcinogens [35].

Table 4. Phytochemical content of sorghum-moringa seed flour blends

Parameters		**Blend ratio of sorghum-moringa seed flours**				
		100:0	**95:5**	**90:10**	**85:15**	**80:20**
alkaloids (mg/100g)	BMSF	1.63^{a} ± 0.00	1.75^{b} ± 0.03	1.93^{c} ± 0.02	2.04^{d} ± 0.04	2.18^{e} ± 0.02
	RMSF	1.63^{a} ± 0.00	1.87^{b} ± 0.01	2.13^{c}±0.04	2.35^{d} ± 0.02	2.57^{e} ± 0.10
T/phenols (mg/100g)	BMSF	13.79^{a} ± 0.02	14.02^{b} ± 0.02	15.10^{c} ± 0.03	15.25^{d} ± 0.02	15.62^{e}±0.03
	RMSF	13.79^{a} ± 0.02	14.30^{b} ± 0.01	15.82^{c} ± 0.01	16.31^{d} ± 0.02	16.85^{e} ± 0.04
Flavonoids (mg/100g)	BMSF	6.09^{a} ± 0.02	6.89^{b} ± 0.01	7.32^{c} ± 0.02	8.49^{d} ± 0.00	9.31^{e} ± 0.01
	RMSF	6.09^{a} ± 0.02	7.29^{b} ± 0.01	8.46^{c} ± 0.01	9.68^{d} ± 0.02	10.83^{e} ± 0.00
Tannin (mg/100g)	BMSF	1.06^{a} ± 0.06	2.01^{b} ± 0.01	2.19^{b} ± 0.04	3.99^{c} ± 0.02	6.85^{d} ± 0.16
	RMSF	1.06^{a} ± 0.06	2.51^{b} ± 0.13	3.05^{c} ± 0.10	5.21^{d} ± 0.01	6.61^{e} ± 0.02
Phytates (mg/100g)	BMSF	4.81^{a} ± 0.02	5.45^{b} ± 0.00	6.15^{c} ± 0.04	6.81^{d} ± 0.04	7.47^{e} ± 0.02
	RMSF	4.81^{a} ± 0.02	5.93^{b} ± 0.05	6.96^{c} ± 0.03	8.14^{d} ± 0.08	9.18^{e} ± 0.02
Cyanides (mg/100g)	BMSF	13.63^{a} ± 0.04	14.09^{b} ± 0.03	14.54^{c} ± 0.00	15.04^{d} ± 0.04	15.50^{e} ± 0.03
	RMSF	13.63^{a} ± 0.04	14.71^{b} ± 0.01	15.86^{c} ± 0.03	16.94^{d} ± 0.02	18.31^{e} ± 0.04
T/sterols (%)	BMSF	5.36^{a} ± 0.06	9.63^{b} ± 0.04	14.00^{c} ± 0.00	18.31^{d} ± 0.01	22.67^{e} ± 0.01
	RMSF	5.36^{a} ± 0.06	9.88^{b} ± 0.11	14.35^{c} ± 0.10	18.78^{d} ± 0.02	23.34^{e} ± 0.1

BM SF, boiled moringa seed flour; RMSF, Roasted moringa seed flour; Values are mean ± standard deviation of duplicate determination. Mean values across a row followed by different superscript letters are significantly different at (p<0.05)

Table 5. Functional properties of sorghum-moringa flour blends

Potassium	BMSF	306.0^{a} ±1.41	305.9^{a} ±0.91	294.6^{b} ±1.34	282.4^{c} ±5.80	278.4^{c} ±1.63
	RMSF	306.0^{e} ±1.41	336.1^{a} ±1.34	326.6^{b} ±0.71	316.2^{c} ±1.34	310.3^{d} ±0.21
Phosphorus	BMSF	284.0^{a} ±1.41	263.0^{b} ±1.43	212.0^{c} ±0.87	183.2^{d} ±6.86	163.0^{e} ±0.78
	RMSF	284.0^{a} ±1.41	232.3^{b} ±1.50	208.2^{c} ±0.84	184.0^{d} ±0.80	160.0^{e} ±0.21
Zinc	BMSF	2.54^{a} ±0.13	2.20^{b} ± 0.10	2.22^{b} ±0.01	2.23^{b} ±0.12	2.30^{b} ±0.10
	RMSF	2.54^{a} ±0.13	2.31^{b} ± 0.14	2.33^{b} ±0.10	2.40^{ab} ±1.71	2.42^{ab} ±0.10
Sodium	BMSF	5.07^{e} ±0.10	31.8^{b} ± 0.16	60.0^{c} ±1.00	86.0^{b} ±0.60	117.3^{a} ±1.10
	RMSF	5.07^{e} ±0.10	32.5^{d} ± 0.22	61.0^{c} ±1.00	90.0^{b} ± 1.00	119.0^{a} ±0.14
Iron	BMSF	3.93^{d} ±0.02	4.10^{d} ±0.10	5.00^{c} ±0.10	5.66^{b} ±0.40	6.60^{a} ±0.30
	RMSF	3.93^{e} ±0.02	6.05^{d} ±0.05	7.00^{c} ±0.10	7.74^{b} ±0.16	8.63^{a} ±0.15
Calcium	BMSF	14.2^{e} ±0.23	27.7^{d} ±0.30	50.2^{c} ±1.00	73.2^{b} ±1.00	96.1^{a} ±1.13
	RMSF	14.2^{e} ±0.23	29.9^{d} ±0.74	53.0^{c} ±0.78	76.0^{b} ±0.78	98.9^{a} ±0.85

BMSF, Boiled moringa seed flour; RMSF, Roasted moringa seed flour; RI, Reconstitution index; WAC, Water absorption capacity; Values are mean ± standard deviation of duplicate determination. Mean values across a row followed by different superscript letters are significantly different at ($p<0.05$)

Table 6. Vitamin content of sorghum-moringa seed flour blends

Parameter		**Blend ratio of sorghum-moringa seed flours (%)**				
(%)		**100:0**	**95:5**	**90:10**	**85:15**	**80:20**
Vitamin A	BMSF	0.13^{e} ± 0.00	0.14^{d} ± 0.00	0.15^{c} ± 0.00	0.17^{b} ± 0.01	0.18^{a} ± 0.01
	RMSF	0.13^{e} ± 0.01	0.14d ± 0.21	0.15^{c} ± 0.01	0.16^{b} ± 0.03	0.17^{a} ± 0.01
Vitamin B1	BMSF	0.18^{a} ± 0.02	0.19^{a} ± 0.00	0.19^{a} ± 0.00	0.20^{a} ± 0.00	0.20^{a} ± 0.00
	RMSF	0.18^{b} ± 0.02	0.19^{b} ± 0.00	0.19^{b} ± 0.01	0.20^{a} ± 0.24	0.22^{ab} ± 0.03
Vitamin B2	BMSF	0.20^{b} ± 0.03	0.18^{b} ± 0.01	0.21^{b} ± 0.00	0.27^{a} ± 0.02	0.29^{a} ± 0.01
	RMSF	0.20^{c} ± 0.03	0.21^{c} ± 0.01	0.25^{b} ± 0.02	0.26^{ab} ± 0.01	0.29^{a} ± 0.01
Vitamin B6	BMSF	0.18^{e} ± 0.01	0.23^{d} ± 0.27	0.30^{c} ± 0.03	0.33^{b} ± 0.01	0.38^{a} ± 0.02
	RMSF	0.18^{c} ± 0.01	0.24^{ab} ± 0.00	0.28^{ab} ± 0.01	0.33^{a} ± 0.01	0.31^{a} ± 0.10
Vitamin C	BMSF	1.57^{e} ± 0.03	2.73^{d} ± 0.01	6.21^{c} ± 0.01	9.08^{a} ± 0.01	11.58^{a} ± 0.01
	RMSF	1.57^{e} ± 0.03	2.73^{d} ± 0.01	6.21^{c} ± 0.01	9.27^{b} ± 0.71	11.59^{a} ± 0.03

BMSF, Boiled moringa seed flour; RMSF, Roasted moringa seed flour; RI, Reconstitution index; WAC, Water absorption capacity; Values are mean ± standard deviation of duplicate determination. Mean values across a row followed by different superscript letters are significantly different at ($p<0.05$)

Tannin increased with the increased addition of moringa seed flour. The control sample had the least Tannin content. Samples with RM had higher values than those with BM. Samples with BM and RM at 5 and 20% moringa seed flour were not significantly (p>0.05) different while samples with 10 and 15% moringa seed flour were significantly (p<0.05) different. A similar increase was reported by [35] but with higher values reported in this work. The increase is due to the increased addition of moringa seed flour. Tannin is known to affect the nutritive value of food products by forming complexes with protein (both substrate and enzyme) thereby inhibiting digestion and absorption [37] They also bind iron thereby making it unavailable [38]

The phytate content increased with the increased addition of moringa seed flour. The control had the least value while samples with RM had higher phytate content than samples with BM. Comparing samples with BM and RM, all samples were significantly (p<0.05) different. [25] reported a similar increase. Phytates are organic acids present in the bran or hulls of seeds, which blocks the uptake of essential minerals such as calcium, magnesium, iron, and especially zinc in the intestinal tract [39].

Cyanides increased significantly (p<0.05) in the samples. There was a significant difference between samples with BM and RM at the same blend ratios. The control had the least value while samples with RM had higher cyanide content than samples with BM. Hydrogen cyanide -consumption of foods with high hydrogen cyanide can result in toxicity of hydrogen cyanide but can be reduced during cooking [21].

T/sterols also increased with a significant (p<0.05) difference observed in samples with 15 and 20% moringa seed flour while at 10 and 5% were not significantly (p>0.05) different. The control had the least value while samples with RM had higher T/sterols content than samples with BM. The presence of sterols in the fortified samples is an indication that moringa is a good source of steroidal compounds which are potent precursors for the synthesis of sex hormones [40,41].

It has been suggested that boiling may solubilize and release some of the phenols and flavonoids that are insoluble at room temperature increasing their contents [42]. Total phenols and flavonoids play a significant role as physiological and dietary antioxidants, thereby augmenting the body's natural resistance to oxidative damage [43],. The increase observed in all the phytonutrients could be attributed to their high concentrations in moringa seed. The quantities of phytochemical compounds observed in the blends could act as immune enhancers, hormone modulators, antioxidants, anti-clothing [32], and anti-inflammatory agents and could also be a potential contender to combat free radicals, which are harmful to our body and food systems [44, 45].

3.4 Mineral Composition of Sorghum-moringa Seed Flour Blends

The results of the mineral composition are shown in Table 5. The magnesium content decreased with the increased addition of moringa seed flour. The control had the highest magnesium content. There was no significant (p>0.05) difference between samples with BM and RM with the same blend ratios. [45] produced *Ogi* from maize, melon seeds, and conophor nut where there was a decrease in magnesium which agrees with this work. The decrease is due to the increased addition of moringa seed flour. Magnesium is important for cellular energy production and enzyme activity [46].

Potassium also decreased with the increased addition of moringa seed flour. The control had the highest value of potassium. Samples with BM and RM were not significantly (p>0.05) different from each other at the same blend ratios. This increase was in line with work reported by [29] due to the increased addition of moringa seed flour. Potassium is needed for the regulation of fluid, muscle control, and normal nerve function [47]. Potassium also maintains the normal balance and distribution of fluids, it also works in conjunction with calcium and magnesium to maintain normal muscle contraction and relaxation and in nerve transmission [48].

There was an increase in the calcium content and samples containing both BM and RM at the same blend ratios were significantly (p>0.05) different at 10 % moringa seed flour. A similar increase was reported by [25]. The increase is due to the increased addition of moringa seed flour. Calcium aids in the formation of bones and plays a role in maintaining the working of the heart and muscles [49]. The control had the lowest value for calcium. Iron increased in the fortified samples with the increased addition of moringa seed flour while the control had the least value. All samples containing BM and RM at the same ratios were not significantly (p>0.05) different from each other. A similar increase was reported by [29] when sorghum-ogi was fortified with moringa flour. The increase in iron is due to the increased substitution of sorghum flour with moringa seed flour. Iron deficiency negatively influences the normal defense systems against infection. It also serves as a carrier of oxygen to tissues within cells and is an integral part of important enzyme systems [50].

Phosphorus decreased with an increased fortification with moringa seed flour with the control having the highest value. Samples with the same ratio of BM and RM were not significantly (p>0.05) different from each other. A similar increase was reported by [51] . The increase is attributed to the increased addition of moringa seed flour because it is rich in minerals.

Sodium increased in the fortified samples with the control having the least sodium content. Samples with both BM and RM were not significantly (p>0.05) different at the same blend ratios. Sodium values were higher than those reported by [52]. Sodium aids in fluid balance and nerve impulse transmission [27, 28, 53].

Moringa seed flour serves as a source of essential minerals needed by the body [25]. The increase in mineral concentration in this study may be attributed mainly to the substitution of sorghum flour with moringa seed flour. Calcium, Magnesium, and potassium are important regulators of the acid-base balance of the body system, Calcium and phosphorus are important for skeletal development, while ironworks in synergy with β-carotene to improve d immune function for the infants and children [51].

3.5 Vitamin Composition of Sorghum-moringa Seed Flour Blends

The vitamin composition is shown in Table 6. There was an increase in pro-vitamin A with increased addition of moringa seed flour. There was a significant (p<0.05) difference between individual samples with BM and RM. While there was no significant (p>0.05) difference between samples with BM and RM with the same blend ratios. An increase in vitamin A was also reported by [29]. The increase in vitamin A can be attributed to the increased addition of moringa seed flour thus indicating that the fortification of sorghum flour with moringa seed flour will help to solve the problem of vitamin A deficiency in Nigeria [29]. Vitamin A is essential in diets because it aids in proper vision [54]. Studies by [55] showed that *M. oleifera* seeds contain provitamin A (2.04%) and B vitamins. Vitamin A plays a key role in vision and possesses antioxidant properties in the form of β-carotene. Vitamin A content could increase by approximately 15-fold with the addition of moringa. The increase in vitamin A could help in forming and maintaining healthy teeth, and skeletal and soft tissue produces the pigments found in the retina of the eye and serves as antioxidants by protecting cells from damage caused by substances called free radicals [56].

There was an increase in vitamin C with the increased addition of moringa seed flour. There was a significant (p<0.05) difference between individual samples with BM and RM. While there was no significant (p>0.05) difference between samples with BM and RM with the same blend ratios. Vitamin C is needed for the growth and repair of tissues in all parts of the body, it aids in the formation of skin, tendons, ligaments, and blood vessels, and aids in the absorption of iron. It also acts as a reducing and capping agent for metal nanoparticles [57] .

Vitamin B1 increased with the increased addition of moringa seed flour. Samples with BM and RM were not significantly (p>0.05) different in samples with 5 and 20% moringa seed flour while samples with 10 and 15% moringa seed flour were significantly (p<0.05) different between the samples. Vitamin B2 also increased with the increased addition of moringa seed flour. Samples with BM and RM were significantly (p<0.05) different at 10% moringa while other samples were not significantly (p>0.05) different [58] reported a similar increase. Vitamin B2 increase is due to the increased addition of moringa seed flour. There was an increase in vitamin B6, as samples were significantly different at 5 and 10% moringa seed flour between samples with BM and RM at the same blend ratios. A similar increase was reported by [58] but the values were higher. The increase is due to the addition of moringa seed flour.

The B vitamins function as coenzymes in central pathways by which fats and carbohydrates are metabolized within a cell. The vitamins are concentrated in the aleurone layer of cereal seeds. Milling and refining of cereals can lead to large losses of vitamins [58,59].

4. CONCLUSION

This study showed that it is possible to produce acceptable gruels from blends of sorghum-moringa oleifera flours at different ratios and observed that as the addition of boiled and roasted moringa seed flour increased the contents of moisture (2-2.4%), protein (18-18.9%), fat (56.3-57.3%), ash (11.9-13.7%) and fibre (7-8%) appreciated while the carbohydrate content, in contrast, decreased by (7.3-7.5%).

The pH showed an inverse relationship with TTA and increased by a maximum of 12.6% with the addition of boiled and roasted moringa flours while the TTA values decreased by 21.8%. All the phytochemicals showed increased content with the addition of BMSF and RMSF with the most significant increase of 300% associated with the T/sterol, which is one of the precursors for the production of testosterone hormone in the body.

The mineral composition of the sorghum-moringa composite flours indicated that there were significant increases in sodium, calcium, zinc, and iron contents, while decreases were observed in potassium, magnesium, and phosphorus contents. Noteworthy was the over 600% recorded increases in vitamin C with the addition of BMSF and RMSF, an endogenous antioxidant that could also be utilized in the management of scurvy disease and improvement of the immune system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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