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Effect of Supplementation with Moringa Leaves Powder (MLP) and Fermentation on Chemical Composition, Total Minerals Contents and Sensory Characteristics of Sorghum Flour

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Abstract: ***Sorghum flour was supplemented with different levels (5, 10 and 15%) of Moringa Leaves Powder (MLP). The effect of supplementation on proximate composition, minerals contents and sensory characteristics was investigated. Supplementation of sorghum flour with different levels of (MLP) increased the proximate composition except the carbohydrate content, moreover supplementation of sorghum flour with MLP slightly decreased the oil content and significantly (P≤ 0.05) decreased the total energy. Fermentation of raw sorghum flour and composite flours supplemented with 5, 10 and 15% MLP significantly (P≤ 0.05) increased the protein content. Moreover the ash, oil and moisture content of raw sorghum flour and supplemented flours with 5% and 15% MLP were increased after fermentation.***

Keywords: Supplementation; Sensory characteristics; Fermentation; Moringa; proximate composition; Minerals

1. Introduction

Among the plant foods, cereals are grown over 73.5% of the world harvested area. Diets in developing countries are based mainly on cereals and legumes. Sorghum is the fifth most important world cereal, following wheat, maize, rice and barely (Onwume and Sinha (1991). Sorghum is cultivated in many parts of the Sudan mainly in Gezira and Gadarief Regions. According to the Ministry of Agriculture (1995) the annual production of sorghum is about 3.7 million tons in Sudan while the area under cultivation ranged from 6.5 to 15.3 million feddans. Sorghum generally consumed as fermented flat bread (*Kisra*), thick Porridge (*Aceda*), thin fermented gruel (Nasha), boiled grain (*Balela*) and beverages like *Abresh*and *Hulu-mur*. It is also used for the production of alcoholic beverage (*merisa*). Grain sorghum as a staple food is also used as feed for animal and as industrial raw material. . Sorghum like other cereals is deficient in lysine (El Tinay *et al.*, 1985). Sorghum Proximate composition varies significantly due to genetics and environment (Ralph, *et al*., 2000). Sorghum grains contain low quality protein and considerable amounts of antinutritional factors. Efforts, however, are directed to improve the nutritional value of the seeds. Processing method, such as soaking, sprouting and cooking has been found to improve the nutritional value of plant grains (Jirapa*et al*., 2001). Fermentation is found to be highly beneficial in improving the quality of cereals, it is one of oldest and most economical methods that provide away to preserve food, destroy undesirable factors enhance nutritive value, and improve appearance and taste of some foods. Moringa *oleifera* leaves as rich in protein source, which can be used by doctors, nutritionists and community health cautious persons to solve worldwide malnutrition or under nutrition problems Thurber and Fahey, (2009). Some articles and research studies have reported that the dry leaves of *M. oleifera* contain 7 times more vitamin C than orange, 10 times vitamin A than carrot, 17 times calcium than milk, 15 times potassium than bananas, 25 times iron than spinach and 9 times proteins than yogurt (Fuglie, 1999). Apart from the medicinal uses, *Moringa oleifera* was reported to be a good source of vitamins and amino acids (Olugbemi*et al*;2010). *M. oleifera* is a miracle tree with a great indigenous source of highly digestible proteins, Ca, Fe and Vitamin C. It contains all the essential nutritional elements that are essential for livestock and human beings (Fahey, 2005).

Recently, researchers have become convinced that nutrients found in fruits and vegetables do more than just prevent deficiency diseases for instance beriberi or rickets. The most publicized findings reveals that certain Vitamin or Vitamins precursors in produce, notably Vitamin C; beta carotene as well as polyphenols are powerful anti oxidants which are helpful in the prevention of muscular damage caused by oxidation process of some food substances that could lead to muscle degeneration, cardio vascular disease and cancer (Yonkers 1988 and Islam et,al 2002).

The objective of this study would to evaluate the effect of supplementation with Moringa leaves and fermentation on proximate composition, total minerals (K, Na, Mg and Fe) and sensory characteristics of sorghum (Tabat) flour.

2. Materials and Methods

Source of Materials

Sorghum (sorghum *bicolor* L. Moench) grains locally known as Tabat was purchased from Omdurman local market, Sudan. The grains were cleaned and freed from foreign materials. Some of these grains were milled into flour (0.4 mm screen) and stored at 4 C^0. Moringa leaves obtained from the farm of Alsamrab , Khartoum North, Sudan. The leaves were dried under optimum condition, then milled into powder (0.4 mm screen) and stored at 4 C^0.

Supplementation

Moringa leaves powder were added using Pearson square to increase nutritive value of sorghum flour by 5, 10 and 15%. The number of samples of composite flour after supplementation were three samples.

Fermentation:

Natural fermentation of sorghum flour and was carried out by mixing flour with distilled water (1:2 w/v). Two hundred and fifty grams of sample was mixed with 500 ml distilled water in 750 ml beaker and then incubated (Gallenkamp, England) at 37°C for 24h. After the incubation period the sample was mixed using a glass rod and transferred to aluminum dishe (30 cm diameter), and dried in a hot air oven at 70°C for 3-4 hours. Dried sample was ground using house blender and mortar to pass through 0.4 mm screen and stored at 4°C for further analysis.

Proximate analysis

Lipid, ash, total carbohydrate and total nitrogen (micro-Kjeldahl) of sorghum flour were determined according to AOAC (1990). Protein was calculated as N% × 6.25. Moisture content was determined by drying a sample at 105 C^0 overnight. Crude fiber content was determined according to the acid/alkali digestion method of Southgate (1976). The energy values of samples were calculated on Atwater factors (Sukkar, 1985), protein (4kcal g^{-1}), oil (9 kcal g^{-1}) and carbohydrates ($4kcal^{-1}$).

Total minerals

Minerals were determined in samples extracts prepared by the dry- ashing method as described by Pearson (1981) according to the analytical method of atomic absorption spectroscopy (Perkin-Elmer 1100 V, Waltham. MA, USA).

Statistical analysis

Replicate of each sample was analyzed using statistical system, the analysis of variance was performed to examine the significant effect in all parameters, Least Significant Difference test (LSD test), was used to separate the means (Peterson, 1985).

3. Results and Discussion

Table 1: proximate composition and total energy of sorghum flour (Tabat) and Moringa leaves

Samples	Moisture %	Ash %	Protein %	Oil %	Fiber %	Carbohydrate %	Total energy (kcal)
Moringa leaves	7.36	11.93	26.71	4.94	11.16	54.46	369.13
Sorghum	7.35	1.32	10.31	2.85	2.43	75.74	369.86

*Each value in the Table is a mean of three replicates ±S.D

The proximate composition and total energy of raw sorghum flour and composite flour supplemented with Moringa Leaves Powder (MLP) are presented in Table 1. The moisture, ash, protein, oil, fiber, carbohydrate and total energy of MLP were found to be 7.36, 11.93, 26.71, 4.94, 11.16, 54.46 and 369.13%, respectively. All these parameters were higher than those reported by Bolaji *et al* , (2013) except the protein, who reported that the proximate composition of Moringa leaves (moisture, ash, fat, fiber, protein and total carbohydrate) were 9.00, 6.00, 2.43, 5.43, 39.13 and 38.21 %, respectively. The variation in proximate composition in this study and other comparable study may be due to genotypes, genetic factor and environmental conditions.

Table 2: Effect of supplementation with different levels of Moringa leaves and fermentation on proximate composition and total energy of sorghum flour

Supplementation Levels (%)	*Treatment*	*Moisture Content (%)*	*Ash content (%)*	*Crude protein (%)*	*Oil content (%)*	*Crude fibre (%)*	*Carbohydrate (%)*	*Total energy (kcal)*
0	Raw	7.35^c (±.07)	1.32^c (±0.08)	10.31^h (±0.01)	2.85^c (±0.09)	2.43^d (±0.08)	75.74^a (±0.32)	369.86^a (±0.41)
	Fermented	6.29^e (±0.08)	1.43^c (±0.01)	12.38^f (±0.4)	2.36^c (±0.05)	2.40^d (±0.59)	75.21^a (±0.11)	364.49^b (±0.29)
5	Raw	8.11^b (±.07)	1.86^c (±0.03)	11.87^g (±0.08)	2.65^c (±0.44)	2.64^d (±0.05)	72.54^b (±0.08)	358.99^c (±2.34)
	Fermented	6.58^d (±.15)	1.76^c (±0.04)	13.32^d (±0.07)	2.81^c (±0.07)	2.63^d (±0.13)	72.53^b (±0.15)	356.90^d (±0.49)
10	Raw	8.39^a (±0..07)	3.36^b (±0.69)	12.89^e (±0.09)	3.75^b (±0.13)	3.19^c (±0.02)	68.41^c (±0.9)	371.37^e (±0.85)
	Fermented	7.50^c (±0.26)	2.94^b (±0.16)	14.83^b (±0.06)	3.68^b (±0.04)	3.15^c (±0.12)	67.39^d (±0.15)	370.09^e (±0.19)
15	Raw	7.39^c (±0.03)	4.51^a (±0.07)	14.31^c (±0.07)	4.17^a (±0.12)	4.09^a (±0.09)	65.51^e (±0.28)	1085.83^f (±0.61)
	Fermented	8.42^a (±0.03)	4.49^a (±0.13)	15.37^a (±0.07)	3.84^b (±0.09)	3.99^a (±0.14)	64.05^f (±0.22)	1056.67^g (±0.75)

*Means not sharing a common letter in the same column are significantly different ($p \leq 0.05$
*Each value in the Table is a mean of three replicates ±S.D.

As shown in Table 2. The moisture content of sorghum flour (Tabat cultivar) was 7.35%. Supplementation of sorghum flour with 5, 10 and 15% of MLP significantly (P≤ 0.05) increased the moisture content to 8.11, 8.39 and 7.39%, respectively. Fermentation after 24h significantly (P≤ 0.05) increased the moisture content of sorghum flour and composite flour supplemented with 5 and 10 % MLP, whereas significant (P≤ 0.05) increase was observed of that flour supplemented with 15% MLP.

The ash content of sorghum flour was found to be 1.31%. Supplementation with 5% MLP insignificantly (P≥ 0.05) increased the ash content to 1.86% , while a significant(P≤ 0.05) increase was observed in ash content of that flours supplemented with 10 and 15% MLP (3.36 and 4.51%), respectively. Fermentation of raw sorghum flour insignificantly (P≥ 0.05) increased the ash content from 1.32 to 1.43%, while it was decreased insignificantly (P≥ 0.05) of those supplemented flour with 5, 10 and 15% MLP to 1.76, 2.49 and 4.49%, respectively.

This finding was agreed with that reported by Mohammed Nour (2013) who reported that the fermentation of supplemented flour with Moringa seeds cake / Fenugreek seeds flours decreased the ash content. The decrease in ash content after fermentation may be due to the utilization of ash by fermentation microorganisms.

The protein content of raw sorghum flour was found to be 10.31% and after supplementation with 5, 10 and 15% MLP it was significantly (P≤ 0.05) increased to 11.87 ,12.89 and 14.31%, respectively. Fermentation of raw and supplemented flour with 5, 10 and 15% MLP significantly (P≤ 0.05) increased the protein content to 12.38, 13.32, 14.83 and 15.37, respectively . A similar trend was reported by Elhaj, (2009) who reported that fermentation for 36h significant(P≤ 0.05) increased the protein content of both sorghum flour sorghum flour supplemented with 20% defatted ground nut flour. This rise in protein content during fermentation might be due to the synthesis of protein by microorganisms (El Hidai, 1978).

The oil content of raw sorghum flour was found to be 2.85%. Supplementation with 5% MLP insignificantly (P≥ 0.05) decreased the oil content to 2.65%, whereas it was significantly (P≤ 0.05) increased after supplementation with 10 and 15% MLP to 3.75 and 4.17% , respectively. Fermentation was decreased the oil content of raw sorghum flour and flour supplemented with 15% MLP to 2.36 and 3.84%, respectively, while the oil content flours supplemented with 5 and 10% MLP insignificantly (P≥ 0.05) increased of oil content to 2.81 and 3.68%, respectively. The result agrees with that reported by Mohammed Nour , (2013) who reported that the oil content was fluctuated during fermentation of millet flour supplemented with Moringa seeds cake / fenugreek seeds flour. The increase in oil content during fermentation of composite flour could be due to the transformation of the carbohydrate to fat , while the decrease in oil content of raw sorghum flour during fermentation may be due to the transformation of some of the oil, which possibly used by microorganisms as a carbon source to some other metabolites Lehninger, 1987). Akindumila and Glatz (1998) reported that certain fungi can reduce microbial oil during fermentation. Fiber content of sorghum flour was found to be 2.43%.Supplementation of sorghum flour with 10 and 15% MLP significantly (P≤ 0.05) increased the fiber content to 3.19 and 4.09%, respectively, while insignificant (P≥ 0.05) increase was observed after supplementation with 5% MLP.

The increase in fiber content of supplemented flour may be due to high content of fiber in Moringa leaves flour. Fermentation of raw sorghum flour and flours supplemented with 5, 10 and 15% insignificantly (P≥ 0.05) decreased the fiber content to 2.40, 2.63, 3.15 and 3.99%, respectively. This study disagrees with that reported by Mohammed Nour , (2013) who reported that fermentation increased the fiber content of millet flour and composite flour supplemented with Moringa seeds cake flour. The decrease in fiber content after fermentation of raw and composite flour may attribute to utilization of fiber by microorganisms. The carbohydrate content of sorghum flour observed to be 75.74%. Supplementation with 5, 10 and 15% ML significantly (P≤ 0.05) decreased the carbohydrate content to 72.54, 86.41, 65.51% ,respectively. The substantially lower carbohydrate content of MLP sorghum composite flour was a result of low carbohydrate content in Moringa leaves. Similarly, it has been reported that compositing marama been flour with sorghum meal significantly reduced the carbohydrate content, Kayites et al ,(2010). Fermentation of raw sorghum flour and flour supplemented with 5, 10 and 15% MLP slightly decreased the carbohydrate content to 75.21, 72.53, 67.39 and 64.05%, respectively. A similar findings was reported by Mohammed Nour ,(2013) who reported that the carbohydrate was reduced during fermentation of millet flour and millet flour fortified with Moringa or fenugreek seeds flours. The reduction in carbohydrate during fermentation may be due to the utilization of sugars as energy source by microorganisms or converted to alcohol by lactic acid bacteria. The total energy of sorghum flour was found to be 369.86kcal. Supplementation of sorghum flour with 5% MLP significantly (P≤ 0.05) decreased the total energy to 358.99kcal, while supplementation with 10 and 15% MLP significantly (P≤ 0.05) increased the total energy to 371.37 and 1085.09 kcal , respectively. The reduction in total energy may attributed to the reduction in carbohydrate and oil of 5% composite flour, whereas the increase in total energy of 10 and 15% MLP composite flour may be as the result of increase carbohydrate content and higher content of oil . A similar observation on the reduction of energy due to supplementation of sorghum / wheat flours with defatted soy flour has recently been reported by Serrem et al, (2011). Fermentation of raw sorghum flour and composite flours supplemented with 5, 10 and 15% MLP significantly (P≤ 0.05) decreased the total energy to 364.49, 356.99, 370.09 and 1056.67kcal, respectively.

Table 3: Minerals composition (mg/100g) of sorghum (Tabat) and Moringa Leaves Powder (MLP)

Samples	Ca	K	Mg	Fe
Moringa leaves	36.49	434.60	233.50	9.18
Sorghum	0.85	181.70	263.50	0.07

*Each value in the Table is a mean of three replicates ±S.D

The minerals content of raw sorghum flour and MLP are shown in Table 3. The Ca, K and Fe content of MLP were found to be 36.49, 434.60, 233.50 and 9.18 mg/100g, respectively, These values were lower than that obtained by Sodamade et al .,(2013) who gave 723.00 , 677.00 and 187.00 mg/100g for Ca, Mg and Fe , respectively except the K content was significantly higher , who reported 23.20 mg/100g for K. The Ca, K, Mg and Fe were found to be 0.85 , 181.70, 263.50 and 0.07mg/100g, respectively, which were lower except Mg content than those reported by Idris et al., (2005) who reported that the values of Ca, K , Mg and Fe contents of sorghum flour were 10.8, 450, 59.3 and 3.8mg/100g, respectively. The variation in minerals contents of MLP and sorghum flour may be attributing to the genotypes and environmental conditions.

As shown in table 4, the Ca content of sorghum flour was found to be 0.85mg/100. Supplementation of sorghum flour with 5 and 10 % MLP insignificant (P≥ 0.05) increased the Ca content to 2.84 and 3.86mg/100g, respectively, whereas supplementation with 15% MLP significantly (P≤ 0.05) increased the Ca content to 5.63mg/100g. The improvement of Ca after supplementation due to the high content of Ca content in Moringa leaves. Fermentation of raw sorghum flour and supplemented flour with 5% MLP insignificantly (P≥ 0.05) increased Ca content to 1.32 and 3.39mg/100g, while the fermentation of composite flours supplemented with 10 and 15 % MLP significantly(P≤ 0.05) increased the Ca content to 5.52 and 10.08mg/100g. The results obtained were comparable with that reported by Mohammed Nour , (2013) who reported that the supplementation of millet flour with Moringa cake flour / Fenugreek seeds flour and fermentation improved the Ca content. The improvement of total Ca content of fermented flour may be to the reduction of phytic acid content.

Table 4: Effect of fermentation on Total (mg /100g) minerals of Sorghum flour supplemented with difference ratios of Moringa leaves

Supplementation level (%)	Treatment	Ca	K	Mg	Fe
0	Raw	0.85[d] (±0.02)	181.7[a] (±28.16)	50.00[a] (±1.23)	1.07[a] (±.02)
	Fermented	1.32[d] (±0.04)	177.2[a] (±1.84)	86.00[b] (±.41)	2.03[b] (±.01)
5%	Raw	2.84[c] (±0.61)	199.5[b] (±3.27)	61.50[c] (±2.12)	1.93[b] (±.07)
	Fermented	3.39[c] (±0.07)	211.8[c] (±2.46)	120.00[d] (±.48)	2.76[c] (±.08)
10%	Raw	3.86[c] (±0.03)	211.89[c] (±23.33)	126.00[e] (±.01)	2.63[c] (±.05)
	Fermented	5.52[b] (±0.43)	227.00[d] (±2.12)	188.83[f] (±0.75)	3.55[d] (±.03
15%	Raw	5.63[b] (±0.44)	271.83[e] (±2.46	263.50[g] (±0.36)	2.94[c] (±.05)
	Fermented	10.08[a] (±0.35)	237.00[f] (±8.73)	2.92[h] (±46.01)	5.04[e] (±.05)

*Means not sharing a common letter in the same column are significantly different (p≤0.05
*Each value in the Table is a mean of three replicates ±S.D

The K content of sorghum flour was found to be 181.7mg/100g. Supplementation of raw sorghum flour with 5, 10 and 15% MLP significantly (P≤ 0.05) increased the K content to 1.99.5, 211.89 and 271.83mg/100g, respectively. The improvement of K after supplementation due to the high content of K content in Moringa leaves. Fermentation of sorghum flour insignificantly (P≥ 0.05) increased the K content to 177.2mg/100g, while a significant (P≤ 0.05) increase was observed after fermentation of supplemented flour with 5, 10 and 15% MLP to 211.8, 227.00 and 237.00mg/100, respectively. The improvement of total K content of fermented flour may be to the reduction of phytic acid content. Mg content of sorghum flour was found to be 50.00mg/100g.

Supplementation of sorghum flour with 5,10 and 15% MLP significantly(P≤ 0.05) increased the Mg content to 61.50 , 126.00 and 263.50mg/100g, respectively. The improvement of Mg content after supplementation due to the high content of Mg in Moringa leaves fermentation of sorghum flour and composite flours supplemented with 5, 10 and 15% MLP significantly (P≤ 0.05) increased the Mg content to 86.00, 120.00, 188.83 and 2.92mg/100g, respectively. The improvement of total Mg content of fermented flour may be to the reduction of phytic acid content.

The Fe content of sorghum flour was 1.07mg/100g.Supplementation of sorghum flour with 5, 10 and 15% MLP significantly (P≤ 0.05) increased the Fe content to 1.93, 2.63 and 2.94mg/100g, respectively. The improvement of Fe content after supplementation due to the high content of Fe in Moringa leaves. Fermentation of sorghum flour and composite flour supplemented with 5, 10 and 15% MLP significantly (P≤ 0.05) increased the Fe content to 2.03, 2.76, 3.55 and 5.04mg/100g, respectively. A similar study was obtained by Mohammed Nour, (2013), who reported that the supplementation with Moringa Seeds cake and fermentation improved the total and extractable Fe. The improvement of total Fe content of fermented flour may be to the reduction of phytic acid content.

Table 5: Sensory evaluation of thick porridge (*aceda*) made from sorghum flour supplemented with different ratios of Moringa leaves

Supplementation level (%)	*Colour*	*Taste*	*Flavour*	*Texture*	*General acceptability*
0	4.30[a] (±0.87)	4.00[a] (±1.26)	3.80[a] (±.98)	3.30[a] (±1.27)	3.48[a] (±0.83)
5	3.50[b] (±0.5)	2.40[b] (±1.4)	2.70[b] (±1.59)	2.80[b] (±1.08)	2.73[b] (±2.58)
10	2.70[c] (±1.27)	2.60[b] (±1.4)	2.80[c] (±1.31)	2.90[b] (±1.4)	2.88[b] (±1.17)
15	2.90[d] (±0.83)	2.30[b] (±1.19)	3.20[d] (±1,35)	3.40[a] (±.51)	3.13[a] (±1.36)

*Means not sharing a common letter in the same column are significantly different ($p \leq 0.05$
*Each value in the Table is a mean of three replicates ±S.D

The sensory evaluation of thick porridge *(Aceda)* of sorghum flour and composite flour supplemented with 5, 10 and 15% Moringa Leaves Powder (MLP) was carried out and data was presented in Table 5. Analysis of variance showed significant difference ($P \leq 0.05$) between thick porridge made from sorghum flour (control) and thick porridge made from raw sorghum flour and composite sorghum flours supplemented with 5, 10 and 15% MLP in terms of colour, taste , flavor , texture and general acceptability, but insignificant ($P \geq 0.05$) variation was observed in terms of texture and overall acceptability between the porridges of sorghum flour (control) and composite flour supplemented with 15% MLP According to the performance of panelists, the majority gave the sensory performance for the colour to thick porridge of raw sorghum flour followed by that flours supplemented with 5, 15 and 10% MLP, respectively. Moreover high sensory performance for taste ,flavor and over all acceptability were also recorded for thick porridge of raw sorghum flour, while the thick porridge of composite flour supplemented with 5% MLP recorded poor taste, flavor and over all acceptability. This may be due to the bitter taste and flavor of Moringa leaves**.** No significance differences($P \geq 0.05$) was observed in texture values of thick porridge made from raw sorghum flour and composite flour supplemented with 15%MLP and also between composite flour supplemented with 5 and 10% MLP, which a high texture score reported for that flour supplemented with 15% MLP while the lowest texture score obtained for 5% MLP supplemented flour . Regarding over all acceptability, the thick porridge of raw sorghum flour had a highest score, while that supplemented with 5% MLP had the lowest score. The higher level of MLP fortification affected the sensory characteristics of the product. This may be attributed to unacceptable flavor and taste imposed by MLP.

4. Conclusion

Supplementation of sorghum flour with Moringa Leaves Powder (MLP) improved the nutritive value of sorghum flour quantitatively; fermentation of raw sorghum flour and composite flour had improved the minerals contents except the K content of raw sorghum flour it was slightly decreased after fermentation. Proximate composition of both raw sorghum and composite flours were fluctuated during supplementation with MLP and fermentation.

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