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NUTRITIONAL VALUE AND CHEMICAL COMPOSITION OF SUDANESE MILLET-BASED FERMENTED FOODS AS AFFECTED BY FERMENTATION AND METHOD OF PREPARATION*

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ABSTRACT

Background. Although kissra and hulu-mur are well known millet-based foods in Sudan, the effect of fermentation and methods of preparation on their chemical compositions has not been thoroughly investigated. The aim of this study was to investigate the method of preparation and the composition of kisra, and hulu-mur.
Material and methods. The effect of fermentation and method of preparation on the composition, and microbiological load were examined in millet flour during the preparation of Sudanese fermented foods (*kisra & hulu-mur*).
Results. A significant ($P < 0.05$) difference in the composition of millet flour and millet-based fermented foods was observed. Protein was significantly increased as a result of fermentation, while oil and carbohydrates were decreased. Most minerals increased significantly after the addition of spices to the hulu-mur batter. The total amino acid in millet flour (97.98 g 100 g^{-1} protein) was influenced by fermentation and preparation method, as it decreased to 86.09 and 88.7 g 100 g^{-1} protein, in millet batter and kisra, respectively.
Conclusion. Kisra, and hulu-mur were found to have apparent dietary qualities, in spite of some compounds being lost during their production.

Keywords: amino acid, fermentation, *hulu-mur*, *kisra*, millet, proximate composition

INTRODUCTION

Fermentation of foods plays a critical role in ensuring food security, enhancing the nutritional situation of millions of people world-wide and enhancing food safety by removing anti-nutritional factors (Ojokoh and Bello, 2014). Pearl millet (*Pennisetum typhodium*) seeds contain numerous components that enhance well-being, including dietary fiber, minerals (calcium, iron, potassium, magnesium, and zinc), vitamins (niacin, B6 and folic acid), and phytochemicals that incorporate phenolic mixes, which have many potential

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health advantages (Saleh et al., 2013). Millet grains are utilized to deliver various types of conventional fermented foods in Africa and Asia. Several types of fermented breads are made in Sudan from sorghum and millet, including kisra, hulu-mur, and abreh (Dirar, 1993). Kisra (a type of bread) ranks first as the staple food, while hulu-mur and abreh flakes are baked sorghum and millet foods prepared for making beverages, particularly during the fasting month of Ramadan. Several differences exist between the breads and flakes of Sudan, including the method of preparation, type of batter, baking method, thickness and nutritional function. *Hulu-mur* has a dark brown color and distinct flavor, both of which are due to non-enzymatic browning resulting from thermal treatment of the fermented starchy batter (Dirar, 1993). Germination and fermentation are preparation techniques used to enhance the nutritive estimation of grains by raising the bioavailability of their components. During germination, lipids, sugars and capacity proteins inside the seed are separated with the specific end goal of acquiring energy and amino acids vital for the plant's advancement (Urbano et al., 2005). Malting is utilized to viably upgrade the healthful/organoleptic status of millet and wheat (Laxmi et al., 2015).

Several millet-based foods are common in Sudan, including sisra and hulu-mur. However, the effect of fermentation and methods of preparation on the chemical compositions has not been thoroughly investigated. This study aims to investigate the method of preparation and composition of kisra, the fermented staple food, and hulu-mur, the highly non-enzymatically browned fermented food.

MATERIALS AND METHODS

All solvents utilized were of analytical grade: All chemicals were obtained from Merck, Darmstadt, Germany, while solvents and other chemicals were obtained from local chemical companies.

Samples collection

Millet grain was purchased from the grain market in north Khartoum, Sudan, and was stone milled into fine flour. The flour was kept at 25°C until analysis. All samples were dried then ground to a fine powder and kept at 4ºC in polyethylene packs until analysis.

Preparation and baking of millet kisra batter

Millet kisra batter fermentation was carried out in the conventional way following Mahgoub et al. (1999). The fermented batter (known as *ajin* is thin in order to behave like a liquid), was performed in triplicate. The process of baking the fermented batter is done in accordance with Mahgoub et al. (1999). Samples were calculated in triplicate.

Hulu-mur batter preparation and baking procedures

Hulu-mur batter was prepared in accordance with the conventional method utilized in Sudanese households. The method outlined by Dirar (1993) was followed. The batter was kept in a refrigerator at 4°C for chemical analysis. A *sajj* or *doka*, which is an iron plate 60×40 cm, was used for baking *hulu-mur*.

Proximate composition. Moisture, ash, lipid, crude protein, and crude fiber contents were investigated in accordance with the AOAC (2012) method. The carbohydrate percentage was calculated by difference. All analyses were carried out in triplicate.

Sugars content procedure. Soluble sugars from 4 grams of every flour and processed samples were separated with 50 mL of 80% ethanol at 60°C for 30 min. Separation and quantitation were carried out on a bonded column with a versatile stage of CH_3CN and water (80:20 V:V; Badr et al., 2014). All analyses were carried out in triplicate.

Mineral elements extraction and determination. The AOAC (2012) method was utilized to determine minerals. All results were expressed in mg 100 g^{-1}. All analyses were performed in triplicate.

Determination of amino acids. Hydrolysis was performed in a closed conical flask for determining all amino acids other than tryptophan. Amino acids were analyzed following AOAC (2012) procedures, and separated using a Beckman 7300 High Performance Amino Acids Analyzer (Beckman Coulter, Mannheim, Germany). The chemical score was calculated in the way described by Stipanuk and Caudill (2013). All analyses were performed in triplicate.

Statistical analysis

Three replicates were accomplished for every investigation. Representative random samples were drawn from the examination. Information was dissected utilizing the Analysis of Variance (ANOVA), and afterwards was subjected to SPSS-20. A One-factor Completely Randomized Design (CRD) was utilized and after that the means were computed utilizing Duncan's Multiple Range Test (DMRT), as reported previously by Montgomery (2001).

RESULTS AND DISCUSSION

Proximate composition of millet and millet fermented products

Table 1 demonstrates the proximate analysis of millet flour and millet-based fermented foods. The moisture content of the millet *kisra* batter, millet *hulu-mur* batter after adding spices and millet *hulu-mur* batter before adding spices were 10.20%, 14.25% and 13.64%, respectively. The batter moisture content increased from 4.32% in millet flour to 7.13% in millet *hulu--mur* and up to 6.62% in millet *kisra*. The sharp decrease of batter moisture content is affected by baking (*Aowasa*) temperature (120 and 150°C for *kisra* and *hulu-mur*, respectively). Statistical examination demonstrated that the changes in the levels of moisture content in millet flour and millet-based fermented foods was significant ($p < 0.05$). The moisture content of millet products (*kisra* 6.62%, *hulu-mur* 7.135) was considered very low when compared with other cereal products, low moisture content in food samples expanded the storage time of the food items, while a high moisture content in foods enhances microbial development, and consequently, food deterioration (Assohoun et al., 2013).

The ash percentage of millet seeds was 0.93% and this was significantly ($P \leq 0.05$) affected during the fermentation and addition of spices. As shown in Table 1, the ash contents of millet flour, millet *kisra* batter, and millet *kisra* were 0.93, 2.11 and 2.34% respectively. The ash contents of millet *hulu-mur* batter before adding spices, millet *hulu-mur* batter after adding spices and millet *hulu-mur* were 1.79, 2.45 and 2.42%, respectively. The increase in ash content of *hulu-mur* batter and *hulu-mur* might be due to the addition of spices (cardamom, ginger, gurunjral, cinnamon and black cumin) and the addition of dates, *Tamaridus indica* and *Hibiscus sabdarifra* extracts. Nnam (1995) observed an increase in ash percentage during fermentation of *Vigna unguiculata* meal. On the contrary, Igbabul et al. (2014) showed a decrease in the ash content of mahogany bean *(Afzelia africana*) seed flour during fermentation. The value obtained for millet flour was less than the range given by Elyas et al. (2002), who reported a range of 1.2–2.1%. As shown in Table 1, the fiber capacity of millet flour, millet *kisra* batter, millet *hulu-mur* batter after adding spices and millet

Table 1. Proximate composition of millet and millet-based products on dry basis

Samples	Parameter, %					
	moisture	ash	fiber	protein	oil	carbohydrate
M	4.32 ±(0.10)^c	0.93 ±(0.04)^c	1.12 ±(0.12)^c	13.20 ±(0.10)^c	6.18 ±(0.25)^a	74.26 ±(0.20)^a
MKB	10.20 ±(0.10)^a	2.11 ±(0.04)^b	1.11±(0.16)^b	14.36 ±(0.17)^b	5.29 ±(0.91)^b	66.93 ±(1.12)^c
MK	6.62 ±(0.08)^b	2.34 ±(0.13)^a	1.26 ±(0.17)^a	15.15 ±(0.13)^a	4.65 ±(0.05)^c	69.98 ±(0.27)^b
MHBS	13.64 ±(0.07)^b	1.79 ±(0.06)^b	1.16 ±(0.12)^c	8.67 ±(0.16)^b	2.87 ±(0.13)^c	71.86 ±(0.42)^a
MHAS	14.25 ±(0.09)^a	2.45 ±(0.12)^a	1.46 ±(0.21)^b	13.76 ±(0.16)^a	4.45 ±(0.41)^a	63.62 ±(0.54)^b
MH	7.13 ±(0.15)^d	2.42 ±(0.06)^a	2.21 ±(0.24)^a	13.81 ±(0.22)^a	3.38 ±(0.22)^b	71.04 ±(0.44)^c

M – millet flour sample. MKB – millet kisra batter sample. MK – millet ksra sample. MHBS – millet hulu-mur batter before adding spices sample. MHAS – millet hulu-mur batter after adding spices sample. MH – millet hulu-mur sample. Values are means (±SD). Values not sharing a common superscript in a column and within a product are significantly ($P \leq 0.05$) different.

hulu-mur batter before adding spices were 1.02, 0.21, 0.24 and 0.28%, respectively. After fermentation and baking the fiber content of kisra and *hulu-mur* was 1.9 and 0.56%, respectively.

Table 1 demonstrates the protein volume of millet flour 13.2, millet *kisra* batter 14.36, millet kisra 15.15, and millet *hulu-mur* batter before adding spices 8.67, millet *hulu-mur* batter after adding spices 13.76, and millet hulu-mur 13.81%. These results demonstrated a significant ($P \leq 0.05$) difference in the content as a result of the fermentation and baking processes, as the protein content of millet flour (13.2%), increased to 14.36 and 15.15% in millet kisra batter and millet kisra, respectively. This increase can be identified with the loss of dry matter, fundamentally carbohydrates (Osman, 2011). There was a significant ($P \leq 0.05$) increase in protein content during millet kisra batter fermentation. At the end of fermentation (millet kisra), there was a significant ($P \leq 0.05$) increase from 13.20% compared to 14.36% as initial level. On the other hand, a significant ($P \leq 0.05$) decrease in protein content from 13.20 to 8.67% was seen during millet *hulu-mur* batter fermentation. This decrease might be related to the germination process, as malting is a biotechnological procedure including the controlled germination of a cereal grain, the intent of which is to enact catalyst frameworks that catalyze the hydrolysis of polymerized reserved food materials, predominantly proteins, starches and cell-wall substances, thus resulting in fermentable materials being produced (Laxmi et al., 2015). At the end of fermentation (millet *hulu--mur*) there was a significant ($P \leq 0.05$) increase from 8.67% in MHBS to 13.76% in MHAS and 13.81% in MH, which was possibly related to fermentation and the addition of spices, mainly black cumin, which contains more than 25.8% protein (Mariod et al., 2012). These results are in agreement with those of Suganya and Kailappan (2013) for fermented pearl millet flour.

Table 1 shows the carbohydrate content of millet flour 74.26%, millet *kisra* batter 66.93%, millet kisra 69.98%, millet *hulu-mur* batter before adding spices 71.86%, and millet *hulu-mur* batter after adding spices 63.62%, and also millet *hulu-mur* 71.04%. Table 1 clearly indicates a significant ($P \leq 0.05$) decrease in carbohydrate content with fermentation. This is due to microbial activity on pearl millet. The available carbohydrates are converted to organic acids due to the fermentation process, significantly ($P \leq 0.05$) reducing the amount of carbohydrates, which may be attributed to the utilization of sugars by the fermenting microflora (Suganya and Kailappan, 2013). Table 1 shows the oil content of millet flour as 6.18; this amount decreased to 5.29% in MKD and to 4.65% in MK and to 2.87% in MHBS, and to 4.46% in MHAS and to 3.38% in millet *hulu-mur*. The decrease in oil content in millet and millet-based products throughout fermentation suggests that the fermenting microorganisms utilized these fats as an energy source. Decreasing fat capacity was previously mentioned by Khetarpaul and Chauhan (1989), who studied the fermentation of pearl millet. The sharp decrease in oil content in *hulu-mur* batter before adding spices might be a result of the germination process that took place in the preparation of these products. Laxmi et al. (2015) mentioned that fat content was reduced due to the malting of millet. The increase in oil content (4.45%) in *hulu-mur* batter after the addition of spices might be due to the addition of these spices, mainly black cumin.

Carbohydrate content of millet and millet-based fermented foods

The analysis of carbohydrates (Table 2) revealed that fermentation initially increased the total amounts of free sugars of millet and millet-based products. The dominant sugar in raw millet flour is sucrose (73.5%) followed by raffinose (19%). Immediately after blending the flour and water (MKB and MHAS), there is a quick yield of glucose, fructose and maltose. Maltose is presumably obtained from starch by means of the activity of endogenous amylases present in the flour. Fructose might be obtained from fructosans or incorporated by some other mechanisms, e.g. isomerization of sucrose. Fructose was found in small amounts of less than 0.1 in MHBS and MHAS. There was a slight and insignificant increase in fructose content in MH. The increase and the decrease in reducing sugars during lactic acid fermentation of pearl millet could be attributed to the action of microflora during fermentation (Khetarpaul and Chauhan, 1990). During the fermentation and production of millet *hulu-mur* there was a significant ($P \leq 0.05$) increase in glucose and maltose due to the germination process of the millet seeds before fermentation. In MHAS the free sugars reach a maximum (9.04), the dominant sugar being

Table 2. Sugar content of millet and millet-based fermented foods on dry basis, %

Samples	Parameters, %					
	fructose	glucose	sucrose	maltose	raffinose	total
M	0.04 ±(0.01)^c	0.10 ±(0.01)^c	1.61 ±(0.02)^a	0.02 ±(0.01)^b	0.42 ±(0.03)^a	2.19 ±(0.05)^b
MKB	0.18 ±(0.02)^a	2.39 ±(1.69)^a	0.15 ±(0.04)^b	0.08 ±(0.01)^a	0.00 ±(0.00)^b	2.79 ±(1.75)^a
MK	0.11 ±(0.01)^b	1.24 ±(0.00)^b	0.06 ±(0.01)^c	0.07 ±(0.00)^a	0.00 ±(0.00)^b	1.48 ±(0.01)^c
MHBS	0.00 ±(0.00)^b	3.72 ±(0.51)^b	0.12 ±(0.01)^b	2.44 ±(0.14)^d	0.25 ±(0.08)^d	6.80 ±(0.57)^c
MHAS	0.00 ±(0.00)^b	6.23 ±(0.02)^a	0.00 ±(0.00)^c	2.87 ±(0.05)^c	0.21 ±(0.02)^e	9.04 ±(0.05)^d
MH	0.28 ±(0.01)^a	2.61 ±(0.12)^d	0.06 ±(0.01)^c	5.02 ±(0.12)^a	0.34 ±(0.01)^c	8.30 ±(0.01)^a

M – millet flour sample. MKB – millet kisra batter sample. MK – millet ksra sample. MHBS – millet hulu-mur batter before adding spices sample. MHAS – millet hulu-mur batter after adding spices sample. MH – millet hulu-mur sample. Values are means (±SD). Values not sharing a common superscript in a column and within a product are significantly ($P \leq 0.05$) different.

glucose (ca. 68.91%), which might be attributed to the addition of *dates*, *Tamaridus indica* and *Hibiscus sabdarifra* extracts. There was a gradual significant ($P \leq 0.05$) decrease in sucrose content during fermentation due to utilization by microorganisms. At the end of *hulu-mur* processing there was a sharp decrease in glucose content 2.61% (Table 2). These results agree with those of Osman (2011), who reported a gradual significant increase in glucose content during the first 20 h of fermentation of pearl millet during the preparation of lohoh, which might be because of the increment in microbial amylase activeness.

Mineral content (mg 100 g^{-1}) of millet and millet-based fermented foods

Table 3 shows the amounts of calcium, potassium, phosphorus, iron, copper, manganese and lead in millet flour and millet-based fermented foods during preparation and after fermentation and baking. The results show very high calcium, potassium, phosphorus and iron levels (3.03, 542.24, 295.55, and 7.56 mg 100 g^{-1} for millet flour (M), respectively. These levels were significantly ($p < 0.05$) increased (except P, Pb and Cu) sharply during fermentation (MKB) and were affected by the method of preparation (MK). This might be as a result of

Table 3. Mineral content of millet and millet-based fermented foods dry basis, mg 100 g^{-1}

Samples	Parameters						
	Ca	K	P	Fe	Pb	Cu	Mn
M	3.03 ±(0.88)^c	542.24 ±(10.19)^c	295.55 ±(0.00)^a	7.56 ±(0.95)^c	0.14 ±(0.09)^b	0.91 ±(0.10)^a	1.08 ±(0.11)^c
MKB	3.55 ±(0.52)^b	889.42±(3.34)^b	18.14 ±(3.8)^c	32.67 ±(0.08)^b	0.08 ±(0.00)^c	0.87 ±(0.01)^b	4.94 ±(0.62)^b
MK	5.10 ±(0.05)^a	935.61 ±(11.03)^a	180.34 ±(0.20)^b	42.61 ±(0.13)^a	0.13 ±(0.00)^a	0.38 ±(0.01)^c	5.13 ±(0.09)^a
MHBS	3.33 ±(0.28)^d	958.66 ±(7.64)^d	192.29 ±(3.31)^c	50.27 ±(0.43)^d	0.13 ±(0.00)^d	0.02 ±(0.00)^d	5.59 ±(0.96)^d
MHAS	43.19 ±(0.08)^b	966.82 ±(5.89)^b	200.23 ±(0.24)^b	56.02 ±(2.62)^b	0.90 ±(0.00)^a	0.82 ±(0.00)^b	8.16 ±(0.02)^b
MH	52.54 ±(0.56)^a	1049.95 ±(8.24)^a	183.49 ±(5.30)^d	91.68 ±(0.05)^a	0.10 ±(0.00)^c	0.36 ±(0.00)^c	9.13 ±(0.07)^a

M – millet flour sample. MKB – millet kisra batter sample. MK – millet ksra sample. MHBS – millet hulu-mur batter before adding spices sample. MHAS – millet hulu-mur batter after adding spices sample. MH – millet hulu-mur sample. Values are means (±SD). Values not sharing a common superscript in a column and within a product are significantly ($P \leq 0.05$) different.

an upgrading of these elements during fermentation. Fermentation is known to reduce phytate, which increases the amount of Fe and Mn. Oyewole and Odunfa (1989) demonstrated that the fermentation procedure created an expansion in the content of calcium (+12%) during the fermentation of cassava in the course of *fufu* production, but a decrease in the levels of potassium, sodium, manganese, iron, copper, zinc and phosphorus. The levels of calcium, iron, potassium, lead, phosphorus and manganese increased significantly ($p \leq 0.05$) after the addition of spices to the *hulu-mur* batter. The millet *hulu-mur* (MH) product showed a significant ($p \leq 0.05$) increase in the levels of calcium, potassium, iron and manganese when compared to millet flour (M). This increase might be due to the addition of different spices. Abdelrahaman et al. (2007) observed an increase in the levels of some minerals after 14 h of lactic acid fermentation in millet. As indicated by Odumodu (2007), fermentation was found to upgrade both the macro elements and the micronutrients of the fermented cereals up to 72 h. These outcomes are in conflict with those of Mahgoub et al. (1999), who stated that fermentation brought about no significant impact ($p < 0.05$) on the mineral levels of *kisra* or *hulu-mur*.

Amino acids of millet and millet-based fermented foods

Table 4 shows changes in the content (g 100 g^{-1} protein) of amino acids of millet and millet-based fermented foods. From this table it can be seen that 17 amino acids were determined in all samples. The total amino acid in millet flour (97.98 g 100 g^{-1} protein) was affected by fermentation and preparation, as it was decreased to 86.09 and 88.7 (g 100 g^{-1} protein) in MKB and MK, respectively. The total amino acid in millet flour (97.98 g 100 g^{-1} protein) decreased to 89.64, 79.79 and 83.3 g 100 g^{-1} protein in MHBS and MHAS, respectively. The fermentation and preparation processes decreased

Table 4. Amino acids content of millet and millet-based fermented foods, g 100 g^{-1} protein

Amino acid	Sample					
	M	MKB	MK	MHBS	MHAS	MH
1	2	3	4	5	6	7
Aspartic	7.45 ±0.42^{b}	7.32 ±0.40^{c}	7.90 ±0.45^{a}	7.48 ±0.4^{b}	7.02 ±0.42^{d}	7.31 ±0.40^{c}
Therionine	3.06 ±0.2^{c}	3.21 ±0.22^{b}	3.70 ±0.21^{a}	3.19 ±0.22^{a}	2.87 ±0.12^{b}	3.03 ±0.2^{c}
Serine	4.29 ±0.12^{b}	3.55 ±0.15^{c}	4.49 ±0.14^{a}	3.78 ±0.22^{a}	3.55 ±0.15^{c}	3.69 ±0.16^{d}
Glutamic	20.82 ±0.52^{a}	17.00 ±0.42^{b}	17.97 ±0.45^{b}	17.85 ±0.46^{c}	16.15 ±0.32^{d}	16.83 ±0.35^{b}
Glycine	3.16 ±0.12^{a}	2.86 ±0.10^{c}	2.97 ±0.11^{b}	3.04 ±0.10^{b}	2.79 ±0.14^{d}	2.88 ±0.16^{c}
Alanine	8.57 ±0.42^{a}	7.67 ±0.32^{c}	8.12 ±0.22^{b}	8.00 ±0.14^{b}	6.57 ±0.31^{d}	7.08 ±0.32^{c}
Valine	4.80 ±0.12^{c}	5.23 ±0.22^{a}	5.51 ±0.24^{b}	5.19 ±0.25^{b}	4.53 ±0.17^{c}	5.24 ±0.32^{b}
Isoleucine	3.78 ±0.14^{b}	3.83 ±0.18^{c}	4.35 ±0.21^{a}	4.22 ±0.20^{a}	3.70 ±0.16^{c}	4.06 ±0.26^{b}
Leucine	12.35 ±0.56^{a}	9.41 ±0.45^{c}	10.07 ±0.43^{b}	10.00 ±0.41^{b}	8.53 ±0.23^{d}	9.15 ±0.52^{c}
Tyrosine	4.80 ±0.13^{a}	3.55 ±0.2^{c}	3.77 ±0.22^{b}	3.85 ±0.22^{b}	3.47 ±0.24^{d}	3.69 ±0.26^{c}
Phenyle alanine	5.92 ±0.32^{a}	5.09 ±0.31^{c}	5.51 ±0.42^{b}	5.41 ±0.52^{b}	4.91 ±0.34^{d}	5.09 ±0.17^{c}
Histidine	2.45 ±0.13^{b}	2.44 ±0.12^{b}	2.61 ±0.14^{a}	2.74 ±0.15^{a}	2.42 ±0.11^{c}	2.66 ±0.12^{b}
Lysine	2.45 ±0.12^{a}	2.37 ±0.11^{b}	2.46 ±0.18^{a}	1.93 ±0.13^{a}	1.81 ±0.10^{b}	1.55 ±0.11^{c}
Arginine	3.88 ±0.13^{b}	3.55 ±0.32^{c}	4.06 ±0.15^{a}	3.41 ±0.17^{a}	3.40 ±0.12^{b}	2.66 ±0.12^{c}
Proline	7.76 ±0.42^{a}	6.27 ±0.41^{b}	6.30 ±0.32^{b}	6.52 ±0.19^{b}	5.58 ±0.25^{d}	5.83 ±0.34^{c}

Table 4 – cont.

1	2	3	4	5	6	7
Cysteine	1.22 ±0.10^{c}	1.74 ±0.14^{a}	1.38 ±0.11^{b}	1.33 ±0.13^{a}	1.13 ±0.11^{b}	1.25 ±0.10^{b}
Methionine	1.22 ±0.11^{c}	1.46 ±0.13^{b}	1.59 ±0.14^{a}	1.70 ±0.15^{b}	1.36 ±0.12^{b}	1.33 ±0.12^{b}
TAA	97.98 ±1.5^{a}	86.09 ±1.2^{b}	88.7 ±2.2^{b}	89.64 ±2.5^{b}	79.79 ±3.2^{d}	83.33 ±4.0^{c}
EAA, %	36.8	36.6	34.1	38.4	37.8	38.6
NEAA, %	63.2	63.4	65.9	61.6	62.2	61.4

M – millet flour sample. MKB – millet kisra batter sample. MK – millet kisra sample. MHBS – millet hulu-mur batter before adding spices sample. MHAS – millet hulu-mur batter after adding spices sample. MH – millet hulu-mur sample. TAA – total amino acids, EAA – essential amino acids, NEAA – non-essential amino acid. Values are means (±SD). Values not sharing a common superscript in a row and within a product are significantly ($P \leq 0.05$) different.

the total amino acid of pearl millet, and this decrease was affected by the period of fermentation. A shorter period of fermentation of MKB and MK showed a low decrease in total amino acids. These outcomes are in concurrence with Osman (2011) who reported that fermentation significantly ($P \leq 0.05$) diminished the levels of amino acids in pearl millet during the preparation of lohoh. The change in individual amino acid levels during the fermentation of millet and millet-based fermented foods is presented in Table 4. A significant ($P \leq 0.05$) sharp decrease in glutamic, proline and leucine was observed after 13 h of fermentation of KM and after 25 h of fermentation of MH. Aspartic, serine, glycine, alanine, tyrosine phenyle alanine, lysine and arginine also showed a significant ($P \leq 0.05$) decrease in their amount. In contrast, the content of therionine, valine, Isoleucine and histidine was increased and affected by the fermentation time and method of preparation. This was in concurrence with the study by Popoola et al. (2005), who reported an increase in values for some of the amino acids in the fermented seeds of *C. altissimum* for use as condiments.

Amino acids score (%) of millet and millet-based fermented foods

The amino acid scores of millet and millet-based fermented food samples are presented in Table 5. From this table the respective amino acid scores for millet

Table 5. Amino acids score of millet and millet-based fermented foods, %

Amino acid score	M	MKB	MK	MHBS	MHAS	MH	FAO reference protein
Therionine	76.53^{c}	80.14^{b}	92.39^{a}	79.63^{a}	71.70^{d}	75.65^{b}	4.00
Valine	95.92^{c}	104.53^{b}	110.14^{a}	103.70^{a}	90.57^{d}	104.80^{b}	5.00
Isoleucine	94.39^{c}	95.82^{b}	108.70^{a}	105.56^{a}	92.45^{d}	101.48^{b}	4.00
Leucine	176.38	134.40	143.89	142.86	121.83	130.73	7.00
Tyrosine + phenyle alanine	178.57^{a}	144.02^{c}	154.59^{b}	154.32^{b}	139.62^{d}	146.37^{c}	6.00
Lysine	44.53^{a}	43.08^{c}	44.80^{b}	35.02^{d}	32.93^{b}	28.18^{c}	5.50
Cyctine + methionine	69.57^{c}	91.07^{a}	84.40^{b}	86.28^{a}	70.75^{d}	73.38^{b}	3.52

M – millet flour sample. MKB – millet kisra batter sample. MK – millet ksra sample. MHBS – millet hulu-mur batter before adding spices sample. MHAS – millet hulu-mur batter after adding spices sample. MH – millet hulu-mur sample. Values are means (±SD). Values not sharing a common superscript in a column and within a product are significantly ($P \leq 0.05$) different.

and millet-based fermented foods can be seen to be 44.5, 43.0, 44.8, 35.0, 32.9 and 28.1% in M, MKB, MK, MHBS, MHAS and MH, respectively, and are significantly different ($P \leq 0.05$). With lysine as the limiting amino acid, a score above 100% would be considered as 100 (Stipanuk and Caudill, 2013). The highest deficient of lysine was in millet hulu-mur (chemical score 28.1), closely followed by MHAS (chemical score 32.9), and MHBS (chemical score 35). Compared with the chemical scores of casein (62), lactalbumin (69), whole egg (100), white flour (28), soya bean (74), cow's milk (95) and human milk (100) (FAO/WHO, 1973), the protein in pearl millet is relatively poor in nutritive quality and its first limiting amino acid is lysine, as in other cereal proteins.

CONCLUSION

In conclusion, millet flour and its fermented foods can be affected by fermentation and the method of preparation. A reduction of some nutritional parameters (carbohydrate and oil) and an increase in others (protein) were observed in this study. In spite of the losses in some nutritional compounds, the fermented millet-base items, kisra, and hulu-mur were found to have obvious nutritious qualities.

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