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Effect of traditional Sudanese processing of *kisra* bread and *hulu-mur* drink on their thiamine, riboflavin and mineral contents

Salah E.O. Mahgoub [a,*], Babiker M. Ahmed [b], Mustafa M.O. Ahmed [c], El Nazeer A.A. El Agib [d]

[a] *University of Botswana, Private Bag 0022, Gaborone, Botswana*
[b] *Department of Pharmaceutical Chemistry, Faculty of Pharmacy, University of Khartoum, Khartoum, Sudan*
[c] *Sudan Atomic Energy Commission, National Centre for Research, Khartoum, Sudan*
[d] *Department of Food Industries, Industrial Research and Consultancy Centre, Khartoum, Sudan*

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Abstract

The effect of fermentation, germination and heating on the levels of thiamine, riboflavin and some mineral elements was studied in Sudanese *kisra* bread and *hulu-mur* drink prepared from the two sorghum cultivars *dabar* and *fetarita*, consecutively. Fermentation of *kisra* increased riboflavin but decreased thiamine significantly ($p < 0.01$), whereas fermentation of *hulu-mur* reduced the levels of both vitamins significantly ($p < 0.01$). Germination of *fetarita* grains for 6 days caused a significant ($p < 0.01$) increase of riboflavin (700%) and a significant ($p < 0.01$) reduction of thiamine (42%). Riboflavin was not affected by baking of *kisra* and thiamine level was slightly reduced. *Hulu-mur* baking caused significant ($p < 0.01$) reduction of both thiamine and riboflavin. Fermentation caused no significant effect ($p < 0.01$) on the mineral contents of *kisra* or *hulu-mur*. Addition of spices to *hulu-mur* dough caused significant increases ($p < 0.01$) of strontium (80%), calcium (60%) and iron (35%). Germination of *fetarita* grains caused significant increases ($p < 0.01$) of zinc (90%), lead (65%) and molybdenum (58%). Baking of *kisra* and *hulu-mur* did not cause any significant loss ($p < 0.01$) in the contents of minerals.

1. Introduction

Kisra is a traditional bread, well known and consumed throughout the Sudan. It is prepared from the fermented dough of sorghum (*Sorghum bicolor*) or pearl millet (*Pennisetum typhodium*) grains. The fermented dough is baked into thin sheets. It is eaten with certain types of stew prepared from vegetables and meat. *Hulu-mur* is a traditional Sudanese non-alcoholic beverage made from a fermented mixture of unmalted sorghum flour and malt flour. The variety commonly used in its preparation is *fetarita*. The fermented dough is baked into brown thick sheets. The sheets are broken down to smaller flakes. To prepare a *hulu-mur* drink, the flakes are soaked in water for a few hours and then strained. The dark reddish-brown extract is sweetened with sugar and then drunk.

The purpose of this study is to investigate the effects of the traditional methods of fermentation, germination and baking of *kisra* and *hulu-mur* on their contents of thiamine, riboflavin and some mineral elements.

* Corresponding author.

2. Materials and methods

2.1. Sample preparation

Samples for analysis were prepared as shown in Fig. 1 (whole grain flour, malt flour, fermented doughs and *hulu-mur*) and Fig. 2 (whole grain flour, fermented and non-fermented doughs and *kisra*).

2.1.1. Milling of grains

Two local cultivars of sorghum (*Sorghum bicolor*) namely *dabar* and *fetarita* were obtained from Khartoum central market. Milling was carried out in a commercial mechanical stone mill. Whole grain flours were obtained and used in the preparation of *kisra* and *hulu-mur*.

2.1.2. Malt flour preparation

Three kg of *fetarita* grains were soaked in distilled water overnight. The grains were then spread on trays and covered with a wetted cloth and were kept wet by frequent spraying with distilled water. The thickness of the grain layer was 5 cm. After 6 days the germination process was complete. The germinated grains were left

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Fig. 1. Flow diagram of *hulu-mur* preparation and analysis.

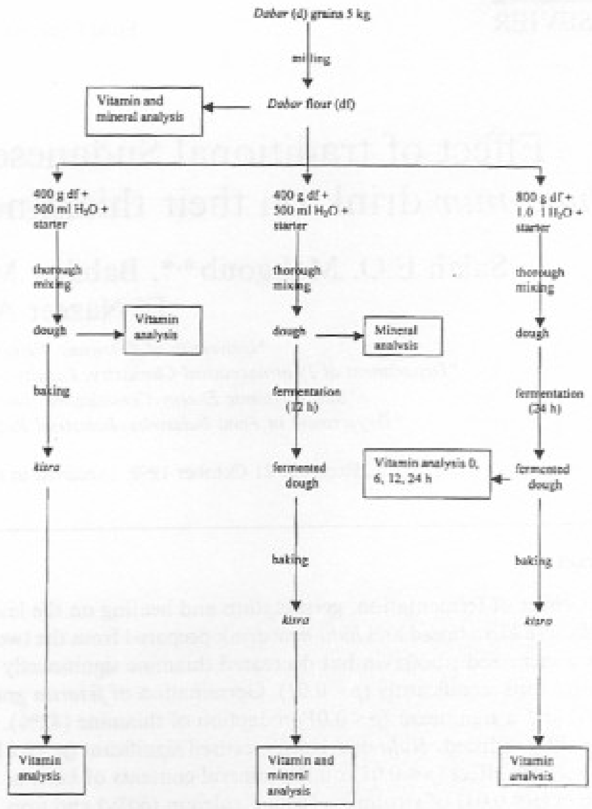

Fig. 2. Flow diagram of *Kisra* preparation and analysis.

to dry for a further 3 days. They were, then, collected and milled into flour (malt flour) in a mechanical stone mill.

2.1.3. Dough production

Doughs were prepared by thorough mixing of flour and distilled water in the ratio of 1:1.25.

2.1.4. Dough fermentation

Dough fermentation was initiated by adding starters from previously fermented doughs of the same nature. For *hulu-mur* preparation (Fig. 1), fermentation was carried out through three stages: initially for 25 h, then for a further 5 h and finally for an extra 10 h. Samples were drawn after each stage for analysis. Fermentation of dough used in *kisra* preparation (Fig. 2) was carried out on two samples: one fermented for 12 h and another fermented for 24 h.

2.1.5. *Preparation of spices and* karkadeh (Hibiscus sabdariffa) *mixture*

The mixture of spices and *karkadeh* was prepared by mixing equal amounts of powdered ginger (*Zingiber officinale*), black cumin (*Cuminum cymicum*), cinnamon (*Cinnamomum cassia*), *khurunjal* (a local Sudanese spice), fenugreek (*Trigonella foenum-graecum*) and *karkadeh*. 200 g of this mixture were added to 2 kg of fermented *fetarita* dough used in the preparation of *hulu-mur* (Fig. 1).

2.1.6. *Baking of* hulu-mur *and* kisra

Baking procedures for both *hulu-mur* and *kisra* were the same. A hot iron plate with a smooth surface was used for baking. Fermented dough was spread as a thin layer on the hot plate and was allowed to bake for 20–30 s. The baked *hulu-mur* or *kisra* sheets were then removed using a wooden scraper.

2.2. Vitamins and minerals analysis

Free thiamine and riboflavin were determined by fluorimetry according to the official methods of analysis of the Association of Official Analytical Chemists (1980), using a Perkin–Elmer LS5 Luminescence Spectrometer. Thiamine was determined at excitation wavelength 375 mn and emission wavelength 428 nm. Riboflavin was determined at excitation wavelength 444 nm and emission wavelength 528 nm. Samples for mineral analysis were dried in an oven at 110°C for 6 h.

Determination of minerals was carried out simultaneously in the same sample by an X-ray fluorescence technique, XRF (Jenkins, Gold & Gedolk, 1981). The elements determined were calcium, copper, iron, zinc, lead, strontium and molybdenum. Samples were prepared for analysis by compressing 1 g portions of each into a self-supporting pellet using a hydraulic press at 20 tonnes per square inch for 2 min. Cd^{109} was used as a source with Li (Si) detector. The collection time was 2000 s. The concentration of iron obtained by XRF was confirmed by determining it in a flour sample by atomic absorption spectrometry (AAS), using a Perkin–Elmer 306 Atomic Absorption Spectrometer. The flour sample for AAS was prepared by ashing, dissolving in 3 N HCI and dilution to appropriate concentrations in accordance with the Association of Offical Analytical Chemists method no. 968.08 (Helrich, 1990).

2.3. Statistical analysis

Six replicates were carried out for each determination. Representative random samples were drawn for analysis. Data were analysed using the Analysis of Variance (ANOVA) in accordance with standard methods of statistical analysis (Snedecor & Cochran, 1976). Tests of significance were carried out using Duncan's multiple range test (Duncan, 1955).

3. Results and discussion

3.1. Vitamins

Thiamine and riboflavin contents of *dabar* and *fetarita* grains are shown in Table 1. The riboflavin contents of the two sorghum cultivars were almost the same (1.08 µg/g for *dabar* and 1.07 µg/g for *fetarita*). The difference in the thiamine content of the two cultivars (3.92 µg/g for *dabar* and 3.47 µg/g for *fetarita*) was insignificant ($p < 0.01$). These results agree with the average contents of thiamine and riboflavin of various sorghum varieties reported by Yousif and Magboul (1972).

Table 1 also shows that germination of *fetarita* grains for 6 days caused significant effects ($p < 0.01$) on the levels of both thiamine and riboflavin. The riboflavin level increased substantially, by 706%, whereas the thiamine level decreased by 42%. These results conform to the observations of Finney (1983) that the thiamine content is generally decreased or remains constant in germinated seeds, whereas riboflavin content increased considerably.

From Table 2 it can be seen that the thiamine level in *kisra* dough decreased with increasing fermentation period, while the riboflavin level increased. The thiamine level decreased by 14% after 6 h and by 25% after 12 h of fermentation. After 24 h fermentation, the decrease was 35%. In the first 6 h of fermentation the increase in riboflavin level was 6%. After 12 h the increase was 13% and after 24 h the increase was 16%. Statistical analysis showed that the change in the levels of both vitamins was significant ($p < 0.01$).

Reports in the literature (El Hidai, 1978) indicate that the dominant bacteria in the fermentation medium of *kisra* are, by far, lactic acid bacteria, which makes the fermentation of *kisra* mainly of the lactic acid type. In many cases lactic acid fermentation was found to cause a decrease in the thiamine and an increase in the riboflavin contents of fermented cereals (Khetarpaul & Chauhan, 1989; Lee, Hanikim, Fields & Tongnval, 1980; Murdock & Fields, 1984; Wu & Chou, 1985). However, El Hidai (1978) reported that, during *kisra* fermentation, the thiamine level increased by an average of 24%.

In contrast to *kisra*, *hulu-mur* fermentation caused reduction in both thiamine and riboflavin levels. After fermentation for 25 h, the contents of thiamine and riboflavin in *hulu-mur* dough (Table 3) were 2.82 and 4.45 µg/g, respectively. Increasing the fermentation period a for further 5 h reduced the levels of both vitamins significantly ($p < 0.01$) (5% for thiamine and 13% for riboflavin). By the end of the fermentation period, the decreases in the thiamine and riboflavin levels were

Table 1
Thiamine and riboflavin contents[a] of *dabar* and *fetarita* grains and germinated[b] *fetarita* flour (dry weight basis)[c]

Sample	Vitamin	
	Thiamine (µg/g)	Riboflavin (µg/g)
Dabar	3.92a (0.17)	1.08b (0.01)
Fetarita	3.47a (0.25)	1.07b (0.01)
Fetarita malt flour	2.02 (0.06)	8.63 (0.15)

[a] Averages of six replicates.
[b] Germinated for 6 days.
[c] Values between brackets are standard deviations; values with same letters (a and b within columns) are not significantly different at $p < 0.01$

Table 2
Thiamine and riboflavin contents[a] of fermented *kisra* dough after different fermentation times (dry weight basis)[b]

Fermentation period (h)	Vitamin	
	Thiamine (µg/g)	Riboflavin (µg/g)
0	3.61 (0.02)	1.24 (0.02)
6	3.10 (0.07)	1.32 (0.02)
12	2.72 (0.02)	1.39 (0.01)
24	2.32 (0.01)	1.44 (0.01)

[a] Averages of six replicates.
[b] Values between brackets are standard deviations.

Table 3
Thiamine and riboflavin contents[a] of *hulu-mur* during fermentation and after baking (dry weight basis)[b]

Fermentation period (h)	Vitamin	
	Thiamine (μg/g)	Riboflavin (μg/g)
25	2.82 (0.06)	4.45 (0.18)
30[c]	2.69a (0.04)	3.86b (0.11)
30[d]	2.64a (0.02)	3.73b (0.09)
40	2.53 (0.05)	3.64 (0.02)
Hulu-mur (after baking)	0.29 (0.00)	1.88 (0.02)

[a] Averages of six replicates.
[b] Values with same letters (a and b within columns) are not significantly different at $p < 0.01$.
[c] Before addition of spices.
[d] After addition of spices.

10% and 15%, respectively, compared to the 25-h fermented dough. Addition of spices had no significant effect ($p < 0.01$) on the levels of either vitamin. The thiamine and riboflavin contents of the 30-h fermented dough (after spices addition) were 2.64 and 3.73 μg/g, respectively. After fermentation for 10 h (i.e. at the end of the fermentation period), the contents of thiamine and riboflavin were slightly decreased to the levels of 2.53 and 3.64 μg/g respectively. That reduction was found to be statistically significant ($p < 0.01$).

Table 4 indicates that the riboflavin content of the unfermented *kisra*, and that of the 12-h fermented *kisra*, remained almost unchanged compared to dough before baking, but the riboflavin content of the 24-h fermented kisra showed a comparatively high loss (8%). On the other hand, the thiamine content of the three *kisra* samples was found to decrease significantly ($p < 0.01$) compared to the dough before baking. The highest decrease in the thiamine content (28%) was observed in the *kisra* produced from the 12-h fermented dough, while the thiamine content of the *kisra* produced from the unfermented dough, and the 24-h fermented dough, decreased by 7 and 12%, respectively.

By contrast, *hulu-mur* baking resulted in considerable and highly significant ($p < 0.01$) losses in the thiamine and riboflavin levels (88.5 and 48.4%, respectively), as is clear from Table 3. These high losses may be attributed to the relatively long baking time (ca 2 min) compared to *kisra* and to the high baking temperature. During baking, *hulu-mur* is subjected to excessive heat treatment which is essential for *hulu-mur* to acquire its characteristic colour and flavour (Marhoum, 1987). Concerning the effect of baking on the thiamine content of *kisra* the results obtained in the present study agree with those of El Tinay, Abdel Gadir, and El Hidai (1979) who studied the effect of baking on the thiamine and riboflavin contents of *kisra* prepared from dough fermented for 18 h. However, El Tinay and his collaborators, in the same study, found that the riboflavin content of *kisra* decreased by an average 34% after baking which was significantly ($p < 0.01$) higher than the result obtained here (8%).

3.2. Minerals

Table 5 shows the contents of calcium, iron, copper, zinc, strontium, molybdenum and lead in *dabar* flour, *fetarita* flour, malt flour, *kisra*, and *hulu-mur* during fermentation and after baking and in spices and *karkadeh* mixture. The most striking result was the very high iron level (352 and 452 μg/g for *fetarita* and *dabar*, respectively as determined by XRF and 487 μg/g for *dabar* as determined by AAS). This high level may be attributed to surface soil contamination, or the effect of the stone used for milling. The average iron contents of some Sudanese sorghum varieties as reported by various investigators were: 8 μg/g (Yousif & Magboul, 1972), 110 μg/g (Budair, 1977), and 34 μg/g (El Hidai, 1978).

Statistical analysis revealed that changes in the levels of minerals during fermentation of *kisra* and *hulu-mur* were insignificant ($p < 0.01$). This result is in conformation with the observations of El Hidai (1978) and Reddy and Salunkhe (1980) who agreed that fermentation had no effect on the levels of mineral elements. The levels of calcium, iron and strontium increased significantly ($p < 0.01$) after the addition of spices. The highest increase (80%) was observed in the level of strontium.

Table 4
Thiamine and riboflavin contents[a] of unfermented dough, dough fermented for 12 and 24 h and *kisra* prepared from each of them[b,c]

Fermentation period (h)	0		12		24	
Sample	Dough	*kisra*	Dough	*kisra*	Dough	*kisra*
Thiamine	3.72	3.46	3.12	2.24	2.35	2.07
(μg/g)	(0.02)	(0.02)	(0.08)	(0.07)	(0.02)	(0.01)
Riboflavin	1.22a	1.21a	1.42b	1.41b	1.54	1.41
(μg/g)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)

[a] Averages of six replicates.
[b] Values between brackets are standard deviations.
[c] Values with same letters (a and b within rows) are not significantly different at $p < 0.01$

Table 5
Mineral content of *Dabar* flour (D), *Fetarita* flour (F), malt flour (M), *kisra* dough (S1, S2), *hulu-mur* dough (H1, H2, H3, H4), 12-h fermented *kisra* (K), *hulu-mur* (H5) and spices (SP)[a,b,c]

Sample	Mineral						
	Ca mg/g (0.30)	Fe µg/g (25.7)	Cu µg/g (0.94)	Zn µg/g (4.28)	MO µg/g (0.17)	Pb µg/g (0.16)	Sr µg/g (0.41)
D	1.63	452	9.19	47.0	0.61	1.53	3.81
F	1.46	352	12.8	44.0	0.53	1.45	3.88
M	1.51	290	12.6	83.7	0.84	2.39	5.02
S1	1.96	473	9.67	51.7	0.80	1.44	3.35
S2	1.62a	504b	12.6	49.1d	0.82e	1.40f	4.67
H1	1.71	541	13.8	57.2	0.78	1.27	4.10
H2	1.52	529	12.8	54.9	1.01	1.30	3.94
H3	2.43	712	12.1	54.0	0.98	1.26	7.10
H4	2.31	718i	12.9	52.4	0.90l	1.30m	6.98n
H5	2.42	728i	11.4	50.8k	0.81l	1.29m	7.80n
K	2.04a	486b	9.50c	52.3d	0.87e	1.72f	4.50g
SP	7.37	1803	7.51	48.6	1.25	1.89	47.3

[a] S1, unfermented dough; S2, fermented for 12 h; H1, fermented for 25 h; H2, fermented for 30 h, without added spices; H3, fermented for 30 h, after spices addition; H4, at the end of fermentation.
[b] Values with same letters (within columns) are not significantly different at $p < 0.01$.
[c] Values between brackets are average standard deviations.

Calcium increased by 60% and iron increased by 35% (H2 and H3, Table 5). The levels of zinc, lead and molybdenum in the ungerminated grain flour (F) showed significant changes ($p < 0.01$) after germination (M). The level of zinc increased by 90%, and that of lead by 65%, while the level of molybdenum increased by 58%. The increase in the amounts of these elements may be explained by their absorption from the water used for soaking of the grains. It could, also, be due to contamination with dust.

Statistical analysis showed insignificant differences ($p < 0.01$) between the mineral content of *kisra* dough before baking (S2) and after baking (K), and between the mineral content of *hulu-mur* dough before baking (H4) and after baking (H5). These results are in good agreement with those obtained by Budair (1977) and El Hidai (1978).

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