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Effects of Malting and Roasting of Millet and Sorghum on Protein Digestibility, Mineral Availability, Soluble Sugar Composition and Consumer Acceptability of Dakuwa

Research Article

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Abstract

The effects of germination and roasting of pearl millet and sorghum on the hydrochloric acid extractability of minerals, in vitro protein digestibility and acceptability of "dakuwa" (a cereal - groundnut based snack food) was investigated. Results show that there was a significant increase ($p < 0.01$) in the extractability of calcium, phosphorous and iron from malted millet and sorghum dakuwa. Germination of pearl millet and sorghum increased calcium extractability of dakuwa samples from 31.51 to 63.45 %, while iron and phosphorus extractabilities increased from 15.48 to 43.20 % and 39.02 to 62.23 % respectively. The apparent protein digestibility of the dakuwa samples produced from malted millet and sorghum grains was significantly ($p < 0.01$) higher than that from the un-germinated grains. The germination of sorghum and millet prior to dakuwa production also significantly ($p < 0.01$) increased the soluble sugars contents (maltose, sucrose, glucose and fructose) of the final products. Sensory evaluation of the dakuwa samples revealed that malted and un-malted samples were all acceptable to consumers, although sorghum based dakuwa was rated slightly higher than the millet based ones. No sample was rated as poor.

Keywords: Sorghum; Millet; Malting; Roasting; Protein digestibility; Mineral availability

Introduction

Pearl millet and sorghum are used in a wide variety of snack foods made in every conceivable manner. In India and some West African countries pearl millet and sorghum are popped or patched, malted, eaten directly or used to produce various snacks, beverages and pregelatinized weaning foods [1-4].

"Dakuwa" is one such snack food product produced from sorghum, pearl millet, maize, tiger nuts and groundnut. It is a common food to the people living in Northern part of Nigeria especially the Hausas. In the traditional method of its production, the grains are cleaned, roasted and ground together to form a cohesive mass with the addition of sugar syrup, which is then moulded into small balls for sale [2] by children hawkers. Because it is a high protein energy food, dakuwa can serve as a good source of nutrient supplement to war torn and famine ravaged areas for growing children, adults, lactating women and the sick. Dakuwa is produced without consideration to the presence of anti-nutritional factors such as phytates and tannins.

Several studies have shown that germination improves the nutritive value of the sprouts over the ungerminated seeds [5,6]. Germination in addition to soaking and roasting has been found to decrease the levels of antinutrients present in the grain and maximize the levels of some utilizable nutrients [8-11]. Nkama & Gbenyi [10] investigated the effects of malting, and roasting on the residual phytate and tannin content of dakuwa. Phytate was reduced by 58 % and 57% receptively in malted millet-groundnut, and malted sorghum - groundnut dakuwa. Tannins were reduced by 91.4% and 72.1% respectively in the same products. There are no reports on the effects of malting and roasting on mineral availability, *in vitro* protein digestibility, sugar composition and acceptability of dakuwa. The objective of this study was to provide this information.

Materials and Methods

Pearl millet (*Peninsetum glaucum*) variety Zango was obtained from Lake Chad Research Institute, Maiduguri, Nigeria. Red sorghum (*Sorghum bicolor*), groundnut (Ex-Dakar), ginger (*Zingiber officinale*), hot pepper (*Capsicum annum*) and salt were purchased from Maiduguri, Monday market, Nigeria.

Sample preparation

All grains, except groundnut were cleaned using a laboratory aspirator (Vegvari Ferenc Aspirator, type OB125, Hungary) to remove stalks, leaves and other foreign matter. They were then separately washed with clean tap water and sun dried. All grains including groundnut were roasted to a light brown colour prior to grinding. The seed coat of the roasted groundnut was removed by first rubbing between the palms of the hand and then winnowing [2]. Defective groundnuts such as burnt and immature ones were removed by manual picking prior to grinding. The roasted grains were separately ground using a laboratory attrition grinder (Amuda, India). Grinding was such that 92.6% of the flour passed through a 400µm mesh sieve. Ginger, pepper were cleaned and dried in air oven (Chirana type HS 201A, Czechoslovakia) set at 100 ˚C for 2 hr before grinding and sieving to pass 400 µm mesh sieve.

Malt preparation

The millet and sorghum were steeped for 12 hr, germinated for 24 hr and then oven dried at 50 ˚C. The roots and shoots were removed by hand rubbing [12].

Proximate analysis

Moisture, protein, fat, crude fiber and ash were determined according to AOAC [13] methods. Carbohydrate was determined by difference [14].

Preparation of dakuwa

The process reported by Nkama [2] was adopted with some modifications (Figure 1). The cereal component was malted and honey was also added. Millet and sorghum grains were malted as described previously, and then roasted, ground before blending. All ingredients were mixed dry and pounded in a wooden mortar with pestle until very sticky. The honey was added as a binder to facilitate mounding of the dakuwa into the desired shapes.

Mineral analysis

Minerals comprising Ca, Cu, Fe, and Mn were determined by the AACC [15] procedure using Atomic Absorption spectrophotometer (model: Perkin -Elmer-2380). The hydrochloric acid (HCl) extractable

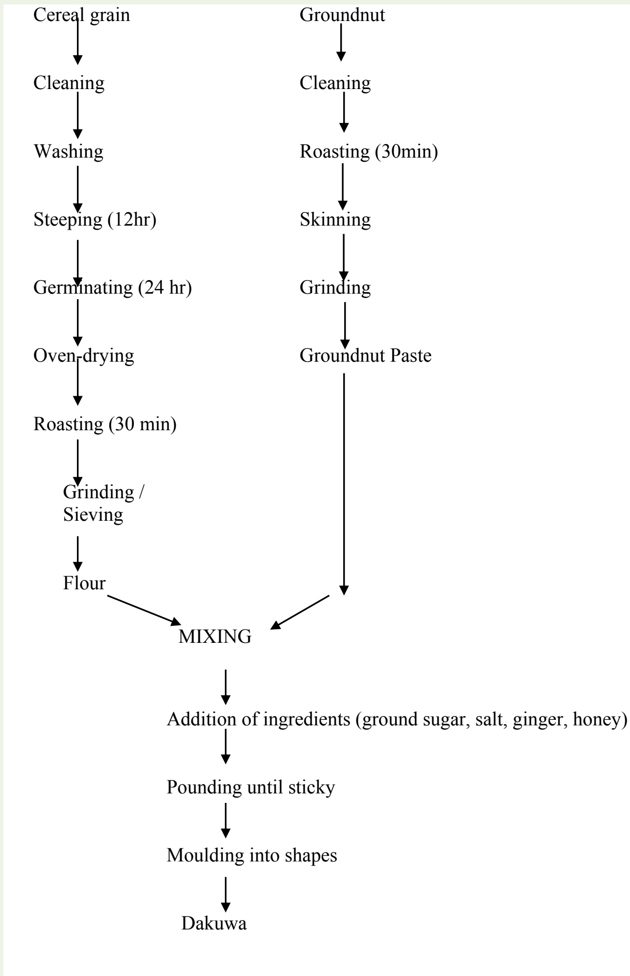

Figure 1: Modified Laboratory Process for the preparation of dakuwa from malted millet and sorghum grains.

mineral was determined by the method described by Khetarpaul & Chauhan [16]. 1 g of sample was extracted with 0.03 N HCl solution for 3 hr at 37 ˚C. The filtrate was dried and the residue reported as the proportion of the total extractable mineral. Total phosphorus was determined spectrophotometrically by method of Osborne and Voogt [17]. The HCl extractable phosphorus was determined by the method reported by Khetarpaul & Chauhan [16].

Soluble protein and *in vitro* protein digestibility

Soluble protein was determined by dissolving 2 g of each sample in 20 ml distilled water at 38 ˚C and filtering. The filtrate was collected, dried in air oven at 100 ˚C for 4 hr and soluble protein content determined by Kjeldahl method [18]. *In vitro* protein digestibility of samples was determined by the procedure described by Oke and Umoh [19]. 1.0 g of defatted meal was suspended in 1.0 ml 0.01 N NH_4Cl and shaken for 48 hr at 35 ˚C. After centrifugation, the residue was re-suspended in 10 ml of distilled water and 10ml of 0.1 N sodium sulphate buffer, pH 8.0 added and then treated with 5 mg of trypsin (Garrad Biological Centre). The mixture was incubated for 16 hr at 35 ˚C and centrifuged at 1000 g. The residue was washed, dried in

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an air oven and analyzed for nitrogen [17]. Percent digestibility was calculated as loss of original nitrogen in the sample after enzymatic digestion.

Soluble sugars

2.5 g of each sample was extracted in 25 ml distilled water at 65 ˚C, cooled and filtered. The filtrate 2 ml was taken into 10 ml volumetric flask and made up to volume with distilled water. The absorbance was read using a spectrophotometer (UNICAM UV2 QUARTZ system) at 280 nm for maltose and fructose, 376 nm for sucrose, and 390 nm for glucose [17].

Sensory evaluation

The hedonic scale was used to assess the degree of acceptability of the modified dakuwa samples in relation to the traditional one using 15 untrained panelists familiar with dakuwa seated in air conditioned individual boots in the sensory evaluation laboratory of the Department of Food Science and Technology, Federal polytechnic, Mubi, Nigeria. Samples molded into cube forms were served in clean plastic plates. The panelists were provided with clean portable water for oral rinsing between samples. They were asked to rate the colour, texture, taste, flavour and overall acceptability of samples. The best sample was ranked 6.0 with descriptive term 'excellent' while the worst sample was ranked 1.0 with descriptive term 'very poor' [20].

Statistical analysis

The statistical analyses were carried out using the analysis of variance procedure of the Statistical Analysis System [21]. Means were separated using Duncan Multiple Range Test (DMRT) method [22].

Results and Discussion

Proximate composition

The proximate composition of dakuwa samples is given in Table 1. There were significant differences ($p \le 0.05$) in the proximate composition of samples with respect to protein, fat, fibre and carbohydrates. Protein ranged from 15.01 to 16.42% and fat 19.87-24.96%. The traditional dakuwa had the highest amount of fat compared to the other samples. The moisture content of samples was low and ranged from 5.93 - 6.36%. Addition of groundnut improved the nutrient composition of the product. The protein content of samples was within the range recommended for high protein food products.

Mineral composition and HCl extractable minerals

The mineral composition of millet flour, sorghum flour, groundnut and dakuwa from them is given in Table 2. There were significant differences ($p \le 0.01$) in the mineral composition of samples. Millet flour had more calcium and copper than sorghum and groundnut flour. Groundnut had more iron and manganese than millet and sorghum flour. The mineral composition of the dakuwa samples followed that of the raw materials used in their preparation. The iron and calcium content of millet, sorghum and groundnut are similar to reported values [23]. Generally mineral composition was low. It is suggested that if dakuwa is to be produced commercially, mineral fortification would be required especially if it is to be used as a supplementary food for the vulnerable groups.

Table 3 shows the effect of germination on the hydrochloric acid (0.03N HCl) extractability of calcium, phosphorus and iron. There was a significant increase ($p \le 0.01$) in the extractability of

Table 1: Proximate composition of dakuwa samples[1,2]

Dakuwa Samples	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Fiber (%)	Carbohydrate %	Energy (Kcal)
Malted millet dakuwa	5.93± 0.58^{a}	16.42± 0.09^{a}	20.62± 0.11^{b}	2.06± 0.08^{a}	3.51± 0.36^{a}	51.46± 0.34^{a}	456.80
Malted sorghum dakuwa	5.99± 0.58^{a}	15.36± 0.07^{b}	20.45± 0.52^{b}	1.92± 0.12^{a}	2.96± 0.05^{b}	53.35± 0.95^{a}	438.90
Unmalted millet dakuwa	6.30± 0.08^{a}	16.37± 0.10^{a}	19.87± 0.21^{b}	1.86± 0.05^{a}	3.33± 0.18^{a}	52.27± 0.21^{a}	453.40
Unmalted sorghum dakuwa	6.35± 0.04^{a}	15.47± 0.12^{b}	20.38± 0.39^{b}	1.92± 0.09^{a}	3.19± 0.16^{a}	52.69± 0.39^{a}	456.10
Traditional dakuwa	6.22± 0.49^{a}	15.09± 0.51^{b}	24.96± 2.93^{a}	1.74± 0.30^{a}	3.15± 0.40^{a}	48.86± 1.50^{b}	480.41

[1]Values are means ± SD of three determinations.
[2]Means in the same column not followed by the same letter are significantly different ($p \le 0.01$).

Table 2: Mineral composition of raw material and dakuwa samples in (mg/100g) [1,2]

Sample	Ca	Cu	Fe	Mn	P
Groundnut	23.11± 0.40^{cd}	3.25± 0.10^{b}	5.11± 0.00^{a}	3.03± 1.06^{a}	223.88± 3.29^{d}
Millet flour	34.39± 0.85^{a}	3.61± 0.21^{a}	2.27± 0.10^{c}	2.63± 0.93^{a}	325.20± 0.00^{a}
Unmalted millet dakuwa	23.13± 0.61^{cd}	2.69± 0.19^{c}	3.44± 0.10^{b}	2.43± 0.61^{a}	275.50± 0.00^{b}
Malted millet dakuwa	23.37± 0.09^{cd}	2.69± 0.12^{c}	2.06± 0.10^{c}	2.02± 0.36^{a}	269.77± 9.93^{c}
Sorghum flour	28.25± 2.44^{b}	3.26±0.12^{b}	2.72± 0.79^{bc}	3.43± 0.35^{a}	225.700.00^{d}
Unmalted sorghum dakuwa	21.52± 0.88^{c}	2.41± 0.12^{cd}	3.94± 0.91^{b}	2.43± 0.61^{a}	183.87± 5.83^{e}
Malted sorghum dakuwa	20.40± 0.21^{c}	2.55± 0.21^{cd}	3.28± 0.25^{bc}	2.62± 0.70^{a}	180.50± 0.00^{e}

[1]Values are means ± SD of three determinations
[2]Means in the same column not followed by the same letter are significantly different ($p \le 0.01$).

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both calcium and iron from the germinated millet and sorghum flours. Germination of pearl millet and sorghum increased calcium extractability from 38.59 to 61.99 % and 26.51 to 61.49 % respectively. Iron extractability increased from 22.03 to 36.56% for millet and 14.34 to 24.63% for sorghum flours. Similarly, phosphorus extractability increased from 28.51 to 43.0 5 % for millet and from 31.02 to 42.09% for sorghum.

These results are similar to values reported by Khetarpaul & Chauhan [16]. The HCl extractability of phosphorus, calcium and iron is indication of their bioavailability to humans [16]. The increases in HCl extractability of calcium, phosphorus and iron may be due to the breakdown of phytates and polyphenols in these cereals by enzymes during germination [8,10]. Nkama & Gbenyi [10] reported phytate reduction of 58 % and 57% respectively for malted dakuwa from sorghum and millet. Also tannin was reduced by 91.4% and 72.1 % respectively in malted millet and sorghum dakuwa. The calcium, phosphorus and iron content of dakuwa samples from germinated millet and sorghum were also observed to double that of the dakuwa from ungerminated ones.

Protein solubility and *in vitro* protein digestibility

Table 4 shows the results of protein solubility and in vitro protein digestibility of raw grain samples, roasted flour and dakuwa samples [23]. There were significant differences in protein solubility and in vitro protein digestibility among samples ($p \leq 0.01$). Roasted groundnut paste had the highest protein solubility of 9.11%, while raw un-germinated sorghum flour gave the least protein solubility (1.66%). The malted sorghum and millet flour and their corresponding dakuwa products showed a significant increase ($p \leq 0.01$) in protein solubility. This may be due to increase in the free amino acids resulting from the germination of the grains.

Table 4 also shows the apparent protein digestibility (*in vitro*) of samples. There were significant differences in apparent protein digestibility ($p \leq 0.01$). Raw sorghum grain flour had the lowest digestibility (38.29%). Hamaker et al. [25] made similar observations. The reason for this low protein digestibility is not very clear. It may however be due to the presence of kiffirins, which are the last proteins to be digested in sorghum flour [25,26] or probably due to the presence of polyphenols, which bind proteins and make them unavailable for digestion [27]. Malted millet dakuwa had the highest apparent protein digestibility (71.47%), while unmalted sorghum dakuwa had the lowest apparent protein digestibility after 16 hr enzyme digestion. Generally, malted cereal based dakuwa samples had higher apparent digestibility values compared to dakuwa from unmalted cereal dakuwa samples. This may be due to the hydrolysis of the anti-nutrients such as phytate and polyphenol during germination

Table 3: Effect of germination and roasting on the percent HCl extractability of divalent cations (minerals) mg/100g [1,2]

Samples	Ca	Percent Extractability	Fe	Percent Extractability	P	Percent Extractability
Millet flour	13.27±0.25[d]	38.59	0.50±0.00[d]	22.03	92.71± 4.26[c]	28.51
Malted millet flour	21.32± 0.25[a]	61.99	0.83±0.00[b]	36.56	140.00±0.00[a]	43.05
Unmalted millet dakuwa	7.49± 0.65[e]	32.38	0.61±0.10[c]	17.73	107.50±0.00[b]	39.02
Malted millet dakuwa	14.83± 0.00[c]	63.45	0.89±0.10[b]	43.20	147.27±3.93[a]	54.59
Sorghum flour	7.49± 0.65[e]	26.51	0.39±0.10[e]	14.34	70.00± 0.00[e]	31.02
Malted sorghum Flour	17.37± 0.42[b]	61.49	0.67±0.00[c]	24.63	95.00± 0.00[c]	42.09
Unmalted sorghum dakuwa	6.78± 0.42[e]	31.51	0.61±0.10[c]	15.48	80.00± 7.45[d]	43.51
Malted sorghum dakuwa	12.71± 0.85[d]	62.30	1.11±0.10[a]	33.84	112.33±6.84[b]	62.23

[1]Values are means ± SD of three determinations
[2]Means in the same column not followed by the same letter are significantly different ($p \leq 0.01$).

Table 4: Apparent protein digestibility of cereal flours and dakuwa samples (units/g) [1,2]

Samples	Protein solubility (%)	Protein digestibility (%)
Groundnut (roasted)	9.1±0.45[a]	89.79± 0.46[a]
Millet flour	1.87±0.07[f]	50.40± 3.40[f]
Sorghum flour	1.56±0.06[f]	38.29± 0.63[g]
Malted millet flour	2.88±0.27[d]	69.63± 0.38[b]
Malted Sorghum flour	2.10±0.10[e]	61.76± 0.20[d]
Unmalted sorghum dakuwa	6.43±0.24[b]	64.17± 0.80[c]
Unmalted millet dakuwa	5.33±0.07[c]	56.44± 0.20[e]
Malted millet dakuwa	6.76±0.37[b]	71.47± 0.40[b]
Malted sorghum dakuwa	6.48±0.17[b]	65.09± 0.21[d]

[1] Values are means ± SD of three determinations
[2]Means in the same column not followed by the same letter are significantly different ($p \leq 0.01$).

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Table 5: Soluble sugar content of various flours and dakuwa samples (mg/ 100g) [1,2]

Samples	Maltose	Fructose	Glucose	Sucrose
Unmalted sorghum flour	452.67±3.41[d]	393.67±0.58[h]	133.67±5.77[g]	142.67±4.51[g]
Unmalted sorghum dakuwa	498.67±0.58[c]	602.67±9.00[d]	270.00±0.00[e]	418.00±0.00[d]
Malted sorghum flour	741.67±6.10[b]	455.00±0.00[g]	343.00±0.00[c]	339.67±2.89[e]
Malted sorghum dakuwa	744.50±1.00[b]	661.33±0.58[b]	394.00±0.00[a]	752.33±1.15[a]
Unmalted millet flour	490.00±2.31[c]	495.00±1.73[f]	189.67±18.48[f]	259.00±2.65[f]
Unmalted millet dakuwa	494.00±0.00[c]	650.67±0.58[c]	306.33±4.51[d]	447.00±0.00[c]
Malted millet flour	833.33±1.15[a]	597.33±2.89[e]	330.33±10.97[c]	416.00±0.00[d]
Malted millet dakuwa	835.67±0.58[a]	751.67±0.58[a]	351.67±7.51[b]	712.00±1.00[b]

[1]Values are means ± SD of three determinations.
[2]Means in the same column not followed by the same letter are significantly different ($p \le 0.01$). Table 6: Sensory evaluation results for dakuwa samples[1,2]

Table 6: Sensory evaluation results for dakuwa samples[1,2]

Samples	Colour	Texture	Taste	Flavour	Overall Acceptability
Malted millet dakuwa	3.00±1.94[b]	4.70±1.06[a]	4.00±0.94[a]	4.30±1.06[a]	3.11±1.17[bcd]
Unmalted millet dakuwa	3.50±0.71[b]	4.20±1.03[a]	4.50±0.85[a]	4.30±0.82[a]	3.56±1.42[bc]
Malted sorghum dakuwa	4.20±1.23[ab]	5.00±0.00[a]	4.80±1.03[a]	4.30±1.03[a]	3.80±1.13[bc]
Unmalted sorghum dakuwa	4.90±0.73[ab]	4.50±0.00[a]	4.80±1.03[a]	4.70±0.92[a]	5.11±0.78[a]
Traditional dakuwa	5.10±.1.20[ab]	5.20±0.92[a]	4.11±1.27[a]	4.92±1.16[a]	4.89±1.27[b]

NS = not significant
[2]Means in the same column not followed by the same letter are significantly different ($p \le 0.01$).

[25,27]. Nkama and Gbenyi (10) reported a significant degradation of phytates (57-58%) and polyphenol (72-91%) in dakuwa produced from malted millet and malted sorghum.

Soluble sugars

There was significant increase ($p \le 0.01$) in the concentration of all sugars in the germinated sorghum and millet and the dakuwa produced from them (Table 5). These increases may be due to diastatic activity caused by germination of the grains. Subramanian et al. [28] and Khetarpaul and Chauhan [25] also reported significant increases in diastatic activity and *in vitro* starch digestibility when sorghum and millet grains were respectively germinated. Maltose increased by 71% in malted millet based dakuwa and 64 % in the malted sorghum based one. Also fructose increased by 52% in malted millet based dakuwa and 68% in malted sorghum based dakuwa [28].

Sensory properties

The results of the sensory properties of the malted and traditional dakuwa samples are given in Table 6. There were no significant differences among samples in terms of texture and flavor. There were however significantly differences ($p \le 0.01$) in overall acceptability and colour. Unmalted sorghum dakuwa had the highest rating, followed by the traditional dakuwa, and then malted sorghum dakuwa. The malted millet dakuwa was rated lowest in overall acceptability. No sample was rated as 'poor' or "very poor". The reason for the low overall acceptability of millet based dakuwa may be due to the fact that the sensory evaluation was conducted in a location (Adamawa State) in Nigeria where sorghum is the most popular cereal and the red sorghum is the most preferred for the production of dakuwa.

Conclusion

The study has revealed that an acceptable dakuwa with increased protein digestibility, soluble sugars and mineral availability can be produced from malted pearl millet and sorghum. Efforts should be directed along this line in attempt to commercialize the product. The storage and packaging studies of dakuwa should be investigated as effort is geared to popularize it in the country. Since one of the major ingredients groundnut is associated with mycotoxins effort should be made to screen groundnuts used for dakuwa production.

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