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Quality characteristics of bread and cookies enriched with debittered *Moringa oleifera* seed flour

B. S. OGUNSINA[1], C. RADHA[2], & D. INDRANI[3]

[1]*United Nations University, Advanced Centre for Food Science and Technology,* [2]*Department of Protein Chemistry and Technology, and* [3]*Department of Flour Milling, Baking and Confectionery Technology, Central Food Technological Research Institute (Council for Scientific and Industrial Research), Mysore, India*

Abstract
The effects of replacing wheat flour with 0–15% debittered moringa seed (DBMS) flour on the dough rheology of wheat flour and physical, sensory and chemical properties of bread were studied. Incorporation of an increasing amount of DBMS from 0 to 15% decreased farinograph water absorption, dough stability, amylograph peak viscosity and overall quality of bread. The bread with 10% DBMS had a typical moringa seed taste and was acceptable. Addition of combination of additives improved the dough strength and quality of bread with 10% DBMS flour. Replacement of wheat flour with 10%, 20% and 30% DBMS grits was found to affect cookies quality. Cookies with 20% DBMS grits had the nutty taste of moringa seeds and were acceptable. Bread with 10% DBMS flour and cookies with 20% DBMS grits had more protein, iron and calcium. Incorporating moringa seeds in baked foods may be exploited as a means of boosting nutrition in Africa and Asia where malnutrition is prevalent.

Keywords: *Debittered moringa seeds, bread, cookies, rheological, sensory and nutritional properties*

Introduction

The use of vegetable proteins, especially from under-utilized or neglected oil seeds and legumes, as enrichment for ready-to-eat snack foods has been identified as a viable alternative for raising the nutritional level of teeming millions in different parts of the world (Kinsella 1976). This is due to widespread shortage of animal proteins and malnutrition occasioned by a high population growth rate and poverty (Enujiugha and Ayodele-Oni 2003). Baked snack foods such as bread and cookies are widely consumed in every part of the world and have become an attractive target for feeding and nutrition improvement programs among low-income groups and disaster relief agencies (Claughton and Pearce 1989). The most popular approach is replacing a portion of wheat flour with non-wheat flours sourced from these oil seeds and legumes. Several previous studies have considered the replacement of wheat dough with oilseed, legume or non-wheat cereals flour in baked foods (Chavan and Kadam 1993). Soybean, peanut, hazel nut, cowpea, cashew nut, almonds and sesame are few among the non-wheat flours on which such works have been carried out (Alobo 2001, Doxastakis et al. 2002, Ribotta et al. 2005, Anil 2007, Gómez et al. 2008) but no such investigation have been reported on moringa seeds.

Drumstick or horseradish (*Moringa oleifera Lam.*), hereafter simply referred to as moringa, has been an important traditional vegetable tree in India for ages (Al-Kahtani and Abou-Arab 1993). The fresh leaves, the flowers and tender immature pods are cooked and eaten as curries (The Wealth of India 1985), especially due to its substantial composition of protein, β-carotene, iron, calcium, potassium and some essential amino acids (Foidl et al. 2001). A mature pod is about 1.8 cm thick and 30–120 cm in length. When dry, it splits lengthwise along three lobed portions; discharging 12–35 dark brown, three-winged whole seeds each embedding a single cream-colored kernel almost the

Correspondence: B. S. Ogunsina, United Nations University, Advanced Centre for Food Science and Technology, Central Food Technological Research Institute (Council for Scientific and Industrial Research), Mysore 570 020, India. Tel: 234 8059881048.
E-mail: bsogunsina@yahoo.com

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size of peanut (Morton 1991, Sabale et al. 2006). Moringa seeds, although slightly bitter and astringent, are used for food seasoning or eaten as roasted nuts in some places (Al-Kahtani and Abou-Arab 1993). The widest known use of powdered moringa seeds as natural flocculent for purifying water has been well documented (Sutherland et al. 1994, Muyibi and Okufu 1995, Ndbigengesere and Narasiah 1998, Okuda et al. 1999, Katayon et al. 2006); but it has also been found to contain 36.18, 43.58, 3.73 and 16.51 g protein, fat, ash, carbohydrate per 100 g sample, respectively (Ogunsina et al. 2010). Tannins, trypsin and amylase inhibitors were not detected in moringa seeds, but saponins, phenols, phytate levels were present up to 1.1%, 0.02% and 2.6% respectively; cyanogenic glucosides and glucosinolates were also present up to 5.2 mg HCN equivalent/kg and 46.4 μmol/g (Foidl et al. 2001). However, Makkar and Bekker (1997) reported that cyanogenic glucoside levels in moringa seeds are much lower than those considered safe by European Commission regulations. Although it is generally accepted that consumption of high levels of glucosinolates is undesirable in human and livestock foods, minimal levels of certain glucosinolates do influence the desirable flavor and aroma of some foods. Previous works on this have established that moringa seeds when fed to rats showed no apparent toxic effects (Barth et al. 1982, Berger et al. 1984).

Nutraceutical application of moringa leaves as a nutrition supplement for malnourished infants and nursing mothers in some parts of the world has been documented (D'souza and Khulkarni 1993, Folkard et al. 1993), but utilization of moringa seeds as a source of vegetable protein is seldom found in the literature. Therefore, the present study investigates the effect of partial replacement of wheat flour with debittered moringa seeds (DBMS) on the dough rheology of wheat flour and on some physical, sensory and chemical properties of bread and cookies. This is with the view to extend the use of moringa seeds as a source of protein and minerals in baked food products.

Materials and methods

Wheat flour

Commercial wheat flour obtained from the local market in Mysore, India was used for the studies. The characteristics of the wheat flour such as moisture (American Association of Cereal Chemists [AACC] 04-16), dry gluten (AACC 38-10), falling number (AACC 56-81B) and Zeleny's sedimentation value (AACC 56-61A) were determined using American Association of Cereal Chemists (1995) methods.

Debittered moringa seeds

Bulk quantities of dry *M. oleifera* seeds (DBMS) procured from a local market in Mysore, India were used for this investigation. The seeds were dehulled and about 2 kg from the bulk was debittered by ordinary boiling in clean water for 35 min using a 1:30 w/v ratio. The gruel was decanted and the debittered seeds were oven-dried at 80°C for 8 h (Ogunsina and Radha 2010). A half-portion of the debittered seeds was milled to 140 μm particle size (Hammer mill model No. 79952, Type 120; Falling Number AB, Huddinge, Sweden).

Chemical analysis of wheat and debittered moringa seed flours

Chemical characteristics of wheat and DBMS flours including the moisture content, crude fat, ash, crude protein, crude fiber (AOAC 2000), iron and calcium (Raghuramulu et al. 1983) were determined.

Preparation of blends and rheological characteristics

Blends were prepared using a mixture of wheat and DBMS flours in the ratios of 100/0, 95/5, 95/10 and 85/15 w/w. The effect of 5%, 10% and 15% DBMS on farinograph characteristics (Brabender Measurements and Control Systems, Model No. 810108004, Duisburg, Germany) and Micro-Visco amylograph (Brabender Measurements and Control Systems, Model No. 803201, Duisburg, Germany) of wheat flour was studied following standard AACC (1995) methods.

Bread preparation and evaluation

Formulation for control bread consisted of 100 g wheat flour, 62.5 ml water, 1 g salt, 2.0 g yeast, 2.5 g sugar and 1.0 g fat. Bread dough was prepared using a Hobart mixer (Model N-50; Hobart, GmbH, Offenburg, Germany) with a flat blade for 3 min at 61 rpm. The dough was fermented at 30°C and 75% relative humidity for 90 min in an enclosed chamber, remixed, hand-rounded, and again fermented for 25 min, molded and proofed for 55 min at 30°C, 85% relative humidity and baked for 25 min at 220°C, cooled to room temperature and packed ready for evaluation.

Preliminary bread baking studies with moringa seeds were carried out by replacing wheat flour with 10% each of raw moringa seeds (RMS), defatted moringa seeds (DFMS) and DBMS flours having a particle size of 140 μm. These were evaluated for sensory attributes in comparison with the control using a quantitative descriptive analysis technique. Specific attributes were identified and the intensity of each descriptor was quantified on the structured scale. Sensory attributes consisting crust color (10), shape (15) and symmetry (15), crumb color (10), grain (20), mouth feel (20) and taste (10) were assessed by a group of panelists suitably trained and oriented towards the sensory technique of the product to be evaluated. The sum of the listed sensory attributes (100), taken as the total sensory score, was used to measure overall acceptability of bread samples. Crumb firmness was measured at 25% compression using

2-mm-thick samples of bread on a Texture Analyzer (Model Tahdi; Stable Microsystems, Godalming, Surrey, UK) having 10 kg load cell, 36 mm plunger diameter and 100 mm/min plunger speed. Further bread baking experiment was carried out using different levels of wheat flour/DBMS flour blends 100/0, 95/5, 90/10 and 85/15 (w/w).

The wheat flour/DBMS flour blend 90/10 (w/w) was repeated with the addition of a combination of additives (CA) consisting of 3% of dry gluten powder, 200 ppm ascorbic acid and 0.5% sodium stearoyl-2-lactylate, because at DBMS flour levels above 10% the crust shape, crumb grain and texture of bread were adversely affected. The physical properties, sensory attributes and proximate composition of all bread samples were analyzed. Values reported are averages of four determinations.

Cookie preparation and evaluation

RMS and DBMS were reduced to grits having particle size of 300 μm. In another experiment, DBMS were reduced to different particle sizes of about 140 μm, 400 μm and 800 μm.

The ingredients used for the studies were commercially available sugar powder, skimmed milk powder (Gujarat Co-operative Milk Marketing Federation Ltd, Anand, India), sodium chloride (Merck Co., Mumbai, India), shortening (Marvo, Hindustan Lever Ltd, Mumbai, India), sodium and ammonium bicarbonate (S.D. Fine Chemicals, Mumbai, India). The cookie formulation consisted of 100 g wheat flour, 60 g sugar powder, 30 g shortening (Marvo), 3 g skimmed milk powder, 1.0 g sodium bicarbonate, 0.75 g ammonium bicarbonate, 1.0 g sodium chloride and water according to requirement. Cookies were prepared according to AACC micro method No. 10–52 (AACC 1995). The cookie dough was sheeted to a thickness of 0.5 cm and cut using a 6.5 cm diameter cutter. The cookies were baked at 200°C and allowed to cool to room temperature. Cookies were prepared a day ahead of evaluation of physical characteristics (diameter, thickness and spread ratio) and sensory properties. The breaking strength was measured using the triple-beam snap technique of Gaines (1991) using an 'Instron' Universal Testing machine (Model No. 4301, Instron Ltd., Canton, Mass, USA) at a crosshead speed of 50 mm/min and load cell of 250 kg. The force required to break a single cookie was recorded and the average value of four replicates is reported. The surface color of the cookie samples with DBMS grits (140, 400 and 800 μm) were measured with the Hunter Lab color measuring system (Model Labscan XE; Hunter Associates Laboratory Inc., Reston, Virginia, USA). Approximately 100 g sample was placed in a small glass bowl with a glass cover in order to provide uniform flat surface. Measured values were expressed as L, a, b and ΔE (colour units) and the L, a and b values of a white standard tile used as a reference were 91.0, −1.0 and −1.7, respectively. Sensory properties were assessed by a group of suitably trained panelists. At the time of evaluation, cookies were placed in small saucers labeled with three-digit random codes and panelists were provided with distilled water to clean their mouth between samples. The cookie samples were presented in random order and panelists were asked to assign scores for various quality parameters, namely surface color (10), surface cracking pattern (15), crumb color (10), texture (15), mouthfeel (10) and flavor (10). The sum of these six quality attributes (70) was taken as the total sensory score and was used to measure the overall acceptability of the cookie samples. Each score was an average of four determinations.

Preliminary investigation was carried out with 10% topping of cookies with RMS and DBMS grits (300 μm particle sizes). These two samples were evaluated for sensory attributes in comparison with the control using quantitative descriptive analysis profiling. Further study was carried out with 10% blend of DBMS (with different particle sizes of about 140, 400 and 800 μm) because the bitter and undesirable taste of the sample with RMS was unacceptable by the panelists, and the presence of RMS affected the surface cracking pattern of the cookies adversely; cracks were very tiny and there was no island formation. From the sensory attributes of the samples, the blend with 800 μm DBMS particles compared favorably with the control in terms of overall quality and acceptability. Consequently, DBMS reduced to 800 μm particle sizes were used for cookies at 0%, 10%, 20%, and 30% levels.

Chemical analysis of bread and cookies

Bread (control, 5%, 10%, 15% and 10% DBMS powder + CA) and cookies (control 10%, 20% and 30% DBMS grits) samples were analyzed for moisture content, crude fat, ash, crude protein, carbohydrate (AOAC 2000), iron and calcium (Raghuramulu et al. 1983).

Statistical analysis of data

Data are presented as the mean of three determinations ± standard deviation. Data were subjected to analysis of variance and means were separated using Duncan multiple-range tests (Statistics Analytical Software, SAS Institute Inc., Cary, North Carolina, USA, 2002).

Results and discussion

Chemical composition of wheat and debittered moringa seed flours

The wheat flour used for studies had 10.1% dry gluten, 19 ml Zeleny's sedimentation value and 450 sec falling number. These results show that the wheat flour is of medium strong quality. The data presented in Table I show that DBMS flour is rich in protein, fat, fiber and minerals.

Table I. Chemical composition of wheat and DBMS flours.

Component	Composition (g/100 g)	
	Wheat flour	DBMS
Protein	11.2 ± 0.1	32.68 ± 0.2
Total ash	0.5 ± 0.01	3.52 ± 0.02
Fat	0.9 ± 0.01	33.5 ± 0.3
Crude fiber	0.3 ± 0.0	4.5 ± 0.1
Iron (mg/100 g)	2.7 ± 0.1	19.8 ± 0.2
Calcium (mg/100 g)	23.0 ± 0.2	88.4 ± 0.4

Data presented as mean ± standard deviation of triplicate analysis. Values expressed on a dry basis.

Table II. Preliminary studies on the effect of RMS, DFMS and DBMS powder on the physical and sensory parameters of bread.

Parameter	Control	RMS	DFMS	DBMS	SEM
Physical					
Volume (ml)	555^{B}	440^{A}	425^{A}	445^{A}	5.5
Specific volume (ml/g)	3.8^{B}	3.0^{A}	2.9^{A}	3.1^{A}	0.05
Crumb firmness (force, g)	450^{A}	$1,660^{B}$	$1,655^{B}$	$1,653^{B}$	8.5
Sensory properties					
Crust					
Color (10)	8.0^{A}	8.0^{A}	8.0^{A}	8.0^{A}	0.2
Shape (15)	13.0^{B}	8.0^{A}	7.0^{A}	8.0^{A}	0.3
Symmetry (15)	12.0^{B}	6.0^{A}	6.0^{A}	6.0^{A}	0.4
Crumb					
Color (10)	8.0^{B}	5.5^{A}	6.0^{A}	5.5^{A}	0.3
Grain (20)	17.0^{B}	13.0^{A}	13.5^{A}	13.0^{A}	0.5
Mouth feel (20)	17.0^{C}	13.0^{A}	14.0^{B}	14.0^{B}	0.2
Taste (10)	8.0^{D}	1.0^{A}	2.0^{B}	6.5^{C}	0.2
Total sensory score (100)	83.0^{D}	54.5^{A}	56.5^{B}	61.0^{C}	0.35

Data in the same row followed by different uppercase superscript letters differ significantly ($P \leq 0.05$). SEM, standard error of the mean.

Preliminary studies on the effect of raw, defatted and debittered moringa seed flours on the quality of bread

The results of the preliminary baking trials carried out on replacing wheat flour with 10% of RMS, DFMS and DBMS flours on the quality of bread are presented in Table II. It was observed that bread baking characteristics of the samples (i.e. crust color, crust shape, crumb color, crumb grain and texture) compared favorably with that of the control. However, the taste of samples differed significant ($P \leq 0.05$). The sample with DBMS flour was acceptable whereas samples with DFMS and RMS flour were bitter and unacceptable. The overall quality showed that the bread sample with DBMS had better acceptability. The bitter and astringent taste of moringa seeds may be responsible for the bitterness of the unacceptable products. Bitterness does affect consumers' attitude and sensitivity towards food. However, it suffices to state that the nutraceutical implication of bitter principles in some foods take bitterness in food products beyond anti-nutritional factors (Ogunsina and Radha 2010), although this is not the focus in the present study.

Effect of debittered moringa seed flour on the rheological properties of dough

The rheological characteristics of wheat flour replaced with 0%, 5%, 10% and 15% of DBMS flour are presented in Table III. Use of increasing amount of DBMS flour from 0 to 15% increased mixing tolerance of the blends but a decrease was observed with water absorption, dough development time, and dough stability. This indicates a decrease in water binding properties and strength of the dough. The decrease in the strength of the dough with the addition DBMS is due to dilution of gluten. A similar strength decreasing effect with addition of protein rich flours from defatted peanut, soyabean and field pea have been reported by Mcwatters (1978). However, with the addition of combination of 3% dry gluten powder +200 ppm ascorbic acid +0.5% sodium stearoyl-2-lactylate (CA), the stability of the dough with 10% of DBMS flour increased from 4 to 9.5 min, which compared favorably with the control. The micro-visco-amylograph characteristics showed that gelatinization temperatures of 10% and 15% DBMS premixes were higher than the control (Figure 1a), and with CA (Figure 1b) no significant difference was observed. However, addition of increasing amount of DBMS decreased peak viscosity, cold paste viscosity, breakdown and set back. The decrease in the above parameters could be due to decrease in the available starch for gelatinization. According to Gómez et al. (2008), use of chickpea flour decreased peak viscosity, break down and set-back due to its decreased carbohydrate content and different protein content affecting the viscosity parameters. Excellent baking stability had earlier been reported for breads fortified with vitamins and mineral supplements and no off-flavor was observed. The micro-visco amylograph

Table III. Effect of DBMS powder on the rheological characteristics of wheat flour.

Parameter	DBMS flour				
	0%	5%	10%	15%	10% DBMS flour + CA
Water absorption (%)	62.8	59.6	57.8	56.6	57.8
Dough development time (min)	6.0	6.0	4.5	4.0	5.5
Stability (min)	10.0	5.5	4.0	3.75	9.5
Mixing tolerance index (BU)	60.0	80.0	80.0	80.0	60.0

Data are mean of two replicates. CA: 3.0% dry gluten powder +200 ppm ascorbic acid +0.5% sodium stearoyl-2-lactylate.

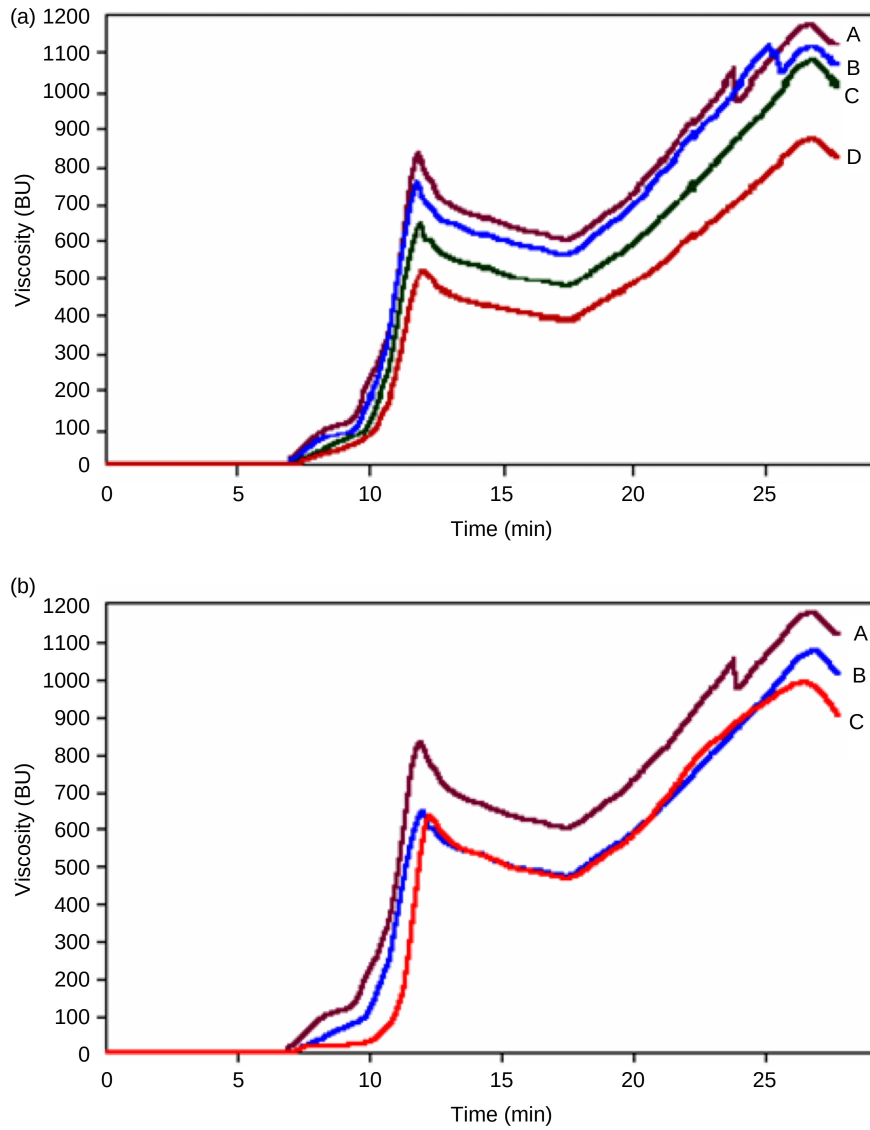

Figure 1. (a) Effect of different levels of DBMS flour on the amylograph characteristics of wheat flour: A, control; B, 5% DBMS flour; C, 10% DBMS flour and D, 15% DBMS flour. (b) Effect of combination additives to 10% DBMS flour on the amylograph characteristics of wheat flour: A, control; B, 10% DBMS flour and C, 10% DBMS flour + CA.

Table IV. Effect of different levels of DBMS powder on the physical and sensory parameters of bread.

	DBMS					
Parameter	0%	5%	10%	15%	10% DBMS + CA	SEM
Physical properties						
Volume (ml)	555^{D}	515^{C}	460^{B}	440^{A}	$575^{D,E}$	4.5
Specific volume (ml/g)	3.8^{C}	3.5^{B}	3.1^{A}	3.0^{A}	$3.9^{C,D}$	0.04
Crumb firmness or texture (g)	450^{B}	$1{,}315^{C}$	$1{,}650^{D}$	$2{,}285^{E}$	420^{A}	5.5
Sensory properties						
Crust						
Color (10)	8.0^{B}	8.0^{B}	8.0^{B}	6.0^{A}	8.0^{B}	0.25
Shape (15)	13.0^{C}	9.0^{B}	8.0^{B}	5.0^{A}	14.0^{C}	0.45
Symmetry (15)	12.0^{D}	9.0^{C}	6.0^{B}	3.0^{A}	13.0^{D}	0.45
Crumb						
Color (10)	8.0^{C}	6.5^{B}	5.5^{B}	3.0^{A}	7.0^{B}	0.20
Grain (20)	17.0^{D}	15.0^{C}	13.0^{B}	8.0^{A}	16.5^{D}	0.40
Mouth feel (20)	17.0^{D}	16.0^{C}	14.0^{B}	11.0^{A}	18.0^{D}	0.45
Taste (10)	8.0^{C}	7.0^{B}	6.5^{B}	5.0^{A}	8.5^{C}	0.15
Total sensory score (100)	83.0^{D}	70.5^{C}	61.0^{B}	41.0^{A}	85.0^{D}	2.0

Data in the same row followed by different uppercase superscript letters differ significantly ($P \leq 0.05$). SEM, standard error of the mean.

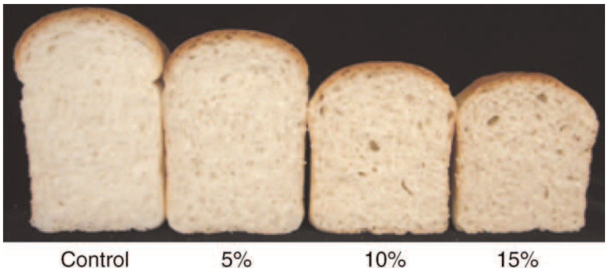

Figure 2. Photograph of breads with different levels of DBMS flour.

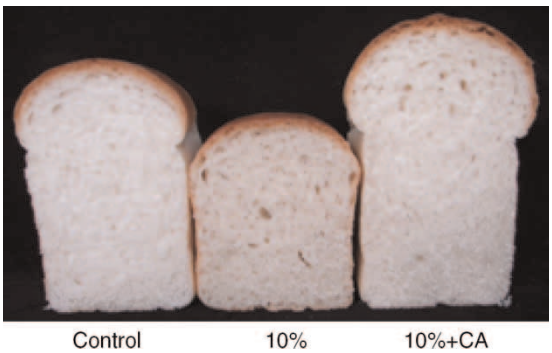

Figure 3. Photograph of bread with 10% DBMS flour and combination of additives (CA).

characteristics of premix showed that gelatinization temperature, peak viscosity and cold paste increased with the addition of vitamins and mineral (Sudha and Leelavathi 2008). Recently, natural plant products have received much attention as sources of protein, fiber, minerals, β-carotene and antioxidants to enrich bakery products. Reddy et al. (2005) utilized three plant foods, namely amla (*Emblica officinalis*), drumstick leaves (*M. oleifera*) and raisins (*Vitis vinifera*), as a source of natural antioxidants in biscuits.

Effect of different levels of debittered moringa seed flour on physical and sensory properties of bread

Table IV presents the effect of 0%, 5%, 10%, 15% DBMS flour and 10% DBMS flour plus CA on the quality of bread. It was observed that addition of increasing amount of DBMS from 0 to 15% had a significant ($P \leq 0.05$) effect on bread volume (Figure 2). The volume decreased from 555 to 440 ml and crumb firmness value increased from 450 to 2,285 g, indicating the adverse effect of DBMS on the volume and texture of bread. At DBMS levels above 5%, the breads showed tendency to collapse and above 10% conspicuous pinholes were noticeable. Symmetry of breads reduced as DBMS levels increased and the crumb color changed progressively from cream to dull cream and later brown. When DBMS flour was above 5%, the crumb grain became dense, with thick cell walls; however, the mouth feel and taste were within acceptable range up to 10% level. Addition of CA to the sample with 10% DBMS improved the volume, texture, crust and crumb characteristics of bread (Figure 3). The physical and sensory properties of the bread sample (i.e. crust shape, crumb color, crumb grain and texture) compared favorably with the control. Chemical improvers have been used for decades in bread-baking as a way of adjusting variations in flour properties and baking conditions (Caballero et al. 2007). Skrbic and Filipcev (2008) reported that sunflower seed could be added to bread up to 16% level without significant adverse effects regarding crust color, crumb grain structure and uniformity. They also found that sunflower seed-supplemented breads contained significantly more tocopherols, essential fatty acids, copper, zinc, fat and crude fiber.

Chemical composition of bread

The chemical composition of bread is resented in Table V. It was observed that a bread sample with 15% DBMS flour had more protein, fat, iron and calcium than the one with 10% DBMS flour plus CA, although the physical properties and sensory attributes presents 10% plus CA as a more acceptable product. At the 10% level of DBMS, no significant difference was observed between the protein, fat, iron and calcium content of samples with and without CA.

Effect of raw and debittered moringa seed grit topping on the physical and sensory properties of cookies

Table VI presents results on the effect of replacing wheat flour with 10% RMS and DBMS as a topping

Table V. Effect of different levels of DBMS powder on the chemical parameters of bread.

	DBMS				
Composition (g/100 g)	0%	5%	10%	15%	10% DBMS + CA
Moisture content	36.24 ± 0.03^{A}	34.59 ± 0.06^{B}	34.5 ± 0.06^{B}	33.00 ± 0.06^{B}	35.48 ± 0.06^{A}
Protein	8.24 ± 0.03^{A}	9.86 ± 0.1^{B}	12.11 ± 0.02^{C}	13.74 ± 0.02^{B}	12.12 ± 0.02^{C}
Ash	1.16 ± 0.04^{A}	2.14 ± 0.02^{B}	2.46 ± 0.02^{C}	2.65 ± 0.02^{D}	2.39 ± 0.02^{C}
Fat	0.87 ± 0.08^{D}	2.54 ± 0.04^{C}	4.39 ± 0.04^{B}	6.21 ± 0.04^{A}	3.98 ± 0.04^{B}
Carbohydrate	52.49 ± 0.07^{A}	50.87 ± 0.06^{A}	46.54 ± 0.07^{B}	44.4 ± 0.05^{C}	46.03 ± 0.07^{B}
Iron (mg/100 g)	2.72 ± 0.1^{A}	3.53 ± 0.09^{B}	4.21 ± 0.02^{C}	5.43 ± 0.1^{D}	4.36 ± 0.06^{C}
Calcium (mg/100 g)	23.01 ± 0.24^{A}	27.17 ± 0.47^{B}	31.45 ± 0.48^{C}	35.84 ± 0.37^{D}	32.01 ± 0.19^{C}

Data presented as mean ± standard deviation of triplicate analysis. Means with the same uppercase superscript letters on same row are significantly different. CA: 3.0% dry gluten powder + 200 ppm ascorbic acid + 0.5% sodium stearoyl-2-lactylate.

Table VI. Effect of addition of 10% grits of RMS and DBMS on the physical and sensory parameters of cookies.

Parameter	Control	RMS	DBMS	SEM
Physical properties				
Diameter (mm)	86.5^{A}	87.0^{A}	87.0^{A}	4.5
Thickness (mm)	11.5^{A}	11.5^{A}	11.5^{A}	0.05
Spread ratio (D/T)	7.5^{A}	7.6^{A}	7.6^{A}	0.05
Breaking strength (g)	4,965^{A}	6,681^{BC}	6,605^{B}	5.5
Sensory properties				
Surface color (10)	9.0^{B}	7.0^{A}	7.0^{A}	0.25
Surface cracking pattern (15)	13.0^{B}	8.0^{A}	8.0^{A}	0.30
Crumb color (10)	9.0^{B}	8.0^{A}	8.0^{A}	0.25
Texture (15)	14.0^{B}	10.0^{A}	11.0^{A}	0.20
Mouthfeel (10)	8.0^{C}	3.0^{A}	6.0^{B}	0.20
Flavor (10)	8. 0^{B}	5.0^{A}	6.0^{A}	0.40
Total sensory score (70)	61.0^{C}	41.0^{A}	46.0^{B}	0.45

Data in the same row followed by different uppercase superscript letters differ significantly ($P \leq 0.05$). SEM, standard error of the mean.

Figure 4. Effect of RMS grits and DBMS grits (300 μm) on the surface cracking pattern of cookies.

on the quality of cookies. It was observed that RMS and DBMS toppings showed acceptable physical characteristics of cookies but the surface cracking pattern was adversely affected (Figure 4). The cracks were very tiny and without noticeable islands. Both cookie samples showed similar textural, crust and crumb characteristics but the samples with RMS topping tasted bitter and were rated as unacceptable by the panelists. Surface cracking pattern is an important feature of cookies. Jacob and Leelavathi (2007) explained that during baking the sugar on the surface of the cookie crystallizes, causing the surface to dry rapidly, and as the cookie spreads the dry surface cracks. In this study, it can be reasoned that as crystallization took place the moringa seed grit topping sat in-between surface cracks, thereby affecting the pattern and preventing formation of islands. This may be attributed to the fact the grits were not blended in the dough.

Figure 5. Effect of different particle size of DBMS grits on the surface cracking pattern of cookies.

Effect of particle size of debittered moringa seed grits on the physical and sensory properties of cookies

The effect of particle sizes of DBMS on the quality of cookies is presented in Table VII. It was observed that a sample with 10% DBMS (800 μm particle size) compared favorably with the control in terms of total sensory scores, 55 for the former and 61 for the latter. Surface cracking pattern showed big islands and crumb color that were similar to the control (Figure 5), whereas this was hardly noticeable in samples with fine and coarse particles (*i*.e. 140 and 400 μm DBMS, respectively). The panelists also observed that with 800 μ. particle size, the cookie was crisp, nutty and left no residue in the mouth.

The Hunter color values of the control cookie were also not significantly different from the cookies having 800 μm DBMS (Table VIII). They both were lighter

Table VII. Effect of particle size of DBMS grits on the physical and sensory parameters of cookies.

		DBMS (10%)			
Parameter	Control	Fine (140 μm)	Coarse (400 μm)	Grits (800 μm)	SEM
Physical properties					
Diameter (mm)	86.5^{C}	61.5^{A}	78.0^{B}	89.5^{C}	5.5
Thickness (mm)	11.5^{A}	12.5^{B}	11.5^{A}	11.0^{A}	0.04
Spread ratio (D/T)	7.5^{C}	4.9^{A}	6.8^{B}	8.1^{D}	0.03
Breaking strength (g)	4,963^{A}	7,886^{C}	6,564^{B}	4,940^{A}	5.0
Sensory properties					
Surface color (10)	9.0^{C}	7.0^{A}	7.0^{A}	8.0^{B}	0.20
Surface cracking pattern (15)	13.0^{D}	6.0^{A}	9.0^{B}	11.5^{C}	0.25
Crumb color (10)	9.0^{C}	6.0^{A}	7.5^{B}	8.0^{B}	0.20
Texture (15)	14.0^{D}	9.0^{A}	10.5^{B}	12.5^{C}	0.25
Mouthfeel (10)	8.0^{C}	6.5^{A}	7.5^{B}	7.5^{B}	0.30
Flavor (10)	8.0^{C}	6.0^{A}	6.0^{A}	7.5^{B}	0.25
Total sensory score (70)	61.0^{D}	40.5^{A}	47.5^{B}	55.0^{C}	0.50

Data in the same row followed by different uppercase superscript letters differ significantly ($P \leq 0.05$). SEM, standard error of the mean.

Table VIII. Effect of particle size of DBMS on the crust surface color of cookies.

Color parameter	Control	Fine (140 μm)	Coarse (400 μm)	Grits (800 μm)
L	60.43^{C}	45.54^{A}	52.00^{B}	59.72^{C}
a	3.98^{A}	5.47^{B}	6.98^{C}	4.48^{A}
b	22.11^{A}	16.36^{B}	22.11^{A}	22.10^{A}
ΔE	37.44^{A}	48.26^{B}	37.44^{A}	36.73^{A}

Data in the same row followed by different uppercase superscript letters differ significantly ($P \leq 0.05$). L, degree of lightness (100, perfect white; 0, black); a, intensity of color in the direction of green (−) to red (+) with grey, 0; b, intensity of the color in the direction of blue (−) to yellow (+) with grey, 0. ΔE, total color difference between the sample and the reference standards.

in color (i.e. higher L values) than other cookie samples containing DBMS. This is attributable to the smaller particle sizes of the DBMS in the other cookie formulations. Smaller particles may have been more thoroughly mixed in the dough than the bigger ones. Consequently, DBMS of 800 μm particle size was adopted for other investigations.

Effect of different levels of debittered moringa seed grits on the physical and sensory properties of cookies

The results showing the effect of different levels of DBMS on the physical properties and sensory attributes of cookies are presented in Table IX. It was observed that at DBMS levels above 20%, the surface cracking pattern and crumb color of the cookies were adversely affected. The cracks were too large; islands were too big and the crumb color was dull cream (Figure 6). The sample had a dominant nutty mouth feel typical of moringa seeds and the flavor was not typical of cookies. The total sensory scores were 60, 56.5, 57 and 38 for the DBMS levels 0%, 10%, 20% and 30%, respectively, and the cookies

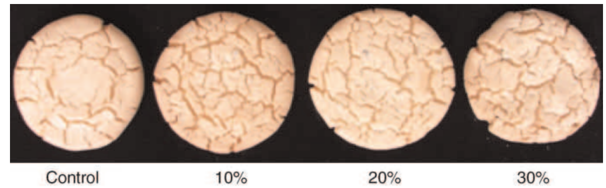

Figure 6. Effect of different levels of DBMS grits on the surface cracking pattern of cookies.

pictures are shown in Figure 3. In general, replacement of wheat flour with increasing levels of DBMS powder grits meant the diameter and spread ratio of cookies increased; whereas the surface cracking pattern, crumb color, texture, mouth feel and flavor reduced. Similar results had been reported for cookies prepared from wheat-cowpea (Mcwatters 1978), wheat-soybean (Shrestha and Noomhorm 2002) and wheat-defatted wheat germ flour blends (Arshad et al. 2007). Different views had been reported on the mechanisms by which the spread is reduced when wheat flour is supplemented with non-wheat flours. Mcwatters (1978) reported that rapid partitioning of free water to hydrophilic sites during mixing increased dough viscosity, and consequently limit cookie spread. Spread ratio is also known to be affected by competition of ingredients for the available water; flour or any other ingredient, which absorbs water during dough mixing.

Chemical composition of cookies

The results of proximate analysis (Table X) suggest that cookies supplemented with DBMS were more nutritious than the control. The cookies with 30% DBMS grits had more protein, fat, iron and calcium than 20%, but the physical properties and sensory attributes shows that the cookie with 20% as a more acceptable product.

Table IX. Effect of different levels of DBMS grits on the physical and sensory parameters of cookies.

Parameter	Control	DBMS 10%	DBMS 20%	DBMS 30%	SEM
Physical properties					
Diameter (mm)	86.5^{A}	89.3^{B}	90.3^{B}	91.0^{B}	5.5
Thickness (mm)	11.5^{C}	11.0^{B}	10.8^{B}	10.5^{A}	0.02
Spread ratio (D/T)	7.5^{A}	8.1^{B}	8.4^{C}	8.7^{D}	0.03
Breaking strength (g)	$4{,}962^{D}$	$4{,}900^{C}$	$4{,}860^{B}$	$4{,}250^{A}$	5.0
Sensory properties					
Surface color (10)	9.0^{C}	8.0^{B}	8.0^{B}	7.0^{A}	0.20
Surface cracking pattern (15)	13.0^{B}	13.5^{B}	14.0^{B}	10.0^{A}	0.25
Crumb color (10)	9.0^{C}	8.5^{B}	8.5^{B}	6.0^{A}	0.20
Texture (15)	13.0^{B}	12.5^{B}	12.5^{B}	5.0^{A}	0.25
Mouthfeel (10)	8.0^{C}	7.0^{B}	7.0^{B}	5.0^{A}	0.30
Flavor (10)	8.0^{C}	7.0^{B}	7.0^{B}	5.0^{A}	0.25
Total sensory score (70)	60.0^{C}	56.5^{B}	57.0^{B}	38.0^{A}	0.50

Data in the same row followed by different uppercase superscript letters differ significantly ($P \leq 0.05$). Debittered moringa seed grits were 800 μm at all levels. SEM, standard error of the mean.

Table X. Effect of different levels of DBMS grits on the chemical parameters of cookies.

		DBMS		
Composition (g/100 g)	Control	10%	20%	30%
Moisture content	3.42 ± 0.03[A]	3.45 ± 0.01[A]	3.46 ± 0.02[A]	3.5 ± 0.01[B]
Protein	7.5 ± 0.03[A]	10.85 ± 0.16[B]	14.21 ± 0.16[C]	18.06 ± 0.16[D]
Ash	1.09 ± 0.04[A]	1.34 ± 0.02[B]	1.39 ± 0.02[B]	1.57 ± 0.02[C]
Fat	15.13 ± 1.5[A]	17.24 ± 0.04[B]	19.02 ± 0.04[C]	20.05 ± 0.04[D]
Carbohydrate	72.86 ± 0.06[D]	67.06 ± 0.05[C]	61.92 ± 0.09[B]	56.82 ± 0.06[A]
Iron (mg/100 g)	2.71 ± 0.02[A]	4.65 ± 0.14[B]	6.67 ± 0.02[C]	8.74 ± 0.25[D]
Calcium (mg/100 g)	23.44 ± 0.25[A]	32.87 ± 0.53[B]	41.89 ± 0.20[C]	50.71 ± 0.38[D]

Data presented as mean ± standard deviation of triplicate analysis. Means with same uppercase superscript letters on same row are significantly different.

Conclusions

Blending of wheat flour with processed moringa seeds flour at different levels was found to affect the organoleptic properties of different blended breads but the differences indicated were not significant ($P \leq 0.05$). Replacing wheat flour with DBMS as a nutritional ingredient in cookies and bread promises value addition in baked food products. The products were of acceptable rheological and sensory characteristics at an optimal wheat flour/DBMS blend of 90/10 for bread and 80/20 for cookies. The bread had an acceptable typical, moringa seed taste and the cookies had a nutty mouth feel. The products were richer in protein and other vital nutrients such as iron and calcium that are seldom found in daily diets. It can be concluded that highly nutritious cookies can be prepared by supplementing wheat flour with DBMS flour at 10% level for bread and 20% level for cookies. This indicates that moringa seeds hitherto known as a flocculent for purifying water have good potential as an alternative source of vegetable protein, especially for the malnourished poor in some parts of Asia and Africa where moringa tree blossoms but its nutritional value is hardly known. This new dimension in the utilization of moringa depicts it as a possible alternative to soybean, cashew, almond and pistachio in baked foods and confectioneries subject to further investigations regarding its anti-nutritional components, especially in the light of the different varieties of *M. oleifera* presently in use.

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