African Journal of Food Science and Technology (ISSN: 2141-5455) Vol. 3(9) pp. 193-203, November 2012
Available Online http://www.interesjournals.org/AJFST

Full Length Research Paper

Functional and physicochemical properties of mango seed kernels and wheat flour and their blends for biscuit production

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Accepted October 09, 2012

Fresh mango seed kernels were processed to reduce tannins, and then after seed kernels flour was prepared to produce value added product. Physicochemical and functional properties of mango seed kernel flour, wheat flour and blends of flour containing 10%, 20% and 30% mango seed kernels as substituting levels for wheat flour were investigated. Results of processing revealed that maximum reduction of tannins and enhancement of proteins attained by combined action of soaking and autoclaving process. The physical property analysis showed that 30% mango seed kernels flour as substituting level for wheat flour blend had falling number (218 sec) and color grade (9.25), which is good enough for bakery added value product processing. The 30% mango seed kernels flour analyses result showed lower oil absorption and emulsion activity among the blends. Flour blends containing up to 30 % mango seed kernel flour were acceptable for biscuit production without adverse effect on sensory qualities. The substitution of wheat flour with mango seed kernel flour can contribute as pertinent resource deployment for value added product manufacturing and waste utilization which might play significance role of food security in African countries where mango fruit is abundant.

Keywords: Biscuits, Functional properties, Mango seed kernels, Processing methods, Chemical composition, Sensory characteristics, Tannins.

INTRODUCTION

Mango (*Mangifera indica L.*), is one of the most cultivated fruit in the tropical and subtropical regions. Mango fruit contain amino acids, carbohydrates, fatty acids, minerals, organic acids, proteins, vitamins (A and C) and dietary-fiber (Pal, 1998). It is one of the most recommended fruits which have medicinal importance to fight beriberi, heal bronchial diseases and cure brain fatigue, mental depression, wrestle heart burn and insomnia (Medina *et al*, 2002). Because of mango is a seasonal fruit, about 20% of fruits are processed for products such as puree, nectar, leather, pickles, canned slices, chutney, frozen mango and dehydrated products (Ramteke and Eipeson, 1997). These products have worldwide popularity and also gained increased importance in the US and European markets (Abdalla *et al*., 2007).

Mango fruit grow in different regions of Ethiopia yielding varying quantities within the private peasant holdings signaling the absence of development in fruit farming. Mango fruit percent of utilization from total production for all holdings in the Ethiopian context indicated that household consumption (54.61%), sale (40.23%), seed (0.29%), wage in kind (0.15%), animal feed (0.02%) and others (4.7%) based on the report of CSA (2011). The world production of mango fruits more

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than 35 million tones while, in Ethiopia, 97.32 thousand tons of mango fruits were produced in 2011 (FAO, 2012). During processing of mango, major by products such as peel and seed kernel are generated. The mango kernel contributed about 17-22% of the fruit (Soong and Barlow, 2006). As seed kernel is not currently utilized for any commercial purposes, it is discarded as a waste and becoming a source of pollution. A preliminary study revealed that the seed represents from 20% to 60% of the whole fruit weight, depending on the mango variety and the kernel inside the seed which represents from 45% to 75% of the whole seed (Maisuthisakul and Gordon, 2009). Mango seed kernel should be treated as a specialized residue due to its high levels of phytochemicals, for instance phenolic contents (tannins). Hence, industry has increasing cost for its waste treatment to utilize it as a good source of natural antioxidants and lipid (Arogba, 2000). The mango seed kernel is a rich source of carbohydrates, proteins, fat and tannins.

A number of workers have investigated the composition of mango seed kernel. The reports indicate that the mango kernel is comparable to most of the cereals in respect to carbohydrates, protein, fat and minerals. The average content of mango kernel comprises carbohydrates (69.22%-79.78%), fat (8.35%-16.13%), protein (5.6%-9.5%), starch constitutes about 92% and a fair amount of fiber (0.14%-2.95%) and ash content from 0.35% to 3.66% (Dhingra and Kapoor , 1985). Many researchers revealed that mango seed kernel contains tannins. Tannins are a group of polyphenols which form insoluble complexes with protein and inhibit several enzymes (Bressani *et al*., 1983).

The biochemical nature of how the food tannins bind to food proteins is difficult to discern, primarily due to the complexity of tannins chemistry as well as the number of tannins species present in food (Sathe and Salunkhe, 1984). Tannins consist mainly of gallic acid residues that are linked to glucose via glycosidic bonds. Tannin-protein complexes can cause inactivation of digestive enzymes and reduce protein digestibility by interaction of protein substrate with ionizable iron. The presence of tannins in food can therefore lowers food efficiency, depress growth, decrease iron absorption, damage the mucosal lining of the gastrointestinal tract, alter excretion of cations, and increase excretion of proteins and essential amino acids. Furthermore, tannins inhibit the activity of trypsin, chymotrypsin, amylase and lipase. Thus, reduction of tannins concentration located in seed kernels via various processing methods is a prerequisite for utilization of mango kernel in forms of flour. Dhingra and Kapoor (1985) showed that tannins can be effectively removed if the kernels are soaked two to three times in water for 20 min each at 80℃. Other optional processing methods of tannins reduction for various crops are elaborated in many research findings.

In traditional food items, 20%-30% of mango seed kernel flour can be used without adversely affecting their acceptability (Dhingra and Kapoor, 1985). Attempts have been made partially to substitute seed kernel flour in bakery products. Biscuits are the most popularly consumed bakery items in the World. Some of the reasons for such wide popularity are their ready to eat nature, affordable cost, good nutritional quality, availability in different tastes and longer shelf-stability (Gandhi *et al*., 2001).

To reduce the environmental pollution of mango byproducts which comes from small scale juice processing industries in the country should be converted to useful products. Therefore, it is resourcefully advantageous and environmental friendly to produce valuable products like mango kernel flour, starch and some value added products via blending with other cereals from by products of the mango processing industry; and moreover this resource utilization can contribute to food security.

The present study attempted to investigate the composition and properties of Ethiopian mango seed kernel flour via treatments of various processing methods to reduce the astringents taste which comes from tannins. Therefore, this study was conducted to investigate the proximate composition, physical and functional properties of mango seed kernels and blended flours. Finally, biscuits were developed from blends of mango kernel with wheat flours; and their chemical composition, water activity, physical measurements and sensory characteristics also analyzed.

MATERIALS AND METHODS

Sample collection, transportation, preparation and storage

The raw materials needed for the research are ripened mango fruits. They were purchased from Et-fruit located in Addis Ababa and transported to Food Engineering laboratory of Addis Ababa Institute of Technology. The mango seeds were washed and then the kernels were removed manually from seeds. The kernels were chopped and dried by tray drier. The dried mango kernel was ground in a hammer mill into a powdery form and kept in a closed dark glass bottle and stored at 4 ^{o}C until further analysis.

Table1: Formulation of dough containing mango kernel flour for biscuit development

Ingredients	Biscuit dough formulation			
	Control	$MKWF_1$	$MKWF_2$	$MKWF_3$
Wheat flour (g)	1000	900	800	700
Mango kernel flour (g)	0.0	100	200	300
Sugar (g)	195	195	195	195
Margarine (g)	50	50	50	50
Milk powder (g)	2.5	2.5	2.5	2.5
Ammonium bicarbonate (g)	15	15	15	15
Sodium metabisulphite (g)	0.1	0.1	0.1	0.1
Water (ml)	325	325	325	325
Salt (g)	3	3	3	3
Vanilla (ml)	1.2	1.2	1.2	1.2

Where: WF- wheat flour, MKWF1- 10% mango kernel flour, MKWF2 - 20% mango kernel flour and MKWF3 -30% mango kernel flour as substituting levels for wheat flour

Processing methods to reduce tannins in the mango seed kernels

Dehulling

It is one of the physical treatments to remove the skin (coats) that contain unwanted substances such as tannins present in the skin. The skin, therefore, should be removed to reduce astringent taste.

Soaking

The soaking process involved slicing the pulp off the mango fruit, cracking the shell of the seed manually; grind the kernel, soaking the freed kernel in sulphited water (730 mg sodium metabisulphite litre^{-1}) at 30^{0}C, 40^{0}C and 50^{0}C for 48 h, with occasional decantation and replacement with an equivalent amount of water until the water remained colorless. Finally, the seed kernels were dried on a nylon fabric by tray dryer to constant weight in order to remove the tannins from mango kernel.

Autoclaving

The ground de-skinned mango kernels were autoclaved in a mango kernel to water ratio of 1:2 (w/v) for 10, 20 and 30 min at 121℃ to remove the tannins from mango kernel.

Combined process

The ground de-skinned mango kernels were soaked in sulphited tap water at 50 ^{o}C for 48 h followed by autoclaving for 30 min at 121 ^{o}C and dried by tray drier at 23 ^{o}C.

Production of mango kernel flour, blend formulation and biscuit processing

The kernels which underwent different processing methods; then dried on a nylon fabric by tray dryer to constant weight and milled into fine powders. Blends of wheat and mango kernel flours for biscuit formulations were prepared and are shown in Table 1. Biscuit samples were processed from dough's containing 10, 20 and 30 % MKF as substituting levels for wheat flour according to a commercial formulation and baking practice of Kality Food Share Company. Biscuit dough was formulated by blending wheat flour, mango kernel flour with other ingredients. The formulated blends were mixed for 15 min at 125rpm (speed 2) using a mixer (type DITO - SAMA, Aubusson, France, 1997). Each batches of the dough were removed from the mixer and allowed to rest for 10 min. The dough pieces were sheeted and flattened using roller into a sheet of about 8 mm thickness, and then cut into rectangular pieces with size, 75 mm × 75 mm. Samples were baked in an electric oven (DiFiore Forensic, Model, MLC80B, Forni morello, Italy, 1999) at 249 ^{o}C for 18 min (Fig 1 to Fig 4). After baking, biscuits were left to cool at room temperature and were wrapped tightly with polypropylene pouches and kept until further analyses took place.

Blending processes were conducted by substituting specified proportions of (10%, 20%, and 30%) mango kernel flour from the total percent of wheat flour (100%), and biscuits were made with these blending ratios using a similar procedure and ingredients as indicated in Table 1.

Figure 1. Wheat biscuits

Figure 2. $MKWF_1$ biscuits

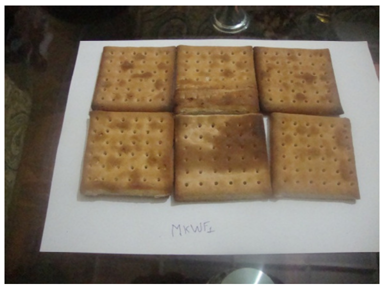

Figure 3. $MKWF_2$ biscuits

Figure 4. $MKWF_3$ biscuits

Analysis methods

Proximate chemical composition

Proximate chemical composition analysis of the kernel flours, wheat flour and biscuits including moisture, total ash, crude protein, crude fiber and crude fat content were performed according to AOAC official methods 925.09, 923.03, 979.09, 962.09 and 4.5.01; respectively, of the Official Methods of Analysis of AOAC (2000) International. The total carbohydrates excluding crude fiber were calculated from the difference. The energy value for 1 g of the three groups of nutrients which provide the body energy were calculated by using specific values of water factors for protein, fat and total carbohydrates as recommended by Birch *et al*. (1980).

Analysis of tannins

Tannins concentration was determined by the modified vanillin assay method of Butler *et al*. (1982).

Physical properties of mango kernel and blend flour

Color grade and falling number of mango kernels and blend flours were determined using color grade (SATAKE, series IV 1998) and Hagberg falling number apparatus (Perten model 1500, Sweden, 2005); respectively. The granularity (particle size) of mango kernel flours and the blends were determined by sieving about 50 g of the sample using 180 mesh size sieves according to the method described by ES 1052:2005. The pH value of flours was determined by the method of AOAC (1984) using official method 14.022. The water activity of mango kernel flours and biscuits samples were measured using water activity measuring unit (Aqua Lab Lite, Decagon a_w meter, 2004).

Functional properties

The functional properties of processed mango kernel flours and blend flours were analyzed. Bulk density was determined according to the method described by Narayana and Narasinga (1984); the emulsion activity (EA) and stability were assessed by the method of Yasumatsu *et al*. (1972); oil absorption capacity according to Beuchat (1977) and dispersibility in water by the method of Kulkarni *et al*. (1991).

Physical measurements of biscuits

The spread factor, width and thickness of biscuits were evaluated according to AACC (2000), method no. 10-

50D. The spread ratio was calculated by dividing width (W) by thickness (T).

Sensory evaluation of biscuits

Biscuits incorporated with mango kernel powder were coded with different numbers and submitted to sensory evaluation by ten member trained panels of food engineering program staff. The panelists were asked to rate each sensory attribute using the control biscuits as the basic for evaluation. Biscuits were evaluated for surface color, texture, taste, flavor and over all quality on a 9-point hedonic scale, where 9 indicated 'like extremely' and 1 'dislike extremely'.

Statistical analysis

Data obtained were tested for differences using analysis of variance followed by Duncan's multiple range tests. The least significant difference was used for multiple mean comparison tests. Significance was accepted at 0.05 level of probability.

RESULTS AND DISCUSSION

Reduction of tannins via processing

Influence processing methods (dehulling, soaking, autoclaving and combined process) on the removal of tannins and nutrient composition are as shown in Table 2. The phytochemical (tannins) contents of the raw mango kernel (4.282g/100g) and the dehulled mango kernel (2.164g/100g) were significantly different at $p<0.05$, and reduced by 49.47% of the tannin level after dehulling process. Binyam et al. (1995) and Ma & Bliss (1979) reported that tannins were located in seed hull and that dehulling processes might be expected to reduce its levels.

The levels of tannins in the mango kernel were affected by hydration in distilled water with sodium metabisulfite solution as shown in Table 2. The tannins levels after soaking were 1.503 g/100g, 1.350 g/100g and 1.203 g/100g for the corresponding soaking temperatures of 30 oC, 40 ^{o}C and 50 ^{o}C; respectively. The study showed that soaking temperature significantly ($p<0.05$) reduced the levels of tannins in the mango kernel. Soaking reduced the tannins levels by 30.54%, 37.61% and 44.4% at 30 ^{o}C, 40 ^{o}C and 50 ^{o}C of soaking temperatures, respectively. These results were in good agreement with Ravindran and Sivakanesan (1996), who reported that soaking mango kernel in water with frequent stirring removed 44% of tannins. Furthermore, Sunday (1999a) observed that soaking of mango kernel in water resulted in reduction of tannins by 48%.

The levels of tannins after autoclaving at 121 ^{o}C for 10, 20 and 30 minutes were found to be 0.71 g/100g, 0.534 g/100g and 0.357 g/100g respectively. As a result, the tannins content of the mango kernels were reduced correspondingly by 67.1%, 75.32% and 83.5%. The study showed that the reduction of tannins from mango kernel were higher than the value obtained by Farag (2001)who reported that the reduction of tannins subjected to autoclaving at 121 ^{o}C for 10, 20 and 30 minutes were 31.9%, 47.6% and 75%; respectively.

Soaking the mango kernel at 50 ^{o}C followed by autoclaving at 121 ^{o}C for 30 minutes was found to reduce the tannins content completely. Combined treatment produced a significant ($p<0.05$) change on the tannins composition of mango kernel compared to the effects of autoclaving for 30 minutes and soaking at 50 ^{o}C. The research finding reported by Khokar and Chanhan (1986) revealed that soaking and autoclaving reduced/eliminated the phytochemicals in crops and improved digestibility.

Influence of processing methods on nutrients composition

Table 3 showed composition of crude protein and fat of mango kernel subjected to soaking at 30 ^{o}C, 40 ^{o}C and 50 ^{o}C were 5.87 g/100g, 6.19 g/100g and 6.37 g/100 for crude protein; and 9.8 g/100g, 9.6 g/100g and 9.2 g/100g for crude fat. The analysis indicated that soaking significantly ($P < 0.05$) affected the crude protein and fat content of the mango kernel. Soaking temperature was also significantly ($P < 0.05$) affected the crude protein content of the mango kernel. However, only soaking temperature of 50 ^{o}C had significant ($P < 0.05$) effect on crude fat content of mango kernel. The results were in agreement with Sunday (1999b) who reported that soaking significantly ($P < 0.05$) increased the protein content and decreased the fat content of mango kernel.

The crude protein contents of a mango kernel subjected to autoclaving at 121 ^{o}C for 10, 20 and 30 minutes were 6.25 g/100g, 6.41 g/100g and 6.42 g/100g; respectively. Whereas the crude fat composition was 12.6 g/100g, 12.7 g/100g and 12.6 g/100g for 10, 20 and 30 minutes autoclaving.

The study showed that autoclaving significantly ($P < 0.05$) increased the crude protein content of the mango kernel. However, the crude protein contents were not significantly ($P > 0.05$) increased for autoclaving time at 20 and 30 minutes. In addition, autoclaving time

Table 2. Influence of processing methods on the reduction of tannins.

Processing methods	Samples	Tannins (g/100 g)	Reduction of Tannins [y] (%)
Dehulling	RM-1	4.282 ± 0.013[a]	-
	RM-2	2.164 ± 0.025[b]	49.47
	SO-30	1.503 ± 0.05[c]	30.54
Soaking	SO-40	1.350 ± 0.07[d]	37.61
	SO-50	1.203 ± 0.05[e]	44.40
	AC-10	0.710 ± 0.02[f]	67.11
Autoclave	AC-20	0.534 ± 0.04[g]	75.32
	AC-30	0.357 ± 0.01[h]	83.50
Combined	SO-50+ AC-30	ND	100

All values are means ± SD.
ND- Not detectable.
[a–h] Means not sharing a common superscript letter with in a column are significantly different ($P < 0.05$). All values are means ± SD.
[y] Reduction indicates (%) decrease over raw value.
Where: RM-1 = raw mango kernel; RM-2 = dehulled mango kernel; SO-30=soaking at 30 °C; SO-40=soaking at 40 °C; SO-50=soaking at 50 °C; AC-10=autoclaving for 10 min; AC-20=autoclaving for 20 min; AC-30=autoclaving for 30 min

Table 3. Effect of processing on nutrient composition **(**g/100g DM[z]**)** of mango seed kernels

Sample	Crude protein	Crude fat
RM2	5.55 ± 0.01[f]	12.8 ± 0.31[a]
SO-30	5.87 ± 0.14[e]	9.8 ± 0.01[b]
SO-40	6.19 ± 0.05[d]	9.6 ± 0.28[b]
SO-50	6.37± 0.09[b]	9.2 ± 0.07[c]
AC-10	6.25 ± 0.23[c]	12.6 ± 0.19[a]
AC-20	6.41± 0.03[b]	12.7 ± 0.04[a]
AC-30	6.42± 0.07[b]	12.6± 0.59[a]
SO-50+ AC-30	6.71±0.00[a]	9.1±0.00[c]

All values are means ± SD.
[a-f] Means not sharing a common superscript letter with in a column are significantly different ($P < 0.05$).
[z]DM, Each values expressed on dry matter basis

had no significant effect on the crude fat content of the mango kernel. The results of the study was in agreement with Farag (2001) who reported that analysis of crude fat in relation to the applied autoclaving time (121 °C, for 10, 20 and 30 minutes) indicated that these treatments had no significant effects on crude fat content of the mango kernel. Moneam (1990) suggested that autoclaving improves the *invitro* protein digestibility of crops and may be attributed not only to the removal of phytochemicals but also to the structural disintegration of the native protein, including enzyme inhibitors.

The combined treatment i.e. soaking at 50 °C followed by autoclaving for 30 minutes, was significantly ($P < 0.05$) affected both the crude protein and fat content of mango kernel. The crude protein was increased from 5.55 g/100g to 6.71 g/100g. This research finding indicates that the reduction of tannins and improvement of protein composition via combined treatment is the aim for production of flour from mango kernel.

Proximate composition of mango kernel flour and blend flour

Moisture content, crude protein, crude fat, total ash, crude fiber and pH value of mango kernel flour and blend flour were presented in Table 4. The raw mango kernel flour was found to contain 9.8% moisture, 5.55% crude protein, 12.8% crude fat, 2.5% crude fiber, 2.1% total ash and 67.25% carbohydrates all are presented in dry weight basis; and pH and energy value of 4.8 and

Table 4. Proximate composition, pH and calorific values of mango seed kernel and blended flours (g/100 g DM[z]).

	Parameters							
Flour Type	**Protein**	**Fat**	**Ash**	**Fiber**	**Moisture**	**Total carbohydrates**	**pH**	**Energy (kcal)**
Control	10.12± 0.08[a]	1.74±0 .06[f]	0.85±0 .02[e]	0.75±0 .01[e]	13.01± 0.02[a]	73.53±0.42[a]	5.91± 0.07[a]	350.26±0.32[f]
MKWF$_1$	9.78± 0.46[b]	2.51±0 .02[e]	1.01±0 .03[d]	0.95±0 .07[d]	12.71± 0.49[a]	73.04±0.37[a]	5.92± 0.05[a]	353.87± 0.41[e]
MKWF$_2$	9.41± 0.29[c]	3.29±0 .74[d]	1.11±0 .02[c]	1.13±0 .21[c]	12.63± 0.57[a]	72.43±0.89[b]	5.82± 0.07[a]	356.97±0.49[d]
MKWF$_3$	9.10± 0.51[d]	3.91±0 .01[c]	1.13±0 .02[c]	1.30±0 .04[b]	12.44± 0.63[a]	72.12±0.07[b]	5.81± 0.03[a]	360.07± 0.52[c]
RMK	5.55± 0.01[f]	12.8±0 .31[a]	2.10± 0.62[a]	2.51± 0.25[a]	9.80± 0.04[b]	67.25±0.19[c]	4.83± 0.05[c]	406.4±0.91[a]
MKF	6.71± 0.00[e]	9.10± 0.01[b]	1.79±0 .05[b]	2.72±0 .03[a]	10.89± ± 0.23[b]	68.84±0.09[c]	5.51± 0.01[b]	384.1± 0.74[b]

All values are means ± SD. [z]DM, each values are expressed on dry matter basis.
[a-f] Means not sharing a common superscript letter with in a column are significantly different at $P < 0.05$.
Where, Control = wheat flour, RMK= dehulled mango kernel, MKF= mango kernel flour, MKWF$_1$=10% MKF and 90% WF, MKWF$_2$= 20% MKF and 80% WF and MKWF$_3$= 30% MKF and 70% WF

406.4 kcal ; respectively.

Proximate composition varied from variety to variety, but the mango kernel grown in Ethiopia were similar to values obtained by Sunday (1999b), Abdalla et al.(2007 and Farag (2001); with respect to moisture, crude fiber, and total ash. However, the crude protein was higher than the value obtained by Sunday (1999b) and lower than Abdalla et al. (2007) which were 5.3 g/100g and 6.7g/100g; respectively.

The mango kernel grown in Ethiopia was found to have high value of crude fat content than the value obtained by Dingra and Kapoor (1985), i.e. 10.7g/100g. But this value was lower than that of Sunday (1999a) which was 14.0 g/100g. Table 4 also indicated that the energy value of raw mango kernel were higher (406.4kcal) as compared to mango kernel flour and wheat flour. The pH value of the kernel, pH=4.8, were similar results with the pH value obtained by Sunday (1999a), where pH=5.0.

Based on the results in Table 4, there is significant (P < 0.05) differences in the protein, fat, ash, fiber, moisture, carbohydrates, pH and energy values of the mango kernel flour and blend flour. The protein value for different flours is shown in Table 4 and it could be seen that wheat flour had higher amount of protein than that of mango kernel flour (MKF). Blending of the mango kernel flour with wheat flour was found an increase of the protein content significantly in all blends. The result showed that blending of the mango kernel flour with wheat flour upgrade of the protein content from 6.71 to 9.10 g/100g for MKF of MKWF3; respectively.

Crude fat and fiber content of the blend was significantly (P < 0.05) increase as the proportion of mango kernel flour increased. Blending of mango kernel flour with wheat flour showed significant increase in the fat content of the blends 3.91 for MKWF3, 3.29 for MKWF2 and 2.51 for MKWF1 (g/100g). The pH value of the mango kernel flour (MKF) was significantly (P < 0.05) differs from the wheat flour and blend. However, the pH values of blends revealed non-significant differences.

Blending of mango kernel flour (MKF) up to 30% was found an increase ash content significantly from 0.85 for WF to 1.13 g/100g for MKWF3. The moisture content of the mango kernel flour was found to be 10.89%. This value was lower than the moisture content of wheat flour (13.01%). However, blending ratio affects non-significantly (P>0.05) the moisture content of the blended flours. From the results in Table 4; one can see that blending of flours when substituting levels for wheat flour increase there is an increase in fat, ash, fiber and energy values

Physical properties of mango kernel and blend flours

The physical properties such as falling number, color and water activity of mango kernel and blend flours were investigated. The falling number analysis results indicate

Table 5. Physical properties of mango seed kernel and blended flours.

Types of flour	Physical parameters			
	Falling number (sec)	Color grade	Particle size (< 180 μ)	Water activity (a_w)
WF	259 ± 5[a]	3.03 ± 0.18[e]	100 ± 0.01[a]	0.51± 0.01 [a]
MKWF1	235 ± 7[b]	7.63 ± 0.21[d]	99.1± 2.11[a]	0.51± 0.00 [a]
MKWF2	227 ± 9[c]	8.15 ± 0.50[c]	98.6± 3.61[a]	0.53± 0.04 [a]
MKWF3	218 ± 2[d]	9.25 ± 0.21[b]	98.1± 1.22[a]	0.53± 0.01 [a]
MKF	121 ± 1[e]	21.12 ± 0.23[a]	91.8 ± 2.97[b]	0.55± 0.03 [a]

All values are means ± SD.
[a–e] Mean values not sharing a common superscript letter with in a column are significantly different (P < 0.05)

Table 6. Functional properties of mango seed kernel and blended flours

Flour Types	Properties				
	Bulk density (g/ml)	Dispersibility (v/v, %)	Oil absorption (ml/g)	Emulsion activity (v/v,%)	Emulsion stability (v/v, %)
WF	0.57±0.01[b]	62.7±0.02[a]	1.21±0.21[a]	21.7±0.33[a]	29.7±0.01[a]
$MKWF_1$	0.58±0.04[b]	61.9±0.36[b]	1.17±0.06[b]	20.9±0.07[b]	29.1±0.51[a]
$MKWF_2$	0.58±0.02[b]	61.7±0.09[b]	1.14±0.01[c]	20.2±0.23[c]	28.3±0.83[a]
$MKWF_3$	0.59±0.00[b]	60.9±0.28[b]	1.11±0.00[d]	19.7±0.19[d]	26.8±0.04[b]
MKF	0.61±0.05[a]	54.2±0.19[c]	0.83±0.00[e]	17.3±0.08[e]	25.1±0.09[c]

All values are means ± SD.
[a-e] Means not sharing a common superscript letter with in a column are significantly different (P < 0.05)

ultimately the activity of alpha-amylase. The analysis showed that falling number of flour was in the range of 256 to 121 seconds. Blending of MKF with WF was significantly (P < 0.05) reduced the falling number as the proportion of MKF increased. But, in this work, blending of MKF up to 30% (MKWF3) was acceptable for biscuit production since the falling number was 218 seconds.

The color of the flour showed that mango kernel flour had higher intensity of color (21.12) and wheat flour had lower (3.03) intensity of color. Higher intensity indicates the darkness of the mango kernel flour. This was because during the autoclaving and milling processes the starch goes under discoloration. Blending of MKF with WF resulted in an increase of the intensity of color of flour significantly at P < 0.05. Table 5 shows that granulation (particle size) of MKF (91.8) were significantly different at P < 0.05. However, blending of MKF with WF was not significantly different at P < 0.05. The particle size of MKF (91.8) < MKWF3 (98.1) < MKWF2 (98.6) < MKWF1 (99.1) < WF (100).

The water activity values of the mango kernel flours and blends indicate in the safe range of keeping quality. Since, the water activity values of the flour are much below the water activity requirements set for the growth of microorganisms and are not prone to microorganisms. As indicated in Table 5, the water activity values of flour samples are in the range of 0.50 - 0.55.

Functional properties of mango kernel and blend flour

The functional properties studied include oil absorption capacity, dispersibility, bulk density, emulsion activity (EA) and emulsion stability (ES). The bulk density value of mango kernel flour grown in Ethiopia was higher (0.61 g/ml) than that obtained by Sunday (1999a) for MKF (0.50g/ml) of Ikanekpo varieties grown in Nigeria. The result of Table 6 shows that the dispersibility of flour were significantly different (P < 0.05) between the mango kernel and blend flours. The values of dispersibilty for WF, MKF, MKWF1, MKWF2, and MKWF3 are 54.21%, 62.75%, 61.96%, 61.70% and 60.96%; respectively.

The oil absorption capacities of each flour mix are shown in Table 6. The oil absorption capacity was higher for wheat flour (control), which is 1.21 ml/g, and the lower was for mango kernel flour (MKF), which is 0.83 ml/g. The analysis showed that blending of MKF with WF significantly reduces the oil absorption capacity.

The emulsion activity and stability of mango kernel flour shows significantly (P < 0.05) differ. The analysis showed that blending of MKF with WF significantly (P < 0.05) decreases the emulsion activity. However, blending of MKF up 30% significantly decrease the emulsion stability. The highest emulsion activity the blend was MKWF1 (20.9), followed by MKWF2 (20.2) and MKWF3

Table 7. Proximate composition (g/100g DM[z]), calorific value and water activity of biscuits containing mango seed kernel flours

Biscuit Type	Parameters							
	Protein	Fat	Ash	Fiber	Moisture	Carbo-hydrates	Energy (kcal)	Water activity
WF	7.81± 0.00[a]	7.42± 0.06[c]	0.92± 0.28[c]	0.25± 0.01[d]	4.69± 0.02[a]	79.16± 0.42[a]	414.66± 0.85[a]	0.45± 0.03[a]
$MKWF_1$	7.25± 1.62[b]	7.81± 0.02[b]	0.98± 0.15[b]	0.29± 0.07[c]	4.85± 0.09[a]	79.11± 0.37[a]	415.73± 1.13[a]	0.46± 0.00[a]
$MKWF_2$	6.61± 2.10[c]	8.21± 0.74[a]	1.01± 0.02[b]	0.32± 0.21[b]	4.91± _0.51[a]	79.26± 0.89[a]	417.37± 0.50[a]	0.46± 0.01[a]
$MKWF_3$	6.14± 0.91[d]	8.27± 0.01[a]	1.11± 0.04[a]	0.36± 0.04[a]	5.00± 0.13[a]	79.48± 0.07[a]	416.91± 1.41[a]	0.47± 0.01[a]

All values are means ± SD. [z]DM, each values expressed on dry matter basis.
[a–d] Means not sharing a common superscript letter with in a column are significantly different (P < 0.05)

Table 8. Physical measurements of biscuits

	Parameters		
Types of Biscuit	**Width, W(mm)**	**Thickness, T(mm)**	**Spread Ratio (W/T)**
Control	75.10 ± 0.49[c]	7.71 ± 0.31[d]	97.41 ± 3.98[a]
$MKWF_1$	76.75 ± 0.42[b]	8.29 ± 0.21[c]	92.57 ± 3.54[b]
$MKWF_2$	78.01 ± 0.23[a]	8.91 ± 0.19[b]	87.54 ± 0.35[c]
$MKWF_3$	78.92 ± 0.61[a]	9.85 ± 0.07[a]	80.10 ± 2.86[d]

All values are means ± SD
[a-d] Means not sharing a common superscript letter with in a column are significantly different (P < 0.05)

(19.7) (v/v, %). The result of emulsion activity and stability of MKF (17.3 and 25.1) obtained in this experiment were higher compared to research findings of other investigators.

Proximate composition of biscuits

The proximate analysis of biscuits containing mango kernel flour with different blend ratios is shown in Table 7. The moisture, carbohydrates and energy value of the biscuits containing mango kernel were not significantly (*P* > 0.05) different. The fat, ash and fiber contents of biscuits were increased as blending ratio of mango kernel flour increases. The protein content of biscuits was significantly (*P* < 0.05) decrease as the incorporation level of mango kernel increases.

As indicated in Table 7, the water activity values of biscuit samples are in the range of 0.45-0.47. The analysis showed that there were no significant differences on the water activity of biscuits. The drying process in biscuit manufacturing contributes for decreasing of the water activity. The water activity values of the biscuit indicate that values are in the safe range of keeping quality. The water activity values of the biscuits are below the recommended water activity requirements for the growth of bacteria (a_w < 0.91) and molds (a_w < 0.81), Decagon (2004). In addition to influencing microbial spoilage, water activity can play a significant role in determining the activity of enzymes and vitamins in foods and can have a major impact on their color, taste, and aroma (Chirife and Buera, 1999).

Physical measurements of biscuits

The physical measurements of biscuits are provided in Table 8. The spread factor, width and thickness values of biscuits and control sample were ranged from 97.41 to 80.10, 78.9 to 75.1, and 7.71 to 9.85; respectively.

The spread factor analysis showed that as the incorporation of mango kernel flour (MKF) increased, the spread ratio decreased; and this could be due to the increase in number of hydrophilic sites available that compete for the limited free water in biscuit dough (Kirssel and Prentice, 1979). These results agreed with

Table 9. Sensory qualities of biscuits incorporated with mango seed kernel flour

Types of Biscuit	Hedonic scales				
	Color	Flavor	Taste	Texture	Overall acceptability
Control	8.29±0.49[a]	7.00±0.81[b]	7.28±0.48[a]	6.86±0.68[c]	7.29±0.76[a]
$MKWF_1$	7.71±0.49[a]	7.03±0.58[b]	7.19±0.54[a]	7.14±0.69[c]	6.92±0.57[a]
$MKWF_2$	6.86±1.21[b]	7.29±0.95[b]	6.83±0.61[b]	7.57±0.53[b]	6.57±0.53[b]
$MKWF_3$	5.57±0.97[c]	8.42±0.53[a]	6.43±0.78[b]	8.14±0.37[a]	6.28±0.49[b]

All values are means ± SD

[a-d] Means not sharing a common superscript letter with in a column are significantly different ($P < 0.05$).

Whereas: 1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4 =dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely

other research workers who reported that incorporation of oat bran, soy flour and black gram flour decreased the spread factor (Sharma and Chauhan, 2002).

There are several views on the mechanisms by which the spread ratio of cookies is reduced when wheat flour is supplemented with non-wheat flours (Giami et al., 2005; Sudha et al., 2006). It has been established that cookie spread is strongly correlated to the water absorption capacities of flour. The higher water absorption capacities values of samples contributed to the lower spread radio. Doescher (1987) reported that rapid partitioning of free water to hydrophilic sites during mixing increased dough viscosity, thereby limiting cookie spread. However, it has been suggested that spread ratio is affected by the competition of ingredients for the available water - flour or any other ingredient which absorbs water during dough mixing might decrease spread ratio (Fuhr, 1962).

Sensory characteristics of biscuits

Results of sensory attributes in terms of color, flavor, taste, texture and overall acceptability are presented in Table 9. Control biscuit showed maximum color mean score of 8.29, which was the highest obtained among the type of biscuit. This is due to the fact that as blending ratio with mango kernel flour increases, this in turn affects and led to the color change of the biscuits to darkness. Findings of sensory attributes on the flavor and texture indicated that in 30% mango kernel flour blend biscuit were found highest.

The sensory results reported in this study are different compared to the research finding of Sunday (1999b) who reported lowest sensory scores of flavor as incorporation levels of mango kernel flour increases. The processing methods (soaking and autoclaving) used in this study perhaps contributes the development of flavor in biscuits.

Blending of mango kernel flour with wheat flour significantly ($P < 0.05$) decreases the color, taste and overall acceptability of biscuit as the proportion of mango kernel flour blend ratio increases. The change in color while increasing the blending ratio of mango seed kernels might be due to the nutrients interaction during processing and baking time with temperature combination. Thus, optimization of baking temperature and time based on the type, size and shape of the product, and the nature of the ingredients. The flavor and texture of biscuit made from MKWF3 (30% mango kernel flour and 70% wheat flour) biscuit rated superior.

CONCLUSION

The reduction of astringent taste which drives from tannins was removed by a combination of soaking followed by autoclaving process. This processing method facilitates the production of flours from mango seed kernels. From the present study it can be concluded that blends containing up to 30% mango kernel flour were suitable for the development of biscuits. Beyond 30% blends of mango seed kernel flour, the color of the biscuits become darken attributable to the Maillard browning reaction, presence of high fiber composition and baking process parameters. Utilization of mango seed kernels for commercial purposes can reduce the environmental pollution which resulted as by-product from mango processing industries; and contribute to food security by converting waste to valuable food products especially to African context where mango fruit is abundant.

Alternatively, mango seed kernel powder could also be used as a potential source for various bakery products and functional food ingredients. Furthermore, it can be processed into vital foods including neutraceuticals and therapeutic functional food products. More research activities have to be done in optimization of baking condition and shelf stability of mango seed kernel based products. Advanced research studies of mango seed kernels for utilization as industrial product, active ingredients characterizations, phytochemicals profile, antimicrobial activity, antioxidant activity via application of various processing for food and medicinal purposes are recommended.

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