PHYSICOCHEMICAL, BIOLOGICAL, RHEOLOGICAL AND FUNCTIONAL PROPERTIES OF MANGO KERNELS AND ITS PROCESSED FLOUR

ATWA, M. A., O. R. M. MASOUD AND K. H. M. EL-WASEIF

Food Technology Research Institute, ARC, Giza

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Abstract

Mango kernels were analyzed for Physicochemical, biological rheological and functional properties and detoxification treatments using two methods: soaking in tap water for 30 hrs at (40° c± 2) or soaking in citric acid solution 2% at the same conditions. These treatments caused decrement in crude protein and nitrogen free extract. Also, mango kernels flour treatments were free from antinutritional factors. Physicochemical characteristics of mango kernels oil were affected by these treatments, acid value and peroxide value were rising while unsaponification matters were reduced. Mango kernels contained 12.30% crude oil approximately, this ratio and fatty acid composition wasn't affected by this treatment. Protein solubility, water absorption, fat absorption, emulsification capacity, foam capacity and foam stability increased by these treatments. Cake supplemented with mango kernels flour contained the highest value of protein, oil, fiber and ash while contained the lowest value of nitrogen free extract. Supplementation of wheat flour by using mango kernels flour promoted rheological properties. Statistical analysis results indicated no significant differences between the control sample and supplemented cake. Gain in the rat body weight in the final nutritional period increased by increasing the mango kernels flour addition. The toxic compounds adhering in the untreated mango kernels flour such as amygdaline caused death of rats after 45-55 day according to the addition ratio.

INTRODUCTION

Mangoes *(Mangifera Indica L)* are considered among the most popular fruits grown in Egypt. The average total annual areas cultivated with mangoes are about 68356 fedans producing about 230873 tons of fruits. Mango kernels represent about 24% of the weight of the whole fruits. There are need to convert these refuse materials into available by products. Mango kernels depend on the variety containing an average of 5.7% protein, 9.3% fat, 79.9% carbohydrates, 20% crude fibers and 3.11% ash *(Bhatnagar and Subramanyam, 1971).* Mango kernel powder was used as an antioxidant agent for ghee. Its effect could be attributed to the phenolic compounds and also to the presence of phospholipids that helped to prolong the time

of the shelf life of stored ghee *(Mona et al., 2006).* The total antioxidant capacity and phenolic content of edible portions and seeds of mango were studied by *Soong and Barlow, (2004).* Several studies had been carried out concerning the toxic compound removal from these kernels to be used as a food and feeding source, *(Solis et al., 2004).* The aim of the present work was to study the Physico chemical, biological, rheological and functional properties of mango kernel and its flour in making cake.

MATERIALS AND METHODS

Materials

Representative samples of mangoes *(Mangifera Indica L.)*, namely Balady, were obtained from juice extraction unit of the pilot plant of the Food Technology Research Institute, Agric. Res. Center, Giza, Egypt. These wastes were dried at 40°c in a drying oven, and then stored at room temperature (25 ± 2 °c) for further uses.

Methods

Preparation of mango kernels samples

Mango stones were cleaned and washed twice with tap water, then left to dry in the air. After the stones were individually hammered to obtain the kernels of which the outer cover was removed by hand after soaking in warm water (40 ± 2°c) for 10-15 minutes.

Detoxification of bitterness from mango kernels

1- The bitterness was removed from de-hulled mango kernels as follows: Mango kernels were soaked in warm tap water (40 ± 2°c) for 30 hours at the same time. The warm tap water was changed periodically at intervals of one hour.

2- The kernels were soaked in citric acid solution (2%) to be dehydrated. In this method 2kg of mango kernels were soaked in (2%) of citric acid solution for 12 hrs at room temperature, then dehydrated under vacuum for 2 hrs. to remove most of the water and the water residue was further eliminated by dehydration at 105°c for another 2 hrs.

Analytical Methods

Moisture, total protein, ether extract, total ash, crude fiber and minerals were determined according to methods in the *A.O.A.C., (1990).* Total carbohydrates were calculated by difference.

Physicochemical characteristics

These include refractive index, acid and peroxide values, iodine value, saponification value, melting point, unsaponification matter which were determined according to the method described in the A.O.A.C. (1990).

Preparation of the fatty materials to methylation

The methyl esters of mango kernel oil were prepared using benzene: methanol: concentrated sulfuric acid (10:86:4). Methylation was carried out at 70°c for 24 hrs according to the method described by Ludy et al., (1968).

Determination of the fatty acid methyl esters

Gas-liquid chromatography (Pye-unicam PRO-GC) was used for fractionation and determination of fatty acid methyl esters according to the method described by Zygadlo et al., (1994).

Nutritional quality

Amygdaline

Determination of the amygdaline content (as hydrocyanic acid) in mango kernels (Amygdaline = HCN x 16.9257).Hydrocyanic acid was extracted from mango kernels samples according to the method reported by Cruess, (1958) while hydrocyanic acid content (raw and during the soaking stage) was determined according to the method described by the A.O.A.C., (1990).

Tannins

Tannins were determined colorimetrically as described in A.O.A.C., (1990).

Phytic acid

Phytic acid was determined according to the method of Wheeler and Ferrel, (1971).

Trypsin inhibitor

Trypsin inhibitor was determined according to the method of Roy and Reo, (1971).

Functional properties

Nitrogen solubility index (NSI)

Nitrogen solubility index was determined according to the method of Smith et al., (1959).

Water and oil absorption

Water and oil absorption were determined according to the methods of Sosulski et al., (1962) and Sosulski et al., (1976), respectively.

Emulsification capacity

Emulsification capacity was measured by the method of Yasumatsu et al., (1972). Refined corn oil was used for absorption and emulsifying capacity studies.

Foaming properties

Foam capacity and stability were measured by the method of Huffman et al., (1975).

Utilization of mango flour in cake preparation

The blend for preparing this product contained 45-55% wheat flour (72% extraction), 20% sucrose, 5% fat, 6% whole dried eggs, 4% baking powder and 5, 10, 15% mango kernels flour. The product was evaluated organoleptically for color, texture and flavor by comparison test according to Larmond (1967).

Rheological properties

Rheological characteristics of the resultant dough under investigation according to the method described in *A.A.C.C, (1990).*

Sensory evaluation

Sensory evaluation was carried out for formulations mango flour detoxified in warm tap water (T1),mango flour detoxified in citric acid solution 2%(T2) and control. The panelists were asked to evaluate taste, odor, color texture and the overall acceptability according to Lanza et al., (1995).

Statistical analysis

Statistical analysis was applied to sensory and biological evaluation of adding different percentages from treated and untreated kernels flour. Data were treated to be for complete randomization design. Least significant difference (L.S.D.) was calculated at 1% level as significance. This analysis was carried out as mentioned by Snedecor and Cochran (1980).

Biological tests using rats

Male albino rats average weight 80-90g. Were obtained from the Research Institute of Ophthalmology, Giza, Egypt.

The biological assays were carried out to determine the gain in weight of rats for best meals. The effects of adding different percentage from untreated and treated mango kernels flour were biologically evaluated. The salt and vitamin mixture used in these experiments were as recommended by A.O. A.C, (1990). Test rats were kept out under normal healthy conditions and fed on basal diet for one week. The test animal includes 18 groups each of 5 rats for each diet (basal diet as control (+) and control (-) containing different

Percentages of untreated mango kernels flour and fed for 8 weeks

RESULTS AND DISCUSSION

Chemical composition of raw materials

Data in Table (1) Show that the chemical composition of mango kernels were 5.89, 12.32, 2.49, 2.27 and 77.03 for crude protein, crude oil, crude fiber, total ash and nitrogen free extract respectively. After detoxification treatment using warm tap water (T1) and citric acid solution 2% we observed the decrease of crude protein and nitrogen

Table 1. Effect of detoxification treatment on chemical composition of mango kernel flours (on dry weight basis).

Compounds %	*Undetoxified sample (Control)*	*Detoxified sample dipped in*	
		Warm tap water	*Citric acid solution 2%*
Crude protein	5.89±0.71	5.11±0.62	5.10±0.70
Crude oil	12.32±1.10	12.90±1.20	12.88±1.11
Crude fiber	2.49±1.20	2.75±1.11	2.70±1.20
Total ash	2.27±0.30	2.35±0.27	2.36±0.29
Nitrogen free extract	77.03±2.11	76.69±2.20	76.96±2.29

Free extract in both cases while slightly increase of crude oil, crude fiber and total ash occurred in their treatments. These results are in agreement with the findings of Seleim et al., (1999).

Table 2. Effect of detoxification treatment on minerals profile of mango kernel flours (on dry weight basis).

Mineral elements (mg/100gm dry matter)	*Undetoxified sample (Control)*	*Detoxified sample dipped in*	
		Warm tap water	*Citric acid solution2%*
Macro-elements			
Ca	37.25±1.51	44.63±1.63	44.97±1.59
P	59.75±1.72	68.76±1.87	69.02±1.91
Mg	169.25±3.22	185.19±3.56	188.35±3.62
K	649.39±9.73	877.29±11.21	880.01±10.72
Na	289.75±5.82	325.46±6.71	327.09±5.92
Micro-elements			
Fe	0.69±0.11	0.79±0.13	0.82±0.12
Zn	4.00±0.13	4.89±0.16	4.93±0.14
Cu	0.46±0.01	0.55±0.10	0.56±0.10

Table (2) Shows that mineral content of mango kernels proved to be a good source for some minerals such as Ca, P, Mg, K, Na, Fe, Zn and Cu. Also, it was observed that slight raising of mineral content after treatment with warm tap water and citric acid solution

Table 3. Effect of detoxification treatment on physicochemical characteristics of mango kernels oil (on dry weigh basis).

Properties	*Undetoxified sample (Control)*	*Detoxified sample dipped in*	
		Warm tap water	*Citric acid solution2%*
Refractive index 40°c	1.4691±0.003	1.4685±0.004	1.4684±0.004
Melting point	34.00±0.92	34.00±0.94	34.00±0.89
Acid value	0.10±0.04	0.11±0.05	0.13±0.04
Peroxide value	0.73±0.02	0.80±0.02	0.80±0.02
Iodine value	43.50±1.10	43.50±1.12	43.50±1.10
Saponification value	189.50±2.06	189.50±2.11	189.5±2.09
Unsaponification matter %	1.50±0.05	1.20±0.03	1.20±0.02

Table (3) shows the effect of detoxification treatment on physicochemical characteristics of mango kernels. From these data, it could be observed that the increase of acid value after treatment with citric solution 2% was more than that treated with warm water. On the other hand less change occurred in unsaponification matters in both treatments while no changes were observed in refractive index, melting point, peroxide value, iodine value and saponification value for both treatments.

Table (4) shows the effect of detoxification treatment on fatty acid composition of mango kernels oil. Mango kernels oil was

Table 4. Effect of detoxification treatment on fatty acid composition of mango kernels oil.

Fatty acids %	*Undetoxified sample (Control)*	*Detoxified sample dipped in*	
		Warm tap water	*Citric acid solution 2%*
Lauric (12:0)	0.22±0.0	0.29±0.0	0.25±0.0
Myristic (14:0)	0.42±0.0	0.38±0.0	0.43±0.0
Palmitic (16:0)	11.74±0.2	11.25±0.2	11.39±0.2
Palmitoleic (16:1)	N.D	N.D	N.D
Stearic (18:0)	40.73±0.91	40.81±0.89	39.88±0.90
Oleic (18:1)	41.43±0.94	41.68±0.92	42.47±0.93
Linoleic (18:2)	5.57±0.20	5.59±0.21	5.58±0.2
Linolenic (18:3)	0.16±0.0	0.15±0.0	0.15±0.0
Total saturated	52.84	52.73	51.95
Total unsaturated	47.16	47.27	48.05

Characterized by equal quantity of oleic and stearic fatty acids and then followed by palmitic acid. Composition of mango kernels oil from different fatty acids had

reverse phenomenon. Also, no effect upon using both treatments was observed on the fatty acids content. These results agree with Solis et al., (2004).

The changes in some antinutritional factors such as hydrocyanic acid, amygdaline, tannins, Phytic acid and trypsin inhibitor during treatment by soaking in warm tap water and citric acid solution 2% for 12 hrs, at 25 ± 2°c are shown in table (5). The results indicate that soaking treatment caused marked reduction in the antinutritional factors of mango kernels flour. The reduction rate in hydrocyanic acid and amygdaline was 100% for both treatments. On the other hand, tannins and Phytic acid removal was higher in citric acid solution (2%) than in warm tap water. Finally, both

Table 5. Effect of detoxification treatment on antinutritional factors of mango kernel flours (on dry weight basis).

Compounds	*Undetoxified sample (Control)*	*Detoxified sample dipped in*	
		Warm tap water	*Citric acid solution2%*
Hydrocyanic acid (gm/100gm sample)	0.04±0.01	N.D*	N.D
Amygdaline (gm/100gm sample)	0.68±0.11	N.D	N.D
Tannins (gm/100gm sample)	56.0±1.2	36.0±0.92	35.0±0.96
Phytic acid (gm/100gm sample)	6.0±0.5	4.0±0.3	3.0±0.22
Trypsin inhibitor (TIU/mg)	N.D.	N.D.	N.D.

N.D= Means not detected

Treatments of mango kernels flour are free from trypsin inhibitor. These results agree with Seleim et al., (1999).

Studying the functionality of samples was essential in order to use them effectively in food products. Water, oil absorption, emulsification capacity as well as foaming properties have some utilizations of the functional properties of raw mango kernels flour and their treatment are represented in table (6). The high values of the flour may be due to the presence of carbohydrates, such as starch, which absorb both water and oil. The emulsification capacity of treated flours was high compared to the untreated samples. The foam capacity of the treated flours of mango kernels was the highest compared to the raw kernel (control).

Table 6. Effect of detoxification treatment on functional properties of mango kernel flours.

Functional properties		*Undetoxified sample (Control)*	*Detoxified sample dipped in*	
			Warm tap water	*citric acid solution 2%*
Protein solubility index using:				
Distilled water		61.39±1.2	73.16±1.4	74.69±1.3
5% Nacl		75.32±1.5	90.76±1.7	92.35±1.8
0.02_M NaoH		90.07±1.4	101.12±1.8	103.76±1.5
Water absorption (gm H_{20}/100gm sample)		117.92±3.2	290.15±4.5	291.76±4.2
Fat absorption (ml oil/100gm sample)		110.76±1.7	246.71±2.1	250.31±2.2
Emulsification capacity (ml oil/gm sample)		47.0±1.1	61.0±1.7	63.0±1.8
Foam capacity in H_{20} (% volume increase)		43.0±1.2	66.0±1.9	69.0±1.7
Foam stability in H_{20}	0.0 min	35.0	40.0	41.0
	15.0 min	30.0	35.0	35.0
	30.0 min	25.0	30.0	31.0
	45.0 min	22.0	24.0	25.0
	60.0 min	19.0	21.0	21.0
	90.0 min	18.0	19.0	19.0

In general, mango kernels flour had promising functional properties which may be used to give benefits to many products, such as bakery products, meat products, milk products and soft drinks.

Table (7) shows the chemical composition of cake and the effect of added mango kernels flour on the chemical composition of cake. From these data, it could be noticed that, protein, fat, fiber and

Table 7. Chemical composition of cake prepared with different levels of mango kernel flours (on dry weight basis).

Type of cake		Component %				
		Protein	Fat	Fiber	Ash	N.F.E
Control		11.63±1.12	16.85±1.2	1.37±0.4	1.59±0.52	68.56±2.2
(T_1)	5%	13.63±1.3	17.26±1.9	1.47±0.5	1.83±0.49	63.81±1.9
	10%	16.17±1.36	17.89±1.31	1.58±0.37	1.89±0.43	62.47±1.8
	15%	18.59±1.29	18.29±1.2	1.66±0.42	1.97±0.57	59.54±2.1
(T2)	5%	14.27±1.37	17.26±1.41	1.48±0.53	1.79±0.61	65.2±1.7
	10%	16.62±1.41	17.96±1.3	1.59±0.62	1.91±0.52	61.92±2.4
	15%	18.79±1.51	18.41±1.5	1.73±0.57	1.98±0.49	59.09±2.3

Control: wheat flour 72%, T1: mango flour detoxified in warm tap water T2: mango flour detoxified in citric acid solution 2%

Ash contents tended to increase by increasing the level of added mango kernels flour. On the contrary, total carbohydrates tended to decrease with increasing the supplementation level.

The rheological properties are considered to be of great importance since they greatly influence the final acceptability of the food products.

Table 8. Rheological properties of wheat flour supplemented with different levels of mango flours.

Rheological data	Control	5%	10%	15%
Water absorption (%)	55.2	59.3	61.2	62.5
Arrival time (min)	1.5	2.0	2.5	3.0
Dough development (min)	2.5	2.6	3.0	3.5
Dough stability (min)	7.5	7.5	7.0	6.5
Degree of weakening (B.u)	45.0	55.0	60.0	65.0
Dough energy (cm^2)	120.2	118.3	115.2	110.1
Dough extensibility (mm)	210.0	210.0	205.0	200.0
Resistance to extension (B.u)	410.0	480.0	540.0	560.0
Proportional number (R/ E)	1095	2.29	2.63	2.80

Control: Wheat flour (72% extraction), Different levels of mango flours (5, 10&15%)

Table (8) indicates that dough stability, dough energy and dough extensibility decreased with increasing the percentage of mango kernels flour in the formula while

water absorption, arrival time, dough development, degree of weakling, resistance to extension and proportional number increased with increasing the percentage of mango kernels flour.

Table 9. Sensory evaluation of cake preparation with different levels of mango kernel flours.

Type of cake		*Color*	*Texture*	*Taste*	*Odor*	*Overall acceptability*
Control		8.02^{ab}	7.53^{b}	7.99^{b}	8.02^{ab}	8.18^{ab}
T_1	5	7.49^{bc}	7.76^{b}	7.0^{bc}	7.44^{bc}	7.32^{bc}
	10	8.54^{a}	8.32^{ab}	8.46^{ab}	8.20^{ab}	8.44^{ab}
	15	6.99^{c}	7.16^{bc}	6.34^{cd}	6.80^{c}	6.99^{c}
T_2	5	8.18^{ab}	7.68^{b}	7.32^{bc}	7.69^{b}	8.00^{ab}
	10	8.69^{a}	8.50^{a}	8.69^{a}	8.36^{ab}	8.74^{a}
	15	7.33^{bc}	7.32^{bc}	7.17^{bc}	7.15^{bc}	7.30^{bc}
L.S.D		0.73	0.62	0.85	0.71	0.78

Control: Wheat flour (72% Extraction) T1: mango flour detoxified in warm tap water T2: mango flour detoxified in citric acid solution 2%

The sensory evaluation was carried out to define the best formula being acceptable among other ones. The measured sensory characteristics included color, texture, taste, odor and overall acceptability. The results and statistical analysis in table (9) indicate no significant difference between the control sample and the formulated meals containing mango kernels flour, especially for color and overall acceptability.

The average change in body weight of rats is summarized in table (10). It could be observed that adding different percentages of mango kernels to the untreated flour was more effective for the growth of rats

Table 10. Food intake, body weigh and feed efficiency ratio for rats fed on mango flours for 35 days.

Diets	Initial body weight (g/ rat)	Final body weight (g/ rat)	Gain in body weight		Daily gain in body weight (g/ rat)	Daily food intake for rat (g/ rat)	Feed efficiency ratio
			g/ rat	%			
Basal diet	85	115	30	35.3	0.86	7.39	0.116
Control	83	106	23	27.7	0.66	5.81	0.114
T_1 5%	81	110	23	35.8	0.83	7.14	0.116
10%	86	117	31	36.1	0.89	7.83	0.114
15%	89	121	32	36.0	0.91	7.87	0.116
T_2 5%	85	112	27	32.0	0.77	6.77	0.114
10%	82	113	31	37.8	0.89	7.83	0.114
15%	88	120	32	36.4	0.91	7.87	0.116

Basal diet: casein, Control: protein free Diet, T1: mango flour detoxified in warm tap water, T2: mango flour detoxified in citric acid solution 2%

Compared to the treated one (control). The increase of growth occurred with the increase in the percentage of added mango kernels flour.

The data in table (11): show the evaluation of diet containing different percentage of control, untreated and treated mango kernels flour. The untreated mango kernels flour caused a decrease in the growth of rats. The rats died after 45 and 55 day when 5, 10 and 15% were fed on a diet containing 5, 10 and 15% untreated mango kernels flour, respectively compared to those fed on added casein. The death of rats could be related to the toxic compounds adhering in the untreated mango kernels such as the amygdaline.

Table 11. Evaluation of diet containing different percentages of control, untreated and treated mango kernel flours.

Days	Control	5%			10%			15%		
		Unt	T_1	T_2	Unt	T_1	T_2	Unt	T_1	T_2
0	83	80	81	82	77	82	80	79	83	84
7	87	75	83	84	75	84	85	75	86	87
14	93	71	86	87	73	87	90	72	88	90
28	98	66	89	89	67	90	92	68	91	92
35	102	62	91	92	61	93	96	59	96	97
49	106	54	93	94	52	96	98	51	99	100
56	109	45	95	96	43	99	102	40	104	107
L.S.D for (A) 0.82										
(B) 0.71										
(A x B) 2.12										

Control: casein, Unt: Undetoxified sample, T1: mango flour detoxified in warm tap water, T2: mango flour detoxified in citric acid solution 2%

In general, mango kernels is a good source of high quality protein important in human and animal nutrition, and by blending with other plant proteins, will produce well balanced diets. Thus experiments must be carried out to study the acceptability of incorporation of mango kernels in some conventional of food items.

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الخواص الطبيعية الكيميائية، البيولوجية، الريولوجية والوظيفية لبذور المانجو والدقيق المعامل بها

محمد عبد الرحمن عطوه ، عمر راضى محمد مسعود، قدري حامد محمد الوصيف

معهد بحوث تكنولوجيا الأغذية- مركز البحوث الزراعية- جيزة

تم تقدير الخواص الطبيعية الكيميائية البيولوجية الريولوجية والوظيفية لبذور المانجو والتى عوملت للتخلص من المواد السامة بنقعها فى ماء ساخن على ٤٠ ± ٢°م لمدة ٣٠ ساعة وكذلك فى محلول حمض ستريك ٢% تحت نفس الظروف وهذه المعاملة أدت إلى نقص فى محتواها من البروتين و الكربوهيدرات والتخلص من مركبات الأمجدالين وحمض الهيدروسيانيك ومثبطات إنزيم التربسين. وهذه المعاملة أدت إلى تأثر الخواص الطبيعية لزيت بذور المانجو مثل حدوث زيادة فى قيمة الحموضة ورقم البيروكسيد ونقص فى المواد الغير قابلة للتصبن. لم يحدث تأثر لبذور المانجو في محتوي الدهون والأحماض الدهنية بهذه المعاملة، كما حدث تحسن ملحوظ فى الخواص الوظيفية لدقيق بذور المانجو المعامل ، كما أن الكيك المدعم بإضافة نسب مختلفة من دقيق بذور المانجو المعامل أدي إلي حدوث زيادة فى محتواها من البروتين والدهن والألياف والرماد بينما انخفض محتواها من المواد الكربوهيدراتية، كما أن هذه الإضافة أدت إلى تحسن فى الخواص الريولوجية للمنتج، و قد أشارت نتائج التحليل الإحصائي إلى عدم وجود اختلاف معنوي فى الخواص الحسية للمنتج المدعم بإضافة دقيق بذور المانجو المعامل وفي التجربة البيولوجية كانت الزيادة فى وزن فئران التجارب ملحوظة فى نهاية فترة التجربة وزادت بزيادة نسبة الإضافة، وفى اختبار السمية ماتت فئران التجارب بعد ٤٥-٥٥ يوم من التغذية على بذور المانجو الغير معاملة بالمقارنة بالفئران التى تغذت على الكازين و دقيق بذور المانجو المعاملة وقد يعزي هذا لوجود مركبات سامة مثل الأمجدالين.