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MANGO SEED KERNEL: NUTRIENT COMPOSITION AND QUALITY CHARACTERISTICS OF OIL

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ABSTRACT

Mango seed kernel, a waste from mango processing factories and fruit drops, is a byproduct rich in starch, fat, protein, polyphenols, minerals, etc. Utilization of mango seed may be an economical way to reduce the problem of waste disposal. In the present investigation, the compositional quality of the mango seed kernel (MSK) and mango seed kernel oil (MSKO) of a few locally grown germplasm were examined. The mango seed kernel is a good source of carbohydrates (70.11 to 77.38 %), moderate source of oil (7.44 to 12.82 %) and proteins (4.69 to 8.60 %). The kernel is a fair source of minerals and has good antioxidant property. The MSKO has good chemical properties (low acid, peroxide and iodine values) and rich in oleic (47.77 %) and stearic acid (36.16 %). These findings suggest that MSK can be utilized for economic benefits as well.

Keywords: Compositional quality, Mango seed flour, Mango seed kernel, Mango seed oil

Mango (*Mangifera indica* L.), the 'King of fruits' is grown for its juicy stone fruits in many tropical regions. The fruit can also be processed for preparing a host of products. Worldwide, it has been stated that 35% to 60% of the weight of the fruit (seed and peel) is wasted each year (Mwaurah *et al*., 2020; Said *et al*., 2021). Depending on the mango variety, seed represents from 10 % to 25 % of the whole fruit weight. Mango seed kernel (MSK) represents about 20 % of the whole fruit and 45 % to 75 % of the stone (Arogba, 1997; Maisuthisakul and Gordon, 2009). The kernel obtained from decorticated mango stone can be utilized as a supplement to wheat flour or for extraction of edible oil. Average oil content of MSK is about 12-15% and has the potential to become a commercial source of edible oil (Nadeem *et al*., 2016). Solis-Frentes and Duran-de-Bazua (2004) reported notable similarities between mango seed kernel oil (MSKO) and cocoa butter. Besides being a source of edible oil, MSK is a potential source of a wide range of bioactive compounds and antioxidants (Jafari *et al*., 2014; Kaur and Brar, 2017). The defatted mango kernel flour is rich in nutrients and phytochemicals and can be blended with wheat flour in the production of bakery products (Awolu *et al*., 2018). Menon *et al.* (2014) also highlighted the significant utilization of MSK in formulation and nutrient enrichment of bread. The major problem affecting the nutritional value of MSK is the presence of antinutritional factors, which are present in trace quantities (Dakare *et al*., 2012) and can easily be removed through simple processing methods (Zein *et al*., 2005).

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Solid food processing waste materials might lead to serious environmental problems, ranging from water pollution, unpleasant odours, asphyxiation and vegetation damage to greenhouse gas emissions (Gupta *et al*., 2015). Disposal of these materials usually represents a problem that is further aggravated by legal restrictions. More than one million tonnes of mango seeds are being annually produced as wastes so that if such seeds could be utilized in some way, probably valuable products could be produced. Assam is endowed with huge varieties of mango germplasm. The tree grows wild everywhere in the state as well as grown for shade, fire wood, timber etc. The fruits of majority of these mango trees are of poor quality because of heavy pest infestation, bigger seed size with little flesh and its fibrous nature. Therefore ripe fruits are not very popular, instead simply wasted as fruit drops. There is no efficient waste disposal system for such fruit drops and they decompose, which might lead to environmental pollution. Thus exploitation of MSK not only eliminates the disposal problem but also results in valuable products.

MATERIALS AND METHODS

The present investigation was designed to estimate the compositional quality of MSK grown locally. Ripe mangoes of 10 unclassified local germplasm were collected from different locations in Jorhat district of Assam. A commercial mango variety, Chausa, was procured from the local market. The peels and pulp were removed by washing in clean water, while the seeds were sun dried for a week. The kernels were cracked manually to remove the shells and hulls and

dried further at 60°C±5 to a constant weight. Dried kernels were converted to powder using a stainless steel grinder and stored in containers at 4°C until used.

The proximate parameters (moisture, crude protein, crude fat, crude fibre and ash) in MSKs were determined by the methods of Association of Official Analytical Chemists, AOAC (2000). Total carbohydrate content was determined as described by Jeon (1995). Iron content was determined using the UV-Visible spectrophotometer (Chemito, UV -2100 model) following Wong's method (1928). Calcium, potassium and magnesium were determined using flame photometer (Systronics; model-MK III) according to the method (AOAC, 1984). Saponification value and iodine value of MSKO was determined as per the method of AOAC (1970). Peroxide value was determined using the method described by Cox and Pearson (1962). Total phenol were assayed by the method of Malik and Singh (1980) and expressed as mg catechol equivalent (CE) of phenol/ g sample. Tannins were estimated by the method described by Folin-Denis Method (Swain and Goldstein, 1964). Antioxidant activity was measured using 2, 2-diphenyl-1-picrylhydrazyl (DPPH) according to the method of Vani *et al.* (1997). All estimations were done in triplicate and the mean of the three estimations was recorded.

For determining the fatty acid composition, oil was first converted to fatty acid methyl esters. Fatty acid analysis was done in a Gas Chromatograph with Mass Spectrometer (GCMS) (Make: Perkin Elmer (USA); Model: Clarus 680 GC/Clarus 600 C MS) equipped with a sealed long photomultiplier detector. The column used was Elite-5MS Capillary Column, 60m long with internal diameter of 250µm. The initial oven temperature was 60°C held for 6 minutes, increased to 180°C with ramp 5°C/min, then without holding with ramp of 10°C per minute, temperature was raised up to 280°C, and then held for 10 minutes. Carrier gas (Helium) was used at a flow rate of 1 ml/min. The amount of oil injected was 1µl. The run time was 50 minutes. After the fats were analyzed, their chromatograms were acquired and the fatty acid contents were calculated. Percent relative fatty acid was obtained from the peak area of a fatty acid species to the cumulative peak area of all the fatty acids in the oil sample. Fatty acid contents were also calculated based on the percentage of peak area.

RESULTS AND DISCUSSION

Proximate and mineral composition of MSK

Proximate composition and mineral contents of MSK are shown in Table 1. The average moisture content in MSK was 6.03 %. The moisture content is a measure of yield and quantity of solid matter and its distribution is an important factor for storage and preservation of MSK. The crude protein content in MSK ranged between 4.69 % and 8.60 % with an average of 7.06 % indicating MSK as a poor source of protein. The average crude fat content in MSK was 10.10 %. The unclassified local germplasm V_{10} was significantly different from the rest of the germplasm in crude fat content. Olajumoke (2013) reported a much higher value (25.57 %) for crude fat extracted by Soxhlet extraction method with petroleum ether in MSK. The average crude fibre content in MSK was 2.58 % and was found in agreement with the earlier reports (Abdalla *et al*., 2007; Nzikou *et al*., 2010). The carbohydrate content (by difference) in MSK was found to be higher than the values reported by Nzikou *et al*. (2010) and Mounica and Subbiah (2014). The results showed that MSK might be relatively a good source of carbohydrate. The average ash content in MSK of all local germplasms along with commercial variety Chausa was found 2.79 %. Lakshminarayana *et al.* (1983) investigated the characteristics and composition seed kernel of 43 varieties of mango fruit and reported 1.0 to 3.7 % of ash along with 3.7 -12.6 % crude fat and 4.0-8.1 % crude protein on dry weight basis. Such variations in the proximate composition in the MSKs might be because of variation in their genetic make-up, their stage of maturity, climate and edaphic factors as well as methods of determination.

Mango seed kernels are also rich in minerals and high in potassium, magnesium, phosphorus, calcium and sodium (Kittiphoom, 2012). Mineral contents of MSK are comparable to that in grains, legumes and nuts but do not provide required RDA (Patel and Kheni, 2018). Average mineral contents of Ca, Fe, Mg and K in the present study were found to be 7.89, 9.07, 21.32 and 152.07 mg per 100 g dry weight (Table 1). Kittiphoom (2012) mentioned higher values for these minerals in MSK.

Properties of MSKO

Saponification value (SV), iodine value (IV), acid value (AN), and peroxide value (PV) are the most commonly used parameters in characterizing the quality of oils and fats. These parameters are widely used to determine purity (SV), number of unsaturated compounds (IV) and free fatty-acid content (acidity). The estimated SV, IV, AV and PV are shown in Table 2.

SV is an index of average chain length (molecular weight) of fatty acids present in oil. Smaller the SV longer is the average fatty acid chain. The average saponification value of MSKO was 177.12 mg KOH per gram oil with a range between 143.22 to 204.44 mg KOH/g oil. Because of high saponification value, MSKO has the potential for use in the industry (Yadav *et al.*, 2017). The AV and PV are assessed to determine the chemical quality of the oils. The AV is a measure of the free fatty acids present in the fat or oil. The low

Table 1. Proximate, mineral, total phenol and tannin contents of MSK (dry weight basis)

Local Germplasm	Moisture (%)	Crude Protein (%)	Crude fat (%)	Crude Fibre (%)	Carbohy-drate (%)	Ash content (%)	Ca (mg/100g)	Fe (mg/100g)	Mg (mg/100g)	K (mg/100g)	Phenol (mg CE/g)	Tannin content mg/g
V_1	5.63 ± 0.04	6.97 ±0.03	7.44 ±0.05	2.34 ±0.03	77.38 ±0.09	2.65 ±0.04	7.77 ±0.05	11.21 ±0.04	21.48 ±0.05	148.27 ±0.51	25.49 ±0.07	18.25 ±0.06
V_2	6.33 ±0.07	7.61 ±0.04	9.77 ±0.08	1.61 ±0.04	73.22 ±0.08	2.18 ±0.03	8.43 ±0.05	8.66 ±0.04	20.62 ±0.06	152.71 ±0.55	28.59 ±0.09	21.75 ±0.05
V_3	4.64 ±0.04	7.29 ±0.03	9.60 ±0.06	2.39 ±0.04	75.85 ±0.08	2.47 ±0.03	7.27 ±0.04	7.54 ±0.03	20.59 ±0.05	148.52 ±0.44	23.21 ±0.07	16.54 ±0.06
V_4	4.57 ±0.06	6.56 ±0.04	11.93 ±0.07	2.89 ±0.03	74.10 ±0.07	2.93 ±0.03	7.27 ±0.03	8.19 ±0.04	21.50 ±0.04	148.87 ±0.42	23.74 ±0.06	18.89 ±0.04
V_5	7.59 ±0.04	8.60 ±0.05	8.31 ±0.07	1.60 ±0.04	73.11 ±0.09	3.60 ±0.02	9.31 ±0.04	10.67 ±0.02	20.77 ±0.04	154.52 ±0.48	27.56 ±0.07	19.28 ±0.06
V_6	5.56 ±0.05	7.56 ±0.04	9.77 ±0.08	2.56 ±0.04	73.84 ±0.09	2.16 ±0.03	8.43 ±0.04	9.45 ±0.04	22.43 ±0.04	149.29 ±0.53	24.80 ±0.09	18.31 ±0.05
V_7	6.14 ±0.05	6.52 ±0.04	10.78 ±0.07	2.52 ±0.05	74.40 ±0.07	2.64 ±0.02	7.45 ±0.04	7.57 ±0.04	20.44 ±0.05	152.46 ±0.55	23.96 ±0.09	19.53 ±0.07
V_8	6.23 ±0.04	7.34 ±0.05	11.05 ±0.06	3.31 ±0.03	72.48 ±0.07	3.11 ±0.03	8.71 ±0.04	8.22 ±0.04	20.86 ±0.04	154.31 ±0.47	28.11 ±0.07	21.60 ±0.07
V_9	7.42± ±0.05	6.66 ±0.04	9.38 ±0.06	3.66 ±0.04	74.31 ±0.08	3.63 ±0.03	6.38 ±0.03	9.23 ±0.04	21.73 ±0.05	150.63 ±0.45	26.66 ±0.08	17.95 ±0.07
V_{10}	6.42 ±0.06	7.89 ±0.04	12.82 ±0.05	2.89 ±0.05	70.11 ±0.08	2.90 ±0.04	8.49 ±0.05	10.55 ±0.03	22.40 ±0.03	158.70 ±0.49	23.68 ±0.09	21.58 ±0.08
Chausa	5.74 ±0.07	4.69 ±0.04	10.30 ±0.07	2.56 ±0.04	76.51 ±0.07	2.47 ±0.03	7.30 ±0.04	8.53 ±0.03	21.70 ±0.04	154.46 ±0.53	24.55 ±0.07	20.59 ±0.08
Mean	6.03	7.06	10.10	2.58	74.12	2.79	7.89	9.07	21.32	152.07	25.49	19.48
S.Ed (±)	0.422	0.256	0.707	0.707	0.838	----	0.232	0.290	0.235	0.307	0.383	0.509
'F' Test	10.32*	30.49*	9.35*	10.75*	11.38*	18.30	26.89*	38.01*	18.30*	299.30*	194.61*	22.77*
$CD_{0.05}$	0.969	0.590	1.625	0.617	1.926	NS	0.532	0.666	0.541	0.705	2.998	1.169

(mean ± S.D of three replicate)

AV (2.15-3.27 mg KOH/g oil) indicates that the freshly extracted oil from the seed kernels has a negligible amount of free fatty acids. The PV determines the concentration of hydroperoxide, the primary oxidation products. A general rule is that PV should be lower than 10–20 meq/kg fat to avoid rancidity flavor (Connell, 1975). High peroxide values make oils unstable and prone to rancidity (Ojeh, 1981). The PV in MSKO varied between 0.35-0.65 mEq peroxide/kg oil suggesting good keeping quality of MSKO. The IV helps to assess the stability of oil for industrial applications and to estimate unsaturation levels (Xu *et al*., 2007; Agu *et al*., 2020). With higher degree of unsaturation, IV increases and the oils become susceptible to rancidity by oxidation. Iodine value allows classification of oils as non drying, semi drying and drying oils. Non drying oils have IV less than 100 and are ideal for use in food, skincare products etc. MSKO in the present study have IV within the range of 38.86 to 48.89 mg I_2/100g oil with an average of 44.74 mg I_2/100g oil, thus come under non drying class (Mahale and Goswami-Giri, 2011) and therefore, can be used for cooking.

Fatty acid composition

The main determinant of oil quality is the fatty acid profile. Fatty acid composition of MSKO was studied using GCMS. Representative fatty acid chromatogram for the mango germplasm is depicted in Fig 1. In all the chromatograms, four major peaks were observed, which corresponded to palmitic, stearic, oleic and linoleic acids. Area percent and relative percent of major fatty acids in MSKO are presented in Table 3. The major saturated and unsaturated fatty acids were found to be stearic acid (36.16 %) and oleic acid (47.77 %) respectively and together these two constituted about 80 % of total fatty acids. The high content of oleic and stearic acids in MSKO was also reported earlier (Sonwai and Ponprachanuvut, 2014; Wu *et al*., 2015). Higher proportion of oleic acid is also an indication of better stability of the oil. GC-MS study demonstrated the predominance of stearic in Alphonso mango kernel oil (MKO), highlighting its use in the food and cosmetics industries (Ohale *et al.,* 2022)

Total phenol, tannin content and antioxidant properties of MSK

Many earlier studies have shown that MSK contains various phenolic compounds. The average phenol content of MSK was found 25.49 mg CE/g (Table 1). Nisha and Bhatnagar (2014) reported polyphenol content of 117mg catechol equivalents /g peel in a 'desi' variety of Indian mango. Total polyphenol content of mango kernel flour was 47.5 mg GAE per g (Yatnatti and Vijayalakshmi, 2017). Tannins are another large diverse group of complex polyphenolic compounds that function as secondary antioxidants. Tannins are also considered as antinutritional factors. The MSK were found to contain 17.16.5 to 21.75mg/g of tannin as tannic acid (Table 1). However, lower levels of tannin in MSK was also reported - 0.39 % by Elegbede *et al.* (1996) and 0.21 % by Gumte *et al.* (2018).

MSK is a potential source of natural antioxidants because of the presence of phenolic compounds. The extracts from MSK were capable of scavenging DPPH in a concentration-dependent manner. The free radical scavenging activities MSK extracts were found to increase with the increase in concentration (Table 4). The reference compound, ascorbic acid had higher inhibitory activity than MSK extracts over each concentration used for the study. There were significant

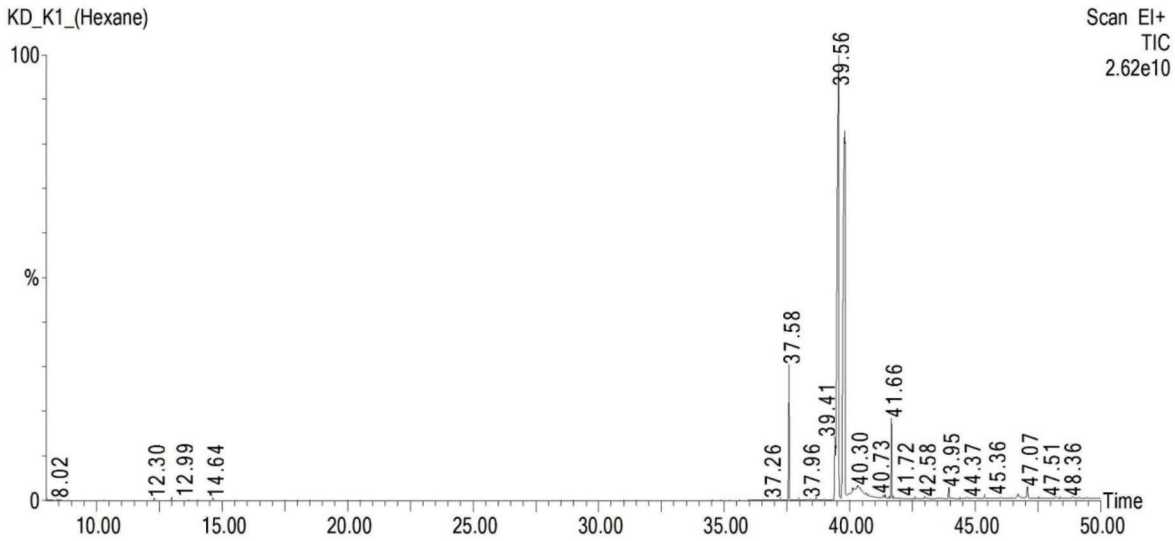

Fig. 1. Representative fatty acid chromatogram of MSKO (V_1)

Table 2. Chemical properties of MSKO

Cultivars	Saponification value (mg KOH/g oil)	Acid Value (Mg KOH/g oil)	Iodine Value (mg I_2/100g oil)	Peroxide Value (meq peroxide/kg oil)
V_1	143.22±0.62	2.58±0.09	47.92±0.09	0.65±0.03
V_2	192.25 ±0.67	3.07±0.08	45.42±0.08	0.54±0.04
V_3	184.74±0.69	2.62±0.09	48.37±0.08	0.43±0.05
V_4	183.35±0.71	2.84±0.09	48.89±0.07	0.53±0.05
V_5	164.13±0.66	2.39±0.06	47.28±0.09	0.49±0.05
V_6	148.22±0.69	3.27±0.07	40.97±0.07	0.56±0.04
V_7	202.59±0.64	2.15±0.08	38.86±0.08	0.52±0.03
V_8	168.48±0.71	2.89±0.05	41.93±0.08	0.38±0.05
V_9	192.59±0.68	2.21±0.07	46.95±0.07	0.35±0.04
V_{10}	164.29±0.49	2.29±0.09	42.58±0.07	0.59±0.04
Chausa	204.44±0.56	2.76±0.08	42.92±0.06	0.46±0.05
Mean	177.12	2.64	44.74	0.50
S.Ed (±)	5.117	0.217	0.623	0.076
'F' Test	33.23*	5.52*	60.09*	2.33*
CD 0.05	11.753	0.500	1.707	0.175

(mean ± S.D of three replicate)

Table 3. Area percent and relative percent of major fatty acids in MSKO

	Palmitic acid		Stearic acid		Oleic acid		Linoleic acid	
	Area (%)	Relative (%)	Area (%)	Relative (%)	Area (%)	Relative (%)	Area (%)	Relative (%)
V1	4.875	4.90	39.430	39.25	39.774	39.60	2.580	2.57
V2	5.494	5.56	41.995	41.52	39.951	39.50	2.094	2.07
V3	3.143	3.10	33.572	33.12	52.473	51.77	2.160	2.13
V4	3.742	3.68	35.791	35.18	51.018	50.15	2.394	2.35
V5	5.486	5.41	36.046	35.55	53.871	53.13	2.493	2.46
V6	4.110	4.01	33.026	32.19	49.008	47.77	1.681	1.64
V7	4.639	4.56	42.073	41.39	42.410	41.72	1.927	1.90
V8	3.239	3.18	31.900	31.32	54.876	53.87	2.517	2.47
V9	4.831	4.79	42.283	41.91	48.117	47.69	3.018	2.99
V10	3.274	3.20	37.828	37.02	49.609	48.55	1.904	1.95
Chausa	5.497	5.42	29.779	29.37	52.446	51.72	2.45	2.42
Average		4.34		36.16		47.77		2.26

differences in the IC_{50} value, a measure of the extract concentration required for 50 % inhibition of DPPH, of mango seed extract (Table 4). Ascorbic acid had the IC_{50} value about 46.56µg/ml, whereas the average IC_{50} value of MSK extract was a little less four times higher (166.92µg/ml). Mounica and Subbiah (2014) suggested the use of MSK extract in different kinds of foods as natural antioxidant.

Mango seeds are a nutritionally rich part of the mango fruit but commonly discarded as waste. Results obtained in the study revealed that MSK flour is a good source of nutrients with antioxidant activity. There were not many differences between the improved variety and the local germplasm of mango in the nutrient and oil content and composition. MSK flour can be used in the bakery products as ingredients in the composite flour and can also be used as animal feed after detailed toxicological studies. MSKO has the potential to be used as edible oil, in cosmetics, candles, soap, bakery products and as cocoa butter alternative. Further research will be necessary to explore the phytochemical profile of different MSKs with their bioavailability and

Table 4. DPPH radical scavenging activities IC50 of MSK extract (µg/ml)

Conc. (µg/ml)	% inhibition (mean ± S.D of three replicate)											
	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	Chausa	Ascorbic Acid
100	42.43 ±0.04	42.56 ±0.04	47.53 ±0.03	44.53 ±0.04	42.45 ±0.03	38.43 ±0.05	42.32 ±0.05	45.12 ±0.03	42.84 ±0.04	41.49 ±0.03	42.43 ±0.03	50.36 ±0.04
200	53.21 ±0.05	52.11 ±0.04	54.21 ±0.03	55.21 ±0.3	53.71 ±0.04	51.11 ±0.05	53.37 ±0.05	53.37 ±0.03	55.67 ±0.05	52.53 ±0.04	53.21 ±0.05	68.43 ±0.05
300	65.76 ±0.05	68.76 ±0.05	70.76 ±0.04	63.56 ±0.05	65.87 ±0.03	62.97 ±0.05	65.72 ±0.04	63.19 ±0.04	66.62 ±0.03	63.4 ±0.03	65.76 ±0.05	79.24 ±0.04
400	76.12 ±0.04	74.12 ±0.03	78.62 ±0.04	70.67 ±0.03	74.62 ±0.05	74.62 ±0.03	77.29 ±0.03	74.64 ±0.04	74.84 ±0.04	71.57 ±0.03	76.12 ±0.04	88.65 ±0.04
500	88.76 ±0.04	85.76 ±0.04	88.76 ±0.04	88.76 ±0.03	88.76 ±0.03	89.83 ±0.05	89.28 ±0.04	85.37 ±0.05	89.17 ±0.03	88.47 ±0.03	88.76 ±0.04	98.04 ±0.04
IC50 (µg/ml)	164.54	133.53	180.79	169.45	160.95	167.36	194.42	159.18	162.01	175.19	168.75	46.56

Mean IC_{50} : 166.92
S.Ed (±) : 0.456
'F' test : 2182.87*
$CD_{0.05}$: 1.046

health effects. Exploiting proper utilization of MSKs and monetizing it should be focused so that might support the Startup India programme.

Authors' contribution

Conceptualization and designing of the research work (KD, SB); Execution of field/lab experiments and data collection (KD, KP); Analysis of data and interpretation (KD, SB); Preparation of manuscript (KP, SB).

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