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SHORT COMMUNICATION

Mango (*Mangifera indica*) Stone Kernel Flour – A Novel Food Ingredient

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ABSTRACT

Introduction: Mango stone kernels constitute the bulk of fruit processing waste. This study aimed to characterise the properties of stone kernel flour prepared from three Indian Mango cultivars (*Neelam, Totapuri* and *Alphonso*) and to identify its functionality as a food ingredient. **Methods:** Mango (*Mangifera indica*) stones of *Neelam, Totapuri* and *Alphonso* cultivars were selected for the study. Mango stone kernel flour (MSKF) was prepared from the stone wastes collected. Functional and nutritional characteristics of MSKF were studied using standard methods. **Results:** MSKF has a water absorption capacity of 3.2-3.4 g/ml and an oil absorption capacity of 0.893 – 1.033g/ml. Flours from the three cultivars depicted a high gelatinisation temperature, wettability and dispersibility. Rheology related property of Least Gelation Concentration identified that at 8%, the MSKF from all three cultivars had the ability to form a stable gel. Properties of emulsion capacity and foaming capacity related to the protein surface of the flours were found to be high. The flours were found to be slightly acidic (4.767 to 4.833) with a high bulk density of 0.791 – 0.816 g/ml. Amongst the nutritional properties of the flours, the *Totapuri* cultivar was found to contain significantly higher protein (7.4 ± 0.265%), crude fat (10.667 ± 0.262%) and crude fibre (1.767 ± 0.208%) content. **Conclusion:** The potential of using this processing by-product as an ingredient in food products was identified from its respective functional and nutritional properties.

Key words: By-product utilisation, food ingredient, functional properties, mango stone kernel flour, nutritional properties

INTRODUCTION

Mango (*Mangifera indica*) is the most important tropical fruit produced in Asia. India has been the most popular traditional centre of mango cultivation with over 100 Indian mango cultivars. *Banganapalli, Bangalora, Neelam, Rumani, Mulgoa, Alphonso* and *Totapuri* are popular cultivars cultivated in the southern region of the Indian subcontinent (Mukherjee & Litz, 2009). Due to the highly perishable nature and seasonal availability of mangoes, it is utilised in the processing industry for the preparation of juice, pulp, canned fruit, jams, pickles, etc. Processing of mangoes generates nearly 45% of fruit waste which comprises primarily of mango peel, mango stone, and spoilt mangoes. This waste is used for the preparation of animal feed and for composting. The kernel is usually obtained by

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breaking open the hard seed coat of the mango stone and it is known for its high starch and fat content (Kittiphoom, 2012).

However, traditional Indian knowledge and practice in the earlier ages suggest that the mango stone kernel had been used in times of acute food shortage as a supplement to wheat flour for the preparation of porridges and unleavened breads. Thus, the current study is aimed at identifying the suitability and functionality of mango stone kernel as a food ingredient.

METHODS

Mango (*Mangifera indica*) stones of *Neelam, Totapuri* and *Alphonso* cultivars were selected as they were extensively used for domestic and industrial consumption thus generating immense stone kernel waste. The stones were collected from an industrial processing unit in Chennai, India

Preparation of MSKF

Mango stone kernels were prepared into flour using a modified method of Ashoush & Gadallah (2011). Stones were cleaned, air-dried and cracked open manually to remove the kernels. Dehulled mango stone kernels were soaked in water for 48 h at 50°C with change of water every 12 h. Soaked kernels were autoclaved at 121°C for 30 min and tray dried at 50°C for 20 h. Dried mango stone kernel pieces were passed through a pulveriser to obtain coarse flour which was sieved. The sieved flour was stored in vacuum pouches until further analysis.

Physical and Functional Properties of MSKF

Physical and functional properties of MSKF from the three Indian cultivars were tested for hydration, rheology, protein surface and structure related properties.

Hydration related properties

Water and oil absorption capacities were determined using Beuchat method mentioned in Sreerama *et al.* (2012) and expressed as volume of water or oil bound by one gram of dried flour sample. Gelatinisation range was recorded as onset and completion temperature for the process (Narayana & Narasinga Rao, 1982). The method of Kulkarni & Kulkarni in Sengev, Akpapunam & Ingbian (2012) was used to determine the wettability and dispersibility of the flour samples.

Rheology related properties

Least gelation concentration was determined by the method of Coffman & Garcia in Fekria *et al.* (2012). The swelling index and solubility were estimated by a process of Leach, McCowen & Schoch, in Fekria *et al.* (2012). Swelling index was expressed as a ratio of the weight of swollen granules divided by the weight of the original dry flour used to make the paste while volume of the supernatant and initial weight of dry flour was expressed as percentage solubility of the flour.

Properties related to protein surface

Emulsification capacity was measured as milliliters of oil per gram of sample. Percentage emulsion stability was also determined (Sreerama *et al.*, 2012). Foaming capacity and stability was measured by a method of Coffman & Garcia in Fekria *et al.* (2012). The pH of the flour was also estimated.

Structure related property

A method of Okaka & Potter in Siddiq *et al* (2010) was used to determine the bulk density and calculated as weight per volume of flour sample.

Chemical and nutritional properties of MSKF

Chemical and nutritional properties such as moisture, total ash, crude protein, crude fat and crude fibre content were estimated by the method of analysis of the Food Safety Standards Authority of India (2012). Total carbohydrate was estimated using the nitrogen free difference method (AOAC, 1990).

Statistical analysis

All data were collected in triplicate and analysed using the Software StatistiXL, version 1.10. Descriptive and inferential statistics were used; mean and standard deviation was calculated. Hypothesis testing was done by one-way Analysis of Variance and *t*-statistical significance was set at $p<0.05$. The separation of means and significant difference comparisons were done using Tukey's honestly significant difference test and statistical significance was set at $p< 0.05$.

RESULTS

Physical and functional properties of MSKF

Physical and functional properties are intrinsic characteristics that affect the behaviour of a food ingredient in a food system during processing, manufacturing, preparation and storage. The successful utilisation of a seed flour as a food ingredient depends on the characteristics that it would impart to the product into which it is incorporated. Hence, a study on the physical and functional properties of MSKF would help to provide information on the utilisation of these flours in the food industry.

Water absorption capacity (WAC)

It was observed that the WAC ranged from 3.2±0.173 to 3.4±0.2 ml/g with *Totapuri* showing the highest WAC. A high WAC is important for expression of properties such as swelling, viscosity and gelation. A WAC value ranging from 1.49 to 4.72 g/g indicates that the flour can offer viscosity to the food product in which it is incorporated such as soups and custards.

Oil absorption capacity (OAC)

It was observed that OAC of the MSKF ranged from 0.893±0.012 to 1.033±0.115 ml/g with no significant difference between cultivars ($p>0.05$). *Totapuri* cultivar recorded the highest OAC (Table 1). A moderate oil absorption capacity for flour suggests its usefulness in the preparation of bakery products and is essential in providing mouth feel and flavour to products.

Gelatinisation range

The onset of gelatinisation was lowest for MSKF from the *Neelam* cultivar (81.93°C) and highest for flour from *Totapuri* cultivar (83°C). Temperatures recorded for completion of gelatinisation was lowest for flour from *Totapuri* (92.93°C) and highest for flour from Neelam cultivar (93.83°C) with no significant difference between temperatures of onset and completion ($p>0.05$) of gelatinisation for all three cultivars (Table1).

Wettability

Alphonso and *Totapuri* had a comparable wettability time while *Neelam* MSKF had the highest wettability at 61.333 sec with no significant differences ($p>0.05$). The property of wettability generally depends on the particle size, density, surface composition and surface activity of the food particle.

Dispersibility

Dispersibility of MSKF ranged from 83.4 % to 85.233% for *Alphonso* and *Neelam* respectively (Table 1) with no significant difference between the three cultivars ($p>0.05$). Several factors affect the dispersibility of flour such as temperature, pH and degree of agitation of the solvent. A higher dispersibility indicates better reconstitution of flour (Sanni *et al.*, 2006).

Least Gelation Concentration (LGC)

LGC is a functional property that helps to determine the ability of flour to form a gel. The LGC of kernel flours from all three mango cultivars was observed to be 8%. Variations in gelling properties have been

Table 1. Physical and functional properties of mango stone kernel flour

Functional Property	*Neelam*	*Totapuri*	*Alphonso*
Water absorption capacity (ml/g)	3.200a ± 0.173	3.400a ± 0.200	3.233a ± 0.153
Oil absorption capacity (ml/g)	0.893a ± 0.012	1.033a ± 0.115	0.967a ± 0.115
Onset gelatinisation temperature (°C)	81.933a ± 0.321	83.000a ± 1.229	82.767a ± 0.569
Completion gelatinisation temperature(°C)	93.833a ± 0.929	92.933a ± 1.537	93.233a ± 1.790
Wettability (seconds)	61.333a ± 0.577	60.333a ± 0.577	60.333a ± 0.577
Dispersibility (%)	85.233a ± 1.904	85.000a ± 1.229	83.400a ± 0.436
Least gelation concentration (%)	8%	8%	8%
Swelling index (g/g)	10.833a ± 0.416	11.067a ± 0.153	10.400a ± 0.361
Solubility (%)	7.300a ± 0.200	7.467a ± 0.153	7.133a ± 0.058
Emulsion capacity (ml/g)	0.247a ± 0.006	0.223a ± 0.012	0.220a ± 0.017
Emulsion stability (%)	43.667a ± 2.082	45.333a ± 3.786	40.667a ± 1.528
Foaming sapacity (%)	51.667a ± 0.577	50.333a ± 0.577	49.667a ± 1.528
Foaming stability at 60 minutes (%)	42.500a ± 0.529	41.733a ± 0.404	41.833a ± 0.850
Foaming stability at 120 minutes (%)	21.600a ± 0.700	20.633a ± 0.681	20.433a ± 0.757
pH	4.833a ± 0.058	4.833a ± 0.115	4.767a ± 0.058
Bulk density (g/ml)	0.798a ± 0.019	0.816a ± 0.021	0.791a ± 0.010

All values have been expressed as mean ± standard deviation. Means in the same row with the same letters are not significantly different at $p < 0.05$.

associated with ratio differences in otheir protein, lipid and carbohydrate contents. A low LGC indicates better gelling capacity and use as an effective thickening agent (Fekria *et al.*, 2012).

Swelling Index

Gelatinisation of starches and flours is characterised by swelling index measurements. From Table 1, it can be observed that *Alphonso* possesses a lower swelling index (10.4 ± 0.361 g/g) while *Totapuri* MSKF has the highest swelling index (11.067±0.153 g/g) with no significant differences between cultivars (p>0.05). A restricted swelling is suitable for flours in preparation of extruded products like noodles.

Solubility

The solubility of MSKF ranged from 7.133 to 7.467 % with no significant difference between the three cultivars (p>0.05). High solubility of flour indicates a positive effect on emulsification, foaming and gelation capacity (Kinsella & Melachouris, 1976).

Emulsion Capacity

The emulsion capacity for MSKF of *Neelam, Totapuri* and *Alphonso* cultivars ranged from 2.2 ± 0.173 to 2.467 ± 0.058 ml/g and did not differ significantly (p>0.05). High fat content in flours can account for higher emulsion capacity as it increases hydrophobicity of the flour and allows a greater amount of oil to be emulsified.

Emulsion Stability

From Table 1, it is evident that the emulsion stability of MSKF of *Neelam, Totapuri* and *Alphonso* cultivars do not differ significantly (p>0.05). The highest emulsion stability was noted for *Totapuri* (45.333 ± 3.786 %) cultivar while the lowest was recorded for *Alphonso* (40.667 ±1.528 %). Research has revealed that flours with a capacity to stabilise emulsions are important as ingredients in food applications such as cakes, coffee whiteners, comminuted meat products and frozen desserts.

Foaming Capacity
The highest foaming capacity was recorded for the MSKF of *Neelam* cultivar. Foaming capacity plays an important role in offering a smoothness, lightness, flavour and palatability to a product.

Foam stability
Foam stability was recorded at 60 min and it was observed that stability ranged from 41.733 – 42.5 % for MSKF Table 1. Foam stability recorded after 120 min of commencement of the experiment was almost half of the stability recoded at 60 min. The lowest foaming stability was observed for *Alphonso* (20.433 %), followed by *Totapuri* (20.633 %) and *Neelam* (21.6 %).

pH
The pH of MSKF of *Alphonso* was the lowest while the highest was for *Totapuri* and *Neelam*. The pH of MSKF prepared in the current study was found to be slightly acidic.

Bulk density
Bulk density of the flours ranged from 0.791 to 0.816 g/ml for *Alphonso* and *Totapuri* respectively (Table 1) with no significant difference observed between three cultivars (p>0.05). Flours with a higher bulk density can increase the viscosity of batters while flours with lower bulk density would reduce thickness of pastes, which is essential during preparation of complementary feeds for children (Fekria *et al*., 2012).

Chemical and nutritional properties of MSKF
Moisture content of MSKF from the three cultivars was found to range from 10.467 to 10.733% with no statistical difference noted between the cultivars (Table 2). Ash content of MSKF ranged from 1.77 to 1.83% with *Neelam* having the highest total ash content though no significant difference was found between the cultivars. The highest protein content was observed for mango stone kernel from the *Totapuri* cultivar (7.4%) while the lowest was observed in the *Neelam* cultivar (6.367%) with a significant difference existing between the cultivars (p<0.05). Crude fat content of MSKF from the three cultivars ranged from 8.233 % to 10.667% (Table 2) with *Totapuri* mango stone kernel recording a significantly high crude fat content (p<0.05). Crude fibre content of mango stone kernels ranged from 1.3 to 1.767%. The *Totapuri* variety had the highest crude fibre content, though no significant difference was recorded between cultivars (p>0.05). Carbohydrate

Table 2. Chemical and nutritional properties of mango stone kernel flour

Nutritional property	*Neelam*	*Totapuri*	*Alphonso*
Moisture (%)	10.733a ± 0.153	10.467a ± 0.153	10.633a ± 0.058
Total ash (%)	1.830a ± 0.046	1.813a ± 0.045	1.770a ± 0.026
Crude protein (%)	6.367a ± 0.153	7.400b ± 0.265	6.600a ± 0.361
Crude fat (%)	8.400a ± 0.361	10.667b ± 0.252	8.233a ± 0.416
Crude fibre (%)	1.300a ± 0.265	1.767a ± 0.208	1.667a ± 0.231
Carbohydrate (%)	71.370a ± 0.226	67.887b ± 0.307	71.097a ± 0.976

All values have been expressed as mean ± standard deviation. Means in the same row with the same letters are not significantly different at p < 0.05.

content of stone kernel flours ranged from 67.887% to 71.370% with significant differences (p<0.05) observed amongst the three cultivars.

DISCUSSION

A good water absorption capacity indicates that the flour could be used as a thickener in liquids since it possesses the ability to absorb water and swell. Oil absorption capacity was lower in these flours than in flours prepared from other mango cultivars, suggesting that it can be used in baked product formulations. A high initial gelatinisation temperature is observed, which indicates that starch granules resist swelling on heating and can be used as a source of starch for thickening. Wettability of MSKF is considerably higher than the wettability of high starch and high protein powders prepared from legumes, milk-based or starchy vegetables indicating its potential in formulations that require greater miscibility in water. Higher bulk density of MSKF is also indicative of its high dispersibility. A lower gelation concentration is indicative of its ability to form a suitable gel and function as a thickening agent.

Swelling index estimated for MSKF indicates that they possess a lower swelling index suitable for preparation of extruded products. Flour prepared in the current study can be used as gelling, thickening or binding agents owing to their solubility characteristics. The emulsion capacity of the MSKF reveals that it can be used in baked products where the attribute of stabilisation of a fat emulsion is essential. It can also be used as a stabilising agent in colloidal food systems. A good foaming capacity for the flour shows that it can be used in the preparation of bread, cakes, whipped toppings, ice creams and frozen dessert.

The low moisture content of MSKF reveals that it is favourable for storage at ambient conditions without spoilage. MSKF was found to have moderate ash content while a significant variation was found between the protein, fat and carbohydrate contents of flour from the three mango cultivars.

CONCLUSION

This study identified the functionality of the MSKF prepared from three Indian mango cultivars namely *Neelam, Totapuri* and *Alphonso.* The unique properties of MSKF offer much potential as a functional ingredient in dough-based foods, baked products setting desserts. The study also assessed the chemical and nutritional properties of stone kernel flours which revealed that MSKF have a moderately highprotein, fat and carbohydrate content. Thus, this agro-waste can be capitalized and used as functional ingredient in various food product categories.

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