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B Kaur
Agricultural and Food Engineering Department, Indian Institute of Technology Kharagpur, West Bengal, India

SK Pyne
Department of Food Technology and Biochemical Engineering, Jadavpur University, Kolkata, India

PP Srivastav
Agricultural and Food Engineering Department, Indian Institute of Technology Kharagpur, West Bengal, India

A Nag
Department of Chemistry, Indian Institute of Technology Kharagpur, West Bengal, India

Correspondence
B Kaur
Agricultural and Food Engineering Department, Indian Institute of Technology Kharagpur, West Bengal, India

Characterization and comparison of mango (*Mangifera indica*) processing waste from five Indian cultivars

B Kaur, SK Pyne, PP Srivastav and A Nag

Abstract
The mango processing results into 20-40% waste, therefore; this study was designed to characterize mango processing waste (MPW) from different cultivars. The Cryogenic Ball mill was used to obtain mango seed kernel powder (MSKP) and mango peel powder (MPP) followed by particle size distribution. The particle size and fineness modulus of all samples ranged from 0.35-0.48 mm and 2.87-4.03 respectively. In MSKP, Chausa had the lowest bulk density (602.08±0.018 g/cm^3). However, the same variety showed highest bulk density (661.76±0.015 g/cm^3) for MPP. The titratable acidity analysis revealed the maximum value (2.35±0.185 %) of MSKP (Dashehari) is same as that of MPP's (Barahmasi) minimum value. During analysis, Duncan's multiple range test revealed significant difference between all MPP varieties for OBC (oil binding capacity) except between Langra and Dashehari. The food industries may take the opportunity to recover and utilize the valuable compounds from agricultural by-products which in turn ensures environmental safety.

Keywords: Mango peel powder, mango seed kernel powder, particle size distribution, density

1. Introduction
Mango (*Mangifera indica*) is extensively planted fruit crop in tropical and subtropical regions and referred as king among all fruits. It is a member of anacardiaceae genera and has more than thousand varieties. A very few of them are commercially grown and traded. In 2016-17, India was the largest producer (19.627 MT) of mangoes with more than 40% share of the total world production (Anonymous, 2017) [4]. The post harvest losses contribute to 9.16%, i.e. due to poor handling, transportation and storage. Additionally, the food industries generate million tons of waste; estimated to be around 30-40% of the fruit weight (Bandyopadhyay *et al*., 2014) [7]. These by-products are highly perishable because of higher moisture content and prone to be attacked by microbes and enzymes (Geerkens *et al*., 2015) [13]. The dumping of by-products is hazardous to environment which ultimately results into soil pollution. Moreover, they can be utilized to eliminate the hazards and probably valuable metabolites could be produced. These metabolites might act as source of fragrances, flavoring compounds, dyes and new drugs.
The mangoes are processed to make numerous products, viz. juice, concentrate, pickles, jam, jelly and canned slices. Mango is rich source of vitamins, proteins, sugars and contains significant amount of bioactive compounds (Abdul Aziz *et al*., 2012) [2]. Its peel is abundant and inexpensive source of pectin, dietry fiber, protein, antioxidants such as phenolic acids, flavanoids, carotenoids, vitamin C and vitamin E (Kim *et al*., 2010; Ashoush *et al*., 2011) [17, 6]. Contrary, Mango seed kernel (MSK) is yet underutilized and promising source of rich quality fat which can be used in chocolates as a replacer for cocoa butter (Puravankara *et al*., 2000) [19]. The MSK oil is rich source of saturated fatty acids and consists of phenolic compounds which exhibit antioxidant activity. The antioxidant activity of the kernel extract is almost 30 to 50 times more than that of the mango pulp and this suggests the possibility to extract useful antioxidants for new product development (Rao, 2015) [22].
Several studies on mango leaves, bark, stem, pulp, peel, peel fiber, seed and seed kernel (Abdalla *et al*., 2007) [1] found that aforementioned parts exhibit different biological activities. The waste utilization and by-product valorization should not only be limited to the by-products of mango processing plants. Moreover, all food industries should widen their focus on research and development of natural bioactive compounds from their by-products.
Grinding is one of oldest and vital mechanical operation for obtaining coarse and fine powdered materials.

Sharma *et al*. (2014) [25] reported that ambient grinding of cumin causes increase in temperature (43-95ºC) which results into loss of volatile oils (18-19%) and flavoring compounds. The fat/oil content in samples is of high concern during ambient grinding. Because heat generated during normal grinding makes the fat to melt which leaks out of vials and degrades the powder quality with lump formation. This leaked fat can be oxidized and there might be generation of dark compounds that is ultimately undesirable and unacceptable. The normal grinding is also detrimental for heat-labile bioactive components and provides final product with poor quality. So, cryogenic grinding is attractive alternative to avoid the quality problems observed in ambient ground products. Cryogenic grinding is a novel technology and with optimal processing conditions, its overall operating cost can be reduced. It helps to retain volatile compounds with increased recovery. The cryo-ground samples have uniform fine particle size, improved color and aroma along with more retention of volatile oil, total phenolics, total flavonoids (Saxena *et al*., 2015) [24]. Ball mill is frequently used for grinding operations and fractures the particles by impact force. There is no chance of choking in ball mill, so; it is easy to operate and comparatively to other small scale mills viz. pin, rotor and hammer mill less amount of energy is needed for the grinding operation (Kaur and Srivastav, 2018; Meghwal and Goswami, 2014) [18, 16]. To the best of the author's knowledge, there is scarcity of data available on implementation of cryogenic grinding in the agricultural commodities.

The key parameters correlated with powder characteristics are moisture content, fat content, physical properties (Bulk, Tapped and Particle density) particle size distribution (PSD) and morphology. Fitzpatrick *et al*. (2004) [12] stated that physical properties plays very important role in designing hoppers, feeders and storage bins. Moreover, they help to understand the problems related to clogging of bulk materials during storage and transportation. The product with high cohesion will result into lump formation along with stickiness which will ultimately result into poor characteristics.

Our previous study was focused on characterization of cryo-ground mango peel powder (Kaur and Srivastav 2018) [16]. The information about physico-chemical and functional characteristics is very critical to decide the ultimate use of powdered product. It is probable that genetic and environmental factors affect the particle size, density, acidity, water/oil binding capacity. However, the variation in mentioned properties influenced by cultivars is still deficient. So far, the effect of cryogenic grinding on the properties of mango by-products is neither determined nor documented. Hence in this study, MSKP and MPP from five cultivars were compared for their physico-chemical and functional characteristics with the aim of exploiting the by-product with superior quality.

2. Material and Methods

2.1 Raw Materials

The mango seed kernel and peel of five varieties (Chausa, Langra, Neelum, Barahmasi and Dashehari) were collected from the Science and Technology Entrepreneurs Park (STEP) of Indian Institute of Technology Kharagpur, West Bengal, India during the month of May-July, 2017. A bottle of refined groundnut oil was purchased from a local market for the experiment. The analytical grade chemical reagents were used for the study.

2.2 Preparation of MSKP and MPP

The kernels were obtained from mango seed using nut shelling machine followed by cutting (1cm width). On the other hand mango peels were sliced with sharp knife into uniform strips of 1cm X 3cm. The cut pieces of seed and peel were placed into tray dryer (50±3°C) for 48 hours. The cryogenic ball mill with Liquid nitrogen as refrigerant was used to obtain MSKP and MPP. The cryo-ground MPP was obtained as described in our previous study (Kaur and Srivastav, 2018) [16]. The dried MSK (100g) slices were pre-cooled with liquid nitrogen and were fed into cryogenic ball mill with feed rate of 2 Kg/h, pin mill speed of 10,000 rpm and screw speed of 3 rpm. Same procedure was followed to obtain MSKP from all the cultivar. A thermocouple (Type K) with NiCr-Ni sensor probe was used to record and monitor temperature at end of each batch. The temperature of final product was -97±10ºC. Afterwards, the samples were allowed to reach in equilibrium with the ambient temperature and were stored in air tight bottles at 4±2ºC until use.

2.3 Particle size distribution

The MSKP and MPP were analyzed for PSD using sieve shaker (Retsch GmbH, Haan, Germany). The samples were passed through set of standard sieves (710, 500, 300, 250, 212, 180 and 150 µm) for period of 10 minutes. After 10 minutes, the powder on every sieve was collected and weighed. The sieve analysis was done to obtain the values for fineness modulus and average particle size (Barnwal *et al*., 2015) [8].

$$\text{Fineness modulus} = \frac{\text{Total percent retained on sieve}}{100}$$

$$\text{Average particle size} = [0.135 \times (1.366)^{\text{FM}}]$$

2.4 Physical Properties

The bulk density was measured with slight modification in ASTM - B 417 method (1995) [3], commonly called as funnel method. The distance of 10 cm was maintained between funnel and cylindrical container. The sample was poured through funnel (5 mm diameter) into cylindrical container (50 cc volume) until it was filled. After filing the container, upper layer of sample was leveled with iron strip followed by weight measurement to obtain the value for bulk density.

The filled container with poured sample was then vertically tapped for 15 minutes until the volume was constant. It is an attempt to obtain the highest packing (and density) before compaction (Santomaso *et al*., 2003) [23].

The true density of samples was recorded using Automatic gas pycnometer (Model ULTRAPYC 1200e, Quantachrome Instruments, Florida, USA) whose principle is gas displacement.

The MSKP and MPP was explored for their flowability and cohesion by finding Hausner Ratio (HR) and Carr Index (CI) according to procedure described by (Rayo *et al*., 2015) [21].

2.5 Chemical Properties

2.5.1 pH and Titratable Acidity (TA)

One gram of MPP/MSKP was dissolved in 100mL of lukewarm distilled water (50ºC) followed by filtration (Sogi *et al*., 2013) [26]. The µC pH system 361 (Systronics Instruments, Gujarat, India) was used to measure pH of the slurry. The data for titratable acidity was recorded by titration of the extract against standard 0.1M NaOH solution using phenolphthalein indicator.

2.6 Functional Properties

2.6.1 Water and oil binding capacity (WBC and OBC)

The MSKP and MPP samples from all the cultivars were analyzed for functional properties, viz. water and oil binding capacities as described by Beuchat (1977) [9] with some alteration. Five grams of sample was weighed in 250 ml beaker followed by addition of 25 ml distilled water/groundnut oil. The mixture was vigorously shaken using handheld homogenizer (MT-13K, UR- Biocoction pvt. Ltd. Kolkata, India) for 30 minutes. The obtained slurry was then centrifuged in cold centrifuge (D-37520, Sigma-Labozentrifugen, Germany) at 10000 g for 20 minutes. The supernatant liquid was collected in small beaker and weighed. Water and oil binding capacity were presented as mL water/oil bound per gram of sample.

2.6.2 Solubility

The solubility was measured by slight modification in method described by Cano-Chauca *et al.* (2005) [10]. A sample concentration of 1:100 (w/v) was prepared for analysis. The solution was homogenized and transferred to blender jar operating at high velocity for 5 minutes. The mixture was then centrifuged at 5000 g for period of 10 minutes. The supernatant was then poured into petri plates and placed in oven drier at 103±5 °C for 24 hours.

2.7 Statistical analysis

The samples were analyzed in triplicates. The findings were presented as mean ± standard deviation which was calculated using standard statistical procedures. The data obtained was analyzed statistically with Duncan's multiple range test (p<0.05) in SPSS (Version 20.0, IBM Corporation, Armonk, NY, USA) software. The level of significance (a-e) was assigned to denote the difference in the parameter values among all cultivars. The difference among samples were defined to be significant, if p≤0.05.

3. Results and Discussion

3.1 Fineness modulus and average particle size

The result of particle size distribution (Table 1) indicates that the average particle size of MSKP and MPP was found to be in the range of 0.35±0.003-0.47±0.006 mm and 0.40±0.005-0.48±0.011 mm respectively. These properties play very crucial role in determining the shelf life of the food.

Table 1: Fineness modulus and Average particle size of Cryo-ground MSKP and MPP from different cultivars (n = 5)

Variety	Fineness modulus		Average particle size (mm)	
	MSKP	MPP	MSKP	MPP
Chausa	3.98±0.021^{a}	4.03±0.077^{a}	0.47±0.006^{a}	0.48±0.011^{a}
Langra	3.90±0.025^{bc}	3.55±0.032^{c}	0.46±0.004^{bc}	0.41±0.004^{c}
Neelum	2.88±0.035^{d}	3.77±0.044^{b}	0.36±0.005^{d}	0.44±0.006^{b}
Barahmasi	2.87±0.021^{d}	3.46±0.037^{d}	0.35±0.003^{d}	0.40±0.005^{d}
Dashehari	3.95±0.035^{ab}	3.65±0.046^{c}	0.46±0.005^{ab}	0.42±0.006^{c}

Values are expressed on dry weight basis. All data are the mean ± SD of three replicates. SD followed by different subscripts in the same column differs significantly (P≤0.05).

The samples became very fragile due to liquid nitrogen during grinding process and results into finer particles. The finer powders are more susceptible to cohesion because of large number of binding sites which ultimately causes difficulty to flow (Teunou *et al.*, 1999) [28]. During the grinding process, there is increase in surface area that may favor in strengthening of bond among particles.

3.2 Physical Properties

Physical properties are very crucial factor while designing and constructing hoppers, storage systems and equipments (Fitzpatrick *et al.*, 2004) [12]. Table 2 illustrates the physial properties of MSKP and MPP that affects flowability of powders. Flowability of powders is affected majorly by moisture content, particle size and density.

3.2.1 Bulk density

In MSKP, Chausa has the lowest value for bulk density. However, the same variety has highest value for bulk density in MPP. No significant difference (P≤0.05) could be recorded for bulk density between Neelum, Barahmasi and Dashehari, meanwhile; significant difference was observed between the aforementioned samples and Chausa, as well as Langra seed powder (Table 2). Both, MSKP as well as MPP are hygroscopic in nature. So, proper care has to be taken.

Table 2: Flowing properties of Cryo-ground MSKP and MPP from different cultivars (n = 5)

Variety		Bulk density (g/cm^{3})	Tapped density (g/cm^{3})	Particle density (g/cm^{3})	Porosity (%)	HR	CI
Dashehari	MPP	655.12±0.006^{a}	915.26±0. 012^{a}	1528.62±0.01^{c}	57.79±0.432^{bc}	1.41±0.006^{a}	29.34±0.475^{a}
	MSKP	704.26±0.017^{a}	1038.94±0.045^{ab}	1548.15±0.006^{a}	54.83±1.252^{b}	1.49±0.029^{b}	32.89±2.570^{b}
Barahmasi	MPP	628.28±0.015^{a}	901.19±0. 023^{ab}	1566.49±0.004^{a}	59.68±1.108^{b}	1.42±0.030^{a}	29.58±1.576^{a}
	MSKP	662.29±0.018^{a}	1055.06±0.058^{a}	1550.21±0.006^{a}	57.48±1.158^{ab}	1.59±0.042^{b}	36.88±2.625^{ab}
Neelum	MPP	664.02±0.025^{a}	874.45±0. 017^{bc}	1564.93±0.005^{b}	57.64±1.475^{bc}	1.33±0.049^{b}	24.45±3.064^{b}
	MSKP	657.60±0.031^{a}	969.38±0.009^{ab}	1539.08±0.006^{a}	56.82±1.965^{ab}	1.47±0.057^{b}	32.00±2.667^{b}
Langra	MPP	588.37±0.025^{b}	792.94±0. 015^{d}	1549.28±0.006^{b}	62.08±1.464^{a}	1.35±0.047^{ab}	25.76±2.375^{ab}
	MSKP	625.83±0.022^{b}	974.14±0.008^{b}	1542.37±0.006^{a}	57.80±1.755^{ab}	1.57±0.062^{b}	36.26±2.601^{b}
Chausa	MPP	661.76±0.015^{a}	868.21±0.021^{bc}	1511.51±0.005^{d}	56.26±0.934^{c}	1.32±0.057^{b}	24.28±3.278^{b}
	MSKP	602.08±0.018^{b}	1039.47±0.052^{ab}	1519.78±0.006^{b}	60.32±1.187^{a}	1.73±0.013^{a}	42.01±2.403^{a}

Values are expressed on dry weight basis. All data are the mean ± SD of three replicates. SD followed by different subscripts in the same column differs significantly (P≤0.05).

by storing them in air tight containers. Raigar and Mishra (2015) [20] reported that the smaller particles occupy less pore volume than the larger ones which is a possible reason for higher bulk density.

3.2.2 Tapped density
Barahmasi and Dashehari had the highest values of tapped density for MSKP and MPP respectively, whereas; the lowest values were observed for Neelum and Langra. The higher density of Barahmasi might be due to the presence of homogenous and finer particles. The grinding process results into the product with greater surface area and decreased pore space among particles which ultimately leads to increase in density.

3.2.3 Particle density
Among all the varieties, Barahmasi has the highest value for particle density in both MSKP and MPP. And, same is the case with Chausa; it has lowest value for both MSKP and MPP.

3.2.4 Porosity
In MPP, Chausa has the lowest value for porosity. However, the same variety has highest value for MSKP.

3.2.5 HR and CI
There is dearth of information available on HR and CI of Mango by-products. Geldart *et al*. (2006) [14] classified the powders as: powders having values of HR<1.25 fall into groups A, B, or D, while powders having values of HR>1.25-1.4 show semi-cohesive properties and powders with HR>1.4 are cohesive and difficult to fluidize. Flowability of powders with CI<15 are classified as very good; CI: 15-20 as good; 20-35 fair; 35-45 bad (Rayo *et al*., 2015) [21]. According to this classification, MSKP (HR>1.4) and MPP (HR>1.25-1.4) are cohesive and semi-cohesive respectively. The higher RH atmosphere is unfavorable for samples because it will add more moisture to the powder and will result into lump formation. The CI values for MPP (CI: 20-35) indicates their fair flowing nature. While, MSKP (CI: 35-45) was revealed to exhibit poor flowability. The Chausa variety has highest HR and CI for MSKP, however; lower values in case of MPP. In MPP, Dashehari resulted to have highest HR and CI, whereas; Neelum had lowest values for both in MSKP.

3.3 Chemical properties
The chemical characterization findings (Table 3) of MSKP revealed to have pH between 4.70±0.015-5.19±0.012 which is similar to results reported by Arogba (1997) [5]. The pH values indicated that the significantly highest pH values were 5.51±0.057 and 5.19±0.012 for Neelum (MPP) and Chausa (MSKP) respectively.

Table 3: pH and titrable acidity of Cryo-ground MSKP and MPP from different cultivars (n = 5)

Variety	pH		Titrable acidity (%)	
	MSKP	MPP	MSKP	MPP
Chausa	5.19±0.012[a]	5.50±0.012[a]	1.94±0.035[c]	2.52±0.075[bc]
Langra	5.01±0.012[b]	4.78±0.006[d]	1.91±0.012[d]	2.88±0.320[ab]
Neelum	4.81±0.012[c]	5.51±0.057[a]	2.04±0.106[b]	3.09±0.185[a]
Barahmasi	4.70±0.015[d]	4.86±0.012[c]	2.04±0.174[b]	2.35±0.370[c]
Dashehari	4.72±0.006[d]	5.38±0.006[b]	2.35±0.185[a]	3.31±0.185[a]

Values are expressed on dry weight basis. All data are the mean ± SD of three replicates. SD followed by different subscripts in the same column differs significantly (P≤0.05).

This result means that the mango cultivars with pH values of more than 4.5 require the acidification before thermal preservation at temperatures less than 100°C (Elsheshetawy *et al*., 2016) [11]. The least value for TA among MPP (Barahmasi) is equal to the highest value of MSKP (Dashehari). The TA reflects the stability of the product throughout the storage period. Moreover, a slight difference in the pH value was observed with the reduction in the grinding temperature that was presumed due to rise in the availability of organic acid because of increased surface area (Ghodki and Goswami, 2016) [15]. The obtained results are in accordance with the pH value of mango pulps reported by Elsheshetawy *et al*. (2016) [11] with pH values in the range of 4.7-5.1.

3.4 Functional Properties
The WBC and OBC are important factors in product formulation, since; this determines the amount of water to be incorporated and oil to be absorbed during development of novel food (Tasneem *et al*., 1982) [27]. The functional characteristics of the MSKP and MPP as a function of varietal difference are shown in Table 4.

The WBC of MPP (1.79±1.345 to 2.81±1.559 mL/g) is almost 1.5-2 fold of MSKP (0.90±0.012 to 1.075±0.253 mL/g) for all the varieties. MPP is good source of crude fiber (Kaur and Srivastav, 2018) [16] which contains hydroxyl functional group in its structure. Hence, fiber can be the possible reason for higher WBC of MPP because it encourages the more interaction with water through hydrogen bonding. The hydration attribute is essential in bakery products to avoid staling and therefore increase in shelf life (Abdul Aziz *et al*., 2012) [2]. This makes MPP, a suitable functional ingredient which can be used in bakery industry for dough, bread and pastry products. There was no significant difference (P≤0.05) in OBC of MPP among Langra and Dashehari cultivar. The OBC of MPP is higher than that of MSKP for all the varieties except Neelum. The higher OBC of Neelum seed kernel powder (1.55±1.702 mL/g) was possibly due to presence of more lipophilic groups than hydrophilic ones. Thebaudin *et al*. (1997) [29] stated that the higher OBC is directly proportional to more flavor retention. The retention of flavor for longer period plays key role in many foods to enhance the mouthfeel. This indicates the possible use of Neelum (MSKP) in the products where high flavor retention is required.

Table 4: Functional properties of Cryo-ground MSKP and MPP from different cultivars (n = 5)

Variety	OBC (mL/g)		WBC (mL/g)		Solubility (%)	
	MSKP	MPP	MSKP	MPP	MSKP	MPP
Chausa	1.55±0.079[a]	1.74± 0.135[a]	0.90±0.012[c]	1.79±1.345[c]	24.80±2.623[a]	26.69±0.929[a]
Langra	1.09±0.186[b]	1.37±0.511[c]	1.01±1.057[bc]	2.10±0.825[b]	23.97±2.237[ab]	27.91±1.350[a]
Neelum	1.55±1.702[a]	1.20±0.187[d]	0.96±0.909[bc]	2.28±1.184[b]	23.70±2.389[ab]	20.03±1.121[c]

Barahmasi	1.56±0.827[a]	1.50±0.748[b]	1.075±0.253[ab]	2.81±1.559[a]	20.20±1.637[b]	18.87±2.006[c]
Dashehari	1.11±1.891[b]	1.34±0.212[c]	1.20±1.422[a]	2.21±1.002[b]	22.80±1.833[ab]	24.28±0.467[b]

Values are expressed on dry weight basis. All data are the mean ± SD of three replicates. SD followed by different subscripts in the same column differs significantly ($P \leq 0.05$).

The solubility of MSKP and MPP of different cultivars are illustrated in (Table 4). The highest solubility was noticed for the Langra (MPP) and Chausa (MSKP). In case of MPP, solubility was highest for Chausa (26.69±0.93%) and least for Barahmasi (18.87±2.006%). The data obtained showed that MSKP (Chausa, Langra and Barahmasi) had lower solubility than that of MPP. The low solubility of MSKP from particular varieties might be due to presence of more fat and starch in kernel than that of peel which may produce the hydrophilic effect. This characteristic is very important for interaction of ingredients during product development.

4. Conclusion

Industries are looking forward for valorization of these by-products. In addition, it reduces problems related to waste dumping and improves functional quality of the food. Out of all cultivars only Langra showed the significant difference for bulk density in MPP. The research showed that MSKP (1.47±0.057-1.73±0.013) has poor flowability as compared to MPP (1.32±0.057-1.42±0.030) because of high HR values. The TA was highest for Neelum (MPP- 3.9±0.185 %) cultivar and citric acid represent a vital part of this value. The data collected is of interest to bakery industry for incorporation of MPP (Barahmasi) and MSKP (Dashehari) in the bakery products because of their higher WBC as 2.815±1.559 mL/g and 1.201±1.422 mL/g respectively. The OBC values for all the verities of MPP are higher than MSKP except for Neelum variety. So, this shows the superior nature MPP to be used as flavor retaining ingredient. It can be clearly predicted that future trend of research will be in the direction of by-products processing and their ultimate use. Moreover, this study proposes the comprehensive understanding about the properties of mango by-products and their dependence on varietal difference.

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Declaration of Interest

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References

1. Abdalla AEM, Darwish SM, Ayad EHE, El-Hamahmy RM. Egyptian mango by-product 2: Antioxidant and antimicrobial activities of extract and oil from mango seed kernel. Food Chemistry. 2007; 103(4):1141-1152.
2. Abdul Aziz NA, Wong LM, Bhat R, Cheng LH. Evaluation of processed green and ripe mango peel and pulp flours (*Mangifera indica* var. Chokanan) in terms of chemical composition, antioxidant compounds and functional properties. Journal of the Science of Food and Agriculture. 2012; 92(3):557-563.
3. American Society for Testing and Materials. Standard test method for apparent density of non-free-flowing metal. ASTM B 417-89 (reapproved 1995), 1989.
4. Anonymous. Horticultural statistics at a glance 2017. National Horticulture Board, 2017.
5. Arogba SS. Physical, chemical and functional properties of Nigerian mango (*Mangifera indica*) kernel and its processed flour. J sci food agric. 1997; 73(3):321-328.
6. Ashoush IS, Gadallah MGE, Analysis P. Utilization of Mango Peels and Seed Kernels Powders as Sourcesof Phytochemicals in Biscuit. World Journal of Dairy & Food Sciences. 2011; 6(1):35-42.
7. Bandyopadhyay K, Chakraborty C, Bhattacharyya S. Fortification of Mango Peel and Kernel Powder in Cookies Formulation. Journal of Academia and Industrial Research. 2014; 2(12):661-664.
8. Barnwal P, Singh K, Mohite A, Sharma A, Saxena S. Grinding Characteristics of Fenugreek Powder. Journal of Food Processing and Preservation. 2015; 39(6):1243-1250.
9. Beuchat LR. Functional and electrophoretic characteristics of succinylated peanut flour protein. Journal of Agricultural and Food Chemistry. 1977; 25(2):258-261.
10. Cano-Chauca M, Stringheta PC, Ramos AM, Cal-Vidal J. Effect of the carriers on the microstructure of mango powder obtained by spray drying and its functional characterization. Innovative Food Science and Emerging Technologies. 2005; 6(4):420-428.
11. Elsheshetawy HE, Mossad A, Elhelew WK, Farina V. Comparative study on the quality characteristics of some Egyptian mango cultivars used for food processing. Annals of Agricultural Sciences. 2016; 61(1):49-56.
12. Fitzpatrick J, Barringer SA, Iqbal T. Flow Property Measurement of Food Powders and Sensitivity of Jenike's Hopper Design Methodology to the Measured Values. Journal of Food Engineering. 2004; 61(3):399-405.
13. Geerkens CH, Nagel A, Just KM, Miller-Rostek P, Kammerer DR, Schweiggert RM *et al*. Mango pectin quality as influenced by cultivar, ripeness, peel particle size, blanching, drying, and irradiation. Food Hydrocolloids. 2015; 51:241-251.
14. Geldart D, Abdullah EC, Hassanpour A, Nwoke LC, Wouters I. Characterization of powder flowability using measurement of angle of repose. China Particuology. 2006; 4(3-4):104-107.
15. Ghodki BM, Goswami TK. Effect of grinding temperatures on particle and physicochemical characteristics of black pepper powder. Powder Technology. 2016; 299:168-177.
16. Kaur B, Srivastav PP. Effect of Cryogenic grinding on chemical and morphological characteristics of mango (*Mangifera indica* L.) peel powder. Journal of Food Processing and Preservation. 2018; 42(4):e13583.
17. Kim HJY, Moon H, Kim D, Lee M, Cho H, Choi YS *et al*. Antioxidant and anti-proliferative activities of mango (*Mangifera indica* L.) flesh and peel. Food Chemistry. 2010; 121(2):429-436.
18. Meghwal M, Goswami TK. Comparative study on ambient and cryogenic grinding of fenugreek and black pepper seeds using rotor, ball, hammer and Pin mill. Powder Technology. 2014; 267:245-255.
19. Puravankara D, Boghra V, Sharma RS. Effect of antioxidant principles isolated from mango (*Mangifera*

indica L) seed kernels on oxidative stability of buffalo ghee (butter-fat). Journal of the Science of Food and Agriculture. 2000; 80(4):522-526.

20. Raigar RK, Mishra HN. Effect of Moisture Content and Particle Sizes on Physical and Thermal Properties of Roasted Bengal Gram Flour. Journal of Food Processing and Preservation. 2015; 39(6):1839-1844.
21. Rayo LM, Chaguri e Carvalho L, Sardá FAH, Dacanal GC, Menezes EW, Tadini CC. Production of instant green banana flour (*Musa cavendischii*, var. Nanicão) by a pulsed-fluidized bed agglomeration. LWT - Food Science and Technology. 2015; 63(1):461-469.
22. Rao VK. Mango kernel extracts as potential antioxidant food additives. Journal of Food Processing and Technology. 2015; 6:66.
23. Santomaso A, Lazzaro P, Canu P. Powder flowability and density ratios: The impact of granules packing. Chemical Engineering Science. 2003; 58(13):2857-2874.
24. Saxena SN, Sharma YK, Rathore SS, Singh KK, Barnwal P, Saxena R *et al*. Effect of cryogenic grinding on volatile oil, oleoresin content and anti-oxidant properties of coriander (*Coriandrum sativum* L.) genotypes. Journal of Food Science and Technology. 2015; 52(1):568-573.
25. Sharma LK, Agarwal D, Sharma Y, Rathore SS, Saxena SN. Cryogenic grinding technology enhances volatile oil, oleoresin and antioxidant activity of cumin (*Cuminum cyminum* L.). International Journal of Seed Spices. 2014; 4(2):68-72.
26. Sogi DS, Siddiq M, Greiby I, Dolan KD. Total phenolics, antioxidant activity, and functional properties of Tommy Atkins mango peel and kernel as affected by drying methods. Food Chemistry. 2013; 141(3):2649-2655.
27. Tasneem Ramsmani R, Subramaja, V. Functional properties of guar seed (*Cyamopsis tetragonoloba*) meal detoxified by different methods. Journal of Food Science. 1982; 47(4):1323-1328.
28. Teunou E, Fitzpatrick JJ, Synnott EC. Characterization of food powder flowability. Journal of Food Engineering, 1999; 39(1):31-37.
29. Thebaudin JY, Lefebvre AC, Harrington M, Bourgeois CM. Dietary fibres: Nutritional and technological interest. Trends in Food Science and Technology. 1997; 8(2):41-48.