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# Influence of particle size on physical and sensory attributes of mango pulp powder

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A b s t r a c t. The present investigation was aimed to observe the effect of particle size on physical, sensory and thermal properties of foam-mat dried mango pulp powder. Mango pulp of *Dussehri* variety was foam-mat dried using 3% egg white at 65°C. Dried foam-mats were pulverized and passed through a sieve shaker for obtaining three grades of powder with 50, 60, and 85 mesh size sieves. The particle size of these samples measured using laser diffraction particle size analyzer ranged from 191.26 to 296.19 µm. The data was analysed statistically using ANOVA of SAS. There was a linear increase in lightness (‘L’ value) with a decrease in particle size, however, ‘a’ value decreased with a decrease in particle size, indicating the decrease in redness. An increase in bulk density and decrease in water solubility index and water absorption index % were observed with a decrease in particle size. Particle size had a significant effect on sensory parameters. Particle size in the range of 258.01 to 264.60 µm was found most acceptable with respect to sensory characteristics. This finding can be exploited for various commercial applications where powder quality is dependent on the particle size and has foremost priority for end users.

K e y w o r d s: particle size, laser diffraction technique, sensory acceptability, colour properties, thermal properties

## INTRODUCTION

Many food materials across many branches of food industry are produced as dry powders or granules. The stability, chemical reactivity, opacity, flowability and material strength of many materials are affected by the size and characteristics of the particles within them. Particle science and technology is a rapidly developing interdisciplinary research area with its core being the understanding of the relationships between micro and macroscopic properties of particulate/granular matter – a state of matter that is widely encountered but poorly understood (Zhu *et al*., 2007). Particle size is an important physical property of powder and can relate to various powder characteristics. Understanding and controlling particle size distribution in the raw material can be critical to the success of today food manufacturing process. Differences in particle size can lead to stratification of the powder with the higher solids concentrated at the top which will affect reconstitution of the dry product. The shape and size of particles will affect the closeness of the particle pack, which in turn will affect the powder bulk density.

In tropical and subtropical countries, an enormous amount of fruits and vegetables are produced which are extremely attractive from a commercial point of view, a typical example being the mango. However, in association with the seasonal problem, most of these products, in a mature state, containing high water content, are quite susceptible to degradation. Mango (*Mangifera indica* L.) is the most important fruit of Asia. Nutritional importance of mango is mainly due to carotenes and other bioactive compounds (Hymavathi and Khader, 2005). Ripe mango processing into juice or drying has been proposed as a solution to reduce post-harvest losses (Kansci *et al*., 2003). Also, there is high preference for mango juice. Since juice and other foods could be produced from mango powder, the process of powder manufacturing from ripe mango seems to be a good technological option for the reduction of postharvest losses in mango. Mango powder has various applications in food and beverage industry.

Various studies have been reported for the development of mango powder using various techniques such as freeze drying, spray drying, vacuum drying, and foam-mat drying (Cano-Chauca, 2005; Harnkarnsujarit and Charoenrein, 2011; Jaya and Das, 2004; Kadam *et al*., 2010; Rajkumar *et al*., 2007; Wilson *et al*., 2012). The challenge in producing fruit powders is to reduce stickiness during drying and safe handling and storage of the powder (Jaya *et al*., 2006). One

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of the promising methods that can be used for this highly viscous, sticky and high sugar containing material is foam-mat drying, where a liquid material is converted into stabilized foam by whipping after the addition of edible foaming agents. Over the past decade, this relatively old technology, known as foam-mat drying, received renewed attention because of its added ability to process hard-to-dry materials to produce products of desired properties, retaining volatiles that otherwise would be lost during the drying of non-foamed materials (Kadam and Balasubramanian, 2011; Ratti and Kundra, 2006). During foam-mat drying, the foam stabilizers, such as glycerol monostearate (GMS), carboxyl methyl cellulose, egg albumin, pectin, and modified soya protein allow retention of the puffed structure (Kadam *et al*., 2010; Rajkumar *et al*., 2007).

Complete knowledge of physical and sensory properties of any food powder has a decisive importance for the realization of many technological processes, especially for monitoring their quality and consumer acceptance. An in-depth and complete understanding of the powder properties is essential in order to optimize the process in terms of functionality and cost (Kurozawa *et al*., 2009). As per our knowledge, the effect of particle size on various properties of foam-mat dried mango pulp powder has not been reported. Thus, with this background, the present investigation was aimed to observe the effect of particle size on various physical properties and sensory attributes of foam-mat dried mango pulp powder.

## MATERIALS AND METHODS

The experiment of foam-mat drying of mango juice/pulp was carried out at Central Institute of Post-Harvest Engineering and Technology (CIPHET), Ludhiana, Punjab (India). The foam-mat dried mango pulp powder was prepared using the method followed by Kadam *et al*. (2010). In brief, ripe mangoes (*M. indica* L.) cv. Dussehri were purchased from the local market of Ludhiana. Fruits of similar ripeness, having uniform visual quality and size were selected. The mangoes were subjected to washing with running water, peeling of skin and stone removal before juice/pulp preparation using a mixer. The pulp was homogenized using a domestic mixer after peeling of skin and stone removal. Foaming was achieved by adding 3% (w/w) egg white in homogenized mango juice/pulp using a hand blender (Orpat-HHB100E, Ajanta Ltd., India) at 18 000 r.p.m. for 3 min. Foamed juice was poured in food-grade stainless steel trays and spread to obtain 3-mm-thick foam-mat and dried at 65°C air temperature in a tray dryer (MSW-210, Macro Scientific Work, India). The dried product (with about 3% moisture content on wet basis) was scraped and pulverized before packing for further studies.

The mango powder was graded based on particle size using a sieve shaker with three mesh sizes *viz*. 50, 60 and 85 mm British Sieve Size (BSS). The sample was placed on the top sieve with the largest mesh size followed by the smaller ones and shaken for 10 min, disassembled and stirred lightly, then shaken for additional 5 min. The residue remaining on each sieve was packed in polythene pouches. The mango powders with different mesh sizes were evaluated for physical and sensory properties. The particle size of the samples was measured using a laser-diffraction particle size distribution analyzer (LA-950, Horiba Ltd., Kyoto, Japan). The experiments were carried out in wet cell using water as the solvent. Particle size analyses were applied for each sample five times and the average of them was taken.

The effect of particle size on colour properties of mango powder was evaluated by a Hunter Colorimeter (Hunter and Harold, 1987). Colorimetric analysis on freshly extracted mango pulp and powder was performed using a Hunter Lab Miniscan XE Plus colorimeter (Hunter Associates Laboratory Inc., Reston, VA, USA) with a 25 mm aperture set for illumination D65 and 10° standard observer angle. Four values were taken for each parameter of all the samples. Thermal conductivity and thermal resistivity were measured by a 10 cm single needle TR-1 probe method (KD2 Pro, Decagon Devices, Pullman, WA, USA) with sample temperature of 20°C. Bulk density of the samples was determined following the modified method of Okaka and Potter (1979). The analyses were done in triplicate. The coefficient of rehydration, rehydration ratio, and content water rehydrated were calculated based upon the method followed by Ranganna (2003). The water solubility index (WSI) and water absorption index (WAI) were determined by the method of Qing-Bo *et al*. (2005).

For conducting sensory evaluation, the mango powder was reconstituted by dissolving 12 mg 100 $ml^{-1}$ of distilled water, which was standardized by preliminary experimentation (data not given). The reconstituted juice was pre-chilled in order to achieve the temperature of 15-18°C before serving to the panelists. The reconstituted mango juices with different particle size were evaluated for sensory acceptability in terms of colour, aroma, taste, consistency, and overall acceptability by the nine-point hedonic scale, where 9 is extremely liked and 1 extremely disliked. 15 semi-trained panelists were selected from CIPHET, Ludhiana including both male and female members. Each sample was given a three-digit code number before tasting.

Statistical analysis was accomplished using SAS version 9.2. The effect of particle size on various properties was analysed using one way ANOVA. Differences between the sample means were analyzed by Duncan multiple range test (DMRT) and least square difference (LSD) at $\alpha$ level of 0.05 and 0.01.

## RESULTS AND DISCUSSION

The particle size of the three grades of mango pulp powders obtained by sieve analysis, determined by the laser diffraction technique was found to be 191.26±1.12 μm for the particles passing through the 85 mesh. The particle size for the powder samples passing through the 50 and 60 mesh sieves were 296.19±5.06 and 260.09± 3.91 µm respectively. Thus, it can be said that the higher the mesh size, the finer are the pores of the sieve and the lesser the particle size of the particles passing through the particular sieve.

There was a significant ($p<0.05$) effect of particle size on various colour properties. 'L' value *ie* lightness of the powder increased with the decrease in particle size, mango powder with particle size of 191.26 µm being the lightest. There was a linear decrease in 'a' value with a decrease in particle size indicating the decrease in redness with size reduction. The means of 'b' values were not significantly different with the changing particle size. There was a significant ($p<0.05$) linear increase in hue angle with the decrease in particle size. TCD (total colour difference) was found to be highest in the largest particle sized powder while the chroma value was the highest for the powder with a 260.09 µm size although there was no significant difference with the variation of particle size on these colour properties (Table 1).

There was an increase in thermal conductivity and a decrease in resistivity with a decrease in particle size. Thermal conductivity values for the 50, 60, and 85 mesh-sized particles were 0.086, 0.091, and 0.099 W $m^{-1}$ $K^{-1}$, respectively and those for thermal resistivity were 11.556, 10.993, and 10.073 Km $W^{-1}$, respectively. A negative correlation (R = -0.998) was observed between thermal conductivity and particle size while a positive correlation (R = 0.999) was ob- served between resistivity and particle size (Fig. 1). This may be due to the fact that smaller particles offer more interfacial area of contact between the powder particles and the heat transfer is faster (France and Choi, 2007).

There was an increase in bulk density with a decrease in particle size. Bulk density of the 50, 60 and 85 mesh-sized particles was in the order of 0.562, 0.628, and 0.683 kg $m^{-3}$, respectively. Typically, a decrease in the particle size of mango pulp powder was associated with an increase in density (R = -0.963). Auffret *et al*. (1994) reported similar results in the case of dietary fibre. According to Clementson and Ileleji (2010), bulk density variation was shown to be primarily caused by particle segregation. The reason might be attributed to highly homogeneous nature of superfine particle size and form, which would lead to a probable decrease in the inter particle voids and offer a larger contact surface with the surroundings, leading to a more compact structure and this would result in an increase in bulk density with size reduction. Mani *et al*. (2004) observed a similar trend for wheat straw, switchgrass, and barley straw, while a similar effect of particle size on the bulk density of dietary fibre prepared from sugarcane bagasse has also been observed (Sangnark and Noomhorm, 2003).

There was a decrease in the rehydration ratio, the coefficient of rehydration and per cent water in the rehydrated sample with a decrease in particle size (Fig. 2). The rehydration ratio for the three powder samples was reported to be 2.847, 1.809, and 1.519, and the values for the coefficient of rehydration were 0.625, 0.396, and 0.222 for powder

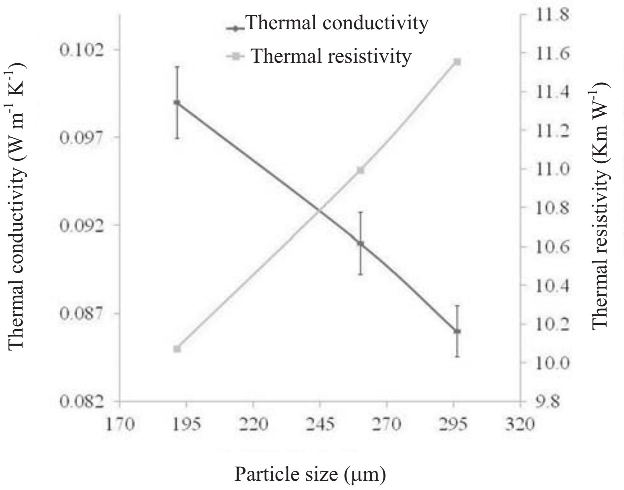


**Fig. 1.** Effect of particle size on thermal properties of mango pulp powder.

**T a b l e 1.** Effect of particle size on colour properties of foam-mat dried mango pulp powder

| BSS No. | Particle size (µm) | L* | a* | $b^{NS}$ | Z%* | Hue* | $Chroma^{NS}$ | $TCD^{NS}$ |
|---|---|---|---|---|---|---|---|---|
| 50 | 296.19 | 70.07c | 17.48a | 57.01 | 9.69b | 72.96c | 59.63 | 7.71 |
| 60 | 260.09 | 72.20b | 16.37b | 58.45 | 10.45b | 74.35b | 60.69 | 6.51 |
| 85 | 191.26 | 76.93a | 13.06c | 54.94 | 14.84a | 76.62a | 56.47 | 6.78 |
| SED | - | 0.643 | 0.340 | 1.540 | 1.047 | 0.267 | 1.554 | 0.956 |
| $CD_{0.05}$ | - | 1.570 | 0.830 | 3.770 | 2.563 | 0.653 | 3.803 | 2.339 |

a, b, c – indicate the best performing treatment followed by poor performing treatments. Mean values with the same letters are not significantly different. *Means significantly different at a 5% level of significance. NS – non significant, SED – standard error of the difference, $CD_{0.05}$ – critical difference at 5% level of significance.

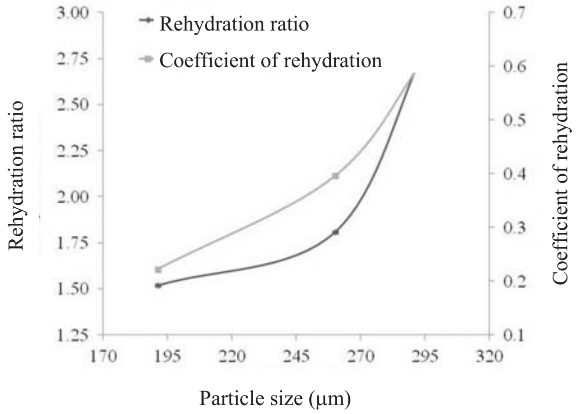


**Fig. 2.** Effect of particle size on the rehydration ratio and the coefficient of rehydration of mango pulp powder.

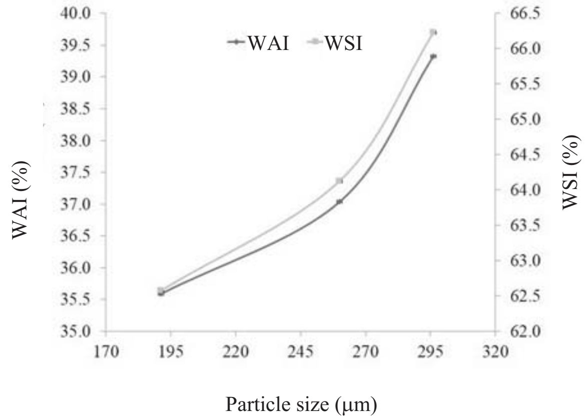


**Fig. 3.** Effect of particle size on the WAI and WSI values of mango pulp powder.

**T a b l e 2.** Effect of particle size on sensory scores* of foam-mat dried mango pulp powder

| BSS No. | Particle size (μm) | Appearance/ colour | Consistency | Taste/flavour | Mouth feel | Overall acceptability |
|---|---|---|---|---|---|---|
| 50 | 296.19 | 6.90b | 7.00b | 7.25b | 7.00b | 7.04b |
| 60 | 260.09 | 8.70a | 8.65a | 8.60a | 8.90a | 8.74a |
| 85 | 191.26 | 6.00c | 6.35c | 6.60c | 6.30c | 6.31c |
| SED | - | 0.187 | 0.116 | 0.156 | 0.072 | 0.090 |
| $CD_{0.01}$ | - | 0.537 | 0.335 | 0.448 | 0.2073 | 0.258 |

*Means significantly different at a 1% level of significance, $CD_{0.01}$ – critical difference at a 1% level of significance. Other explanations as in Table 1.

particle size of 296.19, 260.09, and 191.26 μm, respectively. The content water in the rehydrated sample was found to be 540.46 %, 311.46, and 235.94% for the powder with a mesh size 50, 60, and 85, respectively. Small particle size and symmetrical shape enhance close packing of particles and thus inhibit penetration of water while more space in the interstices for wetting is available in the case of larger particles owing to their irregular shape (Anonymous, 2000).

The results of this study showed that there was a significant difference in the WAI and WSI values between different particle size fractions. The WAI and WSI values for the 50, 60, and 85 mesh sizes were 39.31, 37.03, 35.59 and 66.21, 64.12, 62.57%, respectively (Fig. 3). There was a linear decrease in WAI and WSI as the particle size decreased, with R = 0.953 and 0.965, respectively. A higher value of WAI was observed in particles passing through the 50 mesh sieve (Fig. 3), which may be due to the fact that larger particles have a higher water-holding capacity compared to smaller particles, due to their greater ability to hold water within the cell wall matrix (Cadden, 1987). Small particle size and symmetrical shape enhance close packing of particles and thus inhibit penetration of water. Generally, large particles exhibit good dispersibility (Anonymous, 2000). The larger particles were more irregular in shape and provided more space in the interstices for wetting. The decrease in WSI with decreasing particle size may be attributed to the greater specific surface area, resulting in higher leaching of soluble starch-derived molecules that dissolved in water during the WSI assay.

The scores of sensory attributes *viz*., colour, taste, texture, flavour, and overall acceptability revealed that there was immense variation in the results with different particle sizes. Statistical analysis using LSD revealed that there was a significant ($p<0.01$) difference in the organoleptic parameters with the variation in particle size as the sensory panel could perceive the differences in the reconstituted mango juice prepared from the powder of three different sizes. The values for overall acceptability were found to be 7.04, 8.74, and 6.31 for the reconstituted mango juice prepared from the powder of 296.19, 260.09, and 191.26 μm particle size respectively. The scores for all the other sensory attributes were also found to be highest for 260.09 μm sized powder particles (Table 2) and can be suitably used for beverage preparations. Thus, on the basis of sensory evaluation of the reconstituted mango juice, it was found that the mango pulp powder with the mean particle size of 260.09 μm was found most acceptable compared to the particle size of 296.19 and 191.26 μm.

## CONCLUSIONS

1. Particle size had a significant effect on various physical and sensory properties of foam-mat dried mango pulp powder. Apart from water absorption and sensory parameters, a significant effect was observed on the thermal properties *viz*. thermal conductivity and thermal resistivity.

2. The results presented in this paper for the thermal properties can find application in food industry in such processes where heat transport and storage properties of mango pulp powder are indispensable. They can be applied for instance for adjustments of the drying rate, for calculations of the economical drying time, and for determination of energetic balances of drying processes.

3. A decrease in the rehydration ratio, the coefficient of rehydration and content water in the rehydrated sample was observed with decreasing particle size. However, the powder with the largest particle size was found to have more water solubility, thus leading to better reconstitution or in turn it can be said that this particle size is most suitable for the applications where instant reconstitution is the required phenomenon.

4. Particle size had a significant effect on sensory parameters *viz*. colour/appearance, flavour, mouth feel, taste, and overall acceptability. Mango powder with particle size in the range of 258.01 to 264.60 μm, *ie* the one which passed through the 60 mesh sieve, was found to be most acceptable with respect to sensory characteristics. This finding can be exploited for various commercial applications where powder quality is dependent upon particle size and has foremost priority for the end users.

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