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Effects of drying methods on the quality characteristics of mango powder

Mahendran, T.

Department of Agricultural Chemistry, Faculty of Agriculture, Eastern University, Sri Lanka

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ABSTRACT

Mango pulp of 12.5 °Brix was used to obtain mango powders by freeze drying, spray drying and vacuum drying. The freeze dried product had superior quality, however the spray dried product was stable and more economical. A readily re-hydrateable mango powder of 2.16% moisture content could be produced by freeze drying. The methods used for drying of mango pulp were found to significantly affect the colour parameters. Freeze drying seems to prevent colour changes, resulting in product with improved quality characteristics. The loss of ascorbic acid during freeze and vacuum drying were 21.5 and 31.3% respectively. The total carotenoid content decreased from 51.2 to 40.7 ug/g during freeze drying of the mango pulp. Vacuum drying caused extensive browning in the dried pulp and produced less acceptable powder compared to freeze and spray drying. Addition of maltodextrin in proportion to concentration reduced the stickiness and solubility of the final product. Sensory panelists ranked the juice prepared from the freeze dried powder highest and there were no significant differences (P>0.05) between the juice prepared from spray drying of mango pulp upto 50% maltodextrin. This study indicated that by using appropriate experimental conditions, reasonably good mango powder could be obtained.

***KEY WORDS*:** Ascorbic acid, freeze drying, maltodextrin, mango powder, spray drying

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1. INTRODUCTION

The mango (*Mangifera indica* L.) is grown in large quantities in many tropical countries for export and local consumption. Some of the fruits are however, wasted at the production points due to inadequate processing facilities, transportation and insufficient storage facilities. Mango utilization in the producer country or for export to premium markets is always limited by the perishable nature of the fruit and the short harvest season of the crop. A significant portion of the population prefers mango juice, which may be used in the manufacturing of mango nectar, puree, beverages and mango powder. There is a potential use of mango powder in drinks, desserts, baby foods, confectionaries and other products.

Fruit juice drying has great economic potential. Dehydration of mango juice into powdered particles gives a considerable reduction in volume and is an effective method of prolonging the shelf life. Transportation and storage costs would be reduced significantly when shipping the products to distant markets. Several methods may be used for the production of fruit juice powder, the most successful processes include spray drying, freeze drying, foam mat drying and vacuum drying. Researchers have successfully used freeze drying to convert fruit juice into powder although freeze drying is known to be the most expensive method of drying [1].

Spray drying is a highly appropriate drying process for heat sensitive products such as coffee, fruit juices, milk and egg [2]. Very little literature is available on drying of mango juice, however [3] reported the difficulties in spray drying of mango juice using different maltodextrin products. Currently maltodextrin is the most widely used additive to obtain fruit juice powders since it satisfies the demand and is reasonably cheap. Fruit juice powders obtained by spray drying have problems in their functional properties such as stickiness and solubility. According to [4], these problems arise from the fact that the materials have high contents of low molecular weight sugars such as fructose, glucose and sucrose that making drying difficult.

Based on the above, this research aims to determine the influence of different drying methods and the addition of drying aids on the physico-chemical properties of the mango powder. A consumer preference study was also conducted to evaluate the sensory characteristics of the reconstituted juice and compared with the fresh juice.

2. MATERIALS AND METHODS

Mature green mangoes of cultivar *Tommy Atkins* were ripened at 30 °C. The ripe fruits were washed thoroughly and trimmed to remove the stem and blossom ends. The fruits were peeled, cut into quarters and passed through an Apex mill pulper using a 0.032" mesh sieve.

Drying Methods

Freeze drying: The mango pulp was frozen on trays for 5 hrs at –30°C. After freezing, the samples were transferred to a freeze drier (Edwards Alto, Italy) and dried at 20°C for 48 hrs at 10 mbar Hg pressure. The powder was obtained by grinding the dried material in a blender and stored in plastic airtight containers at room temperature.

Spray drying: A laboratory scale spray drier (Niro Atomizer, Model Minor Laboratory, Denmark) with vaned centrifugal atomizer driven by an air turbine at speed upto 40,000 rpm was used. The inlet temperature of the feed material was 160°C and the outlet temperature was set to 80°C by regulating the feed pump speed. Powders were separated from hot air by a cyclone separator and stored in plastic airtight containers at room temperature. Maltodextrin was added to the pulp before spray drying. Based on the formula developed for spray drying of fruit juices by [4] the following combinations were selected for drying:

1. Mango solids wt 60% + Maltodextrin wt 40%
2. Mango solids wt 50% + Maltodextrin wt 50%
3. Mango solids wt 40% + Maltodextrin wt 60%

Vacuum drying: Approximately 1.5 cm thick layer of mango pulp was placed in trays and dried in a vacuum oven (Townson and Mercer Ltd., UK) operated at 70°C at 1bar for 24 hrs. The powder was obtained by grinding the dried material in a blender for 3 min and stored in plastic airtight containers.

Analytical Methods

Moisture content was determined using a vacuum oven operated at 70°C at 1 bar for 24 hrs. Total sugars were determined by AOAC [5] methods. Total acidity was measured using 1% phenolphthalein solution, titrated against 0.1N NaOH and the result was expressed as citric acid. Ascorbic acid content was estimated using the sodium salt of 2, 6-dichlorophenol indophenol dye. Total soluble solids were measured using a refractometer equipped with a percentage sugar scale and expressed as °Brix. Standard β-carotene (Sigma - Aldrich Company, UK) solutions were prepared in hexane-acetone mixture and the total carotenoids were determined spectrophotometrically. The bulk density of the powder was determined by measuring the volume of a determined weight of the powder in a 100 ml graduated glass cylinder. The solubility of the powder was determined by mixing 1 g powder with 100 ml of distilled water at high speed for 5 min in a mixer. Then, the solution was centrifuged at 25,000 x g for 5 min. An aliquot of 25 ml of the supernatant was placed in previously weighed petri dishes and oven dried at 105°C for 5 hrs. Solubility was calculated by weight difference.

Sensory Analysis

Sensory analysis was carried out by 20 trained panelists to evaluate the colour, sweetness, aroma, flavour, consistency and overall acceptability of the reconstituted mango juice using a descriptive analysis with scaling. A 50 ml of juice at 5-7°C was presented to the panelists during each serving. Testing was conducted twice for each panellist in individual booths equipped with white florescent lights. Samples were expectorated and judges were given distilled water and crackers to cleanse their palates between samples.

Statistical Analysis

Data were statistically examined by analysis of variance and means were separated by Duncan's multiple range tests. All statistical analyses were conducted using SAS version 6.0 (SAS Inst. Cary, USA).

3. RESULTS AND DISCUSSION

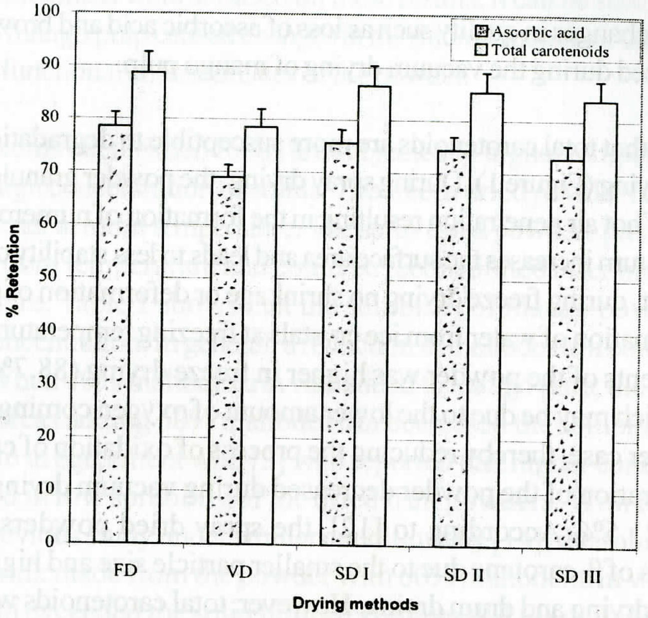
The effects of different drying methods on physico-chemical characteristics of mango powder are presented in Table 1. The moisture content of mango powder ranged from 1.91 – 2.21% on a dry weight basis. Similar results were reported for guava [6], pineapple [7] and star fruit [8] in the dried fruit powders. However, the moisture content reported in the present study was lower than those reported by [9] who had the final moisture content of 5.1% in the spray dried mango powder but this may be due to differences in initial mango quality and processing methods. Increasing the maltodextrin concentration resulted in decreases in moisture content of dried mango powder, probably due to an decrease in mango solids in the feed and increased amount of free water evaporation. A similar effect was observed by [7] during spray drying of pineapple blended with maltodextrin. A reduction in total acidity after drying of mango pulp indicated that some acids are lost during process. A noticeable loss in total acidity after drying of guava juice was reported by [10].

Table 1: Effect of different drying methods on the physico-chemical characteristics of mango powder

Treatments	Moisture content (%)	Total acidity (%)	Total sugars (%)	TSS (°Brix)	Bulk density (g/cm^3)	Solubility (%)
Fresh pulp	87.4	0.52	10.99	12.50	-	-
Freeze-dried	2.16b	0.49d	9.54d	35.4c	0.59c	95.7c
Vacuum-dried	1.91a	0.40c	8.56c	30.7b	0.63d	89.3ab
Spray-dried						
Mango solids 60% + Maltodextrin 40%	2.21b	0.36b	8.37b	33.1bc	0.54b	91.5b
Mango solids 50% + Maltodextrin 50%	2.14b	0.35b	8.28b	31.5b	0.51b	90.4b
Mango solids 40% + Maltodextrin 60%	2.11b	0.30ab	8.13a	27.4a	0.46a	86.7a

Values represent the average of triplicate analytical measurements.
Values in the same column bearing different letters are significantly different at 5% probability level.

Reducing the mango solids concentration before spray drying reduces the ascorbic acid retention in the mango powder. Losses were lower in freeze dried powder compared to vacuum dried powder (Figure 1). The oxidative loss of ascorbic acid following vacuum drying was 31.3% which was higher than following freeze drying (21.5%) and spray drying (25.8%). These observations confirm the findings of [11]. They found that freeze dried tomato powder had a higher level of ascorbic acid than spray dried powder. Ascorbic acid was lost during drying as a result of high temperature and oxidation. There was a reduction in total sugars in the mango powder, which may be due to non-enzymic browning reactions during drying of mango pulp.



FD - Freeze dried, VD - Vacuum dried, SD I - Spray dried : Mango 60%+Maltodextrin 40%,
SD II-Spray dried :Mango 50%+Maltodextrin 50%, SD III-Spray dried :Mango 40%+Maltodextrin 60%

Figure 1: Effect of different drying methods on the stability of ascorbic acid and total carotenoids of mango powder

The various drying methods used in this study were found to have a significant effect on the colour parameters of the mango powder. The mango pulp was high in sugar and low in particulates allowing satisfactory puffing during freeze drying which is responsible for the lighter colour and shiny nature of the fruit powders. All the powders produced by spray drying were a light yellow colour in appearance irrespective of the colour of the feed material. Researchers [10] reported the production of bright white guava powder after spray drying of guava puree with maltodextrin. The mango pulp has a dark yellow colour due to β-carotene while the maltodextrin is white. During spray drying, oxidation of β-carotene reduced the intensity of the yellow colour of the powders increasingly revealing the white colour of the maltodextrin.

Vacuum drying is one of the least expensive methods of drying food materials. However, no literature is available on vacuum drying of mango pulp. The drying method was very slow, requiring approximately 24 hrs to dry the product completely. Due to the long drying process at high temperatures, the mango powder produced by vacuum drying was a golden yellow colour but was very sticky and difficult to remove from the trays and grind. It was noticed that the deteriorative changes in quality such as loss of ascorbic acid and browning reactions, were more pronounced during the vacuum drying of mango pulp.

This study indicated that total carotenoids are more susceptible to degradation during spray drying than freeze drying (Figure 1). During spray drying, the powder granules may undergo shrinkage because of hot air penetration resulting in the formation of numerous tiny pores on the powder, which in turn increases the surface area and leads to less stability of the carotenoid pigments. In contrast, during freeze drying no shrinkage or deformation of granules occurs because of the sublimation of water from ice crystals at freezing temperature. The retention of carotenoid pigments of the powder was higher in freeze drying (88.7%) than in spray drying (85.2%), which may be due to the lower amount of oxygen coming in contact with the pulp in the former case, thereby reducing the process of oxidation of carotenoids. The carotenoid concentration of the powder decreased during vacuum drying and the losses were found to be 21.5%. According to [12], the spray dried powders showed faster degradation kinetics of β-carotene due to the smaller particle size and higher surface area compared to freeze drying and drum drying. However, total carotenoids were not affected as much as ascorbic acid during the process of drying, showing their stability to heat.

The physical properties (moisture content, bulk density, true density, particle porosity, wetting, dispersion, solubility, particle size and distribution) of mango powder were related to ease of reconstitution. These properties are influenced by the nature of the feed (solid content, viscosity and temperature) and operational conditions [13]. The vacuum dried powder had significantly higher bulk density than spray dried powder (Table 1). Researchers [4] found values for bulk density of 0.47–0.58 g/cm^3 for temperate climate fruit powders. An increase in maltodextrin concentration during spray drying led to a significant decrease in bulk density of the powder compared to freeze and vacuum drying. This is probably due to low moisture content of the product. The opposite was found by [14] for dried fruit juices using a pressure nozzle for liquid atomization speeds, while resulted in more porous products due to incorporation of air in the feed and also between the small particles [15].

Stickiness is considered as a major problem of the fruit juice drying. Stickiness is a function of mango solids concentration during the drying process. Spray drying was difficult due to high sugar and acid contents of the mango pulp. It was observed that the stickiness decreased as a function of maltodextrin concentration for the spray drying of mango pulp. When maltodextrin was added to pulp, it formed a film around the solids in the feed that facilitated the production of non-hygroscopic and fine flowing powder [16]. This behaviour occurs because the particles are better dispersed, while decreases cohesive force between them. According to [17], when there is a decrease of an inter-particle attractive force, the system displays lower stickiness values. Based on these results, it can be stated that the addition of maltodextrin to mango pulp caused changes in the microstructure of the dehydrated powder, influencing the functional characteristics of the powder.

Solubility problems occur when foods are subjected to higher temperatures, especially in products with high concentration of solids. The freeze dried powder could be reconstituted instantly with water at room temperature. The spray dried powders produced in this research were stable at room temperature and could be reconstituted after blending with water at room temperature. Table 1 shows that the solubility of mango powder as a function of maltodextrin concentration. In general, a reduction in maltodextrin concentration improved the solubility. When 40% maltodextrin was added to mango pulp, the solubility of powder was 91.5% whereas adding 60% maltodextrin decreased the solubility to around 86.7%. These results are in agreement with [3] who reported that higher concentrations of drying carriers resulted in low solubility of the dried fruit powders. With respect to the results obtained in a previous study under similar conditions by [14], the solubility was 90%. The reconstituted drink made from the powder with 60% maltodextrin was not clear because the maltodextrin exceeded the solid limits recommended for making clear solutions [3]. Maltodextrin as a carrier in juice dehydration by spray drying is one of the most utilised substances due to its solubility in water. However, due to the change in structure of the powder, it influences the functional solubility. The properties of the powdered mango particles change as a function of maltodextrin concentration; the higher concentrations lead to decreased solubility of the powder in water.

Ready-to-serve drinks prepared by reconstituting the dried powder were compared with those prepared from freshly extracted pulp. All the sensory panelists had tasted mango fruit or drink before and all of them liked its taste. There was no significant difference (P>0.05) between the total scores of fresh mango juice and reconstituted freeze dried mango powder (Table 2). This indicated minimal flavour loss during freeze drying of mango pulp.

Table 2: Effects of different drying methods on the sensory parameters of Mango powder

Treatments	Sensory Quality Scores					
	Colour	Sweetness	Aroma	Flavour	Consistency	Total Acceptability
Fresh pulp	8.6c	7.8c	8.3c	8.8c	8.2cd	41.7c
Freeze-dried	8.4c	7.6c	8.0bc	8.6c	7.8c	40.4bc
Vacuum-dried	7.1a	6.3a	6.2a	6.4a	7.1b	33.1a
Spray-dried						
Mango solids 60% + Maltodextrin 40%	8.1b	7.2b	7.6b	7.9b	7.4b	38.2b
Mango solids 50% + Maltodextrin 50%	8.1b	7.0b	7.4b	7.6b	7.0b	37.1b
Mango solids 40% + Maltodextrin 60%	8.0b	6.6ab	6.7a	7.0ab	6.3a	34.6a

Values are the means of two replications with sensory evaluation completed by 20 panelists.
Values in the same column bearing different letters are significantly different at 5% probability level.

Spray dried powder produced from 40% mango pulp was unacceptable to 78% of the panelists because of its thick consistency and lack of mango flavour. This may be due to the addition of maltodextrin at higher concentration than the desirable level from the sensory standard point. Overall 82% of the panelists were either very satisfied or satisfied with reconstituted mango juice and only 7% disliked it. The remainder of the panelists expressed neutral opinion.

4. CONCLUSIONS

This exploratory work examined the feasibility of using different drying methods to produce mango powder of acceptable quality at reasonable cost. The present study indicated that under the experimental conditions employed, desirable powder characteristics could be obtained. Freeze drying produced the best quality mango powder in terms of colour, flavour and ascorbic acid retention though it was quite hygroscopic in nature. Spray drying produced stable powder at room temperature. Addition of maltodextrin as a carrier in mango juice dehydration by spray drying reduced the stickiness and prevented caking of dried powders. Vacuum drying produced dried flakes that were difficult to remove from trays and grind.

The freeze dried and spray dried powder kept their colour intact. On the other hand, the vacuum dried powder suffered significant browning. The freeze dried powder showed higher pigment stability than the spray dried powder. The spray dried reconstituted juice was slightly lacking in flavour compared to freshly prepared juice but was preferred to vacuum dried product. Because freeze drying is an expensive method to apply commercially, spray drying may be the best alternative for producing free-flowing mango powder with good stability.

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