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Mango (*Mangifera indica* L.) fiber concentrates: Processing, modification and utilization as a food ingredient

Ruslan Mehadi Galib, Mahabub Alam, Rahmatuzzaman Rana, Rowshon Ara*

Department of Food Engineering and Tea Technology, Shahjalal University of Science and Technology, Sylhet 3114, Bangladesh

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A B S T R A C T

Dietary fiber (DF) is an important health benefit component found mostly in fruit and vegetable products. The impacts of freeze and oven drying methods (WTC binder, Tuttlingen, Germany, 50 °C for 48 h) on the physicochemical and antioxidant properties of mango fiber concentrates (MFCs) of four varieties such as Amrupali, Ashwina, Himsagor and Fazli were studied. In comparison with oven dried MFCs, the swelling, water and oil holding capacities of the freeze dried MFCs showed a significant value. Freeze dried Ashwina MFCs showed the highest ($p<0.05$) ascorbic acid content of 44.02 mg/100 g whereas, oven dried Fazli MFCs showed the lowest ($p<0.05$) ascorbic acid content of 9.11 mg/100 g compared to all MFCs. Freeze dried Ashwina also had the highest ($p<0.05$) DPPH (2, 2-diphenyl-1-picrylhydrazyl) radical scavenging activity of 40.83% among all MFCs. The significantly maximum total polyphenol contents of 22.77 mg GAE (gallic acid equivalent)/100 g were observed in freeze dried Amrupali among all MFCs. Total soluble solid was significantly higher in freeze dried Amrupali (8.06%) than in freeze dried Ashwina MFCs (7.48%). As a result, freeze dried MFCs might be used as a multifunctional component in a variety of agricultural products as well as in the food industry.

1. Introduction

Though mango (*Mangifera indica* L.) is usually planted in tropical and subtropical areas, it grows well in Bangladesh due to the good agri-climatic environments. A significant number of mango varieties e.g. Fazli, Gopalbhog, Khirsapat, Himsagor, Kohitoor, Amrupali, Laksmanbhog, Misribhog and Mallika are grown in Bangladesh (Ara et al., 2014a, 2014b). These mango varieties have economic importance in food industries due to their rich sources of dietary fiber, vitamins, minerals, and antioxidant compounds. Nutritional values of mango varieties vary with maturity and ripening stages (Jha et al., 2013; Leghari et al., 2013). Dietary fibers (DF) are made up of cellulose, lignin, hemicellulose, pectin, gums and β-glucans (Figuerola et al., 2005). There might be two primary classes of DF: the water soluble fibers viz. pectin and gum; lignin, cellulose and hemicellulose which are water-insoluble fibers (Figuerola et al., 2005; Vergara-Valencia et al., 2007). DF has many physicochemical characteristics such as water and oil holding capacity, swelling capacity, gel forming ability and viscous properties. Moreover, it also possesses positive health benefits (Sarkar et al., 2022). DF inclusion in the everyday diet is linked with preventing and treating diabetes, colon cancer, obesity, cardiovascular disorders, and atherosclerosis (Figuerola et al., 2005). Cereal-derived DFs are more often utilized than fruit ones (Cassidy et al., 2018). Nonetheless, the nutritional content of fruit DF is greater than that found in cereals since there is a considerable quantity of bioactive substances, such as flavonoids and carotenoids in fruit (Dhingra et al., 2012). Since DF is vital to our nutrition, we are looking for novel supplies of DF which may be used as foodstuffs (Chau & Huang, 2003).

Antioxidants are chemical compounds having the capability of inhibiting the oxidative chain reactions to retard or constrain the oxidation of lipids or other molecules (Matkowski & Wołniak, 2005). Work on natural antioxidants present in fruits and vegetables has grown in importance because of abundant health benefits (Ajila & Rao, 2008; Panicker et al., 2014; Vandghanooni et al., 2013). Phenolic compounds in mango demonstrate strong antioxidant potential in human nutrition as a preventive agent against many diseases (Hussain et al., 2016). Epidemiological data consistently demonstrate that consumption of fresh fruits decreases the prevalence and incidence of diabetes, cancer, hypercholesterolemia and heart diseases (Aune et al., 2017).

The processing history of fiber concentrates should be observed, especially the capacity of the fiber matrix to retain its physicochemical characteristics during processing (Femenia et al., 1997). Drying is often used to process and store fruits and vegetables in dry form for a long time by reducing the water activity (a_w) to a degree that prevents the growth and multiplication of microbes (Corzo et al., 2008). Fruits may be dried using a variety of processes, including oven drying and freeze drying. However, quality degradation, i.e. discoloration, case hardening and food shrinkage because of oven drying, is remarkable and high dry-

* Corresponding author.
E-mail address: rowshonara-fet@sust.edu (R. Ara).

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ing temperatures may result in a significant reduction of phenolic compounds in many fruits and vegetables (Sarkar et al., 2020) while freeze drying can minimize those losses and retain more nutritional compounds and removes water by sublimation and passes progressively from ice to gas with the assistance of low pressure (Ciurzyńska & Lenart, 2011).

Bangladesh is a prominent mango-producing country, ranking eighth among the leading mango-producing countries in the world (Islam et al., 2018). Mango varieties such as Amrupali, Ashwina, Himsagor and Fazli are the most popular and commonly grown in Bangladesh. They constitute a possible source of dietary fiber (DF) and phenolic content, both of which have several health advantages. Before storage and use in products to add value, DF derived from mango flesh must be dried. The impact of drying techniques on the bioactive compounds and antioxidant properties of mango fiber concentrates has not been reported yet. The objective of this research was to study the impacts of freeze and oven drying on the physicochemical and antioxidant properties of mango fiber concentrates (MFCs) and to evaluate which one is effective in preserving MFCs.

2. Materials and methods

2.1. Mango samples

Four freshly harvested mango varieties (each 15 kg): Amrupali, Ashwina, Fazli, Himsagor were collected from the local markets at Sylhet division, Bangladesh. The traditional indices such as fruit size and shape were used to assess the maturity of each variety. All the fruits were placed in incubators set at 25 °C to ripen, and for each variety, ripeness was also determined using traditional indicators like the number of days from harvesting, when the fruit started to change color, fragrance, and softness on the touch (Ma et al., 2011). After sorting based on the uniform maturity and ripeness indices, the fruits were washed and cleaned with distilled water in the laboratory. The skins were peeled cautiously, and flesh was separated from the seed. The mango paste obtained from each variety was stored at -20 °C before extraction of the dietary fiber (DF).

2.2. Extraction of mango fiber concentrates (MFCs)

Mango paste was thawed overnight at room temperature. Hot water extraction (70 °C for 20 min) was applied to the mango paste to obtain the MFCs. Then it was filtered with a thin 0.5 mm pore size cloth to segregate the insoluble compounds. These filtration and extraction techniques were repeated six times until a paste was created for obtaining MFCs (Borchani et al., 2011). One extraction and triplicate assay were made to analyze all the parameters.

2.3. Drying of mango fiber concentrates (MFCs)

The MFCs obtained (160 g) were split into two parts. Each one was dried using either a freeze drying or an oven drying technique. The first segment was dried with a freeze dryer (HETO, FD8-SS, Namur, Belgium). In this process, the temperature was set to -40 °C to allow the pastes to become a frozen state, and then it was dried under a vacuum by direct ice sublimation. The second half was dried in an oven dryer (WTC binder, Tuttlingen, Germany) at 50 °C for 48 h. This moderate temperature was chosen to retain DF quality (Garau et al., 2007). Finally, the dried MFCs were milled for 1 min in a grinder before being evaluated.

2.4. Physicochemical properties of mango fiber concentrates

2.4.1. Dry matter

A constant temperature and humidity chamber (Model: VS-8111H-150, Vision Scientific Co. Ltd., South Korea) was used to evaluate the dry matter of the mango fiber concentrates.

2.4.2. Determination of pH

The pH of the MFCs was measured using a pH meter, as described by Roy et al. (2021).

2.4.3. Titratable acidity (TA)

TA was measured by mixing a precise quantity of MFCs in distilled water and afterward titrated with 0.1 N sodium hydroxide (NaOH) by using phenolphthalein as an indicator (Hossain et al., 2021).

2.4.4. Total soluble solid (TSS)

The TSS of MFCs was assessed by the suggested technique of Alam et al. (2020) using a hand refractometer and the data was recorded as degree Brix.

2.4.5. Swelling capacity (SC)

In a graduated measuring cylinder (also calibrated), 0.2 g of fiber and 10 mL deionized water were mixed, and the starting volume was measured. It was kept at 25 °C for 18 h to allow the mixture to hydrate. After that, the ultimate volume was measured after hydration. The SC was determined by following the Eq. (1) and expressing the result as mL/g (Robertson et al., 2000).

$$\text{Swelling capacity} = \frac{\text{Hydrated volume of MFCs}}{\text{Dry MFCs Weight}} \tag{1}$$

2.4.6. Water holding capacity (WHC)

According to the method of McConnell et al. (1974), the WHC of MFCs was evaluated. In a tube, 100 mg of MFCs was dissolved in 10 mL of deionized water and soaked for 12 h at 4 °C. The supernatant was carefully drained after centrifuging the mixture for 20 min at 14,000 g. The WHC was measured using the following Eq. (2):

$$\text{Water holding capacity} = \frac{\text{Wet MFCs weight} - \text{Dry MFCs Weight}}{\text{Dry MFCs Weight}} \tag{2}$$

2.4.7. Oil holding capacity (OHC)

The OHC of MFCs was determined by the suggested technique of Lin et al. (1974). Briefly, 15 mL of corn oil was added to MFCs in a 50 mL tube and stirred for 1 min. The mixture obtained was centrifuged for 25 min at 1600 g. OHC was calculated according to the Eq. (3) and expressed as a measurement of g oil held/g sample.

$$\text{Oil holding capacity} = \frac{\text{Oil absorbed MFCS weight} - \text{Dry MFCs Weight}}{\text{Dry MFCs weight}} \tag{3}$$

2.4.8. Color

The color was determined by the suggested method of Xiao et al. (2012). The CieLab coordinates (L^*, a^*, b^*, c^*, H^*) of MFCs were directly measured using a Colour Meter PCE-CSM 1. The L^* value is a measure of lightness in this coordinate system, ranging from 0 (black) to 100 (white); a^* value ranges from 100 (greenness) to +100 (redness) and b^* value ranges from 100 (blueness) to +100 (yellowness).

$$The\ hue\ angle, H *= tan^{-1}\frac{b^*}{a^*} \tag{4}$$

$$Chroma, C^* = \sqrt{\left(a^2 + b^2\right)} \tag{5}$$

2.5. Antioxidant activities of mango fiber concentrates

2.5.1. Preparation of polyphenolic extracts

About 50 mg MFCs samples were de-esterified for 24 h at ambient temperature in 2 M NaOH (3 mL) in the dark and then they were neutralized with 3 M HCl to pH 2. After that, diethyl ether (33 mL) was used to remove phenolic compounds. The diethyl ether fraction was evaporated at room temperature (25 °C) using nitrogen, and the residue was mixed in 1 mL of methanol/water solution. To obtain a significant volume of extract, the extraction was repeated multiple times. This extract was used to assess both the TPC and the antioxidant properties (Micard et al., 1996).

2.5.2. Total phenolic content (TPC)

TPC of MFCs was estimated by using the method of Slinkard and Singleton (1977) with minor modifications. For measurement, 20 µL of each extract, standard gallic acid was kept in test tubes and added with 1.58 mL of distilled water, followed by 100 µL of Folin – Ciocalteau reagent, correctly blended, and lastly, 300 µL of Na_2CO_3 was mixed for 8 min. The mixture was well stirred before being kept at room temperature for 30 min and centrifuged for 10 min at 2000 rpm. The absorbance was then taken at 765 nm by using a UV–Vis spectrophotometer. The calibration curve $y = 0.009x - 0.012$, $R^2 = 0.9995$ was created using standard solution of gallic acid. The phenolic content was estimated as mg Gallic acid/100 g of MFCs.

2.5.3. DPPH radical scavenging activity

DPPH radical scavenging activity of MFCs was estimated by the technique used in Brand-Williams et al. (1995). Concisely, 100 µL of extracts are combined with 1.4 mL DPPH methanolic solution (10^{-4} M). The absorbance of samples and blank was determined using a UV–Vis spectrophotometer at 517 nm after 30 min. The findings were represented using the following Eq. (6),

$$DPPH\ radical\ scavenging\ activity(\%) = \frac{A_o - A_s}{A_o} \times 100 \quad (6)$$

Where A_o and A_s are the absorbance of control blank and sample extract.

2.5.4. Ascorbic acid

The experimental procedure used to determine the vitamin C content in dried MFCs samples was a modification of that proposed by Ranganna (1986) with slight modification. Firstly, 2 g MFCs were properly mixed with 3% 25 mL metaphosphoric acid and filtered the mixture using filter paper. After that, the filtrate aliquot (5 mL) was titrated until to a pink endpoint using the 2,6- dichlorophenol-indophenol dye.

2.6. Statistical analysis

The tests were repeated in triplicate, and the data were analyzed using the SPSS program (SPSS Inc., Chicago, IL, USA), version 25 for windows. To assess if there was a significant difference between the samples, a one-way ANOVA analysis was employed. The threshold for determining a significant difference was set at $p<0.05$.

3. Results

3.1. Physicochemical properties of mango fiber concentrates

3.1.1. Dry matter

For the four analyzed mango varieties, freeze dried MFCs had greater ($p<0.05$) content of dry matter relative to the oven dried MFCs. Freeze dried Ashwina had the dry matter of 91.42 g/100 g which was higher ($p<0.05$) than oven dried Ashwina MFCs 86.92 g/100 g. However, no significant differences were found among varieties of the same drying treatment (Table 1).

3.1.2. pH

In the case of pH, all the freeze dried MFCs showed significant differences relative to oven dried MFCs except for the Ashwina variety. The pH 5.93 of oven dried Fazli was the highest ($p<0.05$) among all MFCs. However, the lowest ($p<0.05$) pH value of 3.59 was found in freeze dried Ashwina compared to all freeze dried MFCs (Table 1).

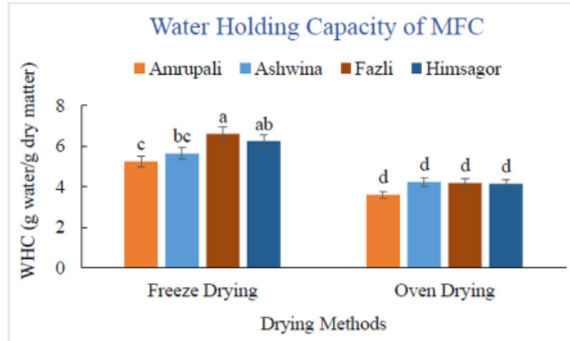

Fig. 1. Water holding capacity of MFCs.

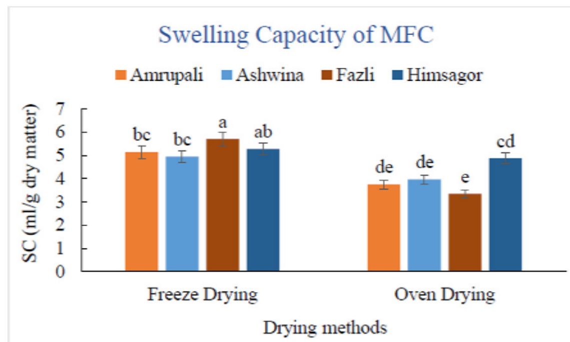

Fig. 2. Swelling capacity of MFCs.

3.1.3. Titrable acidity (TA)

Freeze dried Ashwina exhibited highest ($p<0.05$) TA of 0.791% among all varieties and dried MFCs. On the other hand, oven dried Fazli showed lowest ($p<0.05$) TA 0.208% compared to oven dried MFCs. No significant differences were observed among freeze dried Amrupali, Fazli and oven dried Himsagor. For drying, freeze dried MFCs showed significantly greater TA than oven dried MFCs (Table 1).

3.1.4. Total soluble solid (TSS)

In this present analysis, the highest ($p<0.05$) TSS (8.06%) was observed in freeze dried Amrupali compared to freeze dried Ashwina MFCs (7.48%). Oven dried Amrupali, Himsagor and Fazli showed almost similar TSS content but significantly higher than oven dried Ashwina MFCs (7.26%) (Table 1).

3.1.5. Water holding capacity (WHC)

The WHC of different varieties ranged from 6.61 to 3.61 g water/g dry sample. The highest ($p<0.05$) WHC 6.61 g water/g dry MFCs were found for mango dietary fiber concentrates of freeze dried Fazli (Fig. 1).

3.1.6. Swelling capacity (SC)

The significantly highest SC was 5.71 mL/g dry MFCs found in freeze dried MFCs of Fazli and significantly lowest value was 3.35 mL/g dry MFCs found in oven dried MFCs of Fazli (Fig. 2).

3.1.7. Oil holding capacity (OHC)

In the case of OHC, freeze dried MFCs showed the highest value than oven dried MFCs. However, the oil holding capacity of MFCs of all samples was in the range of 1.51 to 2.02 g oil/g dry MFCs (Fig. 3).

3.1.8. Color

For the four analyzed varieties, freeze dried Ashwina and Fazli MFCs were characterized by significantly higher L^* of 45.12 and 43.92 respectively. But in the case of a^* values, oven dried MFCs for Fazli was

Table 1
Dry matter, pH, total soluble solid, and titratable acidity of mango fiber concentrates.

Fiber Concentrates	Drying Methods	Dry matter (g/100 g)	pH	TSS (°Brix)	TA (%)
Amrupali	Freeze drying	90.15±2.13[a]	4.12±0.07[f]	8.06±0.03[a]	0.423±0.03[e]
	Oven drying	85.51±1.79[b]	4.78±0.09[e]	7.81±0.08[bc]	0.371±0.02[d]
Ashwina	Freeze drying	91.42±3.21[a]	3.59±0.03[g]	7.48±0.03[cd]	0.791±0.01[a]
	Oven drying	86.92±2.50[b]	3.73±0.02[g]	7.26±0.05[d]	0.712±0.02[b]
Fazli	Freeze drying	89.55±1.89[a]	5.65±0.04[b]	7.78±0.17[ab]	0.301±0.07[e]
	Oven drying	84.05±2.13[b]	5.93±0.06[a]	7.31±0.07[ab]	0.208±0.08[f]
Himsagor	Freeze drying	90.62±2.39[a]	5.12±0.05[d]	7.89±0.05[ab]	0.368±0.09[d]
	Oven drying	85.82±1.95[b]	5.45±0.03[c]	7.64±0.08[b]	0.284±0.03[e]

All results are denoted as mean value ± standard deviation. The values are the mean of 3 replicates. Values in columns with distinct letter superscripts differ significantly at $p<0.05$.

Table 2
Color parameters of mango fiber concentrates.

Fiber Concentrates	Drying Methods	L*	a*	b*	c*	H*
Amrupali	Freeze	44.00±0.24[c]	4.40±0.02[d]	42.18±0.11[a]	42.02±0.04[b]	83.90±0.08[b]
	Oven	40.00±0.31[d]	3.05±0.01[g]	41.80±0.13[b]	42.38±0.02[a]	83.10±0.06[d]
Ashwina	Freeze	45.12±0.04[a]	4.65±0.02[c]	41.52±0.04[c]	41.78±0.01[c]	83.61±0.07[c]
	Oven	42.71±0.06[bc]	4.12±0.03[e]	40.98±0.06[d]	41.4 ± 0.03[e]	82.20±0.03[e]
Fazli	Freeze	43.92±0.03[ab]	4.60±0.01[c]	41.52±0.07[c]	41.62±0.05[d]	83.74±0.01[bc]
	Oven	37.82±0.12[e]	6.98±0.09[a]	36.78±0.21[g]	37.13±0.02[g]	79.27±0.40[g]
Himsagor	Freeze	41.59±0.10[c]	3.65±0.02[f]	37.64±0.18[e]	36.77±0.03[d]	85.02±0.01[a]
	Oven	39.22±0.07[d]	5.45±0.05[b]	36.98±0.06[f]	37.82±0.05[h]	80.50±0.02[f]

All results are denoted as mean value ± standard deviation. The values are the mean of 3 replicates. Values in columns with distinct letter superscripts differ significantly at $p<0.05$.

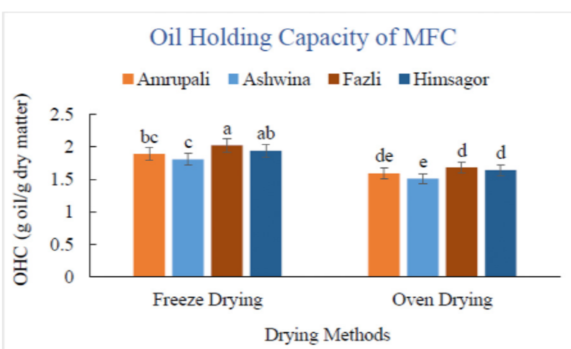

Fig. 3. Oil holding capacity of MFCs.

6.98 which was significantly highest among oven dried varieties. Significantly highest b* values was observed in freeze dried MFCs compared to oven dried MFCs and it was highest in freeze dried Amrupali (42.18). The significantly lowest b* values was 36.78 for oven dried Fazli among all oven dried varieties. Chroma value of 42.38 was found highest ($p<0.05$) in oven dried Amrupali among all MFCs and the lowest 37.13 was observed in oven dried Fazli. The highest ($p<0.05$) hue angle (H*) was 85.02 assessed in freeze dried Himsagor compared to all MFCs. Oven dried Fazli showed lowest ($p<0.05$) H* value of 79.27 among all MFCs (Table 2).

3.2. Antioxidant activities of mango fiber concentrates

Freeze dried MFCs showed a considerably higher quantity of total phenolic content than oven dried MFCs in all cases. Consequently, the maximum ($p<0.05$) total phenolic content was assessed in freeze dried Amrupali fiber 22.77 mg/g dry sample. On the contrary, the lowest was for oven dried MFCs of Fazli 16.78 mg/g dry sample (Table 3).

For DPPH radical scavenging activity, the highest ($p<0.05$) value was 40.83% for freeze dried Ashwina fiber. The lowest ($p<0.05$) quantity was 31.55% found for oven dried MFCs of Himsagor. Overall, the freeze dried MFCs exhibited more prominent antioxidant properties than the oven dried samples (Table 3).

For ascorbic acid content, MFCs of freeze dried Ashwina exhibited a considerably ($p<0.05$) higher ascorbic acid content 44.02 mg/100 g compared to other varieties. The lowest amount was found for oven dried MFCs of Fazli which was 9.11 mg/100 g. From the table, it was clear that freeze dried MFCs retained more ascorbic acid content than oven dried MFCs in every case (Table 3).

4. Discussion

4.1. Physicochemical properties of mango fiber concentrates

Dry matter, titratable acidity (TA), pH, total soluble solids (TSS), swelling capacity (SC), water holding capacity (WHC), and oil holding capacity (OHC) have all been assessed for defined physicochemical properties that are important for processing and utilizing dry products.

Freeze dried MFCs displayed the significantly higher dry matter content relative to oven dried MFCs. These high values account for good preservation of the lyophilized MFCs during storage.

The pH and titratable acidity of certain items are important considerations when mixing them with pH hypersensitive meals e.g., milk and its derived products. Except for the Ashwina variety, all the freeze-dried MFCs had significant variations in pH when compared to oven-dried MFCs. In the case of titrable acidity, freeze dried MFCs exhibited significantly greater titratable acidity than oven dried MFCs. This might be because of less heat involved in freeze-drying process. More precisely, the acidity of the MFCs decreased during oven drying compared to the freeze dried MFCs. The heat can accelerate the reactions between acids and proteins which is called the Maillard reaction, consequently leading to a slight decline in acidity (Sogi et al., 2015). Titrable acidity (such as citric acid) in freeze dried MFCs were greater compared to oven dried

Table 3
Antioxidant activities of mango fiber concentrates.

Fiber Concentrates	Drying Methods	TPC (mg GAE/100 g)	Ascorbic Acid (mg/100 g)	DPPH activity (%)
Amrupali	Freeze drying	22.77±0.04[a]	30.25±0.06[c]	40.10±0.03[b]
	Oven drying	20.15±0.03[c]	28.81±0.03[d]	37.91±0.08[d]
Ashwina	Freeze drying	21.08±0.02[b]	44.02±0.08[a]	40.83±0.26[a]
	Oven drying	18.21±0.01[e]	41.41±0.3[b]	38.80±0.20[c]
Fazli	Freeze drying	19.28±0.05[d]	10.92±0.04[f]	35.04±0.08[e]
	Oven drying	16.78±0.02[g]	9.11±0.07[h]	33.69±0.13[f]
Himsagor	Freeze drying	20.04±0.05[c]	11.52±0.02[e]	33.09±0.21[g]
	Oven drying	17.63±0.02[f]	9.88±0.04[g]	31.55±0.39[h]

All results are denoted as mean value ± standard deviation. The values are the mean of 3 replicates. Values in columns with distinct letter superscripts differ significantly at $p<0.05$.

MFCs as Sarkar et al. (2021) indicated that some acids were lost during evaporation at the higher temperature during drying.

A greater TSS level indicates that the fruit is of excellent grade. The maturation was correlated with increased soluble solids content and total sugar content (Medlicott & Thompson, 1985). On the other hand, the flavor and in particular, the sweetness of the fruit product largely rely on the proportion of total soluble solids content (Shafique et al., 2006). Oven dried MFCs showed considerably lower content of total soluble solid than freeze dried MFCs. It might be due to the decrease of the sugar content during high heat involved in oven drying which could induce a Maillard reaction (Sogi et al., 2015). Yi et al. (2017) described that the reduction in TSS content was caused by cytoplasmic element decay (e.g., protein and sugar) and by chemical processes such as Maillard reactions (de Escalada Pla et al., 2012). There were also significant differences among four mango varieties. It might be due to the inherent sweetness of the varieties and the different horticultural practices of varieties (Caparino et al., 2012).

For all the varieties tested, freeze dried MFCs showed significantly greater water holding capacity compared to oven dried samples. These might be due to their high soluble solid content (Elleuch et al., 2008). According to several publications, the water holding capacity of fiber is highly dependent on pH, total soluble solid content of the samples (Femenia et al., 1997).

In comparison to oven dried MFCs, freeze dried MFCs had the significantly highest swelling capacity values. The study for Valencia orange fibers by Figuerola et al. (2005) agrees with the result of our experiment. In the case of swelling capacity, Femenia et al. (1997) found that cauliflowers had higher swelling capacity values ranging from 17.0 to 17.5 ml/g dry sample. These findings suggest that production procedures such as drying, extrusion, heating, cooking, slicing, and grinding may have an impact on the hydration properties (Guillon & Champ, 2000).

Freeze dried MFCs had also the significantly highest oil holding capacity compared to oven dried MFCs. Moreover, Elleuch et al. (2008) recorded the highest oil holding capacity for the date dietary fiber concentrate, possibly due to its higher dietary fiber content.

Color is affected by numerous parameters such as fruit variety, degree of ripeness, and maturity. The greatest a* value was found in oven dried mango powder, which was darker than freeze dried powder. The vividness and yellow color saturation of freeze dried mango powders vary considerably. On the other hand, the oven dried mango fiber exhibited lower chroma values, indicating less saturation and a dull yellow hue. A comparison result was also recorded for the hue angle between the freeze dried mango fiber and oven dried mango fiber but later one had a lower hue angle value and a dull yellow color. High temperature during oven drying induces a non-enzymatic browning reaction, which blackens the end product (Clotet et al., 1994). As MFCs are colored, they can affect the product by adding it to a food system. A compatible fiber drying method may be chosen, depending on the requirement of the product.

4.2. Antioxidant activities of mango fiber concentrates

MFCs, due to their abundance in polyphenols, may be considered an important source of natural antioxidants. MFCs exhibited a significant deviation in total phenolic content among all the varieties analyzed. The high phenolic content can have beneficial physiological effects and can also prevent chronic diseases such as cancer and coronary heart disease (Besbes et al., 2009). Freeze dried MFCs had significantly more total phenolic content than oven dried MFCs. Ice crystals formed inside the tissue structure during freeze drying disintegrate cell formation, facilitate solvent extraction, and thus increase the amount of phenolic chemical in freeze dried MFCs (Shih et al., 2009).

MFCs produced by various drying processes had a strong influence on radical scavenging activity. Freeze dried MFCs had significantly higher antioxidant properties than oven dried MFCs. The decrease in DPPH radical scavenging activity is associated with the depletion of polyphenolic content (Michalska et al., 2018). Gümüşay et al. (2015) concluded that a proportionate connection between the vitamin C and TPC is seen in the antioxidant properties. One cause of increased DPPH radical activity is the high hydrogen atomic donation capability of the phenolic compounds (Das et al., 2012).

We also found a significant ($p< 0.05$) increase in vitamin C content in freeze dried MFCs than oven dried MFCs. It could be related to ascorbic acid's heat sensitivity during oven drying at high temperatures. But in freeze drying, there was literally no heat involved to dry out MFCs. This might explain why freeze dried MFCs contained more ascorbic acid than oven dried MFCs (Sogi et al., 2015). Ali et al. (2020) indicated that the presence of oxygen and heat may lead to the degradation of ascorbic acid. The main cause for the negative effect on the ascorbic acid concentration of fiber concentrates was the chemical breakdown of ascorbic acid into dehydroascorbic acid by oxidation, then 2,3-diketogulonic acid by hydrolysis and even further polymerization to generate additional nutritionally inactive compounds (Arampath & Dekker, 2021; Das et al., 2012). In Himsagor and Fazli, a substantially lower ascorbic acid content was found compared with that of other varieties. The amount of ascorbic acid in a variety usually depends on weather conditions, cultural practices, ripeness, and post-harvest conditions (Lee & Kader, 2000).

5. Conclusion

The mango fiber concentrates (MFCs) contained several compounds with known health benefits. MFCs produced by the freeze drying process have a high level of DPPH radical scavenging activity, ascorbic acid as well as polyphenol content. The highest swelling capacity, water and oil holding capacity were also reported in freeze dried MFCs. In comparison to those produced by the oven drying methods, the color of the freeze dried MFCs was noticeably lighter. This study's findings will help to discover the best drying procedure for producing dietary fiber and using it as a nutraceutical and functional ingredient in food industries of Bangladesh as well as other countries.

Declaration of Competing Interest

We declare that there is no conflict of interest.

Ethical Statement - Studies in humans and animals

Our study did not involve humans and animals participation. Therefore, we did not require any ethical approval certificate.

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