

## Effect of Spray Drying Parameters on Physicochemical Properties of Sand Pear (*Pyrus pyrifolia* L.) Powder

Lalita<sup>1\*</sup>, Kumar Mahesh<sup>2</sup> & Alam M S<sup>2</sup>

<sup>1</sup>ICAR-Central Institute of Agricultural Engineering, Nabibagh, Berasia Road, Bhopal 462 038, Madhya Pradesh, India

<sup>2</sup>Department of Processing and Food Engineering, Punjab Agricultural University, Ludhiana 141 004, Punjab, India

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Sand pear exhibits favourable nutritional qualities; however, it faces limited consumer appeal due to its firm texture and seasonal availability in the market. Additionally, a notable amount of fresh pear produce goes to waste during harvest due to inadequate processing and value-added utilization. This study investigates the effect of inlet air temperature (170–185°C), feed flow rate (2.50–4.16 mL/min) and maltodextrin concentration (16–29%) on the physicochemical properties of spray-dried sand pear powder using RSM. Moisture content, Total Phenolic Content (TPC), solubility and hygroscopicity of powder were significantly affected by the inlet temperature and maltodextrin concentration. However, feed flow rate did not significantly affect the physicochemical properties except for TPC. As the inlet temperature increased, solubility and hygroscopicity also increased and this change was apparent at low maltodextrin concentrations for hygroscopicity. Total Soluble Solids (TSS) was highly affected by the maltodextrin concentration. The optimized conditions were obtained at an inlet air temperature of 185°C, feed flow rate of 3.12 mL/min and maltodextrin concentration of 29%. A two-tailed paired t-test showed that the model-predicted values were not significantly different from the experimental values, indicating the suitability of the model in predicting the physicochemical properties of sand pear powder. The reconstituted juice under optimized condition had higher TSS and titratable acidity compared to fresh juice. By converting sand pear juice into powder form, its availability can be extended throughout the year. The powder can further be transformed into various ready-to-eat products, such as instant sand pear juice, bar etc. offering enhanced convenience and reduced wastage.

**Keywords:** Ascorbic acid, Hygroscopicity, Maltodextrin, Reconstituted juice, Value-added utilization

### Introduction

Pear is fifth important fruit species after apple, grapes, banana and orange. Sand pear (*Pyrus pyrifolia* L.) is the one of the pear species which in its dormant stage can endure very low temperatures i.e., up to –26°C and as high as 45°C during its maturity stage.<sup>1</sup> Thus, it has wider adaptability to grow in tropical and subtropical regions with high tolerance potential against adverse soil conditions. In India, sand pear is primarily grown in Haryana, North-East, Punjab, Uttarakhand and Uttar Pradesh.<sup>2</sup> Locally, it is known as “pathernakh” because it bears hard texture on exocarp having prominent dots in yellowish green color. Being seasonal fruit, it is available in market for very short period, and having shelf life merely 2 to 4 days. Its nutritional benefits are apparent from its composition, with approximately 11.9 grams of carbohydrates, 19 grams of fiber, 0.6 grams of protein, and 0.2 grams of fat per 100 grams.<sup>2</sup>

Additionally, it contains significant amounts of minerals, vitamins, and polyphenols, and is utilized in treating conditions such as alcoholism, coughs, constipation, and for lung hydration.<sup>3</sup> Although sand pear possesses good nutritional qualities but it is not popular among the consumers due its hard texture and short period availability in market. Also, during harvesting season, a significant amount of fresh pear produce goes waste because of insufficient processing and value-addition. Pears have a short shelf life even under refrigeration, often developing brown to dark-brown areas in the core or flesh without any external signs.<sup>4</sup> Hence the processing of sand pear is required to enhance the sand pear derivative food products.

Spray drying is the one of the best drying methods to reduce the high amount of water from the liquid feed to convert it into solid substance.<sup>5</sup> It is used in various fields particularly in the food, pharmaceutical and agrochemical industries. In food processing sector it is widely used for producing fruit juice powder with great benefits like single process operation, retention of bioactive compounds and produces very fine and

\*Author for Correspondence  
E-mail: lalitapfe@gmail.com

uniform powder.<sup>6</sup> Many heat sensitive, heat resistance and even bioactive compounds can be successfully dried using spray drying.<sup>7</sup> The quality of the obtained powder is mainly affected by the drying parameters like inlet air temperature, feed flow rate, glass transition temperature ( $T_g$ ) and atomization speed. The low glass transition temperature of lower molecular weight constituents such as lactose, maltose, sucrose, glucose, fructose etc., present in fruits is main limitation of spray drying process of juice.<sup>8</sup> During spray drying, fruit juice comes in contact with hot air for very short retention time inside the drying chamber and lower molecular weight constituents of juice transform into soft, rubbery materials and sticks on drying chamber due to low glass transition temperature.<sup>8</sup> The stickiness generally, observed at temperatures about 20°C above  $T_g$ .<sup>7</sup> To prevent the stickiness, suitable wall materials (maltodextrins, cyclodextrins, gum arabic, gum karaya, carboxymethyl cellulose, hydroxypropyl methyl cellulose etc.) are added to the juice.<sup>9</sup> These wall materials have high  $T_g$  and also lowers the thermal and oxidative losses of heat sensitive compounds present in fruit juices. Hence, the optimum drying condition as well as wall material concentration is key factor to produce good quality of fruit powder. The key findings of this investigation were to examine how temperature of inlet air, concentration of wall material and feed rate effects reconstitution and physicochemical properties of spray dried sand pear powder.

## Materials and Methods

### Raw Material Procurement and Feed Preparation

Fresh sand pear (*Pyrus pyrifolia* L.) fruit (var. Punjab Nakh) was procured from the orchard (30.9010° N, 75.8071° E)<sup>10</sup> of Punjab Agricultural University, Ludhiana, India. The fruit was cured by storing it in cold storage (4–6°C) for two days. To remove dust and dirt, it was thoroughly washed followed by manual sorting. The juice was extracted using domestic juice extractor (Make: Sujata, India). To prevent from clogging in atomizer, extracted juice was filtered by the muslin cloth. Total soluble solids of sand pear juices were estimated using hand refractometer using the prescribed procedure. Maltodextrin DE-10 was added in juice and thoroughly blended for its complete dissolution in juice.

### Spray Drying

A laboratory size spray dryer (Make: LSD-48, Jay instruments and systems Pvt. Ltd, Navi Mumbai)

equipped with twin fluid atomizer was used for spray drying. The spray dryer was operated at 50% constant aspirator rate with different range of drying parameters. In order to determine the spray drying operational conditions preliminary trials was done on the basis of literature reviewed.

### Physicochemical Analysis

To examine the impact of drying condition on reconstituted and physicochemical properties of powder viz. Total Phenolic Content (TPC), Moisture Content (MC), Total Soluble Solids (TSS), Hygroscopicity (H) and Solubility (S) were analysed. In addition to this, the measurement of ascorbic acid content and titratable acidity was carried out for comparison of obtained spray dried sand pear powder with pure juice.

#### Total Phenolic Content (TPC)

The TPC was determined according to the method given by Ranganna<sup>11</sup> One gram of sand pear juice powder was refluxed with 5 mL of 80% methanol for 10 min. From this methanol extract, 0.5 mL aliquot was taken and vaporized to dryness followed by addition of 6.5 mL distilled water to the residue. Afterward, Folin's Regent (0.5 mL) was added and mixed well thoroughly. After 5 min, 1 mL of saturated solution of Na<sub>2</sub>CO<sub>3</sub> was added and incubated for 1 h at room temperature. The sample was read against blank at 760 nm in spectrophotometer. The TPC in samples was determined from standard curve prepared using gallic acid as standard (Eq. 1).

$$\text{Total phenolic content, TPC} \left( \frac{\text{mg GAE}}{100\text{g}} \right) = \frac{\text{phenol value from graph} \times \text{final vol. made}}{\text{wt of sample} \times \text{aliquot}} \times 100 \quad \dots (1)$$

#### Moisture Content (MC)

Moisture content of the powder was determined using electronic IR moisture meter (Make: Mettler Toledo, India Pvt Ltd). Two gram of powder was spread on tared aluminium pan of the moisture meter and heated at 105°C. The moisture evaporated from the sample were automatically recorded and given in per cent of wet basis.<sup>12</sup>

#### Total Soluble Solids (TSS)

The powder was reconstituted in the ratio of 1:5 to measure TSS using refractometer (Model: ERB-32; Make: Erma Instruments, Japan; Range: 0–32 °Brix) at 20°C.<sup>13</sup>

**Hygroscopicity (H)**

Hygroscopicity of food powder is based on the equilibrium moisture content at high humid condition. It is determined by method suggested by Wang *et al.*<sup>14</sup> with slight modification. One gram of powder was spread on pre weighted petri dish in triplication and placed in desiccator for seven days at  $85 \pm 1\%$  RH using NaCl solution at constant temperature of  $20^\circ\text{C}$ . After seven days, the samples have attained equilibrium condition and measured the weight of petri dishes with samples. It was quantified as weight (gram) of moisture adsorbed per 100g dry solids (g/100 g) and calculated using Eq. 2:

$$\text{Hygroscopicity (H)} = \frac{\Delta w / W_i + M}{(1 + \Delta w / M)} \quad \dots (2)$$

where,  $W_i$  is initial mass of powder spread on petri dish (g),  $\Delta w$  is increased weight of powder after reaching equilibrium (g) and  $M$  is moisture content of powder (g/100 g).

**Solubility (S)**

Method use for measurement of solubility adopted from Goula *et al.*<sup>15</sup> with some modification. Two gram of powder was agitated in 50 mL distilled water using magnetic stirrer (at 892 rpm) until powder got fully dissolved in distilled water. The total time required to completely dissolve was recorded and reported as solubility in seconds (s).

**Titrateable Acidity (TA)**

The titrateable acidity was calculated by adding 1 mL of juice to 10 mL of pure ethanol (90%). Afterwards, five drops of phenolphthalein indicator were added and followed by titrated against 0.1 N NaOH till pink colour was appeared.<sup>16</sup>

$$\text{Titrateable Acidity (\%)} = \frac{6.4 \times \text{Normality of NaOH Solution} \times \text{Volume of titrant (mL)}}{\text{Volume of Extract (mL)}} \quad \dots (3)$$

**Ascorbic Acid Content (AC)**

A measured volume of juice (10 mL) was combined with 70 mL of acetic acid metaphosphoric acid solution. From the resulting mixture, 5 mL was used for titration with 2, 6-dichlorophenol-indophenol (dye) until a persistent pink colour appeared. The volume of dye used for titrating the sample was recorded as ( $V_2$ ) in the formula below. Additionally, 5 mL of a standard ascorbic acid solution was titrated with the dye until a pink colour appeared and volume

noted in mL ( $V_1$ ). Ascorbic acid (mg/100g) content was calculated by the Eq. 4<sup>(17)</sup>

$$\text{Ascorbic acid} = \frac{1 \text{ mg} \times \text{Volume of dye for sample (V}_2\text{)} \times \text{Total extract}}{\text{Volume of dye for Stdandard (V}_1\text{)} \times 5 \text{ mL} \times \text{Wieht of sample}} \times 100 \quad \dots (4)$$

**Experimental Design**

Response surface methodology was applied to analyse the effect of spray drying parameters on the physicochemical properties of the developed sand pear powder. In this experiment, temperature of inlet air, feed flow rate and maltodextrin concentration were independent variables and selected physicochemical properties (responses) of the powder were moisture content, total soluble solids, total phenol content, solubility and hygroscopicity. A three factor three level Box–Behnken design (BBD) was used (Table 1). The numbers of experimental runs were formulated by Eq. 6 which includes five central points.

$$N = 2K(K - 1) + C \quad \dots (5)$$

where, N is total number of experimental runs, K is number of independent variables and C is number of central points.

**Statistical analysis**

The second order polynomial mathematical models (Eq. 6) were fit to establish regression relationship between independent variables and responses. The significance of models was investigated by ANOVA (Analysis of variance). Lack of fit,  $R^2$ , adj  $R^2$  was examined to check the adequacy of developed models.

$$Y_k = \beta_0 + \sum_{i=1}^n \beta_i X_i + \sum_{i=1}^n \beta_{ii} X_i^2 + \sum_{i=1}^{n-1} \sum_{j=i+1}^n \beta_{ij} X_i X_j \quad \dots (6)$$

Table 1 — Independent variables and their levels in Box-Behnken design

Independent variable	Coded levels			$\Delta X$
	Low (-1)	Centre (0)	High (+1)	
$A_{it}$ , $^\circ\text{C}$	170	177.5	185	7.5
$F_{fr}$ , mL/min	2.5	3.33	4.16	0.83
$M_C$ , %, w/v	16	22.5	29	6.5

$A_{it}$  Inlet air temperature,  $^\circ\text{C}$ ;  $F_{fr}$  Feed flow rate, mL/min;  $M_C$  Maltodextrin concentration, % (w/v);  $\Delta X$  is difference of extreme values from the central value

where,  $Y_k$  response predicted by model,  $X_i$  are the coded independent variable (where,  $i = 1, 2, \dots$  and  $j = 1, 2, \dots$ ),  $\beta_o$  is coefficient of intercept and  $\beta_i$ ,  $\beta_{ii}$  and  $\beta_{ij}$  are regression coefficient due to linear, quadratic and interaction effects respectively.

**Results and Discussions**

**Physicochemical Property of Fresh Sand Pear Fruit**

The fresh mature ripe sand pear fruits were analysed for MC, TSS, TPC, TA and AC. The moisture content, TSS, titratable acidity and ascorbic acid content of fruits were 87.4%, 12°Brix, 0.102% and 3.85 mg/100g, respectively. The TSS content in sand pear was more than the Yalipear<sup>18</sup> and lower than Pingxiangli pear.<sup>19</sup> Total phenolic content was 10.19 mg GAE/100g, this amount was higher than reported in bananas.<sup>20</sup>

**Effect of Spray Drying Parameters on Sand Pear Powder**

The contour plot (Fig. 1 to Fig. 5) obtained from the quadratic model represents the effect of the inlet air temperature ( $A_{it}$ ), feed flow rate ( $F_{fr}$ ) and

maltodextrin concentration ( $M_C$ ) on physicochemical properties of sand pear powder. In each contour plot, one drying parameter kept constant at mid value and other two parameters varied within the range.

**Effect of Spray Drying Parameters on Moisture Content of Sand Pear Powder**

The moisture content is major physicochemical parameter to indicate suitability of the powder for its storability, and lower moisture content (< 10%) is considered as microbiologically safe.<sup>21</sup> The maximum moisture content of powder obtained was 7.34% at temperature 170°C, 3.33 mL/min feed rate and 16% maltodextrin concentration. The individual effect of  $A_{it}$  was significant at  $p < 0.01$ . As it is clearly visible in Fig. 1a and b, that the higher  $A_{it}$  reduced the MCir respective of magnitude of  $F_{fr}$  and  $M_C$ , this is due to reason that higher temperature supplies more heat to the liquid feed solution.<sup>22</sup> At lower value of  $A_{it}$ , the more temperature rise was required in combination with  $F_{fr}$  to reach the same level of MC, but as the  $A_{it}$  had increased the lesser increase in temperature was

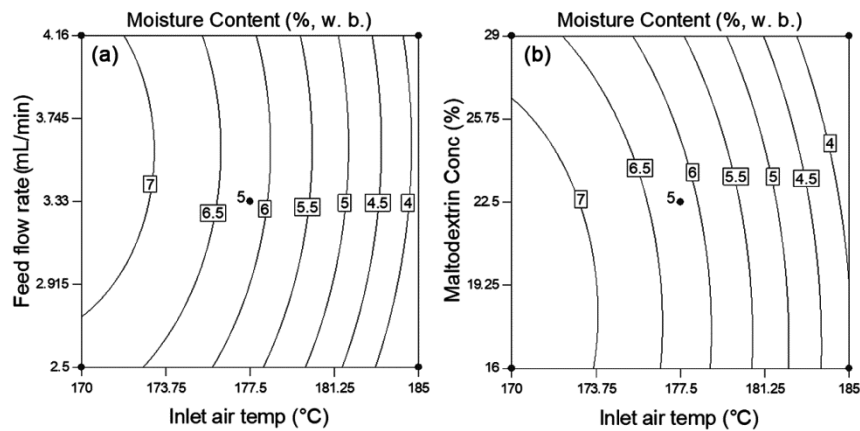


Fig. 1 — Contour plot of Interaction effect of (a)  $A_{it}$  and  $F_{fr}$  on MC; and (b)  $A_{it}$  and  $M_C$  on MC.

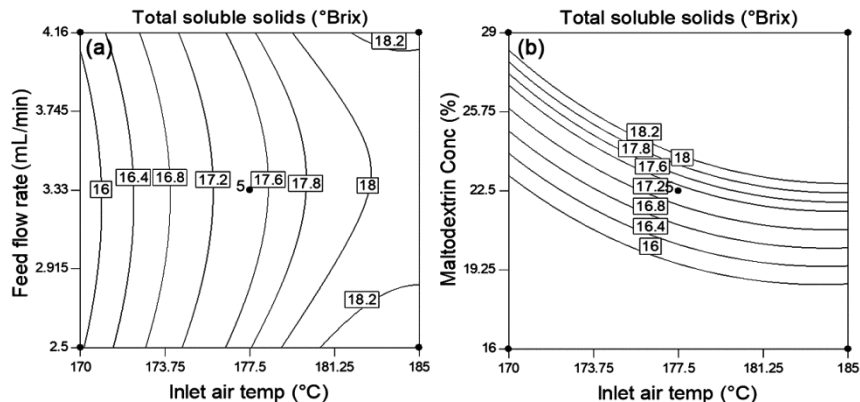


Fig. 2 — Contour plot of Interaction effect of (a)  $A_{it}$  and  $F_{fr}$  on TSS; and (b)  $A_{it}$  and  $M_C$  on TSS.

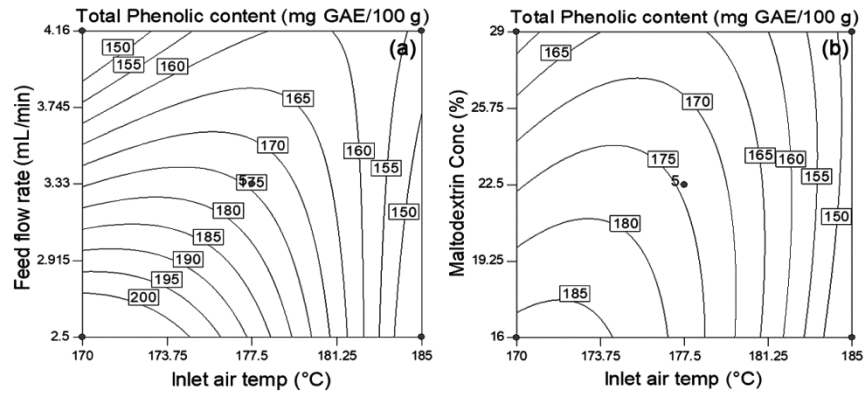


Fig. 3 — Contour plot of Interaction effect of (a)  $A_{it}$  and  $F_{fr}$  on TPC; and (b)  $A_{it}$  and  $M_C$  on TPC.

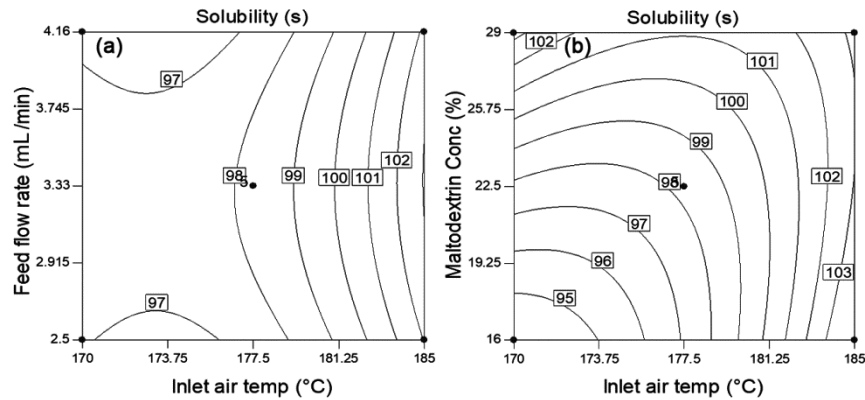


Fig. 4 — Contour plot of Interaction effect of (a)  $A_{it}$  and  $F_{fr}$  on S; and (b)  $A_{it}$  and  $M_C$  on S.

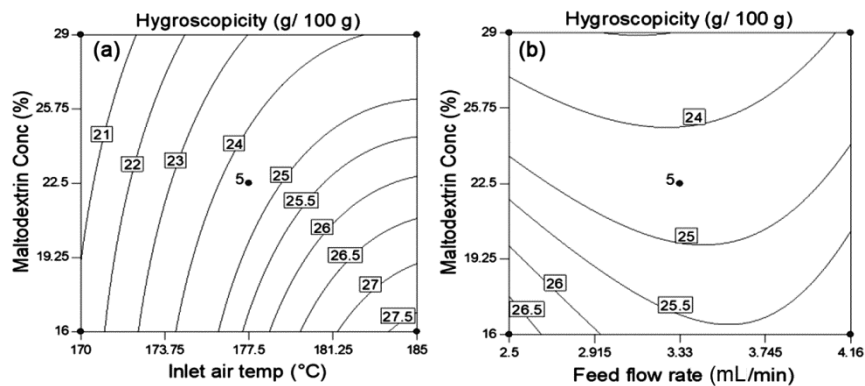


Fig. 5 — Contour plot of Interaction effect of (a)  $A_{it}$  and  $M_C$  on H; and (b)  $F_{fr}$  and  $M_C$  on H.

required to reduce MC at a particular  $F_{fr}$  level (Fig. 1a). The interactive effect of  $A_{it}$  and  $M_C$  has significant effect on MC, with increasing both  $A_{it}$  and  $M_C$  the MC of powder had reduced (Fig. 1b). This was also observed in spray dried onion–stevia leaf<sup>23</sup> and custard apple.<sup>24</sup> The high value of  $M_C$  imparted less free water in powder and more moisture were evaporated at low  $F_{fr}$ .<sup>25</sup> Ultimately this resulted in less MC in sand pear powder.

**Effect of Spray Drying Parameters on Total Soluble Solids of Sand Pear Powder**

The sand pear powder with lower TSS values was observed when  $F_{fr}$  was more and  $M_C$  was less. At higher  $A_{it}$ , TSS has improved with greater extent at a particular  $F_{fr}$  level (Fig. 2a). This is due to the fact that lower  $F_{fr}$  reduces the moisture content in the product, which yielded higher TSS level in sand pear powder.<sup>26</sup> The quantity of TSS present in sand pear

powder had significantly increased with increase in and  $M_C$  and decrease in  $A_{it}$  (Fig. 2b). This was also reported by Caliskan & Dirim<sup>27</sup> for spray dried sumac extract. The highest TSS value was found at 177.5°C  $A_{it}$ , 4.16 mL/min  $F_{fr}$  and 29%  $M_C$ , respectively (Table 2). The individual effect of  $M_C$  shows significant ( $p < 0.01$ ) effect on the TSS i.e. high concentration of  $M_C$  leads to more TSS in sand pear powder.

#### *Effect of Spray Drying Parameters on Total Phenolic Content of Sand Pear Powder*

Generally, rise in the temperature during drying operation to some extent resulted in better retention of TPC. But in spray drying process the synergic effect of process parameters witnessed different trend on phenolic content of dried product as shown in Fig. 3a and b. The  $A_{it}$  and  $F_{fr}$  has negative effect on the TPC i.e., TPC were reduced as inlet air temperature and feed rate was increased. The interactive effect of  $A_{it}$  and  $F_{fr}$  was statistically significant at  $p < 0.01$ . The interactive effect of  $A_{it}$  and  $M_C$  has shown that when both  $A_{it}$  and  $M_C$  were less, more TPC was retained in the powder. As the levels of  $A_{it}$  and  $M_C$  has increased that resulted in more loss of TPC this may be attributed to the fact that at higher temperature phenolic content get destroyed at greater extent.<sup>28</sup>

#### *Effect of Spray Drying Parameters on Solubility of Sand Pear Powder*

The effect of spray drying parameters on the solubility of sand pear powder is shown in Fig. 4a and b. It was observed that the individual effect of  $A_{it}$  and  $M_C$  was statistically significant ( $p < 0.01$ ). Both the  $A_{it}$  and  $M_C$  had individual positive effect on the solubility of sand pear powder ( $p < 0.01$ ). Highest solubility of sand pear powder observed at 8<sup>th</sup> run and minimum at 5<sup>th</sup> run presented in Table 2. Both the above-mentioned runs had same feed rate but as  $A_{it}$  and  $M_C$  were increased that consequently resulted in increase of solubility. Additionally, lower  $F_{fr}$  at higher  $A_{it}$  has imparted more solubility to powder. This may associate as higher  $A_{it}$  and  $M_C$  the powder has less residual moisture and results in more solubility in powder.<sup>23</sup>

#### *Effect of Spray Drying Parameters on Hygroscopicity of Sand Pear Powder*

Hygroscopicity of the powder can be characterised by the ability to absorb the moisture from the surrounding. The rise in  $A_{it}$  had synergetic effect on hygroscopicity of sand pear powder ( $p < 0.01$ ). This may have attributed as the fact that at higher temperature the powder had less moisture content which creates moisture gradient between product and surrounding that resulted in absorption of moisture.<sup>28</sup> The synergic effect of both higher  $A_{it}$  and  $M_C$  had

Table 2 — Box-Behnken design with actual/coded values of variables and responses

Run No.	Actual and coded level of variables			Response				
	$A_{it}$ (°C)	$F_{fr}$ (mL/min)	$M_C$ (%, w/v)	MC (%, w. b)	TSS (°Brix)	TPC (mg GAE/100g)	S (s)	H (g/100 g)
1	170 (-1)	2.5 (-1)	22.5 (0)	6.74	16.2	210.3	96.5	22.18
2	185 (+1)	2.5 (-1)	22.5 (0)	3.15	18.5	138.41	102.2	26.45
3	170 (-1)	4.16 (+1)	22.5 (0)	7.28	16	139.87	96.42	21.87
4	185 (+1)	4.16 (+1)	22.5 (0)	3.76	18	153.55	102.8	25.97
5	170 (-1)	3.33 (0)	16 (-1)	7.34	13	185.58	94.84	20.14
6	185 (+1)	3.33 (0)	16 (-1)	4.12	15	142.58	104.6	27.86
7	170 (-1)	3.33 (0)	29 (+1)	6.64	18	156.54	103.24	19.45
8	185 (+1)	3.33 (0)	29 (+1)	3.12	21	148.4	102.4	25.18
9	177.5 (0)	2.5 (-1)	16 (-1)	5.54	14	201.48	95.62	27.15
10	177.5 (0)	4.16 (+1)	16 (-1)	6.34	14.2	154.55	95.83	26.54
11	177.5 (0)	2.5 (-1)	29 (+1)	5.37	21	173.64	101.32	22.78
12	177.5 (0)	4.16 (+1)	29 (+1)	5.12	21.4	157.43	99.8	23.86
13	177.5 (0)	3.33 (0)	22.5 (0)	5.76	17	167.22	98.5	26.15
14	177.5 (0)	3.33 (0)	22.5 (0)	6.39	17.1	167.44	98.34	24.56
15	177.5 (0)	3.33 (0)	22.5 (0)	5.43	17.2	167.41	98.5	23.45
16	177.5 (0)	3.33 (0)	22.5 (0)	6.56	17.1	167.2	97.54	24.75
17	177.5 (0)	3.33 (0)	22.5 (0)	6.78	19	202.37	98.41	23.68

$A_{it}$  Inlet air temperature, °C;  $F_{fr}$  Feed flow rate, mL/min;  $M_C$  Maltodextrin concentration, % (w/v); MC, Moisture content, % (w. b.); TSS, Total soluble solids, °Brix; TPC, Total phenolic content, mg GAE/100g; S, Solubility, s; H, Hygroscopicity, g/100g

significant effect on hygroscopicity (Fig. 5a). In just opposite of this, at lower  $A_{it}$  and higher  $M_C$  has produced less hygroscopic powder.<sup>14</sup> Additionally, increase in  $M_C$  at higher  $F_{fr}$  has produced lesser hygroscopic powder (Fig. 5b). Similar trend was found by Muzaffar and Kumar.<sup>12</sup>

#### Model Fitting

Total seventeen combination of spray drying parameters were obtained by three-factor three coded-level BBD design, the results are presented in Table 2. A wide variation of response values was observed (standard deviation in brackets) in MC, TSS, TPC, S and H as 3.12–7.34 ( $\pm 0.44$ ) %, 13–21.4 ( $\pm 0.80$ ) °Brix, 138.41–210.33 ( $\pm 11.94$ ) mg GAE/100 g, 94.84–104.6 ( $\pm 0.74$ ) s and 19.45–27.86 ( $\pm 1.18$ ) g/100 g of powder, respectively. The second order polynomial regression model in terms of coded factors corresponds to physicochemical properties of sand pear powder are represented from Eqs 7 to 11. A positive regression coefficient shows synergetic relationship opposite of it negative sign in regression coefficients reflects antagonistic relationship. The significance of the linear, interactive and quadratic effect of drying parameters on physicochemical properties is shown in Table 3.

$$\text{Moisture content} = +6.18 - 1.73A_{it} + 0.21F_{fr} - 0.39M_C + 0.018A_{it}F_{fr} - 0.075A_{it}M_C - 0.26F_{fr}M_C - 0.62A_{it}^2 - 0.33F_{fr}^2 - 0.26M_C^2 \quad \dots (7)$$

$$\text{TSS} = +17.48 + 1.16A_{it} - 0.012F_{fr} + 3.15M_C - 0.075A_{it}F_{fr} + 0.25A_{it}M_C + 0.05F_{fr}M_C - 0.60A_{it}^2 + 0.30F_{fr}^2 - 0.13M_C^2 \quad \dots (8)$$

$$\text{Total phenolic content} = +174.33 - 13.67A_{it} - 14.80F_{fr} - 6.02M_C + 21.39A_{it}F_{fr} + 8.72A_{it}M_C + 7.68F_{fr}M_C - 13.65A_{it}^2 - 0.15F_{fr}^2 - 2.41M_C^2 \quad \dots (9)$$

$$\text{Solubility} = +98.26 + 2.62A_{it} - 0.09F_{fr} + 1.98M_C + 0.17A_{it}F_{fr} - 2.65A_{it}M_C - 0.43F_{fr}M_C + 2.17A_{it}^2 - 0.95F_{fr}^2 + 0.84M_C^2 \quad \dots (10)$$

$$\text{Hygroscopicity} = +24.52 + 2.73A_{it} - 0.04F_{fr} - 1.30M_C - 0.043A_{it}F_{fr} - 0.50A_{it}M_C + 0.42F_{fr}M_C - 1.16A_{it}^2 + 0.76F_{fr}^2 - 0.20M_C^2 \quad \dots (11)$$

Based on analysis of variance, non-significance of lack of fit ( $p > 0.05$ ) and small difference between  $R^2$  and adj.  $R^2$  (Table 3) for model are adequate enough to validate the responses.

#### Optimization and Model Validation

The optimum condition was obtained as the physicochemical properties (Table 4) were set at

Table 4 — Physicochemical properties of sand pear fruit juice and reconstituted juice

Physicochemical property	Fresh fruit juice	Reconstituted juice
Total soluble solids, (°Brix)	12 $\pm$ 0.105	18.66 $\pm$ 0.37
Titrateable acidity, (%)	0.21 $\pm$ 0.32	0.62 $\pm$ 0.14
Total phenolic content, (mg GAE/100g)	11.02 $\pm$ 0.51	10.15 $\pm$ 0.30
Ascorbic acid, (mg/100g)	4.25 $\pm$ 0.25	2.15 $\pm$ 0.26

Table 3 — Regression analysis and ANOVA of second order models for various responses

Predictor	Coefficient				
	MC (% w. b)	TSS (°Brix)	TPC (mg GAE/100g)	S (mL/min)	H (g/100g powder)
Intercept	6.184	17.48	174.328	98.258	24.518
$A_{it}$	-1.7312***	1.1625***	-13.6687**	2.625***	2.7275***
$F_{fr}$	0.2125	-0.0125	-14.8037***	-0.0987	-0.04
$M_C$	-0.3862**	3.15***	-6.0225	1.9837***	-1.3025**
$A_{it} * F_{fr}$	0.0175	-0.075	21.3925***	0.17	-0.0425
$A_{it} * M_C$	-0.075	0.25	8.715	-2.65***	-0.4975
$F_{fr} * M_C$	-0.2625	0.05	7.68	-0.4325	0.4225
$A_{it}^2$	-0.6195**	-0.6025	-13.6478*	2.1747***	-1.1627*
$F_{fr}^2$	-0.332	0.2975	-0.1477	-0.9527**	0.7622
$M_C^2$	-0.2595	-0.1275	-2.4052	0.8372*	-0.1977
ANOVA					
Lack-of-fit	n.s.	n.s.	n.s.	n.s.	n.s.
F-value	16.24***	16.11***	5.26**	28.8***	6.65**
$R^2$	0.95	0.95	0.87	0.97	0.90
adj. $R^2$	0.90	0.89	0.71	0.94	0.76

$A_{it}$  Inlet air temperature, °C;  $F_{fr}$  Feed flow rate, mL/min;  $M_C$  Maltodextrin concentration, % (w/v); MC, Moisture content, % (w. b.); TSS, Total soluble solids, °Brix; TPC, Total phenolic content, mg GAE/100g; S, Solubility, s; H, Hygroscopicity, g/100g; n. s. = non-significant; \*  $p < 0.1$ , \*\*  $p < 0.05$  and \*\*\*  $p < 0.01$

Table 5 — Validation of model at optimized condition

Variable	Goal	Predicted value ( $\mu_o$ )	Actual value @ ( $\mu_1$ ) $\pm$ SD	Standard error	Mean difference	Variation, per cent	$t_{cal}$
MC (% w. b.)	Minimum	3.1	3.39 $\pm$ 0.22	0.10	0.29	8.55	2.92
TSS ( $^{\circ}$ Brix)	Maximum	21.34	21.86 $\pm$ 0.86	0.38	0.52	2.38	1.36
TPC (mg GAE/100g)	In range	143.76	145.04 $\pm$ 2.75	1.23	1.28	0.89	1.05
S (s)	Maximum	103.26	103.6 $\pm$ 1.02	0.46	0.34	0.33	0.75
H (g/100 g powder)	Minimum	24.05	25.44 $\pm$ 0.133	0.60	1.39	5.46	2.34

MC, Moisture content, % (w. b.); TSS, Total soluble solids,  $^{\circ}$ Brix; TPC, Total phenolic content, mg GAE/100g; S, Solubility, s; H, Hygroscopicity, g/100g;  $\mu_o$ :  $\mu_1$ ,  $t_{cal} < t_{table}$  at  $p < 0.01$ ,  $h_o$  was accepted, @ Mean of five replications

maximum, minimum or in range target with different importance for obtaining the best possible quality of powder within the range of drying parameters. The criteria for responses were set as MC and Hat minimum however, TPC in range, and TSS and S set at maximum. The optimized drying condition obtained at  $A_{it}$  185 $^{\circ}$ C,  $F_{fr}$  3.12 mL/min and  $M_C$  29% respectively corresponds to it, the responses were MC 3.10%, TSS 21.34  $^{\circ}$ Brix, TPC 143.76 mg GAE/100g S103.26s and H 24.05 g/100g with 81.7% desirability. To validate the optimized conditions obtained from the model, all the physicochemical properties analysed in triplicate. The results of two-tailed pair t-test (Table 5) for spray dried powder observed that difference between model values and actual values was non-significant. That means model for spray drying process fits well to the sand pear powder produced.

#### Comparison of Fresh Juice and Reconstituted Juice

Powder obtained at optimized condition was reconstituted with water (1:10) and compared with fresh juice (Table 4). Reconstituted juice had higher amount of TSS and Titratable acidity than freshly extracted juice, this may be attributed to addition of carrier material which releases its sugars and acids during drying.<sup>29</sup> The TPC was observed higher in reconstituted juice than fresh juice extracted from fruits. The TPC might have increased due to polymerization and synthesis of polyphenols during spray drying process.<sup>30</sup> The ascorbic content of the reconstituted juice was found to be lower than that of the fresh juice by 38%.

#### Conclusions

Seventeen experimental runs according to the Box–Behnken design were used to study the physicochemical properties of spray-dried sand pear powder at three levels of  $A_{it}$ ,  $M_C$  and  $F_{fr}$ . The  $A_{it}$  greatly influenced the physicochemical properties, whereas the  $F_{fr}$  had the least effect. However, the synergistic effect of these parameters resulted in less

hygroscopic sand pear powder with a high phenolic content. Sand pear powder produced under optimized conditions ( $A_{it}$  185 $^{\circ}$ C,  $F_{fr}$  3.12 mL/min and  $M_C$  29%) had a moisture content of 3.1%, which is a highly desirable factor for extending the shelf life of the product, and it exhibited good solubility in water. The powder exhibited such superior qualities; therefore, this methodology can be applied for large-scale production. To the best of our knowledge, this is the first research work carried out on the spray drying of sand pear. Thus, the effects of other wall materials and the flow properties of spray-dried sand pear powder can be studied.

#### Conflict of interest

The authors declare that they have no conflict of interest for this reported work.

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