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Research Article

Optimization of Spray Drying Conditions for Production of Aloe-Vera Powder

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Abstract

The objective of this research was to optimize the spray drying parameters for the production of aloe-vera juice poswder. A LSD-48 mini spray dryer was utilised for the operation; maltodextrin was employed as stabilizer for drying or aloe vera-juice. Three level Response Surface Methodology (RSM) was executed to analyse the effect of inlet air temperature (140, 150 and 160°C) and maltodextrin concentration (30, 40 and 50%) with a feed flow rate of 25mg/min on powder recovery, moisture content, solubility, porosity, dispersability, TSS,colour and wettability of aloe-vera powder thus prepared. The following optimum process conditions were ascertained: inlet air temperature of 156.9°C and maltodextrin concentration of 42%. These parameters resulted to the powder recovery, moisture content, solubility, porosity, dispersability, TSS, colour and wettability of 9.79%, 3.56%, 101.70 s, 65.82%, 85.03%, 24.31°Brix, 97.21 (L value) and 415 s respectively.

Keywords: Maltodextrin, Aloe-vera powder, Response surface methodology, Spray drying

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Introduction

The aloe-vera plant has been known and used for centuries for its health, beauty, medicinal and skin care properties [1]. It is found only in warm, fertile regions where it is capable of withstanding very long periods of drought. The aloe plant consists of about 99% water with an average pH of 4.5. The remaining solid material consists of 75 different ingredients including vitamins, minerals, enzymes, anthraquinones or phenolic compounds, lignin, saponins, sterols, polysaccharides and salicylic acid. Aloe-vera leaves contain a range of biologically active compounds, the best studied being acetylated mannans, polymannans, anthraquinone C-glycosides, anthrones and anthraquinones and various lectins [2].

Proper scientific investigations on aloe-vera have gained more attention over the last decade due to its well-known medicinal, pharmaceutical and food properties. Over the years, many scientists have related to the functions and utilization of aloe-vera. Present processing techniques aims at producing best quality aloe products but end aloe products contain very little or virtually no active ingredients. Hence, appropriate processing techniques should be employed during processing in order to extend the use of aloe-vera gel [3].

Spray drying is one such technique. It is a common practice in the food and dairy industries to convert liquids into powders to increase the shelf life.The unique features of spray drying include a rapid drying cycle, a short holding or retention of the product in the drying chamber, and a final product which is ready for packaging as it leaves the drier. Heat spoilage to the product is relatively smaller due to short exposure times. The final product may be free flowing powder of individual particles, agglomerates or granules.

The total solids like sugars; organic acids etc. are concentrated exerting osmotic pressure to inhibit the growth of microorganisms. Reduction in water content controls the biological and chemical forces thus facilitating preservation. Drying not only prolongs the period of storage but also minimizes packaging requirements and reduces shipping weight. Considering the aforesaid discussion, present research has been undertaken to examine the effect of various processing parameters on spray drying behaviour of aloe-vera gel and to study the physico-chemical and sensory characteristics of resultant powder.

Materials and Methods

Experimental design and equipment used

Sample preparation

The experiments to meet the set objectives were conducted in the Department of Processing and Food Engineering, P.A.U. Ludhiana. Fresh leaves were procured from the herbal gardens, PAU Ludhiana. Mature and sound leaves of about equal size and shape were selected for the study. Infested, bruised and shriveled leaves were discarded. The experimental scheme for production of aloe juice powder is depicted in **Table 1**.

Table 1 Experimental scheme for production of aloe-vera juice powder

Sr.No.	Particular	Description
1.	Variety	*Aloe Barbadensis Miller*
2.	Treatments	(1) Aloe leaves were washed with water. (2) Both ends of the leaves were cut. (3) Spines and green sheaths were removed and gel was extracted with the help of a Stainless steel scrapper. (5) Gel was homogenized in a mixer grinder and was filtered using muslin cloth (6) Concentration of aloe-vera juice by using 3 different blends of maltodextrin with juice.
3.	Drying conditions	Spray drying of concentrated blends was done at inlet temperature of 140^{0}C, 150^{0}C and 160^{0}C.
4.	Physico-chemical properties of powder	Moisture content, Porosity, Colour, Solubility, Wettability, Total soluble solids, Dispersability

A number of equipment have been used during this study right from simple knife used for peeling and cutting to packaging of aloe juice powder as indicated in Table 2. Maltodextrin was selected as drying agent for the study. The juice was concentrated by using different blends of maltodextrin with juice. The selected blends were 30: 70, 40: 60 and 50: 50. The drying of prepared aloe-vera juice blended with drying agents was carried out in a LSD-48 mini spray dryer (Jay Instruments and Systems Pvt. Ltd., Mumbai) at three different inlet temperatures for production of powder whose physio-chemical analysis was then commenced.

Table 2 Mathematical models of response parameters

Sr. No.	Response	Model fitted	Type of model
1	Powder recovery (R)	$R = 9.05 – 0.53A – 1.47B + 1.12AB + 2.17 A^2 – 0.34B^2$	Quadratic
2	Moisture content (M)	$M = 3.59 – 5E – 3A + 0.11B$	Linear
3	Solubility (S)	$S = 100.54 + 4A + 12.33B$	Linear
4	Porosity (P)	$P = +65.82$	Mean
5	Dispersability (D)	$D = 85.05 – 1.66E – 3A + 0.10B$	Linear
6	Total soluble solids (T)	$T = 22.60 + 0.033A – 1.52B + AB + 3.36A^2 – 1.09B^2$	Quadratic
7	Colour (C)	$C = +97.21$	Mean
8	Wettability (W)	$W = +415$	Mean

Physico-chemical analysis of powder

Determination of powder recovery

The powder recovery in (%age) was calculated by using the formula:

$$\frac{\text{Weight of the powder obtained in (g)}}{\text{Weight of the blended aloe} - \text{vera juice in (g)}} X\ 100$$

Determination of moisture content

Five grams of powder was accurately weighed into a petri- dish previously dried and weighed. The dish containing the powder was heated in an oven (Model NSW 143, range 0-250˚C) at 105 °C for 4 hours. The percent moisture was calculated from the loss of mass after 4 hour drying on wet basis [4].

Determination of solubility

The solubility test of the spray dried powder was carried out by adding 2g of material to 50 ml of distilled water at 26˚C [5]. The mixture was agitated in a low form glass beaker 100 ml with a magnetic stirrer (Falc, 50-60 Hz, 0.2 A) at 892 rpm, using a stirrer bar with a size of 2mm × 7mm. The time required for the material to dissolve completely was recorded.

Determination of Porosity

It is the percentage of voids in the test sample at given moisture content. It was calculated as the ratio of the difference in true density and bulk density to the true density value and expressed in percentage with the following equation [6].

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} X\,100$$

ε = porosity, %; ρ_t = True density, kg/m^3; ρ_b= Bulk density, kg/m^3

Determination of Dispersability

The powder was reconstituted to 10% TS level and dispersability for this level of reconstitution was calculated by following the formula suggested by [7].

$$D = \{T \times 735 / 100 - (W + T)\}$$

D = Dispersability %; T = Total solids of the reconstituted liquid after filtration (10%); W= Moisture % of aloe-vera powder

Determination of Total soluble solids (TSS)

The spray dried aloe-vera powder was reconstituted in the ratio of 1: 5 (specified by Foods and Inns Limited, Mumbai) and total soluble solids were determined with the help of 0-32 ºBx Erma hand refractometer. One or two drops of reconstituted juice were put on the sample plate and the reading was recorded. It was normalised against a standard temperature of 20°C.

Determination ofcolour

The colour properties of the fresh aloe juice and aloe-vera powder were measured by using Miniscan XE plus Hunter Lab Colorimeter (U.S.A.), Model No. 45/0-L. The 'L', 'a' and 'b' values were recorded at D 65/100 and were compared to the standard values of fresh aloe juice. The colour change was calculated from 'L', 'a' and 'b' readings as follows [8].

$$\text{Colour change } = \sqrt{[(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2]}$$

Where, L_0, a_0 and b_0 represent the respective readings of fresh sample.

Determination of wettability

An ideal powder should be wetted quickly and thoroughly, sink into the liquid rather than float on the surface and disperse/dissolve within a short period of time without lump formation. Wettability of aloe powder was estimated by Frending method. In this method one gram of aloe powder obtained was placed on a slide covering a water reservoir (diameter 50 mm) by pulling the slide away, the powder layer was brought into contact with water. The wetting time which is necessary for the submersion of last powder particle, was measured and expressed as wettability of powder in seconds.

Experimental design

RSM was performed to study the effects of spray drying parameters including inlet air temperature (A) and concentration of aloe-vera juice and maltodextrin (B) at feed flow rate of 25 mg/min on powder recovery, moisture content, porosity, colour, solubility, wettability, total soluble solids and dispersability The data were expressed as mean±SD. Thirteen experimental runs were generated based on the three level factorial experimental design. The relationship of the independent variables and the response was calculated by the second-order polynomial equation. Three models (mean, quadratic and linear) were developed to relate the eight responses (Y) to the two process variables (X).

The Analysis of Variance (ANOVA), determination of the regression coefficients and the generation of three-dimensional graphs were carried out using the Design Expert software. The model goodness was checked by R^2, adjusted R^2, Adequate precision, PRESS and Coefficient of Variation (CV).

Results and Discussion

Fitting Models

The mathematical models generated from the experimental data using Design Expert software, respectively, for powder recovery (R), moisture content (M), solubility (S), porosity (P), dispersability (D), total soluble solids (T), colour (C) and wettability (W) are expressed by the following:

The high R^2 and adjusted R^2 values indicate that a high proportion of variability in the response models can be explained successfully by the models (Kim et al. 2002). The CV, which indicates the relative dispersion of the experimental points from the predictions of the Second Order Polynomial (SOP) models, were found to be 14.24, 3.17, 13.92, 1.85, 0.13, 10.95, 1, 13.37 % for R, M, S, P, D, T, C, W respectively. Generally, CV value should not be greater than 15%. The suitable PRESS values also suggest the adequacy of the fitted quadratic models for predictive applications. The adequate precision measures the signal-to noise ratio with a ratio greater than 4 being desirable. The high adequate precision values (21.24–77.50) indicated that the fitted models could be used to navigate the design space. ANOVA also showed that the lack of fit was not significant for any response models at a 5% significance level and that model adequacies were appropriate.

It is important to check the adequacy of the fitted models in order to ascertain their validity. **Figure 1a** shows that the normal plot of residuals for responses was normally distributed, as they lie approximately on a straight line and shows no deviation of the variance. The results of all these plots (Figure 1a) indicated that developed models are adequate to describe the responses. The Cook's distance values are in the determined range (Figure 1b); there is strong evidence for influential observations in these data.

Physico-chemical analysis of powder

Powder recovery

Figure 2(1) shows the influence of inlet air temperature and maltodextrin concentration on the spray drying process yield. The powder recovery increased with the increase in inlet air temperature. The maximum quantity of powder was obtained with the 50% maltodextrin concentration. The maximum recovery of powder was obtained to be 17.23% at inlet temperature 160˚C. It decreased to 4.03% at inlet air temperature of 140˚C. Similar results were reported by [5].

Moisture content

Figure 2(2) shows the influence of inlet air temperature and maltodextrin concentration on moisture content of powder. The moisture content decreased with an increase in inlet air temperature. The value of the moisture content was observed to be in the range of 3.28-3.93%, 3.15-3.94% and 3.10-3.55% at inlet air temperature of 140˚, 150˚ and 160˚C respectively. Increase in maltodextrin concentration led to a decrease in the moisture content, probably due to an increase in solids in the feed and reduced amount of free water.

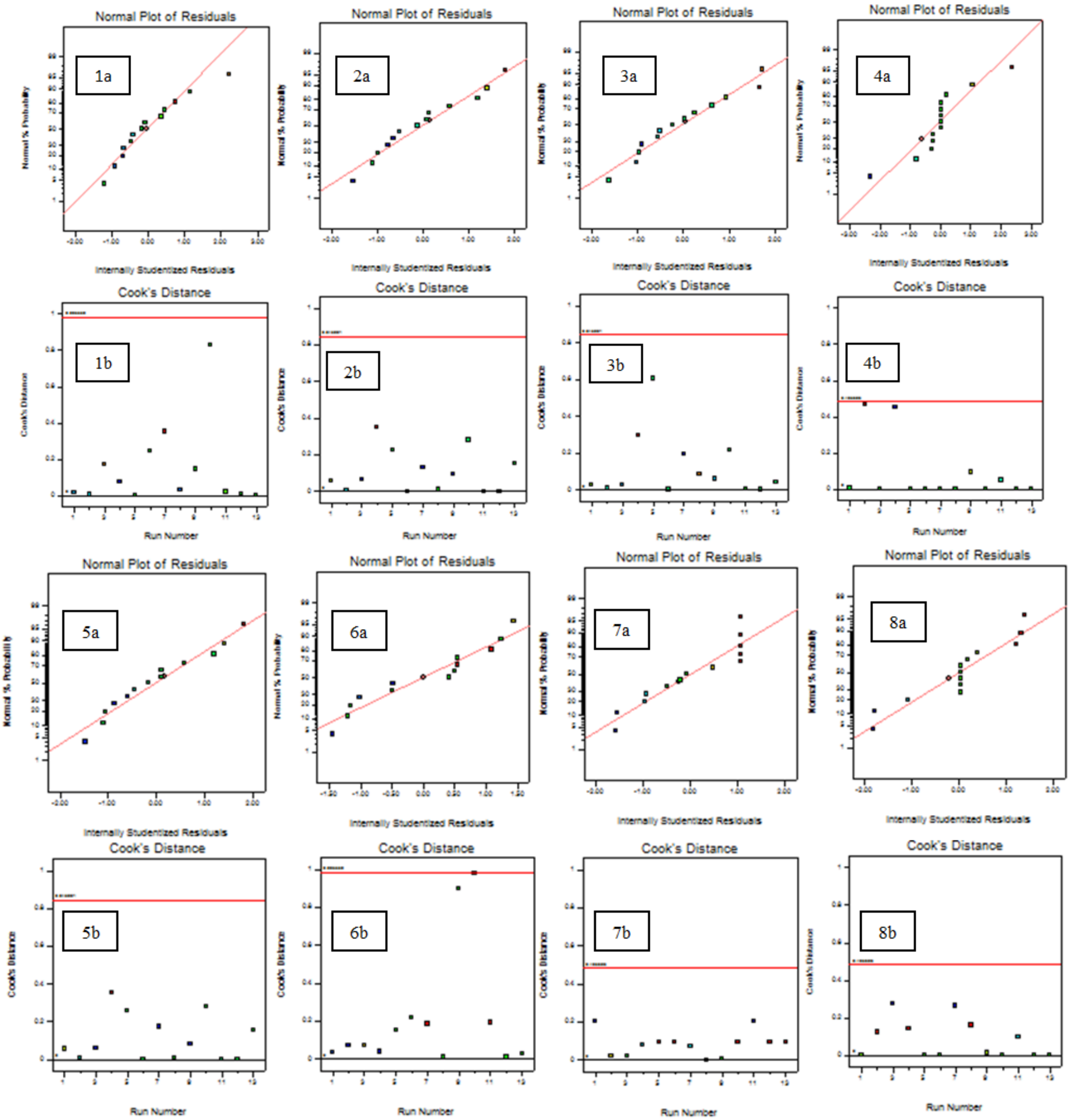

Figure 1 Normal probability of internally studentized residuals (a) and cooks distance vs. run number (b) for powder recovery (1), moisture content (2), solubility (3), porosity (4), dispersability (5), Total soluble solids (6), colour (7) and wettability (8)

Solubility

The effects are as depicted in Figure 2(3). With increased inlet air temperature the dissolution time of the powder decreased. This may be attributed to low moisture content of powders produced at increased temperature. The lesser the moisture content, the faster is the dissolution. Solubility fell in the range of 94-145, 77-122 and 60-98 sec at inlet air temperature of 140, 150 and 160˚C respectively. The dissolution time of the powder also decreased with an increase in maltodextrin concentration. Similar results were reported by [9]

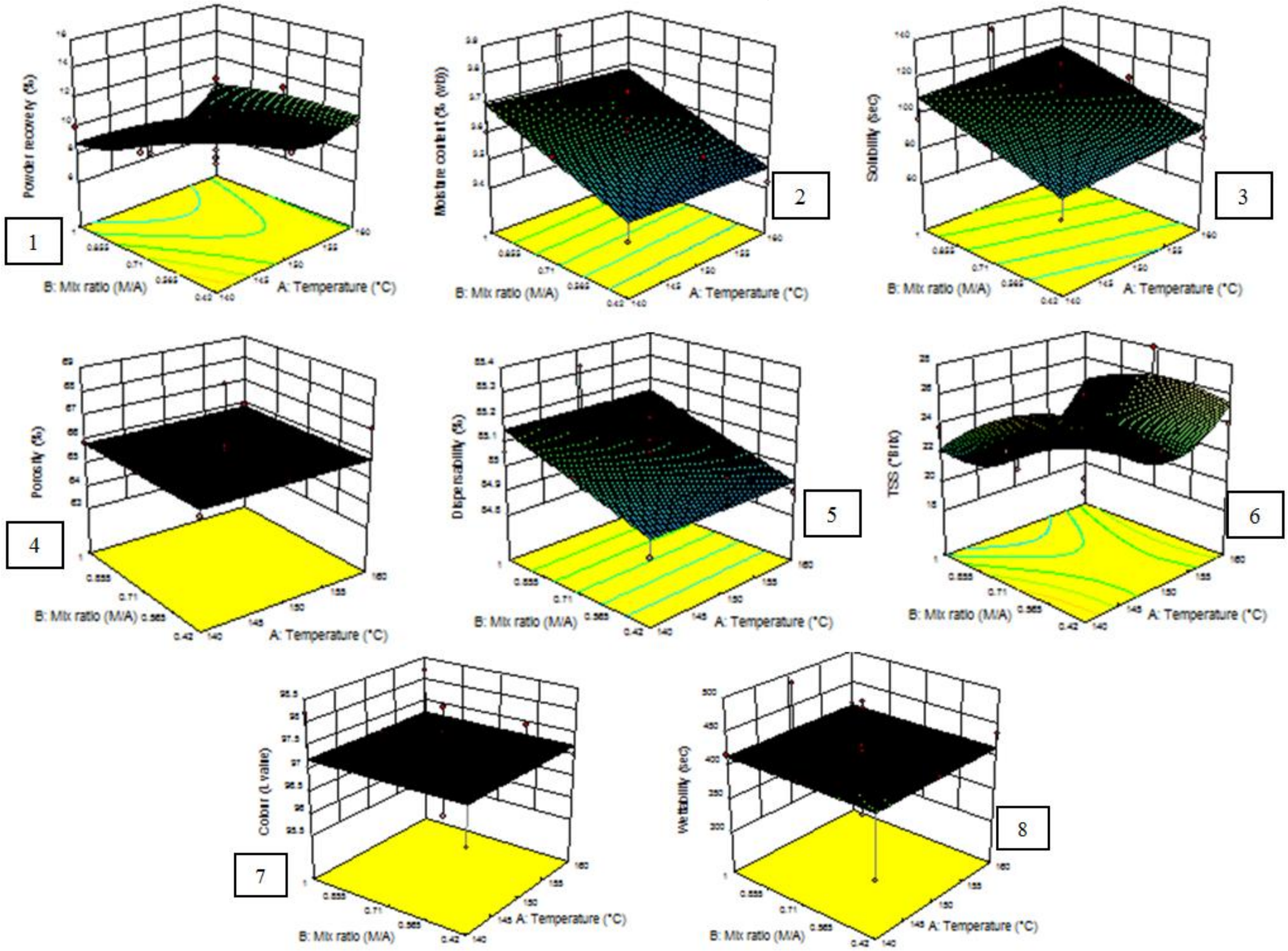

Figure 2 3-D surface model graphs for powder recovery (1), moisture content (2), solubility (3), porosity (4), dispersability (5), Total soluble solids (6), colour (7) and wettability (8)

Porosity

The effects are as depicted in Figure 2(4). No clear trend was observed with any variation in inlet air temperature. It was observed as the value for porosity lied in the range of 61.57-65.55, 63.38-66.06 and 62.40-68.60 at the inlet air temperature of 140˚C, 150˚C and 160˚C respectively. Porosity increased up to maltodextrin concentration of 40% and then decreased with increase in maltodextrin concentration at inlet air temperature of 140˚C. Similar results were shown by [5].

Dispersability

The effects are as depicted in Figure 2(5). With the increase in inlet air temperature and maltodextrin concentration, the dispersability of aloe-vera powder decreased. The value of dispersability was observed to be in the range of 84.75-85.44, 84.62-85.4 and 84.87-85.02% at inlet air temperature 140˚, 150˚ and 160˚C respectively. Similar results were shown by [4].

Total soluble solids

There were no proper responses observed in total soluble solids with the variation in inlet air temperature as shown in Figure 2(6). TSS remained almost constant or slightly increased for the maltodextrin concentration of 30%, 40% and 50% with the increase in inlet air temperature. The TSS value lied in the range of 19.2-20.2, 23.8-24.3 and 26-28 for the maltodextrin concentration of 30, 40 and 50% respectively. Similar results were reported by [9].

Colour

The effects are as depicted in Figure 2(7). It was observed that at higher inlet air temperature, the 'L' value of the aloe-vera powder decreased. With the increase in maltodextrin concentration, the whiteness of the aloe-vera powder increased. This was due to the white colour of maltodextrin.

Wettability

Wettability decreased with increase in inlet air temperature as depicted in Figure 2(8). Increase in maltodextrin concentration showed the declining trend of wettability. This might be due to decrease in moisture content with increase in inlet air temperature and maltodextrin concentration. The lesser the moisture content, lesser is the time to wet the powder. The wettability was found to be in the range of 317-489, 285-434 and 280-495 at the inlet air temperature of 140˚C, 150˚C and 160˚C respectively. Similar results were shown by [10].

Optimization

The second order polynomial models obtained in this study were utilized for each response in order to determine optimum conditions. Regarding response parameters, the following optimum conditions were established for producing spray-dried aloe-vera powder: inlet air temperature of 156.9°C and maltodextrin concentration of 42% at feed flow rate of 25mg/min At this optimum point powder recovery, moisture content, solubility, porosity, dispersability, TSS, colour and wettability were determined to be 9.79%, 3.56%, 101.70 s, 65.82%, 85.03%, 24.31°Brix, 97.21 (L value) and 415 s respectively. The desirability value for the optimum solution was 1.

Conclusion

In this study, experiments to prepare aloe-vera powder from fresh aloe-vera juice were conducted using spray drying technique. The effects of inlet air temperature and maltodextrin concentration on physico-chemical properties of aloe-vera powder were studied. The optimum results indicated that an inlet air temperature of 156.9°C and maltodextrin concentration of 42% at feed flow rate of 25mg/min will produce powder with the best properties. At these optimum conditions, powder recovery, moisture content, solubility, porosity, dispersability, TSS, colour and wettability were determined to be 9.79%, 3.56%, 101.70 s, 65.82%, 85.03%, 24.31°Brix, 97.21 (L value) and 415 s respectively.

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