

Original Research Article

<https://doi.org/10.20546/ijcmas.2018.705.435>

Development of Functional Milk Beverage Powder

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ABSTRACT

Beverages are no longer considered as thirst-quenchers; consumers look for specific functionality and it becomes a part of their lifestyle. In recent years, these changes and developments have led to newer products. Red beetroot (*Beta vulgaris* L.) is a rich source of dietary nitrate which significantly reduces systolic blood pressure in humans. Banana (*Musa spp.*) is a major source of potassium and total dietary fibers. Spray-drying is one of the highly utilized techniques to increase the shelf-life of food products. Hence our project was aimed to develop functional milk beverage powder with fortification of beet and banana. In our preliminary studies, various combination of milk, beetroot and banana were tried (T₁, T₂, T₃, T₄ and T₅). Based on the sensory scores, T₄ was selected for spray drying. Pre-heated toned milk was homogenized with pulp of banana and beetroot. The homogenized beverage was pasteurised at 85° C for 30 minutes and spray dried at the temperature of 140°C, 160°C and 180°C and flow rate of 100 ml/h, 200 ml/h and 300 ml/h. Effects of inlet air temperatures and flow rate on physical properties of spray dried functional milk beverage powder were investigated. Product yield and physical properties such as moisture content, bulk density, true density, porosity, wettability, solubility, hygroscopicity of the powder were examined. An inlet air temperature of 180°C caused a significant decrease in the moisture content, water activity, bulk density and solubility of the spray dried product. The increased inlet air temperature made the product more wettability.

Keywords

Spray drying,
Beverage powder,
Beetroot, Banana,
Functional, Milk

Article Info

Accepted:
26 April 2018
Available Online:
10 May 2018

Introduction

Beverages are considered to be an exceptional medium for the supplementation of nutraceutical components for fortification (Kuhn, 1998) such as soluble fibre or herbal extract (Swientek, 1998). The functional beverages can play a vital role in wellbeing and disease prevention. These reduce increasing encumber on health care system by

an uninterrupted preventive mechanism (Shahidi, 2004). The functional beverages provide necessary nutrients to prevent nutrition-related diseases beyond taste and refreshment satisfaction (Menrad *et al.*, 2000). There is enormous number of food products taken as beverages such as coffees, iced teas, herbal teas, sports drinks, frozen carbonated beverages, fruit and vegetable juices and smoothies (Giese, 1992). Red beetroot (*Beta*

vulgaris L.) is a member of the Chenopodiaceae family grown all over the world and edible part is the root which is consumed in various forms, i.e., as fresh vegetable, juice, desiccated and frozen product and as a natural pigment. Beetroots are low in calories (about 45 kcal per 100 g) and have zero cholesterol and a minute amount of fat. This tuber contains an excellent amount of antioxidants and many other health benefiting compounds like minerals such as calcium, magnesium, iron, potassium, phosphorus, sodium and zinc, vitamins like biotin, folic acid, niacin, vitamin B6, besides soluble fiber and water soluble pigments betalains like betacyanins and betaxanthins. These have antioxidant, antiinflammatory, anti carcinogenic and hepatoprotective activities. Beetroot is a rich source of dietary nitrate and several reports indicated its potential for significantly reducing systolic blood pressure in humans. Banana is a major source of macro elements, especially potassium and contains health good ingredients such as resistant starch, total dietary fibers, rapidly digestible starch and slowly digestible starch. Its role to regulate blood pressure has been associated with the high content of potassium. Foods containing potassium can offset salt intake, as sodium and potassium work together in the body to help lower blood pressure. Milk and milk products are dietary staples of people all over the world. It is a perishable commodity and consists of valuable nutrients such as protein, fat, carbohydrate, vitamins and minerals. Processing technologies are applied to preserve milk in different forms such as condensed products, cream, butter, ice cream, powder and various forms of cheese. Spray drying is a popular technique used for milk, fruit and vegetable powders. As individual the natural fruit with additives like filler diminishes colour and vegetable powder imparts musty flavour. By mixing, the right proportion of fruit and vegetable a vibrant colour and flavourful beverage powder could

be produced. In this study, functional milk beverage powder was produced using banana and beetroot. In addition to the nutritive value, banana and beetroot will act as flavouring agent and colouring agent. The addition of banana will make beetroot more palatable. Milk is used as a natural filler material which will help in sheathing the flavour and colour of the powder.

The physicochemical properties of powders produced by spray drying technique depend upon some process variables like inlet air temperature, feed flow rate, feed characteristics, etc. (Bhusari *et al.*, 2014). Therefore, it is worthwhile to identify the ideal conditions for the production of quality functional milk beverage powder that exhibited high content of vitamin C and anthocyanin.

Materials and Methods

Preparation of functional milk beverage

In our preliminary studies, various combination of milk, beetroot and banana were tried (T₁, T₂, T₃, T₄ and T₅). Based on the sensory scores, T₄ was selected for spray drying. Pre-heated toned milk was homogenized with pulp of banana and beetroot. The homogenized beverage was pasteurised at 85° C for 30 minutes.

Spray drying

The suspension was provided to laboratory scale co-current spray dryer S.M.Scientech's (Kolkata, India) main chamber (500mm x 215mm) through a peristaltic pump and a 0.5mm inner diameter nozzle and the feed flow rate was controlled by the pump rotation speed. The operational conditions of the drying process were inlet air temperature and feed flow rate which were ranged between 140–180 °C and 100–300ml/h

respectively. The outlet temperature was kept just half to the inlet air temperature. Powder was collected in an insulated glass bottle connected at the end of cyclone after drying and packed in polyethylene pouches and stored in a desiccator containing silica gel at 25 °C till it was further analyzed.

Physicochemical properties

Yield (g)

The yield of the spray drying process was calculated by taking into consideration the total solid content of the feed sample and weight of the final dry powder.

$$\text{Yield (\%)} = \frac{W_p}{F_s} * 100$$

Where, W_p is the weight of the solids of dried powder and F_s is the solid content of the feed material.

Moisture content (%)

The moisture content was determined by AOAC 2000 method. An empty dish and the lid was dried in the oven at 105°C for 3h and transferred to desiccator for cooling. About 3 g of sample to the dish was weighed and spread uniformly. The dish with sample was placed in the oven and dried for 3 hours at 105°C. After drying, the dish with partially covered lid was transferred to the desiccator for cooling. The following equation was used to calculate moisture content on wet basis,

$$\text{Moisture Content (\%)} = \frac{(W_1 - W_2)}{W_1} * 100$$

Bulk density (pb)

Bulk density of the powders, which is defined as the weight of a given volume of powder, was determined according to the tapping method with some modifications.

Approximately 0.5 g of the powders was loosely placed into a 5 ml measuring cylinder. The cylinder was tapped on a flat surface by hand until a constant volume was obtained. The bulk density was calculated by dividing the sample weight by the volume and expressed in gcm^{-3} .

True density (pt)

The ratio of mass of sample to the true volume is termed as true density of the sample. It was determined with toluene displacement method. Powder sample of about 10 g was submerged in toluene in measuring cylinder having an accuracy of 0.1 mL.

The increase in liquid volume due to pouring of sample was noted as true volume of the sample, which was then used to determine the true density of sample (gcm^{-3}).

Hygroscopicity (%)

Hygroscopicity was determined according to the method proposed by Cai and Corke (2000) with some modifications. Samples of each powder (approximately 1 g) were placed at 25°C in a glass desiccator prepared with NaCl saturated solution (75.29% RH). After one week, samples were weighed and hygroscopicity was expressed as a gram of adsorbed moisture (g/100 g) dry solids.

Solubility (%)

The solubility was determined according to the method described by Chau *et al.*, (2007). Briefly, samples were mixed with distilled water (1:10 w/v), stirred for 1 h at room temperature and centrifuged at 1500 rpm for 10 min. The supernatant was collected, dried and weighed.

$$\text{Solubility (\%)} = \frac{(W_f)}{S} * 100$$

Where, W_f is the final weight (g) of

supernatant after drying and S is the weight (g) of sample.

Statistical analysis

The experimental design and statistical analysis were performed using design expert software. A D-Optimal design was chosen, the Analysis of Variance (ANOVA) tables were generated and the effect and regression coefficients of individual linear, quadratic and interaction terms were determined. The significances of all terms in the polynomial were judged statistically by computing the F-value at a probability (p) of 0.001, 0.01 or 0.05. The regression coefficients were then used to make statistical calculations to generate contour maps from the regression models.

Results and Discussion

Effect of inlet temperature and flow rate on yield

The increase in inlet air temperature led to higher yield of powder, which could be attributed to the greater efficiency of heat and mass transfer processes. This was in agreement with the results published by Shrestha *et al.*, (2007) and Shishir *et al.*, (2016).

The increased feed flow rate had decreased yield of powder which might be caused by slow heat and mass transfer rate. Similar results were reported by Tonon *et al.*, (2008) during spray drying of Acai pulp.

The figure 1 shows the yield of powder obtained with relation between the independent variables spray drying temperature and flow rate. The yield of powder range was in between 68.59% to 64.99%. The 3D graph is the RSM graph which shows higher yield at higher spray

drying temperature and lower flow rate. The best fit quadratic model was generated in RSM modelling for yield of powder was given in the equation 1.

$$\text{Yield} = +66.73 + 1.12 * A - 0.98 * B - 0.042 * AB - 0.13 * A^2 - 0.20 * B^2 \quad (1)$$

Effect of inlet temperature and flow rate on hygroscopicity

The increase in hygroscopicity values was observed with an increase in feed flow rate. The reason for this could be defined by the lesser time for evaporation in the case of high feed flow rate. The decreasing inlet air temperature led to the decreasing hygroscopicity values which could be well explained by the increasing moisture content with lower inlet air temperature. Tonon *et al.*, (2008) reported a similar trend of hygroscopicity values while working on spray dried acai powder. The figure 2 shows the hygroscopicity of powder obtained with relation between the independent variables spray drying temperature and flow rate. The hygroscopicity of powder obtained ranges between 16g/100g to 22g/100g. The 3D graph is the RSM graph which shows higher hygroscopicity at higher spray drying temperature and higher flow rate. The best fit quadratic model was generated in RSM modelling for yield of powder were given in the equation 2.

$$\text{Hygroscopicity} = +18.21 + 1.30 * A + 1.71 * B + 0.32 * AB + 0.018 * A^2 + 0.51 * B^2 \quad (2)$$

Effect of inlet temperature and flow rate on solubility

According to Manickavasagan *et al.*, (2015), Muzaffar, Dinkarrao and Kumar (2016) and Muzaffar and Kumar (2015 b) the powder produced at the lower feed rate had higher solubility which may be related to lower moisture content of the powder.

Table.1 ANOVA table indicating the yield

Source	Sum of squares	Df	Mean square	p-value Prob> F
Model	20.20	5	4.04	<0.0001
A-Spray Drying	8.42	1	8.42	<0.0001
B-Flow rate	9.82	1	9.82	<0.0001
AB	0.010	1	0.010	0.1422
A ²	0.042	1	0.042	0.0088
B ²	0.078	1	0.078	0.0013
Residual	0.040	4	4.021E-003	
Lack of fit	0.040	4	0.010	
Pure error	0.000	6	0.000	
Cor total	252.66	21		

Table.2 ANOVA table indicating the hygroscopicity

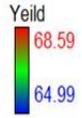
Source	Sum of squares	Df	Mean square	p-value Prob> F
Model	61.90	5	12.38	<0.0001
A-Spray Drying	11.31	1	11.31	<0.0001
B-Flow rate	29.72	1	29.72	<0.0001
AB	0.57	1	0.57	0.0004
A ²	8.140E-004	1	8.140E-004	0.8478
B ²	0.53	1	0.53	0.0005
Residual	0.21	10	0.021	
Lack of fit	0.21	4	0.052	
Pure error	0.000	6	0.000	
Cor total	62.11	15		

Table.3 ANOVA table indicating the solubility

Source	Sum of squares	Df	Mean square	p-value Prob> F
Model	52.34	2	26.17	<0.0001
A-Spray Drying	41.42	1	41.42	<0.0001
B-Flow rate	16.45	1	16.45	0.0026
Residual	15.55	13	1.20	
Lack of fit	1.34	7	0.19	0.9980
Pure error	14.20	6	2.37	
Cor total	67.89	15		

Fig.1 Effect of temperature and flow rate on yeild

Design-Expert® Software



X1 = A: Spray Drying Temperature
X2 = B: Flow raate

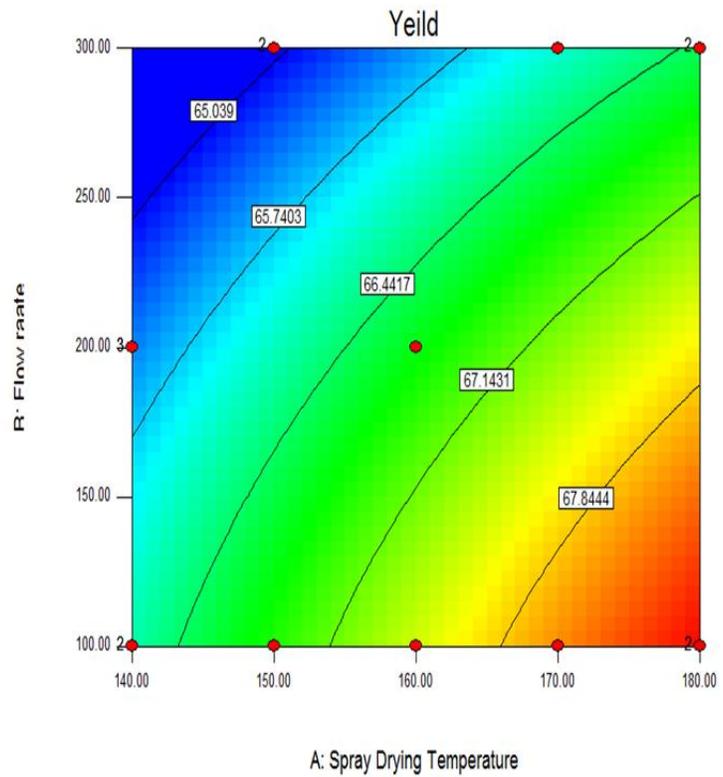
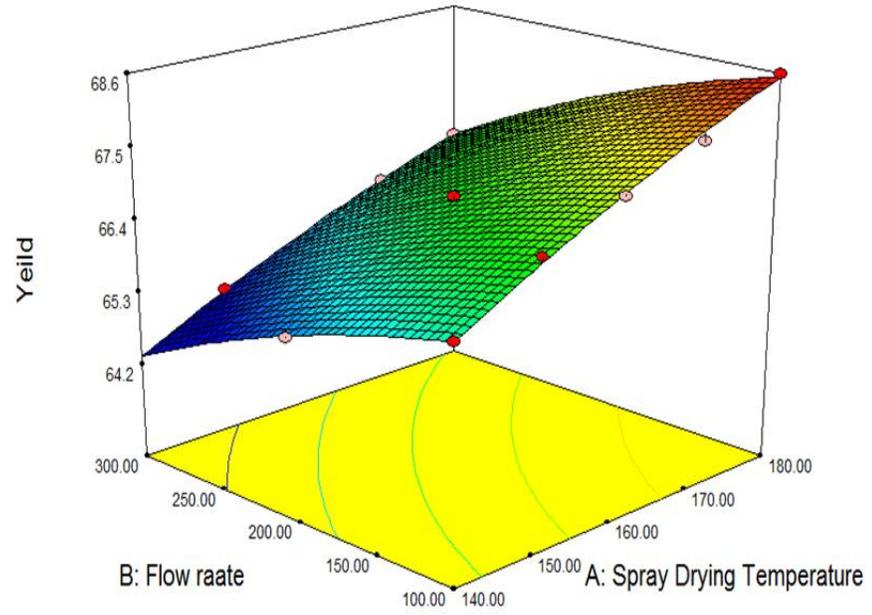


Fig.2 Effect of temperature and flow rate on hygroscopicity

Design-Expert® Software

Hygroscopicity



X1 = A: Spray Drying Temperature
X2 = B: Flow raate

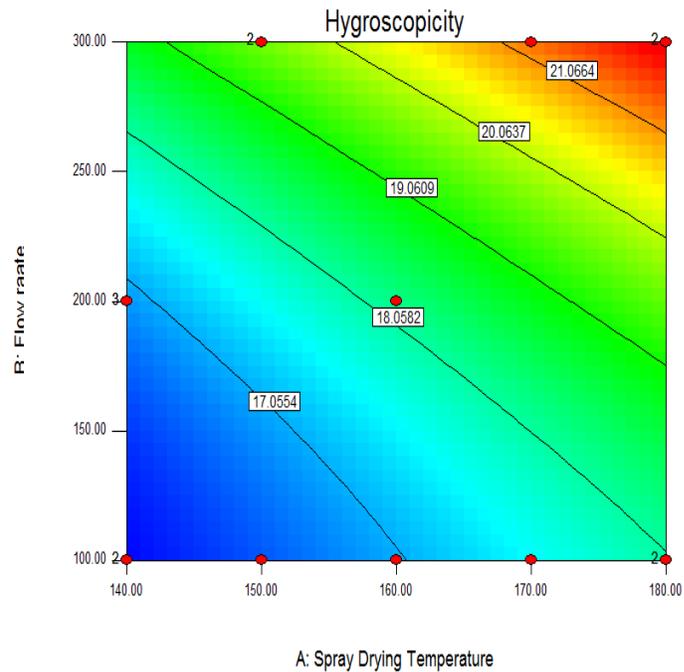
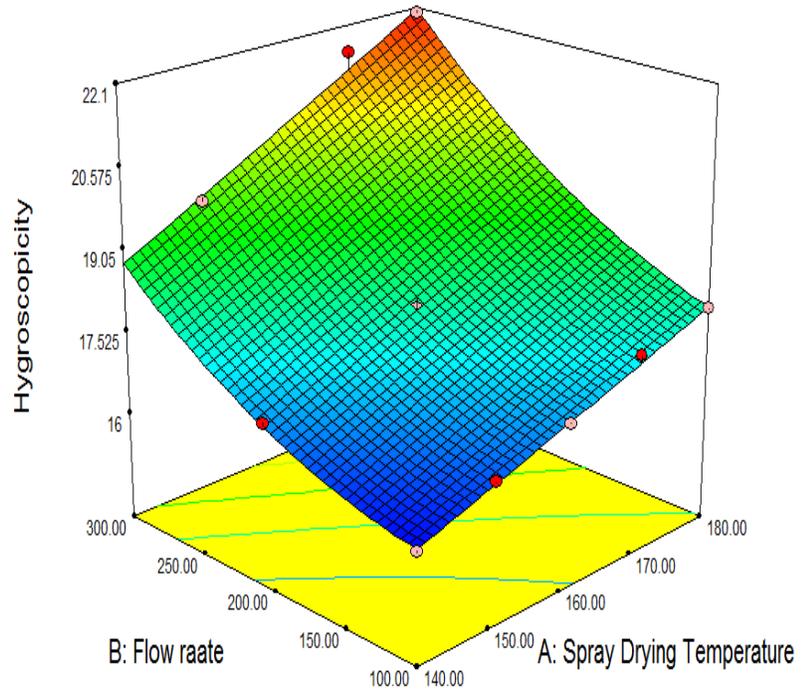
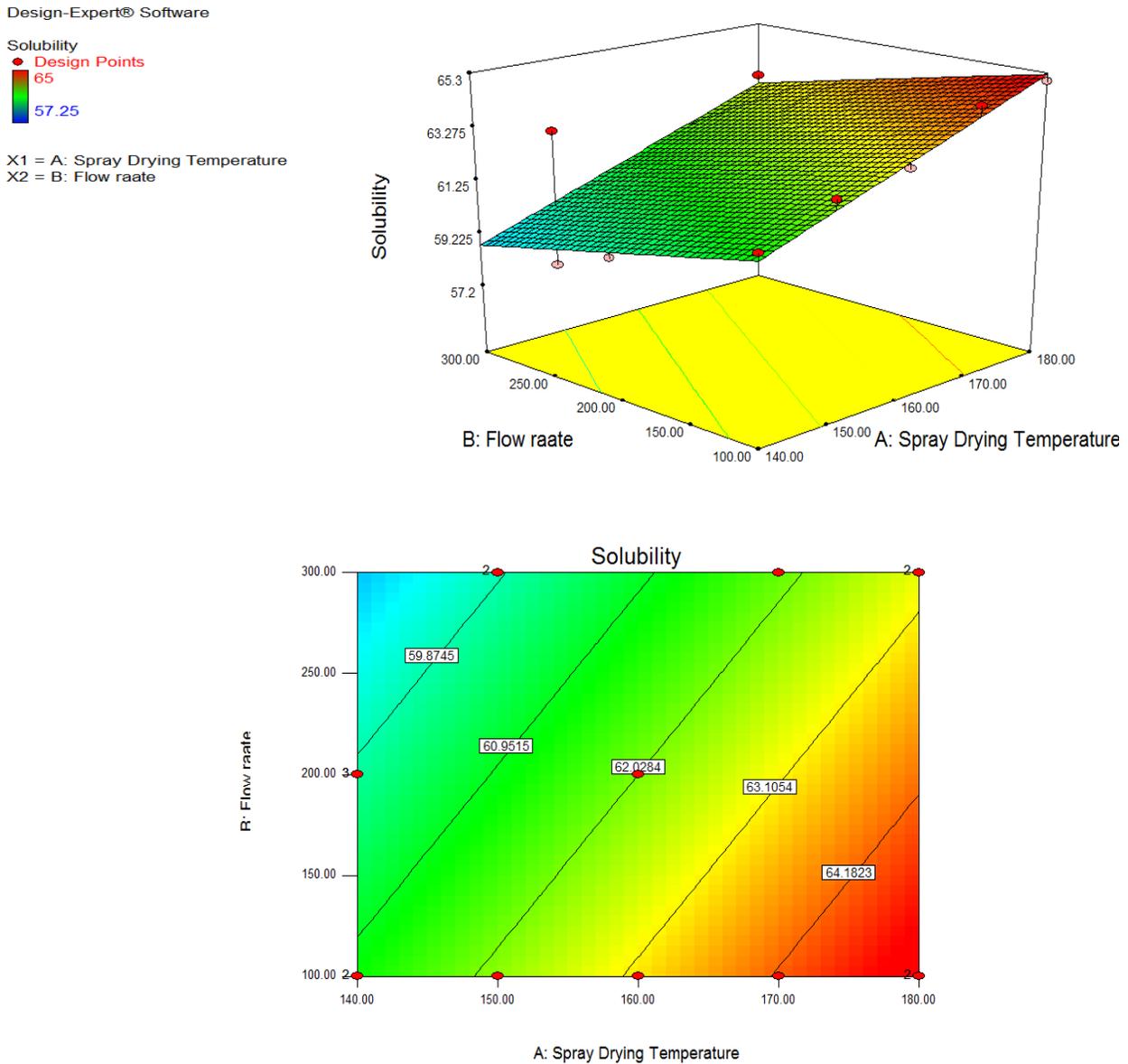


Fig.3 Effect of temperature and flow rate on solubility



In general, the higher inlet temperature results in higher solubility. These results were reported for pitaya (Bakar *et al.*, 2013), tomato (Goula and Adamopoulos, 2005), pomegranate (Vardin and Yasar, 2012), tamarind (Muzaffar and Kumar, 2015b), sour cherry (Moghaddam *et al.*, 2017) and mountain tea (Nadeem *et al.*, 2011). The

increase in solubility with an increase in inlet air temperature is due to its effect on residual moisture content.

The figure 3 shows the solubility of powder obtained with relation between the independent variables spray drying temperature and flow rate. The solubility of

powder obtained ranges between 57.25 % and 65 %. The 3D graph is the RSM graph which shows higher solubility at higher spray drying temperature and lower flow rate. The best fit quadratic model was generated in RSM modelling for yield of powder were given in the Equation 3.

$$\text{Solubility} = +62.03 + 2.04 * A + 1.19 * B \quad (3)$$

Significance was judged by determining the probability level that the F-static (F-Value).

The p-value of the model was <0.0001, which indicated the model fitness was highly significant (Table 1, 2 and 3).

The quadratic model was in good agreement with the experimental results, with R² for yield, hygroscopicity and solubility are 0.9980, 0.9966 and 0.7710 respectively.

The numerical process optimization for spray drying of functional milk beverage powder is 180° C and flow rate of 100 ml/h to get the maximum yield of 68.53%, hygroscopicity of 18g/100g, solubility of 65.23% and the desirability value is 0.868.

The factor inputs used to arrive at optimization were yield, hygroscopicity and solubility. If quality parameters like colour and flavour gets included for optimization, the attained process parameters may vary.

The optimization for the process parameters for spray drying of functional milk beverage powder aiming at attaining highest yield, reduced hygroscopicity and good solubility alone points at highest temperature and lowest flow rate for drying.

An inlet air temperature of 180°C and flow rate of 100 ml/h caused a significant decrease in the moisture content, bulk density and true density of the spray dried product.

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How to cite this article:

Niveadhitha, S., D. Ramasamy, R. Karunakaran, A. Karthiayini, G. Sujatha and Bakaran, D. 2018. Development of Functional Milk Beverage Powder. *Int.J.Curr.Microbiol.App.Sci.* 7(05): 3752-3761. doi: <https://doi.org/10.20546/ijcmas.2018.705.435>