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Parameter optimization for spray drying of tamarind pulp using response surface methodology

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A B S T R A C T

The present study was aimed to optimize the process parameters for production of spray dried tamarind pulp powder using response surface methodology (RSM). The independent variables were soya protein isolate (SPI) concentration, inlet air temperature and feed flow rate. The responses evaluated for deciding the optimum conditions were process yield, moisture content, hygroscopicity and solubility. Statistical analysis showed that independent variables significantly affected all the responses. The derived optimum conditions were used for the production of spray dried tamarind pulp powder to check the validity of the quadratic model. Small deviations were found between the experimental values and the predicted ones and the values were within the acceptable limits, indicating the efficiency of the model in predicting the quality attributes of tamarind pulp powder. The results showed that the most desirable optimum spray drying conditions for development of tamarind pulp powder with optimum quality were 25% SPI concentration, 170 °C inlet temperature and 400 ml/h feed flow rate. At these derived optimum conditions quality tamarind pulp powder with desirable properties of increased process yield, low moisture content, low hygroscopicity and high solubility could be produced.

1. Introduction

Tamarind (*Tamarindus indica* L.) is a member of dicotyledonous family Leguminosae. Every part of the tree finds some use, but the most valuable and commonly used part is the fruit which yields acidic pulp [1]. The pulp constitutes about 30–50% of the ripe fruit and contains reducing sugars, pectin, protein, fiber and cellulosic materials. The percentage of the constituent components varies from sample to sample with tartaric acid ranging from 8 to 18%, reducing sugars 25 to 45%, pectin 2 to 3.5% and protein 2 to 3%. Because of the tartaric acid content, the pulp is acidic in taste and hence is widely used for domestic and industrial purposes [2]. Due to its pleasant acidic taste and rich aroma, it is used as the chief souring agent for curries, sauces and certain beverages. In case of soft drinks, pulp is used as a substitute for chemical acidulants. It is used as a raw material for the preparation of wine-like beverages [1]. The pulp is regarded as digestive, carminative, laxative, expectorant and blood tonic [3]. The pulp has been found to possess hypolipemic activity [4].

India is the major producer of sour tamarind in Asia with its annual production of about 189,980 Tonnes in 2012–13 [5]. Tamarind fruits are rarely used directly, but soaked in water for some time and then pulp is extracted manually. This process is not only clumsy but unhygienic as well. However tamarind pulp in powder form can prove better in this regard [6]. In powder form, it has many benefits and economic potentials which include convenient to use and no need to bother about disposal of residue as is the case when dry tamarind fruit is soaked in water; longer shelf life at ambient temperature due to low water activity; low logistic expenditures due to reduced weight and volume and easy to use as compared with squeezing of pulp from the tamarind fruit [6,7]. Besides this tamarind pulp cannot be kept indefinitely because in storage it loses its original brownish red color and finally becomes black due to Maillard reaction and non-enzymatic browning, resulting in quality loss of the pulp [2,8]. Hence there is a need to process it into powder form of low water activity for easy usage and to minimize the quality loss due to browning reaction.

Among the number of drying technologies spray drying is one method that is widely used to produce fruit juice and pulp powders [9]. Spray dried powders have good quality, low water activity and suitable for storage. The physicochemical properties of powders produced by spray drying depend on some process variables such as concentration of carrier agent in the feed mixture, inlet air temperature and feed flow rate [10]. Therefore it is important to optimize the drying process parameters in order to obtain a good quality powder and high process yield.

Spray drying of fruit juices and pulp may present some problems such as stickiness and hygroscopicity due to the presence of low molecular weight sugars and acids which have low glass transition temperature. Thus they can stick to the dryer chamber wall at normal spray drying

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temperatures, leading to low product yield and operational problems. Part of these problems can be solved by addition of high molecular weight carrier agents like proteins, maltodextrin and gums which have high glass transition temperature [11,12]. Use of protein is a novel way to minimize the stickiness problem during spray drying because of its ability to modify the surface properties of the atomized droplets/particles. It was found that the preferential migration of proteins towards the surface of atomized droplets/particles combined with their film-forming property upon drying is responsible for overcoming the stickiness problem [13].

There are several works related to the good potential of soy protein isolate to be applied as the encapsulating wall material. Microencapsulation of oil or water soluble substances with SPI was particularly investigated using spray-drying [14–16]. So far there has been no work published on the spray drying of tamarind pulp using soya protein isolate as a carrier agent. Therefore it is worthwhile to study the potential of soya protein isolate in the production of tamarind pulp powder and to optimize the process conditions to obtain the quality powder of desirable characteristics.

2. Material and methods

2.1. Materials

Fresh and fully ripened tamarind pods were purchased from local market (Sabzimandi, Sangrur, India) and were stored in refrigerator until needed for the experiment. Soya protein isolate purchased from Nutrimed Health Care Private Ltd. (Delhi, India) was used as a carrier agent. The protein content of soya protein isolate was about 90–92 g/100 g (wet basis) as determined by the micro-kjeldhal method using a nitrogen conversion factor of 6.25.

2.2. Sample preparation and spray drying

The pod of the fruit was removed manually and then soaked in water in the ratio 1:2.5 under optimized conditions of 31 min soaking time and 38 °C soaking temperature to obtain maximum extraction of pulp. The mixture was then homogenized and sieved to separate fiber, rags and seeds from the pulp. After this pulp was filtered using three layers of muslin cloth to obtain fine pulp. Total solids of the pulp was calculated which was about 10 g/100 g of pulp and then stored at 4 °C until utilization. Taking into account the moisture content of the extracted pulp and soya protein isolate mixtures with desired ratio of (tamarind pulp solids)/(soya protein isolate solids) were prepared in a blender until the protein dissolves completely, filtered and used as a feed material for subsequent spray drying.

Spray drying was performed in a tall type laboratory-scale spray-dryer (S.M. Scientech, Calcutta, India) with co-current flow and nozzle orifice diameter of 0.5 mm. The mixture was fed into the main chamber through a peristaltic pump. The independent variables affecting the quality of the powder were soya protein isolate (SPI) concentration, inlet air temperature and feed flow rate. SPI concentration, inlet air temperature and feed flow rate were varied from 15 to 25%, 150 to 170 °C and 400 to 600 ml/h respectively according to an experimental design described in Section 2.4. In all the experiments, blower speed was kept at 2300 rpm and compressor air pressure was 0.06 MPa. After spray drying, the powder was collected from the cyclone and the cylindrical parts of the dryer chamber by lightly sweeping the chamber wall as proposed by Bhandari et al. [17]. Then the powders were weighed, packed in polyethylene bags and stored in a desiccator containing silica gel until further analysis.

2.3. Process yield and powder analysis

2.3.1. Process yield

Process yield is one of the main indices of a spray-dryer performance. It was calculated as ratio of the total solid content in the resulting powder to total solids in the feed mixture.

2.3.2. Moisture content

The moisture content of powders was determined by using an electronic moisture analyzer (Presia Gravimetric AG Dietikon, Switzerland) at 105 °C. A sample of about 2 g was spread on an aluminum pan and placed in the analyzer. The sample was heated at 105 °C and evaporative moisture losses were automatically reported as percent moisture content.

2.3.3. Hygroscopicity

Hygroscopicity was determined according to the method proposed by Tonon et al. [10] with some modifications. Approximately 1 g of the each powder sample was placed at room temperature in desiccators containing saturated solution of sodium chloride (75.29% RH). After one week, the samples were weighed and hygroscopicity was expressed as grams of adsorbed moisture per 100 g dry solids.

Table 1
Experimental design for spray drying runs with their corresponding response values.

Run	SPI concentration (%)	Inlet air temperature (°C)	Feed flow rate (ml/h)	Process yield (%)	Moisture content (%)	Hygroscopicity (%)	Solubility (%)
1	25.00	150.00	400	52.03	2.70	24.01	67.42
2	25.00	170.00	600	52.57	2.71	24.38	68.56
3	15.00	150.00	600	28.00	3.04	28.05	54.16
4	25.00	170.00	400	54.87	2.45	25.54	70.35
5	15.00	170.00	600	33.83	2.90	30.26	56.63
6	20.00	143.20	500	52.54	3.61	25.33	59.82
7	20.00	160.00	500	55.14	3.31	26.44	62.81
8	20.00	160.00	500	54.94	3.38	26.55	63.05
9	20.00	160.00	500	54.86	3.35	26.58	63.11
10	11.60	160.00	500	17.90	2.61	34.04	49.93
11	15.00	170.00	400	38.03	2.66	31.77	57.85
12	28.40	160.00	500	48.24	2.46	20.39	71.58
13	20.00	176.80	500	59.60	3.24	27.62	65.22
14	20.00	160.00	500	55.07	3.34	26.54	62.81
15	20.00	160.00	500	54.86	3.29	26.54	63.11
16	20.00	160.00	332	57.22	2.82	27.83	65.37
17	15.00	150.00	400	32.23	2.81	29.72	55.51
18	20.00	160.00	500	54.96	3.25	26.48	62.33
19	25.00	150.00	600	50.89	2.92	23.13	65.41
20	20.00	160.00	668	51.66	3.62	25.00	59.40

All response values are mean values of three replicates except process yield.