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INFLUENCE OF PROCESS CONDITIONS ON THE PHYSICOCHEMICAL& FUNCTIONAL PROPERTIES OF LITCHIPOWDERPRODUCED BY SPRAY DRYING

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ABSTRACT

Litchi are a good source of vitamin C, dietary fiber & antioxidants. Litchi fruit juice powder containing vitamin C and other nutrients can be produced by spray drying. The objective of this study was to develop litchi fruit juice powder and to evaluate its nutritional, physicochemical & functional properties. Fresh litchi fruits purchased from a local market were peeled, destoned and juiced. Litchi juice with 20-30% maltodextrin (MD) added was spray dried at inlet temperatures of 165-200°C and feed flow rate of 6-10 rpm. Twenty spray dried litchi juice powders were analyzed for moisture, water activity, powder recovery, hygroscopicity, bulk density, WSI, WAI, antioxidant activity & color measurement. Moisture content and hygroscopicity of powder were significantly affected by inlet temperature and maltodextrin level. However, an increase in the level of maltodextrin did not significantly affect the bulk density and water solubility index (WSI). An increase in drying temperature and maltodextrin concentration decreased the free radical scavenging activity of the powder. The optimum operating condition to develop spray dried litchi juice powder were found to be as maltodextrin concentration of 27.97%, inlet air temperature of 193.27˚C and Feed flow rate of 10 rpm.

Keywords: Litchi;Litchi juice; Spray drying; Maltodextrin;Powder.

1. Introduction

Fruit juice powders have many advantages over liquid juice such as longer shelf life, easy in handling and transportation, low weight and volume and reduced packaging. Spray drying is one of the most important techniques used extensively in food related industries to obtained fruit juice powders under the optimal processing conditions.

The Litchi (*Litchi chinensis Sonn.)* is a non-climacteric fruit of South East Asian origin (Nakasone and Paull, 1998).The litchi is the sole member of the genus *Litchi* in the soapberry family, Sapindaceae or Soapberry.It has a white and translucent aril, with a sweet citrus flavor, excellent aroma and high nutritive value.It is covered by a bright red color pericarp due to the presence of anthocyanin (Lee and Wicker, 1991; Rivera-Lopez *et al*., 1999). It is known by some of the terms such as lichi, litchi, lieche, laichi, Leechee, or lychee.It can be usually eaten fresh or processed as jelly or wine, or used in ice creams and sorberts. Due to its highly perishable in nature and seasonal fruit bearing pattern, the litchi fruit may be subjected to further processing like spray drying to increase its application in different food products.In general, dried litchi is marketed in the form of flesh and dried whole fruit. Intact dried litchi is a popular commodity in the Chinese local market. Further, the development of value-added products like spray dried powder reduces the losses and increases postharvest storage life.

The quality of spray-dried food is quite dependent on the spray-dryer operating parameters. The spray-drying conditionwas the best way to explain the change quality factors of the product.Fruit juice powders obtained by spray drying may have some problems in their properties, such as stickiness, hygroscopicity and solubility, due to the presence of low molecular weight sugars and acids, which have low glass transition temperature (Bhandari *et al.*, 1993). Thus they can stick on the dryer chamber wall during drying, leading to low product yield and operational problems.Part of these problems can be solved by the addition of some carrier agents, like polymers and gums, to the product before being atomized.The carrier agents normally used in the spray drying of fruit juices are maltodextrins and gum Arabic mainly due to their high solubility and low viscosity, which are important conditions for the spray drying process (Quek *et al.*, 2007).

The objective of this work was to study the various physicochemical parameters of litchi juice and influence of inlet air temperature, feed flow rate and maltodextrin concentration on moisture content, water activity, powder hygroscopicity, bulk density,water solubility index, water absorption index, antioxidant activity and colour properties of spray dried litchi powder.

2. Material and Methods

2.1 Materials

Fresh Litchi fruits at a commercially mature stage, fully ripened, completely red in colour without blemish and mechanical injuries was purchased from local market. (Azadpur, New Delhi, India). Maltodextrin (DE20) was procured from Himedia laboratories used as carrier agent.

2.2 Sample Preparation

Fruits were washed in cold tap water and drained. After thorough washing, the pericarp was removed and pulp (aril) destoned with the help of knives. A sieve was used to eliminate the seeds, and the extract was then pressed softly in order to increase the yield. The filtered juice with 15% of total soluble solid (TSS) was rapidly cooled and frozen at -25°C and used for further experiments. Maltodextrin was added to the filtered pulp under magnetic agitation, until complete dissolution at the time of experiment.

2.3 Methods

2.3.1 Physico-Chemical Analysis litchi fruit juice

2.3.1.1 % Yield of juice

The juice was extracted from the pulp using muslin cloth and the percentage yield of the pulp was determined. The determination of the yield of pulp (%) was calculated as:

$$\%\,Yield\;\;of\;\;juice = \frac{Weight\;\;of\;\;juice}{Weight\;\;of\;\;pulp} \times 100$$

2.3.1.2 Total Soluble Solids (TSS)

The total soluble solids (%) in the Litchi were recorded by using hand refractometer (A32 Erma Tokyo) and the values were calibrated to 20°C with the help of temperature correction chart (A.O.A.C, 1990) and were expressed in percentage.

2.3.1.3 Total Solid (TS)

A sample of litchi juice (5 g) was weighed and placed in an oven at 105^{0}C for 24 h. The total solid percentage (wet basis) was calculated as (Al-asheh *et al.*, 2003):

$$Total\ solid(\%) = \frac{Weight\ of\ dried\ sample}{weight\ of\ sampele} \times 100$$

2.3.1.4Titratable acidity

Acidity of the litchi juice was determined by titrating known volume of juice with 0.1N sodium hydroxide (Ranganna, 1986). The percentage of titrable acidity was expressed in terms of standard ascorbic acid.

$$(\%)\ Titrable\ acidity = \frac{Titrate\ \times N\ of\ alkali\ \times vol.made\ up \times Eq\ wt\ of\ acid}{Vol.of\ sample\ taken\ x\ Weight\ of\ sample\ taken\ x\ 1000} \times 100$$

2.3.1.5 Viscosity

The viscosity of juice was measured by Brookfield viscometer with spindle no.1 having factor 1.5 at rpm 30. The viscosity (in centipoises) of juice can be measure by

$$viscosity = dia\ reading \times factor$$

2.4 Spray Drying

Spray drying process was performed in a laboratory scale spray dryer (S.M. Scientech, India). Pilot plant Spray-dryer with a co-current air flow was used for spray drying. The speed of blower was kept 2200 rpm. Distilled water was pumped into the dryer at a constant flow rate (10 rpm = 30 ml/min) to achieve the desired inlet and outlet temperatures. The spray dryer was run at the above conditions for about 10 min before the feed were introduced. The product was collected in a pre-weighed, insulated glass bottle connected at the end of drying chamber and cyclone collector.Trials were performed in triplicate, using a new sample for each repetition.

2.5 Analytical Methods

2.5.1 Moisture content and Water activity

Powders and mixtures moisture contents were determined gravimetrically by drying in a vacuum oven at 70^o C until constant weight (A.O.A.C., 1990). A water activity of Litchi powder was determined with the help of Water activity meter (Rotronic Hydrolab-2). Triplicate samples were analyzed and the mean was recorded.

2.5.2 Powder recovery

Process yield expressed as the weight percentage of the final product compared to the total amount of the materials sprayed (Sansone *et al.*, 2011).

$$\% \text{ Powder recovery} = \frac{obtained \;\; spray \;\; dried \;\; powder}{juice \;\; (g) + maltodextri \;\; n \; (g)} \text{ x } 100$$

2.5.3 Hygroscopicity

Hygroscopicity of litchi pulp powder was determined as follow litchi powder Samples were taken (approximately 1 g) were placed at 25 °C in a container with NaCl saturated solution (75.29%RH). After one week, samples were weighed and hygroscopicity was expressed as g of adsorbed moisture per 100 g dry solids (g/100 g) (Tee *et al.*, 2012).

2.5.4 Bulk density

Bulk density (g/ml) was determined by gently adding 2 g of litchi powder into an empty 10 ml graduated cylinder and the samples were repeatedly tapped manually by lifting and dropping the cylinder under its own weight at a vertical distance of 14 ± 2 mm high until negligible difference in volume between succeeding measurements was observed. The ratio of mass of the powder and the volume occupied in the cylinder determines the bulk density (Caparino *et al.*, 2012).

2.5.4 Water solubility index (WSI)

The WSI of the Litchi pulp powder was determined using the method describe by Anderson et al., (1969). Spray-dried Litchi juice powder (2.5 g) taken and added in the distilled water (30 ml) were vigorously mixed in a100 ml centrifuge tube, incubated at 37°C for 30 min and then centrifuged for 20 min at 10,000 rpm in a J2-MC Centrifuge (Beckman, USA). The supernatant was carefully collected in a pre-weighed beaker and oven dried at a temperature of 103 ± 2 °C. The WSI (%) was calculated as the percentage of dried supernatant with respect to the amount of the original 2.5 g Litchi juice powder.

$$Water\ solubility\ index(\%) = \frac{Weightof\ dried\ supernatant}{Weight\ of sample} \times 100$$

2.5.5 Water absorption index (WAI)

WAI of the Litchi powder was determined by using the method of Yamazaki, (1953). 2.5 g of Litchi powder in 25ml distilled water was agitated for 1h and centrifuged at 3000rpm for 10min. The free water was removed from the wet residue, which was then drained for 10min. The wet residue was then weighed.

$$Water\ absorption\ index(\%) = \frac{Weight\ of\ residue}{Weight\ of\ sample} \times 100$$

2.5.6 Antioxidant activity

The antioxidant activity of the litchi pulp powder was evaluated by the DPPH radical scavenging activity method.One hundred microliters of each diluted extract (prepared for TPC analysis) was added into 4 ml of freshly prepared DPPH (2, 2 Diphenyl-1-picryhydrazyl radical) solution (6×10^{-5}M in MeOH). Then the mixtures were shaken and placed in the dark at room temperature for 30 min. Absorbance of the final solutions were recorded at 516 nm using a spectrophotometer with respect to blank DPPH solutions. The inhibition percentage of the DPPH radical was calculated by the following equation (Dincer *et al.*, 2011).

$$\text{activity}\ (\%) = 1 - \left\{\frac{\text{A(sample)}}{\text{A(blank)}}\right\} \times 100$$

Ascorbic acid content of litchi and powder was estimated by 2, 6-dichlorophenol-Indophenol visual titration method (Rangana, 1986).

2.6ColorMeasurement

Colour value measurements of the powder samples were carried out using a Hunter Lab Colour spectrophotometer (I-5 Model, Greath Mackbeth). The instrument was standardized each time with a black and a white (L = 91.10, a = 1.12, b = 1.26) tile. The color values were expressed as L* (whiteness or brightness/ darkness), a*(redness/greenness) and b* value (yellowness/blueness) at any time, respectively.

2.7Experimental Design

A central composite design was used to design the tests for the spray drying of litchi juice, considering three factors (independent variables): inlet air temperature (165-200^{o}C), feed flow rate (6-10 rpm) and maltodextrin concentration (20–30%). Three levels of each variable were chosen for the trials, including the central point and two axial points (Khuri and Cornell, 1996), giving a total of 20 combinations (Table 2.1). The following polynomial equation was fitted to the data.

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{33} x_3^2 + \beta_{12} x_1.x_2 + \beta_{13} x_1.x_3 + \beta_{23} x_2.x_3 + \varepsilon$$

Table 2.1 Experimental design for spray drying of litchi pulp powder under different design conditions

Sl no.	Experiment Number	Maltodextrin concentration (%)		Feed flow rate (R.P.M)		Temperature (°C)	
		Coded	Uncoded	Coded	Uncoded	Coded	Uncoded
1	1	0	25	0	8	1	200
2	2	0	25	1	10	0	182.5*
3	3	1	30	-1	6	1	200
4	4	-1	20	-1	6	-1	165
5	5	1	30	0	8	0	182.5*
6	6	1	30	-1	6	-1	165
7	7	0	25	-1	6	0	182.5*
8	8	0	25	0	8	0	182.5*
9	9	0	25	0	8	0	182.5*
10	10	-1	20	0	8	0	182.5*
11	11	0	25	0	8	0	182.5*
12	12	0	25	0	8	0	182.5*
13	13	-1	20	1	10	1	200
14	14	1	30	1	10	-1	165
15	15	0	25	0	8	0	182.5*

16	16	0	25	0	8	0	182.5*
17	17	-1	20	-1	6	1	200
18	18	-1	20	1	10	-1	165
19	19	0	25	0	8	-1	165
20	20	1	30	1	10	1	200

*Target 183^{o} C

2.8 Statistical analysis

The analysis of variance (ANOVA), test for the lack of fit, determination of the regression coefficients and the generation of three dimensional graphs were carried out using the Design Expert (Version 6.0, Stat-Ease Inc, USA).

3. Result and Discussions

3.1 Physicochemical analysis

From the result it was found that moisture content of litchi juice was about 80.33 % whereas other physico-chemical properties were mentioned in Table 3.1. The vitamin C content of the litchi fruit sample were close to the value of 36 mg reported by USDA National Nutrient Database. The higher amount of vitamin C in litchi pulp may be due to more permeation of vitamin C with the juice due to its solubility towards water.

Table 3.1 Physico-chemical analysis of litchi juice

Parameter	Results
Moisture content (%)	80.33±0.57
TSS (^{0}Brix)	11±0.20
Total solid (%)	14.4±0.52
Acidity (citric acid %)	0.32±0.02
Viscosity (centipoise)	6.33±0.57

Protein (%)	1.13±0.11
pH of juice	4.5±0.05
Vitamin C (mg/100ml)	38.5±0.5

3.2Effect of process variables on moisture, acidity, aW, antioxidant properties& bulk density of spray dried litchi powder

The moisture content of litchi juice powder varied from 1.5 to 2.98 % (Table 3.2), under different experimental designed conditions. Most of the moisture was evaporated during spray drying because of exposure of product to very high temperature therefore the moisture is significantly influenced by inlet air temperature. The data revealed that decrease in moisture content with increase in maltodextrin concentration and increases with feed flow rate. The water activities of the powders were in the range of 0.13–0.21, indicating that litchi powders under the different designed conditions were microbiologically stable.Vitamin C is water soluble vitamin and it's degradation during the drying is influenced by the moisture content, oxygen, pH, and light, but importantly by temperature. Therefore at higher drying temperature, vitamin C content decreased. The vitamin C content of the spray dried litchi powder varied from 12.88 to 5.58 under different experimental designed conditions. The higher antioxidant activity shows more free radical scavenging activity. The fresh juice of litchi was found to be high in antioxidant activity about 89% by DPPH assay (Saxena *et al.*, 2011). The litchi juice powder shows activity from 43.4 to 55%, under different experimental designed conditions. Acidity of litchi pulp was 0.3% citric acid. The measured acidity of reconstituted litchi pulp powder varied from 0.39 to 0.63 %, under different experimental designed conditions. Bulk density was measured as mass per unit of volume of the powder and was ranged from 0.49 to 0.62 g/ml under different experimental designed conditions.

Table 3.2 Effect of process variables on moisture, acidity, aW and antioxidant properties of spray dried litchi powder

Experiment No	Moisture content	Water activity	Acidity (% citric	Vitamin C	DPPH Scavenging capacity	Bulk density

			acid)			
1	1.52	0.17	0.54	8.53	55	0.54
2	2.16	0.15	0.39	7.2	46	0.57
3	2.98	0.21	0.45	12.88	44.54	0.58
4	2.19	0.18	0.5	8.59	50	0.625
5	1.34	0.15	0.63	7.6	48.2	0.49
6	1.65	0.11	0.43	5.75	47	0.56
7	2.29	0.17	0.54	9.74	44.5	0.53
8	1.66	0.15	0.50	5.58	49	0.58
9	2.06	0.16	0.52	10.1	47	0.567
10	1.8	0.14	0.43	7.71	48	0.57
11	1.86	0.17	0.51	9.24	50	0.54
12	2.39	0.18	0.41	11.03	47	0.58
13	2.38	0.17	0.48	10.19	47	0.57
14	1.94	0.13	0.51	7.63	48	0.54
15	1.8	0.15	0.5	9.89	48	0.55
16	1.52	0.15	0.48	9.8	45	0.55
17	2.16	0.15	0.48	9.8	45	0.56
18	2.98	0.15	0.46	10.1	47.5	0.54
19	2.19	0.15	0.49	9.8	47	0.56
20	1.34	0.16	0.49	9.89	43.4	0.54

3.3Effect of process variables on colour, hygroscopicity, WAI and WSI properties of spray dried litchi powder

The color L* value of the litchi powder was in ranged from 90.37-94.33 (Table 3.3), under different experimental designed conditions. The color L* value was increased with increased in maltodextrin concentration.The colour, a-value of different spray dried powder samples ranged from 2.87 to 4.10. A rise in temperature will facilitate Millard reaction, while the starch and carbohydrates are the substrate for Millard reaction.The yellow color of spray dried litchi powder varied from 13.98 to 24.55. The yellowness of the product enhances the appearance of the product and hence enhances the acceptability.This an important property because of the effect of water content on powder flow ability. As powder hygroscopicity decreases, flow ability of powder increases. The hygroscopicity of litchi pulp powder varied from 20 to 30% under different experimental designed conditions.The measured water solubility index of the litchi spray dried powder varied from 90.4 to 104%, under different experimental designed conditions.In this experiment, WAI varied from 2.95 to 14.32 (w/w) for spray dried litchi powder.

Table 3.3Effect of process variables on colour, hygroscopicity, WAI and WSI properties of spray dried litchi powder

Experiment No	Colour			**Hygroscopicity**	**WAI**	**WSI**
	L*	a*	b*			
1	92.01	28	2.67	10.26	94.8	16.56
2	94.13	24	1.87	6.14	96.55	14
3	91.05	24	2.44	8.25	93.6	18.4
4	94.33	20	1.71	7.43	95.6	14
5	90.74	30	3.63	15.22	90.54	14
6	92.45	28	1.53	7.60	92.4	11
7	90.37	25	2.58	9.53	96.21	13
8	92.35	23	1.35	7.87	104	8.4

9	91.63	29	2.92	11.86	96	19
10	93.0	26	1.87	9.08	97.8	13
11	91.79	29	2.87	9.497	94.44	16
12	92.0	25.33	2.4	7.66	99.2	13
13	92.77	27	2	6.88	95.2	16
14	91.69	27.93	2.16	8.55	96	12.4
15	91.85	29	2.57	9.57	97.67	15.27
16	92.0	29	2.95	9.56	98	14
17	91.88	29	2.95	10.36	99.2	15
18	91.23	28	2.95	10.36	99.2	14
19	91.88	28	2.57	9.57	99.2	14
20	91.85	28	2.6	10.36	100	15.2

3.4 Optimization of spray dried litchi powder

The optimum operating condition to develop spray dried litchi pulp powder were found to be as maltodextrin concentration; 27.97%, inlet air temperature; 193.27˚C and Feed flow rate; 10 rpm. The responses predicted by the design expart-6 software for these optimum process conditions resulted water activity 0.16, L* value 92.07, a*value 2.31, b* value 7.89, water solubility index 102.09%, water absorption index 10.30 g/g, hygroscopicity 23.25 g/100g, bulk density 0.58 g/ml, powder recovery 30.40%, moisture content 1.94%, DPPH radical scavenging activity 45.21%,Vitamin C 8.65mg/100g , wettability 18.10 s, acidity 0.47%, porosity 0.58, true density 1.43 g/ml.

Table 3.4 Predicted and actual values of the responses at the optimized condition of experiment

Variables	Optimum value (in the range)	Operated value (Targeted)	
Maltodextrin concentration (%)	27.97	28	
Inlet air temperature (˚C)	193	193	
Feed flow rates	10	10	
Responses	**Predicted value**	**Experimental Value**	**Variation (%)**
Water activity (a_w)	0.16	0.15	6.25
L value	92.07	93.14	0.88
a value	2.31	2.57	0.47
b value	7.89	8.25	4.56
WSI %	102.09	102.48	0.38
WAI (g/g)	10.57	10.23	3.21
Hygroscopicity (g/100g)	23.25	23.26	5.3
Bulk density (g/ml)	0.58	0.60	3.44
Powder recovery (%)	30.40	31.50	3.61
Moisture content (%)	1.94	2.10	8.24
Antioxidant activity (%)	45.21	46.54	2.94
Vitamin C content (mg/100g)	8.65	9.10	5.20

Wettability (seconds)	18.10	17.30	4.41
Acidity (%)	0.47	0.45	4.25

4. Conclusion

The effect of spray drying conditions, i.e. inlet air temperature, feed rate, carrier agent concentration on litchi juice powder drying yield, moisture content, water activity, bulk density, WSI, WAI, antioxidant activity, color and hygroscopicity was studied. Result showed that with increase in maltodextrin concentration level water activity, water absorption index, a* value, b* value, hygroscopicity, moisture content, Vitamin C content, true density, acidity, porosity , free radical scavenging activity were decreased and water soluble index , wettability, bulk density and L*-value were increased. With increase in inlet air temperature level, the colour value, a* and b*, water solubility index, hygroscopicity, powder recovery, acidity were increased and water activity, L*value, water absorption index, vitamin C content , DPPH radical scavenging activity, moisture content, bulk density, true density, porosity, wettability were decreased in spray dried litchi powder. In the set of experiments, numerical optimization studies resulted in 27.97% of maltodextrin concentration, 193˚C of inlet air temperature and 10 rpm of feed flow rate as optimum variables to produce spray dried litchi powder.

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