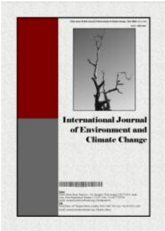

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The Effects of Spray Drying Conditions on Moisture Content, Water Activity, Bulk Density, and Tapped Density of Rice Milk Powder

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Cow's milk is usually consumed by the majority of the population and is well thought of as a wholesome complete food providing major nutrients like fat, proteins, and carbohydrates. Though milk is considered to be a complete food yet limited availability or near absence of certain minerals such as iron, and vitamins restricts its recommendation as a complete food for infants older than 12 months. To meet this requirement the rice milk was prepared by using the broken rice. Spray drying is a method applied to dry a wide variety of food extracts. The resulting powders are conveniently stored, transported, and handled. To increase the shelf life of the rice milk, spray drying of the rice milk was done by using the different inlet temperatures and feed flow rates. An experiment was conducted to study the effects of spray drying conditions on moisture content, bulk density, and tapped density of rice milk powder in 2019 at Bapatla, Andhra Pradesh, India. The broken rice was used to prepare rice milk with the optimized process parameters. Temperature

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and feed flow rate were optimized with the desirability function which satisfied all the responses with the required values to obtain optimum conditions for spray drying. The predicted optimum conditions were T=138°C and Q=35 $^{MLM-1}$. Under these conditions, the response values for bulk density, moisture content, and water activity were 0.51 $^{GML-1}$, 3.8% and 0.30.

Keywords: Rice milk; spray drying; bulk density; tapped density; food extracts.

1. INTRODUCTION

"Cow's milk is usually consumed by the majority of the population and is well thought of as a wholesome complete food providing major nutrients like fat, proteins, and carbohydrates" [1]. "Besides these macronutrients, milk also contains numerous nutrients (micro & macro) such as calcium, selenium, riboflavin, vitamin B12, and pantothenic acid (vitamin B5) which significantly contributes towards the overall growth and maintenance of the body system" [2]. "Though milk is considered to be a complete food yet limited availability or near absence of certain minerals such as iron, and vitamins like folate and some other biomolecules (amino acids) restricts its recommendation as a complete food for infants older than 12 months" [2]. To meet this requirement the rice milk was prepared by using the broken rice. The amount of broken rice produced in the rice industry was about 0.97 mt. The cost of the rice is set by the head rice kernels percentage in each unit of rough rice [3]. Low prices of broken rice in India stimulated its utilization in products where the cereal component had usually been derived from other grains. Consequently, particular interest was given to the possible substitution of processed rice meal for processed corn meal in corn soy milk [2]. Broken rice is still under-utilized and is mostly used as raw material for pet foods, rice flour, wine, and beer [4,5].

"Broken rice has nutritional benefits equal to raw rice and it is processed into flour and utilized as a food product" [6]. According to Hartmann et al. [7], "rice flour is free from gluten therefore, it is an alternative for producing gluten-free products". "Rice flour is also hypoallergenic" [8]. "Rice flour is preferred for baby food and other food products by food companies because of the low risk for people with sensitivities" [9]. The price of the broken rice is less when compared to the raw rice, thus, it has become more economical to get flour from the broken rice [10].

"A liquid derived from rice generally known as rice milk is a suitable substitute for animal milk around the world. Recently, consumers have tended toward a plant-based diet which includes cereal, legumes, seeds, nuts, fruits, and vegetables because of varied reasons such as an aversion to animal cruelty, a desire for a healthy lifestyle, and environmental awareness" [11-13]. Rice milk is the best breakfast food in Southeast Asia, especially in China and Taiwan [14,15]. Soymilk and other non-dairy milk have long been substitutes for raw milk in the U.S [16]. However, "the allergic response that many people have toward soy beverages, the bean-like flavor, and the aftertaste of the soy products have created a demand for rice milk in the U.S. market. The common steps in the production of all almond, cashew, coconut, hazelnut, peanut, sesame, soy, tiger nut, oat, rice, hemp and walnut milk substitutes are wet milling, filtration, the addition of ingredients, sterilization, homogenization, aseptic packaging, and cold storage. Gums are used to improve stability, and salt and sweeteners are used for the development of sensory properties" [17-19]. The texture, color and nutritional values of the rice milk makes it a substitute for animal milk and helps in the preparation of various food products including beverages and non-dairy puddings [14].

"Spray drying is a method applied to dry a wide variety of food extracts. The resulting powders are conveniently stored, transported and handled. Spray drying is used to produce a wide range of products including heat-sensitive materials. It is a powerful tool for delivering cost-effective, high-quality products" [20]. "The products produced by spray drying include pharmaceuticals such as antibiotics, analgesics, vaccines, vitamins, and catalysts, chemicals, such as carbides, ferrite, nitrides, tannins, fine organic/inorganic chemicals detergent and dyestuffs, ceramic, including advanced ceramic formulations, and foods such as milk and milk products, food color, food supplement, soup mixes, spice and herb extracts, coffee, tea, and sweetener. Spray-dried food products are appealing, retain nutritional qualities, and are convenient to consume" [20,21]. "The process is continuous and easily automated which can reduce labor costs" [22]. "There are fewer sticking and corrosion problems in spray drying if the material does not contact the equipment walls until it is dry" [23].

"Spray drying is a dehydration process in which a concentrated solution, suspension, emulsions, or pumpable paste is sprayed, dried, and collected. The particles are dried while they are suspended in the hot drying media. The dried products can be in the form of powder, granules, or agglomerates depending on the physical and chemical properties of the feed, the drier design, and the drying operation" [20]. To increase the shelf life of the rice milk, spray drying of the rice milk was done by using different inlet temperatures and feed flow rates.

The objective of the present study is to determine the effects of spray drying conditions on moisture content, water activity, bulk density, and tapped density of rice milk powder.

2. MATERIALS AND METHODS

2.1 Spray Drying of Rice Milk

The spray drying of rice milk was conducted in the year 2019. Rice milk obtained from the optimized conditions (TSS: 10–12^{o}Brix) was subjected to spray drying at different inlet drying air temperatures (5 levels) and feed flow rates (5 levels) maintaining constant air volume and airflow rate of 60 m^3h^{-1}. A pilot scale spray dryer (Make: S.M. Scientech, Model: B-290, Capacity: 3 L of water evaporation^{-1}) was utilized for the experiment (Fig. 1). The ambient temperature was around 28–32°C and RH was about 58–65%.

Rice milk powder, thus obtained from different experiments as proposed in the design matrix was analyzed for product quality parameters viz., physical and chemical properties. Further, the process conditions were optimized to produce a product with the best sensory attributes. Each response variable in the study was analyzed statistically using the Design Expert 12.0 software. ANOVA was performed with a significance level of 5%. Optimization was done using response surface methodology with two independent factors: (A) Inlet drying air temperature-120, 130, 140, 150, and 160°C and (B) Feed flow rate- 15, 20, 25, 30, and 35 $^{MLM-1}$. The response variables optimized were water activity (range), moisture content (range), bulk density, tapped density, WSI, and WAI. The prepared spray-dried rice milk powder was packed in HDPE (T1P1) and LDPE (T2P2) pouches, and stored under refrigerated (4°C) and ambient (25±5°C) conditions.

2.2 Independent and Dependent Variables

The independent variables are feed flow rate and inlet drying air temperatures, the dependent variables are bulk density, tapped density, and moisture content.

2.3 Determination of Properties of Powder

2.3.1 Moisture content

Moisture analysis has been performed on rice milk samples using an IR Moisture balance (Make: Shimadzu, Model: Mu 63). The moisture content of all rice milk powder samples was determined by subjecting the samples to Infrared heating at 105°C till constant weight (Fig. 2).

2.3.2 Bulk density

The bulk density of rice milk powder was measured by the procedure described by Goula and Adamopoulos (2010) and Goulaet al. (2008). 2 g of rice milk powder was transferred to a 50 ml measuring cylinder. The Bulk density was measured by dividing the weight of the powder by the volume of the sample in the cylinder.

2.3.3 Tapped density

The tapped density was calculated by manually tapping a container containing the rice milk powder on a rubber mat. It was measured after 250±15 taps from a height of 3±0.2 mm. The tapped density was measured by dividing the weight of the powder by the volume of the sample in the graduated cylinder.

3. RESULTS AND DISCUSSION

3.1 Production of Rice Milk Powder by Spray Drying

Spray drying studies were carried out at Post-Harvest Technology Centre, Bapatla using Pilot Scale Spray Dryer (Make: S.M. Science Tech., India). The maximum capacity of the spray dryer was 1.30 Lh^{-1} with the nozzle fitting to 1 mm size. The rice milk was fed at the feed flow rate of 15, 20, 25, 30, and 35 $^{MLM-1}$. The inlet air temperature was maintained at 120, 130, 140, 150, and 160°C temperature.

3.1.1 Variation in moisture content of spray dried rice milk powder at different inlet air temperatures and feed flow rates

The moisture content of the rice milk powder prepared by spray drying is presented in Fig. 3. The moisture content of the rice milk powder varied from 3.26–4.30% (w.b.). The moisture content decreased with an increase in the inlet air temperature but increased with an increase in the feed flow rate. The decrease in moisture content at higher inlet drying air temperature was due to an increase in heat transfer rate that helped more moisture removal [24,25], Goula et al. 2008, [26,27], Ghollasi et al. 2018) in spray dried powders. An f-value of 657.00 shows that the model was significant. The *p*-values less than 0.0500 indicates A (Temperature), B (Feed flow rate), and AB (Interaction between Temperature and Feed flow rate) are significant model terms (Appendix A). The Pred. R^2 was 0.9831, Adj R^2 was 0.9964 and Adeq precision ratio was 96.373 indicating goodness of fit.

Fig. 1. Laboratory model pilot scale spray dryer

Fig. 2. Infrared moisture analyzer

Table 1. ANOVA for moisture content analysis of variance table [Partial sum of squares - Type III]

Source	Sum of squares	df	Mean square	F-value	Prob> F significant	
Model	0.68	5	0.14	657.00	< 0.0001	Significant
A-temp	0.27	1	0.27	1294.91	< 0.0001	
B-feed flow	0.41	1	0.41	1953.81	< 0.0001	
AB	4.225E-003	1	4.225E-003	20.35	0.0028	
A^2	1.324E-003	1	1.324E-003	6.38	0.0395	
B^2	3.027E-003	1	3.027E-003	14.58	0.0066	
Residual	1.453E-003	7	2.076E-004			
Lack of Fit	1.453E-003	3	4.844E-004			
Pure error	0.000	4	0.000			
Cor total	0.68	12				
Std. Dev.	0.014		R-Squared		0.9979	
Mean	3.72		Adj R-Squared		0.9964	
C.V. %	0.39		Pred R-Squared		0.9831	
Press	0.012		Adeq Precision		96.373	

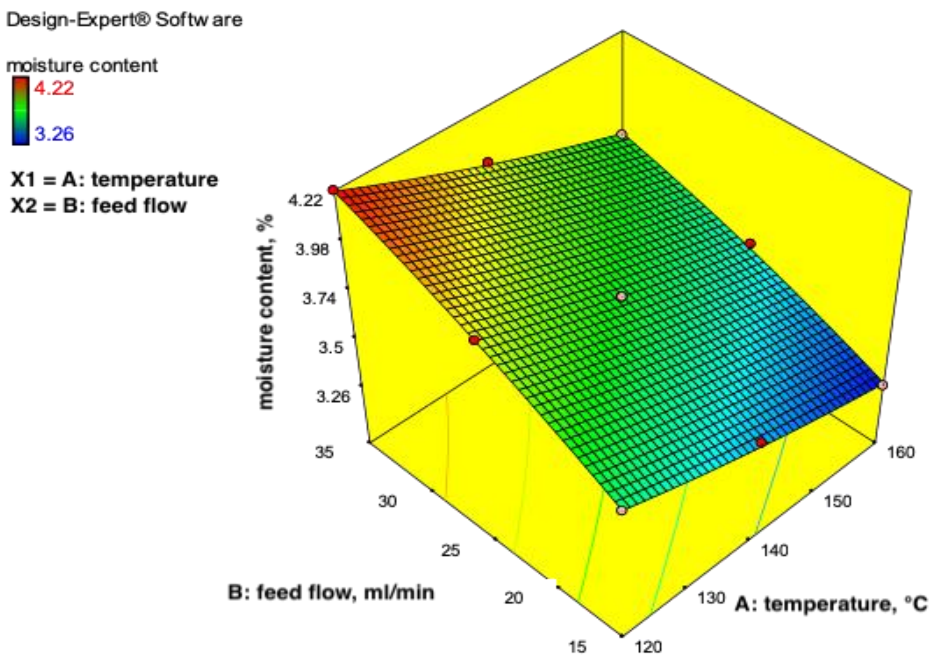

Fig. 3. Variation of moisture content of rice milk powder with spray drying inlet air temperature and feed flow rate

3.1.2 Variation of water activity of rice milk powder at different inlet air temperatures and feed flow rates

From Fig. 4, the water activity of rice milk powder varied from 0.250–0.359. An increase in the inlet air temperature leads to a decrease in the water activity of the resultant rice milk powder. The water activity is low at a temperature of 160°C followed by 150, 140, 130, and 120°C (Appendix A). However, with an increase in the feed flow rate, an increase in the water activity of powder was observed. The higher values of water activity were found at 35 ml m^{-1}, followed by 30, 25, 20, and 15 $^{MLM-1}$. The lower flow rate results in higher contact time between the drying air and the feed, which in turn helps better evaporation of the water from the feed.

The results on water activity of the spray-dried powder were in accordance with results obtained by Adhikari et al. [24], Chegini and Ghobadian [25], Goula et al. (2008), Zariefard et al. [26], Avila et al. [27] and Ghollasi et al. (2018) for spray dried powders. The model F-value of 615.73 indicated the level of significance. A *p*-value less than 0.0500 indicate that A (Temperature), and B (Feed flow rate) was significant (Appendix A). Pred R^2 is 0.9800 and Adj R^2 is 0.9961.

3.1.3 Variation of bulk and tapped density of rice milk powder at different inlet air temperatures and feed flow rates

The spray-dried rice milk powder characterization with reference to bulk density, tapped density, and particle density is shown in Figs. 5 and 6. The bulk density of the rice milk powder varied from 0.25–0.61 $^{GML-1}$. Increase in inlet air temperature, the bulk density of the powder decreased and a negative effect was observed for feed flow rate with respect to bulk density. Ghollasi et al. (2018) reported that a decrease in bulk density and particle density was observed with an increase in the drying air temperature. According to Chegini and Ghobadian [25], the increase in moisture content tend to increase the bulk density as the bulking weight increases with the presence of water, which was considerably denser than the dry solid. The trend was the same with a tapped density of the rice milk powder which varied from 0.35–0.73 $^{GML-1}$. Chegini and Ghobadian [25], Samborska et al. [28], Zareifard et al. [26], and Goula and Adamopoulos (2010) also reported similar results for spray-dried powders. The model F-value of 400.66 indicates its significance. *p*-values less than 0.0500 indicate that the A (Temperature), and B (Feed flow rate) are significant.

Table 2. ANOVA for water activity

Source	Sum of squares	df	Mean square	F-value	*p*-value	Prob> F
Model	5.592E-003	5	1.118E-003	615.73	< 0.0001	Significant
A-temp	3.038E-003	1	3.038E-003	1672.17	< 0.0001	
B-feed flow	2.521E-003	1	2.521E-003	1388.11	< 0.0001	
AB	2.250E-006	1	2.250E-006	1.24	0.3025	
A^2	7.725E-006	1	7.725E-006	4.25	0.0781	
B^2	3.058E-005	1	3.058E-005	16.84	0.0046	
Residual	1.272E-005	7	1.817E-006			
Lack of Fit	1.272E-005	3	4.239E-006			
Pure error	0.000	4	0.000			
Cor total	5.605E-003	12				
Std. Dev.	1.348E-003	R-Squared		0.9977		
Mean	0.29	Adj R-Squared		0.9961		
C.V. %	0.46	Pred R-Squared		0.9800		
Press	1.119E-004	Adeq Precision		93.924		

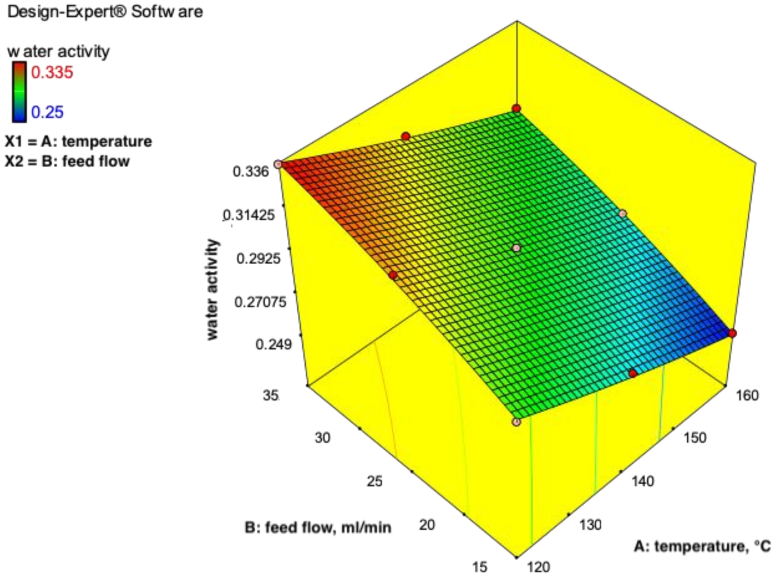

Fig. 4. Variation of water activity of rice milk powder with inlet air temperature and feed flowrate

Table 3. ANOVA for bulk density

Source	Sum of squares	df	Mean square	F-value	*p*-value	Prob> F
Model	0.082	2	0.041	400.66	< 0.0001	Significant
A-temp	0.047	1	0.047	457.03	< 0.0001	
B-feed flow	0.035	1	0.035	344.28	< 0.0001	
Residual	1.024E-003	10	1.024E-004			
Lack of Fit	1.024E-003	6	1.707E-004			
Pure error	0.000	4	0.000			
Cor total	0.083	12				
Std. Dev.	0.010	R-Squared		0.9877		
Mean	0.42	Adj R-Squared		0.9852		
C.V. %	2.43	Pred R-Squared		0.9725		
Press	2.282E-003	Adeq Precision		67.873		

Table 4. ANOVA for tapped density

Source	Sum of squares	df	Mean square	F value	*p*-value	Prob> F
Mean vs Total	3.47	1	3.47			
Linear vs Mean	0.096	2	0.048	379.35	< 0.0001	
2FI vs Linear	6.250E-004	1	6.250E-004	8.85	0.0156	Suggested
Quadratic vs 2FI	2.442E-004	2	1.221E-004	2.19	0.1831	
Cubic vs Quadratic	2.833E-004	2	1.417E-004	6.57	0.0399	Aliased
Residual	1.078E-004	5	2.155E-005			
Total	3.57	13	0.27			

Table 5. Model summary statistics Std. adjusted predicted

Source	Dev.	R-squared	R-squared	R-squared	Press	
Linear	0.011	0.9870	0.9844	0.9692	2.988E-003	
2FI	8.401E-003	0.9934	0.9913	0.9820	1.745E-003	Suggested
Quadratic	7.475E-003	0.9960	0.9931	0.9626	3.619E-003	
Cubic	4.642E-003	0.9989	0.9973	0.8707	0.013	Aliased

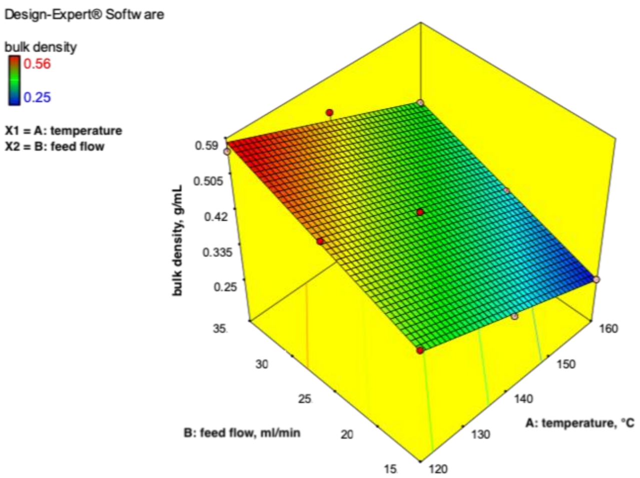

Fig. 5. Variation of bulk density with inlet air temperatures and feed flowrate

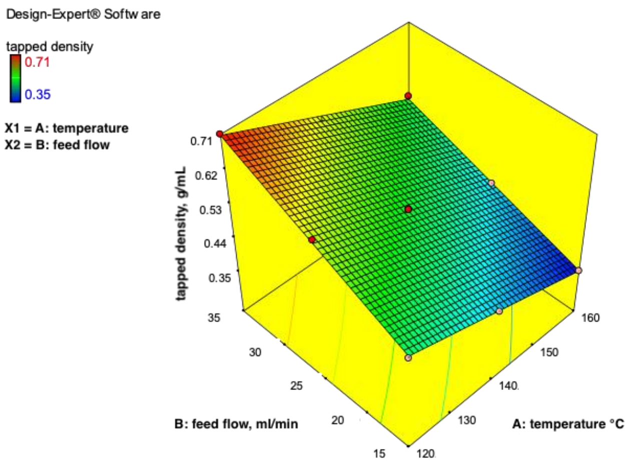

Fig. 6. Variation of tapped density with inlet air temperature and feed flow rate

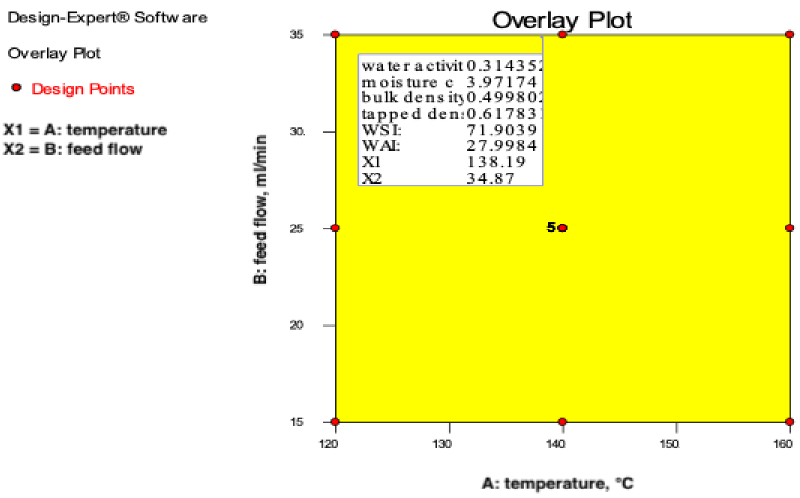

Fig. 7. Optimised spray drying condition for rice milk powder

3.2 Optimization of Spray Drying Process Variable of Rice Milk Powder

The spray Drying temperature and feed flow rates were optimized with a desirability function which satisfies all the responses with required values to obtain optimum conditions for spray drying [29]. The optimized conditions for spray-dried rice milk powder were: Inlet air temperature - 138°C and feed flow rate - 35 ml/min. Under these conditions, the response values were: bulk density - 0.51 (g/mL), tapped density - 0.62 (g/mL), moisture of powder content - 3.8%, water activity- 0.30, Water Solubility Index - 72.8% and Water Absorption Index - 21.7 % and solubility of the sample was 92 s. The RMSE value of 0.490 indicates that the predicted values were close to the observed values.

4. CONCLUSIONS

The rice milk was spray dried at feed flow rates of 15, 20, 25, 30 and 35 $^{MLM-1}$ and inlet drying air temperatures of 120, 130, 140, 150, and 160°C. With the increase in inlet drying air temperature, the moisture content, bulk, and tapped density of the spray-dried powder decreased. With the increase in feed flow rate, the values of the moisture content, bulk density, and tapped density of the powder were increased.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX A

Statistical Analysis of Rice Milk Powder by Spray Drying

Response 1: Water activity

Table A1: ANOVA for Response Surface Quadratic Model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F-value	p-value	Prob> F
Model	5.592E-003	5	1.118E-003	615.73	< 0.0001	**Significant**
A-temp	3.038E-003	1	3.038E-003	1672.17	< 0.0001	
B-feed flow	2.521E-003	1	2.521E-003	1388.11	< 0.0001	
AB	2.250E-006	1	2.250E-006	1.24	0.3025	
A^2	7.725E-006	1	7.725E-006	4.25	0.0781	
B^2	3.058E-005	1	3.058E-005	16.84	0.0046	
Residual	1.272E-005	7	1.817E-006			
Lack of Fit	1.272E-005	3	4.239E-006			
Pure Error	0.000	4	0.000			
Cor Total	5.605E-003	12				

Std. Dev.	**1.348E-003**	**R-Squared**	**0.9977**
Mean	0.29	Adj R-Squared	0.9961
C.V. %	0.46	Pred R-Squared	0.9800
PRESS	1.119E-004	Adeq Precision	93.924

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	0.30	1	5.596E-004	0.29	0.30	
A-temp	-0.023	1	5.502E-004	-0.024	-0.021	1.00
B-feed flow	0.020	1	5.502E-004	0.019	0.022	1.00
AB	7.500E-004	1	6.739E-004	-8.435E-004	2.343E-003	1.00
A^2	1.672E-003	1	8.110E-004	-2.453E-004	3.590E-003	1.17
B^2	-3.328E-003	1	8.110E-004	-5.245E-003	-1.410E-003	1.17

Final Equation in Terms of Coded Factors:

$$Wateractivity=+0.30-0.023*A+0.020*B+7.500E-004*A*B+1.672E-003*A^2-3.328E-003*B^2$$

Sequential Model Sum of Squares [Type I]

Source	Sum of Squares	df	Mean Square	F-value	p-value	Prob> F significant
Mean vs Total	1.13	1				
Linear vs Mean	5.559E-003	2	2.780E-003	603.23	< 0.0001	
2FI vs Linear	2.250E-006	1	2.250E-006	0.46	0.5138	
Quadratic vs 2FI	3.111E-005	2	1.556E-005	8.56	0.0132	
Cubic vs Quadratic	7.500E-006	2		3.750E-006	3.60	
Aliased Residual	5.216E-006	5	1.043E-006			
Total	1.13	13	0.087			

Response 2: Moisture Content

Table A2: ANOVA for Response Surface Quadratic Model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F-value	Prob> F significant	
Model	0.68	5	0.14	657.00	< 0.0001	Significant
A-temp	0.27	1	0.27	1294.91	< 0.0001	
B-feed flow	0.41	1	0.41	1953.81	< 0.0001	
AB	4.225E-003	1	4.225E-003	20.35	0.0028	
A^2	1.324E-003	1	1.324E-003	6.38	0.0395	
B^2	3.027E-003	1	3.027E-003	14.58	0.0066	
Residual	1.453E-003	7	2.076E-004			
Lack of Fit	1.453E-003	3	4.844E-004			
Pure Error	0.000	4	0.000			
Cor Total	0.68	12				

Std. Dev.	0.014	**R-Squared**	0.9979
Mean	3.72	**Adj R-Squared**	0.9964
C.V. %	0.39	**Pred R-Squared**	0.9831
PRESS	0.012	**Adeq Precision**	96.373

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	3.73	1	5.983E-003	3.71	3.74	
A-temp	-0.21	1	5.882E-003	-0.23	-0.20	1.00
B-feed flow	0.26	1	5.882E-003	0.25	0.27	1.00
AB	0.033	1	7.204E-003	-0.050	-0.015	1.00
A^2	0.022	1	8.670E-003	1.396E-003	0.042	1.17
B^2	0.033	1	8.670E-003	-0.054	-0.013	1.17

Final Equation in Terms of Coded Factors:

Moisture content=+ 3.73-0.21 * A+0.26 * B -0.033 * A * B+0.022 * A^2 -0.033*B^2

Lack of Fit Tests

Source	Sum of Squares	df	Mean Square	F-value	p-value	Prob> F significant
Linear	1.024E-003	6	1.707E-004			
2FI	9.244E-004	5	1.849E-004			
Quadratic	6.839E-004	3	2.280E-004			
Cubic	1.724E-005	1	1.724E-005			
Pure Error	0.000	4	0.000			

Response 3: Bulk Density

Table A3: ANOVA for Response Surface Linear Model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F-value	p-value	Prob> F
Model	0.082	2	0.041	400.66	< 0.0001	Significant
A-temp	0.047	1	0.047	457.03	< 0.0001	
B-feed flow	0.035	1	0.035	344.28	< 0.0001	
Residual	1.024E-003	10	1.024E-004			
Lack of Fit	1.024E-003	6	1.707E-004			
Pure Error	0.000	4	0.000			
Cor Total	0.083	12				

Std. Dev.	0.010	**R-Squared**	0.9877
Mean	0.42	**Adj R-Squared**	0.9852
C.V. %	2.43	**Pred R-Squared**	0.9725
PRESS	2.282E-003	**Adeq Precision**	67.873

	Coefficient Estimate	df	Standard Error	95% CI	95% CI	
Factor				**Low**	**High**	**VIF**
Intercept	0.42	1	2.807E-003	0.41	0.42	
A-temp	-0.088	1	4.132E-003	-0.098	-0.079	1.00
B-feed flow	0.077	1	4.132E-003	0.067	0.086	1.00

Final Equation in Terms of Coded Factors:

Bulk density =+0.42-0.088 * A+0.077 * B

Response 4: Tapped Density

Table A4: ANOVA

Sequential Model Sum of Squares [Type I]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Mean vs Total	**3.47**	**1**	**3.47**			
Linear vs Mean	**0.096**	**2**	**0.048**	**379.35**	< 0.0001	
<u>2FI vs Linear</u>	<u>6.250E-004</u>	**1**	<u>6.250E-004</u>	<u>8.85</u>	<u>0.0156</u>	<u>Suggested</u>
Quadratic vs 2FI	2.442E-004	**2**	1.221E-004	2.19	0.1831	
Cubic vs Quadratic	2.833E-004	**2**	1.417E-004	6.57	0.0399	Aliased
Residual	1.078E-004	**5**	2.155E-005			
Total	**3.57**	**13**	**0.27**			

Lack of Fit Tests

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F
Linear	1.260E-003	6	2.100E-004		
2FI	6.353E-004	5	1.271E-004		
Quadratic	3.911E-004	3	1.304E-004		
Cubic	1.078E-004	1	1.078E-004		
Pure Error	0.000	4	0.000		

Model Summary Statistics Std. Adjusted Predicted						
Source	**Dev.**	**R-Squared**	**R-Squared**	**R-Squared**	**PRESS**	
Linear	0.011	0.9870	0.9844	0.9692	2.988E-003	
2FI	8.401E-003	0.9934	0.9913	0.9820	1.745E-003	Suggested
Quadratic	7.475E-003	0.9960	0.9931	0.9626	3.619E-003	
Cubic	4.642E-003	0.9989	0.9973	0.8707	0.013	Aliased

Table A5: Constraints imposed on optimization for spray drying

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
Temp	is in range	120	160	1	1	3
Feed flow	is in range	15	35	1	1	3

Table A6: Solutions for 30 combinations of categoric factor levels for imposed constraints

Solutions Number	Temp	Feed flow	Desirability	
1	138.19	34.87	1.000	Selected
2	128.89	29.21	1.000	
3	123.81	30.38	1.000	
4	145.22	30.72	1.000	
5	137.45	27.60	1.000	
6	145.38	21.14	1.000	
7	136.13	30.19	1.000	
8	131.93	29.65	1.000	
9	126.37	25.87	1.000	
10	133.44	31.00	1.000	
11	134.14	34.00	1.000	
12	144.13	18.47	1.000	
13	152.11	27.16	1.000	
14	139.00	23.72	1.000	
15	125.32	15.09	1.000	
16	155.51	16.74	1.000	
17	136.83	28.91	1.000	
18	133.21	28.90	1.000	
19	134.10	33.78	1.000	
20	142.54	32.34	1.000	
21	157.91	28.27	1.000	
22	133.86	18.70	1.000	
23	134.55	18.38	1.000	
24	158.40	30.55	1.000	
25	153.02	24.41	1.000	
26	151.77	28.24	1.000	
27	128.02	28.84	1.000	
28	151.89	25.77	1.000	
29	130.36	23.26	1.000	
30	122.15	18.45	1.000	

Factor	Name	Level	Low Level	High Level	Std. Dev.	Coding
A	Temp	138.19	120.00	160.00	0.000	Actual
B	Feed flow	34.87	15.00	35.00	0.000	Actual

Table A7: Predicted Values for spray dried rice milk powder

Response	Prediction	SE Mean	95% CI low	95% CI high	SE	Pred 95% PI low	Pred 95% PI high
Water activity	0.314351	9.297E-004	0.31	0.32	1.637E-003	0.31	0.32
Moisture content	3.97173	9.938E-003	3.95	4.00	0.018	3.93	4.01
Bulk density	0.499796	4.964E-003	0.49	0.51	0.011	0.47	0.52
Tapped density	0.617824	4.137E-003	0.61	0.63	9.365E-003	0.60	0.64

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