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Optimisation of Spray-Dried Strawberry Flavour by Box Behnken Design

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Encapsulation is an important technique to enhance the stability of flavouring compounds by providing a protective barrier against moisture, oxygen, and heat. The encapsulation efficiency depends on the drying process and the encapsulation agent employed, which can be obtained through statistical optimisation. Therefore, the objective of this study is to create a stable spray-dried strawberry flavouring powder encapsulated with maltodextrins and β-cyclodextrins. The Box-Behnken experimental design was utilised with the key dependent variables encompassing process yield, moisture content, hygroscopicity, flowability (Carr Index and Hausner Ratio), and solubility. The independent variables were set using the Box-Behnken software at different levels (+1, 0, and -1), maltodextrin (23%, 24%, and 25%), β-cyclodextrin (0%, 1%, and 2%), and pump flow rate (10%, 25%, and 40%). Among the fifteen runs, Run 15 exhibited the most optimum condition as indicated by the Process Yield (61.54%), Moisture Content (1.84%), Carr Index (9.72), Hausner Ratio (1.107), solubility (100%), and hygroscopicity (0.0024). The findings hope to improve the properties of strawberry flavouring powder by highlighting its potential for enhancing innovation and advancement in the food industry. The study recommends comprehensive flavour profiling through sensory evaluation and GC-MS to establish correlations between the physical properties of the strawberry flavouring powder with the industry and consumer standards.

Keywords: Encapsulation; strawberry flavour; Box Behnken Design; maltodextrins; β-cyclodextrins

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The global food flavour market is currently experiencing robust growth. In 2020, the market's estimated value reached approximately USD 12,712.7 million and forecasts suggest a remarkable trajectory with potential to reach USD 19,223.6 million by 2030 [1]. This impressive ascent highlights the indispensable role of flavours within the food and beverage industry. Flavours are used to enhance product aroma and taste in catering to consumer preferences, masking undesirable flavours, fortifying inherent tastes, and ensuring consistency in the products [2]. However, the chemical nature of flavouring compounds such as Hexanal, (E)-Hex-2-enyl acetate, 3-hexenal, and (Z)-Hex-3-enyl acetate, furanones, and furaneol render them susceptible to loss during various stages of production, transportation, and storage [2]. They are also highly sensitive to external factors such as heat, light, and oxygen, making them prone to evaporation and degradation [3]. This susceptibility poses a significant challenge in delivering consistent flavour experiences to consumers.

A practical solution to address these challenges is through encapsulation. It involves enveloping flavour compounds within another substance to shield them from external influences during storage while allowing for controlled release upon consumption [4]. Various encapsulation methods exist, including spray drying, spray chilling, spray cooling, extrusion, freeze drying, coacervation, and molecular inclusion [5]. Among these methods, spray drying is favoured due to its cost-effectiveness, versatility in selecting carrier materials, excellent retention of volatile components, and the stability it imparts to end products [6].

Spray drying operates based on four fundamental principles: atomisation, droplet-hot air contact,

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evaporation of droplet air, and dry product-humid air separation [6]. The process begins by converting the liquid into tiny droplets, followed by exposure to hot air which initiates the drying process. During this phase, a temperature and vapour pressure equilibrium is established between the liquid and gas phases, leading to the evaporation of moisture from the droplets. Finally, the separation of the dry product from the humid air is achieved and it is collected in a cyclone located outside the dryer [6].

Selecting the right wall materials for encapsulation is crucial as it directly influences the characteristics of the encapsulated particles and the efficiency of the drying process. Wall materials used in the food industry include maltodextrins, arabic gum, modified starches, whey protein, cyclodextrin, and cellulose. These materials are often combined to achieve desired encapsulation outcomes [2], [3], [7].

Maltodextrins (MDs), with a dextrose equivalent (DE) of 10 to 20, are favoured for their water solubility, low viscosity, flavour neutrality, and cost-effective encapsulation pine [2], [3], [7]. MDs with DE of 19, in particular, are well-suited for the encapsulation of strawberry flavour due to their versatility in forming a protective film, binding the flavour, and reducing oxygen permeability [8]. Additionally, MDs prevent the stickiness and agglomeration of powdered flavour during storage [7].

Cyclodextrins, particularly beta-cyclodextrin (β-CDs), are widely used as wall materials alongside MDs in spray-dried encapsulated flavour [3]. Their unique structure, characterised by a hydrophilic outside and hydrophobic inside, allows them to form inclusion complexes with various organic and inorganic guest molecules, particularly flavouring compounds [9, 10]. Consequently, it prevents the degradation and complex formation of flavour with other food components. β-CDs-based encapsulation has proven to improve the stability, solubility, and bioavailability of the final product, including powdered flavour [11].

Previous studies on the encapsulation techniques of strawberry flavour have utilised various wall materials, including maltodextrins (MDs), arabic gum, nutriose soluble fibre, cleargum modified starch, and beta-cyclodextrins (β-CDs). Previous study also examined the effects of inlet temperature and the ratio of wall materials using response surface methodology with the Design Expert 10.0 software, but limited research has been conducted using the binary combination of MDs and β-CDs via Box Behnken Design 13.0. However, a contentious issue arises concerning the high production cost attributed toward the industry due to the costly combination of wall materials used. Thus, a binary combination using MDs and β-CDs is more favourable in the flavour industry.

In light of this issue, the present research aims to reduce production expenses by exclusively utilising two types of wall materials: MDs and β-CDs. The experiment consisted of 15 runs with the ratio of each run provided by Box Behnken Design (BBD). The main objectives of this study are to develop an optimised formulation for spray-dried strawberry flavour powder encapsulated with maltodextrin and β-CDs using the Box Behnken Experimental Design 13.0.

EXPERIMENTAL

Chemicals and Materials

Synthetic strawberry flavour and maltodextrins (DE=19) were obtained from Flavo Blitz Sdn. Bhd., Pulau Pinang, Malaysia. Meanwhile, β-cyclodextrin was obtained from BT Science, Malaysia.

Experimental Design

In this research, the Design Expert 13.0 (Stat-Ease Co., USA) software, namely the Box Behnken Design (BBD), was used for the experimental design to determine the effect of different percentages of the pump flow rate and wall materials concentration on the physical properties of the spray-dried strawberry powder. The aim was to investigate the relationship between the independent variables, which was set by three levels of low (-1), middle (0), and high (+1), with the determined variables. A combination of the independent variables (i.e., maltodextrin (MDs), ß-cyclodextrin (ß-CDs), and pump flow rate) was used and represented by 15 runs from BBD. The 15 sets of trial experiments were formed from combinations of maltodextrins (23%, 24%, and 25%) and β-cyclodextrins (0%, 1%, and 2%) with different percentages that were encapsulated using a spray dryer at different pump flow rates (10%, 25%, and 40%) as shown in Table 1 as part of the optimisation process.

Sample Preparation

The combinations of the mixture were prepared using 0% to 2% of ß-cyclodextrins and 23% to 25% of maltodextrins with DE equal to 19 as recommended by BBD. The mixture of such encapsulants was dissolved in 60% of distilled water together with 10% of strawberry flavour. The obtained mixture was homogenised using a homogeniser (WiSeTis, WITEC/HG/15D, UK) at 3 min with 335 x 100% [12].

Table 1. The experiment design for the strawberry powdered flavour.

Run	Pump flow rate (%)	MD (%)	ß-CDs (%)
1	25 (0)	24 (0)	1 (0)
2	25 (0)	25 (+1)	0 (-1)
3	40 (+1)	25 (+1)	1 (0)
4	40 (+1)	24 (0)	0 (-1)
5	25 (0)	23 (-1)	2 (+1)
6	10 (-1)	25 (+1)	1 (0)
7	40 (+1)	24 (0)	2 (+1)
8	10 (-1)	24 (0)	0 (-1)
9	25 (0)	24 (0)	1(0)
10	25 (0)	23 (-1)	0 (-1)
11	25 (0)	24 (0)	1 (0)
12	40 (+1)	23 (-1)	1(0)
13	25 (0)	25 (+1)	2 (+1)
14	10 (-1)	23 (-1)	1(0)
15	10 (-1)	24 (0)	2 (+1)

Spray Drying Process

The encapsulation of the powdered strawberry flavour was performed using a mini–Spray Dryer (BUCHI, B-290, Switzerland). The parameter of the spray dryer was configured with slight modifications, namely the inclusion of an inlet temperature (175 °C), an aspiration rate (75%), and a nozzle (30%) [12]. The mixture was fed into the dryer chamber by the peristaltic pump and the pump flow rate was set as the percentage of the rotational speed of the pump, ranging from 10% to 40% for all 15 runs of the sample. The dried strawberry flavour samples were collected from the vessel attached to the cyclone's base and its metal lid.

Encapsulated Powder Flavour Analysis for Optimisation

The encapsulated powder flavour analysis was conducted to identify suitable process yield, hygroscopicity, moisture content, product flowability, and powder solubility.

Process Yield

The process yield (PY) of the powdered strawberry flavouring was conducted according to the method by [9]. The collected powder in the cyclone was divided with the total solid content used during the mixture's preparation.

Moisture Content

The moisture content of the flavour powder sample was measured using a moisture analyser (ADAM, PMB 53, UK) and the temperature was set at 129 °C for 13 minutes.

Hygroscopicity

The powder's hygroscopicity was determined according to the method described in [13]. It involved spreading 1 g of the powder on petri dishes to create a large surface area between humid air and the flavour powder. The samples were placed in a desiccator at 23 °C and 76% relative humidity using 10 ml HNO_3 solution as humidifier. The weight gained by the powder after two days exposure to the atmosphere was recorded and the hygroscopicity was calculated.

Bulk and Tapped Density

The tapped density of the powder produced was calculated using the weight/volume ratio as described in [12]. The powdered flavour was weighed approximately 1 g, transferred into a 10 ml graduated cylinder, and battered against a firm surface for 20 times until the volume was fixed. The results of bulk density (ρb) and tapped density (ρt) were reported in g/ml.

Powder Flowability

The powdered flavour's flowability was evaluated according to the method proposed by [14]. Flowability was determined by calculating the Carr Index (CI) and the Hausner Ratio (HR) values based on the bulk and tapped densities of the powder.

Powder Solubility

Powder solubility was assessed using a method suggested by [12] with slight modifications. A powder sample of 0.5 ± 0.001 g was transferred into 50 ml of distilled water. The mixture was stirred with a vortex mixture at 600 rpm for 5 minutes. Then, the solution was centrifuged (K9526-M000, Japan) at 3000 g for another 5 minutes.

RESULTS AND DISCUSSION

Table 2 shows the result of the physical parameter obtained from the strawberry powdered flavour analysis. The physical parameters of the samples included process yield (PY), moisture content (MC), hygroscopicity (HC), Carr Index (Cl), Hausner Ratio (HR), and solubility by using 15 different formulations based on feed, maltodextrins (MDs), and β-cyclodextrins (β-CDs). The efficiency of spray drying is significantly impacted by process yield, making it a critical factor that directly influences the production cost of the product [12]. The process yields of the sample produced from the spray drying machine increased as the pump flow rate increased. Samples with less than 50% of the initial feeding volume were rejected since the sample collected in the cyclone was sticky and agglomerates [12].

All samples with the highest pump flow rate (40%) produced PY less than 50%; therefore, it was rejected due to the lower PY. This finding aligns with [15], which claimed that higher pump flow rate leads to shorter contact time between the droplets and hot air, consequently reducing the efficiency of the heat transfer and reducing water evaporation. Hence, it can be inferred that an increase in pump flow rate will promote a decrease in heat and mass transfer that reduces process yield and increases moisture content. The finding is also supported by [16], which reported that higher pump flow rate led to shorter residence time, thus preventing adequate drying of droplets. As a result, the final product yielded higher moisture content, lower solid concentration, and a decrease in process yield. Additionally, one sample with medium pump flow rate (25%), MDs (23%), and β-CDs (0%) also produced PY less than 50%. This demonstrates that the presence of β-CDs as an encapsulant alongside with MDs can improve the PY of the spray-dried strawberry powder. However, most previous studies employed the combination of multiple wall materials. Therefore, there is a lack of justification and interpretation regarding the conclusive effects and efficiency of β-CDs as wall materials in improving the PY of the spray-dried flavour samples.

Moisture content is a crucial parameter in powdered samples as elevated moisture levels can contribute to increased water activity. This poses a significant risk to product quality by fostering enzyme activity and microbial growth. Therefore, it is imperative to maintain moisture content and water activity within desirable limits, specifically below 8%, to preserve the quality and extend the shelf life of strawberry powder [15]. Table 2 shows the moisture content of all the samples increases with increasing the pump flow rate and process yield. The lowest values of the moisture content were recorded by sample 15 which was 1.84% at 10% of pump flow rate and 61.54% of process yield. The highest moisture content can be observed by Run 4 (2.86%) at 40% of pump flow rate and 38.77% of process yield.

Table 2. The physical parameter of the strawberry powdered flavour.

Run	Feed (%)	MDs (%)	β-CDs (%)	PY (%)	MC (%)	HC	CI (%)	HR (%)	Solubility
6	10 (-1)	25 (+1)	1 (0)	62.5	1.86	0.0224	9.81	1.109	100
8	10 (-1)	24 (0)	0 (-1)	58.33	1.91	0.0212	11.3	1.128	100
14	10 (-1)	23 (-1)	1 (0)	61.53	1.89	0.0216	10.4	1.116	100
15	10 (-1)	24 (0)	2 (+1)	61.54	1.84	0.0224	9.72	1.107	100
1	25 (0)	24 (0)	1 (0)	51	2.31	0.0165	14.18	1.165	100
2	25 (0)	25 (+1)	0 (-1)	50	2.33	0.0146	14.23	1.166	100
5	25 (0)	23 (-1)	2 (+1)	52	2.27	0.0191	13.4	1.155	100
9	25 (0)	24 (0)	1 (0)	51	2.29	0.0181	13.62	1.158	100
10	25 (0)	23 (-1)	0 (-1)	48	2.39	0.0105	14.59	1.171	100
11	25 (0)	24 (0)	1 (0)	52.17	2.3	0.0179	14.06	1.163	100
13	25 (0)	25 (+1)	2 (+1)	52.5	2.26	0.0194	13.21	1.152	100
3	40 (+1)	25 (+1)	1 (0)	43.67	2.83	0.0053	15.26	1.180	100
4	40 (+1)	24 (0)	0 (-1)	38.77	2.86	0.0006	16.04	1.191	100
7	40 (+1)	24 (0)	2 (+1)	45.83	2.81	0.0055	14.79	1.173	100
12	40 (+1)	23 (-1)	1 (0)	40.46	2.84	0.0007	15.76	1.187	100

Note: MDs (Maltodextrins), β-CDs (βeta-cyclodextrins), PY (Process Yield), MC (Moisture Content), HC (Hygroscopicity), Cl (Carr Index), and HR (Hausner Ratio).

The encapsulation process for strawberry powdered flavour using MDs was within the range of 23% to 25%. Notably, the increase in MDs percentage prompted a corresponding reduction in moisture content. This phenomenon can be attributed to the distinctive qualities of MDs with a dextrose equivalent (DE) of 19, which facilitate the stabilisation of the core materials by forming a protective barrier around the powder particles. Such barrier effectively acts as a shield against moisture that prevents absorption from the surrounding environment. Consequently, the likelihood of moisture reabsorption is significantly reduced, contributing to the preservation of lower moisture levels in the powdered product [4].

Furthermore, the study revealed a decrease in moisture content with an increase in β-cyclodextrins, which could be due to the formation of inclusion complexes by trapping the hydrophobic molecules within its cavity. This prevents moisture absorption, which ultimately reduces the overall moisture content of the samples [17].

The results in Table 2 further denote that hygroscopicity decreased as the moisture content of the powdered flavour samples increased. This trend aligns with the findings by previous studies where the hygroscopicity values of the powdered flavour decreased correspondingly with the increase in moisture content [18], [19]. It is worth noting that all samples obtained showed low hygroscopicity values ranging from 0.0006 to 0.0224 as indicated by the slight increase in the weight difference of the powder.

The hygroscopicity values were notably influenced by all the independent variables, with inlet temperature emerging as the most influential factor. Lower temperature has been associated with reduced hygroscopicity [19]. In this research, the inlet temperature used was 175 ℃, which aligned with a previous study by [20] that focused on producing *kuini* (*Mangifera odorata*) powder through the spray drying process and found that inlet temperatures ranging from 160 ℃ to 175 ℃ resulted in low hygroscopicity.

Further observation revealed that the Carr Index and Hausner Ratio values increased when the moisture contents, process yield, and pump flow rate increased (Table 2). A study by [15] reported that higher moisture content would allow the sample to be sticky and agglomerate, which resulted in higher Carr Index and Hausner Ratio values. Furthermore, high Carr Index and Hausner Ratio values indicate that the powder sample is more cohesive and less capable of flowing freely [19]. Based on the standard value of the Carr Index and Hausner Ratio, the powdered flavour sample is deemed to have excellent flowability when the Carr Index and Hausner Ratio values range between 0% to 10% and 1.00 to 1.11, respectively.

The sample's excellent flowability was represented by Runs 6 and 15 of the Carr Index and Hausner Ratio, respectively (Table 2). Both runs were produced from 10% of pump flow rate, 2% of β–CDs, as well as 24% and 25% of MDs. Achieving a homogenous distribution of microcapsules obtained through the spray drying method is crucial. Solubility plays a vital role in this process by serving as a significant parameter for assessing the behaviour of powdered products when dissolved in aqueous solutions, thus indicating their capacity to form a solution or suspension in water. High solubility is desired in the context of microcapsules produced via spray drying, which find application as food additives. Additionally, moisture content has been observed to have an impact over its solubility.

Furthermore, solubility has been observed to be influenced by moisture content. The data in Table 2 unequivocally demonstrates that all the strawberry powdered flavour samples exhibited a remarkable 100% solubility. Perhaps, β-cyclodextrins improve the solubility of the samples by forming inclusion complexes while hydrophobic cavity allowed β-cyclodextrins to mask their hydrophobic nature and expose their hydrophilic site. This may enhance their solubility in water or other solvents, thus allowing for easier dissolution and dispersion of the powdered sample [17]. Additionally, maltodextrin is composed of glucose units and thus can act as a soluble carrier or bulking agent in powdered samples. It also carries a hydrophilic property, which can readily dissolve in water. These qualities allow maltodextrin to form a solution that helps to disperse and solubilise other components that are present in the powder by increasing the available surface area for water contact [4].

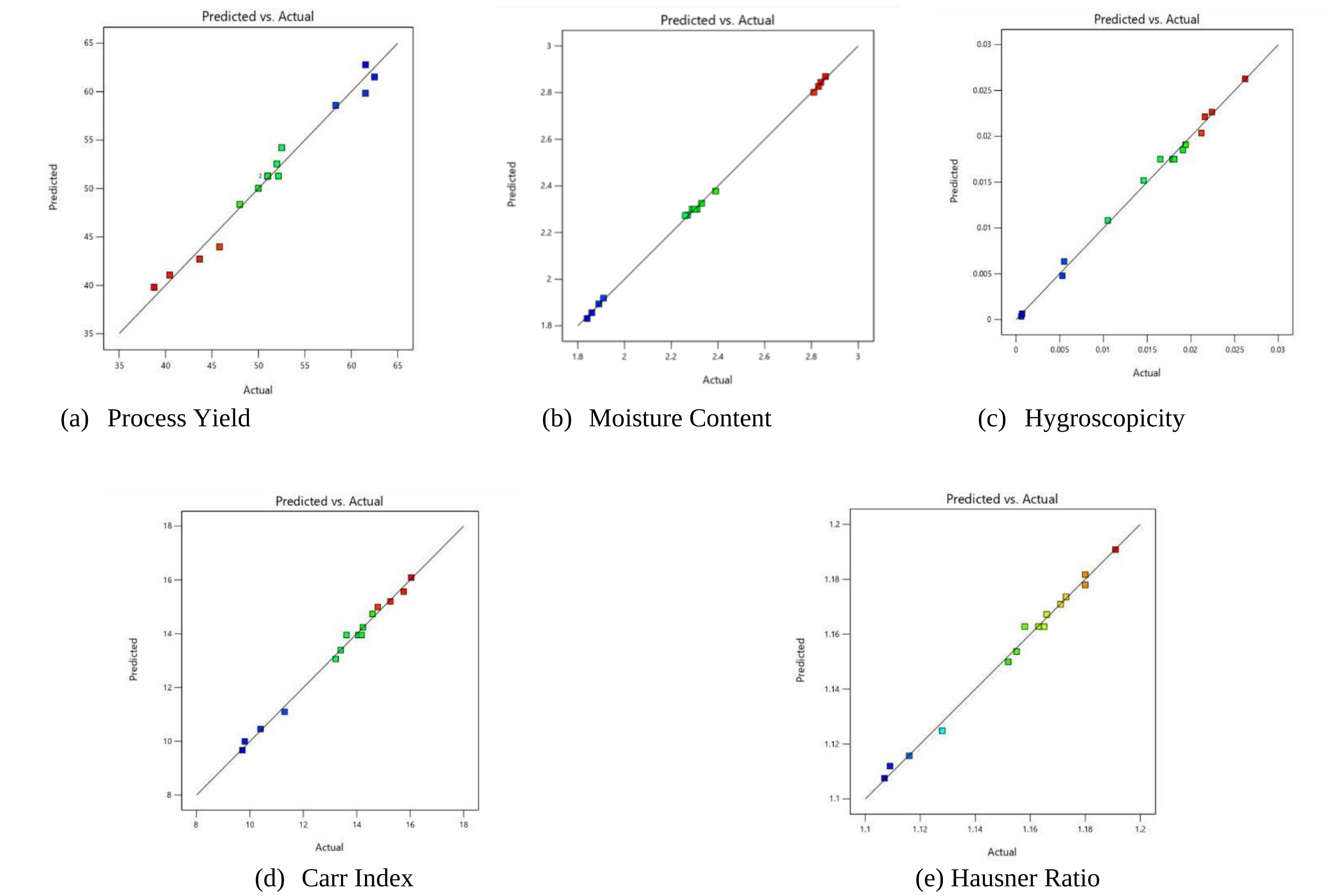
Such result agrees with a study by [12] which reported that strawberry powder flavour encapsulated with MDs and β-CDs gave 100% solubility. Previous studies have also provided evidence that factors like pump flow rate, atomisation size, air inlet temperature, and air outlet temperature significantly influenced the solubility of microcapsules obtained through spray drying [15]. Furthermore, increasing the product feed, reducing the atomisation speed, and lowering the air inlet temperature directly impact the moisture content of the final product, yet decrease the solubility [12]. These findings highlight the importance of carefully controlling these process parameters to achieve the desired solubility characteristics in microcapsule formulations.

Predicted and Actual Value from BBD

Table 3 presents the actual and predicted values for the physical parameter of the strawberry powdered flavour. The actual value represented the observed results obtained during experimental runs while the predicted values were estimated by the regression model generated from the experimental data.

Table 3. The actual and predicted values for the physical parameter of the strawberry powdered flavour.

	Process Yield		**Moisture Content**		**Hygroscopicity**		**Carr Index**		**Hausner Ratio**	
Run	**Actual Value (%)**	**Predicted Value (%)**	**Actual Value**	**Predicted Value**	**Actual Value**	**Predicted Value**	**Actual Value**	**Predicted Value**	**Actual Value**	**Predicted Value**
1	61.53	59.85	1.89	1.89	0.0053	0.0048	10.4	10.46	1.116	1.117
2	58.33	58.59	1.91	1.92	0.0055	0.0064	11.3	11.10	1.128	1.126
3	62.5	61.52	1.86	1.86	0.0007	0.0004	9.81	10.00	1.109	1.110
4	38.77	39.79	2.86	2.87	0.0262	0.0262	16.04	16.09	1.191	1.191
5	51	51.29	2.29	2.3	0.0165	0.0175	13.62	13.95	1.158	1.162
6	61.54	62.78	1.84	1.83	0.0006	0.0006	9.72	9.67	1.107	1.107
7	52.17	51.29	2.3	2.3	0.0179	0.0175	14.06	13.95	1.163	1.162
8	48	48.36	2.39	2.38	0.0194	0.0191	14.59	14.74	1.171	1.172
9	50	50.03	2.33	2.33	0.0191	0.0185	14.23	14.24	1.166	1.167
10	52	52.55	2.27	2.28	0.0146	0.0152	13.4	13.39	1.155	1.154
11	51	51.29	2.31	2.3	0.0181	0.0175	14.18	13.95	1.165	1.162
12	43.67	42.73	2.83	2.83	0.0216	0.0221	15.26	15.20	1.18	1.179
13	40.46	41.06	2.84	2.84	0.0224	0.0227	15.76	15.57	1.18	1.179
14	45.83	43.99	2.81	2.80	0.0212	0.0204	14.79	14.99	1.173	1.175
15	52.5	54.22	2.26	2.27	0.0105	0.0108	13.21	13.07	1.152	1.151



(a) Process Yield (b) Moisture Content (c) Hygroscopicity (d) Carr Index (e) Hausner Ratio

Figure 1. The predicted and actual value for the strawberry powdered flavour: (a) process yield; (b) moisture content; (c) hygroscopicity; (d) Carr Index; (e) Hausner Ratio.

Note: Red cubes represent the highest value while blue cubes represent the lowest value for the physical properties except for the process yield, which is illustrated by red cubes representing the lowest value and blue cubes representing the highest value.

A correlation graph has been generated to compare the actual and predicted values of the physical properties of the strawberry powdered flavour obtained from the response surface model as shown in Figure 1. The actual and predicted values for all physical parameters of the spray-dried strawberry flavour were close to each other. This indicates that the experimental result obtained agreed with the hypothesis generated by BBD.

Fit Statistics for the Strawberry Powdered Flavour

Table 4 shows the fit statistics for all physical properties of the strawberry powdered flavour from the Box Behnken Design. The predicted R^2 for the process yield was 0.9759 with an adjusted R^2 of 0.9743. Next, the predicted R^2 for moisture content was 0.9974 while the adjusted R^2 was 0.9985. Furthermore, the predicted R^2 for hygroscopicity, Carr Index, and Hausner Ratio was 0.9632 with an adjusted R^2 of 0.9886.

It is worth highlighting that the predicted R^2 values for all physical properties of the strawberry powdered flavour demonstrated reasonable agreement with the adjusted R^2. This observation is supported by the fact that the mean difference for each physical property of the strawberry powdered flavour was less than 0.2. Consequently, it can be concluded that all physical properties of the strawberry powdered flavour exhibit a positive strong relationship as indicated by the predicted value being closely aligned to 1.

ANOVA Values of the Strawberry Powdered Flavour

The analysis of variance (ANOVA) was performed to confirm the fit quality of the physical properties of the strawberry powdered flavour (Table 5).

The process yield indicated that A, B, and C were significant models since the p-value was less than 0.05. According to the ANOVA of factors, the model's computed F-value was 177.73, implying that it was significant. Meanwhile, the lack of fitness was 24.02%, which was insignificant relative to the pure error.

Next, the ANOVA results for moisture content indicated that A, B, C, BC, and A^2 were significant models since the p-value was less than 0.05. According to the ANOVA of factors, the model's computed F-value was 2411.32, implying that it was significant. Meanwhile, the lack of fitness was 41.87%, which was insignificant relative to the pure error.

Furthermore, the ANOVA results for hygroscopicity indicated that A, B, C, and A^2 were significant models since the p-value was less than 0.05. According to the ANOVA of factors, the model's computed F-value was 127.02, implying that it was significant. Meanwhile, the lack of fitness was 20.56%, which was insignificant relative to the pure error.

Table 4. The fit statistics for the physical properties of strawberry flavour.

Process Yield	Standard Deviation	1.18	R^2	0.9798
	Mean	51.29	Adjusted R^2	0.9743
	Critical Value (%)	2.31	Predicted R^2	0.9579
			Adeq Precision	37.6035
Moisture Content	Standard Deviation	0.0142	R^2	0.9989
	Mean	2.33	Adjusted R^2	0.9985
	Critical Value (%)	0.6090	Predicted R^2	0.9974
			Adeq Precision	126.5038
Hygroscopicity	Standard Deviation	0.0009	R^2	0.9951
	Mean	0.0146	Adjusted R^2	0.9886
	Critical Value (%)	5.94	Predicted R^2	0.9632
			Adeq Precision	38.2720
Carr Index	Standard Deviation	0.0009	R^2	0.9951
	Mean	0.0146	Adjusted R^2	0.9886
	Critical Value (%)	5.94	Predicted R^2	0.9632
			Adeq Precision	38.2720
Hausner Ratio	Standard Deviation	0.0009	R^2	0.9951
	Mean	0.0146	Adjusted R^2	0.9886
	Critical Value (%)	5.94	Predicted R^2	0.9632
			Adeq Precision	38.2720

Table 5. ANOVA values for the physical properties of the strawberry powdered flavour.

Process Yield	**Source**	**Sum of Squares**	**Degree of Freedom**	**Mean Square**	**F-value**	**p-value**	
	Model	747.05	3	249.02	177.73	< 0.0001	Significant
	A-Pump	706.32	1	706.32	504.12	< 0.0001	
	B-MDs	5.58	1	5.58	3.98	0.0714	
	C-Beta-CDs	35.15	1	35.15	25.09	0.0004	
	Residual	15.41	11	1.40			
	Lack of Fit	14.50	9	1.61	3.53	0.2402	Not significant
	Pure Error	0.9126	2	0.4563			
	Cor Total	762.46	14				
Moisture Content	**Source**	**Sum of Squares**	**Degree of Freedom**	**Mean Square**	**F-value**	**p-value**	
	Model	1.87	5	0.3732	2411.32	< 0.0001	Significant
	A-Pump	1.84	1	1.84	11909.91	< 0.0001	
	B-MDs	0.0015	1	0.0015	9.77	0.0122	
	C-Beta-CDs	0.0120	1	0.0120	77.62	< 0.0001	
	BC	0.0006	1	0.0006	4.04	0.0754	
	A^2	0.0086	1	0.0086	55.25	< 0.0001	
	Residual	0.0014	9	0.0002			
	Lack of Fit	0.0012	7	0.0002	1.70	0.4187	Not significant
	Pure Error	0.0002	2	0.0001			
	Cor Total	1.87	14				
Hygros-copicity	**Source**	**Sum of Squares**	**Degree of Freedom**	**Mean Square**	**F-value**	**p-value**	
	Model	0.0009	4	0.0002	127.02	< 0.0001	Significant
	A-Pump	0.0008	1	0.0008	436.34	< 0.0001	
	B-MDs	0.0000	1	0.0000	6.80	0.0143	
	C-Beta-CDs	0.0001	1	0.0000	37.35	0.0020	
	A^2	0.0000	1	0.0000	27.58	0.00016	
	Residual	0.0000	10	2.718E-06			
	Lack of Fit	0.0000	8	3.207E-06	4.22	0.2056	Not significant
	Pure Error	1.520E-06	2	7.600E-07			
	Cor Total	0.0009	14				
Carr Index	**Source**	**Sum of Squares**	**Degree of Freedom**	**Mean Square**	**F-value**	**p-value**	
	Model	60.60	9	6.73	87.81	< 0.0001	Significant
	A-Pump	53.15	1	53.15	693.18	< 0.0001	
	B-MDs	0.3362	1	0.3362	4.38	0.0904	
	C-Beta-CDs	3.18	1	3.18	41.41	0.0013	
	AB	0.0020	1	0.0020	0.0264	0.8773	
	AC	0.0272	1	0.0272	0.3551	0.5772	
	BC	0.0072	1	0.0072	0.0942	0.7712	
	A^2	3.84	1	3.84	50.14	0.0009	
	B^2	0.0581	1	0.0581	0.7575	0.4239	
	C^2	0.0032	1	0.0032	0.0421	0.8454	
	Residual	0.3834	5	0.0767			
	Lack of Fit	0.2095	3	0.0698	0.8033	0.5960	Not significant
	Pure Error	0.1739	2	0.0869			
	Cor Total	60.98	14				
Hausner Ratio	**Source**	**Sum of Squares**	**Degree of Freedom**	**Mean Square**	**F-value**	**p-value**	
	Model	0.0100	5	0.0020	291.07	< 0.0001	Significant
	A-Pump	0.0087	1	0.0087	1264.25	< 0.0001	
	B-MDs	0.0000	1	0.0000	4.08	0.0181	
	C-Beta-CDs	0.0006	1	0.0006	86.36	< 0.0001	
	A^2	0.0007	1	0.0007	99.64	< 0.0001	
	B^2	0.0000	1	0.0000	2.97	0.1191	
	Residual	0.0001	9	6.891E-06			
	Lack of Fit	0.0000	7	5.146E-06	0.3958	0.8507	Not significant
	Pure Error	0.0000	2	0.0000			
	Cor Total	0.0101	14				

Additionally, the ANOVA results for the Carr Index indicated that A, B, C, AB, AC, A^2, B^2, and C^2 were significant models since the p-value was less than 0.05. According to the ANOVA of factors, the model's computed F-value was 87.81, implying that it was significant. Meanwhile, the lack of fitness was 59.60%, which was insignificant relative to the pure error.

Lastly, the ANOVA results for the Hausner Ratio indicated that A, B, C, A^2, and B^2 were significant models since the p-value was less than 0.05. According to the ANOVA of factors, the model's computed F-value was 291.07, implying that it was significant. Meanwhile, the lack of fitness was 85.07%, which is insignificant relative to the pure error. The significant model and non-significant lack of fitness indicate good model fitness for all physical properties of the strawberry powdered flavour.

All variables in this study, including pump flow rate and the ratio of wall materials provided by BBD for the MDs and β-CDs, exert a significant influence on the process yield for the samples. Theoretically, both wall materials play a crucial role in producing optimal spray-dried strawberry flavour by forming encapsulated flavour powder molecules with appropriate pump flow rates. Optimum encapsulation is achieved on the process yield of the samples exceeding 50% of the initial feeding value [12] as previously mentioned in Table 2.

Concerning moisture content and hygroscopicity, pump flow rate (A^2) plays a crucial parameter in determining the final output for both physical parameters of the spray-dried strawberry flavour. According to the theory of heat transfer in spray drying, higher pump flow rates result in shorter contact times between droplets and hot air, which diminish the efficiency of heat transfer and decrease water evaporation; it consequently results in low moisture content and higher hygroscopicity of the spray-dried flavour [15].

The flowability of the spray-dried strawberry flavour is represented by the Carr Index and Hausner Ratio. Table 5 shows all variables in this experiment, namely pump flow rate (A^2) and ratio for both MDs (B^2) and BDs (β-cyclodextrin) (C^2), demonstrate a significant interrelationship in producing optimum flowability of the spray-dried strawberry flavour.

Statistical Analysis

To provide a more comprehensive understanding about the physical parameters of the strawberry powdered flavour, the equation in Table 6 was derived through statistical analysis of the BBD model.

CONCLUSION

The optimisation for different runs of the physical parameters (process yield (PY), moisture content (MC), hygroscopicity, Carr Index (Cl), Hausner Ratio (HR), and solubility) was evaluated using the Box-Behnken Design. It can be concluded that Run 15 with a 10% pump flow rate, 24% of MDs, and 2% of β-CDs shows an optimised run as it obtained the highest value for PY (61.54%), MC (1.84%), Cl (9.72), HR (1.107), and solubility (100%). It also recorded the highest value of hygroscopicity with 0.0224% against other samples; however, the value is still the lowest for the powdered flavour.

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Table 6. The equation obtained from BBD for the physical properties of strawberry powdered flavour.

$$Process\ Yield = 51.29 - 9.40A + 0.8350B + 2.10C \qquad Eq.\ (1)$$

$$Moisture\ = 2.31 + 0.4800A - 0.0138B - 0.0388C + 0.0125BC + 0.0479A2 \qquad Eq.\ (2)$$

$$Hygroscopicity = 0.0166 - 0.00994A + 0.0017B + 0.0024C - 0.0036A2 \qquad Eq.\ (3)$$

$$Carr\ Index = 13.95 + 2.58A - 0.2050B - 0.6300C + 0.0225AB + 0.0825AC + 0.0425BC - 1.02A2 - 0.1254B2 + 0.0296C2 \qquad Eq.\ (4)$$

$$Hausner\ Ratio = 1.16 + 0.0330A - 0.0019B - 0.0086C - 0.0136A2 - 0.0023B2 \qquad Eq.\ (5)$$

Note: A = Feed, B = Maltodextrins, and C = $\beta -$ cyclodextrins.

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