MODELING ON SPRAY DRYING OF COCOA PULP JUICE BASED ON RESPONSE SURFACE METHODOLOGY (RSM)

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ABSTRACT – *De-sugared cocoa pulp juice was added with maltodextrin DE10-12 and spray dried according to Response Surface Methodology (RSM). Independent variables in the RSM design with central composite were amount of maltodextrin (0.11 – 0.39%) being added and inlet temperature (106pC – 130oC). Dependent variable was yield. Flow rate and spray pressure were kept constant at 200ml/hr and 40 bar respectively. ANOVA results indicated that both factors of drying aids (maltodextrin) amount and inlet temperature are significantly affecting the yield. A drying model can be constructed from the estimated regression coefficients as f(x,y) = -571.47 – 512.75x + 9.46y – 117.13x2 – 0.04y2+ 5.88xy; where x = amount of maltodextrin added; y = inlet temperature; and f(x,y) = yield.*

Keywords: Cocoa pulp, spray dry, response surface methodology

INTRODUCTION

Spray drying technique is broadly used in transforming liquid food products into the powder form. The purpose of drying is to produce a stable and prolong the shelf life of the said liquid food products, besides easy handling. In spray drying, the fluid is atomized to produce a spray of droplets which comes in contact with a flow of hot air (Figure 1). Due to rapid evaporation, a low droplets temperature is maintained and therefore, minimize the effect of high drying temperature on the quality of the products. In addition, the contact time of the droplets with the hot air is indeed very short. Spray drying products are in spherical and are relatively uniform (Roustapour et al., 2009). However, spray drying of sugar and acid rich food materials, such as cocoa pulp, is associated with stickiness problem. During spray drying of these stuffs, the powder particles tends to stick with one another and to the wall of the drying chamber, leading to the operational problem and low product yield (Khalid, et al., 2015).

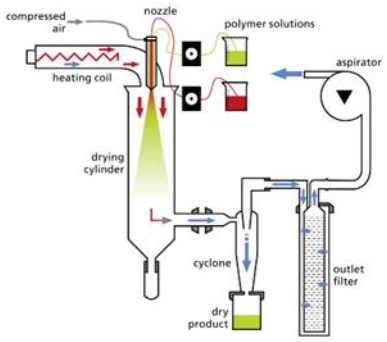

Figure 1: Schematic drawing of a spray dryer

Response Surface Methodology (RSM) is a statistical technique using quantitative data from an experimental design to determine and solve multivariate equations. It is an empirical modelling approach to investigate the relationship between various processing factors and its response parameter. RSM explores entirely the response surface covered by the experimental design and thus making the optimization process effectively (Khuri 2025)..

Cocoa pulp juice is a naturally sweet and nutrient-rich beverage made from the thick white pulp that surrounds the fresh cocoa beans inside the cacao pod. This pulp, which makes up about 5-7% of the total beans weight, is traditionally discarded during the fermentation process of cocoa beans (Jinap, 1993; Lopez, 1984).

Nevertheless, recent innovations have turned this pulp into a delicious and exotic juice. The flavor of cocoa pulp juice is a unique blend of sweet and sour notes. Study showed cocoa pulp with pH 3.3-3.9 contains mainly water (83-86%); sugar, mainly glucose, fructose & sucrose (11-13%); pectin (0.5-1.2%); hemicellulose (0.2-3%); cellulose (0.7-0.9%); lignin (0.1-0.3%) and 0.3-1.3% of citric acid (Haase *et al*., 2023; Cassianne *et al*., 2020; Afolabi *et al*., 2015; Afoakwa *et al.,* 2013; Endraiyani, 2011). Hence, it is gaining popularity as a healthy beverage and is consider a sustainable way to utilize more parts of the cacao.

MATERIALS AND METHODS

Cocoa pulp was obtained from Cocoa Research and Development Center, Bagan Datuk, Perak, Malaysia.

Cocoa Pulp Juice Extraction

Cocoa pulp was added with water at the ratio of 1:1 v/v, mixed mechanically by stirrer and filtered through 200 mess size strainer. Extracted cocoa pulp juice was pasteurized at 80oC for 15 minutes. To remove the sugar contents of the cocoa pulp juice, Saccharomyces cerevisiae of 0.02% (w/v) was added into the cocoa pulp juice and incubated anaerobic at 25ºC until no visible bubble was noticed at the water filled air-lock device attached on top of the incubator cover.

Spray Drying Of Cocoa Pulp Juice

Laboratory mini spray dryer model Buchi B200 was used in this study. The design of experiment (Table 1) was based on Response Surface Methodology (RSM) with central composite. Independent variables were inlet temperature and drying aids (maltodextrin C10-12) amount. Dependant variable was yield. Feed rate and spray pressure were kept constant at 200ml/hr and 40 bar respectively.

Table 1: The Design of Experiment (DOE) for optimisation study on spray drying of cocoa pulp juice based on RSM

StdOrder	RunOrder	PtType	Blocks	MD (%)	T (ºC)
11	1	0	1	0.25	120
4	2	1	1	0.35	130
9	3	0	1	0.25	120
5	4	-1	1	0.11	120
2	5	1	1	0.35	110
8	6	-1	1	0.25	134
12	7	0	1	0.25	120
7	8	-1	1	0.25	106
1	9	1	1	0.15	110
3	10	1	1	0.15	130
13	11	0	1	0.25	120
10	12	0	1	0.25	120
6	13	-1	1	0.39	120

Note: MD = maltodextrin; T = inlet temperature

Sensory Evaluation

The sensory evaluation was designed to assess the organoleptic properties of reconstituted cocoa pulp juice powder.

Sample Preparation

Cocoa pulp juice powder obtained via optimized spray drying was reconstituted with water at three concentration levels: 5%, 10%, and 15% (w/v). Each sample was prepared fresh prior to evaluation and presented at room temperature in identical, coded containers.

Panel Selection and Test Design

A total of 20 untrained panelists from two age groups (young adults aged 18–35, and older adults aged 36–60) were recruited. A two-way factorial design was applied to examine the effects of both age group and sample concentration on sensory perception.

Attributes and Scale

Panelists assessed six sensory attributes: Color, Sweetness, Flavour, Mouth Feel, Taste, and Overall Acceptability. Each attribute was rated on a 10-point hedonic scale, where 1 indicated “dislike extremely” and 10 indicated “like extremely.”

Statistical Analysis

Two-way ANOVA was used to determine the significance of age group, concentration level, and their interaction on each sensory attribute. Box plots were generated to visualize distribution and median scores across treatments.

RESULTS AND DISCUSSIONS

De-sugared cocoa pulp juice was used in this study because sugar generally has low glass transition temperature (Mariia & Ireneusz 2021), posing challenges of stickiness to spray drying processes (Figure 2). Although adding drying aids may improve the situation, too much drying aids means higher dilution factor on the end products, which may have negative impact on the wholesomeness of the products in terms of taste and nutrients.

Figure 2: “Sticky glassy” materials sticking on the wall of drying chamber when spray drying cocoa pulp juice

In spray drying of cocoa pulp juice, we aim to minimize the uses of drying aids while maximizing the yield. ANOVA results (Table 2) indicated that both factors of drying aids (maltodextrin) amount and inlet temperature are significantly affecting the yield. A drying model can be constructed from the estimated regression coefficients (Table 3) as in equation 1.

Table 2: ANOVA table

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	3017.12	3017.12	603.423	798.75	0.000
Linear	2	2763.62	206.24	103.120	136.5	0.000
MD	1	1436.21	66.19	66.194	87.62	0.000
T	1	1327.41	106.01	106.007	140.32	0.000
Square	2	115.31	115.31	57.657	76.32	0.000
MD*MD	1	2.96	9.54	9.543	12.63	0.009
T*T	1	112.35	112.35	112.350	148.72	0.000
Interaction	1	138.18	138.18	138.180	182.91	0.000
MD*T	1	138.18	138.18	138.180	182.91	0.000
Residual Error	7	5.29	5.29	0.755		
Lack-of-fit	3	2.91	2.91	0.971	1.64	0.315
Pure Error	4	2.37	2.37	0.593		
Total	12	3022.4				

S = 0.869173; PRESS = 24.4339; R-sq = 99.83%; R-Sq(pred) = 99.19% R-Sq(adj) = 99.70%

Table 3: Estimated regression coefficients for yield (g)

Term	Coef	SE Coef	T	P
Constant	-571.467	49.4291	-11.561	0.000
Maltodextrin	-512.75	54.7778	-9.361	0.000
Temperature	9.464	0.7989	11.846	0.000
Malto*Malto	-117.125	32.9542	-3.554	0.009
Temp*Temp	-0.04	0.0033	-12.195	0.000
Malto*Temp	5.878	0.4346	13.524	0.000

$$f(x,y) = -571.47 - 512.75x + 9.46y - 117.13x2 - 0.04y2 + 5.88xy \quad (1)$$

where
x = amount of maltodextrin added
y = inlet temperature
f(x,y) = yield

Verification of the drying model was investigated by comparing its predictions against experimental data. The findings demonstrated the drying model accurately predict the drying process (Table 4).

Table 4: Quantitative comparison between experimental and predicted results

MD	T (°C)	Experimental yield	Predicted yield
0.25	125	30.97	34.71

0.25	130	34.18	38.38
0.3	125	40.6	42.59
0.3	130	45.73	47.73
0.35	125	46.59	49.89
0.35	130	50.89	56.5
Average		41.49	44.97
p-value			0.46

Table 5 summarizes a two-way ANOVA testing how two factors, Age Group and Concentration of cocoa pulp juice powder, affect different sensory responses, as well as their interaction effect.

Concentration has statistically significant effects ($p < 0.05$) on every sensory response except Color. Most notably, it influences Overall Acceptability ($p = 0.000$), Taste ($p = 0.000$), Sweetness ($p = 0.000$), Flavour ($p = 0.000$), and even Mouth Feel ($p = 0.001$), which highlights just how much product formulation matters.

Age Group plays a minor role whereby none of the responses show statistically significant differences by Age Group. This suggests perceptions were fairly consistent across age demographics. Interaction effects (Age Group × Concentration) are non-significant across the board, with p-values all comfortably above 0.05 and hence, the impact of concentration on sensory perceptions does not vary much by age.

Figure 3 shows how concentration levels of reconstituted cocoa pulp juice powder affect various sensory perceptions. Taste and Sweetness see the most dramatic improvement as concentration increases. Both are from low median scores at 5% (around 3.65 and 3.4 respectively) to significantly higher scores at 15% (over 7.5 suggests that a higher concentration enhances the palatability and enjoyment of the drink. Overall Acceptability follows a similar trend, jumping from a modest 3.7 at 5% to a solid 7.85 at 15%. Clearly, panelists found the 15% concentration most enjoyable overall. Color is somewhat steady across concentrations but peaks at 15% with a median score of 7.1, showing a slight visual preference for the richer appearance. Mouth Feel and Flavour improve noticeably as well, suggesting that the sensory richness becomes more pleasing with concentration. The spread (box plots) looks relatively tight at 15%, suggesting more consistent positive ratings among panelists. At 5%, wider spreads imply mixed or neutral perceptions.

Table 5: 2-Way ANOVA: Response (Attribute) versus Age Group, Concentration

	p-value		
Response	**Age Group**	**Concentration**	**Interaction**
Overall Acceptability	0.099	0.000	0.896
Color	0.614	0.22	0.812
Taste	0.162	0.000	0.93
Sweetness	0.315	0.000	0.079
Flavour	0.684	0.000	0.679
Mouth Feel	0.752	0.001	0.127

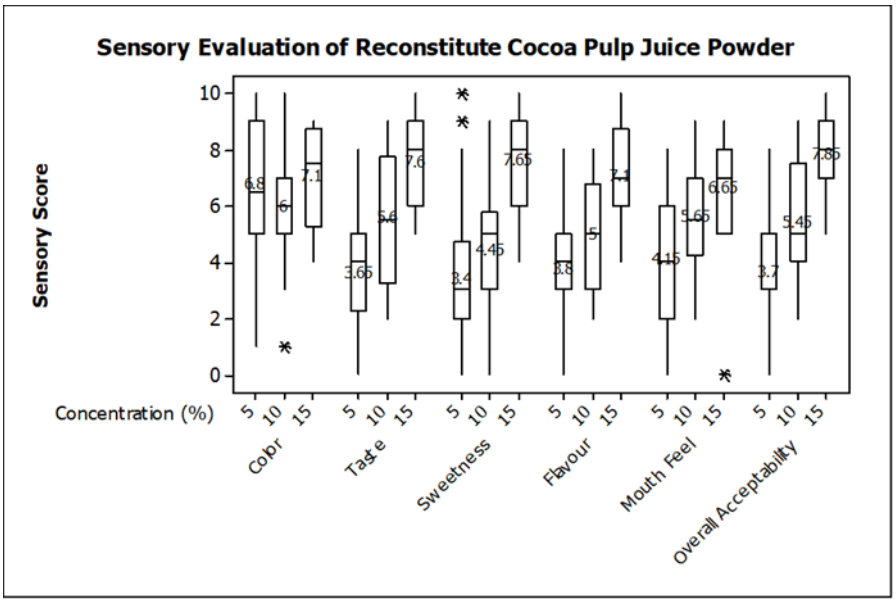

Figure 3: Box plots of sensory attributes score with difference pulp juice powder concentration

CONCLUSIONS

The spray drying of de-sugared cocoa pulp juice with maltodextrin as a drying aid was successfully modeled using Response Surface Methodology (RSM). The findings confirm that both the amount of maltodextrin and inlet temperature significantly influence the yield of the spray drying process. The drying model developed from estimated regression coefficients accurately predicts experimental results, demonstrating its reliability in optimizing cocoa pulp juice spray drying. Minimizing the use of drying aids while maximizing yield remains a critical consideration to preserve the product's taste and nutritional integrity and sensory evaluations confirmed consumer appeal. This study provides valuable insights into the spray drying parameters essential for efficient cocoa pulp juice processing.

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