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Optimisation of Edible Coating to Improve the Postharvest Shelf-life of Guava Using Response Surface Methodology

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The effects of composite edible coating consisting of gum Arabic, beeswax and coconut oil on Cambodia cultivar guava (*Psidium guajava*) were evaluated using response surface methodology (RSM). The optimum coating formulation was determined using the weight loss percentage and total soluble solid (TSS) content as the responses. From the central composite rotatable design in RSM, a total of 15 sets of coating compositions were designed. The optimised coating emulsion was made up of gum Arabic (6.6% w/v), beeswax (5.5% w/v) and coconut oil (3.6% w/v) with Tween 80 (3% w/v) as surfactant. Under this optimised coating emulsion, the predicted mean values of weight loss and TSS were 2.91% and 7.84°Brix respectively, whereas the actual mean values of guava samples were 3.38% and 8.00°Brix respectively, after 6 days of ambient storage. The actual mean values of both responses were within the 95% prediction interval, which was 2.35 – 3.47% for weight loss and 7.22 – 8.45°Brix for TSS. The optimised coating emulsion successfully reduced weight loss with maximised TSS content for guava.

Keywords: Guava; gum Arabic; beeswax; coconut oil; response surface methodology (RSM)

I. INTRODUCTION

Guava (*Psidium guajava*) faces commercial challenges as it easily deteriorates due to insufficient postharvest handling technologies and storage information. It has a short postharvest shelf-life of about 3 – 4 days under the tropical ambient condition at 26 – 30°C (El-Gioushy *et al.*, 2022) due to the natural metabolism processes, like respiration and ripening. These processes cause weight loss and obvious changes in terms of colour, taste, odour, reduction in the sugar content and decaying of guava (Murmu & Mishra, 2018b). It causes unsaleable loss to local sellers and retailers.

Edible coating derived from natural biopolymers is a promising approach to maintain the quality of fruits and extending their postharvest shelf-life. As part of the fruits, they are readily consumed. They are biodegradable and do not leave harmful residues to the environment. It controls the respiration and ripening processes, which can be indicated by the changes in physicochemical properties. For example, there is a reduced rate of weight loss and softening through the application of edible coating (El-Gioushy *et al.*, 2022; Gurjar *et al.*, 2018). The edible coating also improves the fruit's appearance and is more cost-effective to reduce microbial spoilage when refrigeration is unaffordable (Kumar *et al.*, 2020).

The composite coating is produced from multiple biopolymers that are miscible and may include other functional ingredients like pH regulators, antioxidants and antimicrobials. It is more popular than single coating as different sources of biopolymer have different gases and water permeability. Vegetable oil and other types of lipids are

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often added to the coating due to their hydrophobicity. However, lipids have a low barrier against gas transfer (Vargas *et al.*, 2008). Coating fruits simply with wax may lead to undesirable anaerobic respiration (Peñarubia *et al.*, 2014; Vargas *et al.*, 2008). Hydrocolloids, in contrast to lipids, have a low barrier to moisture but moderate permeability to gases. Gum Arabic is a potential coating material for its good adhesion (Gurjar *et al.*, 2018; Kawhena *et al.*, 2021). The design of composite edible coatings, which are based on both hydrocolloid and lipid, can be explored to reduce the drawbacks and utilise the pros of the functional attributes of each group.

Response surface methodology (RSM) has been used extensively to optimise conditions and processes in numerous food studies. As compared to one-variable-at-a-time (OVAT), it allows the analysis of the impacts of numerous factors and their interactions on the response, with a reduced cost and time (Yolmeh & Jafari, 2017).

In this study, gum Arabic, beeswax and coconut oil were used to form the coating emulsion to coat the guavas by dipping method. The central composite rotatable design (CCRD) from RSM was employed as a statistical tool to optimise the coating formulation. It is expected that there will be a reduced weight loss percentage and higher retainment of total soluble solids (TSS) after applying the optimised coating formulation.

II. MATERIALS AND METHODS

A. Materials

The guavas of Cambodia cultivar were procured from a local orchard in Sarikei, Sarawak when they had reached physiological maturity. They were sorted for uniformity in size, shape and weight (300 – 400 g), free from microbial infection and physical injury. The sorted guavas were washed and left to dry at the ambient conditions (24 – 26°C, 65 – 75% RH) as performed by many researchers (Mohd Zahid *et al.*, 2010).

Gum Arabic (Evachem Sdn Bhd, Selangor, Malaysia), beeswax (Sigma-Aldrich, USA) and coconut oil (Mama Lim Handmade, Negeri Sembilan, Malaysia) were used as the edible coating components and Tween 80 (Sigma–Aldrich, France) was used as a surfactant. All materials and chemicals used were food or analytical grade.

B. Preparation and Application of Coating Emulsion

The gum Arabic powder was dissolved in the distilled water at 40°C by constant stirring (El-Gioushy *et al.*, 2022). Beeswax was melted in a hot water bath (62 – 64°C) until the solution became clear (Peñarubia *et al.*, 2014). The coconut oil was added with the surfactant of 3% w/v Tween 80, followed by the gum Arabic solution and the melted beeswax. The mixture was subjected to high-speed mixing at 12000 rp homogeniser (Omni, USA) for 5 min to produce the coating emulsion.

The guavas were labelled and dipped in the coating emulsion at 23°C for 15 s. The coated samples were dried in the circulating air of the table fan for 15 min. They were subjected to ambient storage and the data of weight loss and TSS were measured for the study. The uncoated guavas were used as the control.

C. Weight Loss and Total Soluble Solids (TSS)

The initial weight of coated guavas on Day 0 was recorded as W_o and W_f as the final weight. The weight measurement was done repeatedly with a 2-day interval until Day 6. The weight loss was measured as shown in Equation (1).

$$P_{WL} = \frac{W_o - W_f}{W_o} \times 100\% \qquad (1)$$

At the end of storage, the guava juice was extracted by using a fruit juicer (Panasonic, Malaysia). TSS was determined and expressed in terms of °Brix by using a refractometer (Atago, Japan).

D. Experimental Design and Statistical Analysis

The coating composition that affected weight loss and TSS content of guava was optimised using Design-Expert® Version 13 RSM software (Stat-Ease Inc., USA). As depicted in Table 1, each independent variable was tested at five different levels, namely lower axial, lower factorial, medium, upper factorial, and upper axial, which were coded as --, -, 0, +, ++, respectively. A total of 48 experimental runs based on

15 sets of independent variables were generated randomly by CCRD with axial distance $(\alpha) = 1.6817$. It included six replicates of centre points (0), three replicates of each factorial (-, +) and axial points (--, ++). The data of both responses were subjected to a series of analysis, which were analysis of variance (ANOVA), lack of fit (LOF), R-square (R_2) and predicted error sum of square (PRESS) determinations as well as residuals plotting for fitting the second order polynomial order as shown in Equation 2.

$$Y = \beta_o + \beta_a A + \beta_b B + \beta_c C + \beta_{ab} AB + \beta_{bc} BC + \beta_{ac} AC + \beta_{aa} A^2 + \beta_{bb} B^2 + \beta_{cc} C^2 \quad (2)$$

Where Y was the dependent variable (weight loss or TSS); A, B and C were the independent variables for gum Arabic, beeswax and coconut oil respectively; β_o was linear coefficient at the centre point of the model; β_a, β_b and β_c were linear coefficients; β_{ab}, β_{bc} and β_{ac} were linear interactive coefficients; β_{aa}, β_{bb} and β_{cc} were quadratic interactive coefficients. The model verification was conducted by running the confirmation runs at the end of CCRD. The variation between the predicted and actual responses must be within the 95% prediction interval (Stat-Ease, 2022).

III. RESULT AND DISCUSSION

An effective edible coating should reduce the weight loss and retain the rising of TSS for the guava samples that were stored under the ambient condition for a study period of 6 days. After being harvested, all types of fruits experience moisture loss due to the transpiration and respiration processes that continually take place through the surface of the fruits, resulting in weight loss (Mohd Zahid *et al.*, 2010; Murmu & Mishra, 2018a). TSS depicts the concentration of soluble solids, which are dominated by sugars and some minor portions of organic compounds such as amino acids. TSS will increase in the process of ripening (Bashir & Abu-Goukh, 2003; Patel *et al.*, 2015; Sharma & Saini, 2021) and gradually reduce after hitting the peak as they are utilised as substrates during respiration (Bashir & Abu-Goukh, 2003; Kawhena *et al.*, 2021). A low weight loss percentage and high TSS content were targeted through the optimum control of ripening and respiration.

The information about experimental runs, coating composition and responses are illustrated in Table 1.

Table 1. Results of Weight Loss Percentage (P_{WL}) and TSS in the CCRD based on the Three Independent Variables, Gum Arabic (A), Beeswax (B) and Coconut Oil (C)

Std	A (% w/v)	B (% w/v)	C (% w/v)	P_{WL} (%)	TSS (°Brix)
1	2 (-)	2 (-)	2 (-)	6.27	8.00
2	2 (-)	2 (-)	2 (-)	6.35	8.00
3	2 (-)	2 (-)	2 (-)	6.57	8.50
4	7 (+)	2 (-)	2 (-)	6.23	8.00
5	7 (+)	2 (-)	2 (-)	6.37	8.50
6	7 (+)	2 (-)	2 (-)	6.19	8.50
7	2 (-)	7 (+)	2 (-)	4.71	7.50
8	2 (-)	7 (+)	2 (-)	4.52	8.00
9	2 (-)	7 (+)	2 (-)	4.01	8.00
10	7 (+)	7 (+)	2 (−)	3.33	8.00
11	7 (+)	7 (+)	2 (-)	3.19	8.50
12	7 (+)	7 (+)	2 (-)	2.73	8.00
13	2 (-)	2 (-)	7 (+)	4.56	8.00
14	2 (-)	2 (-)	7 (+)	4.94	8.50
15	2 (-)	2 (-)	7 (+)	4.42	8.00
16	7 (+)	2 (-)	7 (+)	4.79	9.00
17	7 (+)	2 (-)	7 (+)	5.04	8.00
18	7 (+)	2 (-)	7 (+)	4.54	8.50
19	2 (-)	7 (+)	7 (+)	3.46	6.50
20	2 (-)	7 (+)	7 (+)	3.85	6.00
21	2 (-)	7 (+)	7 (+)	4.29	6.00
22	7 (+)	7 (+)	7 (+)	3.25	6.50
23	7 (+)	7 (+)	7 (+)	3.45	5.50
24	7 (+)	7 (+)	7 (+)	3.30	6.00
25	0.3 (--)	4.5 (0)	4.5 (0)	5.92	8.50
26	0.3 (--)	4.5 (0)	4.5 (0)	5.33	7.50
27	0.3 (--)	4.5 (0)	4.5 (0)	4.51	8.00
28	8.7 (++)	4.5 (0)	4.5 (0)	4.32	9.50
29	8.7 (++)	4.5 (0)	4.5 (0)	5.33	9.00
30	8.7 (++)	4.5 (0)	4.5 (0)	4.91	8.00
31	4.5 (0)	0.3 (--)	4.5 (0)	5.64	7.50
32	4.5 (0)	0.3 (--)	4.5 (0)	5.01	8.00
33	4.5 (0)	0.3 (--)	4.5 (0)	5.87	7.50
34	4.5 (0)	8.7 (++)	4.5 (0)	2.82	6.00
35	4.5 (0)	8.7 (++)	4.5 (0)	2.32	5.50
36	4.5 (0)	8.7 (++)	4.5 (0)	1.76	6.50
37	4.5 (0)	4.5 (0)	0.3 (--)	5.92	8.00
38	4.5 (0)	4.5 (0)	0.3 (--)	5.49	7.50
39	4.5 (0)	4.5 (0)	0.3 (--)	5.61	7.50
40	4.5 (0)	4.5 (0)	8.7 (++)	3.56	7.00
41	4.5 (0)	4.5 (0)	8.7 (++)	4.94	8.00
42	4.5 (0)	4.5 (0)	8.7 (++)	4.82	7.00
43	4.5 (0)	4.5 (0)	4.5 (0)	2.89	8.50
44	4.5 (0)	4.5 (0)	4.5 (0)	2.78	7.50
45	4.5 (0)	4.5 (0)	4.5 (0)	1.97	6.50
46	4.5 (0)	4.5 (0)	4.5 (0)	2.62	8.00
47	4.5 (0)	4.5 (0)	4.5 (0)	3.12	7.50
48	4.5 (0)	4.5 (0)	4.5 (0)	2.91	8.00

Notes: Standard number (Std)

A. Model Fitting, ANOVA and Model Reduction

The fit summary suggested that the quadratic model was the most suitable model to describe the effects of factors in both responses. The ANOVA results are illustrated in Tables 2(a) and 2(b). If the p-value is smaller than 0.05, the model term of the factor is significant to the response.

Table 2(a). ANOVA for the Reduced Model of CCRD using Weight Loss Percentage as the Response

Source	SS	df	MS	F-value	p-value
Model	73.00	8	9.13	52.49	<0.0001
A	1.39	1	1.39	8.02	0.0073
B	35.91	1	35.91	206.58	<0.0001
C	6.89	1	6.89	39.64	<0.0001
AB	1.33	1	1.33	7.62	0.0087
BC	3.23	1	3.23	18.56	0.0001
A²	17.00	1	17.00	97.80	<0.0001
B²	3.92	1	3.92	22.55	<0.0001
C²	17.05	1	17.05	98.09	<0.0001
Residual	6.78	39	0.1738		
LOF	1.07	6	0.1789	1.03	0.4207
Pure Error	5.71	33	0.1729		
Cor Total	79.78	47			

Notes: Sum of squares (SS); mean square (MS); lack of fit (LOF)

The ANOVA results revealed that the AC (interaction between gum Arabic and coconut oil) term was insignificant and they had been removed from the initial quadratic model after the step of model reduction. The non-significant term could be removed from the model or set to a constant value for model reduction (Myers *et al.*, 1995). AC had a p-value = 0.1138 (>0.05) and it was removed to enhance the data fitting in the quadratic model and have a better estimation.

From the ANOVA in Table 2(a), LOF was not significant (p-value >0.1) with the F-value of 1.03, so the data fitted well in the reduced CCRD model. There was a 42.07% chance that the LOF F-value this large occurred because of the noise.

Table 2(b). ANOVA for the Reduced Model of CCRD using Weight Loss Percentage as the Response

Source	SS	df	MS	F-value	p-value
Model	31.79	6	5.30	22.66	<0.0001
A	0.9396	1	0.9396	4.02	0.0516
B	13.37	1	13.37	57.22	<0.0001
C	3.93	1	3.93	16.79	0.0002
BC	6.00	1	6.00	25.67	<0.0001
A²	3.08	1	3.08	13.17	0.0008
B²	2.25	1	2.25	9.61	0.0035
Residual	9.58	41	0.2337		
LOF	2.08	8	0.2605	1.15	0.3600
Pure Error	7.50	33	0.2273		
Cor Total	41.37	47			

Notes: Sum of squares (SS); mean square (MS); lack of fit (LOF)

From Table 2(b), the LOF p-value = 0.36 (>0.1) was not significant with the F-value 1.15, so the data fitted well in the reduced CCRD model. There was a 36% chance that the F-value for the LOF occurred because of the noise. The higher F-value for the LOF, the better the reduced model fitted the data. The terms AB (p-value = 0.6847), AC (p-value = 0.6847) and C_2 (p-value = 0.6877) were insignificant towards the TSS. They were dropped from the initial quadratic model. LOF p-value had improved after the model reduction. Likewise, LOF p-value was 0.1565 before reducing the model, whereas 0.36 after reducing the model.

The adequacy of the developed model was checked by examining the predicted and adjusted R_2, PRESS, adequate precision and the diagnostics plots. Table 3 summarize the statistical values for both responses noise.

Table 3. Statistical Summary for the Reduced Model of CCRD

Statistics	P_{WL}	TSS
Standard Deviation	0.4169	0.4835
Mean	4.39	7.64
PRESS	10.40	13.06
R^2	0.9150	0.7683
Adjusted R^2	0.8976	0.7344

Predicted R^2	0.8696	0.6843
Adequate Precision	23.3567	15.1596

Notes: Predicted error sum of square (PRESS)

The mean and standard deviation of the weight loss response on Day 6 was low, which were 4.39 and 0.42, respectively. The weight loss of control had already reached 5.58±0.49% on Day 2, indicating all coated guava samples had a slower rate of moisture loss. In the meantime, the TSS for control had already reached 9.00±0.87°Brix on Day 2. As compared to the control group, the coated guavas had a smaller TSS content. All coating treatments reduced the respiration and ripening rates of the guava samples by controlling the rate of breakdown of carbohydrates into the sugars like fructose, sucrose and glucose (Nandane *et al.*, 2017). Since TSS indicates the sweetness of the fruit samples, the ripening process should be optimally controlled but not completely retarded by the applied coating for a better sensory property.

The PRESS value indicates how well the model fits the points in the design. A low PRESS value in the reduced CCRD model indicated a good model fitting, which was recorded as 10.40 for weight loss analysis and 13.06 for TSS. In the analysis of TSS, the PRESS value before conducting the model reduction was 14.81, but it showed 13.06 after dropping the insignificant terms. A lower PRESS value means a better model fitting. Besides, it was observed that the value of adequate precision had a slight increment (23.36 versus 22.80) after the model reduction for the weight loss analysis. It is normally used to determine the signal-to-noise ratio. The desirable ratio is greater than 4. The model reduction had improved the model by reducing the influence of noises.

R_2 value reflects the percentage of variation in the response that is caused by the changes in the independent variables. The adjusted R_2 is the degree of variation that is depicted by the model, whereas the predicted R_2 is the predicted degree of variation that is depicted by the model. From Table 3, The R_2 value for weight loss response was 0.9150, which was satisfactorily higher than the minimum standardised R_2 value (>0.8). The predicted R_2 of 0.8696 was also in reasonable agreement with the adjusted R_2 of 0.8976, as their difference was less than 0.2. Although the R_2 value in TSS response was slightly lower than 0.8 (0.7683), the predicted R_2 of 0.7344 was in reasonable agreement with the adjusted R_2 of 0.6843 as their difference was less than 0.2.

Overall, both reduced models did not need any amendment. The reduced model using both responses had fulfilled adequacy as the p-value <0.05, LOF p-value >0.05 and the difference between the predicted and adjusted R_2 was within 0.2 (Myers *et al.*, 1995; Stat-Ease, 2022).

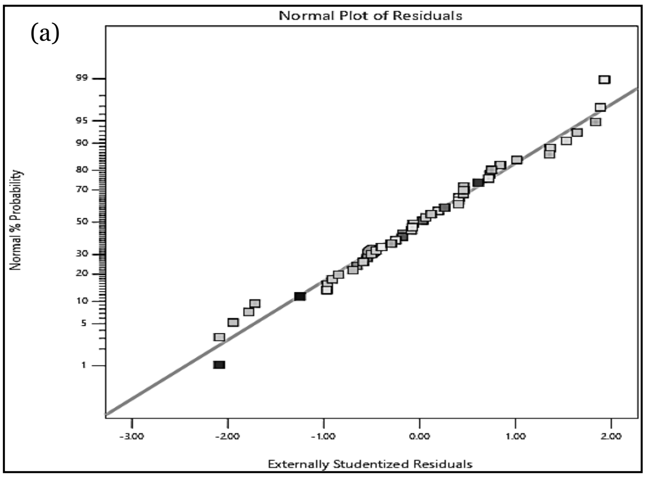
The quadratic models in both responses were expressed in the coded second-order mathematical equation, as shown in Equations (3) and (4). They established the relationship between the independent variables and the responses of weight loss and TSS.

$$P_{WL} = 2.73 - 0.1845A - 0.9363B - 0.4101C - 0.2350AB + 0.3667BC + 0.7821A^2 + 0.3755B^2 + 0.7833C^2 \quad (3)$$

$$\text{TSS} = 7.6 + 0.1514A - 0.5714B - 0.3095C - 0.5BC + 0.3019A^2 - 0.2579B^2 \quad (4)$$

B. Diagnostics Plots

As to further validate the model fitting and adequacy by using the weight loss and TSS as the responses, the diagnostics step was conducted by examining the diagnostics plots like the plots of normal probability versus externally studentized residuals and residuals versus run (Stat-Ease, 2022). Figures 1(a) and 1(b) illustrate the normal probability plots.



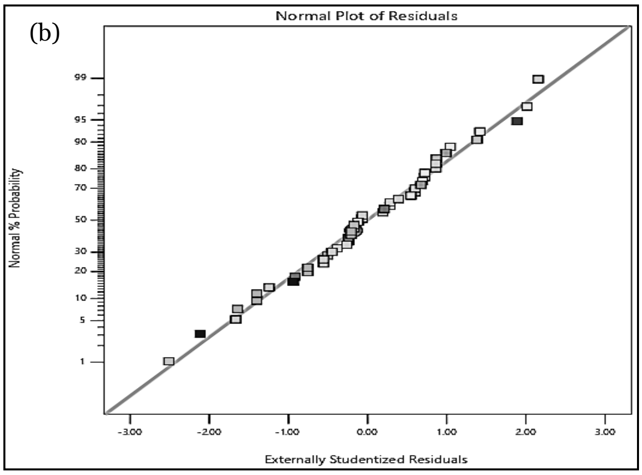
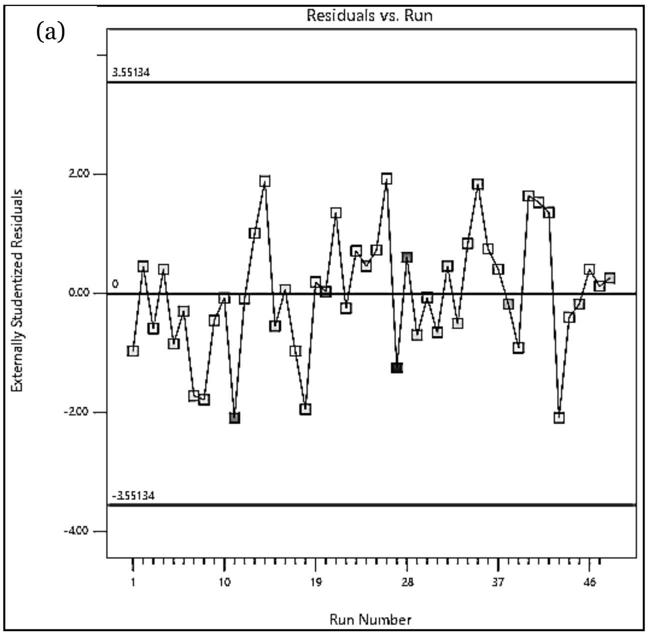


Figure 1. Normal Probability Plot for the Reduced CCRD Model (a) Weight Loss Percentage (b) TSS

From the normal plots of residuals in both responses, there was no issue of abnormality in their reduced models since all the residuals were distributed normally on a straight line. However, if any S-shaped curve is observed (megaphone pattern for the scattered residuals) in the normal probability plot, there is an issue of abnormality for the response of the reduced model. Then, a transformation is required to establish better model adequacy (Stat-Ease, 2022).

Figures 2(a) and 2(b) depict the plots of residuals versus run numbers for both responses.



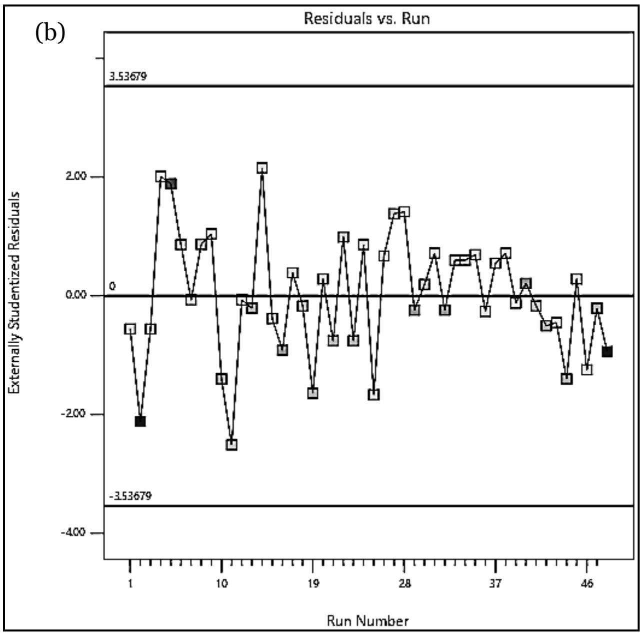


Figure 2. Residuals versus Run Number Plot for the Reduced CCRD Model (a) Weight Loss Percentage (b) TSS

They were diagnosed to check if there was any lurking variable that affected the model validity for both responses. In both responses, the residuals were scattered randomly within the boundaries of ±3.5 (red lines), which were set by the analytical software of Design-Expert. Thus, there was no serious outlier in the responses being observed and no time-related influences lurking behind. Since randomisation was fully used during the experiment, it offered protection against the trends that may ruin the analysis (outliers) (Myers *et al.*, 1995; Stat-Ease, 2022).

C. Optimisation and Verification

As to optimise the coating formulation, the three-dimensional (3D) plots using weight loss as the response were analysed first. Figures 3(a) and (b) show the 3D plots of AB model with different levels of coconut oil.

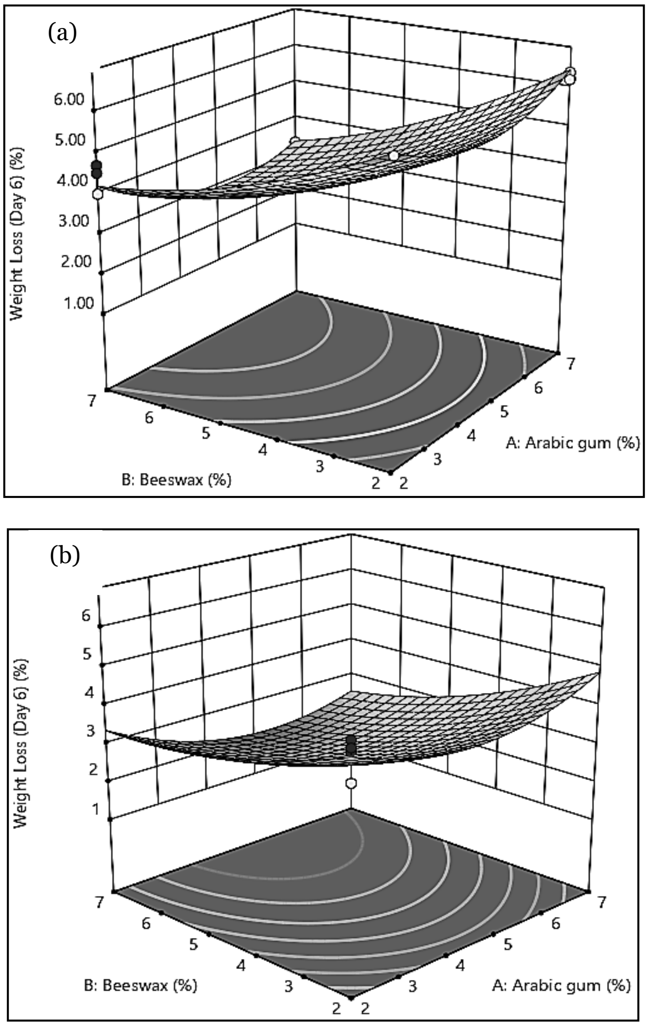


Figure 3. 3D plots of AB Model with Different Levels of Coconut Oil (a) Low Level (2% w/v) (b) Centre Level (4.5% w/v)

From Figure 3(a), it was discovered that when the coconut oil was applied at a low level, the minimum weight loss appeared at the region on the curve where the beeswax should be applied at a high level close to 7% w/v and gum Arabic at a range between 5 – 5.5% w/v. As depicted in Figure 3(b), increasing the level of coconut oil helped to lower down the weight loss of the guava samples. However, the weight loss started to increase again when the level of coconut oil was increased beyond its centre. The optimum weight loss could have occurred at the centre-level setting of the coconut oil. In other words, the coconut oil should be applied in a moderate amount to have the optimum interaction with the others in reducing weight loss. This could be due to the difference in hydrophobicity of the components. The gum Arabic, which had a low hydrophobicity, interacted poorly with the high hydrophobic component like coconut oil when the coconut oil was applied in an amount exceeding a certain level.

Figures 4(a) and (b) show the 3D plots of the BC model with different levels of gum Arabic. The overall weight loss was reduced with an increase in the gum Arabic. However, as shown in Figure 4(b), the further increment in gum Arabic until 7% w/v yielded an opposite response as the weight loss increased. Gum Arabic is a polysaccharide that has a better barrier against gases but a poor barrier against moisture transfers due to its high hydrophilicity (Vargas *et al.*, 2008). In this case, when the gum Arabic is applied in excess amount higher than 5% w/v, the moisture has a higher tendency to escape from the surface tissue of guava samples, resulting in a higher weight loss.

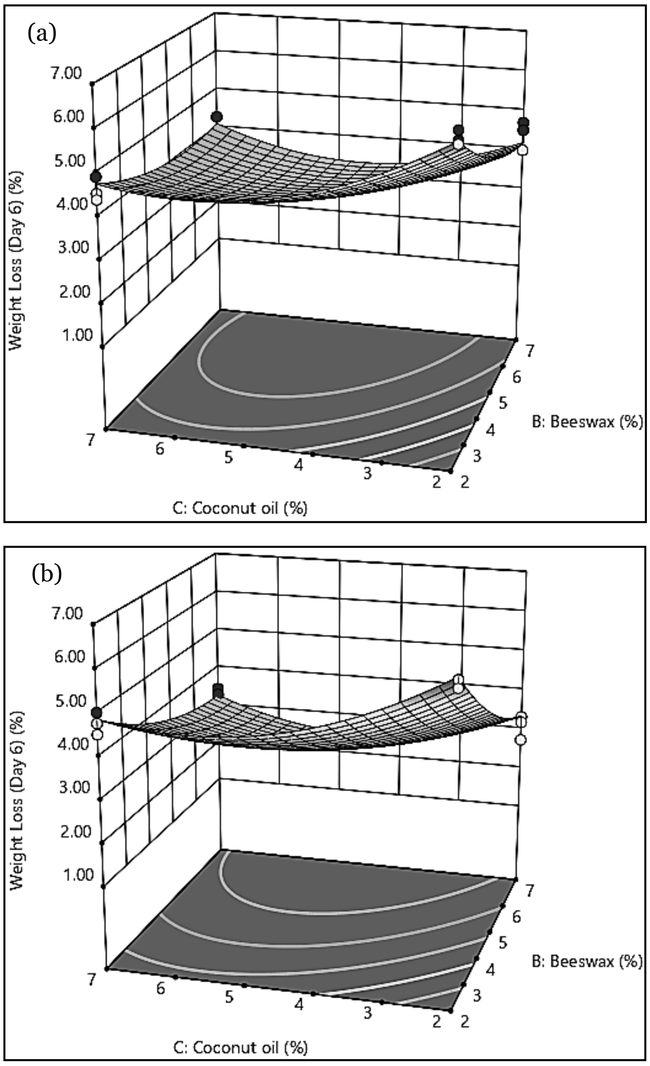


Figure 4. 3D plots of BC Model with Different Levels of Gum Arabic (a) Low Level (2% w/v) (b) High Level (7% w/v)

Next, the 3D plots using TSS as the response were analysed. Figures 5(a) and (b) show the 3D plots of the BC model with different levels of gum Arabic.

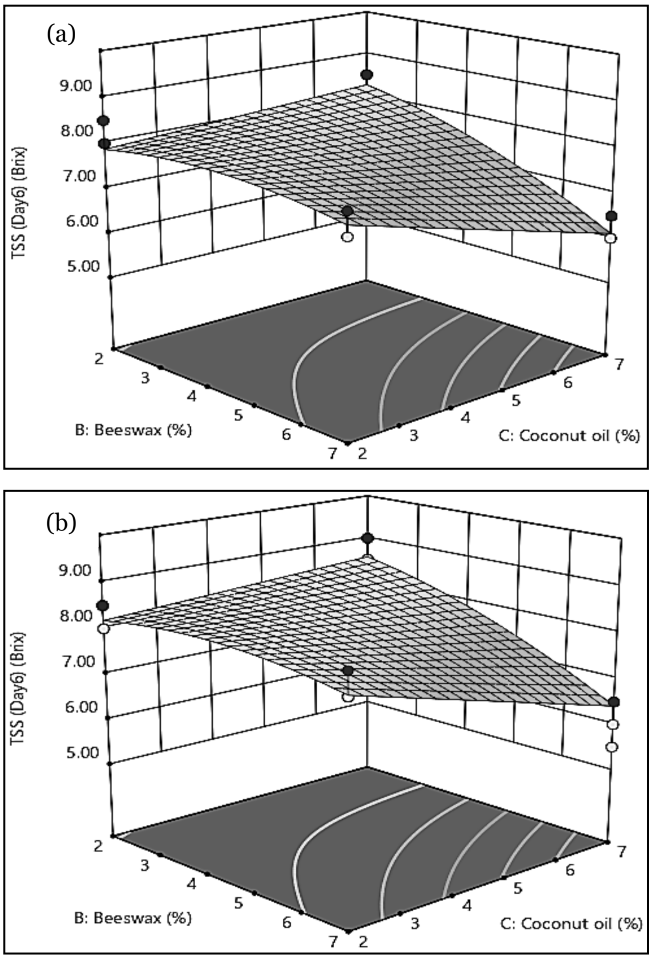


Figure 5. 3D plots of BC Model with Different Levels of Gum Arabic (a) Low Level (2% w/v) (b) High Level (7% w/v)

As the gum Arabic increased, there was an overall rise in the TSS value. It could be observed that the peak TSS value (8.50°Brix) was found in Figure 5(b) with the application of high gum Arabic percentage in the coating formulation. In order to obtain a high TSS, the level of beeswax should be low, but the level of coconut oil should be high when the gum is fixed at a high level. As shown in Figure 5(b), the peak TSS occurred at the region where the gum Arabic, beeswax and coconut oil were at the level of 7% w/v, 2% w/v and 7% w/v, respectively.

The 3D plots based on the weight loss response suggested that a moderate amount of gum Arabic and coconut oil, combined with a high amount of beeswax, were required to minimise the weight loss of guava samples. However, the 3D plots for the TSS recommended that a high amount of gum and coconut oil and a low amount of beeswax were useful in maximising the TSS. In this case, the optimisation procedure was done with the help of Design-Expert software. It was carried out by using the range of independent variables (2 – 7% w/v).

The ultimate goals of the formulated coating emulsion were to minimise the weight loss percentage and maximise the TSS value for the guava samples after being stored at the ambient condition for 6 days. The respiration and ripening rates should be slowed down but not retarded completely by applying the developed coating emulsion. While minimising weight loss was important, the biological metabolism, like rising TSS content, should not be neglected. A similar work was also performed by the other researchers (Kawhena *et al.*, 2021; Nandane *et al.*, 2017).

The optimum composite coating formulation with the highest desirability was given as 6.6% w/v gum Arabic, 5.5% w/v beeswax and 3.6% w/v coconut oil with the aid of 3% w/v Tween 80 surfactant. The predicted values of weight loss and TSS values were 2.91% and 7.84°Brix after 6 days of ambient storage.

At the end of RSM, the verification procedure was conducted by running additional three trials, which had been tabulated as in Table 4.

Table 4. Results of Weight Loss Percentage and TSS Values of the Guavas Coated with Optimised Formulation

Trial	P_{WL} (%)	TSS (°Brix)
1	3.20	8.50
2	3.31	7.00
3	3.62	7.50

The analytical software would calculate the actual mean values and standard deviation (SD) to compare with the predicted values for the verification. In this case, Table 5 showed that the actual mean values of both responses were within the 95% prediction interval. Thus, the model had been verified (Stat-Ease, 2022).

Table 5. Model Verification of CCRD in Optimising Coating Formulation

Response	PM	SD	95% PI Low	Data Mean	95% PI High
Weight Loss % (Day 6)	2.91	0.42	2.35	3.38	3.47
TSS (Day 6)	7.84	0.48	7.22	8.00	8.45

Note: Predicted mean (PM); standard deviation (SD); prediction interval (PI)

IV. CONCLUSION

In this study, RSM could be effectively adapted to optimise the coating composition. The quadratic mathematical model was generated to optimise the coating formulations for guava by using weight loss percentage and TSS as the responses through RSM. RSM optimised the coating formulation by reducing weight loss by at least five-fold while maximising TSS content in the guava samples within 6 days of ambient storage. The composite coating based on gum Arabic as hydrocolloid, together with beeswax and coconut oil as lipids had successfully regulated the respiration and ripening rates for the guava samples.

The study showed that gum Arabic (6.6% w/v), beeswax (5.5% w/v) and coconut oil (3.6% w/v) with the aid of Tween 80 surfactant (3% w/v) as the optimum level for the best coating composition, leading to an overall improvement of the postharvest quality of guava. Future studies are recommended to enhance the characteristics of coating on the fruit surface by looking into its durability and adhesion properties. Besides, the biochemical analysis, like the concentration of carbon dioxide and ethylene gases, could be measured to improve the functionality of the developed coating emulsion. The sensory analysis is also recommended to study the acceptance of the fruits after applying the coating emulsion.

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