International Journal of Applied Science and Engineering

Optimization of vacuum evaporation processing parameters for concentration of jambolan plum (*Syzygium cumini*) juice using response surface methodology

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ABSTRACT

Jambul juice has recently acquired popularity due to its bioactive compounds and antioxidant capacity. However, jambul juice has a high-water content which limits the storage duration and increases the transportation cost. This work, response surface methodology (RSM) was applied to optimize the concentrating process of jambul juice using a vacuum evaporator. Under optimal conditions, a total soluble solid (TSS) of 65.0ºBrix was obtained when the concentration was conducted at a temperature of 65.0ºC for 50.0 min and a rotation speed of 75.8 rpm. The results indicated that the processed parameters had a substantial effect on the TSS. The resulting second-order polynomial model exhaustively describes the relationship between the independent and response variables. Ideal conditions were achieved: 65.0ºC temperature, 50.0 min of time, and 76 rpm rotation speed, which obtained a TSS of 65.4 ± 0.18ºBrix and was confirmed by the validation experiments. These optimum values were designed by the RSM model to produce concentrated jambul juice with Thai Community Product Standard 1307/2014 for concentrated fruit juice. The optimized conditions could also be used to effectively produce high-quality concentrated jambul juice for commercialization.

Keywords: Jambul juice, Concentration, Vacuum-evaporation, Response surface methodology, Central composite design, Optimization.

1. INTRODUCTION

Syzygium cumini (Family Myrtaceae) is also known as *Eugenia cumini* and *Syzygium jambolanum*. Other common names are jambolan plum, jambul, java plum, jamun, black plum, jamblang, Indian blackberry, etc. Currently, these trees are widespread in Eastern Africa, Madagascar, the Asian subcontinent, and South America (Swami et al., 2012) .The tree bears berries once a year, and the fruits taste sweetish-sour. The mature fruits are utilized in the production of jams, squashes, health drinks, wine, and jellies. Jambul juice of superior quality is ideal for making squash, nectar, and sherbet. The berry fruit contains phenolic compounds, particularly phenolic acids, flavonoids, tannins, and ligans. (Qamar et al., 2022). According to scientific studies, jamblang exhibits significant biological activity, particularly antioxidant, antibacterial, antiviral, antifungal, anti-inflammatory, antidiarrheal, antiallergic, anticancer, antidiabetic, and chemoprotective properties (Eswarappa and Somashekar, 2020).

Fruit juice is a valuable semi-finished product that can be used to manufacture fruit beverages, fruit powders, and other products. The initial method by which fruits are transformed into fruit liquids. However, fruit beverages are uneconomical due to their high-water content, which ranges from 75% to 90% (Keshani et al., 2010; Trishitman et

OPEN ACCESS

Received: May 8, 2025
Revised: September 2, 2025
Accepted: October 7, 2025

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Publisher:
Chaoyang University of Technology
ISSN: 1727-2394 (Print)
ISSN: 1727-7841 (Online)

al., 2023). Therefore, it is desirable to eradicate some or all of the water from such liquid. The concentration of liquid foods is a unit operation in the food industry, resulting in decreased packaging, distribution, and transportation costs as well as increased microbiological and biochemical stability (Bozkir and Baysal, 2017). In juice concentration procedures, the final product is still liquid despite an increase in solid content of 65 to 75% (Ramteke et al., 1993; Tavares et al., 2022). Thai Community Product Standard 1307/2014 (Mix fruits syrup) specifies the concentration of concentrated fruit juice by measuring of total soluble solids not less than 60ºBrix. Harmful microorganisms cannot survive at these concentrations, allowing the concentrated fruit liquid with a high solid content to be stored at room temperature (Rektor et al., 2006). Although this concentration process can be carried out using a variety of methods, thermal evaporation remains the most common technique. According to Trishitman et al. (2023), evaporation is the most cost-effective and extensively utilized method for the concentration of liquid foods. Evaporation is likely the oldest technique of concentration. However, the thermal evaporation of juices has some drawbacks associated with the thermal destruction of the product due to the high temperature of the process and lengthy operating periods.

This deficiency may include poor retention of nutritional and/or bioactive compounds, color deterioration, loss of fresh flavors, and the development of a "cooked taste" (Tavares et al., 2022). These effects are involved in a variety of chemical reactions, such as the Maillard reaction of sugars and amino acids, the oxidation of ascorbic acid and lipids, and other complex reactions, such as the thermal degradation of bioactive compounds and the decomposition of pigments such as anthocyanins, carotenoids, and chlorophyll (Kato et al., 2003; Cassano et al., 2011). As can be seen, the heat susceptibility of the product is of particular importance when choosing an evaporator, as it impacts the quality of concentrated fruit juices. Therefore, the vacuum process is favoured in the fruit juice concentration industry, where it is possible to use lower temperatures (Ermolaev et al., 2022). However, numerous variables affected the fruit liquid concentration.

Response Surface Methodology (RSM) is an effective statistical method that uses quantitative data from a reasonable experiment design to determine and solve multiple variable equations at the same time (Abdullah et al., 2007). RSM is an empirical modelling method that looks into how these process parameters significantly affect the coupled responses and the relationship between various process factors and response parameters with different target criteria (Myers et al., 2016). The main benefit of RSM is that it can estimate several factors and their interactions with fewer experimental trials. As a result, it takes less time and effort than other methods to optimize a process. Additionally, by reducing process variation, it is possible to study the interactions between the factors that have been investigated and lower the cost of experiments (Mirhosseini et al., 2008). RSM makes an effort to pinpoint the response that can be conceptualized as a surface across the experimental space for the explanatory variables. To fit an empirical model, it typically employs an experimental design like the central composite design (CCD) (Quanhong, and Caili, 2005). One of the widely used methods for figuring out the ideal conditions for numerous processes is called CCD. The CCD is one of the popular valuable approaches in determining the optimum conditions of many processes. It investigates the response surfaces covered by the experimental design, increasing the effectiveness and efficiency of the process optimization (Capanzana and Buckle, 1997).

RSM is one of the most frequently used optimization techniques in the process-industrial condition sector, potentially due to its high efficiency, comprehensive theory, and ease of use (Pais-Chanfrau et al., 2021). Arteaga et al. (1994), Pua et al. (2010), and Malekjani and Jafari (2020) state that RSM can be utilized in studies with processes and conditions parameters as independent variables. Numerous researchers have effectively applied it to optimize industrial processing operations (Lu et al., 2004; Devi et al., 2015; Hou et al., 2019; Akter et al., 2022; Singh et al., 2022; Kamal et al., 2023; Pawaree et al., 2024; Sirozi et al., 2024). RSM optimization studies have been conducted to obtain high-quality concentrated citrus juice. These are the primary determinants of the concentration efficacy of fruit juices. Keshani et al. (2010) investigated the influence of three key independent variables—rotation speed, temperature, and time—on the concentration of pomelo juice through vacuum evaporation, and they optimized the operational parameters using RSM.

In this study, evaporating temperature, evaporation time, and agitator rotation speed were chosen as the independent variables for optimizing the vacuum-evaporation-based concentration of jambul juice. The purpose of this research is to optimize the process of jambul juice concentration. The CCD was combined with the RSM to optimize the production conditions for vacuum evaporation concentration. The response variables were modelled as a function of three independent variables to determine the optimal condition for concentrated jambul juice.

2. MATERIALS AND METHODS

2.1 Preparation of Jambolan Plum Juice for Concentration

Throughout this research, jambul (*S. cumini*) obtained from a local farm (Muang, Chiangmai, Thailand) was utilized. The jambolan plum was chosen for its uniform maturation, peel color, firmness, size, and shape, as well as its lack of defects. After being harvested, fruits were refrigerated overnight (5°C) before being used. They were manually cleaning and washing the produce to remove debris. The jambolan plums were then manually crushed and filtered to separate the skin and seeds from the liquid, thereby preventing the presence of solids that could interfere with the concentration processes. The juice was cooled to analyze the initial total soluble solid and an initial concentration of 13.2°Brix.

2.2 Total Soluble Solids (TSS)

The content of TSS was investigated in a bench-type pocket refractometer (Atago, Model PAL-3, Japan) with temperature correction to 25°C. The results were expressed in °Brix.

2.3 Evaporation Operator

By vacuum evaporation (ZN-Vacuum Concentrator, ZN-50, China) with a chamber dimensions of 1.2 m x 0.6 m x 2.2 m, jambolan plum liquid was concentrated. The area for heat transmission within the chamber, which is 0.4 m^2, is heated by a hot water medium. The range of selection of process parameters, namely temperature, time and rotation speed were adapted from Keshani et al. (2010). The evaporation temperature was between 60 and 70ºC. The evaporation duration varied between 30 and 70 min. The rotational pace varied from 60 to 90 rpm. Six liters of juice were evaporated under vacuum conditions at approximately pressure of –80 kPa. A paddle was used to stir the juice throughout the procedure. The concentrated jambul juice was separated from the chamber by the bottom valve. The concentrated sample was promptly poured into a bottom glass, sealed, and refrigerated at 5ºC for further analysis.

2.4 Experimental Design

RSM was employed in this study to investigate the effects of temperature, time, and rotation speed—three evaporation parameters—on the TSS concentration in jambolan plum juice. The investigation was conducted by a CCD. In this experimental design, each variable was assigned three coded levels: -1, 0, and +1, which correspond to the minimum, median, and maximum values of the independent variables, respectively. Table 1 details the independent variables along with their respective coded and uncoded levels. The coding of these variables followed the equation provided.

$$x_i = (X_i - X_0) / \Delta X \qquad i = 1, 2, \ldots, k \qquad (1)$$

where xi is the dimensionless value of an independent variable, X_i is the real value of an independent variable, X_0 is the real value of X_i at the center point, ΔX is the step change and k the number of independent variables considered in the experimental design. The specific codes are:

$$x_1 = (\text{Temp.} - 65) / 5 \qquad (2)$$

$$x_2 = (\text{Time} - 50) / 20 \qquad (3)$$

$$x_3 = (\text{Rotation speed} - 75) / 15 \qquad (4)$$

2.5 Statistical Analyses and Optimization of Concentration Process for Jambul Juice

The using the of polynomial regression equation, the behavior of response surface was examined for the response variables (Y_i). Below is a representation of the generalized response surface model:

$$Y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{33} x_3^2 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 \qquad (5)$$

where Y_i represents the response calculated by the model; β_0 is a constant; β_1, β_2 and β_3 are linear effect term, β_{11}, β_{22} and β_{33} are squared effect, and β_{12}, β_{13} and β_{23} are interaction coefficient.

The multiple coefficients of determination (R^2) were used to assess the proportion of variance explained by the polynomial models. The significance of each coefficient was tested using the Student t-test and corresponding p-values. The response surface was analyzed for the total soluble solids (ºBrix) function (Y_i) through the regression equation provided as Equation (5). To identify optimal conditions, a graphical method was employed by holding one variable at its optimal value while adjusting the others (Myers et al., 2016). These optimal conditions were then experimentally validated, and the observed results were compared to the model predictions.

The polynomial equation was fitted as surface plots to illustrate the relationship between the experimental levels of each factor and the response variable, thereby identifying the optimal conditions for the concentration process of jambul juice. The experimental design, data analysis, and optimization procedures were conducted using the Minitab version 15.0 statistical software (Minitab Inc., State College, PA, USA).

3. Results and Discussion

3.1 Statistical Analysis and Model Fitting for Optimization of Concentration Process on Jambul Juice

A CCD was employed to organize a series of 20 experiments, which included six

Table 1. Independent variables and their levels in the central composite design.

Independent variables	Symbol		Level		
	Uncode	Code	-1	0	1
A: Temperature (ºC)	X1	x1	60	65	70
B: Time (min)	X2	x2	30	50	70
C: Rotation speed (rpm)	X3	x3	60	75	90

Table 2. CCD and experimental data obtained with the observed responses and predicted values for the total soluble solids

Run no.	Independent variables			Total soluble solids (°Brix)	
	A: Temperature (ºC)	B: Time (min)	C: Rotation speed (rpm)	Experimental	Predicted
1	60 (-1)	30 (-1)	60 (-1)	20.3	21.5
2	70 (1)	30 (-1)	60 (-1)	25.5	25.0
3	60 (-1)	70 (1)	60 (-1)	53.1	54.5
4	70 (1)	70 (1)	60 (-1)	78.5	79.8
5	60 (-1)	30 (-1)	90 (1)	27.7	27.3
6	70 (1)	30 (-1)	90 (1)	26.1	25.6
7	60 (-1)	70 (1)	90 (1)	59.5	60.8
8	70 (1)	70 (1)	90 (1)	81.2	80.9
9	60 (-1)	50 (0)	75 (0)	55.6	52.1
10	70 (1)	50 (0)	75 (0)	63.9	63.9
11	65 (0)	30 (-1)	75 (0)	29.8	30.1
12	65 (0)	70 (1)	75 (0)	78.0	74.2
13	65 (0)	50 (0)	60 (-1)	68.3	64.9
14	65 (0)	50 (0)	90 (1)	68.4	68.3
15	65 (0)	50 (0)	75 (0)	63.0	64.9
16	65 (0)	50 (0)	75 (0)	63.7	64.9
17	65 (0)	50 (0)	75 (0)	63.5	64.9
18	65 (0)	50 (0)	75 (0)	63.7	64.9
19	65 (0)	50 (0)	75 (0)	64.0	64.9
20	65 (0)	50 (0)	75 (0)	64.2	64.9

central points. The experimental plan is fully detailed in Table 2, which includes the matrix, predicted TSS (°Brix), and the actual TSS (°Brix) observed during the vacuum evaporation of jambul juice. The maximum TSS achieved was 81.2°Brix during run number 8, where the conditions were set at 70°C, 70 min, and 90 rpm. Conversely, the lowest TSS of 20.3°Brix was recorded during run number 1, with parameters set at 60°C, 30 min, and 60 rpm. The predicted TSS values from the RSM closely matched the experimental results. The quadratic model equation, which incorporates linear, interaction, and quadratic terms, was derived from the experimental data to analyze the regression coefficients and their relationships with the independent variables. Table 3 shows the correlation between these variables and the response. The final second-order polynomial equation with significant term, presented in uncoded form, excludes the contributions from interaction terms AC, BC, and quadratic term C^2:

$$\text{Total soluble solid (°Brix)} = 64.904 + 5.90A + 22.09B + 1.72C - 6.91A^2 - 12.76B^2 + 1.690C^2 + 5.44AB - 1.312AC + 0.137BC \quad (6)$$

where A, B, and C represented evaporating temperature, time of evaporation, and rotation speed, respectively.

3.2 Model Adequacy for Optimization of Concentration Process on Jambul Juice

3.2.1 The experimental and predicted values of TSS

The experimental TSS and the predicted ones are represented in Fig. 1. The data fitting concerning the RSM was estimated by plotting predicted values versus experimental data. It was observed that the discrepancies between the experimental and predicted TSS were less than 1.9%, and the predicted values accorded suitably with the experimental data. Furthermore, the coefficient of determination R^2 (0.992) and the adjusted R^2 (0.985) are both approaching 1.0, suggesting that the regression model provides a highly accurate representation of the experimental data. Consequently, the model effectively explains how the TSS responds to variations in the different conditions of the concentration process.

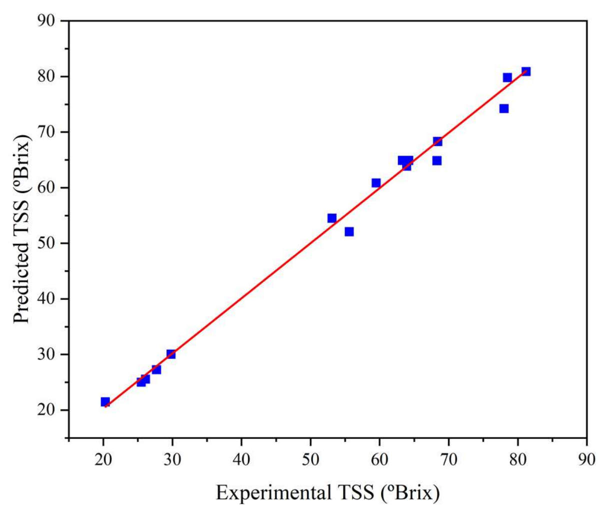

Fig. 1. The validation of the predicted TSS (ºBrix) and experimental TSS (ºBrix).

Table 3. Analysis regression coefficients of the second-order polynomial response models

Team	Regression coefficient (β)	Standard error	t- value	p- value
Constant	64.90	0.804	80.72	< 0.0001
Temperature (A)	5.90	0.740	7.98	< 0.0001
Time (B)	22.0	0.740	29.86	< 0.0001
Rotation speed (C)	1.72	0.740	2.33	0.042
A2	-6.91	1.410	-4.90	0.001
B2	-12.7	1.410	-9.05	< 0.0001
C2	1.69	1.410	1.20	0.258
AB	5.43	0.827	6.58	< 0.000
AC	-1.312	0.827	-1.59	0.144
BC	0.137	0.827	0.17	0.871

Table 4. ANOVA on the independent variables as linear, quadratic and interaction terms on the response variables

Source	df	Sum of square	Mean of square	F- value	p- value
Model	9	6904.15	767.13	140.21	< 0.0001
Temperature (A)	1	348.10	348.10	63.62	< 0.0001
Time (B)	1	4879.68	4879.68	891.89	< 0.0001
Rotation speed (C)	1	29.58	29.58	5.41	0.042
A^2	1	131.27	131.27	23.99	0.001
B^2	1	447.68	447.68	81.83	< 0.0001
C^2	1	7.86	7.86	1.44	0.258
AB	1	236.53	236.53	43.23	< 0.0001
AC	1	13.78	13.78	2.52	0.144
BC	1	0.15	0.15	0.03	0.871
Residual error	10	54.71	5.47		
Lack of fit	5	54.18	10.84	53.58	0.249
Pure error	5	0.53	0.11		
Total	19	6598.87			
R^2			0.992		
Adjusted-R^2			0.985		
Predicted-R^2			0.951		

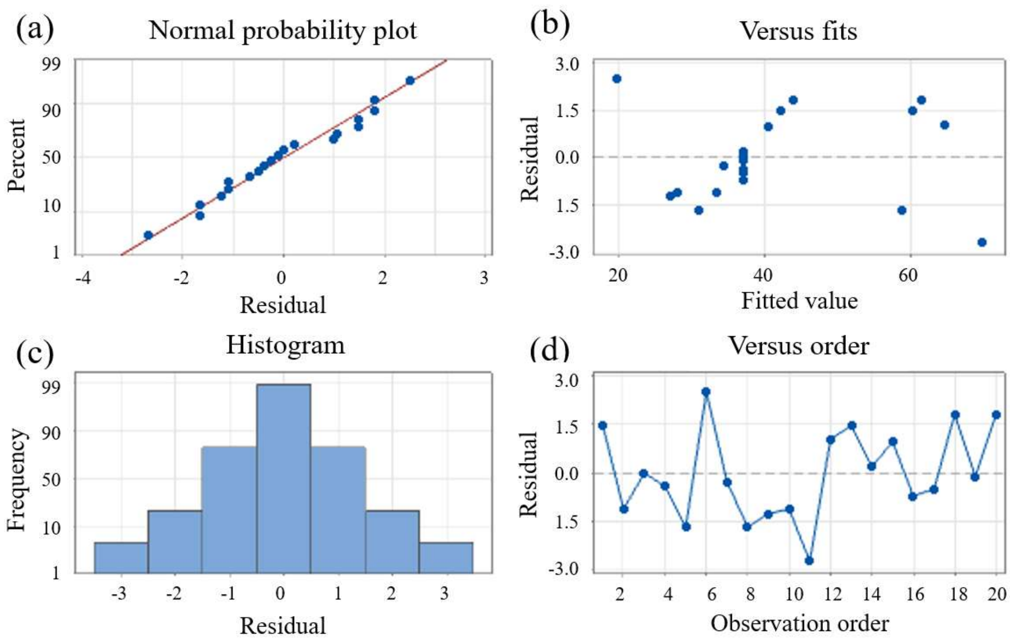

Fig. 2. Residual plots for the concentration of Jambul juice by vacuum-evaporator; (a) Normal probability plot, (b) Versus fits, (c) Histogram and (d) Versus order

3.2.2 Analysis of Variance (ANOVA)

Table 4 shows the results of ANONA for the jambolan plum juice concentration model using a vacuum evaporator. The F-value (140.21), which was very significant (p-value < 0.0001), and the p-value of lack of fit (0.249) was not significant (p-value > 0.05). This demonstrated that the quadratic model was a good way to explain how temperature, time, and agitator speed affected the TSS of concentrated jambul juice. Furthermore, the model demonstrates a strong fit with the actual test results and is capable of accurately predicting TSS, as evidenced by the high coefficient of determination (R^2) of 0.9921 and the adjusted coefficient of determination (Adj. R^2) of 0.9851. Each factor had a distinct impact on TSS within the range of chosen independents. First, the test results were greatly significantly influenced (p-value < 0.01) by the linear effects A and B, the interaction effect of AB, and the quadratic effects A^2 and B^2. Additionally, the test results were also significantly influenced (p-value < 0.05) by the linear effect C. Based on these findings, it is possible to conclude that the quadratic regression model adequately explains the concentration process of jambolan plum juice. Additionally, three parameters affected TSS: evaporating time (B) > evaporating temperature (A) > rotation speed (C).

3.2.3 Interpretation Analysis of Residual Graphs

In addition to the coefficient of determination, a variety of indicative plots, including normal probability, fits and order versus residual, and histogram, were established and shown in Figs. 2(a-d) to assess the adequacy of the model. Evaluation of the adequacy of a quadratic regression model required analysis of residuals (Sirozi et al., 2024; Hadidi et al., 2020). This evaluation of testing for a normal distribution determines how closely the elements on a normal probability plot match a straight line. The normal probability plot corresponds directly to Fig. 2(a). Evidently, the data were ordinarily distributed based on the result of this test, as they were close to the straight line and exhibited no deviation.

The analysis of residuals, or the difference between the predicted value and the experimental data, is a crucial composition of describing models by normalizing and dividing by an estimate of their standard deviations. A decent model should have residuals that are normally and uniformly distributed. The plot of residuals versus the fitted values reveals that the residuals do not represent any specific pattern, but are approximately normally distributed, or that the residual points on the plot fall near to the straight line. Consequently, the RSM experiment data followed a normal distribution. According to the results shown in Fig. 2(b), the residual points of fit were well concentrated around the straight line with random scattering, suggesting that the variances of original observations were constant and immaterial to the response values. Fig. 2(c) represents a graph of residual against observation order that is equal and centered near zero, with no explicit outliers in the observation order. All data points were put within the 3.00 interval, indicating that the RSM model approximation was fitted accurately. Lastly, the histogram reveals a distribution of measurements (frequency vs. residual values) that is moderately symmetrical about the mean, with the majority of measurements concentrated in the middle of the graph, demonstrating a normal distribution of the residuals with no outliers (Fig. 2(d)).

3.3 Effects of Evaporation Parameters on TSS Content

A 3D-response surface (Figs. 3(a), 3(b), and 3(c)) was constructed from the second-order polynomial equation within the RSM framework to visually assess the impact of linear effects on TSS. According to Tables 3 and 4, neither the quadratic effects of C^2 nor the interactive effects of AC and BC were not significant (p-value > 0.05).

3.3.1 Effects of Evaporative Temperature

Jambolan plum juice was concentrated at different temperatures (60, 65, and 70ºC) using vacuum conditions for evaporation. Figs. 3(a) and 3(b) illustrate the relationship between evaporation temperature and TSS. It is evident that TSS increased significantly and attained its maximum level as the temperature enhanced to 70ºC. The observed increase in TSS can be explained to the fact that, while water evaporates at moderate temperatures, the evaporation rate accelerates with rising temperatures. This effect is due to the increased movement of molecules at higher temperatures, which raises the likelihood that molecules will acquire enough energy to separate the liquid phase and turn into a gas (Ermolaev et al., 2022). Accordingly, the addition of energy (heating) enhances the rate of evaporation, confirming previous findings (Keshani et al., 2010). Additionally, Leong and Chua (2020) varied at temperatures (50–70°C) and time (30–120 min) at the fixed pressure, 200 mbar in 13 experimental runs with CCD and RSM for optimization of concentrating process using rotary vacuum evaporation for pineapple juice. The results found that rotary vacuum evaporation was able to reduce 44.3% water content and increase total sugar content from 7.70 to 14.65ºBrix. Prior research indicates that it is difficult to increase the TSS of juice when the evaporator temperature is lowered. During evaporation, an increase in TSS was observed in the juice samples as the temperature increased. It can be clarified by a rise in the boiling point of liquids due to an increase in the concentration of soluble solids (Fazaeli et al., 2013).

3.3.2 Effects of Evaporation Time

Different evaporating times (30, 50, and 70 min) were used to determine the effect of time on the TSS concentration of jambul juice. As shown in Figs. 3(a) and 3(c), the TSS increased as evaporation time increased from 50 to 70 min. This data indicated that the TSS increased between 50 and 70 min of evaporation and reached its maximum at 70 min (Figs. 3(a) and 3(c)). These findings are according to a study by Keshani et al. (2010) who illustrated that the concentration increased when the time increased for the process condition of concentrated pomelo fruit juice. Numerous foods are heat- or temperature-sensitive and desire either low heating temperatures or a short residence time exposed to the heat, or both. This can be accomplished by minimizing the volume of product in the evaporator at any given time, shortening the evaporation time, and lowering the bulk boiling temperature of the product by evaporating at reduced pressures (Glover, 2004). Reducing the internal operating pressure may also make it possible to operate at reduced heating temperatures while maintaining an adequate heat-transfer driving force (Minton, 1986).

3.3.3 Effects of Rotation Speed of Agitator

The rotational speed of the agitator was investigated to determine the optimal level for obtaining the TSS at 60, 75, and 90 rpm. As shown in Tables 3 and 4, rotation speed was a variable that significantly affected the TSS (p-value < 0.05). Different rotation speeds (60–90 rpm) and their effect on TSS were estimated in this investigation. According to Figs. 3(b) and 3(c), the TSS increased within the range of 75–90 rpm as the rotational speed of agitator increased. Keshani et al. (2010) found that the rotation speed increased the TSS of concentrated citrus juice.

3.4 Optimization of the Process Conditions and Model Verification

The primary objective of this experiment is to optimize the concentration of jambul juice using a vacuum evaporator. For this purpose, the response was set to the maximum TSS value of 65.0ºBrix (Ramteke et al., 1993), and the process variables, such as temperature, time, and rotation speed, were maintained within the ranges of 60–70ºC, 30–70 min, and 60–90 rpm, respectively, to achieve the target TSS. Under these optimal variable conditions, the theoretical TSS of jambul juice was calculated to be 65.0ºBrix; 65.0ºC, 50 min, and 75.8 rpm (Table 5). RSM can achieve the process parameters of jambolan plum concentration by using a vacuum evaporator to predict the TSS content model. Fig. 4 shows the evaporative temperature, evaporation time, and paddle rotation speed. The composite desirability is 1.000, indicating the setting to achieve the results for the response variable.

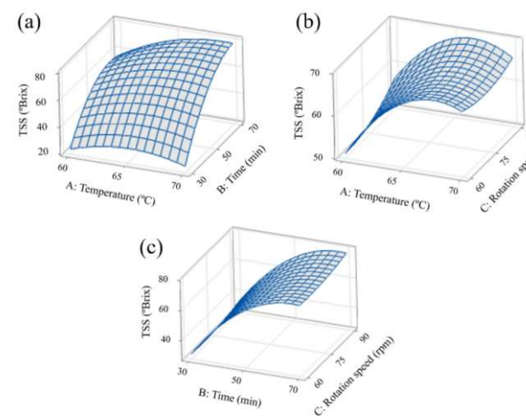

Fig. 3. Response surface (3D) plots showing the combined effect of independent variables; (a) temperature and time, (b) temperature and rotation speed and (c) time and rotation speed upon the TSS of jambul juice

The experimental conditions were modified to validate the model as follows: temperature of 65ºC, evaporation time of 50 min, and rotation speed of 76 rpm. Under these conditions, the experimental results (65.4 ± 0.18ºBrix) were not statistically different from the expected results (65.00ºBrix), indicating that the model utilizing CCD was deemed adequate to represent the experimental results with accurate prediction under ideal conditions. The concentrated jambul juice obtained from these production conditions are according to the specifications of Thai Community Product Standard 1307/2557 (Mix fruits syrup) which specifies that the total soluble solid must not be less than 60ºBrix (Table 5).

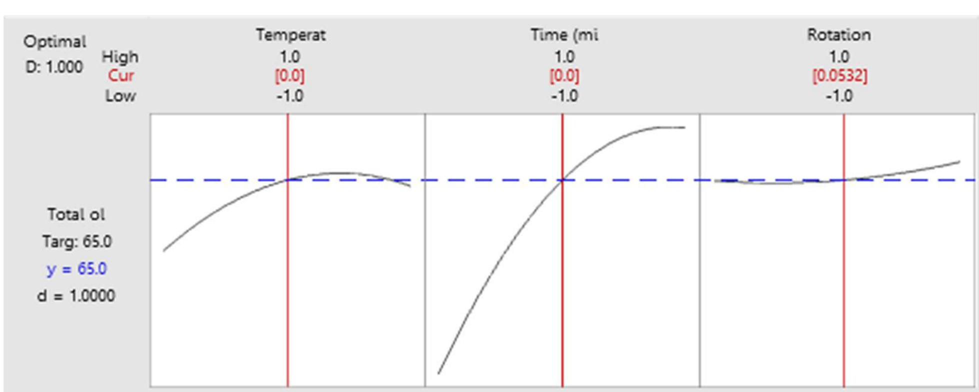

Fig. 4. Response optimization plot for process parameters in the vacuum-evaporative concentration of jambolan plum

Table 5. The predicted and experimental value of response at the optimum condition (based on graphical optimization)

Optimum condition	Coded levels	Actual levels	Thai Community Product Standard 1307/2557
Temperature	0	65.0ºC	
Time	0	50.0 min	
Rotation speed	0.0532	75.8 rpm	
Response	Predicted value	Experimental value[a]	
TSS (ºBrix)	65.0	65.4 ± 0.18	Not be less than 60

[a] Mean value of six determinations.

4. CONCLUSION

In the present study, vacuum-evaporation was used to concentrate jambolan plum juice. Using varying levels of different process parameters (temperature, time, and rotation speed) and RSM as a mathematical method, the concentration process was optimized to attain the optimal TSS for the concentrated jambul juice. The statistical and graphical analysis revealed that temperature, time, and rotation speed are the most significant variables influencing the TSS of concentrated jambul juice. The second polynomial model established provided a plausible mathematical explanation for the concentration of jambolan plum juice. The optimal settings were found to be 65.0ºC, 50.0 min, and 75.8 rpm. Under these conditions, a TSS of 65.0ºBrix was predicted, which was extremely near to the experimental validation TSS of 65.4 ± 0.18ºBrix, demonstrating the ability of the developed model to optimize the experimental parameters for the concentration process of jambolan plum juice. Producers of concentrated jambul juice and other comparable juices can use these findings to develop an efficient and economically viable concentration process, as required by Thai Community Product Standard 1307/2557 (Mix fruits syrup).

DECLARATION OF COMPETING INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGMENT

This research was supported by the Fundamental Fund (FF65) and the University of Phayao through the FF65-RIM032 grant project. Additionally, partial financial support for this study was provided by the Thailand Science Research and Innovation Fund and the University of Phayao (Fundamental Fund 2025, Grant No. 5047/2567). Moreover, we appreciate the apparatus provided by the Division of Food Science and Technology in the School of Agriculture and Natural Resources at the University of Phayao.

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