

Response Surface Methodology-Based Optimization of Papaya Drying for Enhanced Flavonoid Content and Antioxidant Activity

Ferdusee Akter^{1*}, Afia Nawar², Suresh Chakma³

¹Department of Physical and Mathematical Sciences, Chattogram Veterinary and Animal Sciences University, Chattogram, Bangladesh

²Department of Applied Chemistry and Chemical Technology, Chattogram Veterinary and Animal Sciences University, Chattogram, Bangladesh

³Department of Physiology, Biochemistry and Pharmacology, Chattogram Veterinary and Animal Sciences University, Chattogram, Bangladesh

Email: *imferdusee@cvasu.ac.bd, afianawarpeu@gmail.com, sureshchakmacvasu@gmail.com

How to cite this paper: Akter, F., Nawar, A. and Chakma, S. (2026) Response Surface Methodology-Based Optimization of Papaya Drying for Enhanced Flavonoid Content and Antioxidant Activity. *Journal of Applied Mathematics and Physics*, 14, 3763-3776.

<https://doi.org/10.4236/jamp.2026.1410185>

Received: August 26, 2026

Accepted: October 5, 2026

Published: October 8, 2026

Copyright © 2026 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

Fruits and vegetables are highly perishable due to their moisture content. It makes preservation challenging. One effective method for preserving them is drying. It not only helps to extend shelf life but also retains nutrients. This study aimed to explore and optimize the drying parameters for papaya using convective drying. To achieve this, Response Surface Methodology was used to analyze the effects of drying time, temperature, and sample thickness. The study focused on how these factors impacted the total flavonoid content (TFC) and total antioxidant content (TAC) in the dried papaya. Drying time, temperature, and sample thickness were investigated at factorial levels 6 - 8 hours, 60 - 80°C, and 5 - 10 mm, respectively, using a rotatable central composite design with axial distance $\alpha = 1.68179$. A quadratic model was developed to evaluate how these factors influenced TFC and TAC. The results from the experiments were closely aligned with the predictions from the model. The optimal drying conditions were found to be 7.64 hours at 80°C with a sample thickness of 5 mm, which produced the highest TFC and TAC values. The findings from this study could lead to improvements in the food drying process. It will also generate new possibilities for creating nutritious, value-added products from dried papaya.

Keywords

Drying, Modeling, Optimization, Response Surface Methodology, TAC, TFC

1. Introduction

Fruits are important components of the human diet. They serve as major sources of essential micronutrients and diverse bioactive compounds [1] [2]. Among these, phytochemicals such as flavonoids and various antioxidants play a vital role in human health by mitigating oxidative stress and potentially preventing chronic conditions, including cardiovascular diseases, cancers, and neurodegenerative disorders [3]-[5]. Flavonoids, a structurally diverse subgroup of polyphenols, are recognized for their free radical scavenging capacity and ability to modulate critical cellular signaling pathways [6] [7]. Papaya (*Carica papaya L.*) is a widely cultivated tropical fruit valued for its high nutritional and functional properties, containing high levels of carotenoids, vitamins A and C, and essential minerals [1] [8]. Beyond basic nutrition, papaya is a significant source of bioactive compounds, particularly phenolic and flavonoid molecules, which contribute anti-inflammatory, antimicrobial, and antioxidant medicinal properties [9] [10].

Despite its nutritional density, papaya faces significant challenges related to postharvest losses, which can range from 10% to 50% in tropical regions due to inadequate storage, handling, and transportation infrastructure [11]. The high moisture content and rapid metabolic activity of fresh papaya make it highly perishable and susceptible to rapid spoilage and microbial deterioration immediately after harvest [2]. To mitigate these losses, drying is widely recognized as an effective preservation technique for extending the shelf life of perishable fruits [12]. By reducing moisture content and lowering water activity to levels that inhibit microbial proliferation, drying significantly extends the product's shelf life. Furthermore, dehydration processes offer logistical advantages by reducing bulk volume and transportation costs while enabling the development of value-added convenience fruit products [12] [13].

Among various industrial technologies, convective hot air drying is among the most widely used industrial drying methods due to its simplicity, cost-effectiveness, and high throughput [13]. However, drying involves complex simultaneous heat and mass transfer mechanisms that can lead to the deterioration of phytochemical quality [14]. The retention of bioactive compounds like flavonoids is highly sensitive to process conditions such as temperature and drying time [14] [15]. Response Surface Methodology (RSM) has emerged as a powerful statistical and mathematical tool for the modeling and optimization of these multivariate processes [16]. Previous studies have successfully utilized RSM to optimize drying conditions for various agricultural products, including tomatoes [17], okra [16], and corn [18], focusing on the retention of nutrients and antioxidant capacity. For papaya, recent research has applied RSM to optimize the retention of total phenolic content [9].

Although previous studies have investigated individual phytochemicals such as phenolics and carotenoids [8], the combined influence of drying parameters on flavonoid retention and antioxidant capacity in papaya remains insufficiently explored. Understanding these relationships is critical for industrial processing to

ensure that final products maintain high nutritional quality and functional bioactivity while optimizing energy efficiency [11] [19].

The primary objective of this study is to evaluate the influence of drying parameters, specifically air temperature, drying time, and sample thickness, on the total flavonoid content and antioxidant capacity of papaya and to determine optimal drying conditions using response surface methodology. By establishing these optimized parameters, this research aims to provide scientifically grounded insights for food processing, nutritional preservation, and the development of value-added fruit products. The findings are expected to contribute to the reduction of post-harvest waste and enhance the functional quality of processed tropical fruits.

2. Materials and Methods

2.1. Design of Experiment

A three factor central composite design (CCD) was applied to optimize the drying parameters of papaya slices using Response Surface Methodology [16] [20]. Drying time, X_1 (8 h, 9 h, 10 h), temperature, X_2 (60°C, 70°C, 80°C), and slice thickness, X_3 (5 mm, 7.5 mm, 10 mm) were selected as independent variables based on the author's previous work [9]. TFC and TAC were considered as response variables. The rotatable central composite design was constructed with an axial distance $\alpha = 1.68179$. Each independent variable was coded as $(-1, 0, +1)$ and the axial points as $(\pm\alpha)$. Considering the axial points the complete experimental ranges were 5.32 - 8.68 h, 53.18 - 86.82°C, and 3.30 - 11.70 mm. The design consists of 8 factorial points, 6 axial points, and 6 replicated center points, resulting in a total of 20 experimental runs. The experimental design and data analysis were performed using the trial version of Minitab software. Each design point was evaluated using three independent experiments. Details of experimental runs are provided in **Table 1**.

Each response variable in RSM was modeled using a second-order polynomial equation, including linear, quadratic, and interaction terms, as described by Montgomery (2017) [21]. The equation can be expressed as follows:

$$Y = \gamma_0 + \sum_{i=1}^m \gamma_i X_i + \sum_{i=1}^m \gamma_{ii} X_i^2 + \sum_{i=1}^m \sum_{j=i+1}^m \gamma_{ij} X_i X_j \quad (1)$$

where Y is the response variable, γ_0 is the constant; γ_i , γ_{ii} and γ_{ij} are the coefficients of linear terms, quadratic terms and interaction terms respectively; X_i and X_j are the independent variables; m is the number of variables; ε represents the random error of the model. The two-way and quadratic interactions are shown by the variables $X_i X_j$ and X_i^2 , respectively.

Analysis of variance (ANOVA) was performed to evaluate the significance of model terms and estimate regression coefficients. Optimal drying conditions were identified and validated through laboratory experiments by comparing predicted and actual response values.

2.2. Sample Collection and Preparation

Fresh papaya fruits (*Carica papaya L.*) were collected from a commercial farm (cultivar Mr. Sumon Chakma) located in Ghagra, Rangamati, Chattogram, Bangladesh. Fruits of uniform size, shape, and maturity stage approximately 75% yellow coloration and free from visible defects, were selected. A total of 10 papaya fruits were collected from one batch for the experiments.

The fruits were allowed to ripen at ambient temperature ($25 \pm 2^\circ\text{C}$). Ripened papayas were washed thoroughly with distilled water, peeled manually, and cut into slices of predetermined thickness. Drying experiments were carried out using a laboratory hot air oven (Raypa, Model DOD-150, Spain) at three temperature levels (60°C , 70°C , and 80°C). The air velocity in the convective dryer was 1.5 m/s throughout all experiments. After drying, samples were cooled in a desiccator for 30 minutes to prevent moisture absorption. The dried samples were then ground and stored in airtight containers at 4°C until further analysis.

All chemicals used in the study, including methanol, ethanol, and 2,2-diphenyl-1-picrylhydrazyl (DPPH), were of analytical grade and purchased from Merck (Darmstadt, Germany).

2.3. Determination of Bioactive Compounds

2.3.1. Preparation of the Extract

Papaya extracts were prepared following a modified method of Unal *et al.* (2014) [22]. Each dried sample (2 g) was soaked in 100% ethanol (20 mL) and shaken at room temperature for 72 h where solvent-to-sample ratio was 10:1. The filtrates were then collected, and used as sample extract. All filtrates were combined and evaporated at 60°C using a rotary evaporator (Heidolph Hei-VAP Digital). Crude extracts were weighed and stored at 4°C for further analysis.

2.3.2. Determination of Total Flavonoid Content

Total flavonoid content (TFC) was determined following Chang *et al.* (2002) [23]. Extracts (1 mg/mL) and quercetin standards (0.02 - 0.10 mg/mL) were mixed with ethanol, aluminium chloride, potassium acetate, and distilled water. After 30 min incubation at room temperature, absorbance was measured at 415 nm using a UV spectrophotometer (UV-2600). TFC was expressed as mg quercetin equivalent per 100 g extract (mg QE/100 g).

2.3.3. Determination of Antioxidant Capacity

Antioxidant activity was evaluated using the DPPH assay as described by Azlim Almey *et al.* (2010) [24]. Extract (1 mL) was mixed with ethanol (6 mL) and DPPH solution (2 mL, 6 mg/100mL methanol), then incubated in the dark for 30 min. Absorbance was measured at 517 nm, and results were expressed as mg Trolox equivalent per 100 g extract (mg TE/100 g).

3. Results and Discussion

3.1. Experimental Work and Data Collection

The experimental results on the response variables (Total flavonoid content and

Total antioxidant capacity) under different drying conditions are displayed in **Table 1**. The initial values were 1.45 mg QE/100g and 2.45 mg TE/100g. All experiments were done in triplicate.

Table 1. Central composite design of three factors and results of responses.

Run Order	Time (h)	Temp (°C)	Thickness (mm)	Experimental values of responses	
				TFC (mg QE/100g)	TAC (mg TE/100g)
1	8	60	5	5.85 ± 0.04	22.75 ± 0.04
2	6	80	5	18.29 ± 0.01	26.8 ± 0.01
3	7	70	7.5	9.31 ± 0.05	17.55 ± 0.02
4	7	70	7.5	9.40 ± 0.04	17.21 ± 0.02
5	8	60	10	5.97 ± 0.04	10.35 ± 0.02
6	7	70	7.5	9.36 ± 0.02	17.97 ± 0.01
7	7	70	7.5	9.71 ± 0.05	16.99 ± 0.02
8	5.32	70	7.5	4.65 ± 0.05	16.00 ± 0.01
9	8	80	10	20.56 ± 0.03	26.93 ± 0.03
10	7	86.82	7.5	25.93 ± 0.03	25.9 ± 0.02
11	6	60	10	3.314 ± 0.03	17.73 ± 0.01
12	6	80	10	17.89 ± 0.04	24.45 ± 0.01
13	7	70	7.5	10.17 ± 0.01	17.78 ± 0.01
14	7	70	3.30	18.88 ± 0.01	28.88 ± 0.03
15	7	70	7.5	9.72 ± 0.03	18.17 ± 0.03
16	6	60	5	13.58 ± 0.04	20.54 ± 0.01
17	7	53.18	7.5	6.97 ± 0.03	21.72 ± 0.02
18	8.68	70	7.5	7.13 ± 0.03	18.58 ± 0.01
19	7	70	11.70	3.97 ± 0.04	13.31 ± 0.03
20	8	80	5	17.73 ± 0.04	26.89 ± 0.04

3.2. Statistical Analysis and Estimated Regression of the Response Variables

The statistical data was evaluated using Minitab software. An analysis of variance (ANOVA) needs to be conducted to assess the reliability and suitability of the model [20]. A mean value from each trial was utilized to establish a second-order polynomial model, resulting in the regression equations. The predictive performance of a model can be assessed by evaluating its predicted R^2 . In order to assess the performance of the model, various statistical measures were computed, including the mean square, sum of squares, degree of freedom (DoF), P-value, and F-value. Based on the results of the variance analysis, an F-value greater than 2.6 indicates a more precise estimation of the parameters. Furthermore, if the P-value

is below 5%, the statistical model is considered valid.

3.2.1. Effects of Drying Parameters on TFC

Table 2 displays the outcomes of the analysis of variance (ANOVA) conducted on the total flavonoid content (TFC). Since the P-value for the model is less than 0.05, it indicates that there is a statistically significant relationship between the terms in the model. With an F-value of 13.51, the model can be estimated statistically significant. Terms that have P-values below 0.05 are deemed significant.

Table 2. Analysis of variance of TFC and TAC.

Sources	Degrees of freedom	Analysis of Variance for TFC				Analysis of Variance for TAC			
		Adjusted Sum of Squares	Adjusted Mean Squares	F-Value	P-Value	Adjusted Sum of Squares	Adjusted Mean Squares	F-Value	P-Value
Model	9	710.898	78.989	13.51	<0.001	404.227	44.914	5.92	0.005
Linear	3	520.346	173.449	29.66	<0.001	261.597	87.199	11.49	0.001
X_1	1	0.106	0.106	0.02	0.896	0.222	0.222	0.03	0.868
X_2	1	441.490	441.490	75.49	<0.001	121.585	121.585	16.01	0.003
X_3	1	78.750	78.750	13.46	0.004	139.791	139.791	18.41	0.002
Square	3	141.222	47.074	8.05	0.005	107.872	35.957	4.74	0.026
X_1^2	1	14.090	14.090	2.41	0.152	0.229	0.229	0.03	0.866
X_2^2	1	108.493	108.493	18.55	0.002	85.099	85.099	11.21	0.007
X_3^2	1	13.458	13.458	2.30	0.160	31.197	31.197	4.11	0.070
2-Way Interaction	3	49.330	16.443	2.81	0.094	34.758	11.586	1.53	0.268
X_1X_2	1	6.421	6.421	1.10	0.319	7.488	7.488	0.99	0.344
X_1X_3	1	23.157	23.157	3.96	0.075	6.468	6.468	0.85	0.378
X_2X_3	1	19.752	19.752	3.38	0.096	20.801	20.801	2.74	0.129
Error	10	58.486	5.849			75.922	7.592		
Pure Error	5	0.534	0.107			1.025	0.205		
Total	19	769.384				480.149			
		R ² : 0.9237				R ² : 0.8419			
Adj R ² : 0.8329		Predicted R ² : 0.8394				Adj R ² : 0.8349, Predicted R ² : 0.8310			
		Adequate precision: 9.43				Adequate precision: 6.71			

The predicted R² value of 0.8394 and the adjusted R² value of 0.8329 are highly similar. The coefficient of determination (R²) for the response variable was 0.9237, signifying that 92.37% of the overall variability was effectively accounted for by the model. The precision value of 9.43 exceeds 4, so, we can infer that this response is more precise and reliable [20]. Consequently, it is feasible to enhance this dependent variable by implementing the model.

Equation (2) represents the regression model fitted with the total flavonoid con-

tent.

$$\begin{aligned} \text{Total Flavonoid} = & 183.7 + 2.6X_1 + 4.37X_2 - 12.44X_3 \\ & - 0.989X_1^2 + 0.02744X_2^2 + 0.155X_3^2 \\ & + 0.0896X_1X_2 + 0.681X_1X_3 + 0.0629X_2X_3 \end{aligned} \quad (2)$$

In the regression equation, positive linear and interaction factors imply that TFC levels in papaya rise with increases in relevant variables, while negative ones present declines.

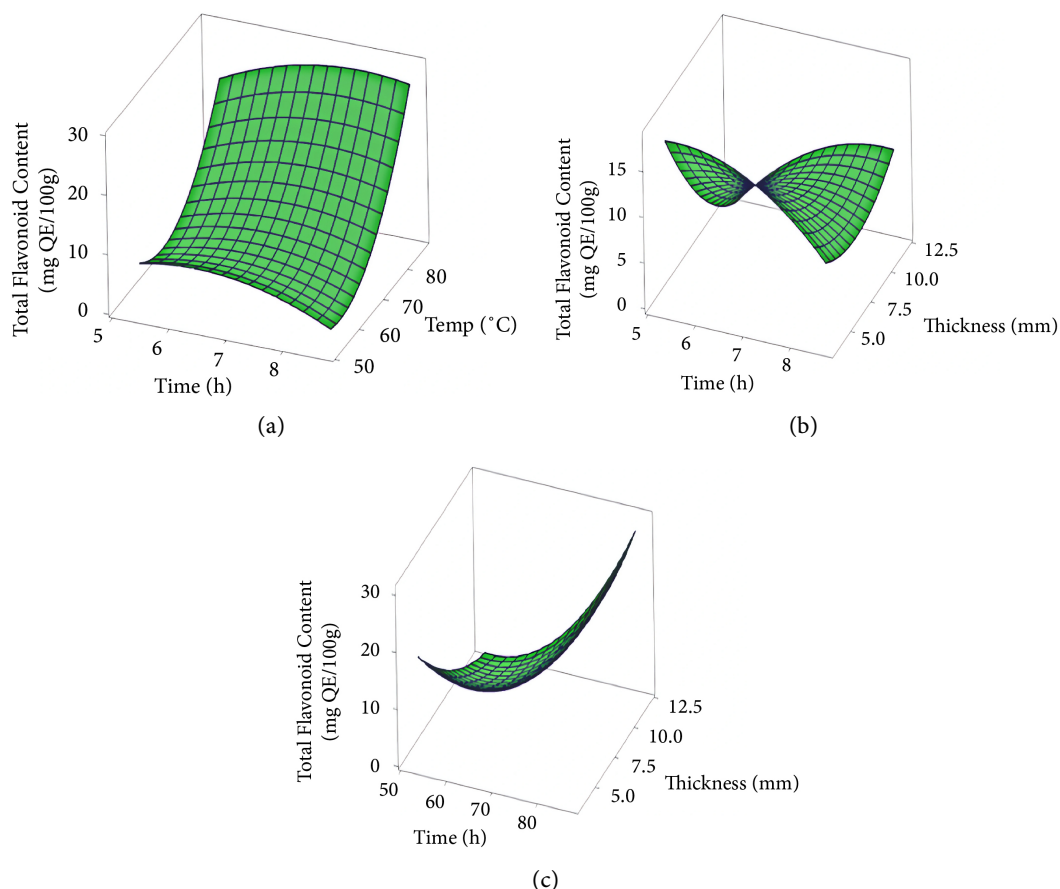


Figure 1. (a)-(c) 3D plots of the variation of TFC.

Figure 1 depicts the overall quantity of TFC present in papaya. The response surface plots were generated to demonstrate the cumulative effects of the factors on the responses in the fitted model. The plots were constructed by varying two independent variables, while keeping the third variable fixed at the center of the plot. A three-dimensional graph is employed to illustrate the links between the experiment's outcomes and its many components.

Table 2 shows that the effect of drying time on the TFC is insignificant. However, drying temperature and sample thickness have a significant effect on TFC. **Figure 1** shows that the increase in temperature and drying time increased total flavonoid content in papaya. On the other hand, the flavonoid content of papaya

slices was significantly reduced with the increase of sample thickness. Besides, it is also clear that temperature had a more significant effect on the total flavonoid content than time and sample thickness.

The findings are consistent with those of a few other studies that have been published [25] [26]. Furthermore, the flavonoid content was found to be higher when the drying process was carried out at medium and high temperatures. As the sample is dried out, its dry matter content increases, for which the total flavonoid content tends to rise. On the other hand, the negative trend of TFC might be attributed to the heat sensitivity of the variable once it has reached its maximum value [14].

3.2.2. Effect of Drying Parameters on TAC

Table 2 presents the ANOVA findings for the total antioxidant capacity (TAC). A statistically significant correlation between model variables is denoted by a P-value below 0.05. A 5.92 F-value signifies a statistically significant model. Terms with P-values less than 0.05 are considered significant. The predicted and adjusted R^2 values of 0.8310 and 0.8349 are comparable. The R^2 of the response variable was 0.8419, signifying that the model accounted for 84.19% of the variability. The dependent variable can be enhanced by the implementation of the model. The regression model incorporating total flavonoid content is represented by Equation (3).

$$\begin{aligned} \text{Total Antioxidant} = & 206.3 + 5.7X_1 + 4.26X_2 - 6.81X_3 + 0.126X_1^2 \\ & + 0.02430X_2^2 + 0.235X_3^2 + 0.0967X_1X_2 - 0.360X_1X_3 \\ & + 0.0645X_2X_3 \end{aligned} \quad (3)$$

The data presented in **Table 2** demonstrates that the drying time has no significant impact on the TAC. On the other hand, the TAC is significantly impacted by the drying temperature as well as the sample thickness. **Figure 2** shows that the total antioxidant capacity of papaya increased as a consequence of the rise in temperature as well as the increase in drying time. However, when the thickness of the sample was increased, there was a significant decrease in the amount of TAC. On top of that, temperature exerted the greatest influence on total flavonoid content, followed by sample thickness, and then drying time. The reduction of moisture from the sample has enhanced the dry matter content, which is the cause of the increasing trends of TAC. There are a few more research on quince fruit and black rosehip fruit that have been published, and the findings are in agreement with those of the studies [11] [27].

3.2.3. Assessment of Model Adequacy

Figure 3 presents the residual analysis for both TFC and TAC, including the normal probability plot, the random distribution of residuals, and residuals versus observation order. For TFC, the values are close to a straight line (**Figure 3(a)**), ranging from -5 to 4 (**Figure 3(b)**), with the largest values observed at orders 5, 12, and 19 (**Figure 3(c)**). It indicates that the model accurately represents the data.

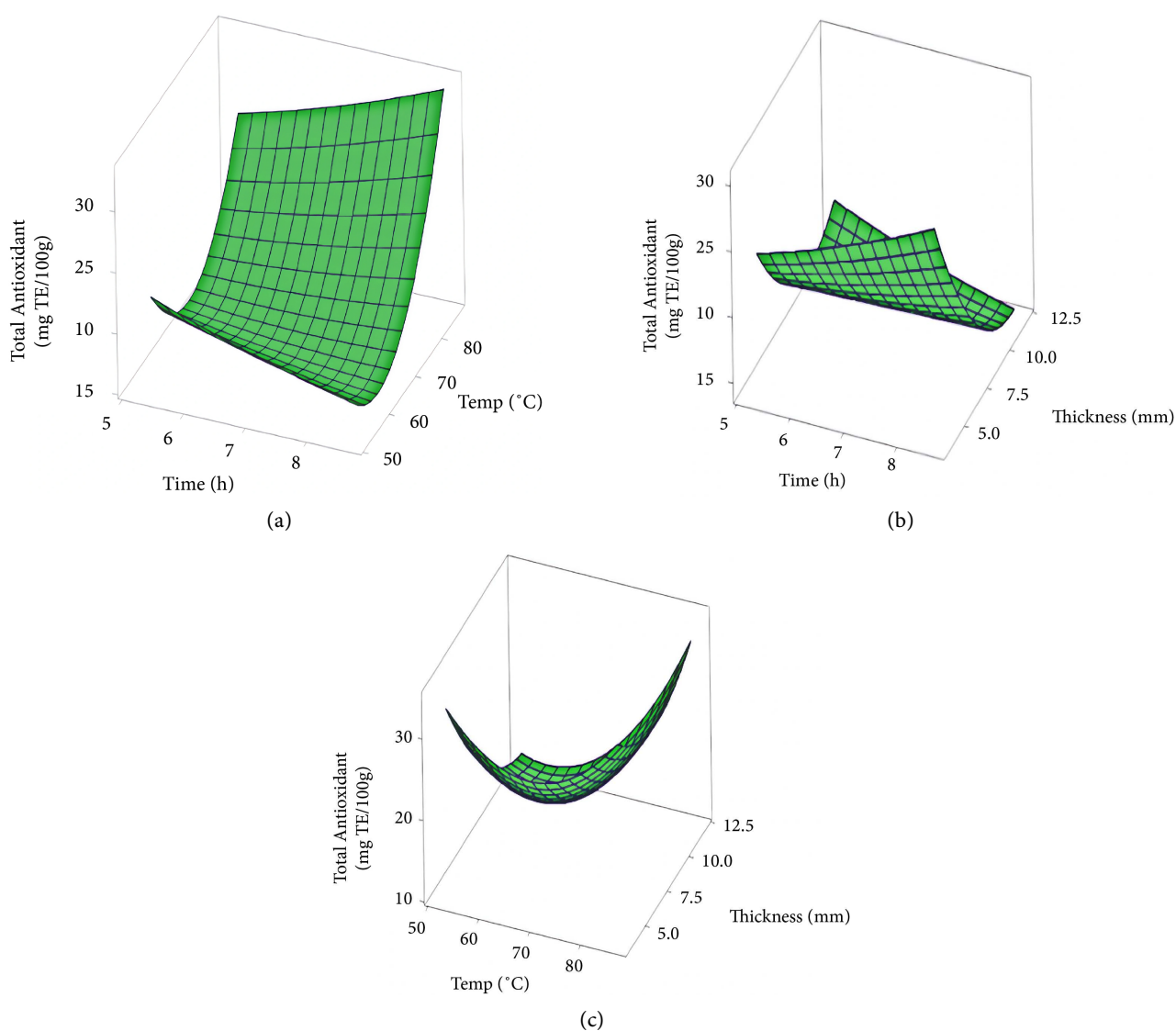
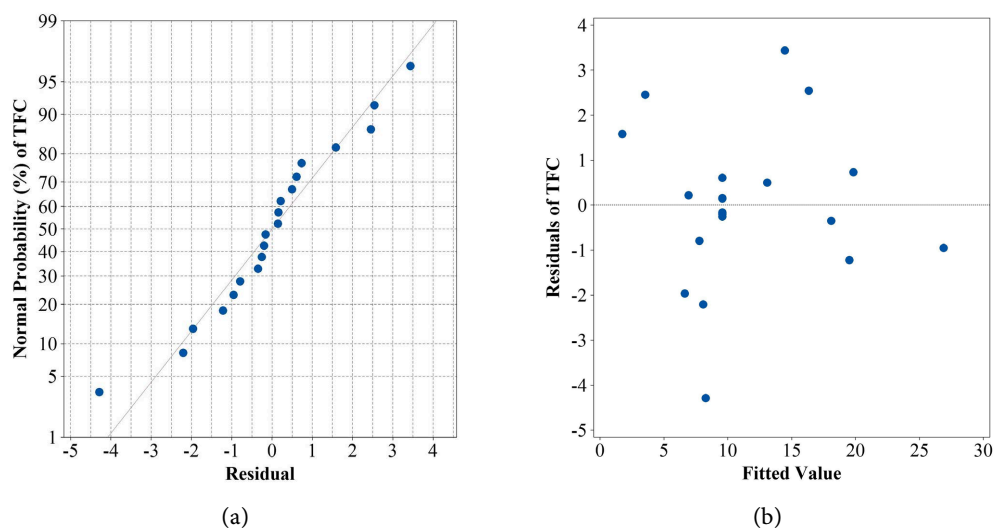


Figure 2. (a)-(c) 3D plots of the variation of TAC.



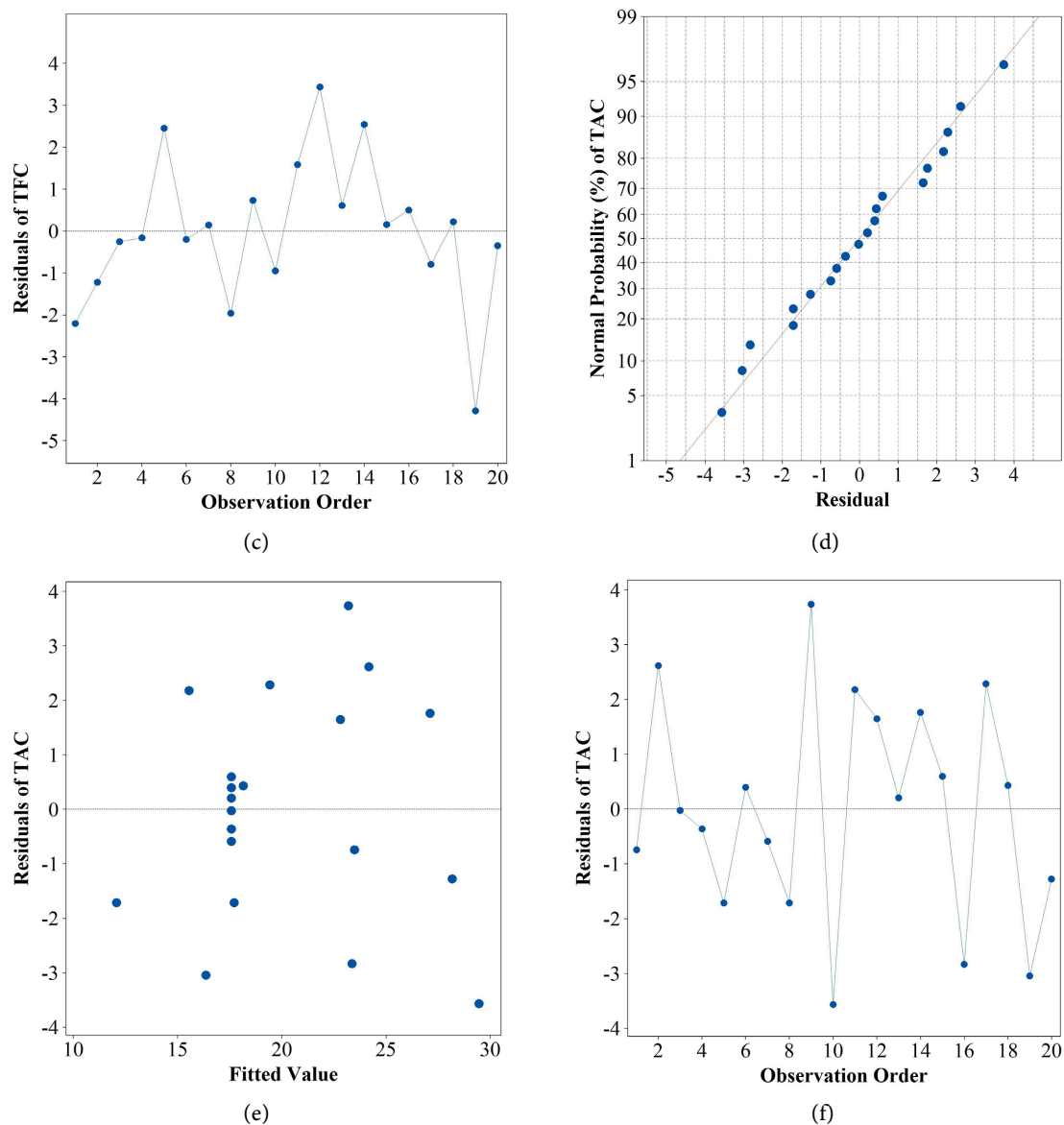


Figure 3. Residual plots for assessing the adequacy of the developed models: Normal probability versus residuals (a, d), residuals versus fitted values (b, e), and residuals versus observation order (c, f) for the total flavonoid content (TFC; a-c) and total antioxidant capacity (TAC; d-f).

Similarly, for TAC, the values approximate a linear trend (**Figure 3(d)**), ranging from -4 to 4 (**Figure 3(e)**), with the highest residuals at orders 9, 10, and 19 (**Figure 3(f)**). These mean the residuals are approximately normally distributed. It confirms the precision of the model. Overall, these plots demonstrate the suitability and reliability of the model in explaining the observed responses.

3.3. Optimization and Model Verification

The optimum drying conditions for papaya, which resulted in the highest flavonoid content and antioxidant content are shown in **Table 3**. These optimal conditions yield the highest possible value for the desired function, which was

achieved by numerical optimization. A composite desirability value close to 1 indicates that the chosen conditions are nearly ideal for achieving all objectives. The optimal drying conditions were found with a composite desirability of 0.796, which confirms that the optimized drying parameters provided an acceptable balance for retaining both flavonoid content and antioxidant capacity in dried papaya. The predicted optimum variables were time 7.64 h, temperature 80°C, and thickness 5 mm. The corresponding response variables were TFC 18.93 mg QE/100g and TAC 27.37 mg TE/100g. After that, a drying experiment was conducted using the optimum drying conditions 7.64 h, 80°C, and 5 mm. The desired response values yielded 19.17 ± 0.14 mg QE/100 g for TFC and 26.51 ± 0.25 mg TE/100 g for TAC, corresponding to errors of 1.25% and 3.2%, respectively. It was found that the experimental results are in good agreement with the predicted response value.

Table 3. Optimum drying conditions for the oven drying of papaya.

	Time X_1 (h)	Temp X_2 (°C)	Thickness X_3 (mm)	TFC (mg QE/100g) (db)	TAC (mg TE/100g) (db)	Composite Desirability
RSM	7.64	80	5	18.93	27.37	0.796
Experimental	7.64	80	5	19.17 ± 0.14	26.51 ± 0.25	--
Error (%)	-	-	-	1.25	3.2	--

4. Conclusion

The impact of drying conditions on the total flavonoid content and total antioxidant content of papaya slices was analysed using Response Surface Methodology. The results showed that increasing temperature significantly increased the total flavonoid content and total antioxidant content, while time had negligible impact. On the other hand, the values showed a substantial drop with an increase in sample thickness. It was observed that temperature had a significantly more pronounced influence on the quantity of TFC and TAC than any other factor. The quadratic model correctly represents the experimental data. The highest value of total flavonoid content and total antioxidant content was obtained when the papaya was dried for 7.64 hours at a temperature of 80°C and a thickness of 5 mm. The predicted response values closely correspond to the experimental findings, with the error 1.25% and 3.2% respectively, and a desirability score of 0.796. These findings provide more evidence supporting the precision of the RSM model. The model enables efficient prediction and optimization of TFC and TAC with reduced effort and resources. This research is expected to improve the food drying process. Moreover, the optimization technique can be used to determine the precise physical and chemical properties of dried papaya. Besides, dried papaya can be utilized in the production of a wide variety of value-added products, including instant beverages, paste, jam, jelly, and other similar items, which can be used for commercial purposes. In addition, the findings of this work may be of interest to

numerous food processing industries, which consider the utilization of dried papaya as an essential component in a variety of food product compositions. Although the present study successfully optimized drying parameters to preserve total flavonoid content and antioxidant capacity in papaya, future research may explore *in vivo* approaches or advanced gastrointestinal simulation models to examine flavonoid bioavailability and gut microbiota mediated metabolism, which could offer deeper insight into the physiological relevance and health-promoting potential of dried papaya products.

Acknowledgements

The authors would like to acknowledge the Department of Physical and Mathematical Sciences and the Department of Food Processing and Engineering, Faculty of Food Science and Technology, Chattogram Veterinary and Animal Sciences University (CVASU), for providing laboratory support for computational and experimental work. The authors also acknowledge Minitab, LLC for providing a trial version of the statistical software Minitab.

Declaration of AI-Assisted Technologies in Writing

AI-assisted technologies were used in the writing process to improve the readability and language of the manuscript.

Funding Statement

This research was carried out under the project “*Modeling and Optimization of Process Parameters for Drying of Fruit using Response Surface Methodology*”, funded by the University Grants Commission of Bangladesh (Grant no. 37.01.0000.073.07.037.22.969).

Author Contributions

Ferdusee Akter: Conceptualization, Methodology, Software, Resources, Project administration, Funding acquisition, Investigation, Formal analysis, Data curation, Validation, Writing—original draft, review & editing. **Afia Nawar:** Investigation, Analysis, Data curation, Writing—original draft, review & editing. **Suresh Chakma:** Sample Collection, Investigation, Data curation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Gomes, W.F., França, F.R.M., Denadai, M., Andrade, J.K.S., da Silva Oliveira, E.M., de Brito, E.S., *et al.* (2018) Effect of Freeze- and Spray-Drying on Physico-Chemical Characteristics, Phenolic Compounds and Antioxidant Activity of Papaya Pulp. *Journal of Food Science and Technology*, **55**, 2095-2102.
<https://doi.org/10.1007/s13197-018-3124-z>

- [2] Kaur Dhillon, G., Kour, A. and Gupta, N. (2022) Optimization of Low-Cost Drying Technology for Preservation of Peach (*Prunus persica*) Using RSM. *International Journal of Fruit Science*, **22**, 525-538. <https://doi.org/10.1080/15538362.2022.2070576>
- [3] Kopustinskiene, D.M., Jakstas, V., Savickas, A. and Bernatoniene, J. (2020) Flavonoids as Anticancer Agents. *Nutrients*, **12**, Article No. 457. <https://doi.org/10.3390/nu12020457>
- [4] Panche, A.N., Diwan, A.D. and Chandra, S.R. (2016) Flavonoids: An Overview. *Journal of Nutritional Science*, **5**, e47. <https://doi.org/10.1017/jns.2016.41>
- [5] Stachelska, M.A., Karpiński, P. and Kruszewski, B. (2025) A Comprehensive Review of Biological Properties of Flavonoids and Their Role in the Prevention of Metabolic, Cancer and Neurodegenerative Diseases. *Applied Sciences*, **15**, Article No. 10840. <https://doi.org/10.3390/app151910840>
- [6] Gulcin, İ. (2020) Antioxidants and Antioxidant Methods: An Updated Overview. *Archives of Toxicology*, **94**, 651-715. <https://doi.org/10.1007/s00204-020-02689-3>
- [7] Khan, H., Ullah, H., Martorell, M., Valdes, S.E., Belwal, T., Tejada, S., *et al.* (2021) Flavonoids Nanoparticles in Cancer: Treatment, Prevention and Clinical Prospects. *Seminars in Cancer Biology*, **69**, 200-211. <https://doi.org/10.1016/j.semcancer.2019.07.023>
- [8] Gayosso-García Sancho, L.E., Yahia, E.M. and González-Aguilar, G.A. (2011) Identification and Quantification of Phenols, Carotenoids, and Vitamin C from Papaya (*Carica papaya* L., cv. Maradol) Fruit Determined by HPLC-DAD-MS/MS-ESI. *Food Research International*, **44**, 1284-1291. <https://doi.org/10.1016/j.foodres.2010.12.001>
- [9] Akter, F., Akther, S., Sultana, A., Rahman, M.M. and Deb, U.K. (2022) Optimization of Drying Parameters for Total Phenolic Content of Papaya Using Response Surface Methodology. *International Journal of Food Science*, **2022**, Article ID: 4819725. <https://doi.org/10.1155/2022/4819725>
- [10] Vij, T. and Prashar, Y. (2015) A Review on Medicinal Properties of *Carica papaya* Linn. *Asian Pacific Journal of Tropical Disease*, **5**, 1-6. [https://doi.org/10.1016/s2222-1808\(14\)60617-4](https://doi.org/10.1016/s2222-1808(14)60617-4)
- [11] Pashazadeh, H., Ali Redha, A. and Koca, I. (2024) Effect of Convective Drying on Phenolic Acid, Flavonoid and Anthocyanin Content, Texture and Microstructure of Black Rosehip Fruit. *Journal of Food Composition and Analysis*, **125**, Article ID: 105738. <https://doi.org/10.1016/j.jfca.2023.105738>
- [12] Nowacka, M., Matys, A. and Witrowa-Rajchert, D. (2024) Innovative Technologies for Improving the Sustainability of the Food Drying Industry. *Current Food Science and Technology Reports*, **2**, 231-239. <https://doi.org/10.1007/s43555-024-00026-8>
- [13] Asrate, D.A. and Ali, A.N. (2025) Review on the Recent Trends of Food Dryer Technologies and Optimization Methods of Drying Parameters. *Applied Food Research*, **5**, Article ID: 100927. <https://doi.org/10.1016/j.afres.2025.100927>
- [14] Nemzer, B., Vargas, L., Xia, X., Sintara, M. and Feng, H. (2018) Phytochemical and Physical Properties of Blueberries, Tart Cherries, Strawberries, and Cranberries as Affected by Different Drying Methods. *Food Chemistry*, **262**, 242-250. <https://doi.org/10.1016/j.foodchem.2018.04.047>
- [15] Patil, S.S., Varghese, E., Rudra, S.G. and Kaur, C. (2016) Effect of Extrusion Processing on Phenolics, Flavonoids and Antioxidant Activity of Millets. *International Journal of Food and Fermentation Technology*, **6**, Article No. 177. <https://doi.org/10.5958/2277-9396.2016.00040.4>
- [16] Kumar, D., Prasad, S. and Murthy, G.S. (2014) Optimization of Microwave-Assisted

- Hot Air Drying Conditions of Okra Using Response Surface Methodology. *Journal of Food Science and Technology*, **51**, 221-232.
<https://doi.org/10.1007/s13197-011-0487-9>
- [17] Abano, E.E., Ma, H. and Qu, W. (2014) Optimization of Drying Conditions for Quality Dried Tomato Slices Using Response Surface Methodology. *Journal of Food Processing and Preservation*, **38**, 996-1009. <https://doi.org/10.1111/jfpp.12056>
- [18] Chen, J., Wu, W., Cheng, R., Jin, Y. and Liu, Z. (2020) Optimization of Hot Air Drying Process of Corn Using Genetic Algorithm and Response Surface Methodology. *International Journal of Food Properties*, **23**, 753-764.
<https://doi.org/10.1080/10942912.2020.1754233>
- [19] Olmos, A., Trelea, I.C., Courtois, F., Bonazzi, C. and Trystram, G. (2002) Dynamic Optimal Control of Batch Rice Drying Process. *Drying Technology*, **20**, 1319-1345.
<https://doi.org/10.1081/drt-120005855>
- [20] Majdi, H., Esfahani, J.A. and Mohebbi, M. (2019) Optimization of Convective Drying by Response Surface Methodology. *Computers and Electronics in Agriculture*, **156**, 574-584. <https://doi.org/10.1016/j.compag.2018.12.021>
- [21] Montgomery, D.C. (2017) Design and Analysis of Experiments. John Wiley & Sons.
- [22] Unal, K., Susanti, D. and Taher, M. (2014) Polyphenol Content and Antioxidant Capacity in Organically and Conventionally Grown Vegetables. *Journal of Coastal Life Medicine*, **2**, 864-871.
- [23] Chang, C.-C., Yang, M.-H., Wen, H.-M. and Chern, J.-C. (2002) Estimation of Total Flavonoid Content in Propolis by Two Complementary Colometric Methods. *Journal of Food and Drug Analysis*, **10**, Article No. 3.
<https://doi.org/10.38212/2224-6614.2748>
- [24] Azlim Almey, A., Ahmed Jalal Khan, C., Syed Zahir, I., Mustapha Suleiman, K., Aisyah, M.R. and Kamarul Rahim, K. (2010) Total Phenolic Content and Primary Antioxidant Activity of Methanolic and Ethanolic Extracts of Aromatic Plants' Leaves. *International Food Research Journal*, **17**, 1077-1084.
- [25] Tuteja, S., Mondal, I.H. and Dash, K.K. (2024) Conductive Hydro Drying of Ripened Papaya: Optimization and Product Characterization. *Food Science and Biotechnology*, **33**, 2571-2584. <https://doi.org/10.1007/s10068-024-01526-y>
- [26] Wang, Z., Liang, Y., Wu, W., Gao, C., Xiao, C., Zhou, Z., et al. (2024) The Effect of Different Drying Temperatures on Flavonoid Glycosides in White Tea: A Targeted Metabolomics, Molecular Docking, and Simulated Reaction Study. *Food Research International*, **190**, Article ID: 114634. <https://doi.org/10.1016/j.foodres.2024.114634>
- [27] Maghsoudlou, Y., Asghari Ghajari, M. and Tavasoli, S. (2019) Effects of Heat Treatment on the Phenolic Compounds and Antioxidant Capacity of Quince Fruit and Its Tisane's Sensory Properties. *Journal of Food Science and Technology*, **56**, 2365-2372.
<https://doi.org/10.1007/s13197-019-03644-6>