



Development and Characterization of Functional Cookies Fortified with Pomegranate Seed Powder and Jackfruit Seed Flour

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Abstract: The food industry produces a large volume of waste, much of which remains underutilized, with most being disposed of in landfills. To address this issue and boost nutritional value, this study developed cookies enriched with jackfruit seed flour and pomegranate seed powder, which are byproducts of food processing. The cookies were assessed for sensory properties using a 9-point hedonic scale and evaluated for their antioxidant content, total phenolic content, and sensory acceptability. Statistical analysis was performed using ANOVA (Data Expert version 13). Findings revealed that the optimized cookies had higher levels of moisture (1.7%), ash (2.3%), fat (19.1%), fiber (1%), and protein (1.57%) but lower energy content (480.14 kcal) than control cookies. The antioxidant capacity was also significantly enhanced in the optimized cookies, with increased total phenolic content (TPC 9.256 mg GAE/100g), total flavonoid content (TFC 0.196 mg QE/gm), and DPPH activity (32.514%). Texture analysis showed that less force was required to break the optimized cookies, indicating a crisper texture than control cookies. This research offers a sustainable solution to reducing food waste by incorporating nutrient-dense byproducts into cookies, providing a novel method for enhancing the nutritional profile of baked goods.

Keywords: Jackfruit seed flour, pomegranate seed powder, antioxidant properties, total phenolic content, cookie formulation, texture analysis, sensory evaluation.

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1. Introduction

The increasing global demand for food has led to a corresponding rise in food production, which generates a significant amount of waste and byproducts.

A substantial portion of this waste ends up in landfills, contributing to environmental pollution and resource wastage. However, a growing emphasis on sustainability and resource conservation has prompted efforts to explore alternative uses for food industry byproducts, transforming them from waste into valuable ingredients. By recycling and valorizing these byproducts, the food industry has the potential to mitigate waste while developing nutrient-rich, functional food products (Temkov *et al.*, 2021).

In this context, byproducts such as jackfruit seeds and pomegranate seeds present an opportunity for sustainable food innovation. Pomegranate seeds are renowned for their high antioxidant and phenolic content, while jackfruit seeds, which are frequently thrown away during fruit processing, are rich in protein, carbohydrates, and dietary fibre (Mateescu *et al.*, 2020). Jackfruit seeds make up more than 15% of the fruit's total weight, making them an important byproduct (Akter *et al.*, 2018). This has a light brown colour and is shaped like an oval, oblong ellipsoid, or spherical. This has a diameter of 1 to 1.5 cm and a length of 2-3 cm. A single jackfruit can contain anywhere between 500 and 550 seeds. Some pasting and antioxidant qualities are present in jackfruit seeds (Tulyathan *et al.*, 2002). Due to the increased nutritional value of jackfruit seeds, they are increasingly employed in bread and other baked goods by combining 10-20% jackfruit seed flour with wheat flour to help with digestion and lower the gluten level because jackfruit is very seasonal and its seeds spoil quickly, they are wasted when there is a seasonal abundance. Jackfruit seeds have a 22% starch content and a 3.19% dietary fibre content. Its phytonutrients, which include lignans, isoflavones, saponins, and antioxidants, have a wide range of health benefits, including anticancer, antihypertensive, antiaging, and antiulcer properties. The contents of jackfruit seeds in terms of protein and carbohydrates are 13.50% and 79.34%, respectively (Anil *et al.*, 2019). Due to the fact that the seeds were gathered from various regions, where samples have somewhat varying nutritional contents, the protein amount is significantly diverse. From these fruits, one can isolate a variety of triterpenes and flavonoids in addition to alkaloids, phenols, tannins, saponins, and steroids (Mandave *et al.*, 2018). The calcium content of the jackfruit seed is extremely high at 3087 mg/kg, iron is 130.74 mg/kg, potassium is 14781 mg/kg, sodium is 60.66 mg/kg, copper is 10.45 mg/kg, and manganese is 1.12

mg/kg. There is 1.12% lactic acid and 5.78 pH and titratable acidity levels (Anil *et al.*, 2019). Incorporating these nutrient-dense byproducts into food products not only reduces waste but also enhances the nutritional profile of the final product (Ayoubi *et al.*, 2022). Cookies, one of the most popular baked goods globally, offer an ideal platform for the incorporation of these functional ingredients. This study aims to develop cookies enriched with jackfruit seed flour and pomegranate seed powder, focusing on improving their nutritional and functional properties while maintaining consumer acceptability. The cookies will be evaluated for their sensory characteristics, antioxidant activity, total phenolic content, and texture properties to determine the effectiveness of these byproducts in enhancing the overall quality of the product.

Through this research, we aim to offer a novel and sustainable approach to food product development, contributing to waste reduction and the promotion of healthier, more nutritious baked goods. The current study's goal is to create nutrient-dense cookies by combining pomegranate seed flour (PSF) and jackfruit seed flour (JSF) and assessing the cookies' proximate composition, antioxidant qualities, textural characteristics, and sensory analysis.

2. Material and Method

2.1. Materials

The pomegranate seed powder and jackfruit seed flour were used in accordance with the experimental design after being bought from online retailers Flipkart and Amazon.

2.2. Cookies Preparation

The study was conducted at the University of Allahabad's Centre of Food Technology. Additional ingredients used in cookies preparation such as; Refined wheat flour, Granulated sugar, Hydrogenated fat and baking powder were sourced from local market in Katra, Prayagraj.

2.3. Standard Recipe for Cookie Preparation

Cookies were prepared using a basic formulation consisting of 100 g refined flour of wheat, 50 g sugar, 75 g oil (hydrogenated), 5 g skim powdered

milk, and 0.5 g baking powder. The local market provided all of the raw ingredients. The preparation process involved sifting the refined wheat flour and baking powder together, followed by creaming of hydrogenated fat and sugar until a light, fluffy consistency was achieved. To create a homogenous dough, the sifted dry ingredients and skim milk powder were added gradually. After being properly shaped and proportioned, the dough was baked for 20 minutes at 150°C in a preheated oven. The cookies were left to cool at room temperature after baking and kept in sealed receptacles to preserve quality.

2.4. Formulated Recipe for Cookies Preparation

Pomegranate seed powder (PSP) was also used to partially replace refined wheat flour and jackfruit seed flour used in the creation of cookie (Table 1). The base recipe remained the same as the standard formulation. (Fig.1(a))

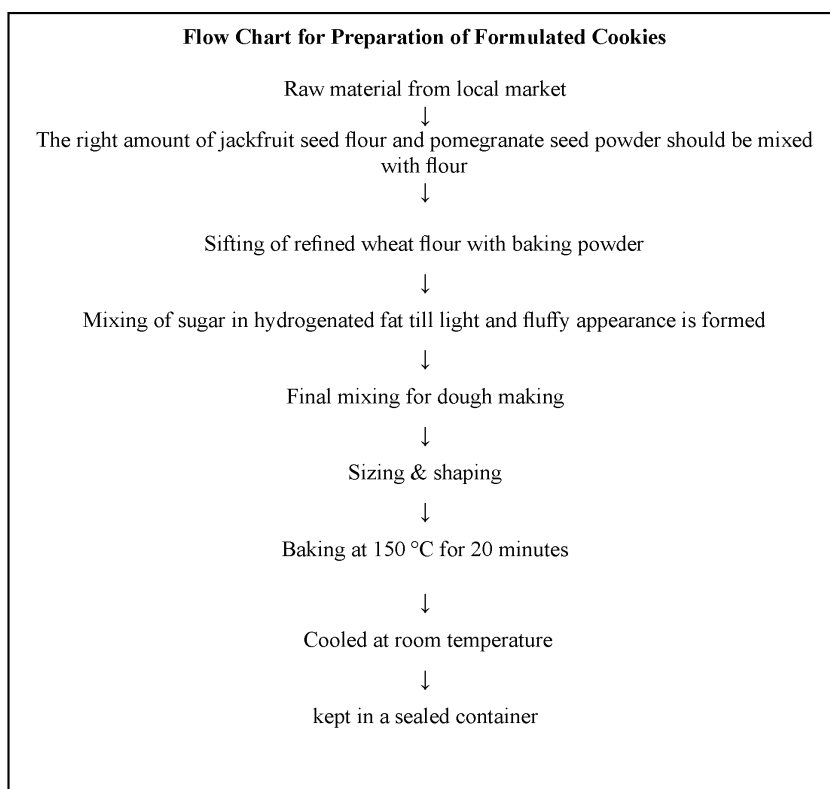


Figure 1(a): Flow chart for preparation of formulated cookies
(HN Ayo-Omogie et al., 2023)

Table 1: Experimental ranges and levels of independent variables used in RSM in terms of actual and coded factors

Run	Factor 1 A: PSF	Factor 2 B: JSF	Response 1: Flavour	Response 2: Colour	Response 3: Texture	Response 4: Over all acceptability	Response 5: Ash (%)	Response 6: TPC (mgGAE /100g)	Response 7: TFC (mgQE/g)	Response 8: DPPH (%)	Response 9: FORCE (Newton)
R- 121	8.53553	32.5	6.91	7.11	7.16	7	2.3	12.5	0.57	31.34	48.115
R- 122	5	32.5	8	7.75	7.95	8.2	2	8.1	0.184	30.299	33.978
R- 123	7.5	25	7.29	7.25	7.08	6.54	1	5.0	0.031	11.2	36.764
R- 124	5	43.1066	7	7.37	6.87	7.37	2.5	12.6	0.115	33.597	59.93
R- 125	7.5	40	6.75	6.91	6.87	6.75	3	12.8	0.018	32.65	46.698
R- 126	2.5	40	7.04	7.16	7.33	7.5	1.8	8.3	0.011	31.28	50.7
R- 127	5	32.5	8	7.75	7.95	8.2	2	8.1	0.184	30.299	33.97
R- 128	5	21.8934	7.4	7.29	7.62	7.45	1	5.3	0.292	18.3	33.454
R- 129	5	32.5	8	7.75	7.95	8.2	2	8.1	0.184	30.299	33.978
R- 130	5	32.5	8	7.75	7.95	8.2	2	8.1	0.184	30.299	33.978
R- 131	2.5	25	7.2	7.41	7.25	7.37	0.8	4.95	0.022	8.6	37.245
R- 132	5	32.5	8	7.75	7.95	8.2	2	8.1	0.184	30.299	33.978
R- 133	1.46447	32.5	7.45	7.62	7.66	7.3	1.5	5.1	0.159	10.2	46.37

*Coded value of JSF, **Coded value of PSF = Control, OAA*** = Overall acceptability

2.5. Experimental design

Response Surface Methodology (RSM) was used to optimise pomegranate seed powder (A; 7.5g–12.5g) and jackfruit seed flour (B; 40g–25g) at various levels. Preliminary laboratory testing was used to determine the amounts of these factors. The effects of A (jackfruit seed flour quantity) and B (pomegranate seed powder quantity) on the cookies' flavour, colour, texture, overall acceptability, Ash, TPC, TFC, DPPH, and force were evaluated using a Central Composite Rotatable Design. Thirteen experiments in all were conducted, with five major points being repeated as shown in Table 1. Fig. 1(b) presents images of the various cookie samples from the thirteen runs. Each experiment was conducted in duplicate using independently prepared samples. Design Expert software (version 7.0.0) was used to analyse the data using the least squares approach and a generalised second-degree polynomial (Equation 1).

$$Y = \beta_0 - \beta_1 A + \beta_2 B + \beta_3 AB + \beta_4 A^2 + \beta_5 B^2 + C \quad (\text{Equation 1})$$

β_0 (constant term), β_1 , β_2 , β_3 , β_4 (linear terms), β_{11} , β_{22} , β_{33} (quadratic terms), and β_{12} , β_{13} , β_{23} (interactive terms) were the coefficients of the polynomial models. The regression equation was used to generate the predicted values, which were then examined for standard error (SE) and coefficient of determination (R^2). To determine the importance of each coefficient, an ANOVA technique was used to analyse the regression models' coefficients. The F ratio and the coefficient of determination (R^2) were used to assess the model's suitability. Moreover, the disparity was deliberate.

When the F-calculated value exceeded the table F-value, the model was deemed suitable. The R^2 score exceeded 70%. At the 1, 5, and 10% confidence levels, the factors' quadratic level significance on the individual response was provided. The magnitude and sign of the coefficients demonstrated how much variance depended on increasing or decreasing the response depending on the positive or negative sign of the coefficient terms.

For every response, response surface plots were created using second order polynomial models, with the two processing variables at the centre. The interaction between two factors and the responses was determined using the response surface. Different limitations were set for the independent and dependent variables based on their relative importance. The fitted

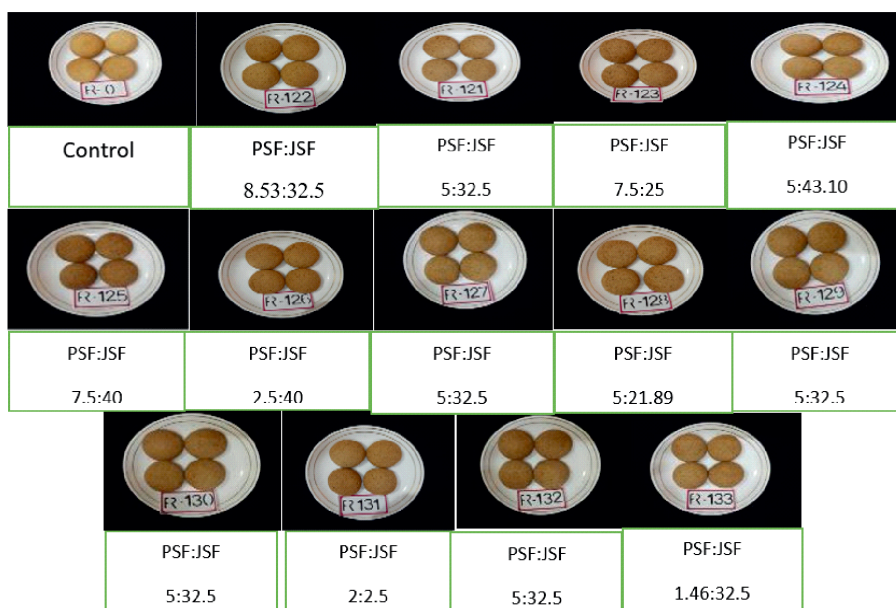


Figure 1(b): Image of Cookies prepared from different formulations of pomegranate seed powder & jackfruit seed

polynomials were optimised using a desired function. To verify the ideal situation, experiments were carried out at the variables' anticipated values. Responses were tracked, and the outcomes were contrasted with the predictions of the model, as described by (Kushwaha *et al.*, 2023). For comparison of optimized sample, control sample of cookies was also prepared from refined wheat flour without adding pomegranate seed powder and jackfruit seed flour.

2.6. Proximate composition

Standard methods were followed in order to ascertain the proximate composition of the raw components and the prepared cookies. As described by AOAC (2019), the Association of Official Analytical Chemists. Moisture content, crude protein, crude fat, ash, and crude fibre were among the variables assessed. By deducting the total amount of moisture, protein, fat, ash, and fibre from 100%, the carbohydrate content was determined. These evaluations offered crucial information about the nutritional characteristics of the final baked cookie goods and the raw components (jackfruit seed flour and pomegranate seed powder).

2.7. Statistical analysis

All experimental trials were conducted in triplicate, and the results were expressed as mean values \pm standard deviation (SD) to ensure data reliability. SPSS software (Version 16.0; SPSS Inc., Chicago, IL, USA) was used for statistical analysis. To discover significant differences among treatments, the data were subjected to one-way Analysis of Variance (ANOVA). Duncan's Multiple Range Test (DMRT) was used for post-hoc comparisons. Statistical significance was considered at a confidence level of $p < 0.05$. (Kushwaha *et al.*, 2023)

2.8. Sensory analysis

Sensory evaluation of the freshly baked formulated cookies was conducted by a semi-trained panel comprising 30 individuals, including research scholars and staff members aged 22 to 45 years, from the Centre of Food Technology, University of Allahabad. The evaluation was carried out using a 9-point hedonic scale, following the procedure described by Rangana (2025). Panelists were instructed to rate the cookies based on key sensory attributes such as appearance, colour, flavour, texture, and overall acceptability, using a score from 1 (dislike extremely) to 9 (like extremely), with higher scores indicating greater preference.

2.9. Functional properties

2.9.1. Bulk Density

The method outlined by (Hettiarachch *et al.*, 2023) was used to measure bulk density. About 10 grammes of the sample was put in a graduated cylinder with a capacity of 25 ml and gently tapped until the volume stabilised. The bulk density was determined as

$$\text{Bulk Density (\%)} = \frac{\text{Weight of the sample (g)}}{\text{Volume of the sample (ml)}}$$

2.9.2. Oil absorption capacity

Oil absorption capacity was determined according to (Omogie, 2023). 1 g of sample was mixed with 10 ml of refined vegetable oil in a centrifuge tube, held at room temperature for 30 minutes, and centrifuged at 3500 rpm for

25 minutes. The supernatant was decanted, and adhesive oil was removed. OAC was calculated using:

$$\text{OAC (\%)} = (\text{Weight of absorbed oil (g)} / \text{Weight of the sample (g)}) \times 100$$

2.9.3. Water absorption capacity

Water absorption capacity was evaluated using the method of (Omogie, 2023). 1 g of sample was mixed with 10 ml of distilled water, held at room temperature for 30 minutes, and centrifuged at 3500 rpm for 25 minutes. After decanting the supernatant, WAC was calculated as:

$$\text{WAC (\%)} = (\text{Weight of absorbed water (g)} / \text{Weight of the sample (g)}) \times 100$$

3. Antioxidant properties

The antioxidant properties were analysed for raw ingredients including pomegranate seed powder, jackfruit seed flour, refined wheat flour, and all prepared cookie samples, including the control. With minor adjustments, the procedure outlined by (Edet *et al.*, 2023) was used to extract antioxidant components. In short, 10 millilitres of 50% methanol were used to dissolve 1 gramme of the sample, which was then allowed to sit at room temperature for a whole day. Following that, the mixture was centrifuged for 15 minutes at 2500 rpm. Whatman filter paper was used to filter the supernatant, which was then refrigerated for a later antioxidant study.

3.1. Estimation of DPPH Radical Scavenging Activity

The technique suggested by Haji *et al.* (2024) was used to measure the DPPH radical scavenging activity. 2 ml of a 0.15 mM methanolic DPPH solution was combined with 3 ml of the sample extract. A UV/VIS spectrophotometer was used to detect the absorbance at 515 nm following a 15-minute room temperature incubation period. The blank was made of methanol and the control was a DPPH solution without a sample.

3.2. Estimation of Total Phenolic Content

The total phenolic content of the extracts was estimated using the folin Ciocalteu reagent in accordance with the method of (Losoya Sifuentes *et al.*, 2023). Four millilitres of 7.5% sodium carbonate solution, five millilitres

of diluted Folin-Ciocalteu reagent, and one millilitre of extract were combined. The solution was thoroughly mixed and then allowed to sit at room temperature for an hour in the dark. The absorbance was measured at 765 nm using an Evolution 600 UV/VIS spectrophotometer. Using a gallic acid standard curve, the results were reported in milligrammes of gallic acid equivalents (GAE) per 100 grammes of material.

3.3. Estimation of Total Flavonoid Content

The method of (Felisiak *et al.*, 2024) was used to calculate the total flavonoid content. One millilitre of 1 M NaOH, 150 microlitres of 10% AlCl₃, and 1.2 millilitres of distilled water were added to two millilitres of methanolic extract. Following a 10-minute pause, the mixture was well agitated, and absorbance at 510 nm was measured.

4. Texture analysis

The textural properties of the cookie samples were evaluated using a TA-XT2i Texture Analyzer (Stable Microsystems, UK), following the standard protocol outlined by AACC Method 74-09 (AACC, 2010). A cube measuring 2 cm × 2 cm × 2 cm was taken from the center of each cookie sample and positioned beneath a P/36 cylindrical probe (36 mm diameter) to ensure a uniform flat surface for compression. A 5 kg load cell was employed to compress each sample to 45% of its original height. The test conditions were set with a pre-test speed of 1.0 mm/s, test speed of 1.7 mm/s, and post-test speed of 10 mm/s, with the trigger force set at 5 g in auto mode. Parameters such as hardness, adhesiveness, springiness, cohesiveness, gumminess, and chewiness were recorded. Data analysis was performed using Texture Expert software (Version 1.05), and each result represents the mean of three independent replicates.

5. Results and Discussion

5.1. Proximate analysis of refined wheat flour (RWF), jackfruit seed flour (JSF), and pomegranate seed powder (PSP)

The moisture, ash, protein, fat, fibre, carbohydrate, and calorie content of pomegranate seed powder were 9.46%, 2.34%, 3.39, 1%, 16.67%, 83.80%, and 357.8 kcal, respectively; jackfruit seed flour's were 9.8%, 2.67%, 2.12%,

0.67%, 6.34%, 84.74%, and 353.46 kcal; and refined wheat flour were 9.27%, 0.82%, 0.37%, 1.47%, 11.5%, 64.72%, and 401 kcal respectively (Table 2(a)). Pomegranate seed powder and jackfruit seed flour were shown to be greater sources of minerals, protein, fibre, and carbohydrates than refined wheat flour, according to the results of proximate analysis. These findings are comparable to those of a study conducted in 2018 by Abiola *et al.* on pomegranate seed powder (6–94% moisture, 27–43% crude fibre). Crude ash is 1-2%, crude protein is 4-15%, fat is 11-26%, and carbohydrates are 12-25%. Similar findings were found by (Chhotaray *et al.*, 2022) for jackfruit seed flour, which has a calorific value of 356 kcal/100 g and contains 1% moisture, 2% fat, 2% ash, 80% carbs, and 14% protein.

Table 2(a) : Proximate analysis of pomegranate seed powder (PSP), jackfruit seed flour (JSF) & refined wheat flour (RWF)

Concentration	Factor 1 A: PSF	Factor 2 B: JSF	Factor 3 C: RWF
Moisture (%)	9.46 ± 0.23 ^a	9.8 ± 0.721 ^a	9.27 ± 0.46 ^a
Ash (%)	2.34 ± 0.288 ^a	2.67 ± 0.288 ^b	0.82 ± 0.1 ^c
Protein (%)	3.39 ± 0.609 ^a	2.12 ± 0.15 ^b	0.37 ± 0.8 ^c
Fat (%)	1 ± 0.5 ^a	0.67 ± 0.288 ^b	1.47 ± 0.7 ^b
Fibre (%)	16.67 ± 2.081 ^a	6.34 ± 2.565 ^b	11.5 ± 0.1 ^c
Carbohydrate (%)	83.8 ± 0.646 ^a	84.74 ± 0.628 ^b	64.72 ± 1.2 ^c
Energy (kcal)	357.8 ± 4.423 ^a	353.46 ± 2.236 ^b	401 ± 3.1 ^c

5.2. Functional Properties of pomegranate seed powder (PSP) & jackfruit seed flour (JSF) & refined wheat flour (RWF)

According to Table 2(b), PSF had higher total phenolic content and DPPH (30.169 mg GAE/100g, 90.016%), while JSF had higher total flavonoid content (1.955 mg QE/gm) than PSF and RWF. The cookies' antioxidant activity rose as the amount of pomegranate seed powder added increased. (Terdal *et al.*, 2022).

5.3. Antioxidant Properties of pomegranate seed powder (PSF) & jackfruit seed flour (JSF) & refined wheat flour (RWF)

Table 2(c) showed that Total phenolic content and DPPH was found to be higher in PSF 30.169 mg GAE /100g, 90.016 % respectively, while Total

Table 2(b): Functional Properties of pomegranate seed powder (PSF) & jackfruit seed flour (JSF) & refined wheat flour (RWF)

Concentration	Factor 1 A: PSP	Factor 2 B: JSF	Factor 3 C: RWF
Bulk density %	20.266 ± 0.057 ^a	10.433 ± 0.115 ^b	0.68 ± 0.00 ^c
Oil Absorption Capacity%	140.666 ± 1.154 ^a	147.666 ± 0.577 ^b	120.25 ± 0.03 ^c
Water Absorption capacity	129 ± 1.732 ^a	168.333 ± 0.577 ^b	125.38 ± 0.10 ^c

flavonoid content was found to be higher in JSF 1.955 mg QE/gm, than PSF and RWF. Antioxidant activity of the cookies was increased with the increasing level of incorporation of pomegranate seed powder (Terdal *et al.*, 2022).

Table 2(c): Antioxidant Properties of pomegranate seed powder (PSF) & jackfruit seed flour (JSF) & refined wheat flour (RWF)

Concentration	Factor 1 A: PSF	Factor 2 B: JSF	Factor 3 C: RWF
TPC (mg GAE /100g)	30.169 ± 0.212a	13.247± 0.435b	11.46±0.2c
TFC (mg QE/gm)	1.278 ± 0.019a	1.955± 0.052a	1.028± 0.21a
DPPH (%)	90.016 ± 0.309a	22.271± 0.253b	19.6± 0.32c

5.4. Optimization and characterization of developed cookies

From the solutions obtained from the RSM in design expert software one solutions with variation of PSP 5g & JSF 32.5g is used to make cookie sample in triplicates and analysed for sensory evaluation and antioxidant properties. The results of experimental values are compared with predicted values from RSM are given in Table 1. It was observed that experimental values are found to be more than predicted values for each parameter with desirability 1.00, therefore combination of PSP 5g & JSF 32.5g is found to be optimized for the development of PSP & JSF incorporated cookies. (Table 3(a),(b))

Table 3(a): ANOVA analysis of the response data

CHARACTERS									
Source	Flavour	Colour	Texture	Over all acceptability	Ash (%)	TPC (mg GAE /100g)	TFC (mgQE/g)	DPPH (%)	FORCE (Newton)
Model SS	2.68	0.9154	2.04	3.91	3.70	90.94	0.0814	915.70	834.27
Model DF	5	5	5	5	5	5	5	5	5
Mean MS	0.5364	0.1831	0.4088	0.7812	0.7404	18.19	0.0163	183.14	166.85
Std.. Deviation	0.1005	0.1354	0.1626	0.2097	0.0624	0.9953	0.1413	4.77	3.04
Mean	7.46	7.45	7.51	7.56	1.89	8.23	0.1845	25.28	40.7
F- value	53.05	9.98	15.46	17.76	190.19	18.36	0.8147	8.06	18.08
P- value	<0.000	0.0044	0.0012	0.0007	<0.0001	0.0007	0.5749	0.0081	0.0007
R2	0.9743	0.877	0.917	0.9269	0.9927	0.9292	0.3679	0.8520	0.9281
R ² Adjusted	0.7892	0.7892	0.8577	0.8748	0.9875	0.8785	-0.0837	0.7463	0.8768
Lack of Fit	0.0236	0.0428	0.0617	0.1026	0.0091	2.31	0.0466	53.02	21.53

Table 3(b): Regression coefficient for the second-order polynomial equation that shows how answers and cookie process factors are related

Variables	Intercept	A	B	AB	A ²	B ²
Flavour	-1.73128	0.8205	0.5011	-0.005	-0.07	-0.008
Colour	7.75	-0.141	-0.06	-0.023	-0.234	-0.251
Texture	7.95	-0.167	-0.149	-0.073	-0.319	-0.401
Over all acceptability	8.2	-0.251	0.0284	0.02	-0.585	-0.455
Ash (%)	2.00	0.2289	0.5527	0.4250	-0.0500	-0.1250
TPC (mgGAE /100g)	1.80	1.88	2.68	1.11	0.0719	0.1469
TFC (mgQE/g)	0.1840	0.0825	-0.0017	0.0153	0.0407	-0.0398
DPPH (%)	30.30	4.23	8.22	-0.03075	5.37	-2.78
FORCE (Newton)	33.98	-0.252	7.6	-0.88	5.6	5.33

5.5. Response surface methodology

Table 1 displays the impact of pomegranate seed powder and jackfruit seed flour on the flavour, colour, texture, ash percentage, TPC (mg GAE/100g), TFC (mg QE/G), DPPH%, force (Newton), and overall acceptability (OAA) of cookies that contain both ingredients (Kushwaha *et al.*, 2023).

5.5.1. Impact of independent variable on flavour of cookies made with jackfruit seed flour (g) and pomegranate seed powder (g)

The association between the process variables and responses is shown by the regression coefficients for the quadratic model equation (Table 3(c)). It displays how independent variables interact to affect the responses. Pomegranate seed powder (A) and jackfruit seed flour (B) have a substantial ($p < 0.05$) impact on cookie flavour, as does the square term of pomegranate seed powder (A²) and jackfruit seed flour (B²). This demonstrated that cookies' flavour increased as the amounts of PSP and JSF increased up to a certain point, after which flavour values decreased as the amounts of PSP and JSF increased further (Fig. 4). The central point trial no. (2,7,9,10,12) with 5g of pomegranate seed powder (A) and 32.5g of jackfruit seed flour (B) had the highest flavour (8.00). The taste was negatively impacted by the quadratic term of variables, as indicated by the size of the coefficients (β) values. Jackfruit seed flour and pomegranate seed powder had a beneficial effect ($\beta_1 = +0.820483$, $\beta_2 = 0.501127$), but pomegranate seed flour and powder had a negative effect (-1.73128). Flavour was negatively impacted by the square term ($\beta_{12} = -0.0704$), the interaction term ($\beta_1 \beta_2 = -0.005067$), and the square term ($\beta_2^2 = -0.007644$). The response surface quadratic model's F-value was 53.05 at $p < 0.05$ (Table 7). The lack of fit is not statistically significant, according to the "lack of fit value" of 0.0236. With a coefficient of determination (R²) of 0.9743, the model accounted for 97% of the variation. The model was able to explain 95% of the variation with an adjusted R² of 0.9559. According to coded factors, the model's multiple regression equation for flavour is as follows:

$$\text{Flavour} = -1.73128 + 0.820483A + 0.501127B - 0.005067AB - 0.0704A^2 - 0.007644B^2 \text{ (equation 2)}$$

The 3D response plot (Figure 4) was used to graphically illustrate the regression equation. It allowed for the simultaneous visualisation of the effects of two factors on the responses, with the curve lines representing the responses' lines. As seen by the contour line in Figure 4, As PFS and JSF levels grow above a particular threshold, the flavour of the cookies made with pomegranate seed powder and jackfruit seed flour decreases. (Fig. 2(a))

Table 3(c): Response values for cookies that were predicted and tested using the ideal process parameter

Response variables	Response predicted values	Response experimented optimum Values
Flavour	8.000	8.333 ± 0.152
Color	7.750	7.866 ± 0.025
Texture	7.950	7.97 ± 0.01
Over all acceptability	8.200	8.733 ± 0.152
Ash (%)	2.000	2.333 ± 0.288
TPC (mgGAE /100g)	8.100	9.256 ± 0.056
TFC (mgQE/gm)	0.184	0.196± 0.003
DPPH (%)	30.299	32.514 ± 0.012
Force (N)	33.976	33.995 ±0.005
Desirability		1.00

Factor Coding: Actual

3D Surface

Flavour

Design Points:

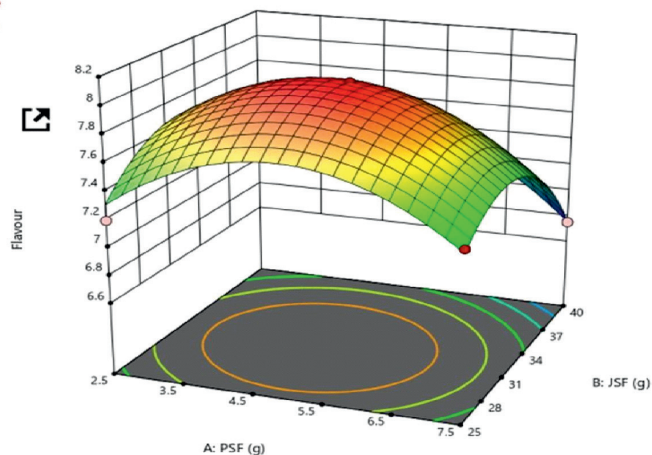
● Above Surface

○ Below Surface

6.75  8

X1 = A

X2 = B

**Figure 2(a): Response surface plot illustrating how independent factors affected the flavour of cookies made with jackfruit seed flour and pomegranate seed powder (g)**

5.5.2. Effect of independent variable on color of cookies incorporated cookies pomegranate seed powder (g) & jackfruit seed flour (g)

The association between the process variables and responses is shown by the regression coefficients for the quadratic model equation (Table 3c). It displays how independent variables interact to affect the responses. Pomegranate seed

powder (A) and jackfruit seed flour (B) have a substantial ($p < 0.05$) impact on cookie colour, as does the square term of pomegranate seed powder (A^2) and jackfruit seed flour (B^2). This demonstrated that cookies' flavour increased as the amount of PSP and JSF increased up to a certain point, after which flavour values decreased as PSP and JSF increased further (Figure 5). The central point experiment no. (2,7,9,10,12) using 5g of pomegranate seed powder (A) and 32.5g of jackfruit seed flour (B) yielded the colour 7.75. The quadratic term of variables had a positive effect on the colour, as indicated by the magnitude of the coefficients (β) values. While pomegranate seed powder and jackfruit seed flour have a negative effect ($\beta_1 = -0.1414$, $\beta_2 = 0.0596$), pomegranate seed powder and jackfruit seed flour (A) have a good effect (+7.75).

Colour was negatively impacted by the square term ($\beta_{12} = -0.2337$) & ($\beta_2^2 = -0.2513$), as well as the interaction term ($\beta_1 \beta_2 = -0.0225$). At $p < 0.05$, the response surface quadratic model's F-value was 9.98 (Table 9).

$$\text{Colour} = +7.75 - 0.1414A - 0.0596B - 0.0225AB - 0.2337A^2 - 0.2513B^2$$

(equation 3)

The 3D response plot (Figure 5) provided a graphic representation of the regression equation, with the curve lines representing the responses and allowing for the simultaneous visualisation of the effects of two factors on the responses. The contour line in Figure 5 shows that when PFS & JSF levels climb above a particular threshold, the colour of the cookies made with pomegranate seed powder and jackfruit seed flour decreases. (Fig. 2(b))

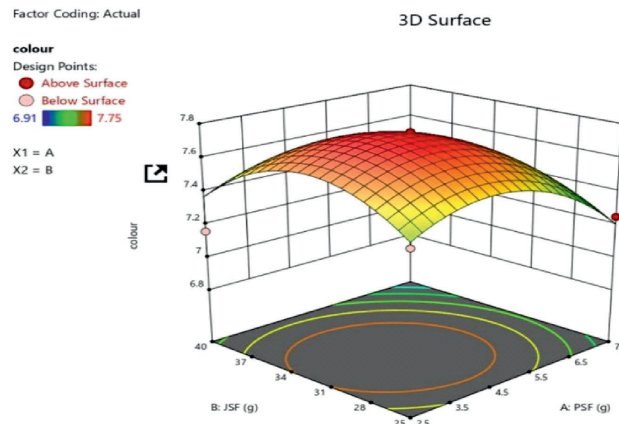


Figure 2(b): Response surface plot illustrating how independent variables affected the colour of cookies made with jackfruit seed flour (g) and pomegranate seed powder (g)

5.5.3. Effect of independent variable on texture of cookies incorporated with pomegranate seed powder (g) & jackfruit seed flour (g)

The association between the process variables and responses is shown by the regression coefficients for the quadratic model equation (Table 3c). It displays how independent variables interact to affect the responses. Pomegranate seed powder (A) and jackfruit seed flour (B) have a substantial ($p < 0.05$) impact on cookie texture, as does the square term of pomegranate seed powder (A²) and jackfruit seed flour (B²). This demonstrated that adding more pomegranate seed powder and jackfruit seed flour was mostly responsible for the textural improvements. The central point experiment no. (2,7,9,10,12) using 5g of pomegranate seed powder (A) and 32.5g of jackfruit seed flour (B) had the texture (7.95). The quadratic term of variables exhibited positive coefficient magnitudes (β) values.

In contrast to pomegranate seed powder and jackfruit seed flour, which have negative effects ($\beta_1 = -0.1671$ and $\beta_2 = -0.0725$), pomegranate seed powder (A) and jackfruit seed flour (B) have positive effects (+7.95). Texture was negatively impacted by the square term ($\beta_{12} = -0.3187$), the interaction term ($\beta_1 \beta_2 = -0.0725$), and the square term ($\beta_2^2 = -0.4013$). At $p < 0.05$, the response surface quadratic model's F-value was 15.46 (Table 9). The "lack of fit value" of 0.0617 indicates that the lack of fit is not statistically significant. 91% of the variation was described by the model, according to the coefficient of determination (R²) of 0.9170. The model was able to explain 85% of the variation with an adjusted R² of 0.8577. The model's multiple regression equation was acquired.

$$\text{Texture} = +7.95 - 0.1671A - 0.1488B - 0.0725AB - 0.3187A^2 - 0.4013B^2$$

(equation 4)

The 3D response plot (Figure 6) was used to graphically illustrate the regression equation. It allowed for the simultaneous visualisation of the effects of two factors on the responses, with the curve lines representing the responses' lines. The contour line in Fig. 2(c) illustrates how the texture of the cookies made with jackfruit seed flour and pomegranate seed powder deteriorates as PFS & JSF levels rise above a particular threshold.

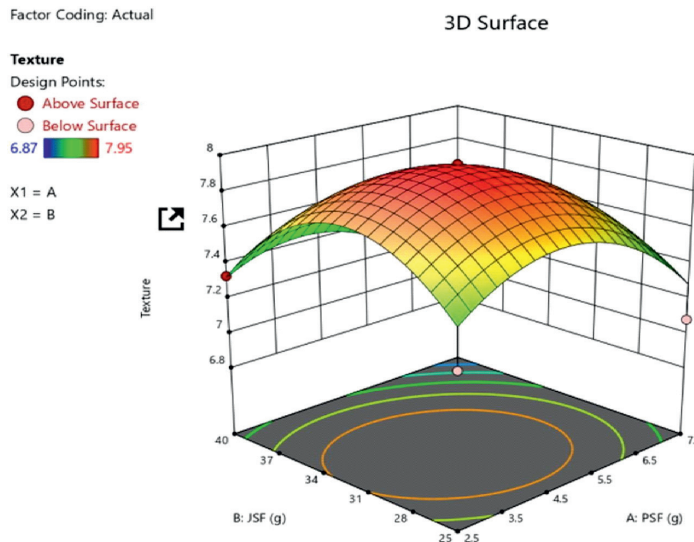


Figure 2(c): Response surface plot demonstrating how independent variables affected the texture of cookies made with jackfruit seed flour (g) and pomegranate seed powder (g)

5.5.4. Effect of independent variables on over all acceptability of cookies incorporated with pomegranate seed powder (g) & jackfruit seed flour (g)

The regression coefficients for the quadratic model equation (Table 3c) illustrate the relationship between the process variables and responses. It illustrates how responses are influenced by the interaction of independent variables. Both the square term of pomegranate seed powder (A²) and jackfruit seed flour (B²) and pomegranate seed powder (A) have a significant ($p < 0.05$) effect on the over acceptability of the cookies. This showed that the taste improvements were primarily caused by adding additional jackfruit seed flour and pomegranate seed powder.

In the centre point experiment no. (2,7,9,10,12), where pomegranate seed powder (A) weighed 5g and jackfruit seed flour (B) weighed 32.5g, the overall acceptability (8.2) was determined. The quadratic term of variables was demonstrated by the size of the coefficients (β) values.

The positive effect of pomegranate seed powder (A) and jackfruit seed flour (B) is (+8.20); the negative effect of pomegranate seed powder is ($\beta_1 = -0.2505$), while the positive effect of jackfruit seed flour is ($\beta_2 = 0.0284$).

Overall acceptance was negatively impacted by the interaction term ($\beta_1 \beta_2 = 0.0200$), the square term ($\beta_{12} = -0.5850$), and ($\beta_2^2 = -0.4550$). The response surface quadratic model's F-value was 17.76 at $p < 0.05$ (Table 7). The lack of fit is not statistically significant, with a "lack of fit value" of 0.3078. The coefficient of determination (R^2) of 0.9269 indicates that 92% of the variation was explained by the model. The model was able to explain 87% of the variation with an adjusted R^2 of 0.8748.

The model's multiple regression equation for overall acceptability (as measured by coded factors) is as follows:

$$\text{Overall acceptability} = +8.20 - 0.2505A + 0.0284B + 0.0200AB - 0.5850A^2 - 0.4550B^2 \text{ (equation 5)}$$

The 3D response plot (Fig. 2(d)) was used to graphically illustrate the regression equation. It allowed for the simultaneous visualisation of the effects of two factors on the responses, with the curve lines representing the responses' lines. The overall acceptability of the cookies made with pomegranate seed powder and jackfruit seed flour decreases as PFS and JSF levels climb above a particular threshold, as shown by the contour line in Fig. 2(d).

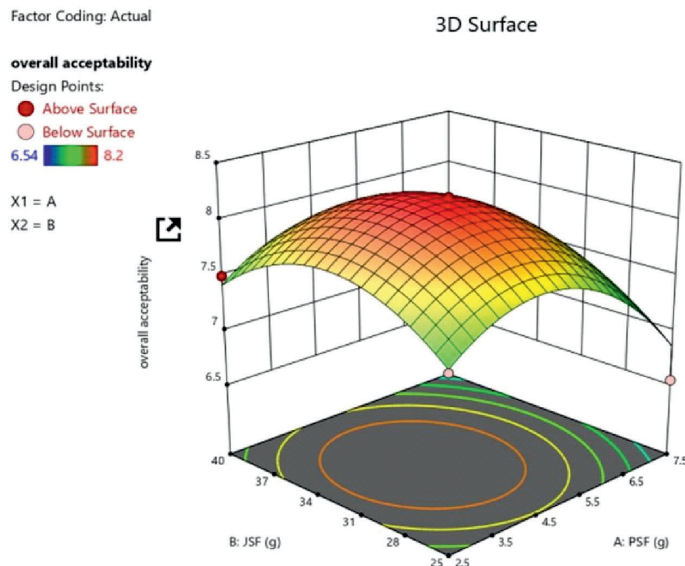


Figure 2(d): Response surface plot illustrating the impact of independent factors on the overall acceptability of cookies made with jackfruit seed flour (g) and pomegranate seed powder (g)

5.5.5. Effect of independent variable on ash of cookies incorporated with pomegranate seed powder (g) & jackfruit seed flour (g)

The association between the process variables and responses is shown by the regression coefficients for the quadratic model equation (Table 3c). It displays how independent variables interact to affect the responses. Pomegranate seed powder (A), jackfruit seed flour (B), and the square term of pomegranate seed powder (A²) and jackfruit seed flour (B²) have a significant ($p < 0.05$) effect on cookie ash. This demonstrated that an increase in jackfruit seed flour and pomegranate seed powder was the primary source of the ash increase. The central point experiment no. (2,7,9,10,12) containing 5g of pomegranate seed powder (A) and 32.5g of jackfruit seed flour (B) contained the ash (2.00). The quadratic term of variables exhibited positive coefficient magnitudes (β) values. While pomegranate seed powder and jackfruit seed flour have a favourable effect ($\beta_1 = +0.2289$, $\beta_2 = +0.5527$), pomegranate seed powder and jackfruit seed flour (B) have a positive effect (+2.00). The square term ($\beta_{12} = -0.0500$) & ($\beta_2^2 = -0.1250$) and the interaction term ($\beta_1 \beta_2 = 0.4250$) had a negative effect on colour. The F-value for the response surface quadratic model was 190.19 at $p < 0.05$ (Table 7). The “lack of fit value” of 0.0091 indicates that the lack of fit is not statistically significant. 99% of the variation was described by the model, with a coefficient of determination (R²) of 0.9927. 98% of the variation could be explained by the model, with an adjusted R² of 0.9875. The multiple regression equation for the model was obtained.

$$\text{Ash} = +2.00 + 0.2289A + 0.5527B + 0.4250AB - 0.0500A^2 - 0.1250B^2 \text{ (equation 6)}$$

The 3D response plot was used to graphically illustrate the regression equation. It allowed for the simultaneous visualisation of the effects of two factors on the responses, with the curve lines representing the responses' lines. The plot demonstrated that rising pomegranate seed powder and jackfruit seed flour led to rising ash levels. As the amount of jackfruit seed flour and pomegranate seed powder increased, the contour line showed that both the texture and ash content of the cookies increased. (Fig. 2(e))

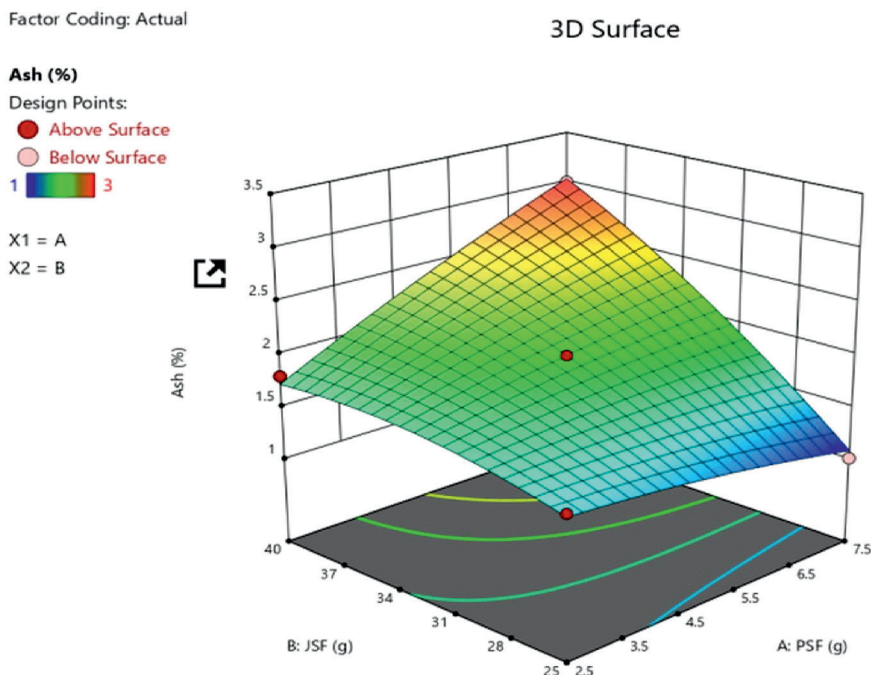


Figure 2(e): Response surface plot illustrating the impact of independent factors on the ash of cookies containing jackfruit seed flour (g) and pomegranate seed powder (g)

5.5.6. Effect of independent variables on total phenolic content (TPC) of cookies incorporated with pomegranate seed powder (g) & jackfruit seed flour (g)

The regression coefficients for the quadratic model equation demonstrate the relationship between the process factors and responses (Table 7). It displays how independent variables interact to affect the responses. Pomegranate seed powder (A) and jackfruit seed flour (B) have a substantial ($p < 0.05$) impact on cookies' TPC, as does the square term of pomegranate seed powder (A²) and jackfruit seed flour (B²).

This demonstrated that the larger levels of jackfruit seed flour and pomegranate seed powder were primarily responsible for the increases in the overall phenolic content. With 5g of pomegranate seed powder (A) and 32.5g of jackfruit seed flour (B), the centre point experiment no. (2,7,9,10,12) had a total phenolic content of 8.1. The quadratic term of variables had a positive impact on the TPC, as indicated by the size of the coefficients (β)

values. While pomegranate seed powder and jackfruit seed flour have a favourable effect of ($\beta_1 = +1.88, \beta_2 = 2.68$), pomegranate seed powder and jackfruit seed flour have a positive effect of +8.10.

Interaction term ($\beta_1 \beta_2 = 1.11$). The F-value for the response surface quadratic model was 18.36 at $p < 0.05$ (Table 7). The lack of fit is not statistically significant, as indicated by the “lack of fit value” of 2.31. 92% of the variation was described by the model, according to the coefficient of determination (R^2) of 0.9292. The model explained 87% of the variation with an adjusted R^2 of 0.8785. The multiple regression equation for the total phenolic content (in terms of coded factors) in the model is as follows:

$$\text{TPC} = +8.10 + 1.88A + 2.68B + 1.11AB + 0.0719 A^2 + 0.1469B^2. \text{ (equation 7)}$$

The 3D response plot was used to graphically illustrate the regression equation. It allowed for the simultaneous visualisation of the effects of two factors on the responses, with the curve lines representing the responses' lines. The plot demonstrated that the total phenolic content rose when pomegranate seed powder and jackfruit seed flour levels increased. The TPC of the cookies made with pomegranate seed powder and jackfruit seed flour showed that the contour line showed that the total phenolic content of cookies increased as the amounts of these ingredients increased (Fig. 2(f))

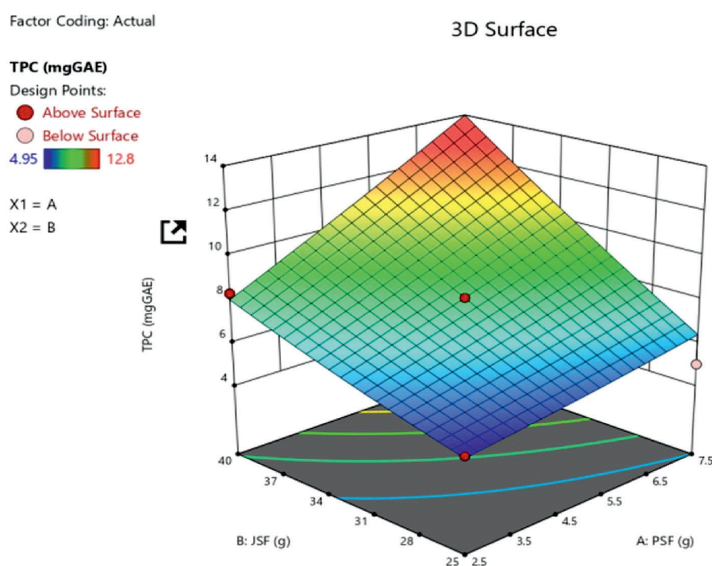


Figure 2(f): Response surface plot illustrating the impact of independent variables on TPC of cookies containing jackfruit seed flour (g) and pomegranate seed powder (g)

5.5.7. Effect of independent variables on total flavonoids content (TFC) of cookies incorporated with pomegranate seed powder (g) & jackfruit seed flour (g)

The total flavonoids content (0.184) was found in the central point experiment no. (2,7,9,10,12) where pomegranate seed powder (A) 5g and jackfruit seed flour (B) 32.5g. The size of the coefficients (β) values shows that the quadratic term of variables had a favourable effect on the total flavonoid content.

Jackfruit seed flour ($\beta_2 = -0.00017$) has a negative effect, while pomegranate seed powder ($\beta_1 = +0.0825$) has a favourable effect (+0.1840). Total flavonoids content was positively impacted by the interaction term ($\beta_{12} = +0.0153$) and negatively impacted by the square terms ($\beta_{11} = 0.0864$) and ($\beta_{22} = -0.0691$). The response surface quadratic model's F-value was 0.8147 at $p < 0.05$ (Table 7). The "lack of fit value" of 0.0466 indicates a significant lack of fit. The coefficient of determination (R^2) of 0.3679 indicates that the model explained 36% of the variation.

The model explained 8% of the variation, according to the corrected R^2 of -0.0837. According to coded factors, the model's multiple regression equation for the TFC is as follows:

$$\text{TFC} = +0.1840 + 0.0825 A - 0.0017B + 0.0153 AB + 0.0407 A^2 - 0.0398B^2$$

(equation 8)

The 3D response plot was used to graphically describe the regression equation. The responses are displayed as curve lines in this plot, and it is possible to observe the simultaneous effects of two factors on the replies. The plot demonstrated that adding jackfruit seed flour and pomegranate seed powder increased the amount of total flavonoids. The contour line showed that the overall flavonoid content of the cookies increased along with the amount of pomegranate seed powder and jackfruit seed flour. (Fig. 2(g))

5.5.8. Effect of independent variables on (DPPH) of cookies incorporated with pomegranate seed powder (g) & jackfruit seed flour (g)

The regression coefficients for the quadratic model equation (Table 7) demonstrate the relationship between the process variables and responses.

It displays how independent variables interact to affect the responses. Pomegranate seed powder (A) and jackfruit seed flour (B), as well as the square term of pomegranate seed powder (A²) and jackfruit seed flour (B²), have a substantial ($p < 0.05$) effect on the DPPH% of cookies. This proved that the rise in pomegranate .The increases in the DPPH were primarily caused by seed powder and jackfruit seed flour. The centre point experiment no. (2,7,9,10,12) containing 5g of pomegranate seed powder (A) and 32.5g of jackfruit seed flour (B) yielded the DPPH (30.299). The quadratic term of variables exhibited positive coefficient magnitudes (β) values.

Jackfruit seed flour (B) and pomegranate seed powder (A) have a beneficial effect (+30.30), and pomegranate seed powder and jackfruit seed flour have a positive effect ($\beta_1 = +4.23$, $\beta_2 = 8.22$). The interaction term ($\beta_{12} = -0.3075$) had a negative influence on DPPH, but the square terms ($\beta_{1^2} = +5.37$) and ($\beta_{2^2} = -2.78$) had positive and negative effects, respectively. At $p < 0.05$, the response surface quadratic model's F-value was 8.06 (Table 7). The "lack of fit value" of 53.02 indicates that the lack of fit is not statistically significant. The model accounted for 85% of the variation, with a coefficient of determination (R²) of 0.8520. 74% of the variation was explained by the revised R² of 0.7463. the model. The model's multiple regression equation for the DPPH is as follows based on coded factors.

$$DPPH = +30.30 + 4.23A + 8.22B - 0.3075AB + 5.37A^2 - 2.78B^2 \text{ (equation 9)}$$

The 3D response plot was used to graphically illustrate the regression equation. It allowed for the simultaneous visualisation of the effects of two factors on the responses, with the curve lines representing the responses' lines. The plot showed that increases in jackfruit seed flour and pomegranate seed powder cause DPPH to rise. The contour line indicated that the cookies' DPPH increased with the amount of pomegranate seed powder and jackfruit seed flour utilise and their texture rating is greater.(Fig. 2(h))

5.5.9. Effect of independent variable on Force (Newton) required to break cookies that incorporated with pomegranate seed powder (g) & jackfruit seed flour (g)

The association between the process variables and responses is shown by the regression coefficients for the quadratic model equation (Table 7). It displays how independent variables interact to affect the responses. The

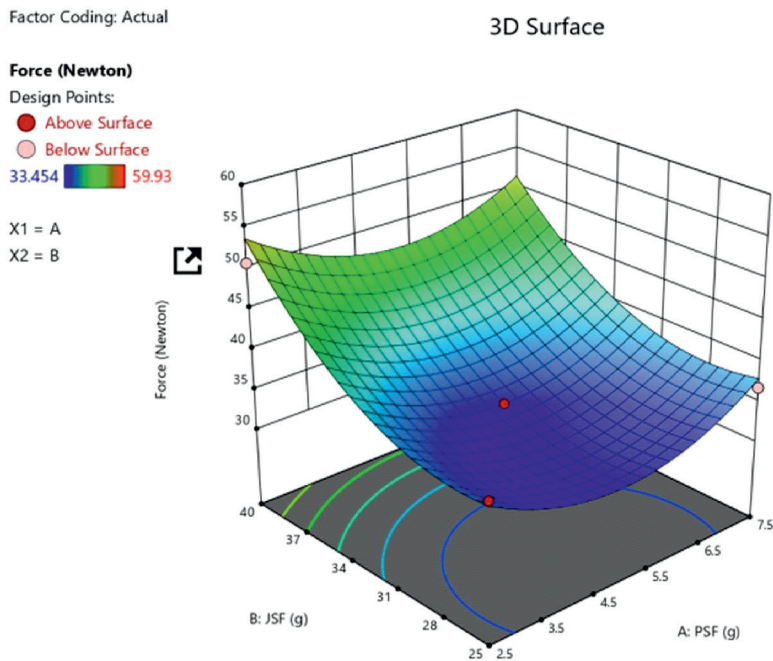


Figure 2(h): The response surface plot illustrate how the independent Variable affects the force of cookie made with pomegranate seed powder (g) and jackfruit seed flour(g)

force required to break the cookies is significantly ($p < 0.05$) affected by pomegranate seed powder (A) and jackfruit seed flour (B), as well as by the square term of pomegranate seed powder (A^2) and jackfruit seed flour (B^2). This proved that the rise in the power increases were primarily caused by jackfruit seed flour and pomegranate seed powder. The central point experiment no. (2,7,9,10,12) with 5g of pomegranate seed powder (A) and 32.5g of jackfruit seed flour (B) yielded the force (33.978 N). The force was positively impacted by the quadratic term of variables, as indicated by the size of coefficients (β) values.

Pomegranate seed powder has a negative effect ($\beta_1 = -0.2519$), but jackfruit seed flour (B) and pomegranate seed powder (A) have a favourable effect (+33.98). The interaction term ($\beta_1 \beta_2 = 0.8802$), the square term ($\beta_{12} = +5.60$), and the square term ($\beta_2^2 = +5.33$) all had a positive effect on force. The F-value for the response surface quadratic model was 18.08 at $p < 0.05$ (Table 7). It is not statistically significant that the "lack of fit value" is 64.60. 92% of the variation was described by the model, according to the coefficient

of determination (R^2) of 0.9281. The model was able to explain 87% of the variation with an adjusted R^2 of 0.8768. For the force (in terms of coded components), the model's multiple regression equation was derived.

$$\text{Force} = +33.98 - 0.2519A + 7.60B - 0.8802AB + 5.60A^2 + 5.33B^2 \text{ (equation 10)}$$

The 3D response plot (Figure -12) was used to graphically illustrate the regression equation. It allowed for the simultaneous visualisation of the effects of two factors on the responses, with the curve lines representing the responses' lines. The figure showed that as pomegranate seed powder and jackfruit seed flour levels rise, so does force. The contour line showed that the more pomegranate seed powder and jackfruit seed flour used, the more effort was required to break the biscuits. (Fig. 2(i))

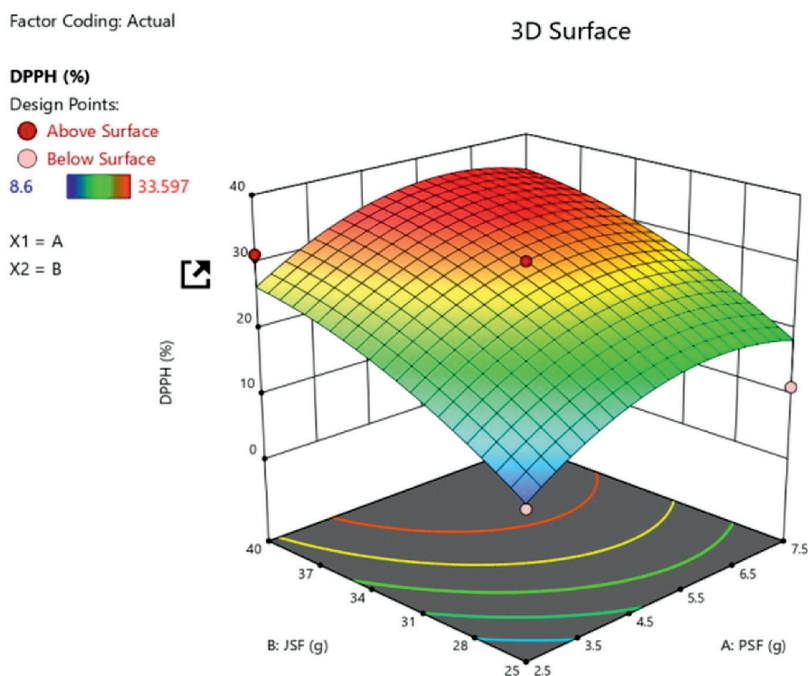


Figure 2(i): Response surface plot illustrating how independent variables affected the DPPH of cookies made with jackfruit seed flour (g) and pomegranate seed powder (g)

6. Conclusion

In conclusion, including pomegranate seed powder and jackfruit seed flour into cookie recipes offers a practical way to produce cookies with more nutrients. According to the proximate study, adding jackfruit seed flour

and pomegranate seed powder enhanced the potential source of natural antioxidants contributing to the cookies' healthy phytochemical percentage and high antioxidant content, both of which may provide additional health benefits.

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