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EVALUATION OF THE PHYSICAL PROPERTIES OF COOKIES PREPARED FROM COMPOSITE FLOUR OF PEARL MILLET AND NIGER SEED

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ABSTRACT

The present investigation optimized the formulation of cookies prepared from composite flour by partially replacing refined wheat flour with pearl millet and Niger seed flours. Thirty treatments were formulated using a Response Surface Methodology varying the proportions of composite flour (10–50 g/100 g), sugar (35–55 g/100 g), fat, and baking powder (0.35–0.55 g/100 g). Physical properties including diameter, thickness, spread ratio, weight, and color (CIELAB L*, a*, b*) were measured. Results indicated that increased pearl millet flour significantly reduced diameter and spread ratio ($p < 0.01$) while enhancing thickness and weight ($p < 0.05$). Baking powder positively influenced diameter, and composite flour level was the primary determinant of weight. Color analysis revealed darker, more yellow-hued cookies with higher composite flour content. These findings demonstrate the feasibility of using pearl millet and Niger flours to develop nutrient-dense, gluten-reduced cookies without compromising key quality attributes, offering a promising approach for creating functional bakery products.
Keywords: Pearl millet, Niger, Cookies, Physical properties, Response surface methodology (RSM)

Introduction

Cookies are among the most popular baked products consumed globally, especially favored by children and young adults due to their delightful taste, texture, and aroma. As low-moisture foods, cookies have a longer shelf life and are commonly prepared using refined wheat flour, sugar, and fats. The fat content contributes significantly to the sensory characteristics of cookies, particularly in terms of flavor and texture. However, refined wheat flour, a staple ingredient in traditional cookie recipes, is largely composed of starch and lacks essential nutrients such as dietary fiber, protein, and minerals. It's refining process strips away the bran and germ layers, reducing the overall nutritional profile of the final product. Given the increasing demand for healthier food alternatives, there is a growing need to enhance the nutritional value of cookies by incorporating more wholesome and nutrient-dense flours (Hussain *et al.*, 2006).

Pearl millet (*Pennisetum glaucum* L.), commonly known as bajra, is a nutrient-rich grain widely cultivated in the arid and semi-arid regions of India, particularly in Gujarat, Rajasthan, Madhya Pradesh and Haryana. Bajra is gluten-free and recognized for its superior nutritional qualities, including high protein (12%), fat 5%, , carbohydrate 67%, calcium 42mg,Phoshphorus 242mg and iron 8mgdietary fiber, and a wealth of vitamins and minerals (Malik, 2015). It contains essential amino acids like lysine and methionine and exhibits significant antioxidant activity due to the presence of flavonoids and phenolic compounds. Pearl millet's low glycemic index (GI 55) and high energy content make it an excellent alternative to refined wheat flour for developing health-oriented food products (Adebiy *et al.,* 2017).

Niger (*Guizotia abyssinica*), also known as Ramtil or Jagni, is a lesser-known oilseed crop with yellow flowers, cultivated primarily in tribal regions of India and Ethiopia. Niger seeds are rich in oil (30–40%), protein (10–25%), soluble sugars (12–18%), crude fibre (10–20%), moisture (10–11%), and ash (4%) (Getinet *et al*., 1996; Maravi, 2022; Dwivedi and Bhatt, 2023). They also contain essential micronutrients, including iron (56.7 mg/100 g), niacin, thiamine, calcium, and phosphorus (Gopalan *et al*., 2012). The oil extracted from Niger seeds is predominantly composed of unsaturated fatty acids, such as linoleic and oleic acids, which are known for their cardiovascular health benefits (Nasirullah *et al.,* 1982).

Despite the promising nutritional attributes of pearl millet and Niger, their utilization in bakery products remains limited. Few studies have explored the development of cookies using pearl millet with refined wheat flour and niger with wheat flour (Maravi *et al.,* 2022). Therefore, this research aims to formulate nutrient-dense cookies by partially replacing refined wheat flour with pearl millet and Niger flour, to improve the Physical characteristics of cookies. This study could contribute significantly to the development of functional bakery products that align with current health and nutrition trends.

Materials and Methods

Raw materials such as refined wheat flour and other materials such as sugar, vanaspati ghee, sodium bicarbonate and ammonium bicarbonate were procured from the nearby market. The Niger seed were procured from Chandangaon, Chhindwara (MP). The Niger flour were prepared from Niger seed by utilizing brabender flour mill and sieved through 40 mesh sieve.

Preparation of cookies: Thirty treatments of cookies dough were prepared using different ratio of sugar, fat and varied baking powder. Wheat flour was partially replaced using pearl millet and Niger flour at five levels (10, 20, 30, 40 and 50 g/100g), sugar were used at five levels i.e. (35, 40, 45, 50 and 55 g/100g) and baking powder added at five level (0.35, 0.40, 0.45, 0.50, and 0.55 g/100g). The dough was prepared, rolled in the cookie dropper machine, and divided into pieces using a cookie cutter. The pieces were placed on a heating plate that had been oiled, and they were baked for 18 minutes at 180 to 200 °C. The cookies were cool, packed and stored. (Flow chart).

Preparation of Ingredients
(Weighing and Recipe calculation)
↓
Hydrogenated vegetable fat and powdered sugar mixed thoroughly in Mixture (5-8 min)
↓
Wheat flour + pearl millet flour + Niger (Mixed both the blends)
↓
Add baking powder + ammonium bicarbonate Mix Properly
↓
Dough forming with the addition of water and salt
↓
Put the dough in cookies dropper machine
↓
Developed cookies in tray
↓
Baking at 175ºC for 20 minutes
↓
Cooling and Packaging
↓
Storage

Flow Chart: Preparation of cookies from composite flour

Analysis of product: Developed composite flour cookies along with control (refined wheat flour cookies) were evaluated for various physical characteristics as per standard methods.

Diameter (D)

The diameter of the cookies was determined in accordance with the American Association of Cereal Chemists (AACC, 2000) approved methods. Six cookies were randomly selected, and their diameters were measured using a digital vernier caliper. To ensure accuracy, each cookie was rotated 90° and re-measured, with the final value being the average of the two readings.

Weight (W)

Cookie weight was measured following the AACC (1995) standard procedures. An electronic digital weighing balance was used to determine the mass of individual cookies in grams.

Thickness (T)

To measure cookie thickness, four cookies were stacked, and the combined thickness was measured using a digital vernier caliper. The average thickness of a single cookie was then calculated by dividing the total by four, as per AACC (2000) guidelines.

Spread Ratio (D/T)

The spread ratio was calculated by dividing the diameter (D) by the thickness (T) of the cookies. This ratio provides insight into cookie spread during baking and was determined in accordance with AACC (2000) methodology.

Spread factor = (Spread ratio sample/Spread ratio control) × 100

Measurement of colour and appearance

The colour scanning machine (Model: Colour Flex EZ) was used for measurement of colour of crust and crumb of cookies. The colour was measured by using CIELAB (1976/D65) scale at 10 observers at D65 illuminant. The instrument was calibrated before placing the sample by placing black tile and white tile provided with the instrument. It provides readings in terms of L*, a*, b*, C* and H* where, L* indicate darker, a* indicate green, b* indicate yellow, C* indicate brighter and H* indicate hue.

Experimental Design

The prime objective of study was to replace wheat flour with pearl millet and Niger flour. There was also need of varying the proportion of other ingredients included in the ranges of variables were selected taking into consideration the maximum and minimum values used for control samples of preparation. Responses surface methodology (Mayer's, 1973) was used to reduce the number of experiments, without affecting the accuracy of result. The experiment was planned in central composite rotatable the formulation for getting optimum quality of product. Thus, based on information available in the literature, four variables viz. composite flour like (refined wheat flour, pearl millet and Niger flour) Sugar, baking powder were selected for development of the formulation. Design with half replicate which consisted of 30 experiments. First 16 experiments in first order part, 8 experiments in second order part and next 6 experiments were at central point or replication. (Table 1 and 2)

Statistical analysis

The data obtained from each treatment were processed on an i3 processor computer using Design Expert 11 software. Response surface graphs of selected response were developed to study the effect of independent variables and to optimize the levels of ingredients. The gathered data were individually examined using a second order mathematical model. The model's suitability was examined using Fisher's F-test and coefficient of determination, and the impacts of the variables were deciphered. To show how variables affect reactions, response surface graphs were created, and an optimization point for cookies of acceptable quality was identified.

$$Y = \beta_0 \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \beta_{ii} X_i^2 + \sum_{i=1}^{k-1} \sum_{j=i+1}^{k} \beta_{ii} X_i X_j$$

Table 1 : Experimental variables their coded and un-coded (actual) values for production of Composite Flour Cookies

S. No.	Variables	Units	Code	Coded levels				
				-2	**-1**	**0**	**+1**	**+2**
1	RWF: PMF: NF	g	X_1	100	500	300	200	400
2	Sugar	g	X_2	350	550	450	400	500
3	Fat	g	X_3	300	500	400	350	450
4	Baking Powder	g	X_4	3.5	5.5	4.5	4	5

a: ±values, b: centre point, RWF – Refined Wheat flour, PMF-pearl millet flour NF: Niger flour

Table 2 : Experimental design matrix for production of composited flour cookies

Coded Form					Un-Coded Form			
Expt. No.	**A**	**B**	**C**	**D**	**PMF:NF: RWF (g) A**	**Sugar (g) B**	**Fat (g) C**	**Baking powder (g) D**
First Order Interaction								
1.	-1	-1	-1	-1	200	400	350	4
2.	1	-1	-1	-1	400	400	350	4
3.	-1	1	-1	-1	200	500	350	4
4.	1	1	-1	-1	400	500	350	4
5.	-1	-1	1	-1	200	400	450	4

Coded Form					Un-Coded Form			
Expt. No.	A	B	C	D	PMF:NF: RWF (g) A	Sugar (g) B	Fat (g) C	Baking powder (g) D
6.	1	-1	1	-1	400	400	450	4
7.	-1	1	1	-1	200	500	450	4
8.	1	1	1	-1	400	500	450	4
9.	-1	-1	-1	1	200	400	350	5
10.	1	-1	-1	1	400	400	350	5
11.	-1	1	-1	1	200	500	350	5
12.	1	1	-1	1	400	500	350	5
13.	-1	-1	1	1	200	400	450	5
14.	1	-1	1	1	400	400	450	5
15.	-1	1	1	1	200	500	450	5
16.	1	1	1	1	400	500	450	5
Second Order Interaction								
17.	-2	0	0	0	100	450	400	4.5
18.	2	0	0	0	500	450	400	4.5
19.	0	-2	0	0	300	350	400	4.5
20.	0	2	0	0	300	550	400	4.5
21.	0	0	-2	0	300	450	300	4.5
22.	0	0	2	0	300	450	500	4.5
23.	0	0	0	-2	300	450	400	3.5
24.	0	0	0	2	300	450	400	5.5
Centre Point								
25.	0	0	0	0	300	450	400	4.5
26.	0	0	0	0	300	450	400	4.5
27.	0	0	0	0	300	450	400	4.5
28.	0	0	0	0	300	450	400	4.5
29.	0	0	0	0	300	450	400	4.5
30.	0	0	0	0	300	450	400	4.5

Results and Discussion

Diameter

The diameter of cookies prepared with composite flour exhibited significant variation across the thirty treatments (Table 3). Diameters ranged from a minimum of 44.01 mm (treatment 18: PMF:NF:RWF = 10:10:80) to a maximum of 47.12 mm (treatment 17: PMF:NF:RWF = 50:10:40). ANOVA revealed an F-value of 3.75 ($p < 0.05$), confirming that the model was statistically significant in explaining diameter variation, although the R^2 of 66.35% indicated only moderate predictive power. Regression coefficients indicated a significant negative linear effect of pearl millet flour (PMF) on diameter ($\beta_1 = -0.2583$, $p < 0.10$), while baking powder had a positive effect ($\beta_4 = 0.7550$, $p<0.01$). The PMF × baking powder interaction was also significant ($\beta_{14} = -0.3225$, $p < 0.05$), suggesting that at higher levels of baking powder, the diameter-decreasing impact of PMF was partially mitigated.

Response surface plots (Figures 1,2 and 3) illustrate these trends at low baking powder levels, increasing PMF sharply reduces diameter, whereas at high baking powder, the negative slope is less steep. This behavior likely reflects the competing influences of water-binding capacity of PMF, which limits dough expansion, and the leavening action of baking powder. An additional positive correlation between fat content and diameter was observed; treatments with higher fat (e.g. treatment 6 vs. treatment 5) exhibited up to 1.5 mm greater diameter, consistent with fat's role in promoting spread through lubrication of the dough matrix. Furthermore, an increase in cookie diameter was associated with higher fat content in the dough, consistent with findings by Maravi *et al.* (2022),Gernah *et al.* (2010) and Siddiqui *et al.* (2003), who reported similar diameter increases with varying flour compositions.

Thickness

Cookie thickness also varied significantly, from 13.12 mm (treatment 17) to 15.75 mm (treatment 18). The ANOVA F-value of 5.08 ($p < 0.01$) and R^2 = 72.77% confirm a robust model fit. In contrast to diameter, PMF exerted a strong positive linear effect on thickness ($\beta_1 = 0.6446$, $p < 0.01$), indicating that higher inclusion of pearl millet yields thicker cookies (Figure 4). No interactive terms reached significance, implying that the thickness response is driven primarily by PMF level rather than ingredient interactions. This increase in thickness with higher PMF is attributable to the flour's greater water-binding and structural properties, which limit lateral expansion and promote vertical build-up. The range of thickness observed (12.05–15.14 mm across treatments) echoes findings from Chopra *et al.* (2014), who reported increased biscuit thickness with incorporation of non-wheat flours such as buckwheat. The interplay between diameter reduction and thickness increase suggests a volume-conserving effect when replacing refined wheat flour as the cookie spreads less, it necessarily builds height.

Spread Ratio (D/T)

The spread ratio, defined as diameter divided by thickness, is a key quality parameter reflecting consumer perception of cookie crispness and shape. Spread ratios ranged from 2.79 (treatment 18) to 3.51 (treatment 17) depicted in Table 3. ANOVA indicated a significant model ($F = 5.92$, $p < 0.01$; R^2 = 75.69%). Regression analysis showed a significant negative linear effect of PMF on spread ratio ($\beta_1 = -0.9908$, $p < 0.01$), while no interactive terms were significant. As pearl millet content increased, spread ratio declined in a nearly linear fashion (Figure 5).

The diminished spread ratio at higher PMF levels can be explained by increased dough viscosity and water retention, resulting in reduced lateral flow during baking. Similar phenomena have been documented by (Maravi *et al* 2022) who noted that fortification of niger flour increase the spread ratio also increased 6.43mm to 7.25 mm followed by incorporation of 15% and 20% Niger flour.

Weight

Cookie weight varied significantly among formulations, from 11.42 g (treatment 17) to 14.28 g (treatment 18) represented in Table 3. The model F-value of 31.25 ($p < 0.001$) and R^2 = 94.27% demonstrate a very strong fit. PMF exhibited a significant positive linear effect on weight (β_1 = 0.7646, $p < 0.01$), indicating that cookies become heavier as the proportion of pearl millet increases (Figure 6). This likely reflects the higher density and water-binding properties of PMF compared to refined wheat flour.

No significant interactions were detected, suggesting that weight is primarily a function of total flour composition rather than the interplay of multiple ingredients. The increase in weight with PMF contrasts with findings in soybean-fortified cookies and Niger fortified cookies (Ayo *et al.*, 2014, Maravi *et al* 2022), where weight decreased; this discrepancy may be due to differing oil and protein content between Nile soybean and Niger seed flours. Overall, the heavier cookies at higher PMF levels will affect portion size and nutritional density, an important consideration for caloric and sensory balance.

Hunter Colour Value of Cookies Developed from Composite Flour

The Hunter colour values (L*, a*, b*) provide insight into the visual quality of cookies made from varying blends of pearl millet flour (PMF), Niger seed flour (NF), and refined wheat flour (RWF). As shown in Table 4.5, the L* (lightness) values varied significantly, indicating the influence of ingredient proportions on cookie darkness. The darkest cookie (L* = 41.94) was observed in treatment 16, using a 40:10:50 blend with 50g sugar, 45g fat, and 0.5g baking powder, whereas the lightest (L* = 58.31) occurred in treatment 14 with a similar composition.

For the a* values, which reflect the red-green spectrum, results ranged from a low of 1.18 (treatment 28, blend 20:10:70, 45g sugar, 45g fat, 0.4g baking powder) to a high of 9.30 (treatment 1, blend 30:10:60, 40g sugar, 35g fat, 0.4g baking powder). Yellow coloration (b*) ranged from 22.04 in treatment 7 to 29.51 in treatment 12. Notably, treatments 14 and 1 with blends 20:10:70 and 40:10:50 respectively, contributed to higher b* values, indicating greater yellowness. The hunter L*(Darkness), a*(Green) b*(Yellow) values of developed cookies for the colour of product varied from 49.94-55.31, 1.18-9.03, and 22.04-29.11, respectively. Reported similar results by Maravi *et al.* (2022) in niger flour fortified cookies. Kulthe *et al* (2017) reported the values L* and b* decreased from 74.347 to 55.351 and from 21.143 to 16.314, respectively where as a* increased from 1.220 to 3.633 with increasing level of PMF.

Table 3: Physical properties of cookies developed from composite flour

Treatment	Diameter (mm)	Thickness (mm)	Spread Ratio (D/T)	Weight (g)
1	44.51	13.22	3.36	11.83
2	45.15	14.32	3.15	13.87
3	44.55	13.34	3.33	11.83
4	45.18	14.55	3.1	13.87
5	44.56	13.15	3.38	12.24
6	45.22	14.12	3.2	13.46
7	44.52	13.18	3.37	12.24
8	45.18	14.34	3.15	13.46
9	46.95	13.55	3.46	12.24
10	46.75	14.78	3.16	13.46
11	46.9	13.45	3.48	11.83
12	45.65	14.91	3.06	13.46
13	46.91	13.55	3.46	11.83
14	46.15	14.97	3.08	13.46
15	46.91	13.35	3.50	11.83
16	46.55	15.01	3.10	13.46
17	**47.12**	**13.12**	**3.51**	**11.42**
18	**44.01**	**15.75**	**2.79**	**14.28**
19	45.95	14.75	3.11	12.65
20	46.15	14.71	3.13	12.65
21	46.45	14.65	3.17	13.06
22	46.75	14.78	3.16	12.65
23	44.86	14.71	2.98	13.06
24	46.97	14.95	3.14	13.06
25	46.33	14.71	3.14	13.06
26	46.32	14.67	3.15	12.65
27	46.12	14.71	3.13	12.65
28	46.17	14.65	3.15	13.06
29	46.15	14.79	3.12	12.65
30	44.44	14.71	3.02	13.06

Table 4 : Regression coefficients of two factor interaction model and significant terms for physical properties of cookies

Coefficient	Diameter (mm)	Thickness (mm)	Spread Ratio (D/T)	Weight (g)
Intercept	45.85	14.32	3.87	12.81
Linear				
β1 A	-0.2583	0.6446	-0.9908	0.7646
β2 B	-0.0150	0.0162	-0.8383	-0.0171
β3 C	0.0400	-0.0079	0.8383	-0.0513
β4 D	0.7550	0.1596	-0.8092	-0.0513
Interactive				
β 1.2 AB	-0.0412	0.0481	1.24	0.0256
β 1.3 AC	0.0238	0.0131	-1.25	-0.0769
β 1.4 AD	-0.3225	0.0831	1.21	-0.0256
β2.3 BC	0.0875	-0.0181	-1.24	0.0256
β2.4 BD	-0.0462	-0.0456	1.26	-0.0256
β 3.4 CD	0.0113	0.0519	-1.26	-0.0256

*****significant at 1%,** β1A-PMF:RWF,β2B-suger, β3C-Fat, β4D-Baking powder

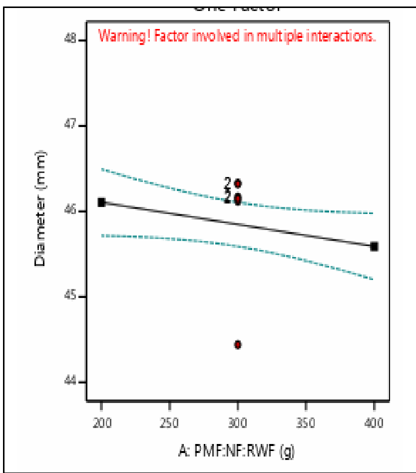

Fig.1: Linear effect of PMF:NF: RWF on Diameter of cookies

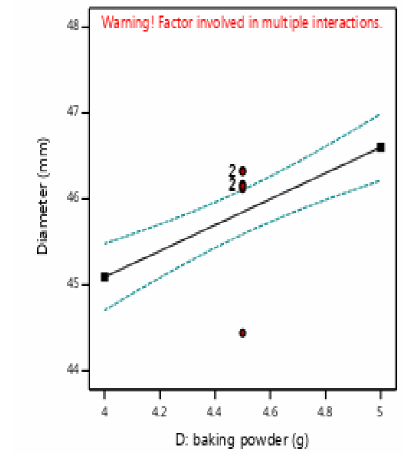

Fig.2: Linear effect of baking powder on Diameter of cookies

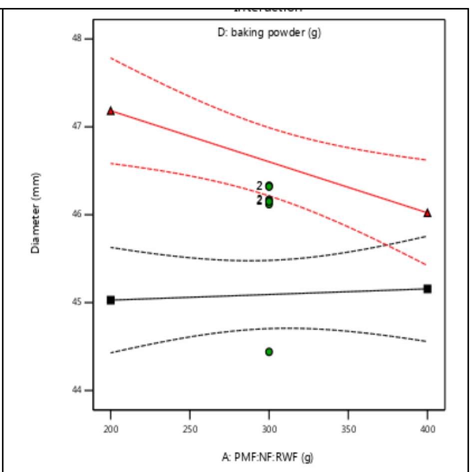

Fig. 3: Interaction effect of PMF:NF: RWF& baking powder on Diameter of cookies

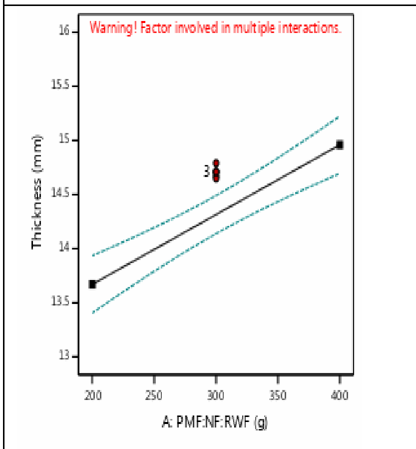

Fig. 4: linear effect of PMF:NF: RWF on thickness of cookies

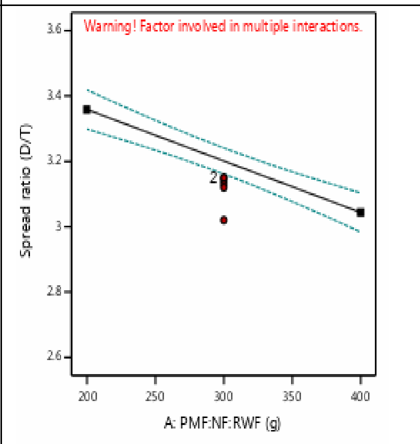

Fig. 5: linear effect of PMF:NF: RWF on spread ratio of cookies

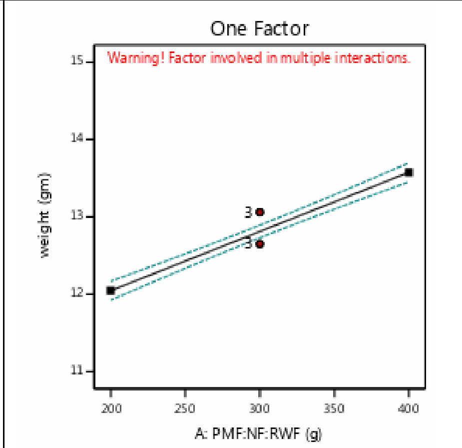

Fig. 6: linear effect of PMF: NF: RWF on weight of cookies

Table 5: Hunter colour Value of composited flour cookies

Treatment	Hunter Colour Value		
	L*	a*	b*
1	56.09	9.3	26.13
2	54.9	3.37	24.58
3	48.45	2.51	24.77
4	52.5	3.39	24.34
5	54.85	6.39	27.08
6	48.9	1.87	25.98
7	51.66	1.45	22.04
8	53.15	2.19	24.37
9	54.92	8.77	26.6
10	58.43	5.28	28.07
11	50.66	4.79	27.23
12	51.77	3.31	29.11
13	50.31	3.69	28.57
14	55.31	6.43	27.41
15	51.59	7.52	27.78
16	49.94	7.15	28.19
17	41.33	6.91	28.8
18	58.71	3.21	27.3
19	52.66	7.21	26.16

20	53.83	2.61	28.25
21	55.3	1.19	27.22
22	50.25	2.42	25.43
23	50.54	5.14	27.67
24	57.68	7.19	27.91
25	56.02	3.93	25.15
26	58.78	4.82	27.36
27	50.55	6.15	26.62
28	49.44	1.18	27.59
29	50.58	2.19	25.25
30	54.52	8.77	26.16

Conclusion

This study demonstrated that partial substitution of refined wheat flour with pearl millet and Niger flour significantly affects the physical properties of cookies. PMF had a favorable impact on cookie thickness and weight but reduced diameter and spread ratio. The optimized composite flour cookies exhibited acceptable physical quality and offer enhanced nutritional potential. These gluten-reduced cookies may benefit individuals with gluten intolerance and support the valorization of underutilized crops like Niger.

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