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Archana Maravi
PG Scholar, Department of Food Science and Technology, JNKVV, Jabalpur, Madhya Pradesh, India

Deepali Bajpai
Scientist, Directorate of Extension Services, JNKVV, Jabalpur, Madhya Pradesh, India

Priyanka Patel
PG Scholar, Department of Food science and Technology, JNKVV Jabalpur, Madhya Pradesh, India

Shashi Bala Ahirwar
Department of Post Harvest Processing and Food Engineering, College of Agricultural Engineering, Jawaharlal Nehru Krishi Vishwa Vidhyalaya, Jabalpur, Madhya Pradesh, India

SS Shukla
Professor and Head, Department of Food Science and Technology, JNKVV, Jabalpur, Madhya Pradesh, India

Corresponding Author:
Archana Maravi
PG Scholar, Department of Food Science and Technology, JNKVV, Jabalpur, Madhya Pradesh, India

Effect of baking ingredients on physical properties of Niger (*Guizotia abyssinica*) fortified cookies using response surface methodology (RSM)

Archana Maravi, Deepali Bajpai, Priyanka Patel, Shashi Bala Ahirwar and SS Shukla

Abstract
The present research work aimed to develop Niger fortified cookies with a replacement level of sugar, baking ingredients, and whole Niger flour (WNF) in control (refined wheat flour (RWF) using response surface methodology (RSM) as a standard process. The mathematical approach based on CCRD RSM was successfully used to beneficially optimize and develop the Niger flour fortified cookies. The optimal combination of the composite ingredients is required to produce cookies with desired physical properties as criteria of quality due to acceptance of the consumer. Therefore, the independent parameter, i.e. RWF:WNF (90:10, 85:15,80:20, 75:25 and 70:30), Sugar (20 g, 30 g, 40 g, 50 g and 60 g), shortening (15 g, 20 g, 25 g, 30 g and 35 g), baking powder (2.5 g, 3.0 g, 3.5 g, 4.0 g and 4.5 g) were taken and 30 treatments of cookies were prepared. The optimal combination of composite ingredients required to produce cookies with desired physical properties were thickness 8.346mm, diameter 58.267mm, Spread ratio 8.528 and moisture content 6.955% at WNF:RWF 20:80 g, sugar 40.00 g, shortening 25.099 g, baking powder 3.500 g respectively.

Keywords: Cookies, Niger, RSM, spread ratio, thickness, diameter, bakery products

Introduction

One of the food industries with the fastest global growth is the bakery sector. The most popular bakery items include bread, biscuits, and cookies. A baked good known as cookies or biscuits contains refined wheat flour, fat, shortening agent, sugar, and salt. The cookies are a widely consumed, convenient, ready-to-eat snack and wonderful substitute for blended flour, making them a practical and convenient option to increase nutrients. These items should be enjoyed as wholesome snacks by both adults and kids. Refined wheat flour is used to make the bulk of bread goods. However, as health issues like obesity, constipation, and other chronic diseases become more prevalent, there is an increasing need for diets that are high in dietary fibre, minerals, vitamins and protein in addition to the major carbohydrate. With a yearly demand of more than 630 thousand metric tonnes and revenue of about Rs. 3000 crores, the biscuit or cookie sector is regarded as the primary centre of the baking industry (Bibiana *et al*., 2018) [4]. The only grain flour that forms an elastic mass when combined with an exact proportion of water is refined wheat flour due to the presence of protein called gluten. The gluten forming proteins (glutenin and gliadin) constitute about 75-80% of the total flour proteins (Mukhopadhyay, 1990) [14]. Cookies are mainly prepared from three ingredients refined wheat flour, fat, sugar and other leavening agent which is low in nutrition content (Hussain *et al*., 2006) [10].

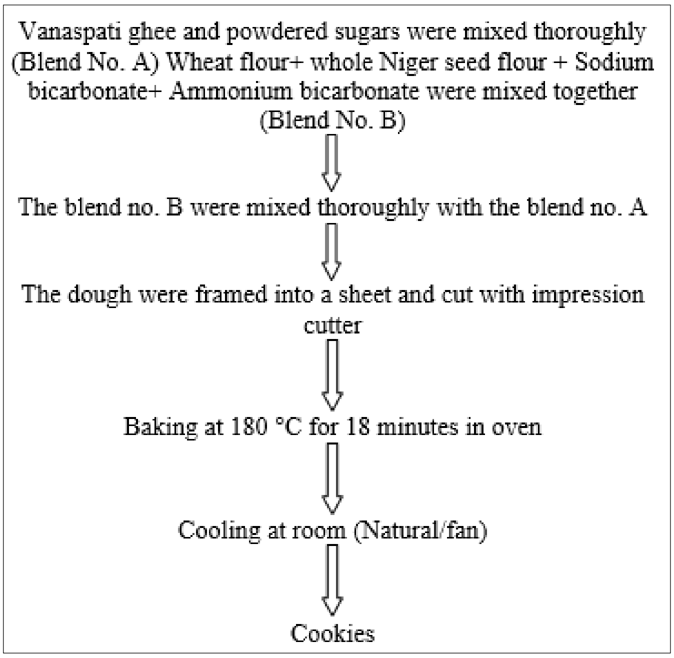
The Niger (*Guizotia abyssinica*) is a yellow flowering kharif crop belongs to family Asteraceae, commonly known as Ramtil and Jagni in Hindi (Nagaraj, 2009) [15]. Niger seed oil is used for human consumption such as for frying and for preparation of vegetables, meat and cereal products (Soloman, 2008) [18]. It is good source of phospholipids, linoleic acid and phytosterol and contain two per cent oleic and 55 per cent linoleic acid (Getinet, 1996) [6]. Niger seed contain 23.9 g protein, 39.0 g fat, 17.1 g carbohydrate, 300 mg calcium, 515 Kcal energy and 56.7 mg iron per 100 gm (Gopalan, 2007) [7]. Among the commonly consumed various nuts and oilseeds, Niger seeds are richest source of iron and good source of protein and energy. Malnutrition is a major nutritional problem existing in India. It is a wide spectrum of symptoms caused by an inadequate intake of nutrients. Most prevalent forms of malnutrition in India are protein energy malnutrition, anemia and vitamin 'A' deficiency.

Fortification of Niger flour can be made and if used in place of refined wheat flour in cookies can accumulates the benefits of nutritional properties of the various ingredients of above mix and simultaneously harvest the benefits of the baking process, which makes the final product more acceptable, nutritious, delicious and acceptable. Therefore the present study was conducted to identify suitable combination to access the physical properties of cookies. The ultimate customer views the cookies' physical characteristics as a sign of their quality.

Materials and Methodology

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 bra bender flour mill and sieved through 40 mesh sieve.

Preparation of cookies Cookies were prepared by replacing refined wheat flour in different proportion of Niger seed flour. By adding the necessary amount of water with sugar, sodium bicarbonate, and ammonium bicarbonate, the batter was completely altered (Table 1 and 2). 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 No.1).



Flow chart 1: Preparation of Niger flour fortified cookies

Analysis of product: Developed Niger flour fortified cookies along with control (refined wheat flour cookies) were evaluated for various physical characteristics – thickness, diameter and spread ratio from circular-shaped cookies (Ajila *et al*., 2008) [2];

Diameter (D)

The diameter of cookies was calculated by taking six cookies and diameters were estimate through digital vernier caliper as per AACC (2000). Cookies were turned 90°, and diameter were measured as a check determinates.

Weight (W)

The weight of cookies was calculated as per AACC (1995) [1] methods. Weight in terms of grams was measured using electronic weighing balance.

Thickness (T)

Four cookies were stacked, thickness of cookies was measured using digital vernier calipers, and the average value was calculated according to AACC 2000.

Spread ratio (D/T)

Spread ratio was calculated from diameter and thickness. It is the ratio of diameter (D) to thickness (T) of the cookies determined as perD/T, AACC (2000)

$$\text{Speread factor} = (\text{Spreadratio}_{sample}/\text{Spread ratio}_{control}) \times 100 \quad (1)$$

Moisture loss (%)

The moisture loss in the cookies was calculated by subtracting the weight of the cookies sample after heating from the initial weight of the sample. The percent of moisture loss was obtained using Equation

Weight loss = (Initial weight) - (Final weight)

$$\%\ \text{Moisture loss} = \frac{\text{Weight loss (g)}}{\text{Initial weight (g)}} \times 100 \quad (2)$$

Experimental Design, Statistical Analysis, and Optimization

In this study, process variable RWF:WNF, Sugar, Shortening, Baking powder were represented by with codes X_1, X_2, X_3, X_4 were analyzed by using Central Composite rotatable design. All independent variable were controlled at five different levels discussed in Table 2. A second polynomial equation was then used to fit the measured, dependent variable (Thickness, diameter, spread ratio, moisture loss) as a function of independent extrusion variable. Response Surface Methodology (RSM) which explore the relationship between several explanatory variables (Gaines and Tsen, 1980).

Table 1: Experimental combination of cookies coded and decoded

S. No.	Variables	Units	Code	Coded levels				
				-2	-1	0	+1	+2
1	RWF: WNF	G	X1	90:10	85:15	80:20	75:25	70:30
2	Sugar	G	X2	20	30	40	50	60
3	Shortening	G	X3	15	20	25	30	35
4	Baking powder	G	X4	2.5	3.0	3.5	4.0	4.5

Response surface methodology

The effect of independent variable on some predominant responses *viz*. physical properties of Niger flour fortified cookies, response surface methodology was used. A full second order equation of following form was fitted in each response to describe it mathematically and to study the effect of variables. The adequacy of models was tested using F ratio and coefficient of determination (R2). The model is generally considered adequate when (I) the calculated F ratio is more than that of Table value and (II) the R2 value is more than 70 per cent (Frazier *et al.*, 1983, Henika, 1982) [5]. The effect of variables at linear, quadratic and interactive levels of the response was described using significance at 1 and 5 per cent level of confidence.

$$Y = \beta_0 \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \beta_{ii} X_i^2 + \sum_{j=i+1}^{k} \sum_{j=i+1}^{k} \beta_{ii} X_i X_j$$
...........(3)

Table 2: Experimental design matrix for preparation of fortified cookie (RSM)

Treatments	Factor 1 A:RWF:WNF (g)	Factor 2 B:Sugar (g)	Factor 3 C:Shortening (g)	Factor 4 D:Baking Powder (g)
T_1	15	30	20	3
T_2	25	30	20	3
T_3	15	50	20	3
T_4	25	50	20	3
T_5	15	30	30	3
T_6	25	30	30	3
T_7	15	50	30	3
T_8	25	50	30	3
T_9	15	30	20	4
T_{10}	25	30	20	4
T_{11}	15	50	20	4
T_{12}	25	50	20	4
T_{13}	15	30	30	4
T_{14}	25	30	30	4
T_{15}	15	50	30	4
T_{16}	25	50	30	4
T_{17}	10	40	25	3.5
T_{18}	30	40	25	3.5
T_{19}	20	20	25	3.5
T_{20}	20	60	25	3.5
T_{21}	20	40	15	3.5
T_{22}	20	40	35	3.5
T_{23}	20	40	25	2.5
T_{24}	20	40	25	4.5
T_{25}	20	40	25	3.5
T_{26}	20	40	25	3.5
T_{27}	20	40	25	3.5
T_{28}	20	40	25	3.5
T_{29}	20	40	25	3.5
T_{30}	20	40	25	3.5

Statistical analysis

.The data were subjected to analysis of variance (ANOVA) before Duncan's Multiple Range test (SPSS v. 20.0 for Windows; SPSS Inc., Illinois, USA) was used to ascertain differences in means. A p value of 0.05 or less was deemed significant. Using Design-Expert® version 11.0.0, regression analysis was done on the biscuits' sensory quality traits (Stat-Ease, Inc., USA). The analysis revealed the model significance (p0.05), lack of fit, and adjusted coefficient of determination (R2 adj), which show the model fitness.

Results and Discussion

In present study, physical properties of Niger fortified cookies and were evaluated using standard procedures.The results presented in Table-3.

Table 3: Physical properties of Niger fortified cookies

Treatment	Thickness (mm)	Diameter (mm)	Moisture loss (%)	Spread ratio (D/T)
Control	8.32	57.21	8.60	6.54
T_1	8.32	57.24	8.50	6.87
T_2	8.34	57.27	8.50	7.05
T_3	8.42	57.97	8.50	6.88
T_4	8.38	58.76	8.60	7.01
T_5	8.38	57.96	8.80	6.91
T_6	8.02	58.07	8.60	7.24
T_7	8.88	57.98	8.90	6.52
T_8	8.07	59.02	8.80	7.19
T_9	8.03	57.22	9.00	7.33
T_{10}	8.94	58.01	8.60	6.48
T_{11}	8.21	58.63	8.50	7.14
T_{12}	8.21	58.23	8.60	7.09
T_{13}	8.22	58.86	8.60	7.16
T_{14}	8.88	58.09	8.60	6.54
T_{15}	8.22	59.34	8.30	7.07

T_{16}	8.17	58.87	8.60	7.2
T_{17}	8.21	57.29	8.30	6.97
T_{18}	8.23	58.76	7.80	7.13
T_{19}	8.29	58.03	8.40	7.00
T_{20}	8.87	58.83	8.10	6.63
T_{21}	8.44	57.88	9.00	6.85
T_{22}	8.21	58.63	8.40	7.11
T_{23}	8.36	57.42	8.60	7.25
T_{24}	8.23	58.76	8.30	7.13
T_{25}	8.22	58.86	8.50	6.52
T_{26}	8.44	57.88	8.60	6.92
T_{27}	8.38	58.76	8.90	7.00
T_{28}	8.38	57.96	8.40	6.87
T_{29}	8.15	58.61	8.20	7.19
T_{30}	8.34	58.82	8.40	6.48

Table 4: ANOVA of full second order Regression model for physical properties of Niger fortified cookies

Source	Thickness (mm)	Diameter (mm)	Spread ratio (D/T)	Moisture loss (%)
Model SS	0.0342	0.0317	0.0345	0.0227
Model MS	0.0034	0.0032	0.0035	0.0023
model DF	10	10	10	10
Error SS	0.0027	0.0036	0.0075	0.0049
Error MS	0.0005	0.0007	0.0015	0.0010
Error DF	5	5	5	5
F Ratio	3.27	4.47	3.00	2.38
F table	2.38	2.38	2.38	3.06
R Square	0.6323	0.7060	0.6124	0.1669
Std dev.	0.0323	0.0266	0.0339	0.0272
Mean	2.89	7.63	2.64	2.93
C.V	1.12	0.3489	1.28	0.9288

Physical properties

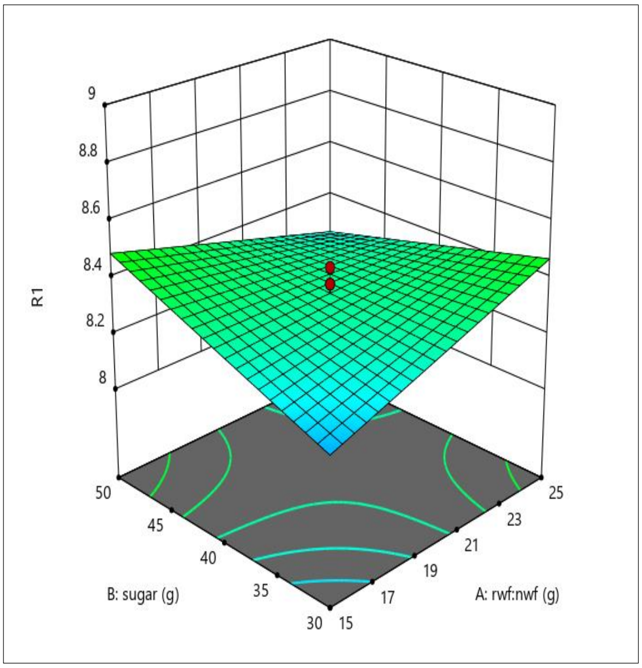
These experiments represented the combination of ingredients RWF: WNF as 90:10, 85:15, 80:20, 75:25 and 70:30, sugar at level of 20, 30, 40, 50 and 60 with shortening agent and baking powder at level of 10 to 30 per cent and 2.5, 3.0, 3.5, 4.0 and 4.5 per cent respectively.

Thickness

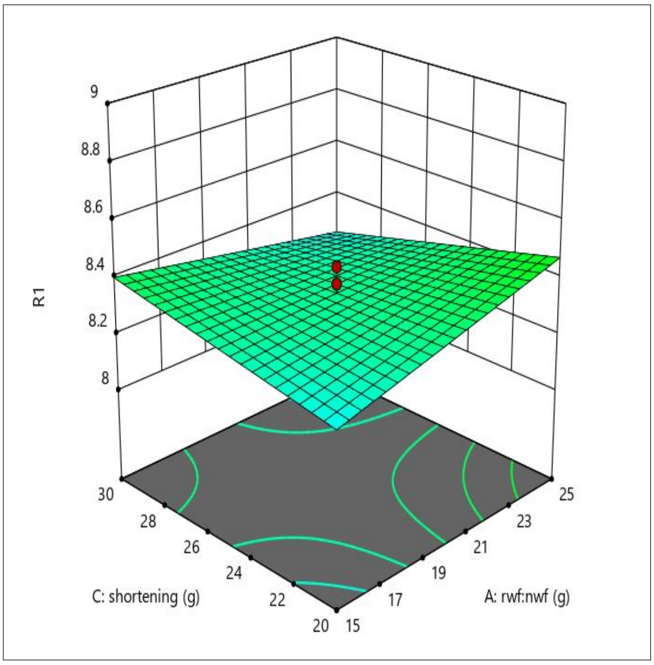
The effect of different ingredient and their combination on thickness of cookies is given in (Table 3). The thickness of Niger seed fortified cookies varied from 8.2 mm to 8.94 mm. The minimum and maximum thickness of Niger flour fortified cookies was 8.94 mm for 25 percent incorporated treatment and 57.22 mm for 30 per cent Niger seed flour incorporated treatment respectively. The Model F-value of 3.27 is more than the table value i.e., 2.38 that implies the model is significant; also the R^2 value of model is 63.23 percent. The finding indicates that model is significant effect at 5% level of significance.

No vital distinction for thickness between different cookies sample was observed because the Niger seed flour level increased, unfold quantitative relation for various treated cookies bit by bit diminished from 8.20 to 8.94. This reduction in unfold quantitative relation may be because of increase in macromolecule and dietary fiber proportion with increasing level of linseed flour as a result of protein and dietary fiber has a lot of water binding power. Once more water is gift within the dough; more sugar is dissolved throughout mixing. This lowers the initial dough and therefore the cookie is in a position to spread at a quicker rate during heating. The flour elements that absorb giant quantities of water cut back the number of water that's offered to dissolve the sugar in the formula. Thus, initial viscosity is higher and the cookies spread less during baking (Hoseney and Rodger, 1994) [9].

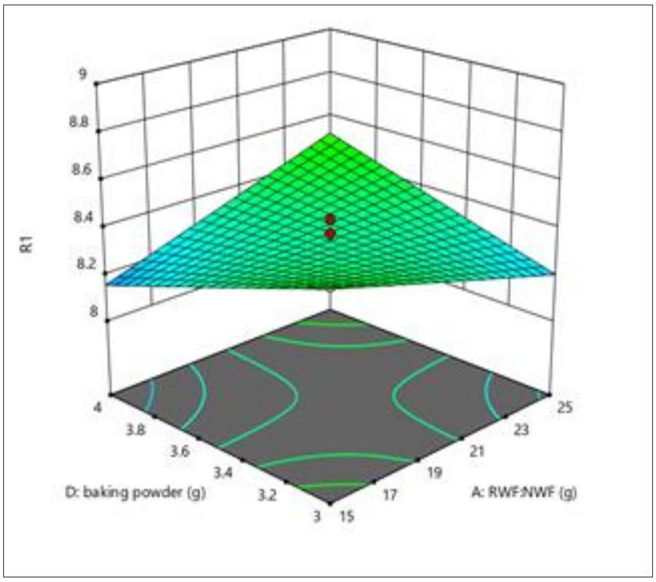
Thickness = +2.89+0.026+0.0042-0.0035-0.0015-0.0228-0.0157+0.0291+0.0026-0.0208+0.0025 ....(4)



(a)



(b)



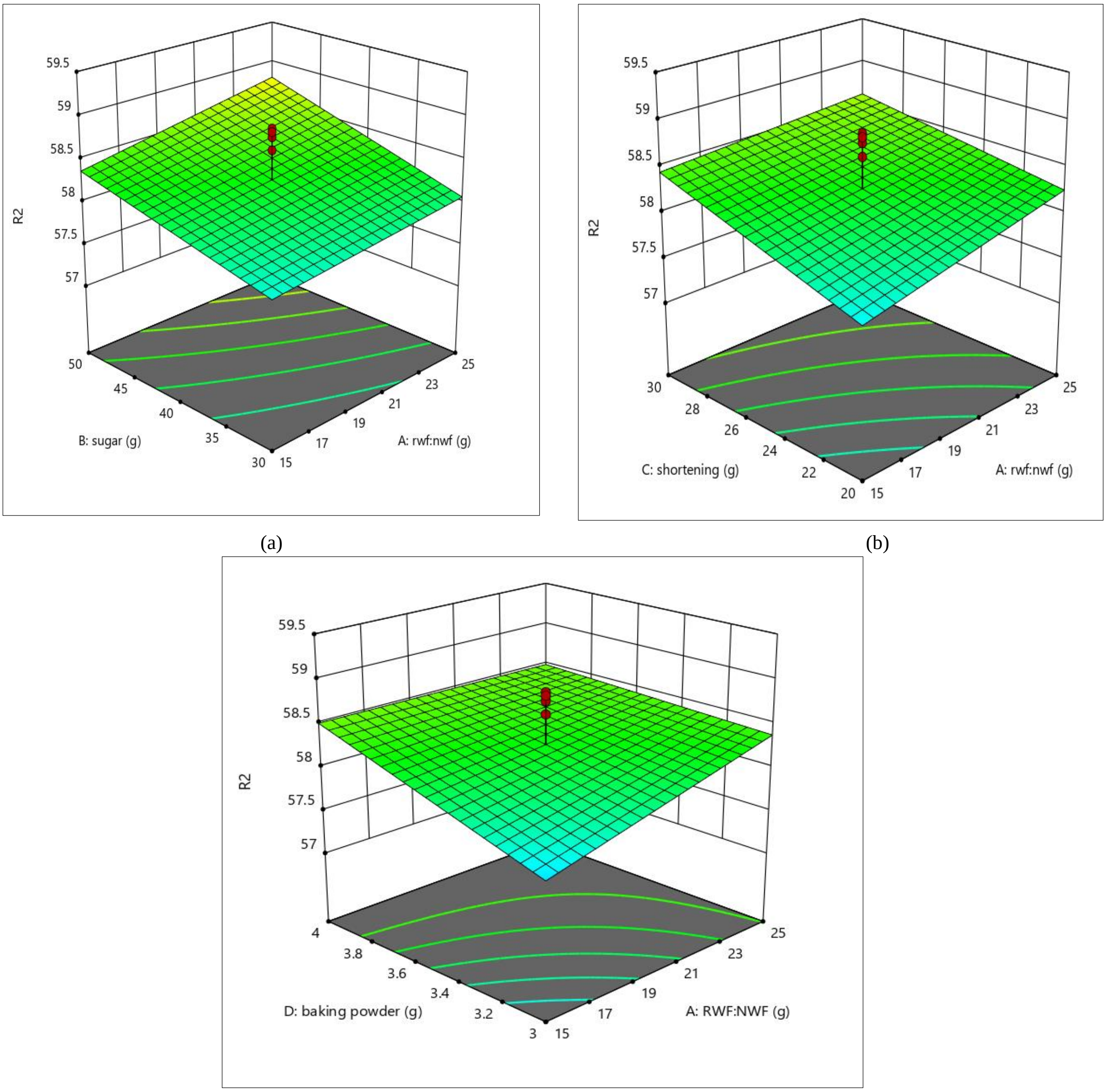
(c)

Fig 1 (a, b, c): Three-dimensional response surface plots representing interaction effect: (a) sugar with RWF:WNF, (b) shortening with RWF:WNF (c) baking powder with RWF:WNF on thickness of Niger cookies.

Diameter (D)

The effect of different ingredient and their combination on diameter of cookies is given in (Table 3). The thickness of Niger flour fortified cookies varied from 57.24 mm to 58.86 mm. The minimum and maximum diameter (after baking) of Niger seed fortified cookies was 58.88 mm for 25 percent incorporated treatment and 57.24 mm for 15 per cent Niger seed flour incorporated treatment respectively. The Model F-value of 4.47 is more than the table value i.e., 2.38 that implies the model is significant, also the R^2 value of model is 70.6 percent. The finding indicates that model is significant effect at 1% level of significance. The physical characteristics of cookies are shown in Table. 3. Results of these studies indicated that there's vital distinction (p<0.05) between control and treated samples except T17 (10% Niger flour) treatment. As Niger seed flour level increased, thickness and diameter of cookies increased. Macromolecule influences the dough viscosity and this is often as a result of the growth of protein. Protein isn't resumed within the creating of cookies. Inverse correlation was obtained between diameter and protein content (Leon *et al*., 1996) [12]. Throughout baking, the gluten goes through an understandable glass transition, thereby, gaining quality that enables it to act and kind a net. The formation continuous web will increase body and stops the flow of cookie dough (Miller *et al*., 1997) [13].

Diameter = +58.27+0.1692+0.3200+0.2650+0.2358+0.0500-0.0812-0.1762-0.1012-0.0187+0.0800 ....(5)



(a) (b)

(c)

Fig 2 (a, b, c): Three-dimensional response surface plots representing interaction effect: (a) sugar with RWF: NWF, (b) shortening with RWF: NWF, (c) baking powder with RWF: NWF on diameter of Niger cookies.

Spread ratio

Different ingredient and their incorporation on spread ratio of Niger fortified cookies is given in (Table 3). The spread ratio of Niger fortified cookies ranged from 6.43 mm to 7.25 mm. It is clearly seen that the minimum and maximum Spread ratio of Niger fortified cookies was 7.25 mm for 20 percent incorporated treatment and 6.43 mm for 15 per cent Niger seed flour incorporated treatment respectively. The Model F-value of 3.00is more than the table value i.e., 2.38 that implies the model is significant; also the R^2 value of model is 61.24 percent. The finding indicates that model is significant effect at 5% level of significance. Cookie unfold rate seems to be controlled by dough body (Yamazaki, 1959, Miller *et al*., 1997) [19, 13]. It's the explanation because of that wheat varieties are suggested with low macromolecule content to arrange cookies (Miller *et al*., 1997) [13]. Results obtained within the gift study are in line with Bashir *et al*., 2006 [3] and Hussain, 2006 [10]. Moreover, Hoojat and Zebik (1984) [8] conjointly showed that 20% and 30% replacement of navy bean, *Sesamumindicum* flour reduced the spread issue of the flour cookies. Rajiv *et al*., (2012) [17] reportable the similar result trends for spread ratio.

$$R4= +2.64+0.0018-0.0017+0.0039+0.0007+0.0220+0.0130-0.0321-0.0032+0.0176-0.0012 \quad ....(6)$$

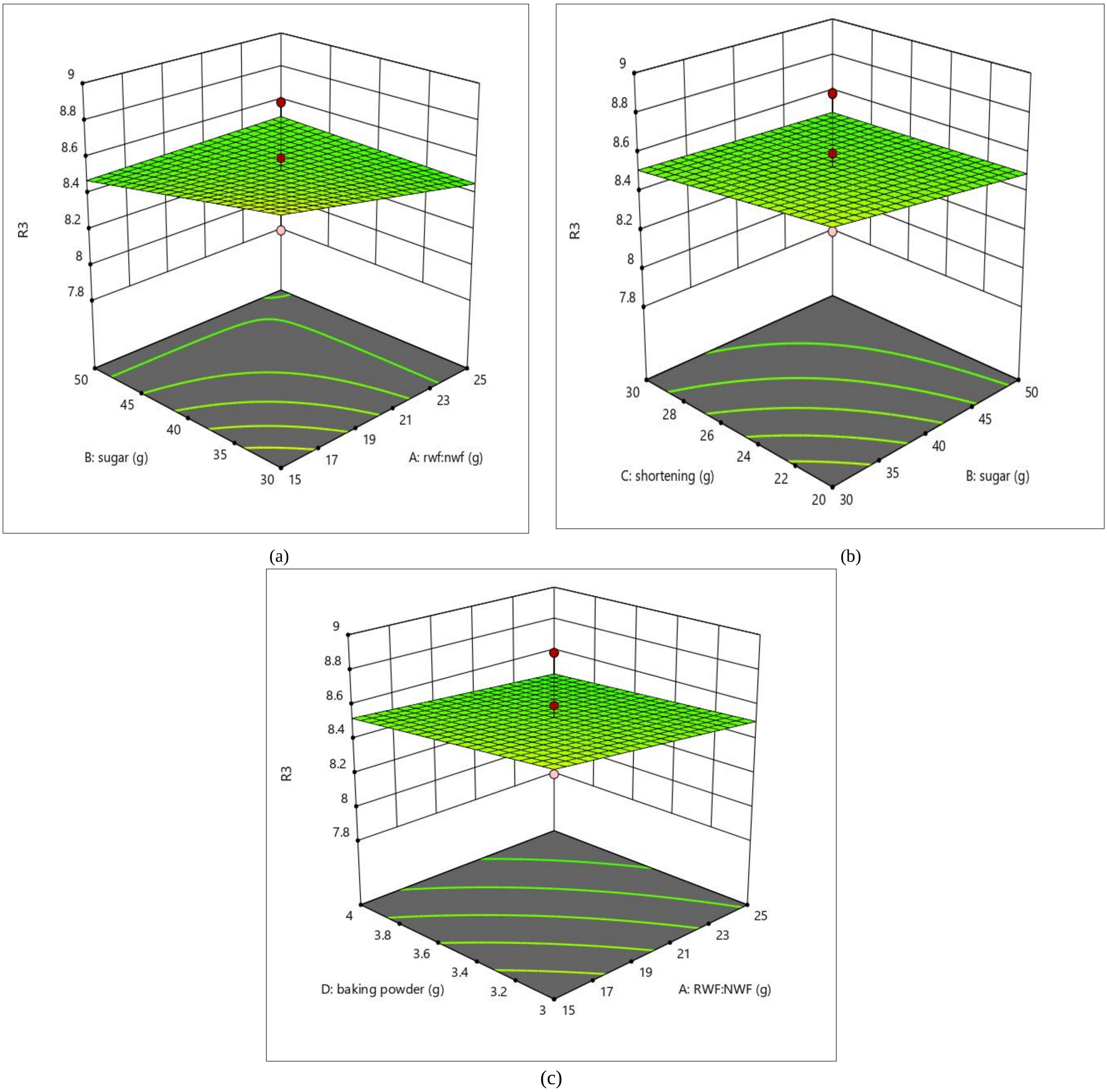


Fig 3 (a, b, c): Three-dimensional response surface plots representing interaction effect: (a) sugar with RWF:NWF, (b) shortening with RWF:NWF, (c) baking powder with RWF:NWF on Spread ratio of Niger cookies.

Moisture loss in cookies (after baking)

The Moisture loss in Niger fortified cookies (after baking) ranged from 7.8to 9.0 per cent. The minimum and maximum moisture loss in Niger fortified cookies was recorded at treatment 18 and 9 respectively. These experiments represented the combination of ingredients RWF: WNF as 90:10, 85:15, 80:20, 75:25 and 70:30, sugar at level of 20, 30, 40, 50 and 60 with Shortening and baking powder at level of 10to 30 per cent and 2.5, 3.0, 3.5, 4.0 and 4.5 per cent respectively.The Model F-value of 4.33 is more than the table value i.e., 2.38 that implies the model is significant, also the R^2 value of model is 16.69 percent. The finding indicates that model is significant effect at 5% level of significance. Indicate table 3.3.The Moisture loss in Niger fortified cookies (after baking) ranged from 7.8 to 9.0 per cent.

Moisture loss = +2.92-0.0087-0.0072-0.0056-0.0072+0.0106+0.0021+0.0022+0.0042-0.0127-0.0170 ....(7)

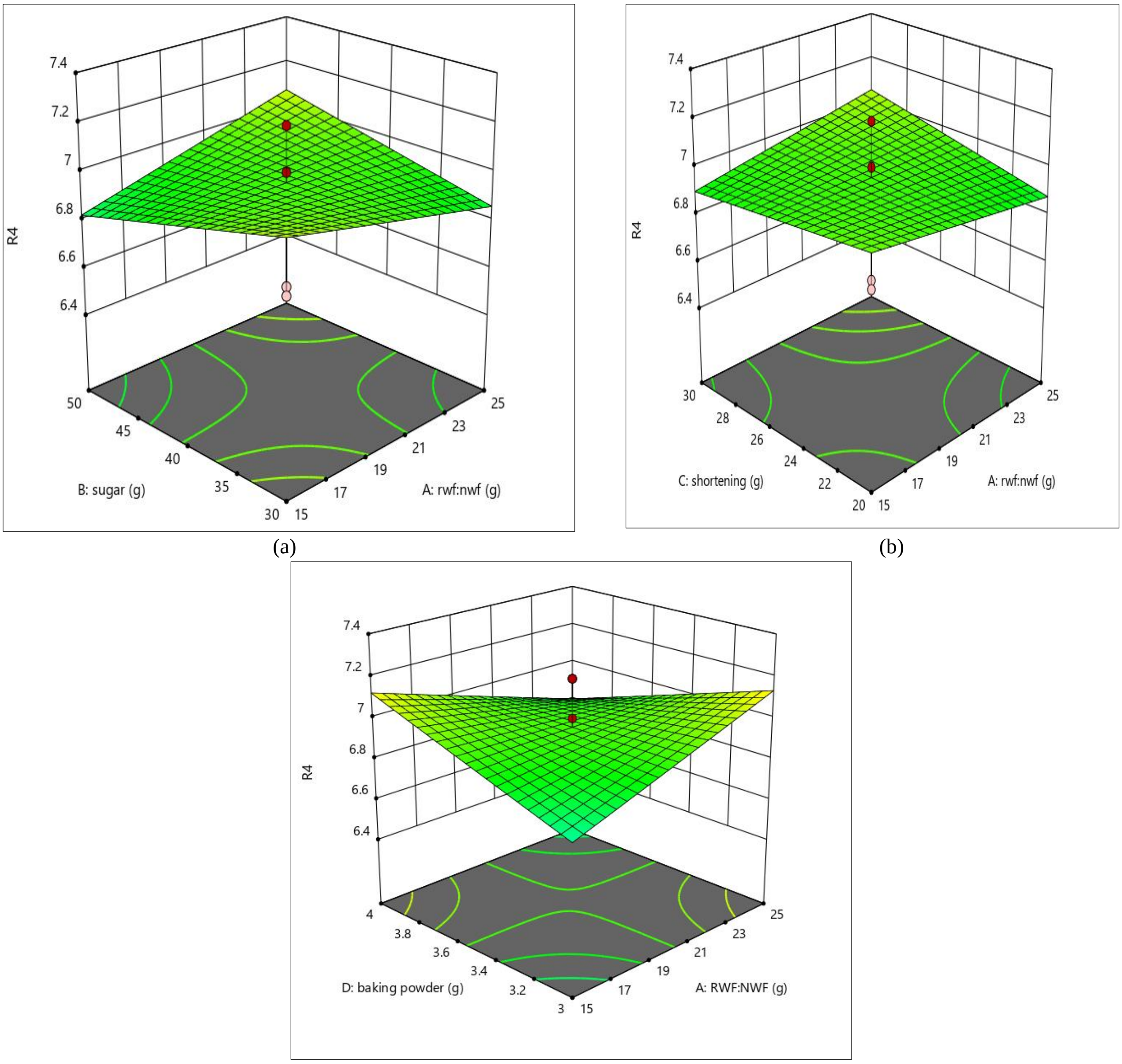


Fig 4 (a, b, c): Three-dimensional response surface plots representing interaction effect: (a) sugar with RWF: NWF, (b) shortening with RWF: NWF, (c) baking powder with RWF: NWF on moisture loss of Niger cookies.

Conclusion

The thickness of Niger seed fortified cookies varied from 57.24 mm to 58.86 mm. The minimum and maximum diameter (after baking) of Niger seed fortified cookies was 58.88 mm for 25 percent incorporated treatment and 57.24 mm for 15 per cent Niger seed flour incorporated treatment respectively. The spread ratio of Niger fortified cookies ranged from 6.43 mm to 7.25 mm. The minimum and maximum Spread ratio of Niger fortified cookies was 7.25 mm for 20 percent incorporated treatment and 6.43 mm for 15 per cent Niger seed flour incorporated treatment respectively. The load of the Niger seed cookies changed into maximum weight before baking (18.82 gm.) in 30 percent incorporated treatment and minimum (18.70 gm.) in 15 per cent Niger seed variant whereas after baking weight maximum weight (17.22 gm.) found in 30 per cent Niger seed flour treatment and minimum (17.10 gm.) found in 10 per cent Niger seed variant. The Moisture loss in Niger fortified cookies (after baking) ranged from 7.8 to 9.0 per cent. The present findings indicated that new formulations can be explored with nutrient dense food to combat protein calorie malnutrition and anaemia with consumer acceptability in terms of physical properties.

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