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Formulation, Optimization and Characterization of Dietary Cookies from Blends of Corn, Peanut, Sweet Potato and Soybean

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Abstract: Traditionally wheat is used for cookies production but the harsh climatic conditions in the tropical regions is not conducive for the growth of wheat. There are locally grown crops that can be used to produce high quality cookies that meet consumer's dietary requirements. The aim of this study was to develop, characterize, and optimize the formulation and some production processes of dietary cookies from blends of corn, peanut, sweet potato and soybean. A four-component, constrained, randomized, combined, D-optimal mixture-process experimental design; with 34 randomized experimental runs, was employed. The formulation design constraints were: roasted corn flour (20% - 70%), defatted peanut meal (10% - 30%), blanched soybean (10% - 30%), and sweet potato extract/gel (5% - 20%). The four major components comprise 95% of the total mixture. Other minor components of the formulation, which were kept constant throughout the experimentation, were: sugar (1 %), baking powder (0.8 %), baking fat (0.2 %), and water (3 %). The processing parameters investigated were: baking temperature (120^{0}C - 180^{0}C) and baking time (10min – 25min). The formulated dietary cookies were analyzed and evaluated for the proximate properties, physicochemical properties and sensory characteristics using standard procedures. The result of the dietary cookies optimization gave optimal formulated dietary cookie with overall desirability index of 0.531, based on the set optimization goals and individual quality desirability indices. The optimal cookie was obtained from 22.744% roasted corn, 26.589% defatted peanut, 25.666% blanched soybean, 20.0% sweet potato extract/gel, 1380C baking temperature, and 25 minutes baking time. The quality properties of this optimal cookies are 14.071% moisture content, 25.699% crude protein, 4.957% crude fibre, 16.033% fat content, 34.388% carbohydrate, 7.234% ash content, 386.440 Kcal/100g energy value, 381.514 mg/100g potassium, 80.0 mg/100g calcium, 3.789 mg/100g iron, 0.552 mg/100g zinc, 75.088% digestibility, 20.566 D/T spread ratio, 0.657 g/cubic cm bulk density, 1.695g breaking strength, and overall acceptability of 5.96, based on 9-point hedonic scale. The result of the study showed that the formulated dietary cookies was of high quality and that improving nutritional quality of cookies is possible through composite formulation. It is recommended that further study be carried out on formulation of nutritionally improved dietary cookies using other nutritionally rich roots and legumes. Enrichment of cookies with these protein-rich sources will result in cookies with improved nutrient quality that meets the consumer's dietary needs.

Keywords: Dietary Cookies, Composite Flours, Formulation, Characterization, Optimization

1. Introduction

Cookies are widely consumed all over the world by adults and children alike and they represent the largest, most popular category of snack foods in most parts of the world. They are convenient, easy and light to carry around, ready-to- eat and tasty, easy to be consumed, have long shelf life, wide acceptance by consumers of all ages, and their costs is reasonable) [1-4], Traditionally, the key ingredients generally used in the manufacture of cookies are flour, sugar and fat. However, wheat does not grow well in the tropics and has to be imported by countries in these regions. Incessant increases in the cost of wheat have in turn led to constant increases in the price of these products. This had led to the need to develop alternatives to the use of wheat flour in the production of baked goods [5-15]. Beside these, traditional biscuits and cookies are deficient in nutrients, phytonutrients and fiber; they are high in carbohydrates, fat, and calorie, but low in fiber, vitamin, and mineral which made their consumption unhealthy. Generally, biscuits are characterized not only by low content of protein, vitamins, dietary fiber and minerals but also contain high amount of sugar and fat; making them not so healthy option for consumers. The association of wheat consumption with such health problems as celiac disease makes it pertinent to utilize composite flour in cookies manufacture [14, 16].. This situation has created the need for the development of gluten free baked food products. This has led to the composite flour concept in which flours with high nutritional and sensory properties are derived from cereals, roots and tubers, legumes etc. with or without the addition of wheat flour [5, 8, 17, 18, 19, 20].

A current trend in nutrition is the consumption of foods that not only supply basic nutrients but also help to prevent disease, advocated by world nutrition bodies due to different health problem related with wheat consumption such as celiac disease, diabetes and coronary heat diseases (WHO/FAO, 2003). This situation has created the need for the development of gluten free baked food products. Composite flour formulation can enhance the nutritional, functional as well as sensory quality of cookies. Composite flour formulation/bakery products have many functional forms, (providing protein and energy), enriched with minerals and vitamins, nutritious (providing protein and energy), gluten-free, and can serve as good vehicle for carrying the added proteins to target populations for use in combating the protein malnutrition prevalent in many parts of the world. Composite flour cookies can be formulated to meet the dietary needs of different categories of consumers. They are considered as an essential source of energy by the majority of the population. [22, 24-26]). There are many flours which can be used as base materials for the formulation of composite flours. Products made from non-wheat flour or from composite flour are latest trend in producing baked goods. Currently, composite flour formulation or additive food manufacturing has evolved to enhancing nutritional quality of cookies [9, 13, 14, 27 - 30]. The increasing consumer demand for foods that combine additional benefits in addition to common nutrients imposes on the food industry a need for advances in ingredients and formulations [11, 25].

Today foods are not intended to only satisfy hunger and to provide necessary nutrients for humans but also to prevent nutrition-related diseases and improve physical and mental well-being. Now a day's cookies are being considered to be most efficacious means of delivering supplementary nutritional on to weaker and vulnerable sections suffering from calories malnutrition. Development of diabetic friendly cookies and biscuits (especially designed for diabetes patients) prepared by incorporation of multigrain is becoming popular in the developed countries. Efforts have been made to promote the use of composite flour in in cookie productions, thereby decreasing the demand for imported wheat, improving the nutritional content of cookies, and also enhancing indigenous crop utilization. Protein-rich cookies are gaining popularity in countries where protein energy malnutrition is prevalent. Cookies are looked upon as carriers of nutrition and provide a good source of energy [1, 3, 4, 11, 20, 31-36]. The aim of this study was to develop, characterize, and optimize the formulation and some production processes of dietary cookies from blends of corn, peanut, sweet potato and soybean.

2. Materials and Methods

2.1. Materials

The materials used in this study were roasted corn flour, defatted peanut meal, blanched soybean and sweet potato extract/gel. These were obtained locally from Kure market, Minna Nigeria.

2.2. Methods

2.2.1. Experimental Design for the Cookies Formulation Experiments

A four-component, constrained, randomized, combined, D-optimal mixture-process experimental design; with 34 randomized experimental runs, was employed. The formulation design constraints were: roasted corn flour (20% - 70%), defatted peanut meal (10% - 30%), blanched soybean (10% - 30%), and sweet potato extract/gel (5% - 20%). The four major components comprise 95% of the total mixture. Other minor components of the formulation, which were kept constant throughout the experimentation, were: sugar (1%), baking powder (0.8%), baking fat (0.2%), and water (3%). The processing parameters investigated were: baking temperature (120°C - 180°C) and baking time (10min – 25min). The formulated dietary cookies were analyzed and evaluated for the proximate properties, physicochemical properties and sensory characteristics using standard procedures. The design matrix for the formulation experiment`t was presented in Table 1.

Table 1. *Design matrix for the cookies formulation experiments.*

Run	x_1 (%)	x_2 (%)	x_3 (%)	x_4 (%)	z_1 (deg C)	z_2 (min)
1	35	10	30	20	135	13.75
2	50	30	10	5	180	10
3	35	10	30	20	120	25
4	20	25	30	20	180	25

Run	x_1 (%)	x_2 (%)	x_3 (%)	x_4 (%)	z_1 (deg C)	z_2 (min)
5	40	30	10	15	180	25
6	70	10	10	5	165	21.25
7	50	10	30	5	180	25
8	37.5	27.5	10	20	120	10
9	45	10	20	20	180	25
10	55	10	10	20	180	25
11	50	30	10	5	120	25
12	35	25	30	5	180	10
13	30	30	30	5	120	25
14	55	10	10	20	120	10
15	40	30	10	15	150	17.5
16	50	10	30	5	120	10
17	50	30	10	5	180	10
18	27	25.5	30	12.5	120	10
19	35	25	30	5	120	25
20	20	25	30	20	180	25
21	35	30	10	20	180	10
22	40	30	15	10	180	25
23	27	25.5	30	12.5	120	10
24	35	30	10	20	180	10
25	35	10	30	20	180	10
26	50	30	10	5	120	10
27	55	25	10	5	180	25
28	35	25	30	5	180	10
29	35	30	10	20	120	25
30	47	20	19.5	8.5	150	17.5
31	70	10	10	5	135	13.75
32	70	10	10	5	180	10
33	70	10	10	5	120	25
34	45	25	20	5	120	10

x_1 = Roasted Corn (%), x_2 = Defatted Peanut (%), x_3 = Blanched Soybean (%), x_4 = Sweet Potato Extract / Gel (%), z_1 = Baking Temperature (deg C), z_2 = baking Time (min)

2.2.2. Statistical Analysis of Experimental Data

The experimental data were analyzed and appropriate Scheffe canonical models, relating the quality indices with the mixture component proportions and process parameters, were fitted to the quality and sensory properties. The statistical significance of the terms in the Scheffe canonical models were tested using analysis of variance (ANOVA) for each response, and the adequacy of the models were evaluated by coefficient of determination, F-value, and model p-values at the 5% level of significance. The models were also subjected to lack-of-fit and adequacy tests. The fitted models for each of the response was used to generate contour, mix-process, as well as the 3-D response surface for the quality properties using the DESIGN EXPERT 13.0.0 statistical software package. A Numerical optimization approach, exploiting the desirability function technique, was utilized to generate the optimal formulation with the anticipated responses. Numerical optimization maximizes, minimizes, or targets desired response based on set criteria for all variables, including components proportions. Optimization goals are assigned to parameters and these goals were used to construct desirability indices (di). A goal may be to maximize, minimize, or target specific quality parameter to satisfy the dietary needs of the consumers of the formulated food product. Components can be allowed to range within their pre-established constraints in the design or they can be set to desired goals. Also, components can be set equal to specified levels. Desirabilities range from zero to one for any given response and individual desirability for all the responses, in the case of multi-response optimization, are combined into a single number known as overall desirability index. A value of one represents the case where all goals are met perfectly. A zero indicates that one or more responses fall outside desirable limits.

Numerical optimization solutions are given as a list in their order of desirability, detailing the components proportions and process variables values that satisfies the set criteria and the overall desirability. The numerical solution can also be presented in the form of bar graph, desirability contour and desirability mix-process graphs. Furthermore, optimization can also be achieved through graphical method. Graphical optimization yields the overlay contour and the overlay mix-process plots (Wendell, 2005; ReliaSoft, 2015; Raymond et al., 2016; Dharmaraja et al., 2018). A contour graph of overall desirability indicates the desirable formulation. Overlay plots of the responses indicates regions that meet specifications.

3. Experimental Data and Results of Statistical Analyses of Experimental Data

3.1. Experimental Data

Table 2. *Proximate Properties and energy values of the formulated cookies.*

Run	y_{mc}	y_{cp}	y_{cf}	y_{fat}	y_{cho}	y_{ac}	y_{ev}
1	13.29	25.3	5.32	20.5	29.59	6	404.06
2	10.29	21.3	4.76	10.14	47.47	6.04	366.34
3	17.61	26	6	15	30.89	4.5	362.56
4	11.31	30.3	3	18.61	30.28	6.5	409.81
5	10.21	20.95	4	12	48.34	4.5	385.16
6	13.11	16.45	6.31	8.5	52.13	3.5	350.82
7	11.06	22.15	4.11	14.33	43.35	5	390.97
8	14.69	14.25	4.5	8	53.06	3.5	341.24
9	9.38	16.5	5.5	7.72	54.4	5.5	353.08
10	8.7	12.45	5.5	8.5	61.35	3.5	371.7
11	12.11	24.05	4.91	14.26	37.17	7.5	373.22
12	10.08	28.05	4.32	16.81	33.74	7	398.45
13	16.15	26.5	3.5	17	31.05	5.5	383.2
14	15.15	11.5	2.5	9	59.35	2.5	364.4
15	12.52	17.5	5.5	11	50.48	3	370.92
16	16.63	14.15	6	12.5	46.34	4.38	354.46
17	11.33	17.05	3.98	10.5	51.34	5.8	368.06
18	16.84	22.75	4	18.11	35.16	3.14	394.63
19	15.37	25.75	5	17.24	33.05	3.61	390.36
20	12.05	20.9	4.22	15	40.33	7.5	379.92
21	15.19	19.25	4.11	18.63	36.11	6.11	389.11
22	11.66	22.8	3.5	10	47.54	4.5	371.36
23	16.14	24	4.32	16.18	34.66	4.7	380.26
24	12.89	25.4	5	14	36.21	6.5	372.44
25	10.92	23.8	6.11	17.5	34.17	7.5	389.38
26	17.46	24.7	5.31	10.14	37.59	4.8	340.42
27	11.55	23.83	6	11	42.12	5.5	362.8
28	14.46	24.95	6.5	12.5	40.09	2	372.66
29	16.53	26.2	4.81	16.5	33.46	2.5	387.14
30	15.11	18.8	4.33	16.11	37.15	8.5	368.79
31	13.48	18.2	5.21	13	47.11	3	378.24
32	12.11	18.55	5.5	14.33	43.01	6.5	375.21
33	16.72	19	3.61	13	42.27	5.4	362.08
34	16.28	28.9	4	17.61	28.31	4.9	387.33

y_{mc} = *Moisture Content* (%), y_{cp} = *Crude Protein* (%), y_{cf} = *Crude Fiber* (%), y_{fat} = *Fat Content* (%), y_{cho} = *Carbohydrate* (%), y_{ac} = *Ash Content* (%), y_{ev} = *Energy Value* (*Kcal*/100*g*)

Table 3. *Some minerals contents, physical and physicochemical properties of the formulated cookies.*

Run	y_{pot}	y_{cal}	y_{ir}	y_{zinc}	y_{dig}	y_{spr}	y_{bd}	y_{break}
1	340.11	79.24	3.24	0.38	76.2	24.5	0.78	0.815
2	332.66	76.28	2.81	0.22	71.9	20	0.77	3.746
3	348.62	75.32	2.72	0.36	76.3	19.6	0.65	0.795
4	350.33	80.28	3.33	0.42	76	20	0.67	3.246
5	358	81.63	4.81	0.51	71.3	20	0.65	3.246
6	355.24	82.18	4.32	0.43	71	19	0.61	2.246
7	342.16	80.73	3.92	0.36	76.5	16.5	0.65	3.5
8	350.28	77.28	3.96	0.44	71.5	24.8	0.69	0.5
9	402.11	74.19	4.61	0.3	74	16.3	0.71	2.74
10	393.28	76.38	4.72	0.3	71.3	16.7	0.69	2.398
11	349.12	86.32	4	0.33	70.9	24.5	0.68	0.5
12	378.63	86.32	3.33	0.32	76.5	19.8	0.65	0.746
13	370.11	84.21	3	0.44	76	24.8	0.67	2.246
14	380.66	79	2.83	0.38	71	20	0.61	0.5
15	382.12	72.18	2.94	0.32	71.5	16.3	0.68	3.246
16	374.11	70.28	2.63	0.41	75.9	20.4	0.63	0.746
17	402.98	74.74	3.98	0.46	71.3	20	0.68	3.746
18	400	79.92	3.9	0.52	76.6	20	0.65	0.5
19	378.31	83.12	4.11	0.55	76.4	24.8	0.64	2.246
20	378.67	83	3.22	0.57	76.1	20	0.61	3.246
21	360	80.21	2.62	0.48	71.2	19.6	0.62	1.246

Run	y_{pot}	y_{cal}	y_{ir}	y_{zinc}	y_{dig}	y_{spr}	y_{bd}	y_{break}
22	364.28	84.31	2.99	0.41	72.3	20	0.58	3.246
23	370	84.11	3	0.36	75.9	19.6	0.75	0.5
24	363.22	84.32	3.33	0.4	71	19.6	0.7	1.246
25	340.11	79.33	4.16	0.42	76.1	19	0.66	3.246
26	360.48	76.21	4.43	0.39	71.8	24.5	0.61	0.5
27	358.11	80.43	5.11	0.4	72.1	16.7	0.58	1.246
28	354.04	79.23	5.18	0.52	76.5	19.4	0.61	1.246
29	368.11	83.31	5	0.57	71.3	20	0.63	0.5
30	261.14	77.77	4.32	0.48	73.7	16.7	0.66	1.246
31	300.48	78.61	2.91	0.52	71.5	19.6	0.7	1.246
32	320.01	80.11	4.28	0.57	71.9	16.3	0.64	3.246
33	340.21	80.11	3.12	0.53	71.1	19.6	0.68	0.746
34	342.18	82.63	3.63	0.55	74.4	20	0.64	0.746

y_{pot} = Potassium (mg/100g), y_{cal} = Calcium (mg/100g), y_{ir} = Iron (mg/100g), y_{zinc} = Zinc (mg/100g), y_{dig} = Digestibility (%), y_{spr} = Spread Ratio (D/T), y_{bd} = Bulk Density (g/cubic cm), y_{break} = Breaking Strength (g).

***Table 4.** Sensory Characteristics of the formulated cookies.*

Run	y_{col}	y_{tast}	y_{flav}	y_{tex}	y_{oa}
1	2.5	1.5	1.5	3.8	4
2	6.8	5.8	4.3	4.5	5
3	4.5	3	3	3.5	5.5
4	6.8	4.5	5.5	4	6
5	2.3	3	2.5	3.8	4
6	6.8	6.3	5.5	6.3	5.5
7	3.8	3.3	2	2.3	3
8	3	2.8	2	3.8	4.5
9	4.8	3.3	2.3	2.5	5
10	2.5	3	2	1.8	4.5
11	8	6	5	5.5	5
12	4.5	6.3	5.3	5.3	4
13	4.5	5.3	4.3	4.5	4.5
14	6.5	6.3	5.5	4.8	5
15	4.3	4.3	3.3	4.5	4.5
16	6.8	3.3	2.8	4.8	4
17	6.8	5.8	4.3	4.5	5
18	4.8	4.8	4	3	5.5
19	4.5	5.3	4.3	4.5	4.5
20	6.8	4.5	5.5	4	6
21	4.8	5.5	4.3	4.8	4.5
22	6.8	6.3	6	7.5	5.5
23	5	4.5	4.3	4.3	6.5
24	4.8	5.5	4.3	4.8	4.5
25	3.5	4.3	4.5	3.8	6
26	5.3	4.5	5	4	5
27	7.3	5.8	5.3	6	5
28	4.3	4	4.8	4.3	4
29	2.3	3	3.5	2.8	5
30	2.8	2.8	3.3	3.5	3.5
31	4.5	4	4.5	5.5	4.5
32	6	5.5	5	5.3	4
33	5.8	4.5	4.5	4.8	4.5
34	5.3	5	3.8	4.3	5.5

y_{col} = Colour, y_{tast} = Taste, y_{flav} = Flavor, y_{tex} = Texture, y_{oa} = Overall Acceptability

The formulated dietary cookies were analyzed and evaluated for the proximate properties, minerals, some physical properties, physicochemical properties, and sensory characteristics (Tables 2 - 4); using standard procedures.

3.2. Results of Statistical Analyses of Experimental Data

The summary statistics of the regression analyses (indicating only the significant terms) of the formulated cookies quality and sensory properties were presented in Table 5.

Table 5. *The summary statistics of the regression analyses of the formulated cookies quality and sensory properties.*

Response	Sources	F-value	p-value	R^2	Adj R^2	Pre R^2	C.V. (%)	Adeq Precision
	Model	32.81	0.0001					
y_{mc}	z_1	61.49	0.0001	0.6792	0.6585	0.6110	11.15	11.632
	z_2	2.36	0.1344					
	Model	4.91	0.0008					
y_{cp}	L/Mixture	12.95	0.0001	0.7613	0.6061	0.2545	13.92	7.7608
	$x_1x_2x_4$	5.44	0.0302					
y_{cf}	Model	1.31	0.2915	0.5212	0.1223	-1.6741	19.40	4.7516
	L/Mixture	1.29	0.3082					
	Model	4.14	0.0023					
	L/Mixture	9.61	0.0004					
	x_1x_4	8.23	0.0095					
y_{fat}	x_2x_4	9.87	0.0051	0.7291	0.5530	-1.0682	17.35	6.8936
	x_3x_4	7.21	0.0142					
	$x_1x_2x_4$	10.48	0.0041					
	$x_2x_3x_4$	8.26	0.0094					
	Model	6.95	0.0001					
	L/Mixture	15.80	0.0001					
	x_1x_4	6.22	0.0215					
y_{cho}	x_2x_4	9.45	0.0060	0.8187	0.7009	-0.8270	11.71	9.2979
	x_3x_4	6.39	0.0200					
	$x_1x_2x_4$	11.12	0.0033					
	$x_2x_3x_4$	8.95	0.0072					
y_{ac}	Model	1.42	0.2365	0.3467	0.1017	-0.3460	31.06	4.5849
	L/Mixture	0.3504	0.7892					
y_{ev}	Model	4.27	0.0126	0.2993	0.2292	0.0852	3.88	5.8802
	L/Mixture	4.27	0.0126					
y_{pot}	Model	1.72	0.1324	0.5285	0.2220	-6.4095	36.49	4.8432
	L/Mixture	1.76	0.1867					
y_{cal}	Model	0.8891	0.5865	0.4256	-0.0531	-1.3438	4.97	3.8424
	L/Mixture	1.49	0.2500					
	Model	2.59	0.0277					
y_{ir}	L/Mixture	0.6239	0.6071	0.5642	0.3463	0.1145	16.92	5.8751
	x_1z_1	9.72	0.0050					
	x_2z_1	9.50	0.0055					
y_{zinc}	Model	1.59	0.1755	0.3731	0.1380	-0.1896	19.55	4.1976
	L/Mixture	0.2233	0.8793					
y_{dig}	Model	597.50	0.0001	0.9835	0.9819	0.9791	0.4253	47.7666
	L/Mixture	597.50	0.0001					
y_{spr}	Model	7.16	0.0028	0.3160	0.2718	0.1851	11.02	4.9909
	z_1	14.06	0.0007					
y_{bd}	Model	0.4540	0.9121	0.1850	-0.2225	-0.8234	7.95	2.3136
	L/Mixture	0.3313	0.8028					
y_{break}	Model	17.89	0.0001	0.5358	0.5059	0.4409	46.65	9.2174
	z_1	30.78	0.0001					
y_{oa}	Model	3.16	0.0118	0.5420	0.3702	-0.0339	12.74	8.5261
	L/Mixture	2.30	0.1028					

P-values less than 0.05 indicate models and model terms that are significant. A negative Predicted R^2 implies that the overall mean may be better predictors of the response than the fitted model. Adequacy of Precision measures the signal to noise ratio. A ratio greater than 4 indicates an adequate signal. For such, the models can be used to navigate the design space and to make predictions about the responses for given levels of the factors (ingredient proportions). The models are useful for identifying the relative impact of the ingredient proportions on the quality parameters by comparing the model's regression coefficients.

The fitted models in terms of L-pseudo components for the quality parameters of the formulated dietary cookies are presented as equations 1 - 16. The equation in terms of coded factors can be used to make predictions about the quality parameters for given levels of each ingredient proportion and process factor. The coded equations are useful for identifying the relative impact of the factors by comparing the factor coefficients.

$$y_{mc} = 13.62x_0 - 2.17z_1 - 0.4250z_2 \Big\} \quad (1)$$

$$\left. \begin{aligned} y_{cp} &= 18.09x_1 + 16.87x_2 - 2.77x_3 - 307.91x_4 + 19.66x_1x_2 + 34.32x_1x_3 + 436.45x_1x_4 + 60.26x_2x_3 \\ &+ 1000.31x_2x_4 + 669.71x_3x_4 + 110.94x_1x_2x_3 - 1604.86x_1x_2x_4 - 297.00x_1x_3x_4 - 1760.38x_2x_3x_4 \end{aligned} \right\} \quad (2)$$

$$\left.\begin{aligned} y_{cf} &= 5.24x_1 + 3.57x_2 + 4.96x_3 + 5.02x_4 + 0.6670x_1z_1 + 0.0006x_1z_2 - 0.9162x_2z_1 - 0.3679x_2z_2 - 0.2424x_3z_1 \\ &\quad - 1.31x_3z_2 + 0.6550x_4z_1 + 1.82x_4z_2 + 0.3299x_1z_1z_2 + 0.2004x_2z_1z_2 - 1.06x_3z_1z_2 - 2.11x_4z_1z_2 \end{aligned}\right\} \tag{3}$$

$$\left.\begin{aligned} y_{fat} &= 12.22x_1 - 25.51x_2 - 1.24x_3 - 429.48x_4 + 56.73x_1x_2 + 27.07x_1x_3 + 612.92x_1x_4 + 109.99x_2x_3 \\ &\quad + 1275.24x_2x_4 + 818.76x_3x_4 - 8.44x_1x_2x_3 - 1763.77x_1x_2x_4 - 377.56x_1x_3x_4 - 1995.35x_2x_3x_4 \end{aligned}\right\} \tag{4}$$

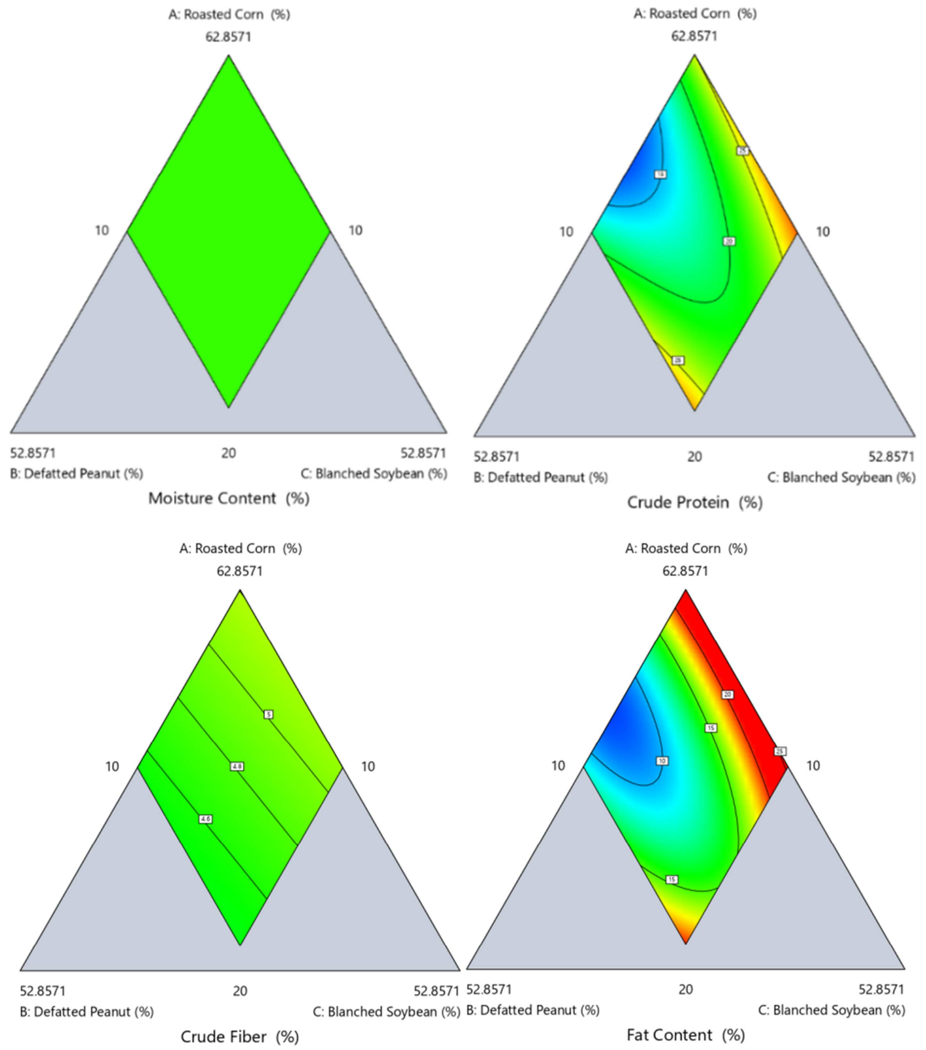
$$\left.\begin{aligned} y_{cho} &= 46.03x_1 + 133.12x_2 + 95.29x_3 + 858.64x_4 - 153.24x_1x_2 - 85.52x_1x_3 - 1088.50x_1x_4 - 300.90x_2x_3 \\ &\quad - 2550.41x_2x_4 - 1574.90x_3x_4 + 21.93x_1x_2x_3 + 3712.75x_1x_2x_4 + 554.78x_1x_3x_4 + 4243.21x_2x_3x_4 \end{aligned}\right\} \tag{5}$$

$$\left.\begin{aligned} y_{ac} &= 4.73x_1 + 4.18x_2 - 18.13x_3 + 37.18x_4 + 5.33x_1x_2 + 37.37x_1x_3 \\ &\quad - 55.52x_1x_4 + 34.68x_2x_3 - 43.25x_2x_4 + 10.52x_3x_4 \end{aligned}\right\} \tag{6}$$

$$\left. y_{ev} = 360.44x_1 + 379.82x_2 + 405.77x_3 + 378.33x_4 \right\} \tag{7}$$

$$\left.\begin{aligned} y_{pot} &= 328.75x_1 + 959.90x_2 + 1017.49x_3 + 1311.07x_4 - 882.43x_1x_2 - 1027.68x_1x_3 - 1109.79x_1x_4 - 2158.58x_2x_3 \\ &\quad - 2742.21x_2x_4 - 4066.14x_3x_4 + 878.29x_1x_2x_3 + 756.17x_1x_2x_4 + 4393.69x_1x_3x_4 + 7458.95x_2x_3x_4 \end{aligned}\right\} \tag{8}$$

The quality parameters contour plots, mix-process plots, 3-D surface plots, and 3-D surface mix-process plots; for the formulated dietary cookies are presented in Figures 1 – 4, respectively.



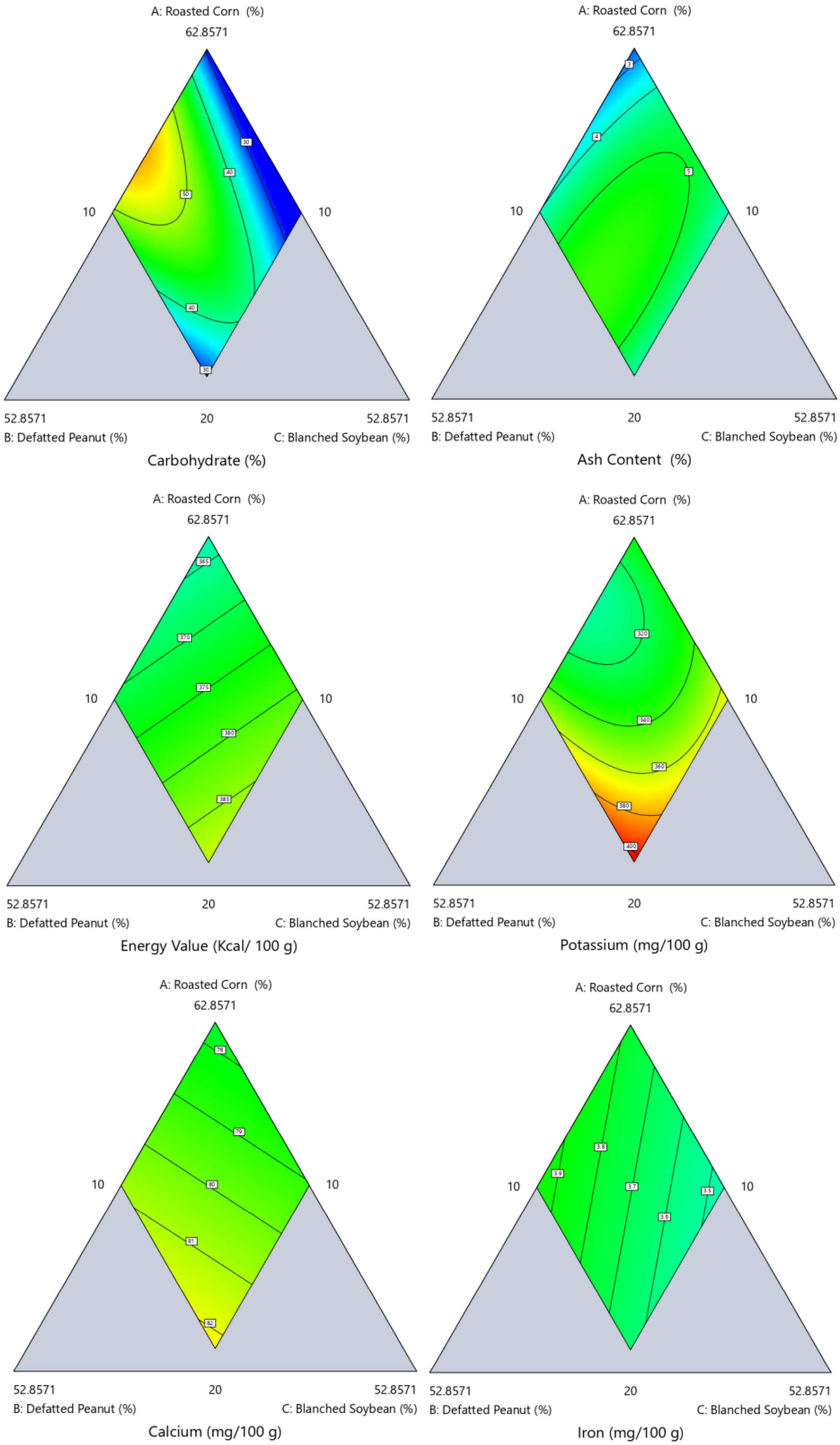

A: Roasted Corn (%)
62.8571
10
10
52.8571
B: Defatted Peanut (%)
20
52.8571
C: Blanched Soybean (%)
Carbohydrate (%)
A: Roasted Corn (%)
62.8571
10
10
52.8571
B: Defatted Peanut (%)
20
52.8571
C: Blanched Soybean (%)
Ash Content (%)
A: Roasted Corn (%)
62.8571
10
10
52.8571
B: Defatted Peanut (%)
20
52.8571
C: Blanched Soybean (%)
Energy Value (Kcal/ 100 g)
A: Roasted Corn (%)
62.8571
10
10
52.8571
B: Defatted Peanut (%)
20
52.8571
C: Blanched Soybean (%)
Potassium (mg/100 g)
A: Roasted Corn (%)
62.8571
10
10
52.8571
B: Defatted Peanut (%)
20
52.8571
C: Blanched Soybean (%)
Calcium (mg/100 g)
A: Roasted Corn (%)
62.8571
10
10
52.8571
B: Defatted Peanut (%)
20
52.8571
C: Blanched Soybean (%)
Iron (mg/100 g)

***Figure 1.** The Quality Parameters Contour Plots for the Formulated Dietary Cookies.*

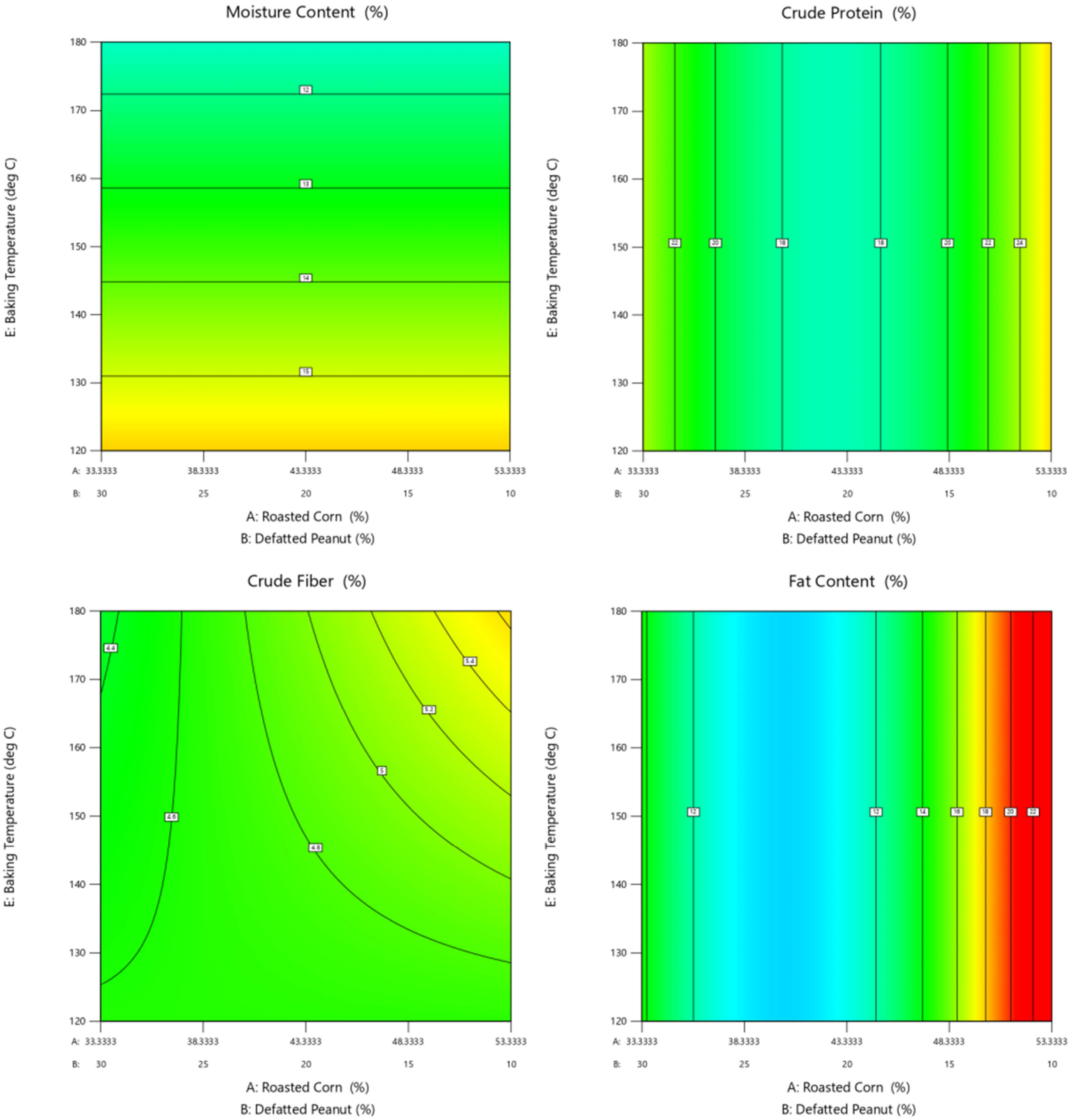
$$\left.\begin{array}{l} y_{cal} = 77.96x_1 + 85.96x_2 + 81.60x_3 + 75.46x_4 + 0.7077x_1z_1 + 1.96x_1z_2 - 2.24x_2z_1 + 5.32x_2z_2 + 3.46x_3z_1 \\ -0.6671x_3z_2 - 0.1400x_4z_1 - 8.21x_4z_2 - 1.72x_1z_1z_2 + 0.6610x_2z_1z_2 + 0.4928x_3z_1z_2 - 0.3855x_4z_1z_2 \end{array}\right\} \quad (9)$$

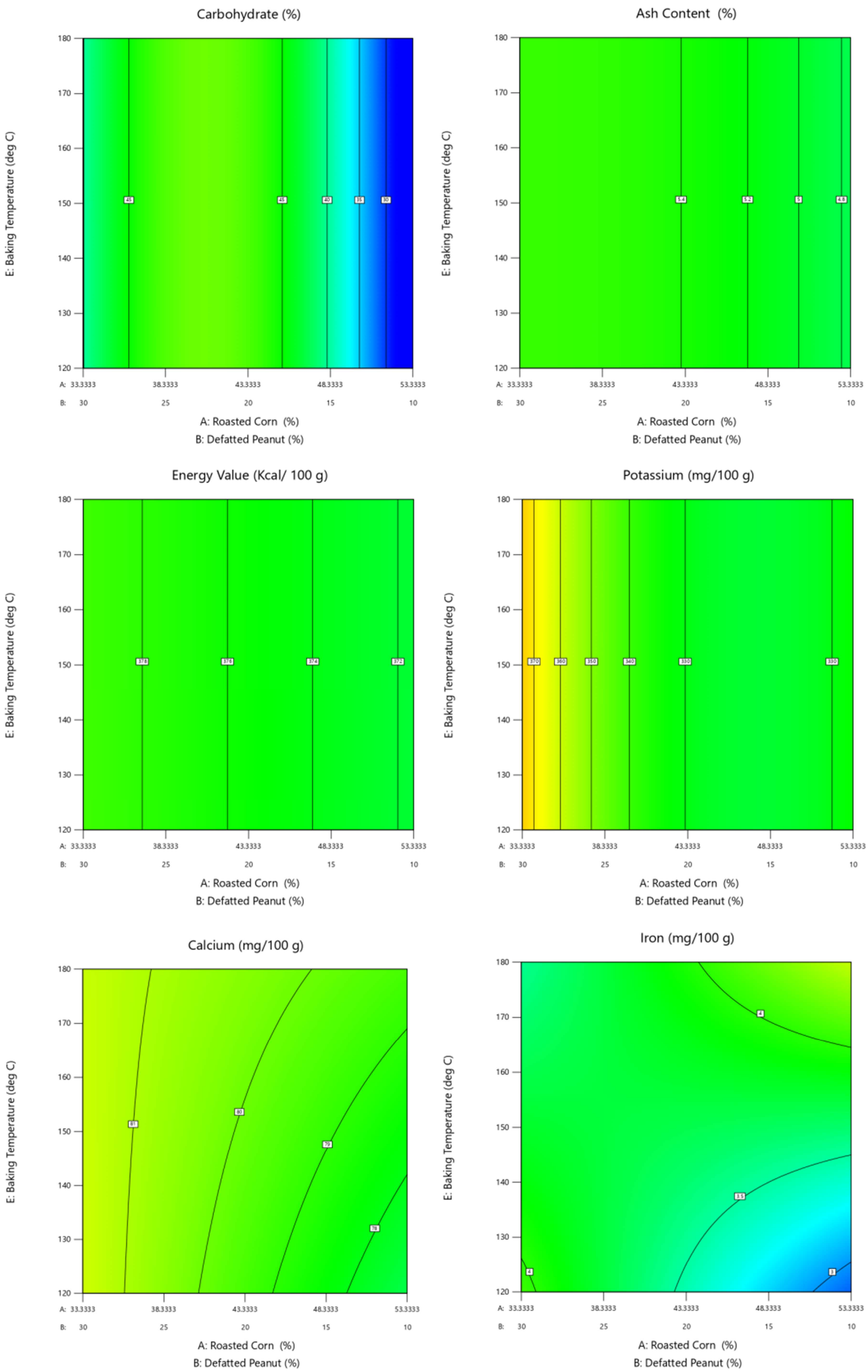
$$\left.\begin{array}{l} y_{iron} = 3.81x_1 + 4.23x_2 + 3.01x_3 + 3.60x_4 + 0.8887x_1z_1 + 0.3236x_1z_2 - 1.67x_2z_1 \\ + 0.2330x_2z_2 + 1.08x_3z_1 - 1.05x_3z_2 - 0.2144x_4z_1 + 0.9794x_4z_2 \end{array}\right\} \quad (10)$$

$$\left.\begin{array}{l} y_{zinc} = 0.4966x_1 - 0.2220x_2 - 0.2234x_3 + 1.15x_4 + 0.6810x_1x_2 \\ + 0.9223x_1x_3 - 1.61x_1x_4 + 2.35x_2x_3 + 1.01x_2x_4 - 0.2241x_3x_4 \end{array}\right\} \quad (11)$$

$$\left. y_{dig} = 71.47x_1 + +71.55x_2 + 83.64x_3 + 70.73x_4 \right\} \quad (12)$$

$$\left. y_{spr} = 20.07x_0 - 1.52z_1 - 0.1106z_2 \right\} \quad (13)$$




Carbohydrate (%)
Ash Content (%)
Energy Value (Kcal/ 100 g)
Potassium (mg/100 g)
Calcium (mg/100 g)
Iron (mg/100 g)
E: Baking Temperature (deg C)
A: Roasted Corn (%)
B: Defatted Peanut (%)

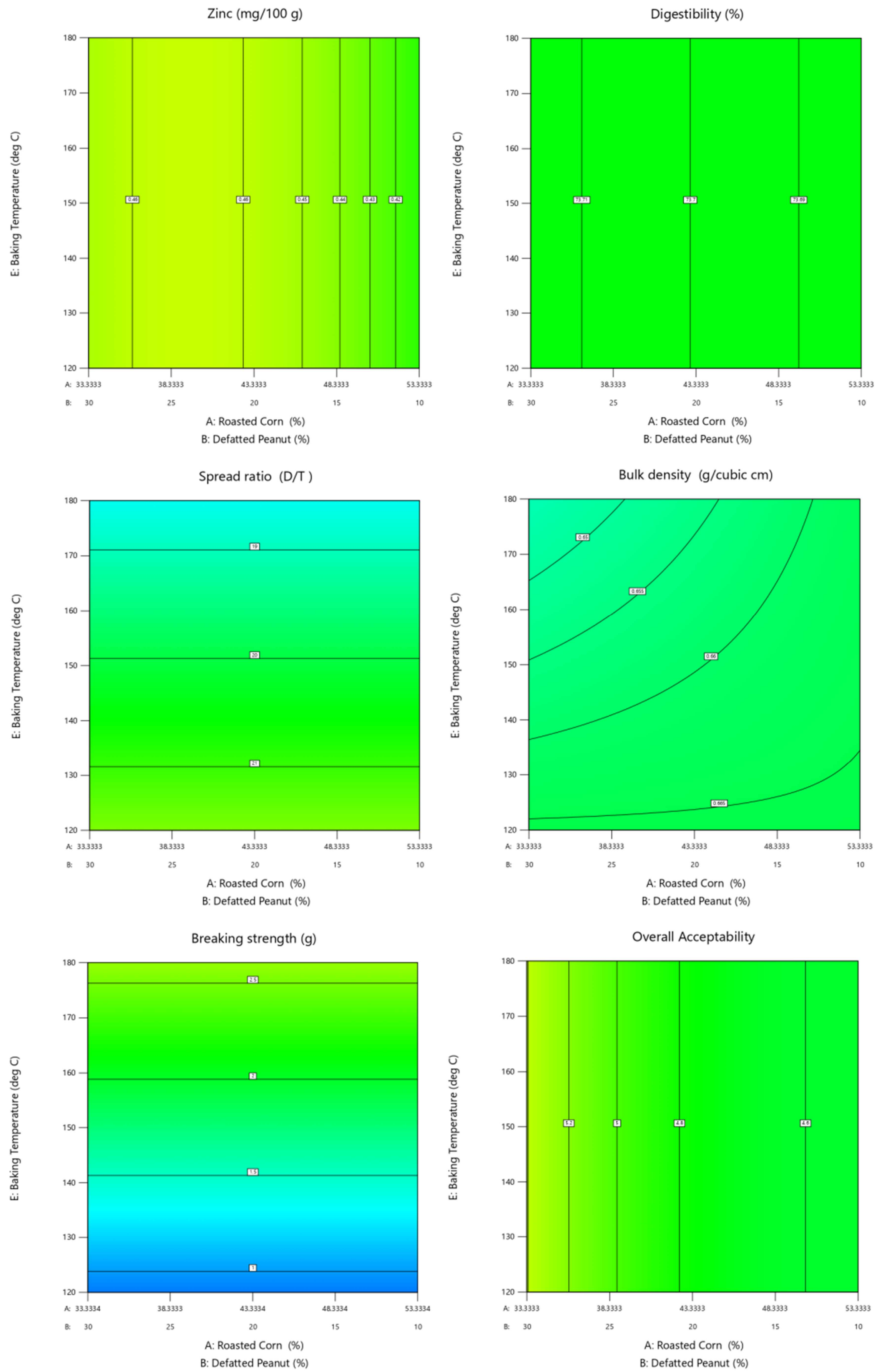
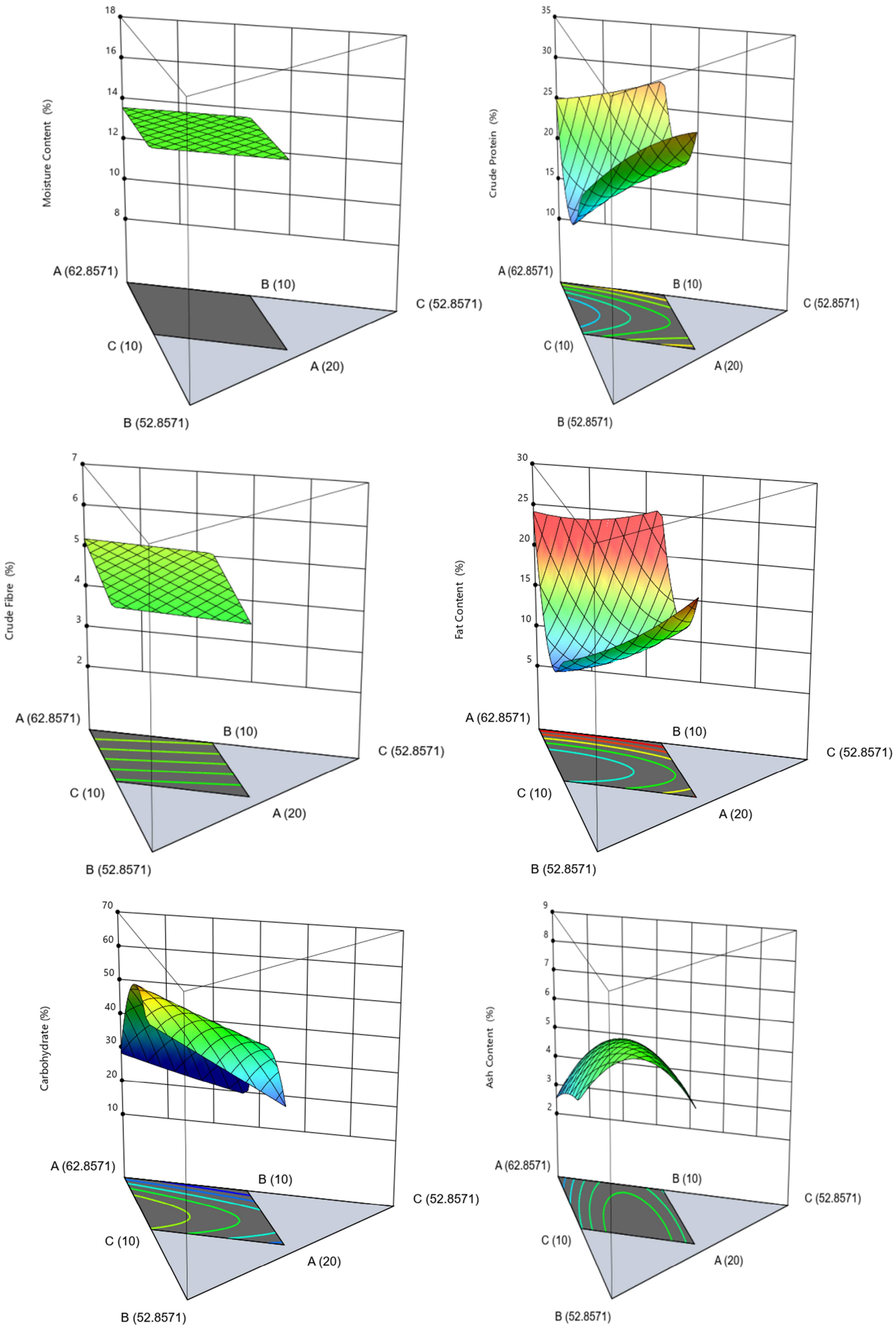
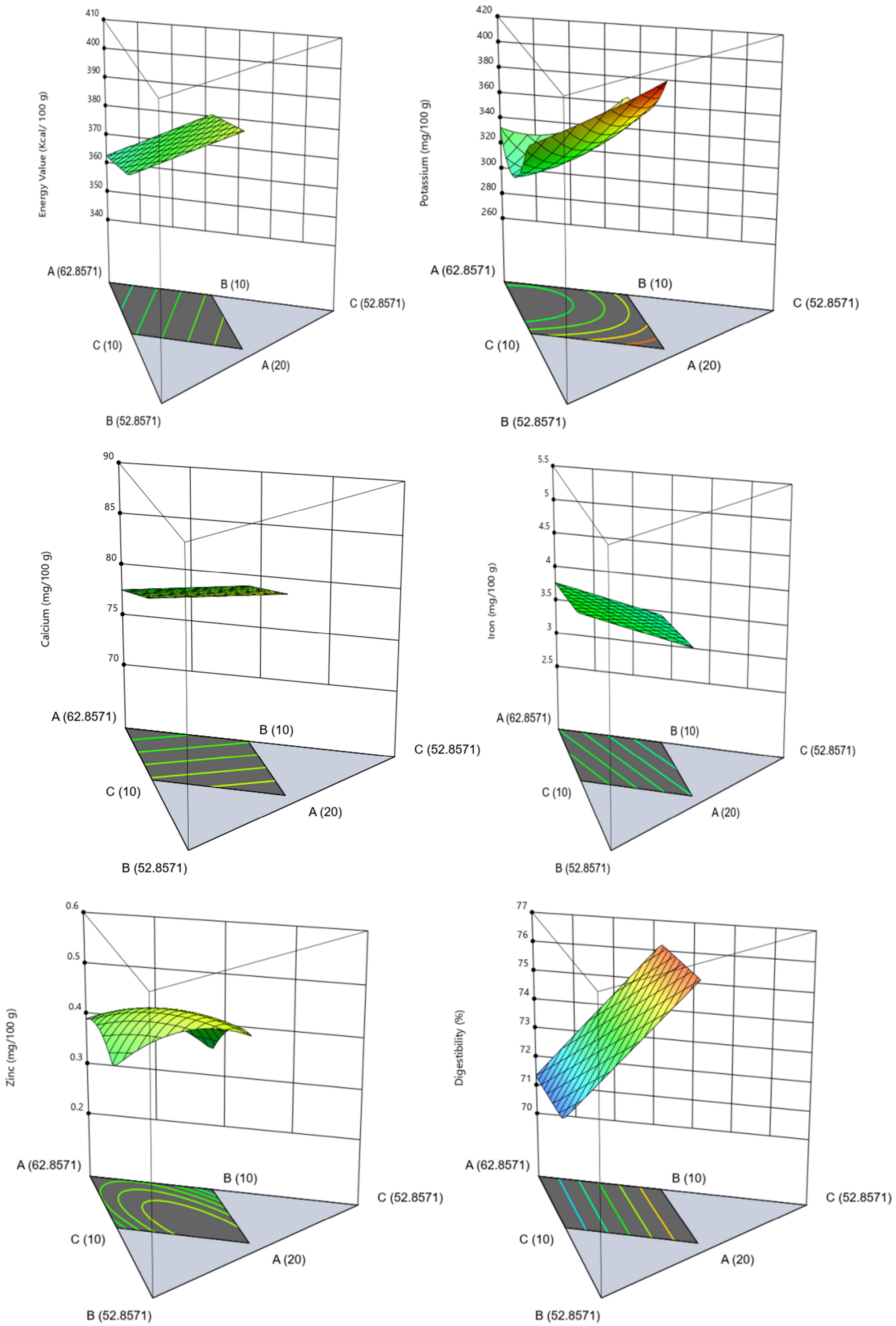


Figure 2. *The Quality Parameters Mix-Process Plots for the Formulated Dietary Cookies.*


Moisture Content (%)
18
16
14
12
10
8
A (62.8571)
B (10)
C (52.8571)
C (10)
A (20)
B (52.8571)
Crude Protein (%)
35
30
25
20
15
10
A (62.8571)
B (10)
C (52.8571)
C (10)
A (20)
B (52.8571)
Crude Fibre (%)
7
6
5
4
3
2
A (62.8571)
B (10)
C (52.8571)
C (10)
A (20)
B (52.8571)
Fat Content (%)
30
25
20
15
10
5
A (62.8571)
B (10)
C (52.8571)
C (10)
A (20)
B (52.8571)
Carbohydrate (%)
70
60
50
40
30
20
10
A (62.8571)
B (10)
C (52.8571)
C (10)
A (20)
B (52.8571)
Ash Content (%)
9
8
7
6
5
4
3
2
A (62.8571)
B (10)
C (52.8571)
C (10)
A (20)
B (52.8571)


Energy Value (Kcal/ 100 g)
410
400
390
380
370
360
350
340
A (62.8571)
B (10)
C (52.8571)
C (10)
A (20)
B (52.8571)
Potassium (mg/100 g)
420
400
380
360
340
320
300
280
260
A (62.8571)
B (10)
C (52.8571)
C (10)
A (20)
B (52.8571)
Calcium (mg/100 g)
90
85
80
75
70
A (62.8571)
B (10)
C (52.8571)
C (10)
A (20)
B (52.8571)
Iron (mg/100 g)
5.5
5
4.5
4
3.5
3
2.5
A (62.8571)
B (10)
C (52.8571)
C (10)
A (20)
B (52.8571)
Zinc (mg/100 g)
0.6
0.5
0.4
0.3
0.2
A (62.8571)
B (10)
C (52.8571)
C (10)
A (20)
B (52.8571)
Digestibility (%)
77
76
75
74
73
72
71
70
A (62.8571)
B (10)
C (52.8571)
C (10)
A (20)
B (52.8571)

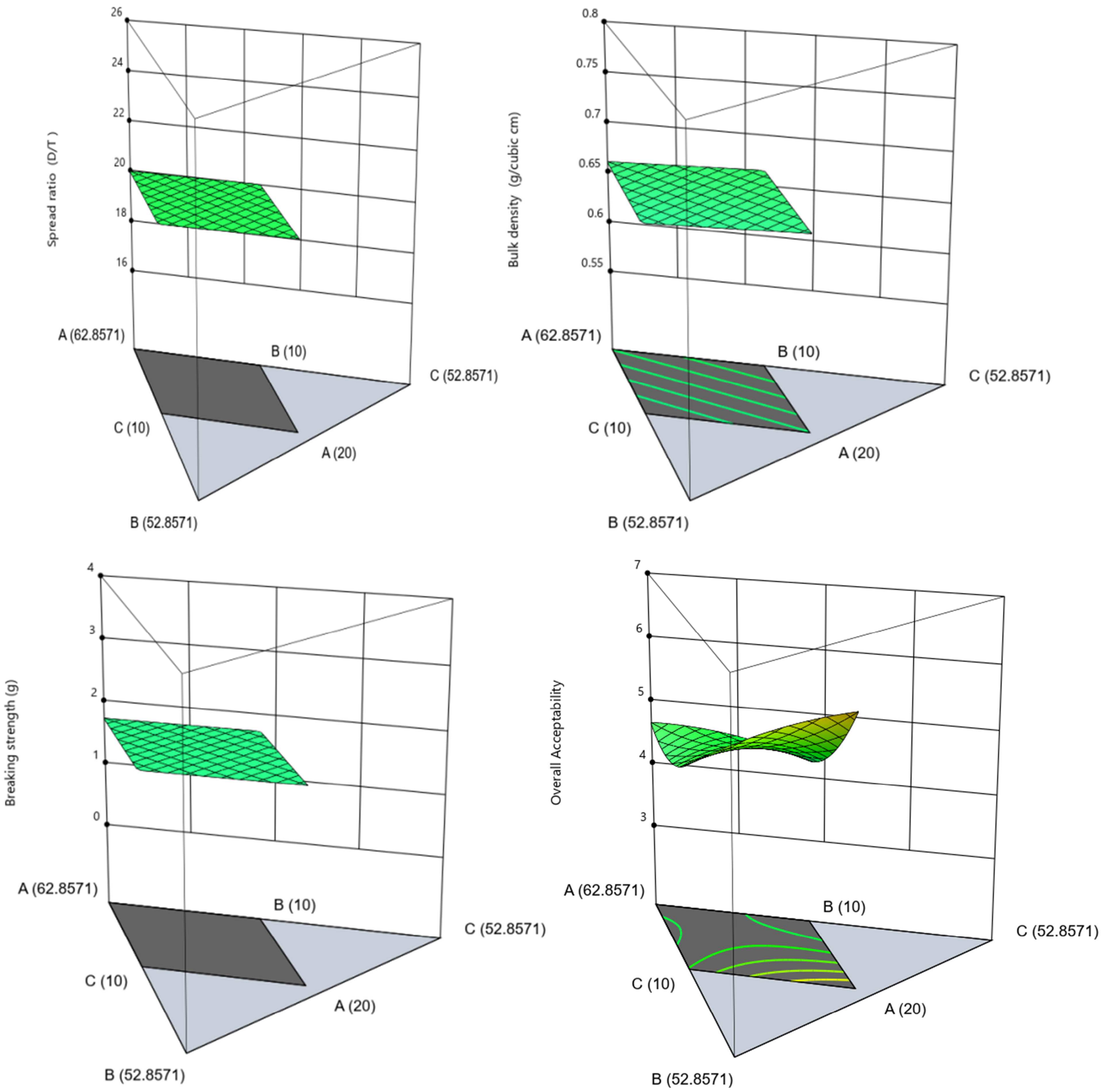
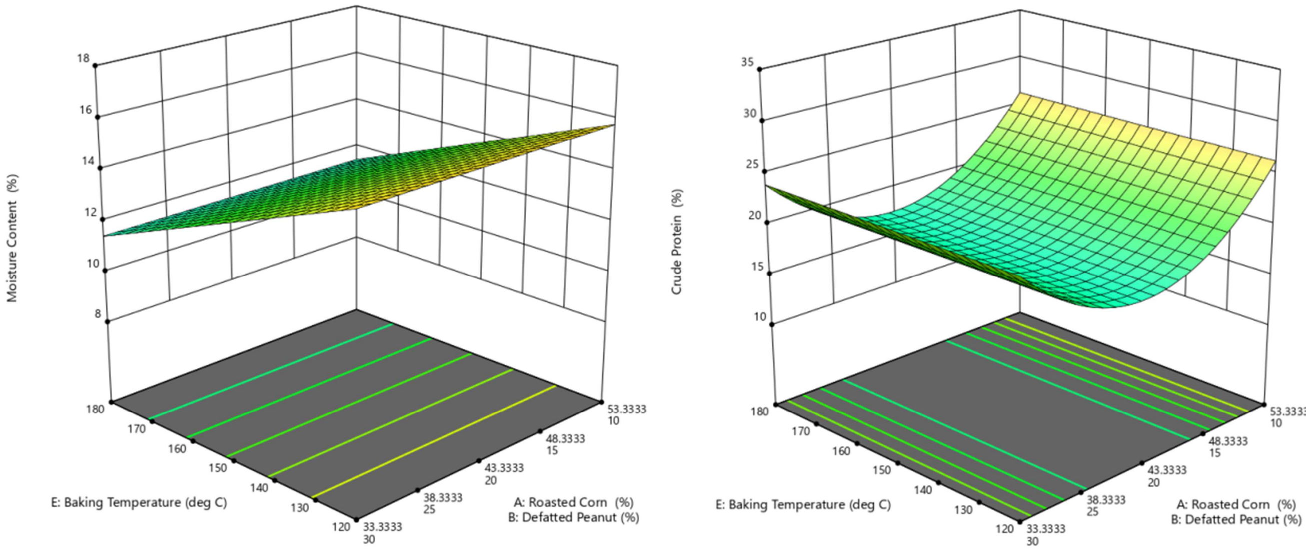
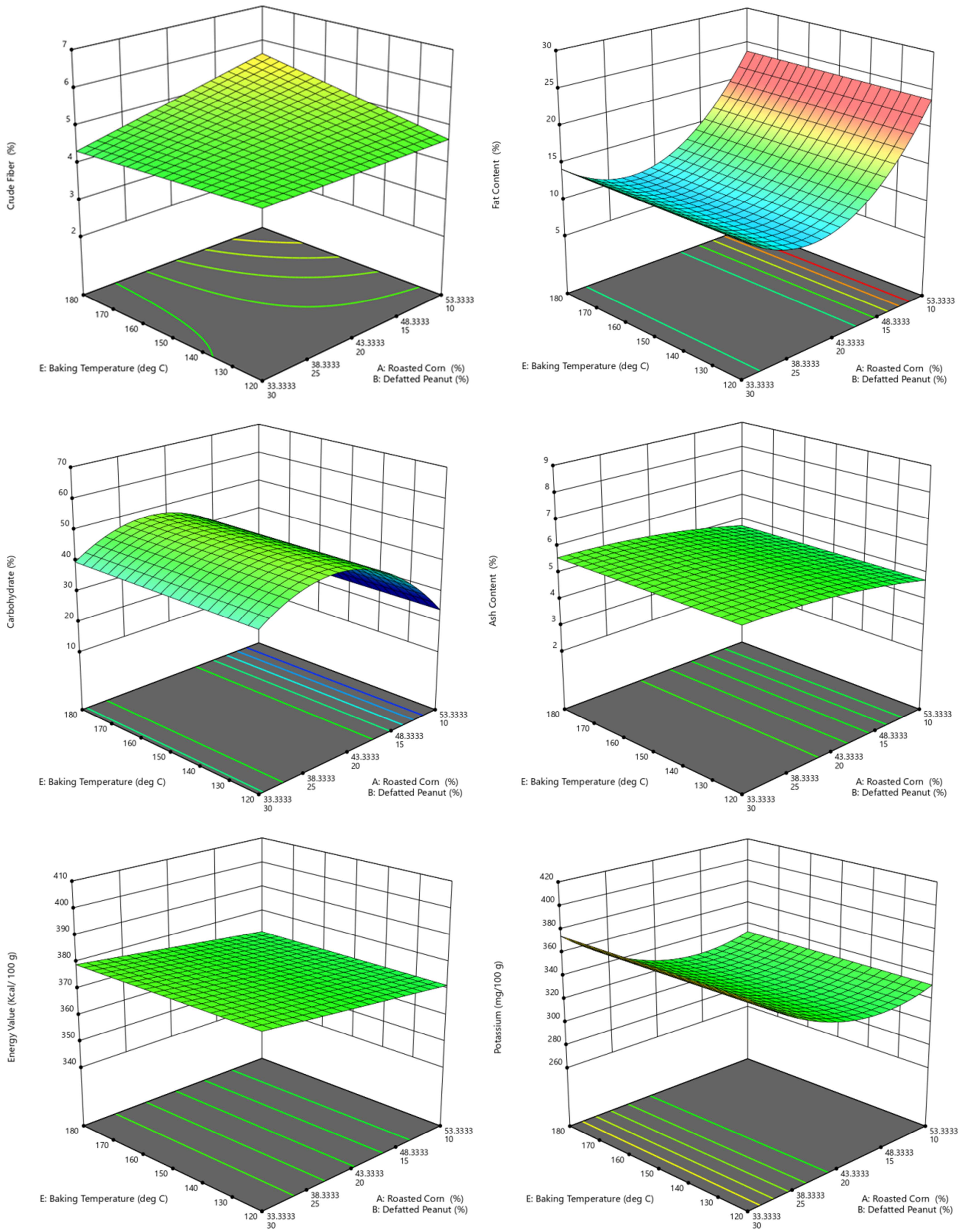
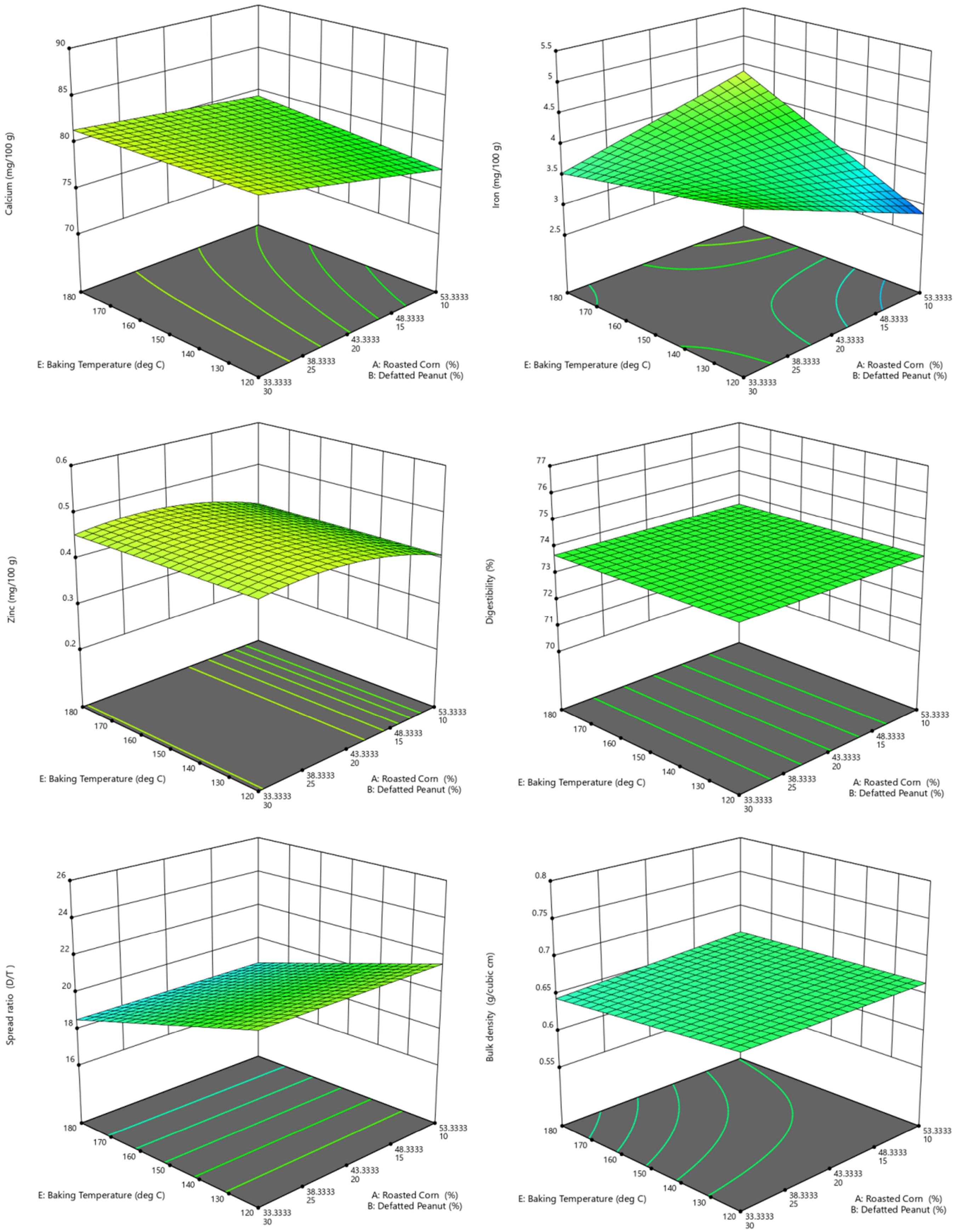


Figure 3. *The Quality Parameters 3-D Surface Plots for the Formulated Dietary Cookies.*




Crude Fiber (%)
7
6
5
4
3
2
E: Baking Temperature (deg C)
180
170
160
150
140
130
120
A: Roasted Corn (%)
B: Defatted Peanut (%)
33.3333
30
38.3333
25
43.3333
20
48.3333
15
53.3333
10
Fat Content (%)
30
25
20
15
10
5
Carbohydrate (%)
70
60
50
40
30
20
10
Ash Content (%)
9
8
7
6
5
4
3
2
Energy Value (Kcal/ 100 g)
410
400
390
380
370
360
350
340
Potassium (mg/100 g)
420
400
380
360
340
320
300
280
260


Calcium (mg/100 g)
E: Baking Temperature (deg C)
A: Roasted Corn (%)
B: Defatted Peanut (%)
Iron (mg/100 g)
E: Baking Temperature (deg C)
A: Roasted Corn (%)
B: Defatted Peanut (%)
Zinc (mg/100 g)
E: Baking Temperature (deg C)
A: Roasted Corn (%)
B: Defatted Peanut (%)
Digestibility (%)
E: Baking Temperature (deg C)
A: Roasted Corn (%)
B: Defatted Peanut (%)
Spread ratio (D/T)
E: Baking Temperature (deg C)
A: Roasted Corn (%)
B: Defatted Peanut (%)
Bulk density (g/cubic cm)
E: Baking Temperature (deg C)
A: Roasted Corn (%)
B: Defatted Peanut (%)

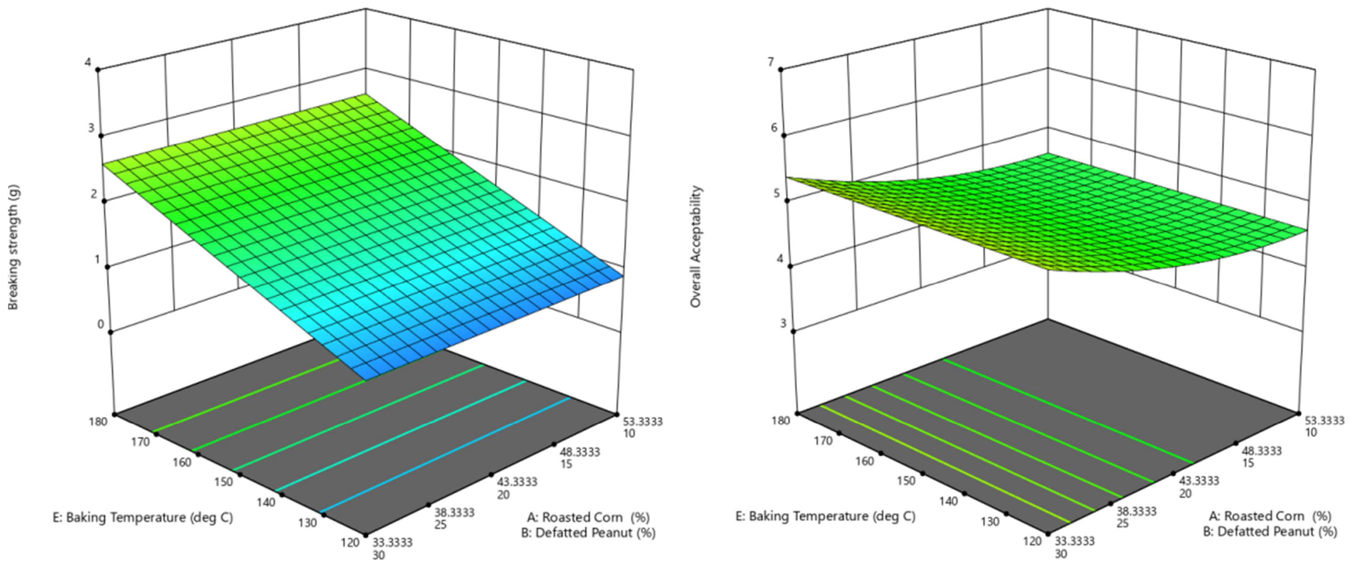


Figure 4. *The Quality Parameters 3-D Surface Mix-Process Plots for the Formulated Dietary Cookies.*

$$\left.\begin{array}{l} y_{bd} = 0.6521x_1 + 0.6299x_2 + 0.6629x_3 + 0.7221x_4 + 0.0051x_1z_1 + 0.0075x_1z_2 - 0.0168x_2z_1 \\ - 0.0636x_2z_2 - 0.0434x_3z_1 + 0.0010x_3z_2 + 0.0224x_4z_1 + 0.0100x_4z_2 \end{array}\right\} \tag{14}$$

$$y_{break} = 1.75x_0 + 0.8579z_1 + 0.2909z_2\} \tag{15}$$

$$y_{oa} = +4.69x_1 + 8.93x_2 - 0.4973x_3 + 3.07x_4 - 5.88x_1x_2 + 2.88x_1x_3 + 1.75x_1x_4 + 5.69x_2x_3 - 6.53x_2x_4 + 21.94x_3x_4\} \tag{16}$$

3.3. Optimization Constraints/Settings

The summary of the optimization constraints employed for the formulated dietary cookies are presented in Table 6.

Table 6. *Optimization constraints for the formulated dietary cookies".*

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
Roasted Corn	in range	20	70	1	1	3
Defatted Peanut	in range	10	30	1	1	3
Blanched Soybean	maximize	10	30	1	1	3
Sweet Potato Extract/Gel	in range	5	20	1	1	3
Baking Temperature	target = 100	100	150	1	1	3
Baking Time	in range	10	25	1	1	3
Moisture Content	target = 10	8.7	15	1	1	5
Crude Protein	target = 30	20	30	1	10	5
Crude Fibre	maximize	2.5	6.5	1	1	3
Fat Content	minimize	7.72	20.5	1	1	5
Carbohydrate	minimize	28.31	50	1	1	3
Ash Content	in range	2	8.5	1	1	3
Energy Value	target = 400	340.42	409.81	1	10	5
Potassium	target = 400	261.14	402.98	1	10	5
Calcium	target = 80	70.28	86.32	1	10	5
Iron	maximize	2.62	5.18	1	1	3
Zinc	in range	0.22	0.57	1	1	3
Digestibility	in range	70.9	76.6	1	1	3
Spread ratio	maximize	16.3	24.8	1	1	3
Bulk density	in range	0.58	0.78	1	1	3
Breaking strength	in range	0.5	3.746	1	10	5
Colour	in range	2.3	8	1	1	3
Taste	in range	1.5	6.3	1	1	3
Flavor	in range	1.5	6	1	1	3
Texture	in range	1.8	7.5	1	1	3
Overall Acceptability	in range	3	6.5	1	1	3

3.4. Results of Numerical Optimization of the Formulated Cookies

Optimal production conditions were obtained, based on set optimization goals and individual quality desirability indices; using numerical optimization, via desirability function technique [17-20]. Thirty-seven desirability optimal formulation conditions (component proportions) were found and summarized in Table 7, with the quality properties of the optimal formulation for the formulated cookies presented in Tables 8-10.

Table 7. *Optimal formulation conditions for the formulated dietary cookies.*

No	x_1 (%)	x_2 (%)	x_3 (%)	x_4 (%)	z_1 (deg C)	z_2 (min)	D_i	
1	22.744	26.589	25.666	20.000	137.945	25.000	0.531	Selected
2	22.692	26.557	25.750	20.000	138.479	25.000	0.531	
3	22.995	26.692	25.314	20.000	135.971	25.000	0.530	
4	24.135	27.004	23.861	20.000	138.277	25.000	0.520	
5	22.264	26.111	27.340	19.285	136.135	25.000	0.519	
6	22.990	26.578	25.742	19.690	133.050	24.937	0.518	
7	22.789	26.432	25.779	20.000	133.664	24.071	0.516	
8	20.365	24.795	29.839	20.000	139.129	25.000	0.509	
9	25.278	27.678	22.044	20.000	138.164	25.000	0.506	
10	32.213	29.998	27.788	5.000	144.799	10.000	0.501	
11	32.156	29.989	27.854	5.000	144.357	10.000	0.501	
12	32.616	30.000	27.384	5.000	144.597	10.166	0.501	
13	33.032	29.478	27.489	5.000	143.962	10.218	0.497	
14	33.176	29.953	26.870	5.000	144.117	10.000	0.497	
15	35.077	30.000	24.923	5.000	144.667	11.051	0.496	
16	32.400	27.799	29.800	5.000	144.657	10.000	0.495	
17	32.294	27.832	29.874	5.000	144.142	10.000	0.495	
18	31.792	29.553	28.655	5.000	141.628	10.000	0.491	
19	34.846	30.000	25.154	5.000	145.810	10.094	0.491	
20	34.918	24.930	30.000	5.152	144.777	10.000	0.479	
21	33.417	25.395	30.000	6.189	143.690	10.013	0.476	
22	35.700	10.000	29.300	20.000	141.827	24.999	0.457	
23	37.095	16.741	30.000	11.164	140.804	25.000	0.445	
24	37.270	16.506	30.000	11.224	140.546	25.000	0.444	
25	37.266	16.539	30.000	11.195	140.281	25.000	0.444	
26	36.584	17.099	30.000	11.317	139.434	25.000	0.444	
27	37.042	16.761	30.000	11.197	141.084	24.165	0.444	
28	37.186	16.755	30.000	11.060	141.184	23.652	0.444	
29	37.091	16.771	30.000	11.138	140.952	23.289	0.443	
30	36.864	16.970	30.000	11.166	141.447	22.522	0.442	
31	38.103	16.341	29.406	11.150	141.098	25.000	0.442	
32	37.869	16.894	30.000	10.237	141.322	19.758	0.440	
33	38.240	16.869	30.000	9.891	141.747	18.977	0.440	
34	40.703	18.132	30.000	6.165	145.141	10.000	0.437	
35	47.778	21.111	21.111	5.000	143.051	16.216	0.425	
36	48.095	10.000	30.000	6.905	143.390	24.995	0.399	
37	48.098	10.000	30.000	6.902	143.585	22.325	0.398	

x_1 = *Roasted Corn* (%), x_2 = *Defatted Peanut* (%), x_3 = *Blanched Soybean* (%), x_4 = *Sweet Potato Extract / Gel* (%), z_1 = *Baking Temperature* (*deg C*), z_2 = *baking Time* (*min*), D_i = *Overall Desirabiity Index*

Table 8. *The quality properties of the optimal formulated dietary cookies.*

No	y_{mc}	y_{cp}	y_{cf}	y_{fat}	y_{cho}	y_{ac}	y_{ev}	D_i	
1	14.071	25.699	4.957	16.033	34.388	7.234	386.440	0.531	Selected
2	14.032	25.686	4.938	16.038	34.410	7.228	386.504	0.531	
3	14.214	25.657	5.025	15.914	34.501	7.254	386.160	0.530	
4	14.047	25.187	4.959	15.160	35.585	7.301	384.964	0.520	
5	14.202	25.309	4.974	16.402	34.772	6.777	387.517	0.519	
6	14.429	25.435	5.102	15.934	34.828	7.097	386.393	0.518	
7	14.433	25.326	5.045	15.663	35.188	7.224	386.481	0.516	
8	13.985	25.134	4.904	16.568	35.332	6.713	389.528	0.509	
9	14.055	25.675	4.969	15.455	34.569	7.280	383.578	0.506	
10	14.424	27.514	5.093	15.594	33.932	5.078	384.320	0.501	
11	14.456	27.496	5.096	15.603	33.924	5.058	384.376	0.501	
12	14.430	27.617	5.074	15.550	33.948	5.199	383.954	0.501	
13	14.473	27.594	5.084	15.730	33.609	5.192	383.847	0.497	
14	14.474	27.733	5.079	15.506	33.949	5.348	383.470	0.497	

No	y_{mc}	y_{cp}	y_{cf}	y_{fat}	y_{cho}	y_{ac}	y_{ev}	D_i
15	14.374	28.023	4.968	15.218	34.256	5.832	381.723	0.496
16	14.435	26.874	5.177	16.336	32.961	4.509	385.292	0.495
17	14.472	26.849	5.178	16.332	32.984	4.481	385.371	0.495
18	14.654	27.272	5.124	15.815	33.661	4.823	384.934	0.491
19	14.346	28.001	5.034	15.254	34.211	5.780	381.933	0.491
20	14.426	26.325	5.234	16.719	32.723	4.519	384.414	0.479
21	14.504	25.425	5.167	16.339	34.238	4.338	384.966	0.476
22	13.790	24.264	5.275	16.619	33.724	6.157	383.303	0.457
23	13.864	22.503	4.664	17.141	35.803	4.197	383.390	0.445
24	13.882	22.584	4.678	17.295	35.526	4.196	383.321	0.444
25	13.902	22.579	4.680	17.281	35.549	4.195	383.323	0.444
26	13.963	22.296	4.682	16.823	36.409	4.214	383.584	0.444
27	13.891	22.482	4.682	17.114	35.858	4.199	383.410	0.444
28	13.913	22.535	4.688	17.169	35.736	4.191	383.358	0.444
29	13.950	22.499	4.702	17.129	35.822	4.196	383.393	0.443
30	13.958	22.407	4.712	16.976	36.107	4.202	383.480	0.442
31	13.842	22.566	4.682	17.263	35.475	4.335	382.692	0.442
32	14.123	22.759	4.775	17.316	35.337	4.163	383.118	0.440
33	14.137	22.869	4.799	17.399	35.123	4.158	382.985	0.440
34	14.400	23.778	5.331	16.768	34.918	4.454	382.141	0.437
35	14.199	25.866	4.840	16.392	32.594	6.510	374.821	0.425
36	13.677	22.045	4.667	18.460	34.917	4.192	379.253	0.399
37	13.814	22.040	4.803	18.453	34.930	4.192	379.252	0.398

y_{mc} = *Moisture Content* (%), y_{cp} = *Crude Protein* (%), y_{cf} = *Crude Fiber* (%), y_{fat} = *Fat Content* (%), y_{cho} = *Carbohydrate* (%), y_{ac} = *Ash Content* (%), y_{ev} = *Energy Value* (*Kcal*/100*g*)

Table 9. *The quality properties of the optimal formulated dietary cookies continue.*

No	y_{pot}	y_{cal}	y_{ir}	y_{zinc}	y_{dig}	y_{spr}	y_{bd}	y_{break}	D_i	
1	381.514	80.000	3.789	0.552	75.088	20.566	0.657	1.695	0.531	Selected
2	381.220	80.000	3.780	0.552	75.109	20.539	0.657	1.710	0.531	
3	382.594	80.000	3.823	0.553	75.003	20.666	0.657	1.638	0.530	
4	386.076	80.135	3.878	0.553	74.649	20.549	0.655	1.704	0.520	
5	377.160	80.000	3.699	0.537	75.506	20.658	0.658	1.643	0.519	
6	381.498	80.000	3.815	0.548	75.111	20.815	0.658	1.552	0.518	
7	380.712	80.000	3.804	0.551	75.115	20.796	0.661	1.536	0.516	
8	363.075	79.539	3.547	0.532	76.101	20.506	0.661	1.729	0.509	
9	390.206	80.325	3.979	0.552	74.208	20.555	0.653	1.701	0.506	
10	374.072	80.000	3.906	0.434	75.833	20.440	0.674	1.309	0.501	
11	374.351	80.000	3.907	0.434	75.849	20.462	0.674	1.296	0.501	
12	372.076	80.000	3.898	0.435	75.734	20.448	0.673	1.310	0.501	
13	369.296	79.958	3.888	0.438	75.759	20.479	0.673	1.293	0.497	
14	369.346	79.871	3.897	0.437	75.609	20.474	0.674	1.289	0.497	
15	361.766	80.000	3.858	0.440	75.135	20.431	0.669	1.346	0.496	
16	373.744	80.000	3.885	0.438	76.319	20.447	0.673	1.305	0.495	
17	374.404	80.000	3.885	0.437	76.337	20.473	0.673	1.290	0.495	
18	376.002	80.000	3.911	0.434	76.043	20.601	0.676	1.218	0.491	
19	362.595	79.722	3.873	0.440	75.191	20.387	0.672	1.342	0.491	
20	363.974	79.732	3.830	0.447	76.361	20.441	0.670	1.308	0.479	
21	370.614	79.919	3.819	0.442	76.346	20.496	0.673	1.278	0.476	
22	349.101	76.223	3.256	0.347	75.948	20.369	0.685	1.806	0.457	
23	364.102	80.000	3.215	0.414	76.259	20.421	0.662	1.777	0.445	
24	363.973	79.923	3.207	0.412	76.258	20.434	0.663	1.769	0.444	
25	363.976	79.929	3.203	0.412	76.259	20.448	0.663	1.762	0.444	
26	364.501	80.000	3.204	0.416	76.258	20.490	0.663	1.737	0.444	
27	364.140	79.982	3.238	0.414	76.259	20.419	0.663	1.752	0.444	
28	364.036	80.000	3.248	0.414	76.261	20.422	0.663	1.735	0.444	
29	364.106	79.968	3.254	0.414	76.260	20.439	0.663	1.714	0.443	
30	364.287	80.000	3.282	0.415	76.260	20.425	0.663	1.699	0.442	
31	360.467	79.927	3.238	0.416	76.115	20.406	0.663	1.785	0.442	
32	363.306	80.000	3.331	0.417	76.273	20.472	0.664	1.588	0.440	
33	362.812	80.000	3.353	0.418	76.279	20.462	0.664	1.570	0.440	
34	353.832	79.158	3.693	0.445	76.336	20.423	0.664	1.319	0.437	

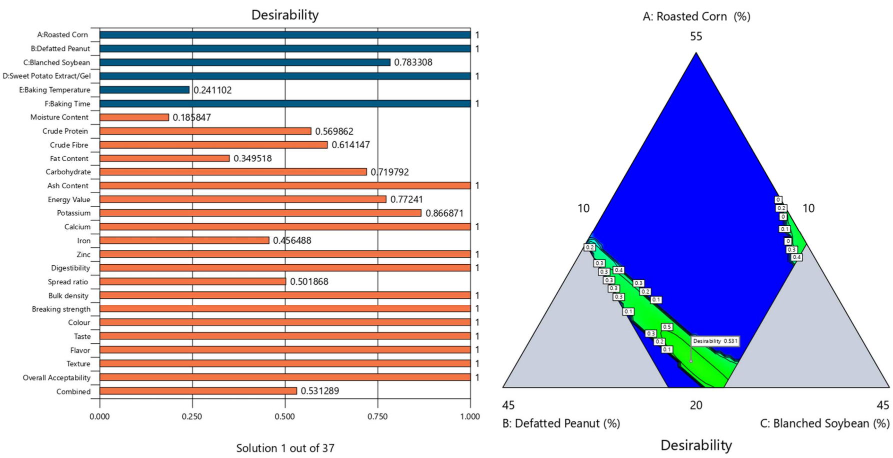
No	y_{pot}	y_{cal}	y_{ir}	y_{zinc}	y_{dig}	y_{spr}	y_{bd}	y_{break}	D_i
35	303.743	80.000	3.643	0.491	74.194	20.437	0.654	1.500	0.425
36	362.590	79.624	3.078	0.403	76.312	20.290	0.667	1.850	0.399
37	362.584	79.385	3.156	0.403	76.312	20.320	0.665	1.752	0.398

y_{pot} = Potassium (mg/100g), y_{cal} = Calcium (mg/100g), y_{ir} = Iron (mg/100g), y_{zinc} = Zinc (mg/100g), y_{dig} = Digestibility (%), y_{spr} = Spread Ratio (D/T), y_{bd} = Bulk Density (g/cubic cm), y_{break} = Breaking Strength (g).

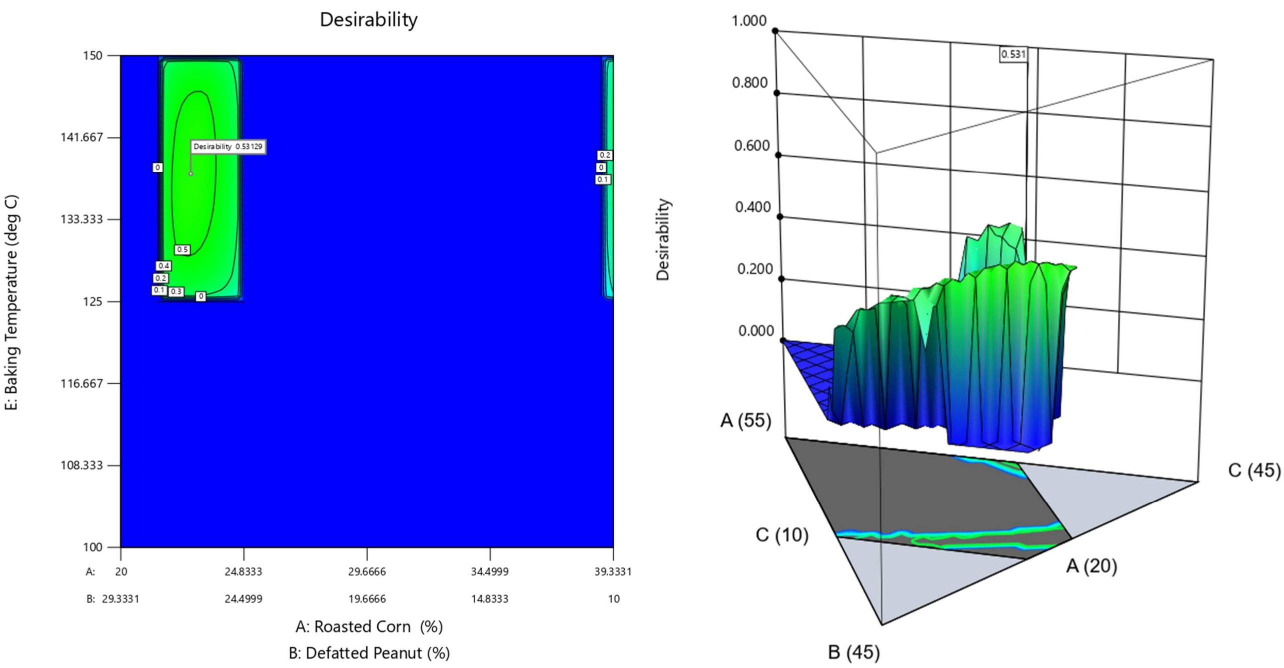
***Table 10.** The quality properties of the optimal formulated dietary cookies continue.*

No	y_{col}	y_{tast}	y_{flav}	y_{tex}	y_{oa}	D_i	
1	7.468	3.959	5.011	3.255	5.960	0.531	Selected
2	7.460	3.955	5.017	3.261	5.964	0.531	
3	7.487	3.972	4.981	3.235	5.940	0.530	
4	7.474	4.020	4.841	3.322	5.846	0.520	
5	7.052	3.948	5.024	3.253	5.984	0.519	
6	7.340	3.978	4.965	3.211	5.941	0.518	
7	7.403	3.950	5.000	3.196	5.955	0.516	
8	6.719	3.784	5.253	3.097	6.099	0.509	
9	7.503	4.092	4.706	3.392	5.739	0.506	
10	5.065	5.085	5.161	3.930	5.023	0.501	
11	5.052	5.083	5.163	3.919	5.021	0.501	
12	5.141	5.095	5.140	3.950	5.030	0.501	
13	5.056	5.072	5.059	3.964	4.966	0.497	
14	5.229	5.106	5.106	3.940	5.033	0.497	
15	5.574	5.157	5.021	4.092	5.064	0.496	
16	4.512	4.949	4.882	3.986	4.709	0.495	
17	4.502	4.948	4.891	3.974	4.710	0.495	
18	4.852	5.046	5.132	3.865	4.952	0.491	
19	5.535	5.151	5.031	4.025	5.062	0.491	
20	4.362	4.822	4.385	4.120	4.396	0.479	
21	4.371	4.768	4.388	4.048	4.576	0.476	
22	3.620	3.224	2.961	2.458	5.255	0.457	
23	3.963	4.085	2.945	3.814	4.462	0.445	
24	3.958	4.072	2.913	3.798	4.455	0.444	
25	3.960	4.075	2.917	3.803	4.453	0.444	
26	3.962	4.088	3.000	3.814	4.504	0.444	
27	3.962	4.084	2.949	3.840	4.467	0.444	
28	3.968	4.093	2.945	3.872	4.450	0.444	
29	3.965	4.088	2.949	3.877	4.461	0.443	
30	3.966	4.094	2.978	3.905	4.477	0.442	
31	3.962	4.085	2.888	3.812	4.451	0.442	
32	4.011	4.156	2.953	4.078	4.354	0.440	
33	4.032	4.179	2.948	4.129	4.308	0.440	
34	4.316	4.488	3.260	4.421	3.912	0.437	
35	4.778	4.908	3.992	4.713	4.386	0.425	
36	4.907	4.121	2.184	3.988	3.570	0.399	
37	4.907	4.121	2.184	4.133	3.570	0.398	

y_{col} = Colour, y_{tast} = Taste, y_{flav} = Flavor, y_{tex} = Texture, y_{oa} = Overall Acceptability



***Figures 5.** The numerical solution desirability bar graph and desirability contour plot for the optimal formulated dietary cookies.*



Figures 6. The numerical solution desirability mix-process and 3-D surface plots for the optimal formulated dietary cookies.

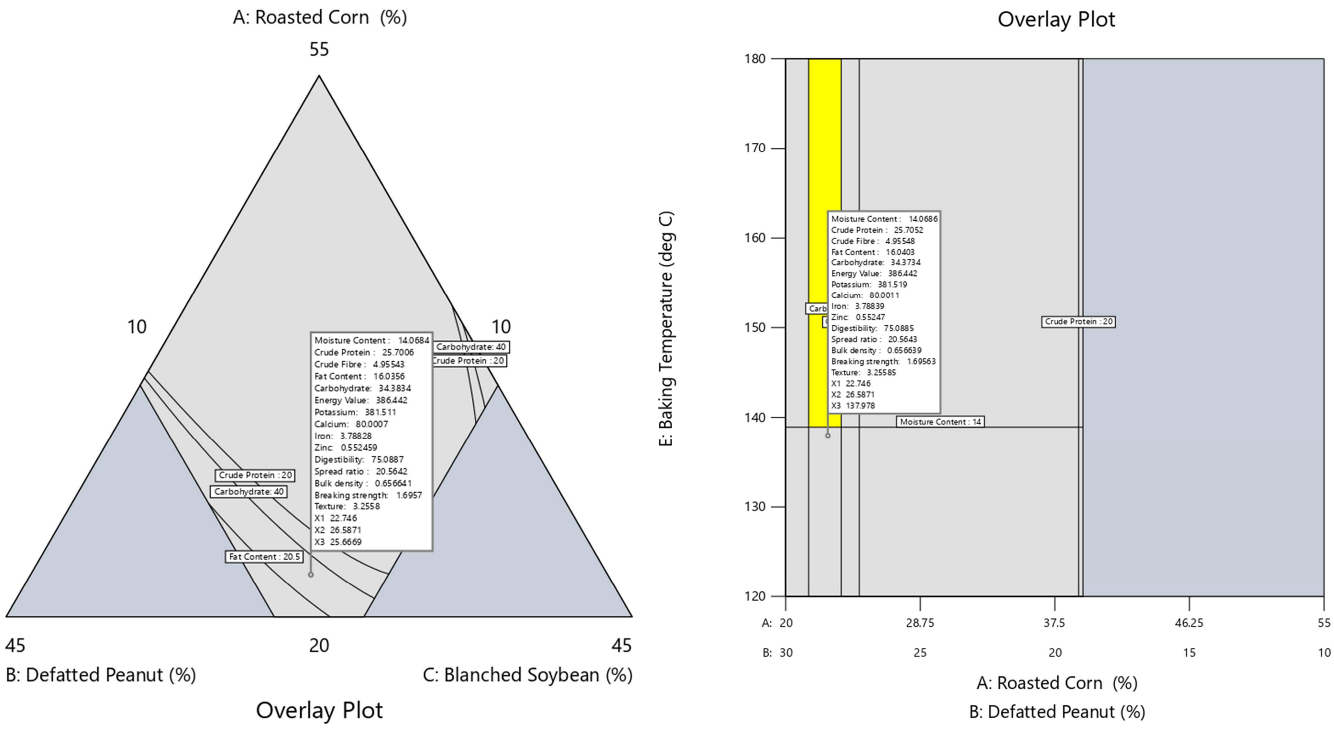


Figure 7. The graphical optimization contour and mix-process overlay plots for the optimal formulated dietary cookies.

The numerical solution desirability bar graph and desirability contour plot for the optimal formulated dietary cookies are presented in Figure 5. The numerical solution desirability mix-process and 3-D surface plots are presented in Figure 6. The graphical optimization contour and mix-process overlay plots are presented in Figure 7.

Exploiting the desirability function technique, the formulation that produced cookies of the highest desirability index of 0.531 was 22.744% roasted corn, 26.589% defatted peanut, 25.666% blanched soybean, 20.0% sweet potato extract/gel, 1380C baking temperature, and 25 minutes baking time. The quality properties of this optimal cookies are 14.071% moisture content, 25.699% crude protein, 4.957% crude fibre, 16.033% fat content, 34.388% carbohydrate, 7.234% ash content, 386.440 Kcal/ 100 g energy value, 381.514 mg/100g potassium, 80.0 mg/100g calcium, 3.789 mg/100g iron, 0.552 mg/100g zinc, 75.088% digestibility, 20.566 D/T spread ratio, 0.657 g/cubic cm bulk density, 1.695g breaking strength, and overall acceptability of 5.96, based on 9-point hedonic scale.

4. Conclusion

In this study, using composite products technology, dietary cookies were developed, characterized and optimized, via a four-components, constrained, randomized, combined, D-optimal mixture-process experimental design; from blends of roasted corn, defatted peanut, blanched soybean, sweet potato extract/gel. The development of dietary cookies from indigenous local food ingredients aimed at meeting the dietary needs of different consumers. Composite novel food products technology has many advantages. It plays a vital role in complementing the deficiency of essential nutrients; it is suitable for enhancing and solving the problems of malnutrition, especially in the African continent, it promotes the use of locally available food ingredient. However, this study encouraged exploitation of more underutilized local food resources in the production of dietary-based cookies. There is the need for research on formulating dietary-based snacks from blends of different unique local food ingredients.

5. Recommendations

Most of the developing countries are seasonally blessed with varieties of agricultural resources (tubers, roots, grains, legumes, cereals, pulses, fruits, vegetable, nuts, herbs, and other rich sources of protein, micronutrients, essential amino and fatty acids, minerals, vitamins, and lots more); but a high percentage of these are lost while malnutrition/nutrition insecurity, micronutrient deficiencies dietary deficit, and concurrent diseases are a persistent problem, particularly in rural areas.

This research has shown that locally available food resources can be blended to produce high quality cookies that meets the populace's nutrition needs and of acceptable sensory properties. The research has shown that additive food manufacturing and/or composite food formulation is an excellent way to achieve nutrition revolution; the road to healthier diets and optimal nutrition in the developing nations. Therefore, this study recommends exploitation of more local food resources in the production of high-quality cookies to improve the nutritional status and tackle the lingering problems of malnutrition/nutrition insecurity, micronutrient deficiencies dietary deficit, and concurrent diseases that are ravaging our developing countries. There is the need for concerted researches on formulating cookies from blends of different local food ingredients.

Competing Interests

The authors declare no conflicts of interest. The authors alone are responsible for the content and writing of the manuscript.

Data Availability

All data generated and analyzed during this study are included in this submitted manuscript.

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