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Development and Modelling of Value-Added Sesame Seed Candy

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Abstract

Sesame seed candy is a cheap traditional snack mostly consumed by children in Nigeria. This research is aimed at developing and characterizing sesame seed candy from sesame seed, cinnamon, ginger, and honey. A four-component constrained D-optimal mixture-process experimental design was employed for the study, and the formulated candies were characterized. The design constraints for the formulation were sesame seed (40–70%), cinnamon (10–30%), ginger (10–30%), and honey (10–30%); while the processing factors were roasting temperature (100–1500C) and roasting time (10–30 mins). Ingredient proportions were found to have significant influences on the quality properties of the candy, with the exception of vitamin C, energy value, color, and crispness ($p > 0.05$). The crispness model was found insignificant at the 5% level of significance ($p>0.05$), while the other quality models are significant (have strong signals) and can be used to make predictions about the quality parameters of sesame seed candy for given levels of each factor (ingredients proportions and process parameters) and also for optimization. The relative impact of the ingredient proportions and process parameters on the quality parameters of the sesame seed candy are given by the models.

Keywords: Formulation; Value-Added; Candy; Models; Sesame seed; ANOVA; Quality

Introduction

Sesame (Sesamum indicum) is a flowering plant in the genus Sesamum. Cultivated for its edible seeds, it is one of the oldest oilseed crops known, and it has one of the highest oil contents of any seed. It is grown on over 5 million acres (20,000 km^2). In many parts of the world. The largest producers of sesame in 2007 were India, China, Myanmar, Sudan, Ethiopia, Uganda, and Nigeria. The seed of sesame is an excellent source of high-quality oils. The oil is very stable and free from undesirable flavor components. It has been regarded as a health food; its oil has a natural antioxidant property, such as prevention of aging, and it is vital for the production of the liver cells. It is rich in fat, protein, carbohydrates, fiber, and some minerals. The oil seed is renowned for its stability because it strongly resists oxidative rancidity even after long exposure to air [1-3].

Candy is a confection that features sugar or sugar substitutes such as honey as a principal ingredient. Sesame seed candy is a confection made from sesame seeds and sugar or honey pressed into a bar or ball. The texture may vary from chewy to crisp. It is popular from the Middle East through South Asia to East Asia [4]. Traditionally, processing of sesame seed candy is mostly done by teenage girls using simple household utensils and equipment. The processed candies are usually cut into shapes and packed into large, transparent rubber containers for distribution. The shape may be a cube, cuboid, cylinder, etc. [1].

Design of experiments (DOE) is widely regarded as one of the most efficient techniques used for new product development and for manufacturing process improvement. It is a scientific data-based decision-making tool extensively adopted in industry to improve processes, product design, or obtain an optimal parameter setting for process parameters. Through analysis of variance (ANOVA) and response surface methodology (RSM), an equation (i.e., response function) representing the approximate relationship between a single response and design/control factors is obtained based on experimental data.

The ANOVA is where the descriptive statistics and statistical tests are presented. The descriptive statistics are used as a secondary check for the usefulness of the model. In general, we look at the p-values to identify important terms in the model and to determine if the model explains a significant portion of the variance. P-values less than 0.05 indicates models and model terms that are significant. R^2 is the coefficient of determination, which measures the proportion of the total variation in the dependent variable (final product quality parameters) that is explained by the independent variable (ingredients proportions and the process factors). The R^2 value ranges from 0 to 1, with a higher value indicating a better fit of the model to the data. The adjusted R^2 is a modified version of R^2 that takes into account the number of independent variables in the model. It penalizes the R^2 value for including irrelevant/insignificant variables that don't contribute much to explaining the variation in the dependent variable. Predicted R^2 is a measure of how well the model predicts new data that was not used to fit the model. A higher value indicates better predictive power of the model. A negative Predicted R^2 implies that the overall mean may be better predictors of the response than the fitted model. If the predicted R-squared is subtracted from the
Adjusted R-squared and the difference is less than 0.2, then the

model is fitting the data and can reliably be used to make predictions about the response for given levels of each independent variable. C.V. % is the coefficient of variation, expressed as a percentage. It measures the relative variability of the data points around the mean. A lower value indicates less variability and greater precision. CV% is used in some industries to judge the capability of a process. Adequacy of precision is a measure of the signal-to-noise ratio in the data. It compares the range of the predicted values to the average distance between adjacent points. A higher value indicates a better signal-to-noise ratio, meaning that the predicted values are more precise. If the value of the Adequacy of Precision is greater than 4, then the model has a strong enough signal to be used for optimization. For such, the models can be used to navigate the design space and to make predictions about the responses (dependent variables) for given levels of the independent variables (ingredient proportions and/or process factors). Fitted models are useful for identifying the relative impact of the ingredient proportions and/or process factors on the quality parameters by comparing the model's regression coefficients. Contour plots are used to characterize the response surface graphically and determine the optimal parameter setting. When multiple responses are considered, the optimal parameter setting is obtained by observing overlay contour plots [5-11]. This research is aimed at developing and characterizing sesame seed candy from sesame seed, ginger, cinnamon, and honey. Empirical models for the production of the value-added sesame seed candy were also developed.

Materials and Methods

Materials

Samples of sesame (Sesamum indicum) seed, ginger, cinnamon, and honey were purchased from Kure market in Minna, Niger State, Nigeria. The preparation of sesame seed candy was carried out at the department of Agricultural and Bioresources Engineering laboratory, while the analysis was carried out at the department of Food Science and Technology laboratory at Federal University of Technolo, Minna.

Reagents and Apparatus

The reagents used during the experiment include ferric chloride, ammonium thiocyanate, ammonium solution, concentrated H_2SO_4, sodium hydroxide, ethanol, petroleum ether, HCl, n-hexane, and distilled water. The apparatus used during the experiment includes an electric oven, burette, desiccator, muffle furnace, measuring cylinder, pipette, crucible, stopwatch, digital weighing balance, thermometer, conical flask, petri dish, gas cooker, stirrers, frying pan, knife, flat plates, spectrophotometer, and parchment paper.

Methods

Sesame seed candy preparation

Sesame seeds, ginger, and cinnamon were washed to remove foreign materials and were then sundried. Ginger and cinnamon were milled and packaged separately. Sesame seed is roasted using a temperature-regulated oven. Honey was mildly heated to froth and bubble up after about 5 minutes. Formulations were done based on the design matrix (Table 1). The sesame seed candy dough was formed and cut into the desired shape.

Experimental Design and Statistical Data Analysis

Design-Expert software (version 13, Stat-Ease Inc., USA) was used for both experimental design and statistical evaluation of data. A four-component constrained D-optimal mixture-process experimental design, totaling 50 randomized experimental runs, was employed. Four major variable components with two processing factors were investigated. The respective formulation design constraints were sesame seed (40%-70%), ginger (10%-30%), cinnamon (10%-30%), and honey (10%-30%). The processing factors investigated were roasting temperature (100-150 0C) and roasting time (10 min-30 min). The quality properties of the value-added sesame seed candy monitored were moisture content, dietary fiber, protein, carbohydrate, fat content, calcium, vitamin C, energy value, hardness, taste, color, chewiness, gumminess, crispness, flavor, and overall acceptability.

Proximate Analysis and Sensory Evaluations

Most of the quality characteristics of the value-added sesame seed candy were measured using the methods described by the Association of Analytical Chemists with some modifications by some researchers [12-15]. The sensory evaluation of the samples was conducted using a total of 30 semi-trained panelists. The samples were evaluated for taste, flavor, sweetness, color, texture, and overall acceptability. A 9-point hedonic scale ranging from 9 = like extremely and 1 = dislike extremely was used to evaluate the samples.

Table 1: *Design Matrix for the Value-Added Sesame Seed Candy Formulation Experiments.*

Run	Sesame Seed (%)	Ginger (%)	Cinnamon (%)	Honey (%)	Roasting Temperature (^0C)	Roasting Time (min)
1.0	40.0	10.0	30.0	20.0	150	10
2.0	40.0	20.0	30.0	10.0	150	10
3.0	40.0	20.3	19.1	20.6	100	10
4.0	40.0	20.3	19.1	20.6	100	10
5.0	40.0	19.7	20.7	19.5	150	10
6.0	70.0	10.0	10.0	10.0	150	10
7.0	56.8	20.2	13.0	10.0	150	30
8.0	56.4	10.0	12.1	21.5	150	10

9.0	55.5	21.6	11.4	11.4	100	30
10.0	40.0	10.0	30.0	20.0	150	30
11.0	42.3	12.8	14.9	30.0	150	10
12.0	55.5	11.6	22.9	10.0	100	30
13.0	43.1	16.9	10.0	30.0	100	10
14.0	40.0	20.0	10.0	30.0	150	30
15.0	40.0	19.5	19.8	20.7	150	30
16.0	41.3	13.3	30.0	15.4	100	30
17.0	40.0	27.0	10.0	23.0	150	10
18.0	43.6	10.0	16.4	30.0	150	30
19.0	55.3	10.0	13.9	20.8	100	30
20.0	40.0	28.8	21.2	10.0	100	10
21.0	55.4	10.0	22.3	12.3	150	30
22.0	56.0	11.6	22.3	10.0	100	10
23.0	40.0	21.7	28.3	10.0	150	30
24.0	40.0	21.5	28.5	10.0	124	27
25.0	40.0	10.0	20.8	29.3	100	10
26.0	40.0	19.7	20.7	19.5	150	10
27.0	55.8	10.0	13.2	21.0	100	10
28.0	70.0	10.0	10.0	10.0	150	30
29.0	41.4	30.0	10.0	18.7	100	10
30.0	40.9	30.0	10.0	19.1	100	30
31.0	40.0	28.2	21.8	10.0	100	30
32.0	40.0	20.2	19.2	20.6	100	30
33.0	43.8	16.2	10.0	30.0	100	30
34.0	43.3	30.0	16.7	10.0	150	10
35.0	47.7	12.3	10.0	30.0	119	22
36.0	55.4	21.4	11.5	11.7	100	10
37.0	70.0	10.0	10.0	10.0	100	10
38.0	56.0	20.8	10.0	13.2	150	10
39.0	55.2	13.7	10.0	21.0	150	30
40.0	70.0	10.0	10.0	10.0	100	30
41.0	40.0	19.5	19.8	20.7	150	30
42.0	40.0	10.0	20.0	30.0	100	30
43.0	47.8	10.0	20.8	21.4	144	20
44.0	50.0	10.0	30.0	10.0	107	20
45.0	48.1	20.6	19.9	11.5	125	13
46.0	55.2	12.3	21.6	10.9	150	10
47.0	43.5	30.0	12.4	14.1	150	30
48.0	41.6	13.8	30.0	14.6	100	10
49.0	40.0	20.2	19.2	20.6	100	30
50.0	55.5	21.6	11.4	11.4	100	30

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 was tested using analysis of variance (ANOVA) for each response, and the adequacy of the models was 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 responses were used to generate contour, mix-process, as well as the 3-D response surface for the quality properties.

Figure 1 shows a sample of sesame seed candy. Using the standard methods, the formulated value-added sesame seed candy was analyzed and evaluated for the moisture content, dietary fiber, protein, carbohydrate, fat content, calcium, vitamin C, energy value, hardness, taste, color, chewiness, gumminess, crispness, flavor, and overall acceptability (Tables 2 and 3).

Figure 1: *Sesame Seed Candy.*

Table 2: *Quality Properties of the Formulated Value-Added Sesame Seed Candy.*

Run	Moisture Content (%)	Dietary Fibre (%)	Protein (%)	Carbohydrate (%)	Fat Content (%)	Calcium (mg)	Vitamin C (mg/100g)	Energy value (kcal)
1	6.8	23.61	20.25	19.06	26.28	273	0	393.76
2	7.4	20.14	21.13	21.13	26.2	269	0	304.84
3	7.6	20.63	24.85	17.31	25.11	233	0	398.23
4	9.6	21.11	20.65	19.3	25.34	234	0.04	387.9
5	6.4	22.63	19.25	21.54	26.18	216	0.02	398.78
6	4.6	19.84	21	25.95	24.11	222	0.03	304.78
7	5.2	19.72	25.76	20.49	24.33	241	0	399.97
8	4.2	21.66	19.56	26.46	23.62	256	0	396.66
9	7.4	22.06	20.88	23.58	21.14	278	0.06	368.1
10	8.2	21.72	20.65	25.21	20.22	281	0.03	365.42
11	7.2	20.11	30.8	13.91	21.48	283	0.03	372.16
12	10.6	20.63	28.7	14.46	20.11	291	0.04	353.63
13	7	19.84	38.5	10.24	19.92	206	0	369.74
14	9.8	19.33	42	4.84	19.33	218	0	360.13
15	6.2	19.78	43.5	3.11	17.41	216	0	343.13
16	8.4	21.62	41.65	3	20.33	233	0.07	361.57
17	8.6	21.63	31.5	11.84	21.63	247	0.07	368.03
18	7.6	20.11	33.25	15.26	19.48	272	0.05	369.36
19	7.2	20.22	35	14.02	18.36	262	0.04	361.32
20	6.2	20.63	33.6	13.61	20.66	252	0.02	375.18
21	9	23.24	28.72	16.22	18.22	271	0	365.43
22	5.2	22.11	29.33	18.33	20.63	273	0	376.31
23	6.8	23.24	25.66	19.8	19.11	222	0	354.19
24	7.4	23	25.38	20.6	18.32	227	0	348.8
25	6	22.14	26.11	21.92	18.73	229	0	360.69
26	6.9	21.43	24.74	18.48	23.72	240	0.02	386.33
27	6.1	20.77	27.79	19.18	21.68	256	0.03	382.97
28	6.1	20.54	24.63	22.73	21.16	264	0.05	379.91
29	7.1	20.22	32.96	12.61	21.86	221	0.03	378.99
30	8.5	19.91	40.27	7.19	18.1	222	0.05	352.76
31	8.4	21.21	34.65	10.99	19.07	235	0.04	354.21
32	8.5	20.86	37.52	9.49	17.95	240	0.04	349.56
33	8.5	19.88	41.37	7.61	16.96	238	0	348.56
34	6.6	21.12	23.45	19.21	24.73	228	0.02	393.24

35	7.6	20.1	35.52	12.43	19.16	245	0.04	364.29
36	6	20.65	26.82	19.14	22.66	242	0	387.78
37	5	20.74	22.52	24.66	22.91	264	0	394.94
38	5.8	20.59	22.5	22.08	24.45	241	0.03	398.38
39	7.3	20.23	31.2	16.09	19.92	249	0.05	368.46
40	6.3	20.44	29.58	19.48	19.21	265	0.05	369.16
41	8.3	21.02	32.37	12.91	19.89	241	0.04	360.12
42	8.7	20.88	38.95	9.09	16.95	252	0.04	344.74
43	7.1	21.39	26.75	18.52	21.49	257	0.03	374.47
44	6.9	22.4	24.38	20.51	21.25	269	0	370.83
45	6.6	21.43	24.65	19.55	23.07	245	0	384.46
46	5.7	21.82	18.16	25.39	24.7	261	0	396.55
47	8	20.34	32.74	12.54	20.6	225	0.05	366.5
48	6.9	22.37	24.99	18.96	22.3	258	0	376.51
49	8.5	20.86	37.52	9.49	17.95	240	0.04	349.56
50	7.4	20.35	33.8	14.03	18.99	243	0.05	362.26

Table 3: *Sensory Properties of the Formulated Value-Added Sesame Seed Candy.*

Run	Hardness	Taste	Colour	Chewiness	Gumminess	Crispness	Flavour	Overall Acceptability
1.0	6.4	6.1	6.3	5.7	6.4	5.9	5.9	6.2
2.0	4.8	4.6	5.3	5.5	5.7	4.6	5.1	5.7
3.0	5.2	5.1	5.7	5.7	6.0	4.9	5.6	5.5
4.0	4.9	5.1	5.4	6.0	5.5	5.2	5.7	5.6
5.0	5.8	5.3	6.6	6.0	6.0	5.6	5.7	5.9
6.0	6.2	4.4	5.7	5.2	4.8	6.2	4.9	5.4
7.0	6.9	4.9	5.9	5.5	5.1	6.1	6.1	6.1
8.0	6.0	6.3	6.9	6.0	6.2	5.8	6.7	6.9
9.0	6.0	5.8	6.3	6.0	5.2	6.2	5.9	6.2
10.0	7.1	6.7	6.6	6.6	6.4	6.5	6.4	6.6
11.0	6.8	6.4	6.3	6.2	6.5	6.1	6.6	6.7
12.0	6.4	6.1	6.6	6.2	5.5	5.3	5.7	6.5
13.0	6.3	6.3	6.6	6.3	6.7	5.4	6.3	6.5
14.0	6.7	6.5	6.0	6.9	6.0	6.6	6.8	7.2
15.0	6.3	5.5	6.2	5.8	5.7	5.1	5.9	6.5
16.0	6.2	5.5	5.0	5.9	5.3	5.7	5.8	6.1
17.0	6.6	5.8	6.3	6.1	6.2	5.5	5.9	6.2
18.0	6.2	6.1	6.4	6.0	6.3	5.6	6.5	6.5
19.0	5.8	5.6	5.9	5.8	6.1	5.3	6.0	5.8
20.0	5.4	5.4	5.9	5.6	5.5	5.2	5.5	5.6
21.0	6.0	5.5	6.2	6.2	5.9	5.4	5.3	6.2
22.0	5.1	5.1	4.8	5.2	5.6	5.1	5.3	5.4
23.0	5.9	5.1	5.7	5.6	6.0	5.8	5.3	5.8
24.0	5.2	5.7	6.1	6.0	6.1	5.9	5.6	5.9
25.0	5.0	5.7	5.5	5.8	6.2	5.4	6.0	6.5
26.0	5.3	5.0	5.5	5.4	5.9	5.7	5.4	5.9
27.0	5.3	4.7	5.2	5.3	5.2	5.1	4.8	5.3
28.0	4.6	4.4	4.3	5.0	5.0	5.1	4.4	4.8

29.0	5.3	5.4	5.4	5.5	5.8	5.0	5.6	5.7
30.0	4.9	4.9	6.0	5.8	5.7	5.9	5.4	5.3
31.0	5.5	5.0	5.9	5.5	5.4	5.7	5.0	5.6
32.0	5.7	4.7	6.2	5.5	5.6	5.9	5.3	5.8
33.0	5.9	5.6	6.1	5.7	6.0	5.9	5.7	6.1
34.0	6.0	6.2	5.3	6.0	5.1	5.4	6.2	6.2
35.0	6.4	6.2	5.7	5.7	5.4	5.6	6.3	6.3
36.0	6.2	6.0	6.0	6.4	6.1	5.9	6.5	6.3
37.0	6.2	5.6	5.8	5.3	5.3	5.7	6.0	6.4
38.0	6.1	5.6	5.7	5.7	6.0	5.6	6.0	6.3
39.0	6.8	6.2	6.4	6.1	6.3	6.3	6.4	6.8
40.0	6.2	5.6	5.5	5.4	6.0	5.6	5.6	6.2
41.0	6.4	5.3	5.9	5.9	5.6	5.7	5.7	5.7
42.0	5.8	5.7	5.4	5.9	6.0	5.6	6.0	6.2
43.0	6.4	5.7	6.0	6.0	5.5	5.8	6.1	6.1
44.0	6.2	5.1	5.7	5.8	5.5	5.2	5.5	5.9
45.0	5.1	4.9	5.2	5.2	5.6	5.2	5.1	5.3
46.0	5.4	5.7	5.4	5.2	5.5	5.7	5.5	5.6
47.0	5.1	5.1	5.2	5.6	5.6	5.3	5.6	6.0
48.0	5.3	5.1	5.2	5.3	5.3	5.3	5.1	5.5
49.0	5.2	4.8	5.3	4.9	5.5	5.4	4.7	5.3
50.0	5.2	5.0	5.7	5.2	5.8	5.3	5.5	5.5

Results of Statistical Analyses of Experimental Data

The summary statistics of the regression analyses from the respective ANOVA Tables, indicating only the significant terms, of the formulated value-added sesame seed candy' quality and sensory properties were presented in Tables 4.

***Table 4:** 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
y_{mc}	Model	4.11	0.0009	0.8563	0.6479	-0.1574	11.04	8.7252
	L/Mixture	11.97	0.0001					
	$x_2x_3z_1$	8.08	0.0101					
	$x_3x_4z_1$	4.87	0.0392					
y_{df}	Model	13.08	< 0.0001	0.4603	0.4251	0.3617	3.72	10.9832
	L/Mixture	13.08	< 0.0001					
y_{pc}	Model	8.32	< 0.0001	0.7065	0.6215	-0.5061	14.68	10.9655
	L/Mixture	13.01	< 0.0001					
	x_3z_1	6.58	0.0144					
	x_4z_2	8.4	0.0062					
y_{cho}	Model	7.18	< 0.0001	0.6752	0.5811	0.4216	23.41	11.0376
	L/Mixture	14.61	< 0.0001					
	x_3z_1	6.75	0.0133					
	x_4z_2	5.2	0.0284					
y_{fat}	Model	5.66	< 0.0001	0.7959	0.6552	0.4583	7.25	8.6602
	L/Mixture	4.28	0.0128					
	x_1z_2	4.37	0.0454					
	x_2z_2	5.51	0.0259					

	x_3z_2	13.28	0.001					
y_{cal}	Model	3.67	0.0008	0.7168	0.5216	0.1249	5.7	7.1616
	L/Mixture	13.36	< 0.0001					
	x_1z_2	4.21	0.0494					
	x_4z_1	9.42	0.0046					
y_{vc}	Model	2.81	0.0056	0.6596	0.4249	-0.0012	70.51	6.826
	L/Mixture	2.82	0.0564					
	x_1z_2	7.95	0.0086					
	x_3z_1	7.04	0.0128					
	x_3z_2	5.63	0.0245					
	z_1z_2	8.25	0.0076					
y_{ev}	Model	7.05	0.0012	0.9649	0.8279	-41.246	2.34	12.2776
	L/Mixture	2.5	0.1187					
	x_1x_2	9.63	0.0112					
	x_1x_3	5.56	0.0401					
	x_1x_4	8.89	0.0138					
	x_1z_1	20.29	0.0011					
	x_1z_2	7.96	0.0181					
	x_3x_4	18.67	0.0015					
	x_3z_2	9.03	0.0132					
	x_4z_2	11.11	0.0076					
	$x_1x_3z_1$	12.97	0.0048					
	$x_1x_3z_2$	18.18	0.0017					
	$x_1x_4z_2$	15.6	0.0027					
	$x_1z_1z_2$	33.96	0.0002					
	$x_2x_4z_2$	7.2	0.023					
	$x_3x_4z_1$	7.43	0.0214					
	$x_3x_4z_2$	27.13	0.0004					
	$x_4z_1z_2$	6.38	0.0301					
	$x_1x_3z_1z_2$	8.97	0.0134					
	$x_1x_4z_1z_2$	12.05	0.006					
	$x_3x_4z_2z_2$	10.34	0.0092					
y_{hard}	Model	2.8	0.0057	0.6590	0.4238	0.1184	8.12	6.4722
	L/Mixture	3.32	0.0335					
	x_3z_2	14.65	0.0006					
	x_4z_1	10.62	0.0029					
y_{tast}	Model	2.98	0.0037	0.6727	0.4469	-0.0987	7.73	7.6982
	L/Mixture	6.29	0.002					
	x_1z_1	4.41	0.0445					
	x_2x_3	5.63	0.0245					
	x_2x_4	7.08	0.0126					
	x_2z_2	5.18	0.0305					
	x_3x_4	5.9	0.0216					
	x_3z_2	5.15	0.0309					
	x_4z_1	10.94	0.0025					
y_{color}	Model	2.6	0.0141	0.4297	0.2647	-0.0920	7.73	7.4234
	L/Mixture	2.44	0.0789					

	x_3z_1	4.41	0.0424					
	x_3z_2	4.74	0.0357					
	x_4z_1	7.51	0.0093					
y_{chew}	Model	2.77	0.0097	0.4448	0.2840	0.0409	6.04	6.8723
	L/Mixture	4.18	0.0119					
	x_3z_2	7.18	0.0108					
	x_4z_1	6.59	0.0143					
y_{gum}	Model	3.13	0.0033	0.5309	0.3615	0.0353	5.85	7.1661
	L/Mixture	8.12	0.0033					
	x_2x_3	6.21	0.0174					
	x_2x_4	6.91	0.0125					
	x_3x_4	5.83	0.021					
	$x_2x_3x_4$	9.62	0.0037					
y_{crisp}	Model	1.81	0.0713	0.5548	0.2478	-0.3632	6.49	5.1947
	L/Mixture	1.41	0.2593					
	x_4z_1	6.13	0.0194					
y_{flav}	Model	4.87	0.0054	0.9500	0.7550	-22.305	4.59	10.3284
	L/Mixture	17.71	0.0003					
	x_1x_2	8.61	0.0149					
	x_1z_1	20.64	0.0011					
	x_2x_3	6.62	0.0278					
	x_3z_2	7.42	0.0214					
	$x_1x_4z_1$	7.68	0.0198					
	$x_2z_1z_2$	7.14	0.0234					
	$x_1x_2z_1z_2$	12.75	0.0051					
	$x_1x_4z_1z_2$	7.49	0.021					
	$x_2x_4z_1z_2$	5.05	0.0484					
$y_{overall}$	Model	3.68	0.0018	0.8421	0.6133	0.1916	5.06	8.4197
	L/Mixture	8.68	0.0007					
	x_1z_1	14.45	0.0011					
	x_3x_4	9.06	0.0069					
	$x_1x_4z_1$	12.5	0.0021					

y_{mc} = Moisture Content (%), y_{df} = Dietary Fiber (%), y_{pc} = Protein (%), y_{cho} = Carbohydrate (%) y_{fat} = Fat Content (%), y_{cal} = Calcium (mg), y_{vc} = Vitamin C (mg/100g), y_{ev} = Energy Value (kcal), y_{hard} = Hardness, y_{tast} = Taste, y_{color} = Colour, y_{chew} = Chewiness, y_{gum} = Gumminess, y_{crisp} = Crispness, y_{flav} = Flavour, $y_{overall}$ = Overall Acceptability.

P-values less than 0.05 indicate models and model terms that are significant. R^2 is the coefficient of determination, which measures the proportion of the total variation in the dependent variable (quality parameters) that is explained by the independent variable (ingredients proportions and the process parameters). The R^2 value ranges from 0 to 1, with a higher value indicating a better fit of the model to the data. The adjusted R^2 is a modified version of R^2 that takes into account the number of independent variables in the model. It penalizes the R^2 value for including irrelevant variables that don't contribute much to explaining the variation in the dependent variable. Predicted R^2 is a measure of how well the model predicts new data that was not used to fit the model. A higher value indicates better predictive power of the model. A negative Predicted R^2 implies that the overall mean may be better predictors of the response than the fitted model. C.V. % is the coefficient of variation, expressed as a percentage. It measures the relative variability of the data points around the mean. A lower value indicates less variability and greater precision. Adequate precision is a measure of the signal-to-noise ratio in the data. It compares the range of the predicted values to the average distance between adjacent points. A higher value indicates a better signal-to-noise ratio, meaning that the predicted values are more precise. 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 (ingredients proportions and the process parameters).

The result of the analyses shows that only the crispness model was insignificant at the 5% level of significance ($p > 0.05$). The ingredient proportions have significant influences on all the quality parameters of the sesame seed candy, with the exception of vitamin C, energy value, color, and crispness ($p > 0.05$). Ingredient proportions and the process parameter have significant influences on the majority of the quality properties of the sesame seed candy, as shown in Table 4. Prominent among these were energy value, vitamin C, flavor, taste, and gumminess ($p < 0.05$). The value of the adequacy of precision of all the models was greater than 4. Hence, they have strong enough signals to be used to make predictions about the quality parameters of the sesame seed candy, for given levels of each factor (ingredients proportions and process parameters) and also to be used for prediction and optimization. The models are useful for identifying the relative impact of the ingredient proportions and process parameters on the quality parameters of the sesame seed candy.

The final equations of the formulated value-added sesame seed candy's quality indices, in terms of L pseudo components and coded factors, are summarized in Table 5. 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 2-17, respectively.

Table 5: *Models Coefficients of Formulated Noodles' Quality Indices*.

$$\left.\begin{aligned} y_{mc} = {} & 5.47x_1 + 7.03x_2 + 8.05x_3 + 7.85x_4 - 1.01x_1x_2 + 3.76x_1x_3 - 1.71x_1x_4 - 0.1912x_1z_1 + 0.7327x_1z_2 \\ & - 1.45x_2x_3 + 5.89x_2x_4 + 2.28x_2z_1 + 2.18x_2z_2 - 3.28x_3x_4 + 2.56x_3z_1 + 1.23x_3z_2 + 1.42x_4z_1 \\ & + 1.76x_4z_2 - 5.56x_1x_2z_1 - 4.70x_1x_2z_2 - 4.09x_1x_3z_1 + 5.87x_1x_3z_2 - 2.07x_1x_4z_1 - 1.32x_1x_4z_2 \\ & - 11.24x_2x_3z_1 - 5.78x_2x_3z_2 - 5.82x_2x_4z_1 - 5.79x_2x_4z_2 - 8.83x_3x_4z_1 - 2.95x_3x_4z_2 \end{aligned}\right\} (1)$$

$$\left. y_{df} = 20.63x_1 + 20.16x_2 + 23.36x_3 + 19.94x_4 \right\} \quad (2)$$

$$\left.\begin{aligned} y_{pc} = {} & 23.64x_1 + 33.03x_2 + 21.96x_3 + 38.00x_4 - 2.02x_1z_1 + 1.70x_1z_2 \\ & - 0.3985x_2z_1 + 2.09x_2z_2 - 5.86x_3z_1 + 4.37x_3z_2 - 0.5514x_4z_1 + 6.49x_4z_2 \end{aligned}\right\} (3)$$

$$\left.\begin{aligned} y_{cho} = {} & 23.71x_1 + 11.53x_2 + 20.72x_3 + 9.72x_4 + 1.60x_1z_1 - 1.87x_1z_2 \\ & - 0.2098x_2z_1 - 1.22x_2z_2 + 5.35x_3z_1 - 2.98x_3z_2 - 0.6698x_4z_1 - 4.60x_4z_2 \end{aligned}\right\} (4)$$

$$\left.\begin{aligned} y_{fat} = {} & 21.55x_1 + 18.29x_2 + 22.12x_3 + 15.30x_4 + 11.44x_1x_2 - 4.99x_1x_3 + 5.55x_1x_4 \\ & + 0.9963x_1z - 1.21x_1z_2 + 3.82x_2x_3 + 12.63x_2x_4 + 0.6920x_2z_1 - 1.96x_2z_2 + 7.81x_3x_4 \\ & + 0.7811x_3z_1 - 3.05x_3z_2 + 0.7904x_4z_1 - 1.46x_4z_2 - 0.1931z_1z_2 + 1.56z_1^2 - 1.30z_2^2 \end{aligned}\right\} (5)$$

$$\left.\begin{aligned} y_{cal} = {} & 243.19x_1 + 233.51x_2 + 262.21x_3 + 248.62x_4 - 19.19x_1x_2 + 60.91x_1x_3 + 3.85x_1x_4 \\ & - 10.72x_1z_1 + 10.89x_1z_2 - 86.65x_2x_3 - 126.14x_2x_4 - 14.17x_2z_1 - 8.93x_2z_2 - 23.76x_3x_4 \\ & + 2.12x_3z_1 - 6.58x_3z_2 + 22.88x_4z_1 + 5.22x_4z_2 - 2.82z_1z_2 - 1.57z_1^2 + 12.38z_2^2 \end{aligned}\right\} (6)$$

$$\left.\begin{aligned} y_{vitc} = {} & 0.0309x_1 + 0.0784x_2 + 0.0049x_3 - 0.0111x_4 - 0.0938x_1x_2 - 0.0760x_1x_3 + 0.1013x_1x_4 \\ & - 0.0015x_1z_1 + 0.0180x_1z_2 - 0.1132x_2x_3 - 0.0126x_2x_4 + 0.0016x_2z_1 - 0.0057x_2z_2 + 0.1361x_3x_4 \\ & - 0.0247x_3z_1 + 0.0220x_3z_2 + 0.0153x_4z_1 + 0.0029x_4z_2 - 0.0073z_1z_2 + 0.0068z_1^2 - 0.0062z_2^2 \end{aligned}\right\} (7)$$

$$\left.\begin{aligned} y_{ev} &= 362.47x_1 + 367.24x_2 + 339.70x_3 + 323.35x_4 + 103.57x_1x_2 + 74.31x_1x_3 + 100.8x_1x_4 - 19.45x_1z_1 \\ &+ 12.18x_1z_2 + 6.55x_2x_3 + 63.52x_2x_4 + 19.40x_2z_1 - 6.23x_2z_2 + 171.33x_3x_4 - 30.06x_3z_1 + 42.31x_3z_2 \\ &- 2.42x_4z_1 + 43.28x_4z_2 + 70.97x_1x_2z_1 - 13.76x_1x_2z_2 + 118.23x_1x_3z_1 - 140.12x_1x_3z_2 + 32.31x_1x_4z_1 \\ &- 136.11x_1x_4z_2 - 25.63x_2x_3z_1 - 82.38x_2x_3z_2 - 53.54x_2x_4z_1 - 114.91x_2x_4z_2 - 19.29x_2z_1z_2 \\ &+ 119.78x_3x_4z_1 - 232.32x_3x_4z_2 + 25.23x_3z_1z_2 + 32.90x_4z_1z_2 + 8.40x_1x_2z_1z_2 - 99.62x_1x_3z_1z_2 \\ &- 119.80x_1x_4z_1z_2 + 27.33x_2x_3z_1z_2 + 3.33x_2x_4z_1z_2 - 145.38x_3x_4z_1z_2 \end{aligned}\right\} (8)$$

$$\left.\begin{aligned} y_{hd} &= 5.68x_1 + 4.82x_2 + 6.50x_3 + 6.92x_4 + 3.57x_1x_2 - 2.22x_1x_3 - 1.14x_1x_4 - 0.1863x_1z_1 \\ &- 0.1077x_1z_2 - 1.50x_2x_3 - 0.3058x_2x_4 + 0.1882x_2z_1 - 0.4309x_2z_2 - 3.40x_3x_4 \\ &+ 0.0657x_3z_1 + 0.9918x_3z_2 + 0.8181x_4z_1 - 0.0581x_4z_2 - 0.0246z_1z_2 + 0.9857z_1^2 - 0.8570z_2^2 \end{aligned}\right\} (9)$$

$$\left.\begin{aligned} y_{tast} &= 4.86x_1 + 5.97x_2 + 6.24x_3 + 7.51x_4 + 0.5825x_1x_2 - 0.9933x_1x_3 - 1.18x_1x_4 - 0.3355x_1z_1 \\ &+ 0.0036x_1z_2 - 4.86x_2x_3 - 5.43x_2x_4 - 0.0828x_2z_1 - 0.5245x_2z_2 - 4.69x_3x_4 + 0.1040x_3z_1 \\ &+ 0.5250x_3z_2 + 0.7419x_4z_1 - 0.1286x_4z_2 - 0.0157z_1z_2 - 0.3452z_1^2 + 0.5226z_2^2 \end{aligned}\right\} (10)$$

$$\left.\begin{aligned} y_{color} &= 5.61x_1 + 5.60x_2 + 5.56x_3 + 6.40x_4 - 0.1506x_1z_1 - 0.0239x_1z_2 - 0.5081x_2z_1 \\ &+ 0.0120x_2z_2 + 0.4484x_3z_1 + 0.5291x_3z_2 + 0.6409x_4z_1 - 0.3178x_4z_2 \end{aligned}\right\} (11)$$

$$\left.\begin{aligned} y_{chew} &= 5.42x_1 + 5.65x_2 + 5.63x_3 + 6.25x_4 - 0.1247x_1z_1 + 0.0880x_1z_2 - 0.0125x_2z_1 \\ &- 0.3184x_2z_2 + 0.0316x_3z_1 + 0.5036x_3z_2 + 0.4642x_4z_1 - 0.0879x_4z_2 \end{aligned}\right\} (12)$$

$$\left.\begin{aligned} y_{gum} &= 5.27x_1 + 3.49x_2 + 4.40x_3 + 4.73x_4 + 3.32x_1x_2 + 3.17x_1x_3 + 2.56x_1x_4 + 7.60x_2x_3 \\ &+ 8.34x_2x_4 + 7.58x_3x_4 - 15.87x_1x_2x_3 + 17.69x_1x_2x_4 - 10.19x_1x_3x_4 - 30.06x_2x_3x_4 \end{aligned}\right\} (13)$$

$$\left.\begin{aligned} y_{crisp} &= 5.62x_1 + 5.28x_2 + 6.17x_3 + 6.29x_4 + 1.91x_1x_2 - 2.38x_1x_3 - 1.49x_1x_4 + 0.1348x_1z_1 \\ &- 0.1991x_1z_2 - 1.86x_2x_3 - 0.5723x_2x_4 - 0.2424x_2z_1 + 0.3277x_2z_2 - 2.01x_3x_4 \\ &+ 0.0827x_3z_1 + 0.3162x_3z_2 + 0.4753x_4z_1 + 0.0233x_4z_2 - 0.0633z_1z_2 - 0.0603z_1^2 + 0.0974z_2^2 \end{aligned}\right\} (14)$$

$$\left.\begin{aligned} y_{flav} &= 5.25x_1 + 5.88x_2 + 6.17x_3 + 7.20x_4 + 2.97x_1x_2 - 1.34x_1x_3 - 0.3490x_1x_4 - 0.5953x_1z_1 \\ &- 0.2183x_1z_2 - 3.23x_2x_3 - 2.74x_2x_4 + 0.1018x_2z_1 - 0.5586x_2z_2 - 2.51x_3x_4 + 0.1222x_3z_1 \\ &+ 1.16x_3z_2 + 0.2096x_4z_1 - 0.3079x_4z_2 + 0.8421x_1x_2z_1 + 1.14x_1x_2z_2 + 0.8803x_1x_3z_1 \\ &- 1.00x_1x_3z_2 + 2.87x_1x_4z_1 + 1.47x_1x_4z_2 - 0.0245x_1z_1z_2 - 0.5412x_2x_3z_1 - 1.87x_2x_3z_2 \\ &+ 0.3724x_2x_4z_1 + 1.44x_2x_4z_2 - 1.14x_2z_1z_2 + 0.3686x_3x_4z_1 - 1.31x_3x_4z_2 - 0.0236x_3z_1z_2 \\ &+ 0.3399x_4z_1z_2 + 3.72x_1x_2z_1z_2 - 0.7257x_1x_3z_1z_2 - 2.87x_1x_4z_1z_2 + 2.34x_2x_3z_1z_2 \\ &+ 2.93x_2x_4z_1z_2 - 1.17x_3x_4z_1z_2 \end{aligned}\right\} (15)$$

$$\left.\begin{aligned} y_{overall} = {} & 5.71x_1 + 5.72x_2 + 6.78x_3 + 7.61x_4 + 2.19x_1x_2 - 1.56x_1x_3 - 1.28x_1x_4 - 0.5761x_1z_{12} \\ & - 0.2081x_1z - 2.45x_2x_3 - 1.87x_2x_4 + 0.3525x_2z_1 - 0.7089x_2z_2 - 4.16x_3x_4 + 0.3773x_3z_1 \\ & + 0.5535x_3z_2 - 0.1392x_4z_1 - 0.4120x_4z_2 + 0.6751x_1x_2z_1 + 0.8569x_1x_2z_2 + 0.2501x_1x_3z_1 \\ & + 1.65x_1x_3z_2 + 4.21x_1x_4z_1 + 0.7343x_1x_4z_2 - 1.42x_2x_3z_1 + 0.3352x_2x_3z_2 + 1.22x_2x_4z_1 \\ & + 2.53x_2x_4z_2 + 0.0667x_3x_4z_1 - 0.4869x_3x_4z_2 \end{aligned}\right\} \quad (16)$$

The result of the analyses shows that only the crispness model was insignificant at the 5% level of significance ($p > 0.05$). The ingredient proportions have significant influences on all the quality parameters of the sesame seed candy, with the exception of vitamin C, energy value, color, and crispness ($p > 0.05$). Ingredient proportions and the process parameter have significant influences on the majority of the quality properties of the sesame seed candy, as shown in Table 4. Prominent among these were energy value, vitamin C, flavor, taste, and gumminess ($p < 0.05$). The value of the adequacy of precision of all the models was greater than 4. Hence, they have strong enough signals to be used to make predictions about the quality parameters of the sesame seed candy, for given levels of each factor (ingredients proportions and process parameters) and also to be used for prediction and optimization. The models are useful for identifying the relative impact of the ingredient proportions and process parameters on the quality parameters of the sesame seed candy.

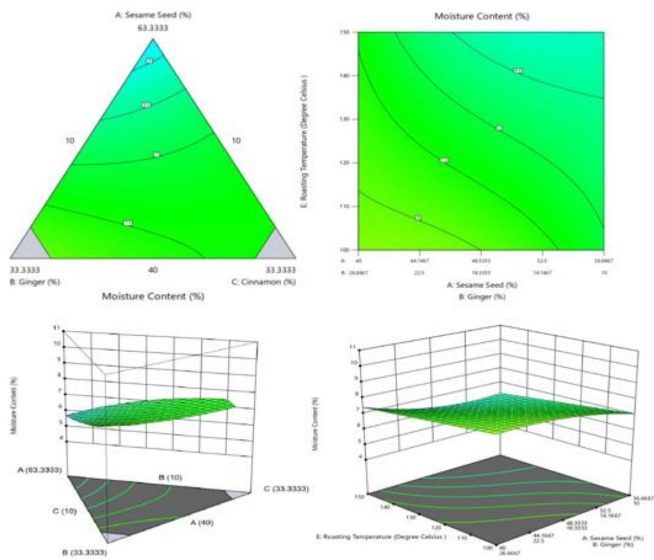

Figure 2: *Moisture Content Contour, Mix-Process, 3-D Surface, and 3-D Surface Mix-Process Plots.*

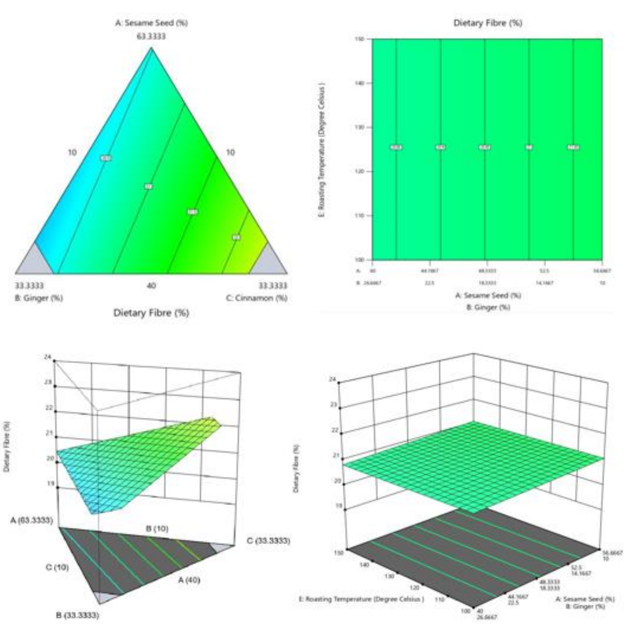

Figure 3: *Dietary Fibre Contour, Mix-Process, 3-D Surface, and 3-D Surface Mix-Process Plots.*

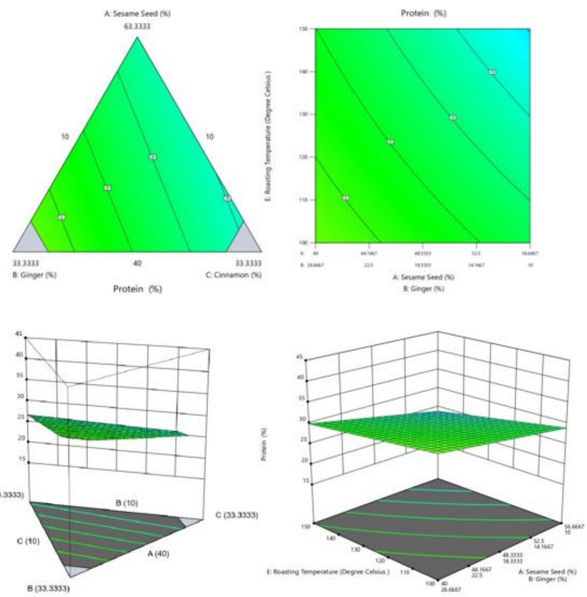

Figure 4: *Protein Contour, Mix-Process, 3-D Surface, and 3-D Surface Mix-Process Plots.*

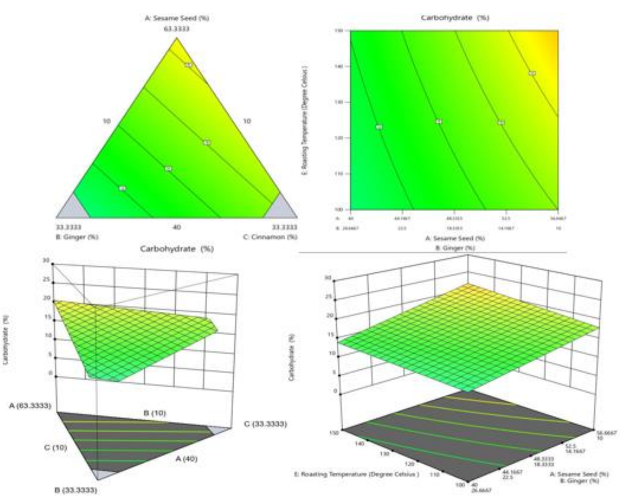

Figure 5: *Carbohydrate Contour, Mix-Process, 3-D Surface, and 3-D Surface Mix-Process Plots.*

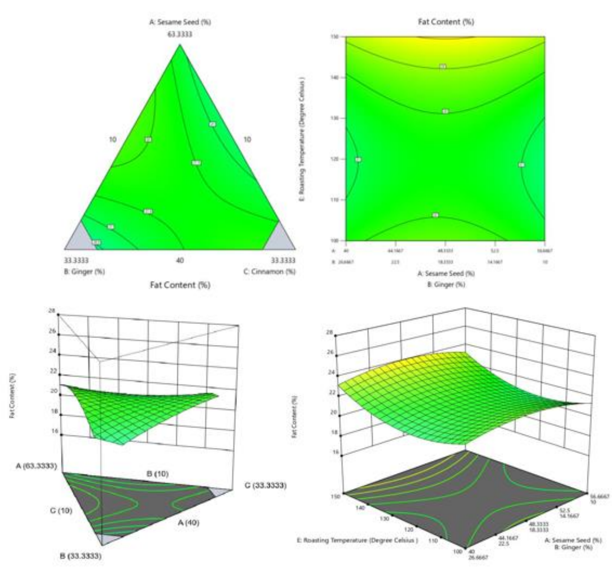

Figure 6: *Fat Content Contour, Mix-Process, 3-D Surface, and 3-D Surface Mix-Process Plots.*

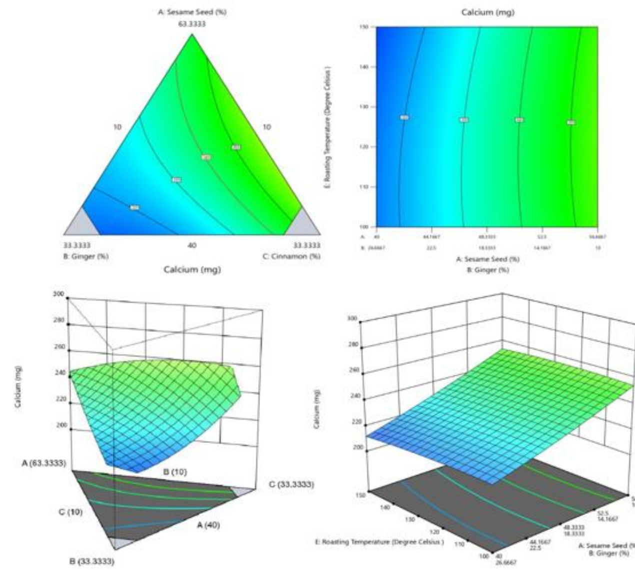

Figure 7: *Calcium Contour, Mix-Process, 3-D Surface, and 3-D Surface Mix-Process Plots.*

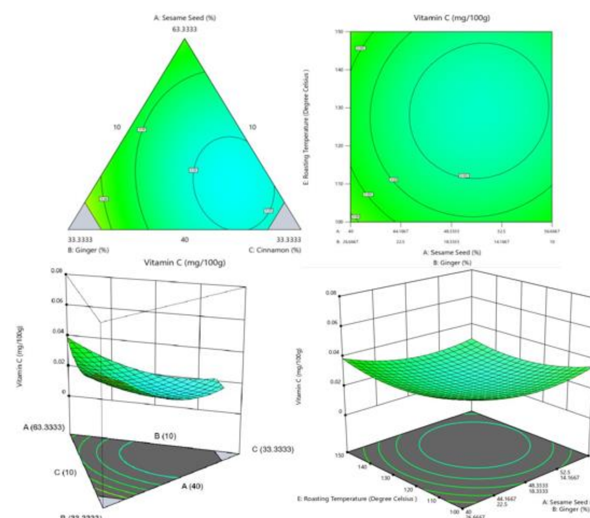

Figure 8: *Vitamin C Contour, Mix-Process, 3-D Surface, and 3-D Surface Mix-Process Plots.*

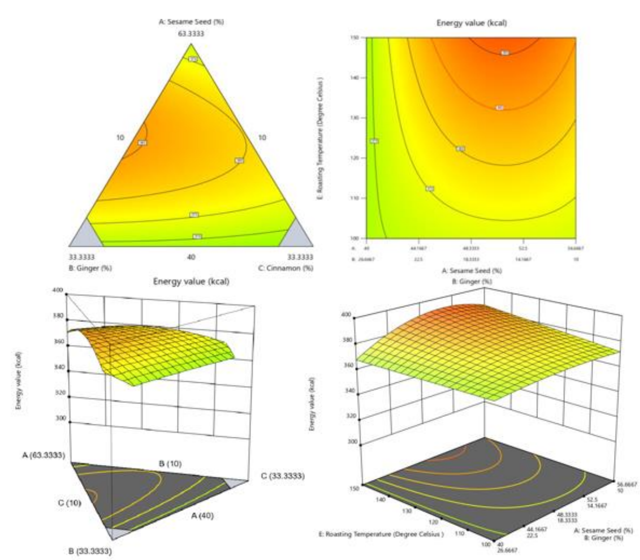

Figure 9: *Energy value Contour, Mix-Process, 3-D Surface, and 3-D Surface Mix-Process Plots.*

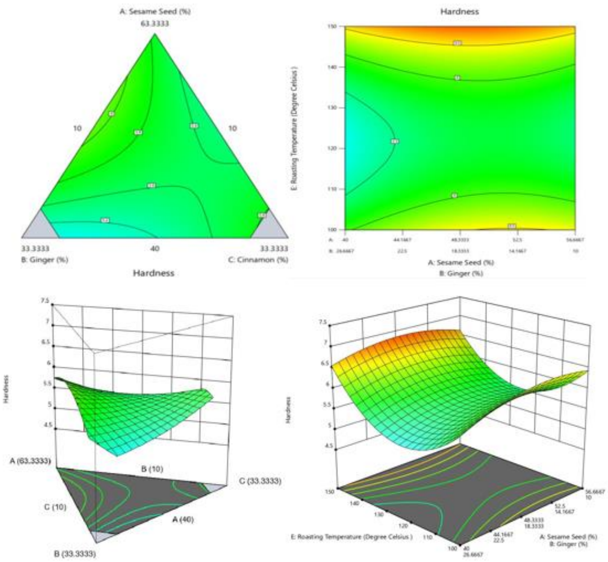

Figure 10: *Hardness Contour, Mix-Process, 3-D Surface, and 3-D Surface Mix-Process Plots.*

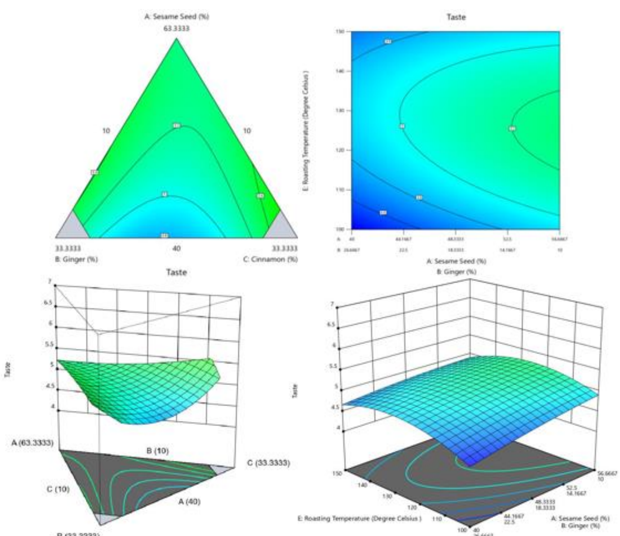

Figure 11: *Taste Contour, Mix-Process, 3-D Surface, and 3-D Surface Mix-Process Plots.*

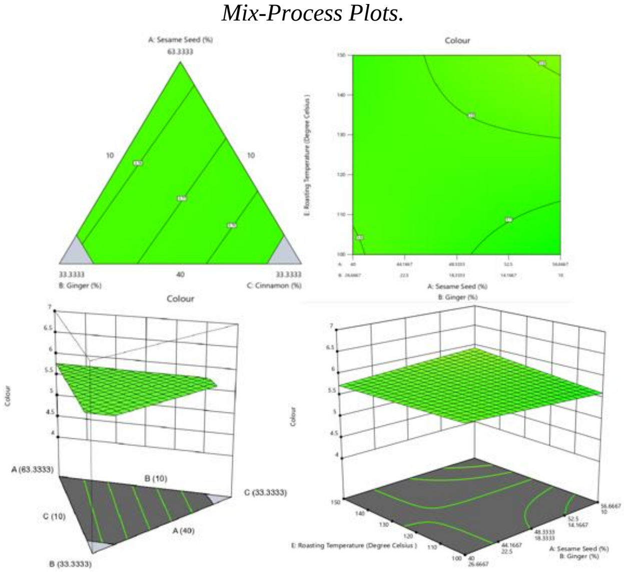

Figure 12: *Colour Contour, Mix-Process, 3-D Surface, and 3-D Surface Mix-Process Plots.*

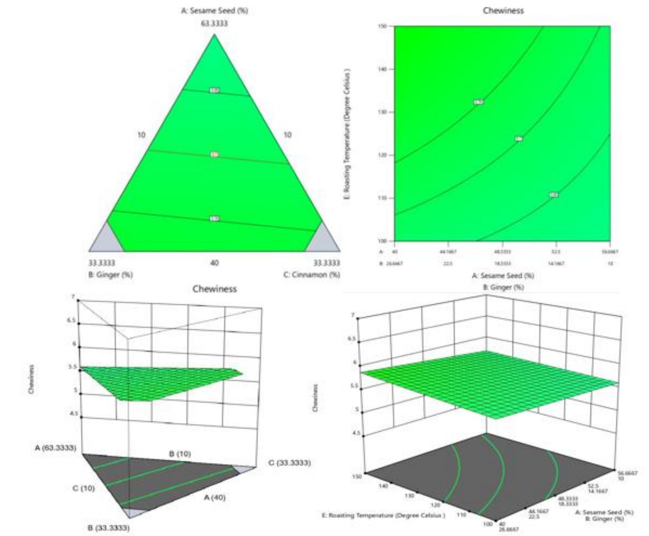

Figure 13: *Chewiness Contour, Mix-Process, 3-D Surface and 3-D Surface Mix-Process Plots.*

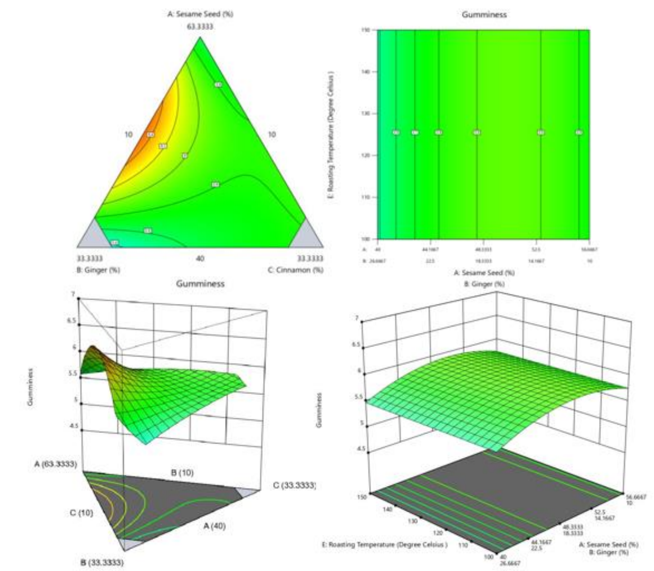

Figure 14: *Gumminess Contour, Mix-Process, 3-D Surface, and 3-D Surface Mix-Process Plots.*

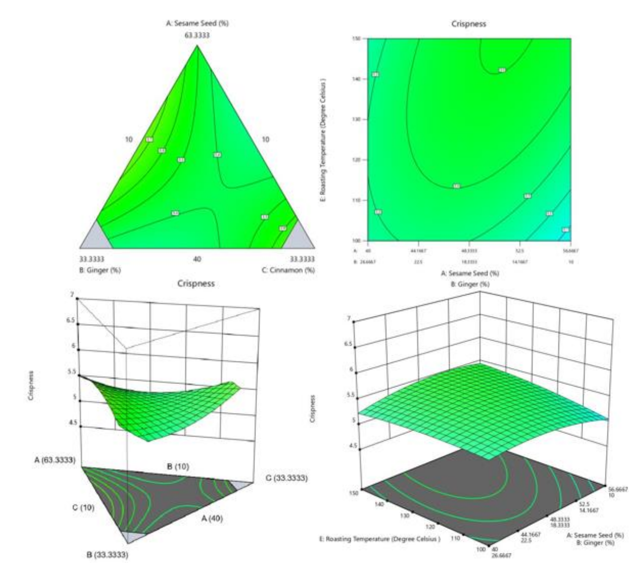

Figure 15: Crispness Contour, Mix-Process, 3-D Surface, and 3-D Surface Mix-Process Plots.

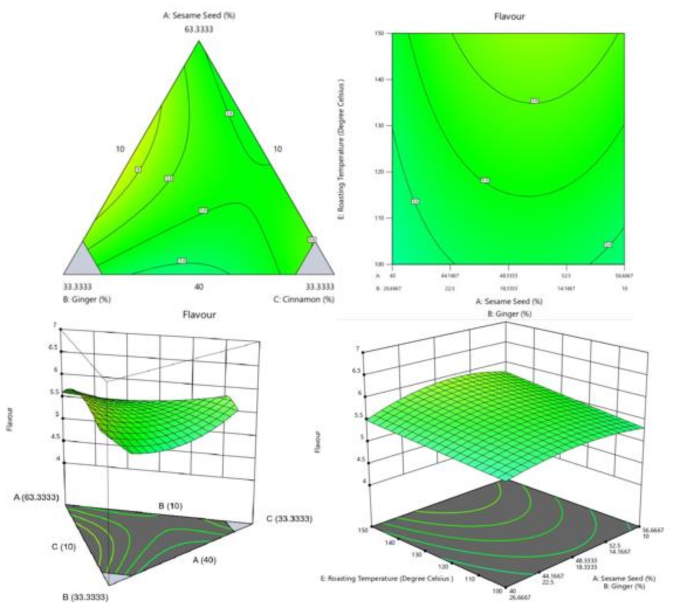

Figure 16: *Flavour Contour, Mix-Process, 3-D Surface, and 3-D Surface Mix-Process Plots.*

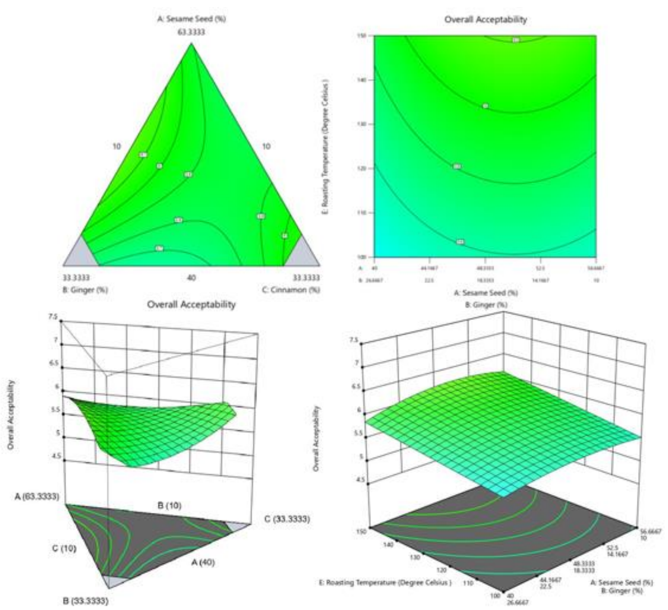

Figure 17: *Overall Acceptability Contour, Mix-Process, 3-D Surface, and 3-D Surface Mix-Process Plots.*

Conclusion

The study shows that only the crispness model was insignificant at the 5% level of significance ($p > 0.05$). The ingredients proportions have significant influences on all the quality parameters of the sesame seed candy, with the exception of vitamin C, energy value, color, and crispness ($p > 0.05$). Ingredient proportions and the process parameter have significant influences on the majority of the quality properties of the sesame seed candy. Prominent among these were energy value, vitamin C, flavor, taste, and gumminess ($p < 0.05$). The value of the adequacy of precision of all the models was greater than 4. Hence, they have strong enough signals to be used to make predictions about the quality parameters of the sesame seed candy, for given levels of each factor (ingredients proportions and process parameters) and also to be used for prediction and optimization. The models are useful for identifying the relative impact of the ingredient proportions and process parameters on the quality parameters of the sesame seed candy.

Conflict of Interests

The authors declare that they have no competing interests.

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