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Development, Optimization and Evaluation of Enriched Custard Powder from Selected Local Food Ingredients

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Abstract: Custard powder is a breakfast cereals meal, primarily, made from corn starch; processed with added flavour and fortified with vitamins and minerals. The aim of this study is to formulate, characterize, and optimize enriched custard powder from bio-fortified cassava, pearl millet, soybeans, Africa locust beans fruit pulp, ginger, egg powder, and milk powder; using a seven-component constrained, D-optimal mixture experimental design, with thirty-eight randomized experimental runs. The formulation design constraints were: bio-fortified cassava (10% - 70%), pearl millet (10% - 70%), soybeans (10% - 60%), Africa locust beans fruit pulp (5% - 30%), ginger (1% - 2%), egg powder (0.5% - 1.5%), and milk powder (0.5% - 1%). The formulated samples were analyzed and evaluated for proximate properties, functional properties, vitamin contents, mineral contents, anti-nutritional contents, and sensory properties; using standard procedures. The result of the numerical optimization gave optimized enriched custard with an overall desirability index of 0.833, based on the set optimization goals and individual quality desirability indices. The optimal formulated enriched custard was obtained from 51.3% bio-fortified cassava, 30.469% pearl millet, 10.0 % soybeans, 5.0% Africa locust beans fruit pulp, 2.0% ginger, 0.5% egg powder, and 0.731 % milk powder. The quality properties of this optimal enriched custard are 6.202 % moisture content, 1.139 % crude fibre, 2.548 % ash content, 20.0 % protein content, 6.668 % lipid, 61.786 % carbohydrate, 0.157 (mL/g) water absorption capacity, 0.121 (mL/g) oil absorption capacity, 19.005 (% vol) foaming capacity, 8.886 (%) foaming stability, 52.474 (deg C) gelation temperature, 5.178 (%) least gelation concentration, 0.758 (g/cubic metre) bulk density, 88.383 (mg/100g) vitamin C, 1.832 (mg/100g) beta carotene, 0.6 (%) tannin, 3.072 (mg/100g) cyanide, 19.032 (%) phytate, 5.313 (mg/100g) oxalate, 16.737 (mg/100g) sodium, 469.150 (mg/100g) potassium, 201.332 (mg/100g) calcium, 167.254 (mg/100g) magnesium, 585.770 (mg/100g) phosphorus, 4.694 (mg/100g) iron, and 6.10 overall acceptability, The result of the study showed that the formulated enriched custard was found to be of higher quality than the traditional custard which are produced from mono-cereals. Improving the nutritional quality of food and tackling nutrient deficiencies, particularly protein energy malnutrition in populations, is possible through the application of numerical optimization technique in the development of new food products.

Keywords: Custard, Breakfast Cereals, Formulation, Characterization, Optimization

1. Introduction

Custard powder is a breakfast cereals meal, primarily, made from corn starch; processed with added flavour and fortified with vitamins and minerals. It is a good source of digestible carbohydrate for a fast energy boost and dietary fibre. However, the prolonged consumption of most traditional custard can lead to protein-energy malnutrition and chronic malnutrition, which is common in most developing countries. There is need the to develop and optimize value added custard that combines nutritional and health benefits with good sensory properties from our locally available food ingredients. Food supplementation is the process of increasing in a food the level of specific nutrients previously identified as inadequate and their intake by the use of another food rich in that specific nutrient. This is usually done to prevent malnutrition in developing countries [1]. The following issues have influenced the current research:

i. High competition for maize which is the major ingredient for the traditional custard
ii. Vitamin and mineral imbalances in the traditional custard powder.
iii. There is no or less fibre in the present marketed custard powder which increases the development of obesity in consumers.
iv. Existing traditional custard powder has relatively low carotenoid.

Thus, the supplementation of corn with high-quality product such as biofortified cassava, pearl millet, soybeans, Africa locust beans fruit pulp, ginger, egg powder, and milk powder, in the production of custard powder could improve its quality and quantity.

Biofortified cassava is a high-quality yellow cassava rich in vitamin A (provitamin A carotenoids), an essential nutrient responsible for the yellow, orange, and red color in many fruits and vegetables. Since one of the most common micronutrient deficiencies worldwide are those of vitamin A, supplementation of corn with biofortified cassava could help in reducing the effect of vitamin A deficiency. Millet is rich in dietary fiber, both soluble and insoluble. The outstanding nutrients in millets include protein, ash, minerals (Ca, Fe, K, Mg and Zn) and B vitamins (B6 and folic acid). Millets are non-glutinous and non-acid forming foods. They have many nutraceuticals and health promoting properties especially the high fibre content [2-4]. Pearl millet has high-grade macro and micronutrients, making it excellent for enriched custard powder. Soybeans is rich in quality protein and digestible energy and are a rich source of various vitamins, minerals, and beneficial plant compounds, such as isoflavones [5, 6]. Soybeans and soy foods may reduce the risk of a range of health problems, including cardiovascular disease, stroke, coronary heart disease (CHD) and some cancers, as well as improving bone health. In Nigeria, African locust bean fruit pulp is underutilized. Bot (2011) discovered that the macro and micronutrient content of pulp fruit was abundant, making it appropriate for custard powder production [7]. The fruit pulp of the African locust bean is sweet to the taste, which indicates the presence of natural sugars and thus a potential energy source. The attractive yellow colour indicates the presence of phyto-nutrients, possibly carotenoids, which are important precursors of retinol (vitamin A). It has a sour taste which indicates the presence of ascorbic acid [8]. Ginger is loaded with antioxidants, compounds that prevent stress and damage to the body's DNA. They help the fight off chronic diseases like high blood pressure, heart disease, diseases of the lungs, and also promote healthy aging [9]. The aim of this study was to formulate, characterize, and optimize enriched custard powder from bio-fortified cassava, pearl millet, soybeans, Africa locust beans fruit pulp, ginger, egg powder, and milk powder; using a seven-component constrained, D-optimal mixture experimental design, with thirty-eight randomized experimental runs.

2. Materials and Methods

2.1. Materials

Bio-fortified cassava (TMS 593), pearl millet, soybeans, Africa locust beans fruit pulp, ginger, egg powder, milk powder, sodium metabisulphite, hydrogen peroxide, and sodium bicarbonate were among the items used for the study. Bio-fortified cassava (TMS 593) was gotten from Moniya market in Ibadan, Oyo state, Nigeria. Soybean, pearl millet, fresh ginger stem, fresh poultry egg, and powder milk were purchased from Kure market, Minna, Niger State. The fresh African locust bean fruit's pulp with the pod was sourced from Zugurma, Niger State's Mashegu Local Government Area.

2.2. Equipment

Gas cookers, a weigh scale, an oven drier, an electric kettle, a plastic container with a lid, a stainless-steel knife, a stainless tray, and a spatula Plastic bucket, hammer milling machine and mixing machine were part of the items used.

2.3. Methods

2.3.1. Custard Powder Ingredients Processing

The fresh bio-fortified cassava (pro-vitamin A cassava) root starch was produced using the method adopted by Akinwale et al. (2017) [10], with little modifications. Millet starch was obtained using the standard wet milling and starch extraction technique reported by Ajanaku et al. (2012) [11], with minor modifications. The soybean flour was prepared as stipulated by Amankwah et al. (2009) [12], with minor modification. The method by Gernah et al. (2007) [8], was employed for locust bean fruit powder processing. The method employed by Akinwale et al. (2017) [10], was used for ginger powder processing. Preparation of whole egg powder was done using the method employed by Ndife et al. (2010) [13].

2.3.2. Formulation Experiments Experimental Design

A seven-component constrained, D-optimal mixture experimental design, from Design-Expert software (version 11, Stat-Ease Inc., Minneapolis, U.S.A), with thirty-eight randomized experimental runs was employed for the formulation of the enriched custard powder. The formulation design constraints were: bio-fortified cassava (10% - 70%), pearl millet (10% - 70%), soybeans (10% - 60%), Africa locust beans fruit pulp (5% - 30%), ginger (1% - 2%), egg powder (0.5% - 1.5%), and milk powder (0.5% - 1%). The design matrix for the formulation experiment was presented in Table 1.

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

Run	x_1	x_2	x_3	x_4	x_5	x_6	x_7
	%	%	%	%	%	%	%
1	10	70	12	5	1	1	1
2	28.5	10	28.5	30	1	1.5	0.5
3	70	10.75	10	5.75	1	1.5	1
4	10	10	47.5	30	1.5	0.5	0.5
5	10	70	12	5	1	1	1
6	10	21	60	5	1.5	1.5	1
7	22.4688	19.5938	42.9271	11.6354	1.75	0.75	0.875
8	43.7188	19.5938	17.9271	15.3854	1.75	0.75	0.875
9	19.5938	49.5938	18.6771	8.76042	1.5	1.25	0.625
10	70	10	11.5	5	2	0.5	1
11	70	10	11	5	2	1.5	0.5
12	47.5	10	10	30	1	0.5	1
13	10	10	47	30	1	1	1
14	10	10	45.75	30	2	1.5	0.75
15	70	10	11	5	2	1.5	0.5
16	15.75	10	60	10.75	2	0.5	1
17	10	29	29	30	1	0.5	0.5
18	10	22.5	60	5	1	0.5	1
19	10	70	10.25	5.25	2	1.5	1
20	45.5	10	10	30	2	1.5	1
21	10	46.5	10	30	2	0.5	1
22	29.0625	29.0625	25.7292	12.3958	2	1	0.75
23	11.5	70	10	5	1.5	1.5	0.5
24	70	10.75	10	5.75	1	1.5	1
25	10	46.5	10	30	1	1.5	1
26	10	46.5	10	30	2	1	0.5
27	10	46.5	10	30	1	1.5	1
28	29	29	10	30	1	0.5	0.5
29	10	70	11.75	5	2	0.5	0.75
30	10	46	36	5	2	0.5	0.5
31	70	10	13	5	1	0.5	0.5
32	10	46.5	10	30	2	0.5	1
33	46.25	10	36.25	5	1	0.5	1
34	41.5	41.5	10	5	1	0.5	0.5
35	58.5	10	10	18.5	2	0.5	0.5
36	10	10	60	16.5	1.5	1.5	0.5
37	22.5	10	60	5	1	1	0.5
38	10	59	10	19	1	0.5	0.5

$x_1 = Bio-fortified\ Cassava$, $x_2 = Pearl\ Millet$, $x_3 = Soybeans$, $x_4 = Africa\ Locust\ Beans\ Fruit\ Pulp$, $x_5 = Ginger$, $x_6 = Egg\ Powder$, and $x_7 = Milk\ Powder$

2.3.3. Quality Analyses and Sensory Evaluations

The formulated samples were analyzed and evaluated for proximate properties, functional properties, vitamin contents, mineral contents, anti-nutritional contents, and sensory properties; using standard procedures and some other procedures, with little modifications [14-16, 10]. The responses were moisture (%), crude protein (%), crude fibre (%), lipid (%), ash content (%), carbohydrate contents (%), water absorption capacity (ml/g), oil absorption capacity (ml/g), foaming capacity (%), foaming stability (%), bulk density (g/cm3) gelation temperature (oC), least gelation concentrate (%), tannin (mg/g), cyanide (mg/g), phytate (%), oxalate (%), vitamin C (mg/100g), vitamin A (mg/100g), sodium (mg/100g), calcium (mg/100g), potassium (mg/100g), magnesium (mg/100g), phosphorous (mg/100g), iron (mg/100g), colour, taste, aroma, texture and overall acceptability.

2.4. Statistical Analysis of Experimental Data

The experimental data were analyzed and appropriate Scheffe canonical models relating the quality indices with the mixture component proportions were fitted to the mean quality and sensory properties (experimental data). The statistical significance of the terms in the Scheffe canonical regression 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 3-D response surface as well as the contour plots for the proximate properties using the DESIGN EXPERT 13.0.0 statistical software package. Optimal production conditions were obtained, based on set optimization goals and individual quality desirability indices; using numerical optimization, via desirability function technique [17-20].

3. Experimental Data and Results of Statistical Analyses of Experimental

Data

3.1. Experimental Data

The results of quality analyses and sensory evaluations of the formulated custard were presented in Tables 2 - 6. The summary statistics of the regression analyses (indicating only the significant terms) of the enriched custard's proximate properties, functional properties, vitamin contents, mineral contents, anti-nutritional contents, and sensory properties were presented in Table 7.

Table 2. *Proximate Properties of Custard Powder.*

Run	y_{mc}	y_{cf}	y_{ac}	y_{pc}	y_{lip}	y_{cho}
	%	%	%	%	%	%
1	5.77	0.65	2.09	14.1	6.12	71.27
2	4.88	0.69	3.68	19.2	5.25	68.38
3	4.91	0.55	1.65	12.2	5.07	75.62
4	5.66	1.16	3.05	18.88	8.4	62.85
5	5.84	0.62	3.58	16.36	7.82	65.78
6	5.02	0.8	3.45	17.5	8.8	64.43
7	6.27	0.74	2.79	15.96	7.52	66.38
8	5.3	1.1	3.83	17.26	5.88	66.63
9	7.22	0.86	1.95	15.28	8.22	66.47
10	7.43	0.81	1.49	15.98	7.5	66.79
11	5.87	1.25	2.74	22.2	9.22	58.72
12	6.16	1.28	3.88	21.4	6.1	61.18
13	5.31	1.1	5.19	19.1	7.87	61.43
14	7.16	0.66	1	15.58	6.25	68.46
15	6.33	0.75	3.74	16.26	9.2	63.72
16	5.94	0.79	2.55	16.18	7.82	66.72
17	6.41	0.48	3.19	14.68	6.65	68.59
18	6.63	0.55	3.49	14.7	8.4	66.63
19	8.47	1.13	4.55	17.75	6.12	61.98
20	8.04	1.05	1.34	16.98	8.55	64.08
21	6.46	0.94	4.68	20.4	4.37	63.15
22	6.98	0.54	1.35	14.6	8.02	68.51
23	7.22	0.98	1.16	16.84	8.51	65.29
24	5.44	0.42	1.53	13.52	9.27	69.82
25	6.12	0.81	3.02	16.86	4.32	68.87
26	6.85	0.74	2.93	16.2	6.1	65.18
27	6.23	1.12	2.49	20.54	6.6	63.02
28	6.59	0.76	3.02	16.04	6.74	66.85
29	4.98	0.52	2.08	14.85	5.55	72.02
30	5.65	0.44	1.54	13.22	6.25	72.9
31	7.15	0.48	1.44	12.78	4.12	74.07
32	5.74	0.62	1.71	14.03	5.08	73.06
33	5.92	1.22	3.52	21.67	7.26	60.41
34	7.27	1.31	3.31	21.25	6.9	59.96
35	5.55	0.62	1.31	13.22	4.44	74.82
36	6.85	0.74	1.87	15	6.1	69.44
37	6.52	1.08	3.18	20.12	8.52	60.54
38	7.05	0.68	1.57	14.45	4.36	71.89

y_{mc} = *Moisture Content*, y_{cf} = *Crude fibre*, y_{ac} = *Ash content*, y_{pc} = *Protein*, y_{lip} = *Lipid*, y_{cho} = *Carbohydrate*

Table 3. *Functional and Operational Parameter of Custard Powder.*

Run	y_{wac}	y_{oac}	y_{fc}	y_{fs}	y_{gt}	y_{lgc}	y_{bd}
	mL/g	mL/g	% vol	%	deg C	%	g/cubic metre
1	0.18	0.1	13.72	6.8	55	6	0.64
2	0.2	0.12	13.72	7.75	48	6	0.61
3	0.18	0.1	9.8	5.86	45	2	0.63
4	0.16	0.14	17.64	9.74	52	4	0.69
5	0.14	0.14	27.45	15.6	55	6	0.71
6	0.14	0.14	17.64	11.22	45	4	0.69
7	0.16	0.14	7.84	4.28	48	4	0.71
8	0.16	0.14	19.6	13.2	50	4	0.69
9	0.12	0.14	7.84	2.85	45	8	0.76
10	0.2	0.08	11.76	4.8	47	4	0.78
11	0.18	0.16	17.64	8.4	49	6	0.83
12	0.16	0.14	21.56	12	52	6	0.66

Run	y_{wac} mL/g	y_{oac} mL/g	y_{fc} % vol	y_{fs} %	y_{gt} deg C	y_{lgc} %	y_{bd} g/cubic metre
13	0.2	0.1	21.56	10.86	58	6	0.59
14	0.14	0.12	15.68	8.22	55	4	0.71
15	0.16	0.1	15.68	8.6	60	6	0.68
16	0.14	0.16	17.64	9.12	58	4	0.71
17	0.18	0.14	11.76	5.2	55	8	0.66
18	0.2	0.16	17.64	9	60	6	0.68
19	0.2	0.12	7.84	2.6	58	6	0.66
20	0.16	0.1	13.72	5.65	55	6	0.74
21	0.22	0.1	27.45	16.24	55	4	0.64
22	0.14	0.14	15.68	8.9	58	8	0.83
23	0.14	0.08	17.64	8.6	54	6	0.64
24	0.12	0.08	7.84	3.55	55	4	0.64
25	0.16	0.1	15.68	7.34	60	8	0.71
26	0.14	0.1	17.64	8.48	52	4	0.69
27	0.16	0.1	27.45	18	48	6	0.66
28	0.16	0.1	11.76	7.15	45	4	0.71
29	0.12	0.14	25.49	15.15	60	6	0.76
30	0.14	0.12	23.52	12.9	56	6	0.76
31	0.14	0.08	21.56	14.76	58	6	0.68
32	0.16	0.12	19.6	10.4	52	8	0.68
33	0.14	0.12	13.72	6.68	55	4	0.69
34	0.16	0.12	9.8	5.74	48	4	0.68
35	0.14	0.12	25.49	18.3	60	6	0.8
36	0.12	0.1	7.84	4.65	44	4	0.71
37	0.1	0.14	15.68	6.86	44	6	0.71
38	0.16	0.12	5.88	2.2	40	8	0.81

y_{wac} = *Water Absorption Capacity*, y_{oac} = *Oil Absorption Capacity*, y_{fc} = *Foaming Capacity* y_{bd} = *Bulk density*
y_{fs} = *Foaming Stability*, y_{gt} = *Gelation Temperature*, y_{lgc} = *Least Gelation Concentration*

Table 4. *Vitamin Contents and Anti-nutritional Properties of Custard Powder.*

Run	y_{vc} mg/100g	y_{bc} mg/100g	y_{ta} %	y_{cy} mg/100g	y_{phy} mg/100g	y_{oxa} mg/100g
1	53.6	0.64	1.82	1.23	18.2	8.62
2	38.4	0.4	1.58	1.84	18.72	8.48
3	40.8	0.42	1.7	3.3	18.3	8.75
4	95.36	1.49	1.65	2.25	16.2	5.28
5	62.5	0.8	1.62	1.82	16.84	5.46
6	84.8	1.13	1.64	1.88	16.36	6.62
7	81.6	0.98	1.6	2.2	18.74	4.4
8	24.3	0.33	1.54	2.54	16.88	6.82
9	85.7	1.42	1.33	3.66	18.74	6.74
10	116.1	2.28	1.2	2.2	22	5.36
11	84	0.94	1.15	1.8	18.62	4.85
12	22.6	0.12	1.28	2.26	15.4	6.3
13	24	0.14	1.04	2.4	20.12	5.15
14	28.9	0.21	1.16	1.85	16.86	3.78
15	73.4	0.27	1.35	3.3	22.3	5.2
16	68	0.33	0.84	2.86	18.55	6.35
17	80.1	0.86	1.2	4.4	16.84	10.2
18	36	0.14	0.88	4.26	16.65	8.42
19	43	0.21	0.82	4.54	20.2	6.38
20	66.3	0.5	1.16	3.62	24.1	6.92
21	84	0.47	0.65	3.1	22.32	8.22
22	69.7	0.61	0.72	2.88	19.54	6.4
23	104	0.59	1.2	2.55	16.36	5.96
24	76.6	0.37	1.28	3.72	16.85	8.36
25	68.4	0.5	1.4	4.55	21.2	12.1
26	54.6	0.48	1.32	4	18.65	8.25
27	65.3	0.55	1.1	4.24	22.4	11.08
28	74.5	0.64	0.85	4.9	20.12	10.45
29	62.5	0.35	1.08	3.25	20.86	7.2
30	84.8	0.48	1.2	4.18	16.37	9.45
31	80.6	0.51	1.28	3.94	18.6	8.69

Run	y_{vc} mg/100g	y_{bc} mg/100g	y_{ta} %	y_{cy} mg/100g	y_{phy} mg/100g	y_{oxa} mg/100g
32	78	0.47	1.35	3.98	15.95	8.84
33	80.4	0.41	1.12	4.22	17.28	10.42
34	84.5	1.41	0.94	2.75	20.11	6.2
35	112.7	1.07	0.86	3.3	18.35	8.35
36	89.5	0.51	1.12	2.62	18.9	6.84
37	42.3	0.21	0.75	3.15	20.43	8.08
38	88.7	0.72	0.96	3.43	16.72	10.12

y_{ta} = *Tannin*, y_{cy} = *Cyanide*, y_{phy} = *Phytate*, y_{oxa} = *Oxalate*, y_{vc} = *Vitamin C*, y_{bc} = *Beta Carotene*

Table 5. *Mineral Composition of Custard Powder.*

Run	y_{sod} mg/100g	y_{pot} mg/100g	y_{cal} mg/100g	y_{mag} mg/100g	y_{pho} mg/100g	y_{ir} mg/100g
1	6.88	234	84	66	282	2.35
2	7.42	251	88	54	256	2.86
3	6.95	222	72	58	258	2.74
4	7.83	285	88	64	262	2.82
5	10.97	317	68	52	234	2.42
6	8.35	288	96	76	268	2.9
7	12.15	342	122	88	315	3.86
8	13.66	353	135	104	410	3.94
9	13.94	398	142	112	438	5.36
10	16.2	444	158	124	452	5.44
11	16.65	456	165	128	466	5.73
12	18.34	472	182	140	478	5.86
13	18.65	488	144	118	422	5.22
14	15.22	426	186	152	460	5.64
15	13.12	355	164	158	482	5.92
16	10.65	322	118	84	267	3.88
17	14.48	358	184	146	486	8.2
18	16.35	451	166	122	448	5.24
19	14.8	346	142	135	455	5.48
20	10.1	320	106	86	268	2.34
21	16.65	472	184	148	445	5.55
22	9.2	288	102	74	277	3.08
23	16.84	465	155	82	224	2.87
24	16.3	455	170	136	435	5.34
25	11.15	351	168	142	470	6.16
26	11.33	354	144	118	440	5.43
27	15.42	366	168	122	456	5.82
28	12.3	358	172	138	468	5.94
29	10.38	313	78	55	240	3.32
30	10.76	322	84	62	257	3.44
31	10.48	343	173	144	474	5.77
32	16.14	438	154	88	275	3.87
33	16.72	445	180	145	488	6.22
34	11.25	361	176	140	475	6.18
35	10.16	333	138	133	448	5.96
36	11.34	347	145	115	426	5.15
37	16.8	425	162	131	435	5.46
38	7.38	228	82	56	232	3.45

y_{sod} = *Sodium*, y_{pot} = *Potassium*, y_{cal} = *Calcium*, y_{mag} = *Magnesium*, y_{pho} = *Phosphorus*, y_{ir} = *Iron*

Table 6. *Sensory Characteristics of Custard Powder.*

Run	y_{col}	y_{tast}	y_{tex}	y_{arom}	y_{oa}
1	7.4	7.4	7.8	6	6.6
2	5.4	4.6	4.2	4.7	5.1
3	5.8	5.1	5.5	4.9	6
4	4.5	4.3	5.3	4.1	4.6
5	5.6	5.1	6.3	5.3	5.7
6	6.2	5.3	4.9	4.7	5.6
7	6.1	5.8	5.3	5.2	6.1
8	5.5	5.2	4.1	4.5	5
9	6.7	5.7	6	5.9	5.6

Run	y_{col}	y_{tast}	y_{tex}	y_{arom}	y_{oa}
10	5.1	4.9	5	4.9	5.4
11	5.5	5.4	4.7	4.9	5.7
12	5	4.8	5.2	4.3	5.3
13	6	5.5	5	4.6	5.7
14	5.9	5.7	4.5	10.3	5.2
15	6.3	5.8	6.3	5.5	6
16	6.1	6.4	6.1	6.1	6.4
17	6.8	6.5	5.9	6.3	6.8
18	5.9	6.2	5.8	4.8	6.1
19	6	5.5	6.3	6.2	6.7
20	5	6.2	5.2	5	5.9
21	5.4	5.8	5.9	5.5	6.2
22	5.6	6.5	7	4.6	6.1
23	6.1	5.8	4.6	5.2	5.7
24	6.9	6.7	6.8	6.1	7.8
25	7.2	7.1	6.4	5.7	6.3
26	6.3	6.3	6.6	6.7	6.1
27	6.2	5.9	5.6	6.3	6.1
28	6	5.1	5.4	6.4	5.9
29	6.2	6.1	5.6	7.1	6.9
30	6.4	6.4	5.1	6.7	6.6
31	6.2	6.4	5.7	5.8	6.4
32	5.4	5.6	5.8	6.3	6.5
33	6.3	5.7	6.5	6.3	6.6
34	5.8	5.4	6.2	5.4	6.4
35	5.1	6.5	6.2	6.7	6.9
36	5.7	6.5	6.4	6.6	7.3
37	6.2	6.1	6.6	5.2	5.8
38	6.7	6.4	7.6	7.4	6.7

$y_{col} = Colour$, $y_{tast} = Taste$, $y_{tex} = Texture$, $y_{arom} = Aroma$, $y_{oa} = Overall\ Acceptability$

3.2. Results of Statistical Analyses of Experimental Data

The summary statistics of the regression analyses (indicating only the significant terms) of the enriched custard's proximate properties, functional properties, vitamin contents, mineral contents, anti-nutritional contents, and sensory properties were presented in Table 7.

Table 7. *Summary Statistics of the Regression Analyses of enriched custard's proximate properties, functional properties, vitamin contents, mineral contents, anti-nutritional contents, and sensory properties.*

Response	Sources	F-value	p-value	R^2	Adj R^2	Pre R^2	C.V. (%)	Adeq Precision
y_{mc}	Model	4.05	0.0124	0.9162	0.6899	-2.4740	7.67	8.5040
	L/Mixture	1.94	0.1688					
y_{cf}	Model	1.82	0.1615	0.8306	0.3734	-8.1387	25.22	4.8398
	L/Mixture	0.4272	0.8450					
y_{ac}	Model	1.21	0.3918	0.7659	0.1337	-9.0900	38.26	5.5103
	L/Mixture	1.08	0.4334					
y_{pc}	Model	1.04	0.5033	0.7373	0.0280	-9.8104	15.99	4.1257
	L/Mixture	0.4486	0.8306					
y_{lip}	Model	2.51	0.0425	0.3272	0.1969	-0.0429	20.29	5.8439
	L/Mixture	2.51	0.0425					
y_{cho}	Model	1.55	0.2379	0.8070	0.2858	-4.4210	5.60	4.7981
	L/Mixture	0.4940	0.7994					
	x_1x_2	6.93	0.0250					
y_{wac}	Model	1.29	0.2916	0.1995	0.0446	-0.2532	16.88	4.3759
	L/Mixture	1.29	0.2916					
y_{oac}	Model	2.18	0.072	0.2967	0.1606	-0.0963	17.89	5.4316
	L/Mixture	2.18	0.072					
y_{fc}	Model	1.05	0.4926	0.7401	0.0383	-6.4095	36.49	4.0178
	L/Mixture	0.9877	0.4819					
y_{fs}	Model	Nil	Nil	0.0000	0.0000	-0.0548	47.91	NA
	L/Mixture	Nil	Nil					
y_{gt}	Model	Nil	Nil	0.0000	0.0000	-0.0548	10.64	NA
	L/Mixture	Nil	Nil					
y_{lgc}	Model	1.42	0.2398	0.2152	0.0633	-0.1397	26.87	3.9371
	L/Mixture	1.42	0.2398					

Response	Sources	F-value	p-value	R^2	Adj R^2	Pre R^2	C.V. (%)	Adeq Precision
y_{bd}	Model	2.88	0.0238	0.3581	0.2339	0.0444	7.23	5.9888
	L/Mixture	2.88	0.0238					
y_{vc}	Model	1.82	0.1268	0.2609	0.1178	-0.1157	33.03	4.7647
	L/Mixture	1.82	0.1268					
y_{bc}	Model	1.78	0.1693	0.8280	0.3637	-5.0702	56.90	7.2938
	L/Mixture	1.20	0.3817					
y_{ta}	Model	1.54	0.2402	0.8063	0.2833	-6.8573	21.02	4.7843
	L/Mixture	1.10	0.4274					
	x_1x_2	14.83	0.0032					
	x_2x_2	14.77	0.0032					
	x_3x_2	14.92	0.0031					
	x_4x_2	14.92	0.0031					
y_{cy}	Model	1.55	0.2375	0.8071	0.2863	-13.9812	25.76	4.7286
	L/Mixture	0.8836	0.5404					
y_{phy}	Model	1.11	0.3779	0.1771	0.0179	-0.2757	11.39	4.4596
	L/Mixture	1.11	0.3779					
y_{oxa}	Model	2.94	0.0386	0.8880	0.5858	-6.3604	17.09	6.9893
	L/Mixture	5.21	0.0112					
y_{sod}	Model	1.01	0.5222	0.7324	0.0098	-7.3843	27.10	3.7185
	L/Mixture	0.4566	0.8252					
y_{pot}	Model	1.04	0.5046	0.7370	0.0268	-5.6279	19.97	3.9642
	L/Mixture	0.5093	0.7887					
y_{cal}	Model	1.37	0.3084	0.7875	0.2139	-6.5592	24.16	4.1109
	L/Mixture	1.07	0.4386					
y_{mag}	Model	1.02	0.5161	0.7340	0.0157	-9.1546	31.32	3.4632
	L/Mixture	1.05	0.4505					
y_{pho}	Model	1.17	0.4190	0.7589	0.1080	-10.336	24.56	3.3502
	L/Mixture	1.25	0.3575					
y_{ir}	Model	1.06	0.4046	0.1708	0.0103	-0.2577	30.91	4.1726
	L/Mixture	1.06	0.4046					
y_{oa}	Model	Nil	Nil	0.0000	0.0000	-0.0548	10.71	NA
	L/Mixture	Nil	Nil					

P-values less than 0.05 indicate models and model terms that are significant. A negative Predicted R² 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 responses or quality parameters of the formulated enriched powdered custard are presented as equations 1 - 26. The contour and 3-D surface plots of the quality parameters of the formulated enriched powdered custard are presented in Figures 1 - 26.

$$\left.\begin{aligned}y_{mc} =\; & 7.37x_1 + 6.57x_2 + 8.86x_3 - 2.48x_4 + 8921.64x_5 - 1508.23x_6 + 3490.99x_7 \\ & + 1.49x_1x_2 - 6.20x_1x_3 + 10.21x_1x_4 - 9175.12x_1x_5 + 1400.80x_1x_6 - 3467.05x_1x_7 \\ & + 0.7856x_2x_3 + 14.12x_2x_4 - 9176.41x_2x_5 + 1596.32x_2x_6 - 3649.66x_2x_7 \\ & + 10.83x_3x_4 - 9197.62x_3x_5 + 1405.23x_3x_6 - 3777.02x_3x_7 - 9081.48x_4x_5 \\ & + 1605.37x_4x_6 - 3467.80x_4x_7 + 3493.47x_5x_6 - 324.21x_5x_7 - 5742.91x_6x_7\end{aligned}\right\} \quad (1)$$

$$\left.\begin{aligned}y_{cf} =\; & 0.4183x_1 + 0.7338x_2 + 1.04x_3 + 3.33x_4 - 4510.59x_5 + 115.13x_6 + 18833.87x_7 + 2.71x_1x_2 + 1.96x_1x_3 \\ & - 138.82x_1x_6 - 18955.34x_1x_7 - 2.82x_2x_3 - 4.42x_2x_4 - 3.80x_1x_4 + 4611.79x_1x_5 + 4604.44x_2x_5 \\ & - 141.25x_2x_6 - 18967.66x_2x_7 - 4.37x_3x_4 + 4589.26x_3x_5 - 143.89x_3x_6 - 18987.01x_3x_7 \\ & + 4543.08x_4x_5 - 139.82x_4x_6 - 18869.69x_4x_7 + 6219.77x_5x_6 - 16954.72x_5x_7 - 17790.08x_6x_7\end{aligned}\right\} \quad (2)$$

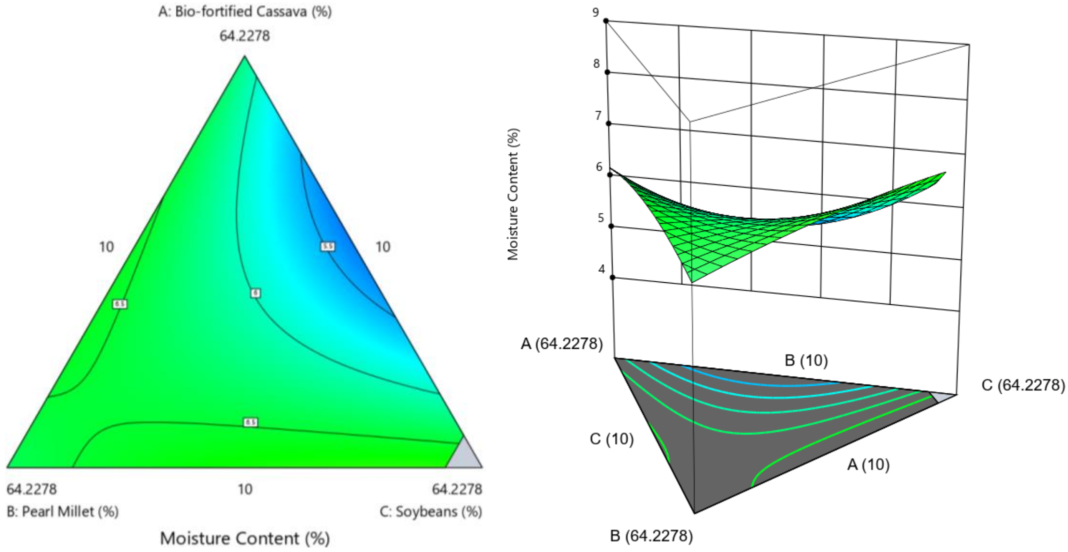

Figure 1. Moisture Content Contour and 3-D Surface Plots.

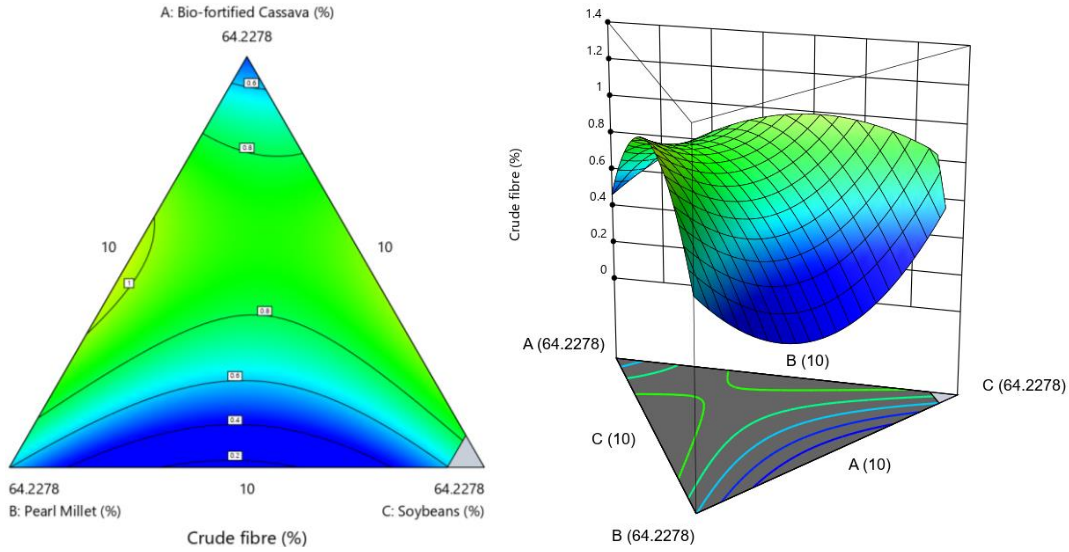

Figure 2. Crude fibre Contour and 3-D Surface Plots.

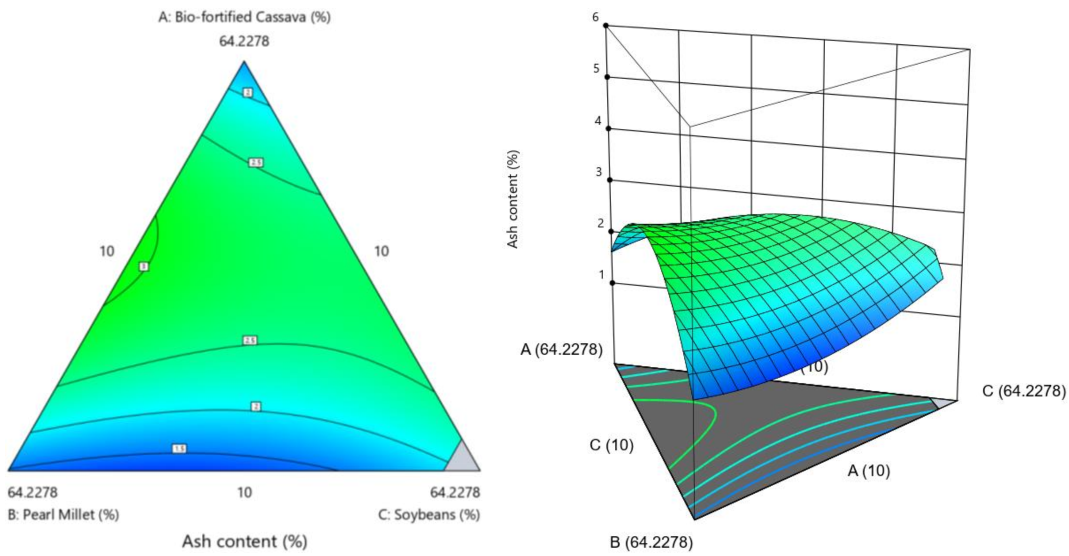

Figure 3. Ash content Contour and 3-D Surface Plots.

$$\left.\begin{aligned} y_{ac} = {} & 1.51x_1 + 0.3416x_2 + 1.74x_3 + 10.32x_4 - 10666.88x_5 - 10939.87x_6 + 99211.84x_7 \\ & + 8.23x_1x_2 + 4.45x_1x_3 - 7.17x_1x_4 + 10855.81x_1x_5 + 11118.97x_1x_6 - 99968.20x_1x_7 \\ & - 2.53x_2x_3 - 7.02x_2x_4 + 10994.73x_2x_5 + 10998.54x_2x_6 - 99624.77x_2x_7 \\ & - 5.75x_3x_4 + 10788.88x_3x_5 + 11078.82x_3x_6 - 99714.26x_3x_7 + 10507.12x_4x_5 \\ & + 11061.79x_4x_6 - 99987.18x_4x_7 + 27304.25x_5x_6 - 93679.88x_5x_7 - 91369.70x_6x_7 \end{aligned}\right\} \quad (3)$$

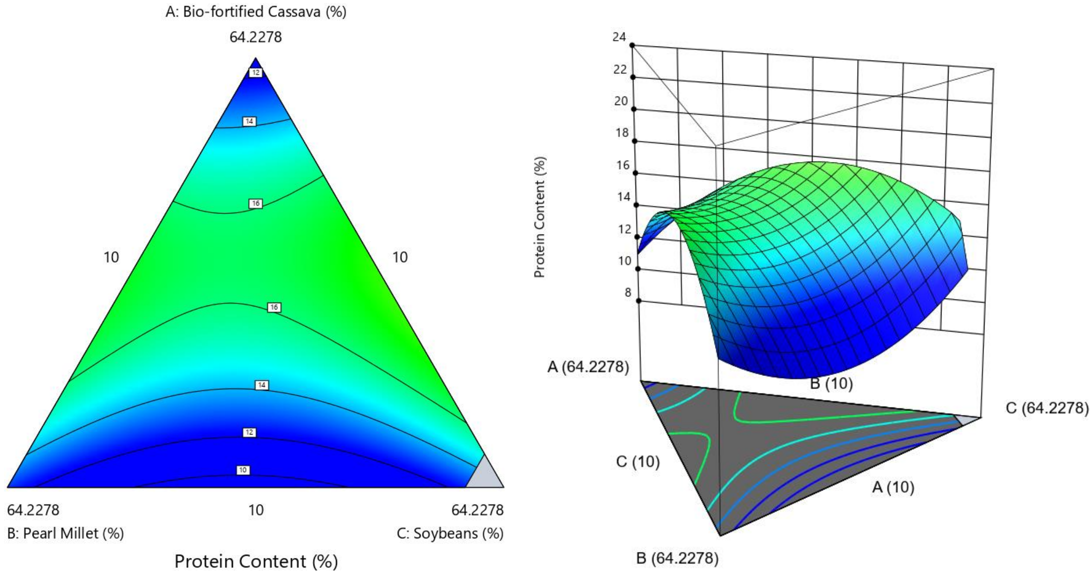

Figure 4. *Protein Contour and 3-D Surface Plots.*

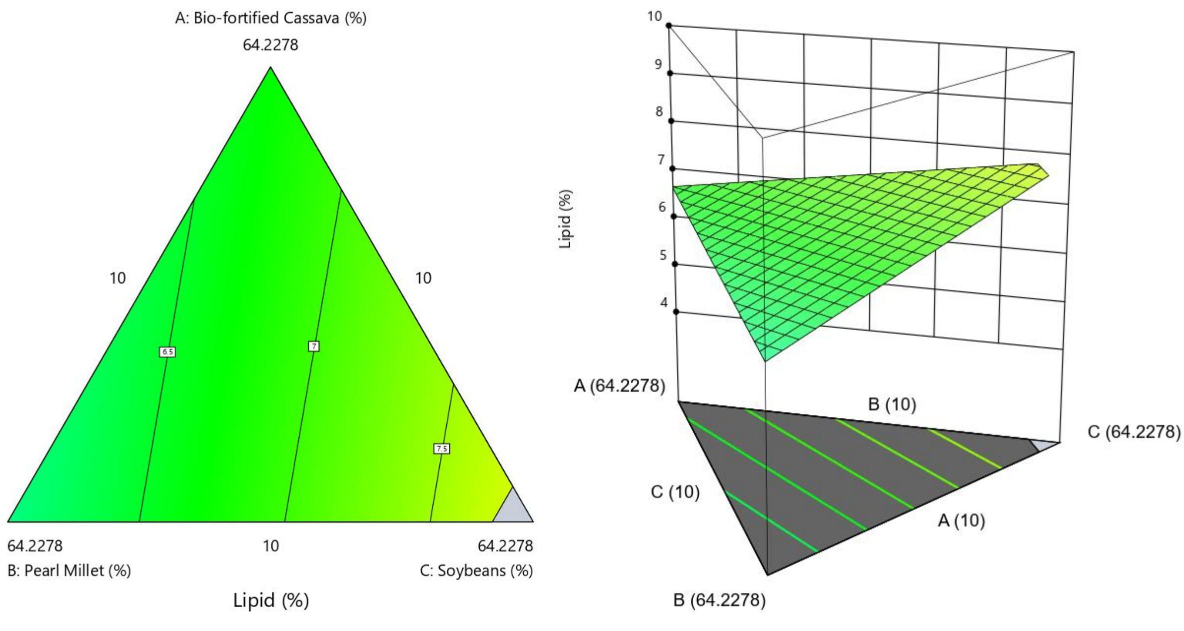

Figure 5. *Lipid Contour and 3-D Surface Plots.*

$$\left.\begin{aligned} y_{pc} = {} & 11.74x_1 + 15.34x_2 + 16.43x_3 + 66.77x_4 - 26253.81x_5 + 7723.27x_6 + 1.509E+05x_7 \\ & + 26.76x_1x_2 + 28.95x_1x_3 - 74.49x_1x_4 + 26994.94x_1x_5 - 7868.10x_1x_6 - 1.518E+05x_1x_7 \\ & - 21.19x_2x_3 - 79.20x_2x_4 + 26888.39x_2x_5 - 8019.09x_2x_6 - 1.517E+05x_2x_7 \\ & - 81.00x_3x_4 + 26824.05x_3x_5 - 7823.22x_3x_6 - 1.519E+05x_3x_7 + 26189.69x_4x_5 \\ & - 8025.19x_4x_6 - 1.512E+05x_4x_7 + 29239.79x_5x_6 - 1.510E+05x_5x_7 - 1.629E+05x_6x_7 \end{aligned}\right\} \quad (4)$$

$$y_{lipid} = 6.64x_1 + 5.90x_2 + 8.00x_3 + 3.77x_4 + 21.09x_5 + 67.30x_6 + 17.13x_7 \Big\} \quad (5)$$

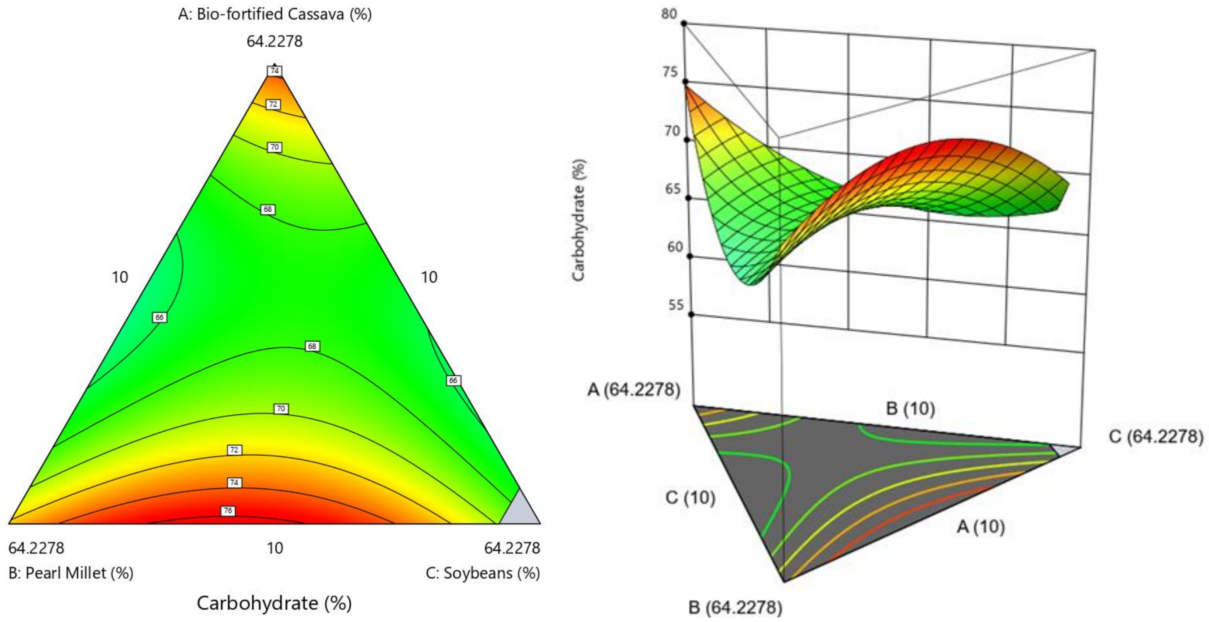

Figure 6. Carbohydrate Contour and 3-D Surface Plots.

$$\left.\begin{aligned} y_{cho} = {} & 75.18x_1 + 70.17x_2 + 61.65x_3 - 20.57x_4 + 42848.73x_5 + 25200.37x_6 - 2.366E+05x_7 \\ & -45.77x_1x_2 - 25.92x_1x_3 + 135.19x_1x_4 - 43886.11x_1x_5 - 25378.99x_1x_6 + 2.379E+055x_1x_7 \\ & +34.61x_2x_3 + 134.99x_2x_4 - 43684.72x_2x_5 - 25274.83x_2x_6 + 2.382E+05x_2x_7 \\ & +146.31x_3x_4 - 43520.33x_3x_5 - 25182.28x_3x_6 + 2.383E+05x_3x_7 - 42515.88x_4x_5 \\ & -24979.42x_4x_6 + 2.375E+05x_4x_7 - 1.052E+05x_5x_6 + 2.257E+05x_5x_7 + 2.131E+05x_6x_7 \end{aligned}\right\} \quad (6)$$

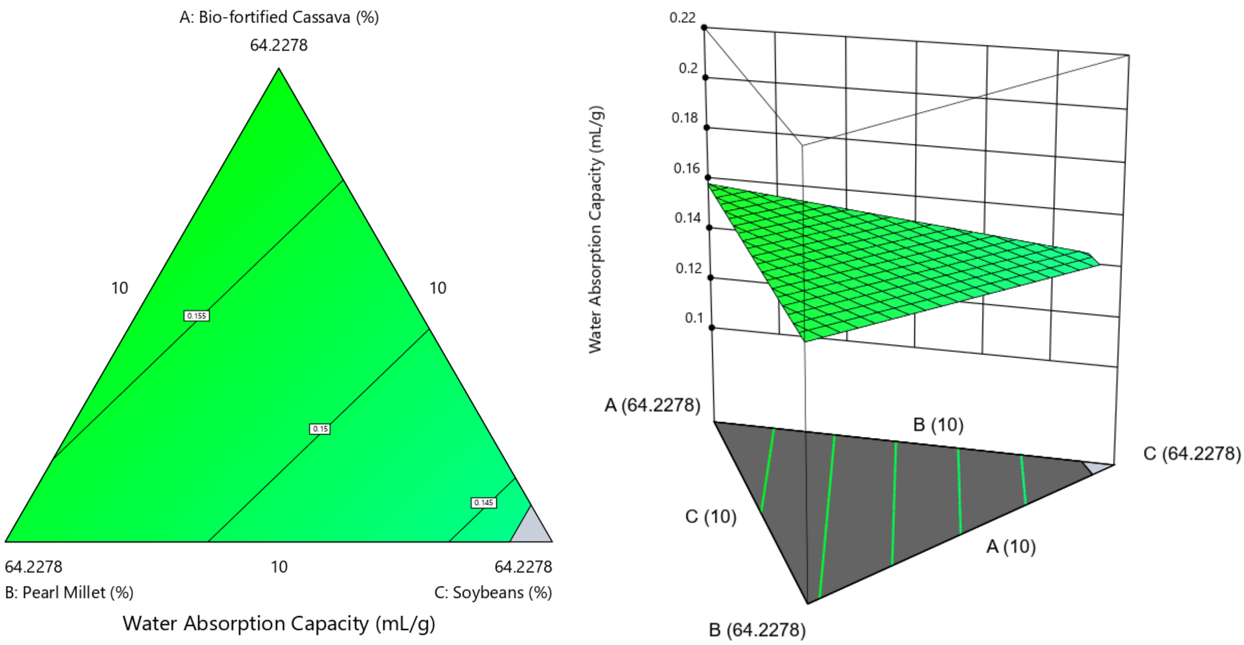

Figure 7. Water Absorption Capacity Contour and 3-D Surface Plots.

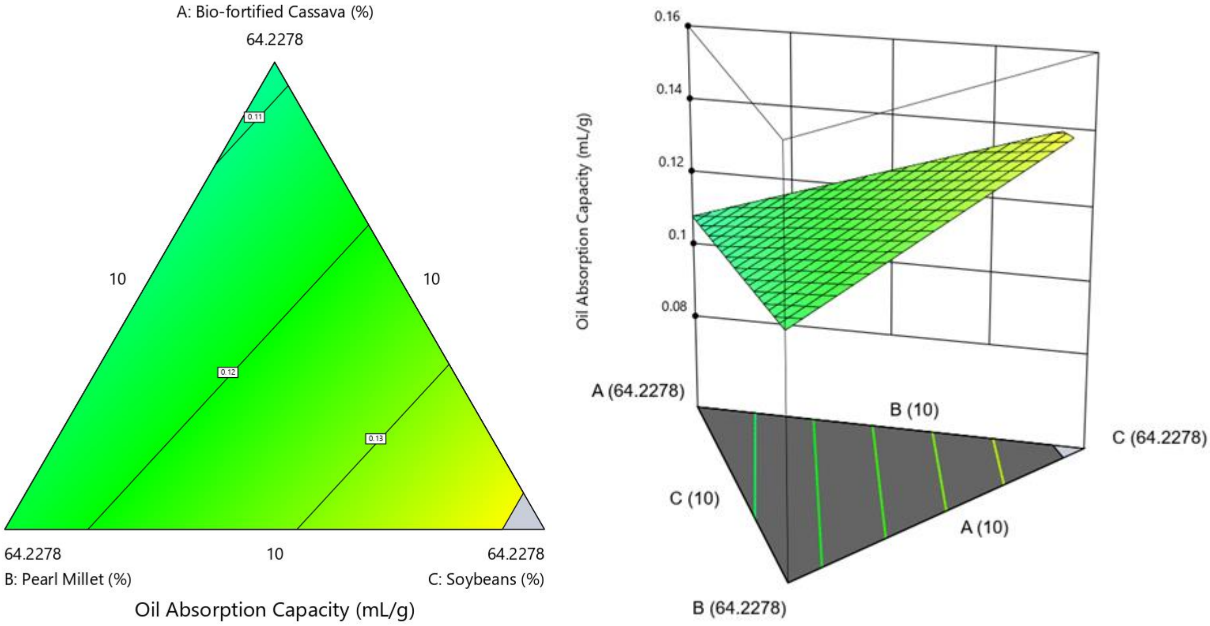

Figure 8. *Oil Absorption Capacity Contour and 3-D Surface Plot.*

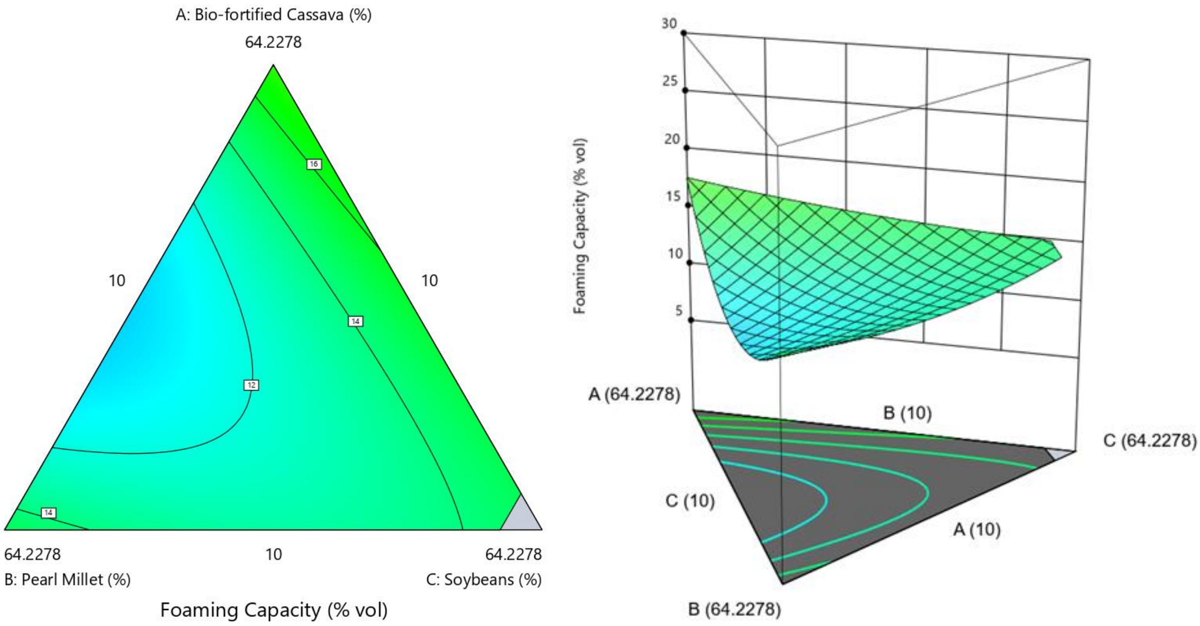

Figure 9. *Foaming Capacity Contour Plot 3-D Surface Plots.*

$$y_{wac} = 0.1508x_1 + 0.1455x_2 + 0.1323x_3 + 0.1859x_4 + 0.0948x_5 - 0.2445x_6 + 2.44x_7 \Big\} \tag{7}$$

$$y_{oac} = 0.1107x_1 + 0.1197x_2 + 0.1497x_3 + 0.1024x_4 + 0.5698x_5 - 0.6567x_6 + 0.1897x_7 \Big\} \tag{8}$$

$$\left.\begin{array}{l} y_{fc} = 20.39x_1 + 16.32x_2 + 14.42x_3 + 101.89x_4 - 357.31x_5 - 4820.92x_6 - 1.882E+05x_7 \\ \quad -31.12x_1x_2 - 2.83x_1x_3 - 135.81x_1x_4 + 1087.53x_1x_5 + 4751.17x_1x_6 + 1.885E+05x_1x_7 \\ \quad -8.70x_2x_3 - 164.62x_2x_4 + 957.80x_2x_5 + 5012.02x_2x_6 + 1.900E+05x_2x_7 \\ \quad -162.16x_3x_4 + 1054.40x_3x_5 + 5067.23x_3x_6 + 1.903E+05x_3x_7 + 1350.03x_4x_5 \\ \quad +4573.67x_4x_6 + 1.921E+05x_4x_7 - 41987.13x_5x_6 + 1.200E+05x_5x_7 + 2.058E+05x_6x_7 \end{array}\right\} \tag{9}$$

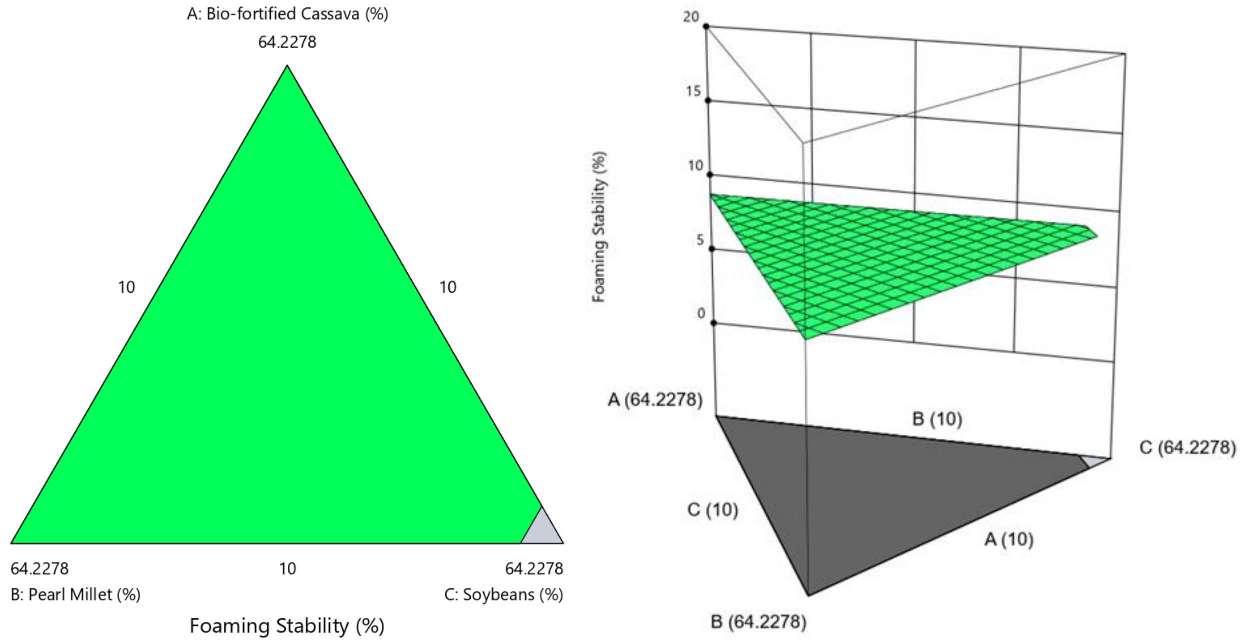

Figure 10. *Foaming Stability Contour and 3-D Surface Plots.*

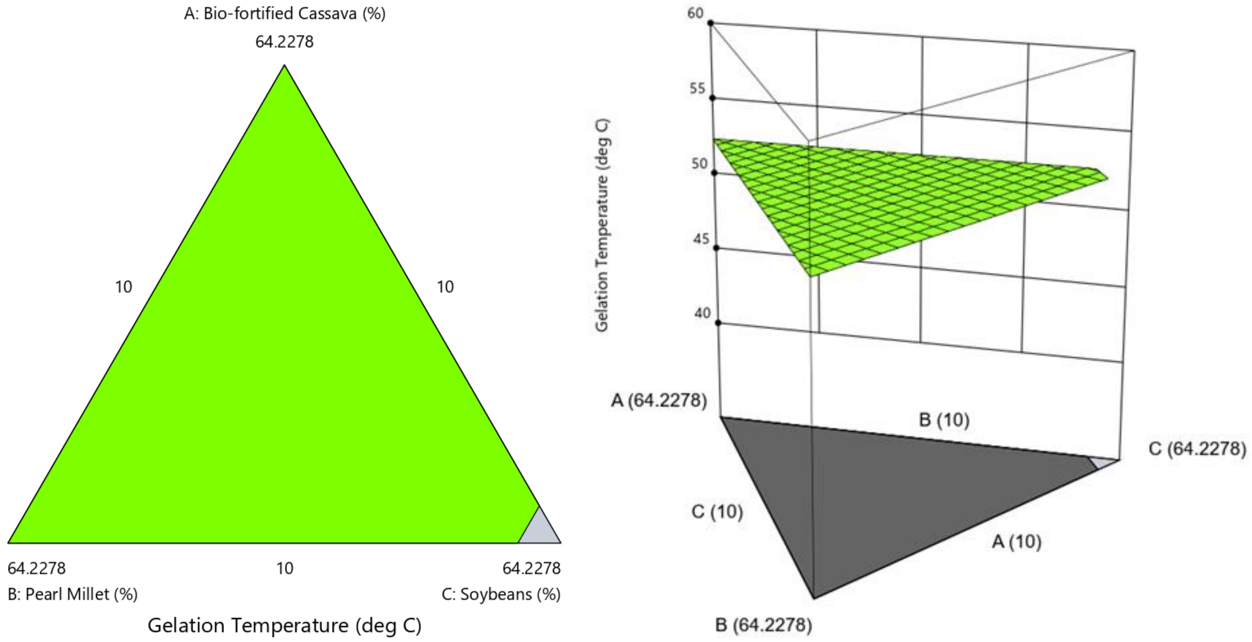

Figure 11. *Gelation Temperature Contour and 3-D Surface Plots.*

$$y_{fs} = 8.89x_0 \quad \} \tag{10}$$

$$y_{gt} = 52.47x_0 \quad \} \tag{11}$$

$$y_{\lg c} = 5.09x_1 + 6.84x_2 + 4.93x_3 + 6.65x_4 - 8.92x_5 + 7.79x_6 - 64.63x_7 \} \tag{12}$$

$$y_{bd} = 0.7206x_1 + 0.7118x_2 + 0.7018x_3 + 0.6504x_4 + 4.20x_5 - 0.7500x_6 - 3.24x_7 \} \tag{13}$$

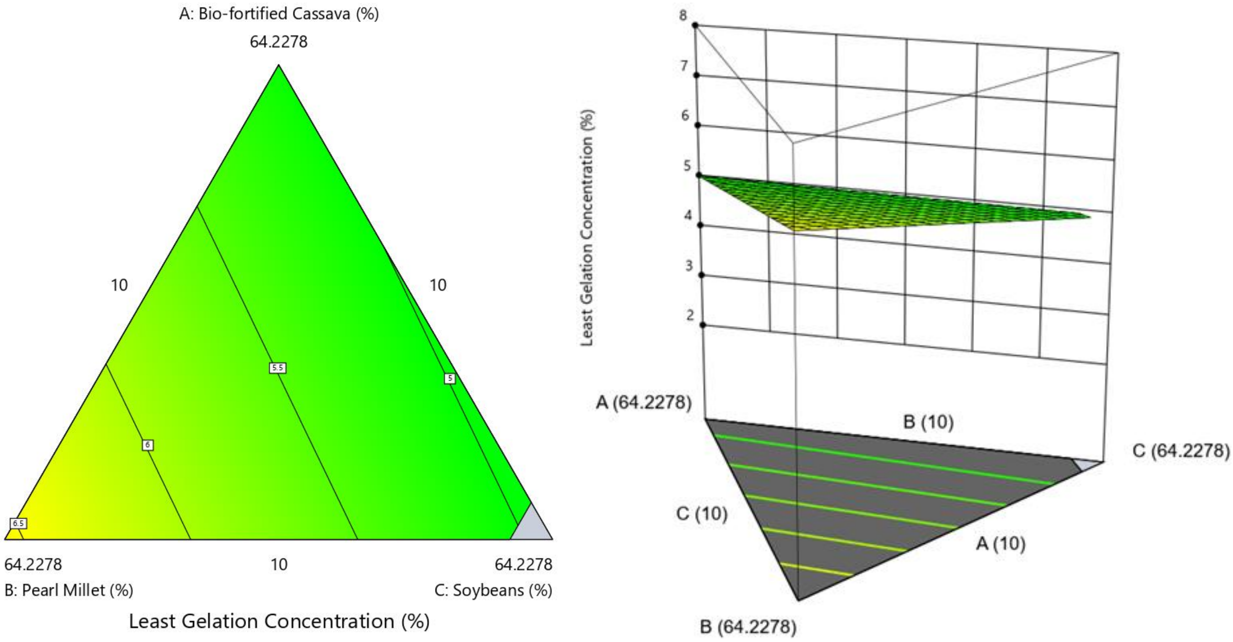

Figure 12. *Least Gelation Concentration Contour and 3-D Surface Plots.*

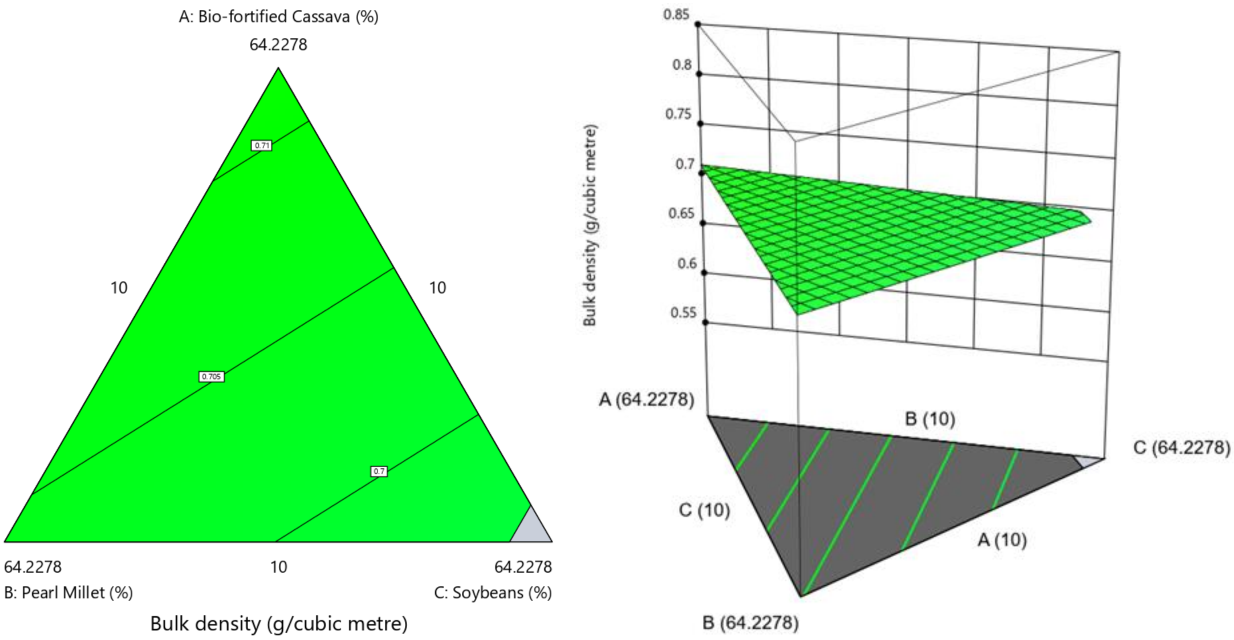

Figure 13. *Bulk density Contour and 3-D Surface Plots.*

$$y_{vc} = 84.48x_1 + 84.37x_2 + 70.54x_3 + 55.07x_4 + 797.43x_5 - 556.92x_6 - 1926.64x_7 \Big\} \quad (14)$$

$$\left.\begin{aligned} y_{bc} = {} & 0.5655x_1 + 0.8706x_2 + 0.1248x_3 + 6.84x_4 - 8217.55x_5 + 317.32x_6 + 7770.45x_7 \\ & + 2.36x_1x_2 + 0.1587x_1x_3 - 11.36x_1x_4 + 8426.10x_1x_5 - 362.21x_1x_6 - 7809.63x_1x_7 \\ & + 1.24x_2x_3 - 9.38x_2x_4 + 8318.16x_2x_5 - 330.33x_2x_6 - 7858.47x_2x_7 \\ & - 8.73x_3x_4 + 8363.93x_3x_5 - 310.08x_3x_6 - 7870.55x_3x_7 + 8356.32x_4x_5 \\ & - 343.46x_4x_6 - 8003.03x_4x_7 + 6087.33x_5x_6 + 3042.45x_5x_7 - 5533.62x_6x_7 \end{aligned}\right\} \quad (15)$$

$$\left.\begin{aligned} y_{ta} &= 1.36x_1 + 1.25x_2 + 0.0301x_3 + 5.96x_4 - 11513.42x_5 - 4076.26x_6 + 11318.94x_7 \\ &- 1.96x_1x_2 + 0.8037x_1x_3 - 7.75x_1x_4 + 11687.36x_1x_5 + 4151.86x_1x_6 - 11393.40x_1x_7 \\ &+ 1.46x_2x_3 - 8.00x_2x_4 + 11684.47x_2x_5 + 4104.34x_2x_6 - 11338.55x_2x_7 \\ &- 6.88x_3x_4 + 11742.62x_3x_5 + 4141.91x_3x_6 - 11366.96x_3x_7 + 11683.35x_4x_5 \\ &+ 4192.91x_4x_6 - 11492.41x_4x_7 + 15604.09x_5x_6 - 207.38x_5x_7 - 7673.22x_6x_7 \end{aligned}\right\} \tag{16}$$

$$\left.\begin{aligned} y_{cy} &= 3.78x_1 + 1.99x_2 + 5.91x_3 - 6.03x_4 + 7476.00x_5 + 9856.02x_6 - 5270.64x_7 \\ &+ 1.37x_1x_2 - 0.9326x_1x_3 + 14.70x_1x_4 - 7655.79x_1x_5 - 10092.12x_1x_6 + 5276.34x_1x_7 \\ &+ 1.71x_2x_3 + 21.79x_2x_4 - 7506.42x_2x_5 - 10024.04x_2x_6 + 5244.82x_2x_7 \\ &+ 11.91x_3x_4 - 7716.52x_3x_5 - 10216.80x_3x_6 + 5179.26x_3x_7 - 7640.54x_4x_5 \\ &- 9986.08x_4x_6 + 5219.69x_4x_7 - 13342.72x_5x_6 - 4067.25x_5x_7 + 4703.76x_6x_7 \end{aligned}\right\} \tag{17}$$

$$\left. y_{phy} = 18.16x_1 + 17.38x_2 + 16.08x_3 + 19.09x_4 + 76.90x_5 + 80.04x_6 + 70.82x_7 \right\} \tag{18}$$

$$\left.\begin{aligned} y_{oxa} &= 7.76x_1 + 7.79x_2 + 8.75x_3 - 7.29x_4 + 12906.50x_5 + 24010.52x_6 + 32394.28x_7 \\ &- 3.31x_1x_2 + 10.66x_1x_3 + 28.22x_1x_4 - 13168.96x_1x_5 - 24422.85x_1x_6 - 32718.77x_1x_7 \\ &+ 7.74x_2x_3 + 37.35x_2x_4 - 13103.59x_2x_5 - 24416.72x_2x_6 - 32683.48x_2x_7 \\ &+ 20.09x_3x_4 - 13234.22x_3x_5 - 24441.55x_3x_6 - 32818.74x_3x_7 - 13093.19x_4x_5 \\ &- 24251.95x_4x_6 - 32959.94x_4x_7 - 42884.23x_5x_6 - 52392.47x_5x_7 - 42986.35x_6x_7 \end{aligned}\right\} \tag{19}$$

$$\left.\begin{aligned} y_{sod} &= 11.20x_1 + 7.95x_2 + 18.07x_3 + 28.71x_4 + 53262.28x_5 + 21776.67x_6 - 1.777E+05x_7 \\ &+ 7.68x_1x_2 - 3.98x_1x_3 - 39.58x_1x_4 - 54023.38x_1x_5 - 22104.05x_1x_6 + 1.799E+05x_1x_7 \\ &+ 1.85x_2x_3 - 23.63x_2x_4 - 54055.13x_2x_5 - 21416.44x_2x_6 + 1.790E+05x_2x_7 \\ &- 25.71x_3x_4 - 54625.36x_3x_5 - 21887.39x_3x_6 + 1.792E+05x_3x_7 - 54148.60x_4x_5 \\ &- 22913.23x_4x_6 + 1.814E+05x_4x_7 - 67694.89x_5x_6 + 1.139E+05x_5x_7 + 1.135E+05x_6x_7 \end{aligned}\right\} \tag{20}$$

$$\left.\begin{aligned} y_{pot} &= 359.62x_1 + 273.48x_2 + 459.50x_3 + 918.30x_4 + 8.211E+05x_5 + 4.882E+05x_6 - 3.308E+06x_7 \\ &+ 220.61x_1x_2 - 185.45x_1x_3 - 1271.50x_1x_4 - 8.318E+05x_1x_5 - 4.957E+05x_1x_6 + 3.348E+06x_1x_7 \\ &+ 2.71x_2x_3 - 970.13x_2x_4 - 8.324E+05x_2x_5 - 4.813E+05x_2x_6 + 3.331E+06x_2x_7 \\ &- 1005.48x_3x_4 - 8.435E+05x_3x_5 - 4.897E+05x_3x_6 + 3.340E+06x_3x_7 - 8.276E+05x_4x_5 \\ &- 5.094E+05x_4x_6 + 3.382E+06x_4x_7 - 1.272E+06x_5x_6 + 2.135E+06x_5x_7 + 1.815E+06x_6x_7 \end{aligned}\right\} \tag{21}$$

$$\left.\begin{aligned} y_{cal} &= 183.59x_1 + 60.68x_2 + 205.47x_3 + 311.61x_4 + 5.689E+05x_5 + 4.827E+05x_6 - 2.208E+06x_7 \\ &+ 212.11x_1x_2 - 106.63x_1x_3 - 412.96x_1x_4 - 5.794E+05x_1x_5 - 4.927E+05x_1x_6 + 2.228E+06x_1x_7 \\ &+ 0.5534x_2x_3 - 75.70x_2x_4 - 5.793E+05x_2x_5 - 4.830E+05x_2x_6 + 2.227E+06x_2x_7 \\ &- 322.25x_3x_4 - 5.823E+05x_3x_5 - 4.889E+05x_3x_6 + 2.225E+06x_3x_7 - 5.768E+05x_4x_5 \\ &- 4.966E+05x_4x_6 + 2.239E+06x_4x_7 - 9.011E+05x_5x_6 + 1.529E+06x_5x_7 + 1.336E+06x_6x_7 \end{aligned}\right\} \tag{22}$$

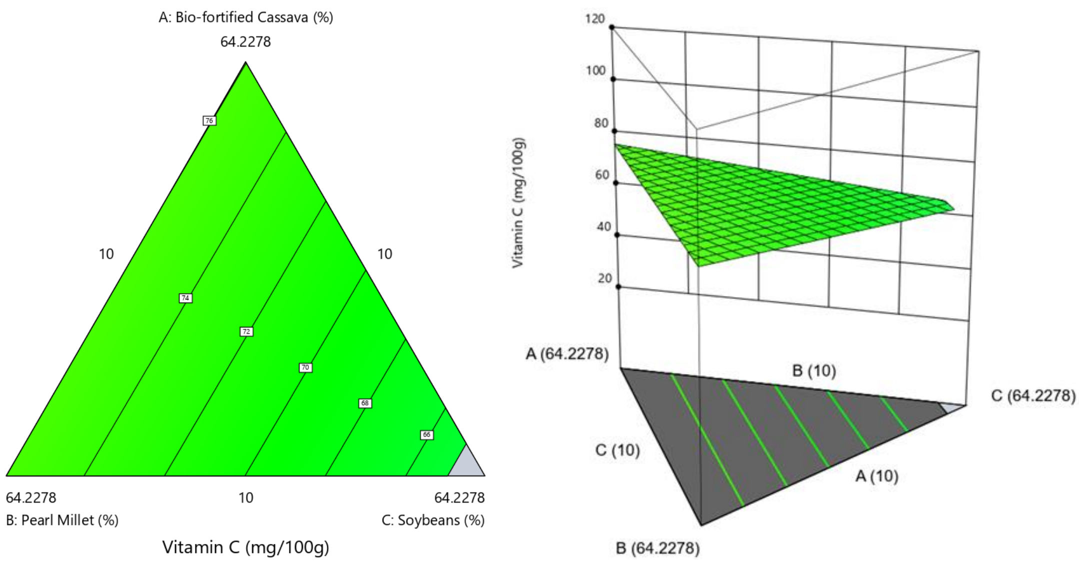

Figure 14. *Vitamin C Contour and 3-D Surface Plots.*

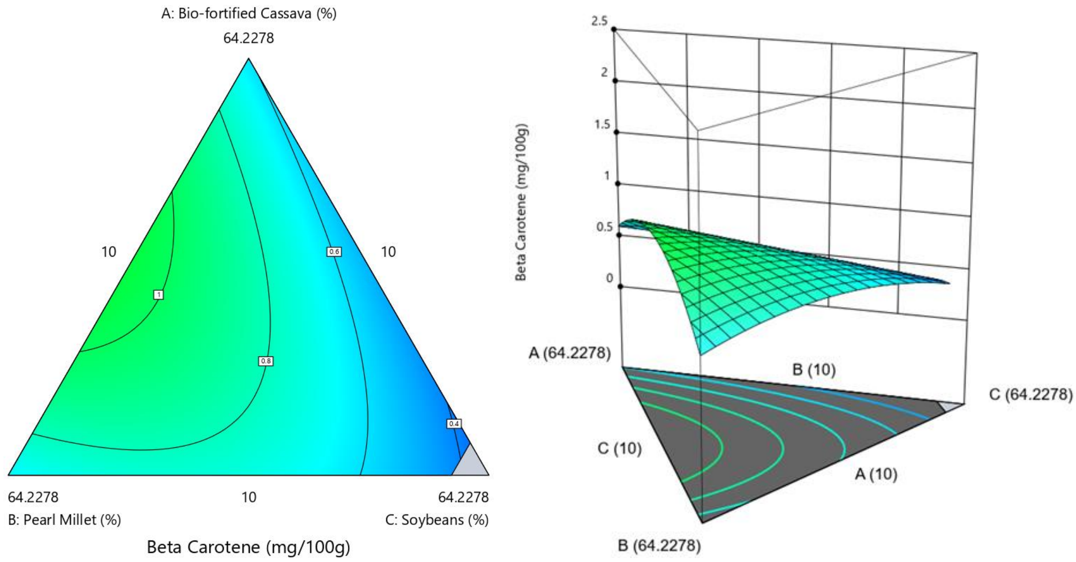

Figure 15. *Beta Carotene Contour and 3-D Surface Plots.*

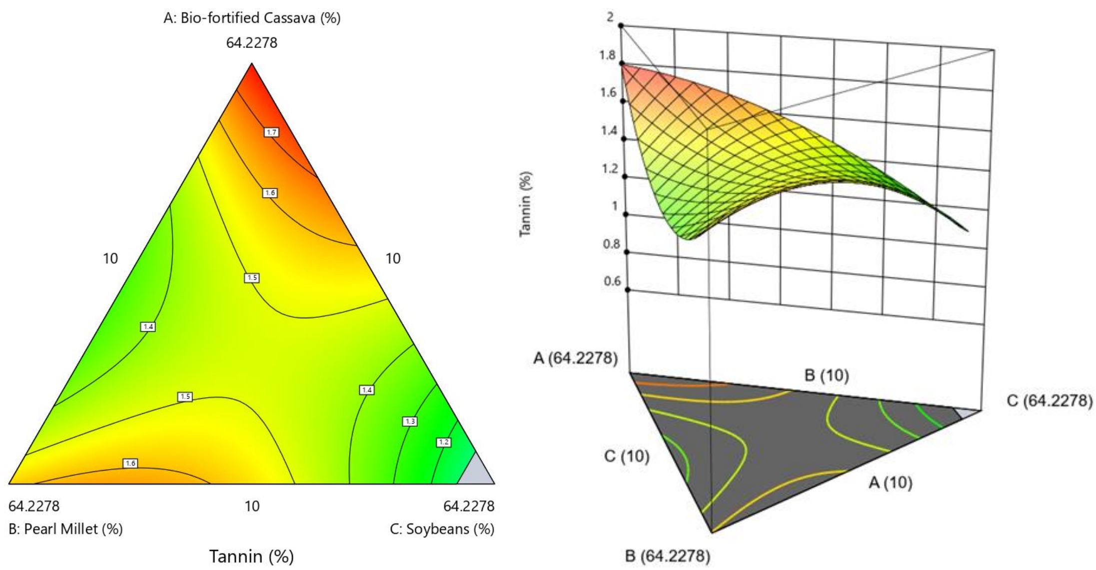

Figure 16. *Tannin Contour and 3-D Surface Plots.*

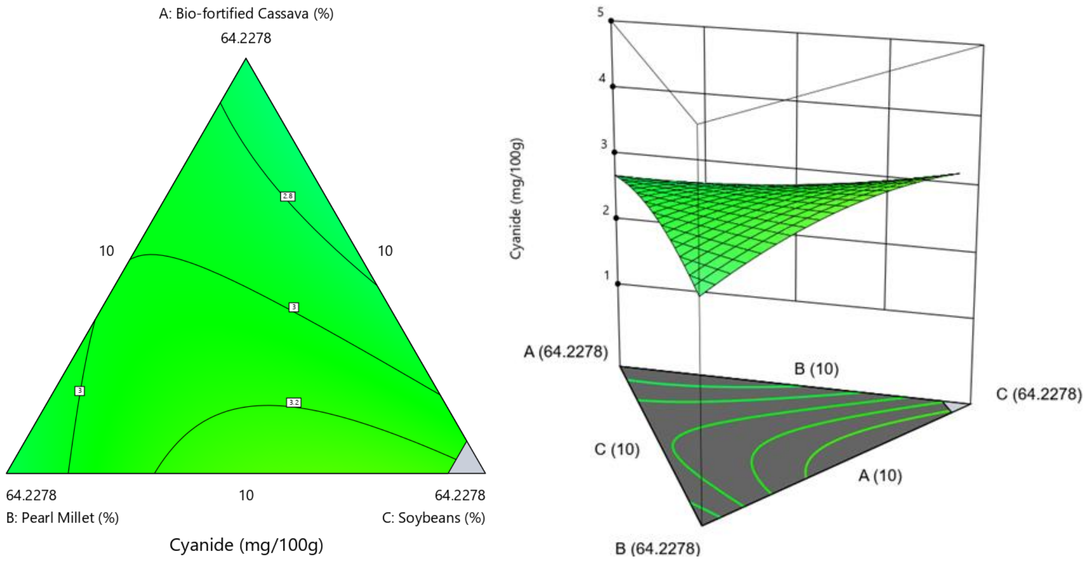

Figure 17. *Cyanide Contour and 3-D Surface Plots.*

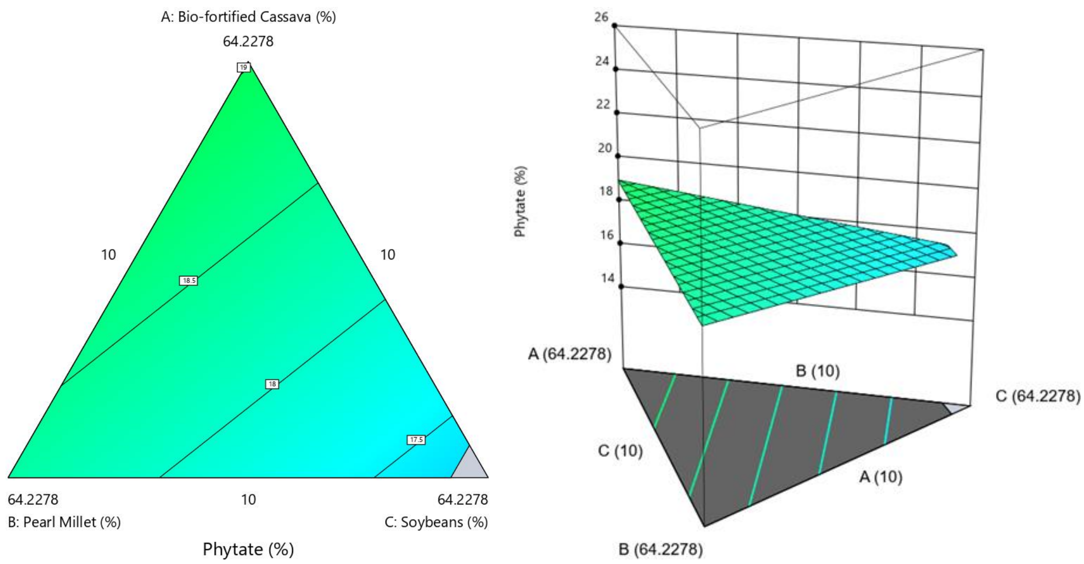

Figure 18. *Phytate Contour and 3-D Surface Plots.*

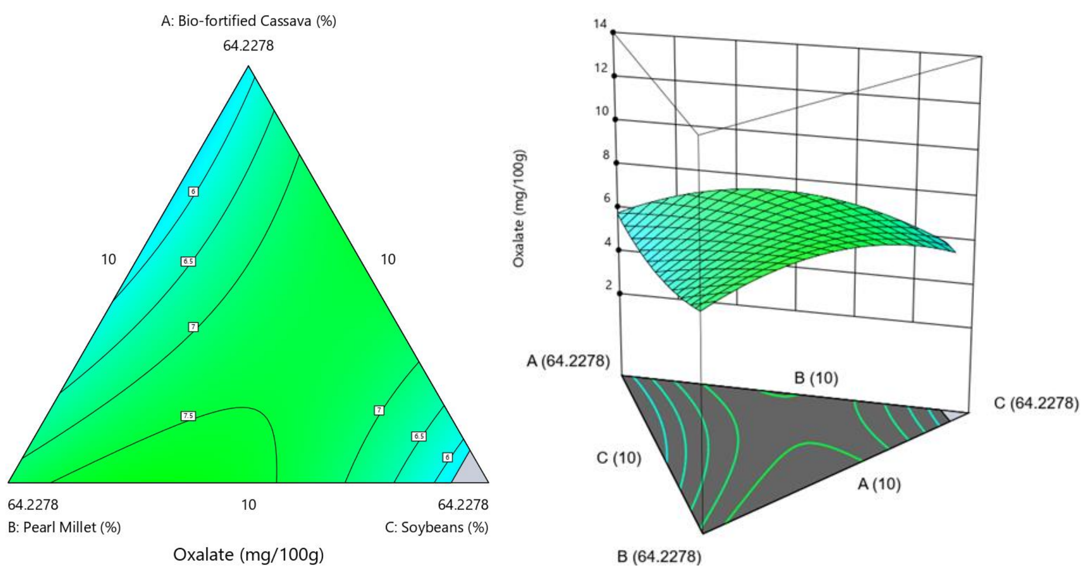

Figure 19. *Oxalate Contour and 3-D Surface Plots.*

$$\left.\begin{array}{l} y_{mag} = 155.83x_1 + 25.76x_2 + 170.05x_3 + 177.31x_4 + 5.528E+05x_5 + 3.229E+05x_6 - 1.397E+06x_7 \\ + 193.34x_1x_2 - 95.11x_1x_3 - 207.24x_1x_4 - 5.620E+05x_1x_5 - 3.319E+05x_1x_6 + 1.410E+06x_1x_7 \\ - 38.67x_2x_3 + 83.11x_2x_4 - 5.614E+05x_2x_5 - 3.240E+05x_2x_6 + 1.412E+06x_2x_7 \\ - 129.52x_3x_4 - 5.649E+05x_3x_5 - 3.279E+05x_3x_6 + 1.407E+06x_3x_7 - 5.616E+05x_4x_5 \\ - 3.339E+05x_4x_6 + 1.416E+06x_4x_7 - 6.719E+05x_5x_6 + 6.099E+05x_5x_7 + 9.775E+05x_6x_7 \end{array}\right\} \quad (23)$$

$$\left.\begin{array}{l} y_{pho} = 521.14x_1 + 82.43x_2 + 570.19x_3 + 359.47x_4 + 1.113E+06x_5 + 4.357E+05x_6 - 2.972E+06x_7 \\ + 682.72x_1x_2 - 467.79x_1x_3 - 220.73x_1x_4 - 1.131E+06x_1x_5 - 4.568E+05x_1x_6 + 3.008E+06x_1x_7 \\ - 98.28x_2x_3 + 741.50x_2x_4 - 1.126E+06x_2x_5 - 4.366E+05x_2x_6 + 3.018E+06x_2x_7 \\ - 7.04x_3x_4 - 1.141E+06x_3x_5 - 4.457E+05x_3x_6 + 2.993E+06x_3x_7 - 1.140E+06x_4x_5 \\ - 4.478E+05x_4x_6 + 3.005E+06x_4x_7 - 8.209E+05x_5x_6 + 8.549E+05x_5x_7 + 2.128E+06x_6x_7 \end{array}\right\} \quad (24)$$

$$\left. y_{ir} = 5.78x_1 + 4.56x_2 + 4.84x_3 + 6.72x_4 - 23.47x_5 - 23.76x_6 - 54.50x_7 \right\} \quad (25)$$

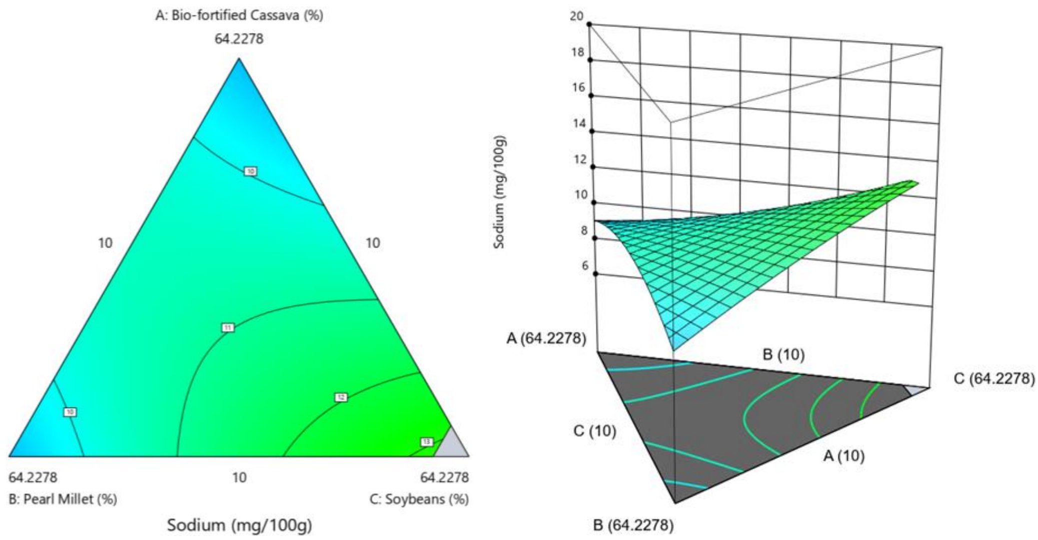

Figure 20. *Sodium Contour and 3-D Surface Plots.*

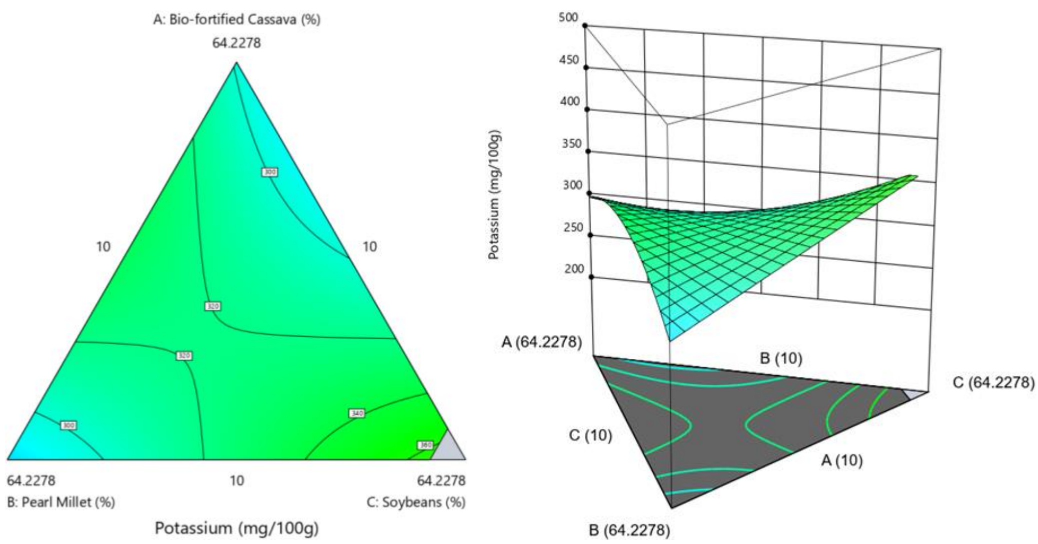

Figure 21. *Potassium Contour and 3-D Surface Plots.*

$$y_{ir} = 6.10x_0 \quad \} \tag{26}$$

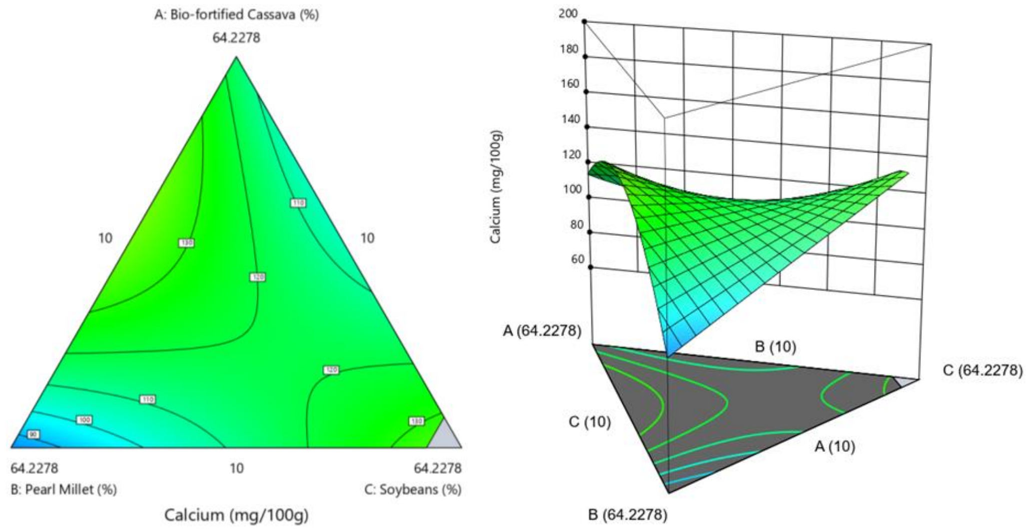

Figure 22. Calcium Contour and 3-D Surface Plots.

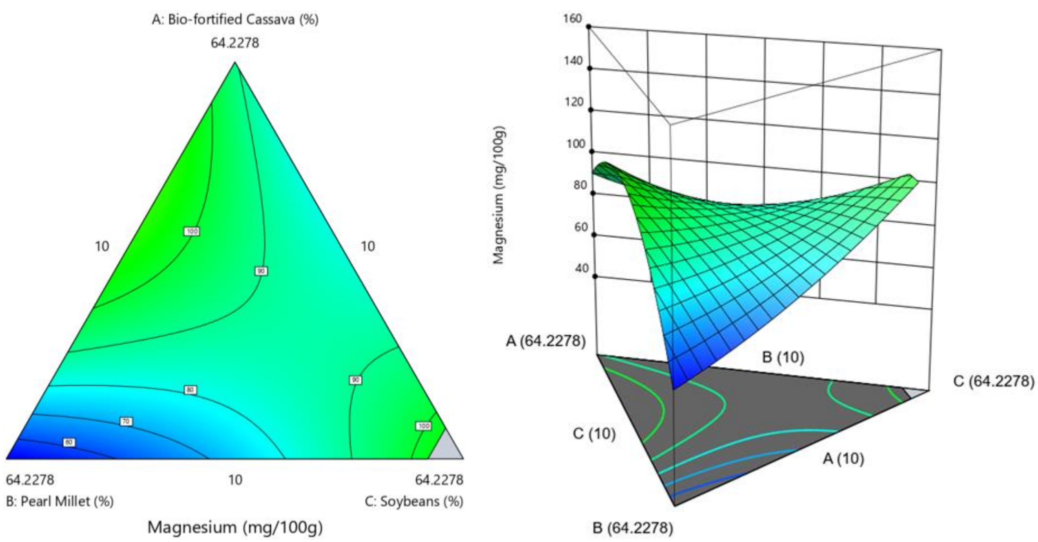

Figure 23. Magnesium Contour and 3-D Surface Plots.

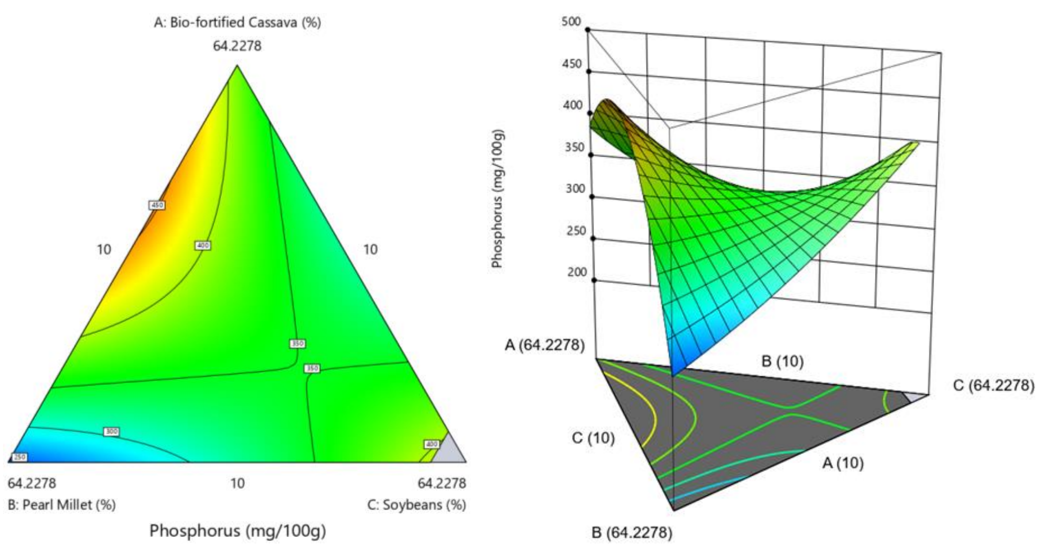

Figure 24. Phosphorus Contour and 3-D Surface Plots.

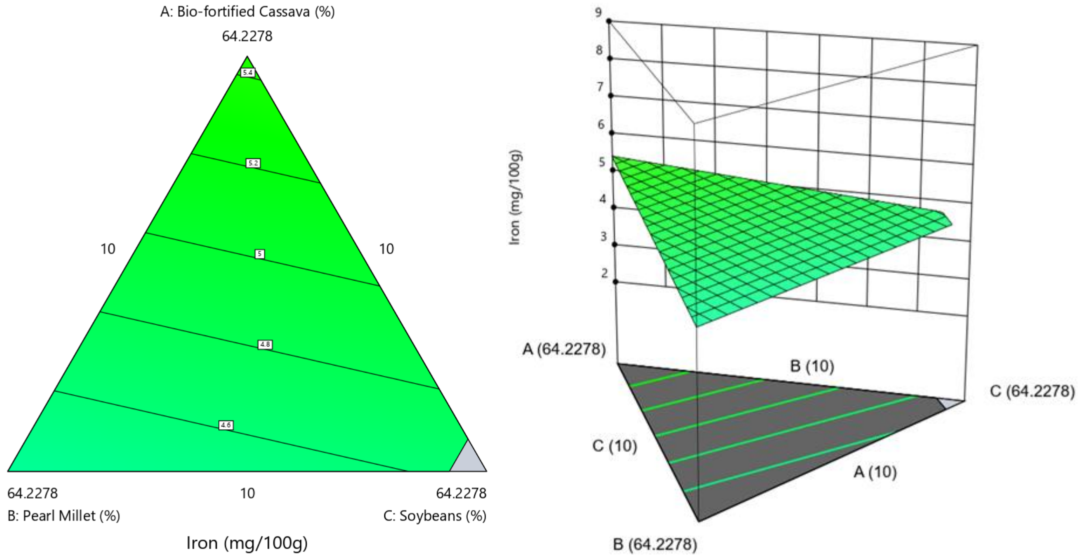

Figure 25. *Iron Contour and 3-D Surface Plots.*

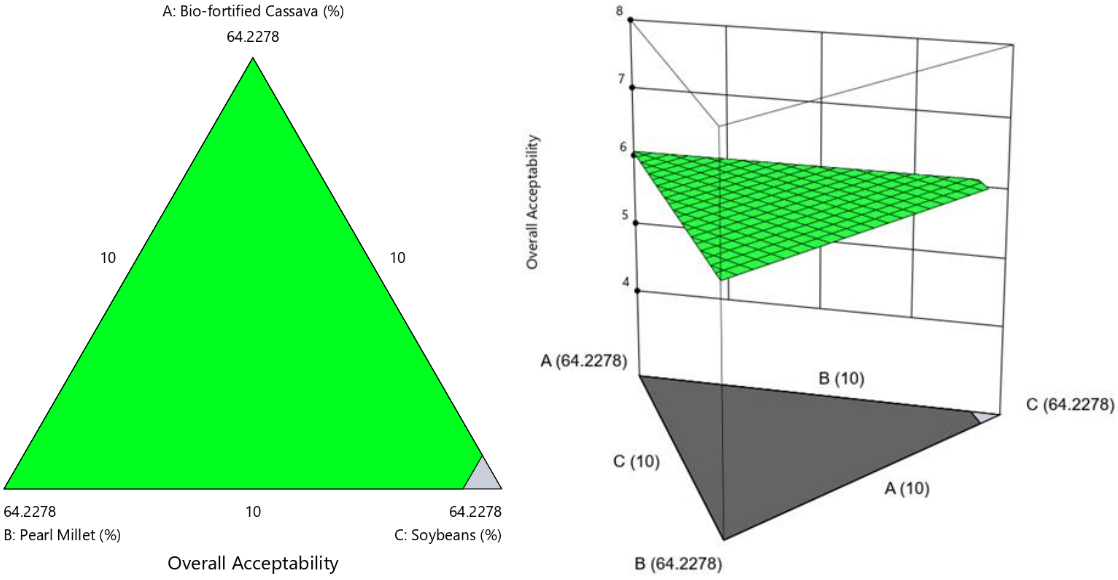

Figure 26. *Overall Acceptability Contour and 3-D Surface Plots.*

3.3. Optimization Constraints/Settings

The summary of the optimization constraints employed for the formulated enriched custard powder are presented in Table 8.

Table 8. *Optimization constraints for the formulated enriched custard powder.*

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
Bio-fortified Cassava	in range	10	70	1	1	3
Pearl Millet	in range	10	70	1	1	3
Soybeans	in range	10	60	1	1	3
Africa Locust Beans Fruit Pulp	in range	5	30	1	1	3
Ginger	in range	1	2	1	1	3
Egg Powder	in range	0.5	1.5	1	1	3
Milk Powder	in range	0.5	1	1	1	3
Moisture Content	in range	4.88	8.47	1	1	3
Crude fibre	in range	0.42	1.31	1	1	3
Ash content	in range	1	5.19	1	1	3
Protein Content	target = 20	12.2	22.2	1	10	5
Lipid	in range	4.12	9.27	1	1	3
Carbohydrate	minimize	58.72	75.62	1	1	3
Water Absorption Capacity	in range	0.1	0.22	1	1	3

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
Oil Absorption Capacity	in range	0.08	0.16	1	1	3
Foaming Capacity	in range	5.88	27.45	1	1	3
Foaming Stability	in range	2.2	18.3	1	1	3
Gelation Temperature	in range	40	60	1	1	3
Least Gelation Concentration	in range	2	8	1	1	3
Bulk density	in range	0.59	0.83	1	1	3
Vitamin C	target = 100	22.6	116.1	1	10	5
Beta Carotene	maximize	0.12	2.28	1	1	3
Tannin	minimize	0.65	1.82	1	1	3
Cyanide	in range	1.23	4.9	1	1	3
Phytate	minimize	15.4	24.1	1	1	3
Oxalate	minimize	3.78	12.1	1	1	3
Sodium	maximize	6.88	18.65	1	1	3
Potassium	maximize	222	488	1	1	3
Calcium	maximize	68	186	1	1	3
Magnesium	maximize	52	158	1	1	3
Phosphorus	maximize	224	488	1	1	3
Iron	maximize	2.34	8.2	1	1	3
Colour	in range	4.5	7.4	1	1	3
Taste	in range	4.3	7.4	1	1	3
Texture	in range	4.1	7.8	1	1	3
Aroma	in range	4.1	10.3	1	1	3
Overall Acceptability	in range	4.6	7.8	1	1	3

3.4. Results of Numerical Optimization of the Formulated Powdered Custard

Eighty-five desirability optimal formulation conditions (component proportions) were found and summarized in Table 9, with the quality properties of the optimal formulation for the powdered custard presented in Tables 10-12.

Table 9. *Optimal formulation conditions for the formulated enriched custard powder.*

No	x_1	x_2	x_3	x_4	x_5	x_6	x_7	D_i	
1	51.300	30.469	10.000	5.000	2.000	0.500	0.731	0.833	Selected
2	52.223	29.579	10.000	5.000	2.000	0.500	0.698	0.833	
3	46.235	34.600	10.000	5.758	2.000	0.681	0.726	0.817	
4	49.618	30.912	10.029	5.713	2.000	1.052	0.675	0.806	
5	52.877	28.195	10.003	5.000	2.000	1.214	0.711	0.806	
	………	………	………	………	………	………	………	………	
80	10.000	10.000	45.953	30.00	2.000	1.500	0.547	0.530	
81	18.957	37.589	10.000	30.000	1.112	1.500	0.842	0.518	
82	10.000	10.000	49.005	27.036	1.974	1.486	0.500	0.493	
83	22.068	41.393	10.017	23.147	1.400	1.475	0.500	0.448	
84	18.480	14.152	51.835	12.023	1.933	1.078	0.500	0.441	
85	13.095	63.393	13.781	6.289	1.052	1.390	1.000	0.403	

$x_1 = Bio-fortified\ Cassava\ (\%)$, $x_2 = Pearl\ Millet\ (\%)$, $x_3 = Soybeans\ (\%)$, $x_4 = Africa\ Locust\ Beans\ Fruit\ Pulp\ (\%)$
$x_5 = Ginger(\%)$, $x_6 = Egg\ Powder(\%)$, $x_7 = Milk\ Powder$, $D_i = Overall\ Desirability\ Index$

Table 10. *The quality properties of the optimal powdered custard continue.*

No	y_{mc}	y_{cf}	y_{ac}	y_{pc}	y_{lip}	y_{cho}	y_{wac}	y_{oac}	y_{fc}	Desirability	
1	6.202	1.139	2.548	20.000	6.668	61.786	0.157	0.121	19.005	0.833	Selected
2	6.120	1.144	2.500	20.000	6.673	61.901	0.155	0.121	20.033	0.833	
3	6.504	1.184	3.246	20.000	6.759	59.812	0.155	0.119	16.155	0.817	
4	7.012	1.216	3.580	20.000	7.154	57.391	0.151	0.114	13.239	0.806	
5	7.219	1.200	3.392	20.000	7.379	56.803	0.152	0.112	11.174	0.806	
……	………	………	………	………	………	………	………	………	………	………	
80	7.294	0.697	1.419	16.707	7.478	66.777	0.149	0.125	13.268	0.530	
81	6.213	0.826	1.861	17.531	6.224	66.950	0.168	0.100	18.445	0.518	
82	7.387	0.770	1.912	16.682	7.651	66.835	0.145	0.127	9.853	0.493	
83	7.164	0.941	2.827	16.780	6.477	66.633	0.152	0.104	6.251	0.448	
84	6.553	0.976	2.684	17.815	7.945	63.634	0.138	0.136	13.516	0.441	
85	6.000	0.690	2.296	15.260	6.989	69.331	0.158	0.111	17.299	0.403	

$y_{mc} = Moisture\ Content\ (\%)$, $y_{cf} = Crude\ fibre$, $y_{ac} = Ash\ Content\ (\%)$, $y_{pc} = Protein\ Content\ (\%)$, $y_{lip} = Lipid$
$y_{cho} = Carbohydrate$, $y_{wac} = Water\ Absorption\ Capacity$, $y_{oac} = Oil\ Absorption\ Capacity$, $y_{fc} = Foaming\ Capacity$

***Table 11.** The quality properties of the optimal powdered custard continue.*

No	y_{fs}	y_{gt}	y_{lgc}	y_{bd}	y_{vc}	y_{bc}	y_{tan}	y_{cy}	y_{phy}	Desirability	
1	8.886	52.474	5.178	0.758	88.383	1.832	0.600	3.072	19.032	0.833	Selected
2	8.886	52.474	5.190	0.761	89.458	1.824	0.603	3.097	19.015	0.833	
3	8.886	52.474	5.325	0.753	86.357	1.529	0.650	2.985	19.166	0.817	
4	8.886	52.474	5.294	0.748	84.224	1.230	0.719	2.934	19.532	0.806	
5	8.886	52.474	5.167	0.743	81.754	1.219	0.721	3.010	19.745	0.806	
……	………	………	………	………	………	………	………	………	………	………	
80	8.886	52.474	5.387	0.711	64.493	0.413	1.303	1.776	19.298	0.530	
81	8.886	52.474	6.113	0.650	52.933	0.659	1.309	4.092	19.561	0.518	
82	8.886	52.474	5.363	0.715	66.550	0.331	1.257	1.893	19.075	0.493	
83	8.886	52.474	6.362	0.695	70.552	0.805	1.425	3.911	19.370	0.448	
84	8.886	52.474	5.091	0.738	76.611	0.297	1.197	2.418	18.271	0.441	
85	8.886	52.474	6.065	0.661	58.512	0.926	1.339	2.582	18.736	0.403	

$y_{fs} = Foaming\ Stability$, $y_{gt} = Gelation\ Temperature$, $y_{lgc} = Least\ Gelation\ Concentration$, $y_{bd} = Bulk\ density$

$y_{vc} = Vitamin\ C$, $y_{bc} = Beta\ Carotene$, $y_{\tan} = Tannin$, $y_{cy} = Cyanide$, $y_{phy} = Phytate$

***Table 12.** The quality properties of the optimal powdered custard continue.*

No	y_{oxa}	y_{sod}	y_{pot}	y_{cal}	y_{mag}	y_{pho}	y_{iron}	y_{oa}	Desirability	
1	5.313	16.737	469.150	201.332	167.254	585.770	4.694	6.1	0.833	Selected
2	5.419	16.544	467.093	200.618	168.016	585.775	4.744	6.1	0.833	
3	4.474	16.105	445.937	183.714	155.914	566.206	4.546	6.1	0.817	
4	3.544	16.789	448.910	185.816	161.032	576.755	4.491	6.1	0.806	
5	3.368	17.795	462.180	196.986	169.171	587.390	4.423	6.1	0.806	
……	………	………	………	………	………	………	………	………	………	
80	4.623	11.552	365.449	164.570	137.465	458.837	4.640	6.1	0.530	
81	9.676	13.448	377.969	180.041	129.248	461.600	4.770	6.1	0.518	
82	5.094	10.365	332.753	149.260	129.579	457.337	4.614	6.1	0.493	
83	8.840	9.308	310.960	140.705	94.202	390.807	4.799	6.1	0.448	
84	6.171	9.682	285.997	106.726	98.368	373.414	4.476	6.1	0.441	
85	8.458	11.472	324.663	120.487	93.790	323.119	3.786	6.1	0.403	

$y_{oxa} = Oxalate$, $y_{sod} = Sodium$, $y_{pot} = Potassium$, $y_{cal} = Calcium$, $y_{mag} = Magnesium$, $y_{pho} = Phosphorus$

$y_{iron} = Iron$, $y_{oa} = Overall\ Acceptability$

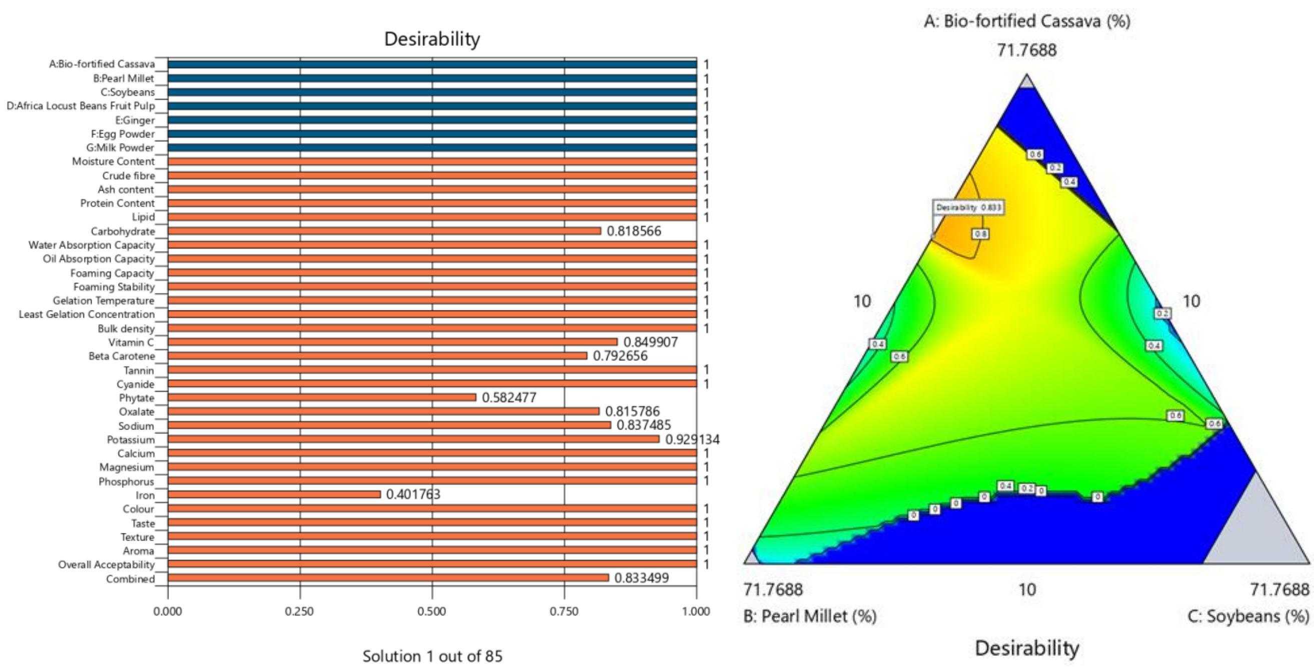

***Figure 27.** Desirability Bar Graph and Contour Plot.*

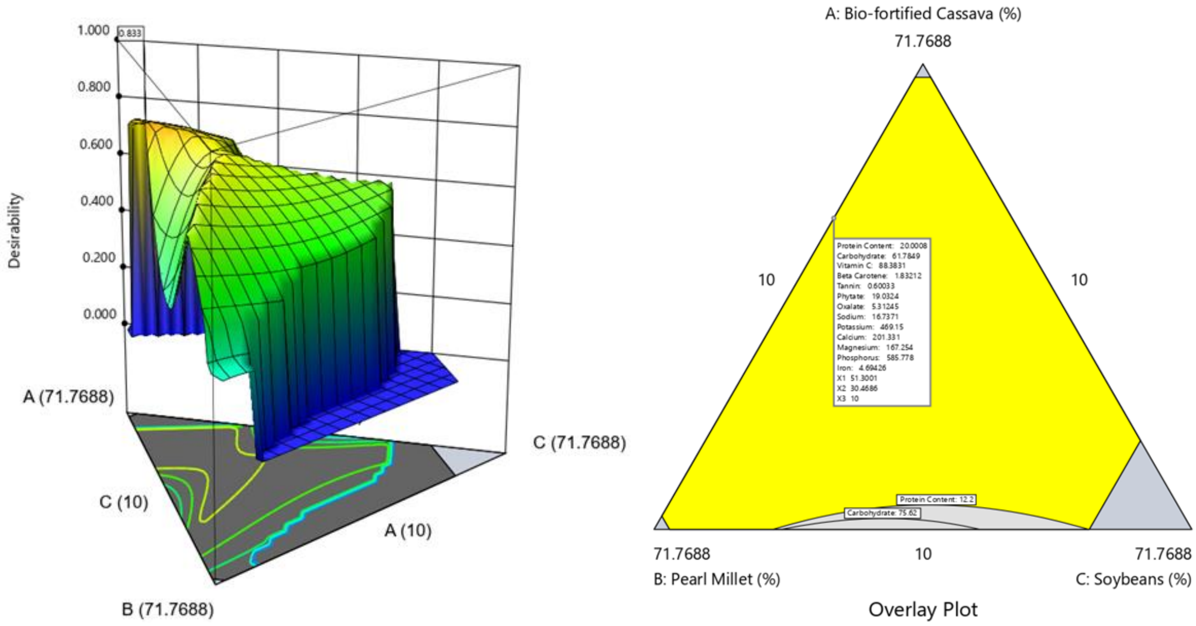

Figure 28. *Desirability 3-D Surface and graphical optimization overlay contour plots.*

The numerical solution desirability bar graph and contour plots are presented in Figure 27. The 3-D Surface and graphical optimization overlay contour plots are presented in Figure 28. Exploiting the desirability function technique, the formulation that produced enriched custard powder of the highest desirability index of 0.833 was 51.3% bio-fortified cassava, 30.469% pearl millet, 10.0 % soybeans, 5.0% Africa locust beans fruit pulp, 2.0% ginger, 0.5% egg powder, and 0.731 % milk powder. The quality properties of this optimal enriched custard were 6.202 % moisture content, 1.139 % crude fibre, 2.548 % ash content, 20.0 % protein content, 6.668 % lipid, 61.786 % carbohydrate, 0.157 (mL/g) water absorption capacity, 0.121 (mL/g) oil absorption capacity, 19.005 (% vol) foaming capacity, 8.886 (%) foaming stability, 52.474 (deg C) gelation temperature, 5.178 (%) least gelation concentration, 0.758 (g/cubic metre) bulk density, 88.383 (mg/100g) vitamin C, 1.832 (mg/100g) beta carotene, 0.6 (%) tannin, 3.072 (mg/100g) cyanide, 19.032 (%) phytate, 5.313 (mg/100g) oxalate, 16.737 (mg/100g) sodium, 469.150 (mg/100g) potassium, 201.332 (mg/100g) calcium, 167.254 (mg/100g) magnesium, 585.770 (mg/100g) phosphorus, 4.694 (mg/100g) iron, and 6.10 overall acceptability.

4. Conclusion

In this study, using composite products technology, enriched custard powder was developed, characterized and optimized, via a seven-component constrained, D-optimal mixture experimental design, from blends of bio-fortified cassava, pearl millet, soybeans, Africa locust beans fruit pulp, ginger, egg powder, and milk powder. The development of enriched custard powder from indigenous local food ingredients offers end users with novel choices to the traditional custard which are produced from mono-cereals. 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 value-added custard powder. There is the need for research on formulating custard powder from blends of different unique local food ingredients.

Competing Interests

The authors declare that they have no competing interests.

Data Availability

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

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