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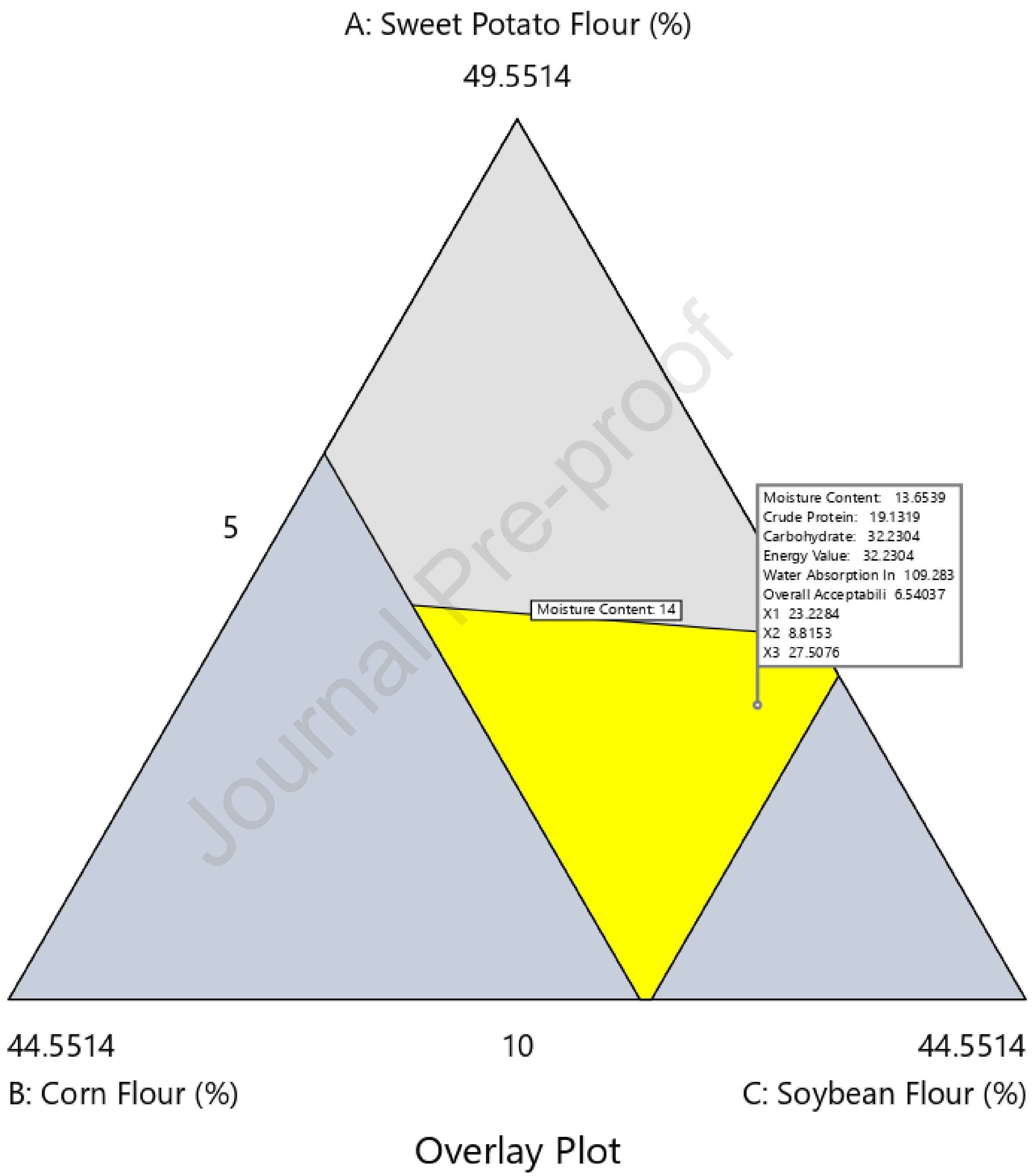
Graphical Abstract



Development, Optimization and Characterization of Enriched Noodles

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Abstract:

Noodles are one of the staple foods consumed in Nigeria. Wheat, which is a major component in noodles formulation has suffered decline in production in recent times and in addition to this, noodles made from wheat lacks adequate essential nutrient needed for growth considering the awareness that the demography of the population that consumes noodles are mostly children. This study developed and optimized and characterized instant noodles from blends of sweet potato flour, corn flour, and soybean flour. Experiments were conducted using a four-component constrained D-optimal mixture-process experimental design, with thirty-nine (39) randomized experimental runs. The formulation design constraints were: sweet potato flour (10% - 61%), soybean flour (5% - 20%), corn flour (5% - 30%), and water (25% - 37%). Other components of the formulation were salt (2.5%), sodium carbonate (0.5%), guar gum (0.5%), and Soy lecithin (0.5%). The processing factors investigated were mixing time (2min - 10 min), frying time (1min - 3 min), and frying temperature (140^0C - 160^0C). The formulated noodles were analyzed and evaluated for the moisture content, crude protein, crude fibre, ash content, crude fat, carbohydrate, energy value, water absorption index, cooking time, cooking weight, bulk density and sensory characteristics, using standard procedures. The result of the formulated noodles optimization gave optimal formulated noodles with overall desirability index of 0.518, based on the set optimization goals and individual quality desirability indices. The optimal noodle was obtained from 23.228% sweet potato flour, 8.815% corn flour, 27.508% soybean flour, 36.449% water, 2.500% salt, 0.500% sodium carbonate, 0.500% guar gum, 0.500% soy lecithin; with 8.169min mixing time, 2.5min frying time, and 144^0C frying temperature. The quality properties of this optimal noodle were 13.654% moisture content, 19.131% crude protein, 5.171% crude fibre, 7.798% ash content, 21.818% crude fat, 32.231% carbohydrate, 32.231 kcal/100g energy value, 109.275 g/g water absorption index, 6min cooking time, 20.928 (% increase in g) cooking weight, 0.645 (g/cubic centimeters) bulk density, and overall acceptability of 6.54, based on 9-point hedonic scale. The result of the study showed that the optimal formulated noodles was of high quality and that improving nutritional quality of noodles is possible through composite formulation. It is recommended that further study be carried out on formulation of nutritionally improved noodles using other nutritionally rich resources. Enrichment of noodles with protein-rich sources will result in noodles with improved nutrient quality that meets the consumer's dietary needs.

Keywords: Formulation, D-optimal, Multiresponse Optimization, Quality, Noodles, Composite flours.

1. Introduction

Instant noodles are gaining wider acceptability especially in the developing world due to their versatility, simplicity, organoleptic appeal, satiety, and affordability. Noodles are widely consumed throughout the world and their global consumption is second only to bread [1]. The consumption of noodles in Africa is on the increase. Nigeria, has been ranked as the 12th highest consumer of noodles in the world by the World Instant Noodles Association [2], Nigeria recorded the highest consumption level of 941 million tons of noodles, pasta and rice in Africa. In comparison, Kenya consumed a total of 105 million tons, while South Africa consumed 597 million tons. In Nigeria, consumers were reported to have a noodle portion of 240 and 280 g per meal, which was the highest in Africa and also higher than some South Asian markets such as India. In 2015, the five-year sales revenue recorded by the noodle category was 25 per cent for Nigeria versus 11 per cent for South Africa [3]. Noodles have become more widely accepted by consumers far beyond the shores of Asia, where it is a staple food, particularly in Nigeria. This sudden increase in the popularity of noodles and current trends in its consumption pattern in Nigeria, where wheat production is extremely poor and is a non-traditional food, suggests that noodles will continue to grow rapidly in popularity [4, 5].

The main ingredients for noodles production are wheat flour, seasoning, flavor enhancer, salt, grease, chili powder and some additives. Basically, noodles are high in carbohydrates and fat but low in fibre, protein, vitamins and minerals. The use of locally available inexpensive cereals and legumes in noodle production is gaining more popularity since it reduces the importation of wheat. Some locally available crops such as sweet potato, yam, cassava, protein-rich flour such as soybean, peanut and other cereal including rice, millet and sorghum, which are produced in large quantities locally, can be used as total or partial substitute for wheat in noodles production, thereby bringing their utility potentials to limelight. The quality characteristics of noodles produced from blends of wheat flour and starch of African breadfruit (*Artocarpus altilis*) was studied [5]. It was observed that as the levels of addition of starch of African breadfruit increased, there was a steady increase in carbohydrate and fiber contents. However, the 100% wheat noodle (control) sample was highly rated and accepted more than other formulations. Acha and soybean were processed into flours and used to substitute wheat flour (*Titicum aestivm*) in the production of noodles [6]. It was observed that soybean improved the protein content noodles. However, the sensory evaluation results indicated that generally, noodles produced from 100% wheat were preferred to others. Dry noodles were formulated from blend of mocaf flour, rice flour and corn flour [7]. It was observed that the protein content of noodle increased as the percentage of mocaf flour in the formulation decreases. A study was conducted on the effect of extrusion parameters (feed moisture content, barrel temperature, and screw speed) on the quality of noodles produced from sweet potato starch [8]. The results showed that noodles obtained from sweet potato starch were of desirable proximate, functional, and sensory qualities. The best noodles in terms of functionality and sensory acceptability were obtained using barrel temperature of 110◦C, screw speed of 100 rpm, and feed moisture content of 47.5%. The effect of starch characteristics on the quality of noodle made from reconstituted flours; in which the wheat starch was substituted by different cereal starches, including waxy and non-waxy rice starches, waxy wheat starch and waxy corn starch were investigated [9]. It was observed that cereal starches with different granular sizes and amylose content significantly affected the rheological properties of raw and cooked noodles. Reports have indicated that noodles can be made from cereals such as millet, rice, wheat flour, potato flour, tapioca or legume flours. Composite flour is considered advantageous in developing countries as it reduces the importation of wheat flour and encourages the use of locally grown crops as flour [10, 11].

The aim of this work was to develop, optimize, and characterize noodles from the blends of sweet potato flour, soybean flour, corn flour, and some other minor ingredients such as salt, sodium carbonate, guar gum, and soy lecithin; employing a D-optimal mixture-process experimental design methodology. The work was based upon the hypothesis that the quality of instant noodles may vary significantly as a result of the incorporation of different types and/or proportions of ingredients used in the formulation as well as the processing parameters applied during manufacture. The impact of baking temperature mixing time, frying time and frying temperature on noodles quality were also investigated. D-optimal designs are straight optimizations techniques based on chosen optimality criteria and model fitting. Both process parameters and mixture/ingredients proportion optimizations are possible by this method. Mixture design of experiment involves blending two or more ingredients together. The design factors are the proportions of the components of the blends and the response variables vary as a function of these proportions. The component proportions cannot vary independently as in factorial experiments since they are considered to sum up to a constant. The total of amount of input variables are fixed and constrained to sum 1 or 100%, for standard designs. Imposing such constraint on the component proportions complicates the design and the analysis of mixture experiments. Response surface methodology consists of a group of empirical techniques devoted to the evaluation of relations existing between a cluster of controlled experimental factors and the measured responses, according to one or more selected criteria [12 - 15]. Prior knowledge and understanding of the process variables under investigation is necessary for achieving a realistic model. The significance of a model is shown by the r^2, p-value and the F-value of each variable factor at specified level of significance. In numerical optimization, optimal formulations will be found by multiple criteria optimizations using desirability function/indices.

2. Materials and Methods

2.1. Materials

Soybean, yellow maize, sweet potato and salt were purchased from the local market at Mile 12 in Lagos, Nigeria. Other ingredients were obtained from a food chemical market in Lagos. The chemicals used were of analytical grade. The equipment and apparatus used were obtained locally.

2.2. Methods

2.2.1. Experimental Design for the cookies formulation experiments

Design-Expert software (version 13, Stat-Ease Inc., USA) was used for experimental design and statistical evaluation of data. A four-component constrained D-optimal mixture-process experimental design, totaling 39 randomized experimental runs, was employed. Four major variable components, four constant components, with three processing factors were investigated. The respective formulation design constraints were: sweet potato flour (10%-61%), soybean flour (5%-20%), corn flour (5%-30%), and water (25%-37%). Other components of the formulation were salt (2.5%), sodium carbonate

(0.5%), guar gum (0.5%), and Soy lecithin (0.5%). The processing factors investigated were mixing time (2min-10 min), frying time (1min-3 min) and frying temperature (140^0C-160^0C). The responses were the main proximate, cooking and physical qualities of instant noodles. The design matrix for the D-Optimal mixture – process design is presented in Table 1. The formulation of the composite blend, with the other constant components, as well as the variation of the processing parameters were based on the design matrix.

***Table 1.**: Design matrix for the noodle's formulation experiments*

	x_1	x_2	x_3	x_4	c_1	c_2	c_3	c_4	z_1	z_2	z_3
Run	%	%	%	%	%	%	%	%	mins	mins	deg C
1	46	20	5	25	2.5	0.5	0.5	0.5	10	3	140
2	21	20	30	25	2.5	0.5	0.5	0.5	10	1	160
3	22	20	17	37	2.5	0.5	0.5	0.5	10	1	160
4	49	5	5	37	2.5	0.5	0.5	0.5	10	1	140
5	36.4808	5	17.75	36.7692	2.5	0.5	0.5	0.5	2	1	140
6	41.3846	12.8462	5	36.7692	2.5	0.5	0.5	0.5	2	3	160
7	33.5385	19.7115	17.75	25	2.5	0.5	0.5	0.5	10	3	160
8	10	19	30	37	2.5	0.5	0.5	0.5	2	2	150
9	21	20	30	25	2.5	0.5	0.5	0.5	10	3	140
10	43	15	13	25	2.5	0.5	0.5	0.5	6	2	150
11	61	5	5	25	2.5	0.5	0.5	0.5	2	1	160
12	36	5	30	25	2.5	0.5	0.5	0.5	10	3	140
13	49	5	5	37	2.5	0.5	0.5	0.5	10	1	140
14	21	20	30	25	2.5	0.5	0.5	0.5	2	1	160
15	61	5	5	25	2.5	0.5	0.5	0.5	10	3	140
16	28.6346	12.8462	29.5192	25	2.5	0.5	0.5	0.5	2	3	160
17	55	5	5	31	2.5	0.5	0.5	0.5	2	3	140
18	15.8846	19.7115	29.5192	30.8846	2.5	0.5	0.5	0.5	2	3	160
19	46	20	5	25	2.5	0.5	0.5	0.5	2	3	140
20	53.1538	12.8462	5	25	2.5	0.5	0.5	0.5	2	1	140
21	21	20	30	25	2.5	0.5	0.5	0.5	2	3	140
22	46	20	5	25	2.5	0.5	0.5	0.5	10	1	140
23	25	14	20	37	2.5	0.5	0.5	0.5	10	3	140
24	10	19	30	37	2.5	0.5	0.5	0.5	10	3	160
25	10	19	30	37	2.5	0.5	0.5	0.5	6	3	150
26	23.0769	9.72781	30	33.1953	2.5	0.5	0.5	0.5	2	1	140
27	48.25	5	17.75	25	2.5	0.5	0.5	0.5	2	1	140
28	24	5	30	37	2.5	0.5	0.5	0.5	10	3	160
29	34	20	5	37	2.5	0.5	0.5	0.5	2	1	140
30	34	20	5	37	2.5	0.5	0.5	0.5	10	3	160
31	22	20	17	37	2.5	0.5	0.5	0.5	2	3	140
32	21	20	30	25	2.5	0.5	0.5	0.5	2	1	140

33	36	5	30	25	2.5	0.5	0.5	0.5	2	3	140
34	10	19	30	37	2.5	0.5	0.5	0.5	2	1	140
35	21	20	30	25	2.5	0.5	0.5	0.5	10	1	140
36	10	19	30	37	2.5	0.5	0.5	0.5	6	1	150
37	10	19	30	37	2.5	0.5	0.5	0.5	10	2	150
38	33.5385	19.7115	17.75	25	2.5	0.5	0.5	0.5	2	2	160
39	42.3654	5	17.75	30.8846	2.5	0.5	0.5	0.5	10	3	160

$x_1 = Sweet\ Potato\ Flour\ (\%)$, $x_2 = Corn\ Flour\ (\%)$, $x_3 = Soybean\ Flour\ (\%)$, $x_4 = Water\ (\%)$, $c_1 = Salt\ (\%)$, $c_2 = Sodium\ carbonate\ (\%)$, $c_3 = Guar\ gum\ (\%)$, $c_4 = Soy\ Lecithin\ (\%)$, $z_1 = Mixing\ time\ (mins)$, $z_2 = Frying\ time\ (mins)$, $z_3 = Frying\ Temperature\ (deg\ C)$

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 [12 - 15]. 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

The formulated noodles were analyzed and evaluated for the moisture content, crude protein, crude fibre, ash content, crude fat, carbohydrate, energy value, water absorption index, cooking time, cooking weight, bulk density and sensory characteristics (Tables 2)..

Table 2.*: Quality Properties of the formulated noodles*

Run	y_{mc}	y_{cp}	y_{cf}	y_{ac}	y_{cf}	y_{cho}	y_{ev}	y_{wai}	y_{ct}	y_{cw}	y_{bd}	y_{tex}	y_{tast}	y_{apea}	y_{flav}	y_{oa}
1	3.74	17.48	3.41	6.28	33	36.09	36.09	170	5.15	27	0.66	7	6	6	5	6
2	7.12	26.32	4.34	9.28	28.11	24.83	24.83	70	7.45	17	0.68	2	3	4	2	1
3	24.28	15.11	5	7.41	21.62	26.58	26.58	70	6	17	0.72	7	7	7	7	7
4	10	14.7	6.43	8.5	26.5	33.87	33.87	20	7.15	12	0.64	3	2	3	4	1

5	20.33	14	6.38	8.32	18	32.97	32.97	80	7	18	0.65	4	5	6	5	4
6	34.66	10.5	4.41	8.42	20.72	21.29	21.29	20	5.45	12	0.6	1	1	1	1	1
7	2.81	19.25	3.94	13	22.5	38.5	38.5	120	5.45	22	0.67	7	7	6	6	5
8	8.11	20.11	2.57	8.46	26.32	34.43	34.43	140	6	24	0.72	8	7	7	6	6
9	3.14	19.88	7.26	5.5	29	35.22	35.22	140	6.15	24	0.59	7	7	6	7	6
10	7.11	18.18	8	6.42	25.22	35.07	35.07	80	7.45	18	0.77	5	5	7	5	5
11	13.75	16.48	4.5	11.5	23.5	30.27	30.27	120	7.3	22	0.65	7	6	7	7	7
12	10.95	19.18	7.91	7.32	24	30.64	30.64	130	6.15	23	0.68	6	7	6	7	6
13	4.89	25.55	5.32	5.42	24	34.82	34.82	30	7	13	0.69	4	5	7	5	5
14	10.49	21	4.32	9.5	20.5	34.19	34.19	100	5.3	20	0.73	7	7	7	6	6
15	8.24	15.75	7.24	8.91	25.11	34.75	34.75	130	6.3	23	0.6	7	8	7	0	7
16	10.48	17.28	3.94	9.24	20.14	38.92	38.92	140	6	24	0.62	7	7	6	7	6
17	9.84	17.81	6.32	7.28	22.11	36.64	36.64	110	6.3	21	0.63	6	5	3	3	2
18	24.51	15.32	4.06	6.32	20.11	29.68	29.68	180	7	28	0.7	6	5	5	6	4
19	6.38	27.28	3.18	6.32	26.22	30.62	30.62	180	6.3	28	0.74	6	5	4	4	4
20	5.11	21	6	6	21.32	40.57	40.57	190	5.3	29	0.65	6	6	5	6	6
21	7.41	26.11	2.88	8.11	30.48	25.01	25.01	230	7.45	33	0.7	6	6	6	6	6
22	7	21.35	6.33	11.28	23.11	30.93	30.93	190	5.15	29	0.62	7	7	7	7	7
23	7.38	29.4	4.48	6.62	26.32	25.8	25.8	190	7.15	29	0.6	6	6	5	5	5
24	12.11	24.5	4.11	7.24	20.16	31.88	31.88	110	5.3	21	0.68	8	8	8	8	8
25	9.22	20.63	4.94	9.85	23.18	32.18	32.18	150	6	25	0.61	8	8	6	6	7
26	6.38	22.75	7.33	7.33	22.5	33.71	33.71	160	5.15	26	0.68	9	9	9	9	9
27	10.11	18.55	3.21	8.32	19.32	40.49	40.49	130	5	23	0.6	7	7	7	7	7
28	12.69	17.5	4.18	9.5	16	40.13	40.13	100	5.3	20	0.65	9	8	8	8	8
29	8.24	25.63	4.32	8.41	27.22	26.18	26.18	150	7.3	25	0.66	1	1	1	1	1
30	34.04	20.63	7.81	8.18	27.32	2.02	2.02	30	5.15	13	0.6	1	1	1	1	1
31	6.38	22.28	5.11	7.43	28.63	30.17	30.17	170	7	27	0.64	2	2	2	2	2
32	9.24	23.8	3.38	7.11	19.42	37.05	37.05	140	5.15	24	0.67	8	8	9	7	7
33	6.11	23.48	7.24	8.11	25.11	29.95	29.95	140	5.3	24	0.65	7	7	6	7	7
34	6.33	20.11	6.81	6.33	27.32	33.1	33.1	150	5.45	25	0.7	9	9	9	9	9
35	11.11	14	4	5.33	22.11	43.45	43.45	130	5	23	0.63	8	8	9	8	8
36	7.48	20.11	4.11	4.11	27.32	36.87	36.87	160	5.45	26	0.65	9	8	8	7	8
37	8.23	19.11	5.32	10.11	24.63	32.6	32.6	150	6.3	25	0.65	9	8	7	8	8
38	8.11	18.18	7.55	6.42	25.22	34.52	34.52	80	7.3	18	0.75	3	3	5	3	1
39	31.42	16.38	4.04	8.33	22.33	17.5	17.5	120	4.15	22	0.6	7	8	6	7	7

$y_{mc} = Moisture\ Content\ (\%)$, $y_{cp} = Crude\ Protein\ (\%)$, $y_{cf} = Crude\ Fibre\ (\%)$, $y_{ac} = Ash\ Content\ (\%)$, $y_{cf} = Crude\ Fat\ (\%)$, $y_{cho} = Carbohydrate\ (\%)$, $y_{ev} = Energy\ Value\ (kcal/100g)$, $y_{wai} = Water\ Absorption\ Index\,(g/g)$, $y_{ct} = Cooking\ Time\ (mins)$, $y_{cw} = Cooking\ Weight\,(\%\ increase\ in\ g)$,

y_{bd} = Bulk density $(g / cubic\ centimeters)$, y_{tex} = Texture, y_{tast} = Taste, y_{apea} = Appearance, y_{flav} = Flavour, 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 formulated noodles' quality and sensory properties were presented in Tables 3.

Table 3. *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	1.89	0.1495	0.1393	0.0656	-0.0713	69.77	3.8747
	L/Mixture	1.89	0.1495					
y_{cp}	Model	1.11	0.3572	0.0870	0.0088	-0.1284	20.84	2.6124
	L/Mixture	1.11	0.3572					
y_{cf}	Model	-	-	0.000	0.000	-0.0533	30.55	NA
y_{ac}	Model	1.00	0.286	0.0239	-0.0597	-0.2023	23.77	1.6043
	L/Mixture	1.00	0.286					
y_{cf}	Model	2.85	0.0513	0.1963	0.1275	-0.0038	14.08	5.4842
	L/Mixture	2.85	0.0513					
y_{cho}	Model	2.36	0.0879	0.1685	0.0972	-0.0661	21.77	5.4376
	L/Mixture	2.36	0.0879					
y_{ev}	Model	2.36	0.0879	0.1685	0.0972	-0.0661	21.77	5.4376
	L/Mixture	2.36	0.0879					
y_{wai}	Model	3.02	0.0425	0.2058	0.1377	0.0226	36.75	5.4557
	L/Mixture	3.02	0.0425					
y_{ct}	Model	-	-	0.000	0.000	-0.0533	14.91	NA
y_{cw}	Model	3.02	0.0425	0.2058	0.1377	0.0226	20.46	5.4557
	L/Mixture	3.02	0.0425					
y_{bd}	Model	1.54	0.2204	0.1169	0.0412	-0.0768	6.88	3.5443
	L/Mixture	1.54	0.2204					
y_{oa}	Model	4.58	0.0083	0.2819	0.2204	0.1084	40.28	6.7210
	L/Mixture	4.58	0.0083					

P-values less than 0.05 indicate models and model terms that are significant. R^2, this 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. Adeq 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 (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 final equations of the formulated noodles' quality indices, in Terms of L_pseudo components and Coded Factors, are summarized in Table 4.

Table 4: Models Coefficients of Formulated Noodles' Quality Indices

$$y_{Moisture\ Content} = 11.0654x_1 + 5.48883x_2 + 5.96072x_3 + 34.4925x_4 \tag{1}$$

$$y_{Crude\ Protein} = 17.9467x_1 + 26.528x_2 + 19.5389x_3 + 17.2334x_4 \tag{2}$$

$$y_{Crude\ Fibre} = 5.17128x_0 \tag{3}$$

$$y_{Ash\ Content} = 8.43953x_1 + 7.01888x_2 + 8.00114x_3 + 6.9173x_4 \tag{4}$$

$$y_{Crude\ Fat} = 23.0706x_1 + 35.1645x_2 + 18.8634x_3 + 21.7317x_4 \tag{5}$$

$$y_{Carbohydrate} = 33.4814x_1 + 22.9269x_2 + 42.4024x_3 + 13.8909x_4 \tag{6}$$

$$y_{Energy\ Value} = 33.4814x_1 + 22.9269x_2 + 42.4024x_3 + 13.8909x_4 \tag{7}$$

$$y_{Water\ Absorption\ Index} = 107.27x_1 + 201.135x_2 + 157.452x_3 - 13.733x_4 \tag{8}$$

$$y_{Cooking\ Time} = 6.05769x_0 \tag{9}$$

$$y_{Cooking\ Weight} = 20.727x_1 + 30.1135x_2 + 25.7452x_3 + 8.6267x_4 \tag{10}$$

$$y_{Bulk\ density} = 0.640744x_1 + 0.744466x_2 + 0.659314x_3 + 0.590058x_4 \tag{11}$$

$$y_{Texture} = 5.19215x_1 + 2.36733x_2 + 11.3404x_3 + 2.26993x_4 \tag{12}$$

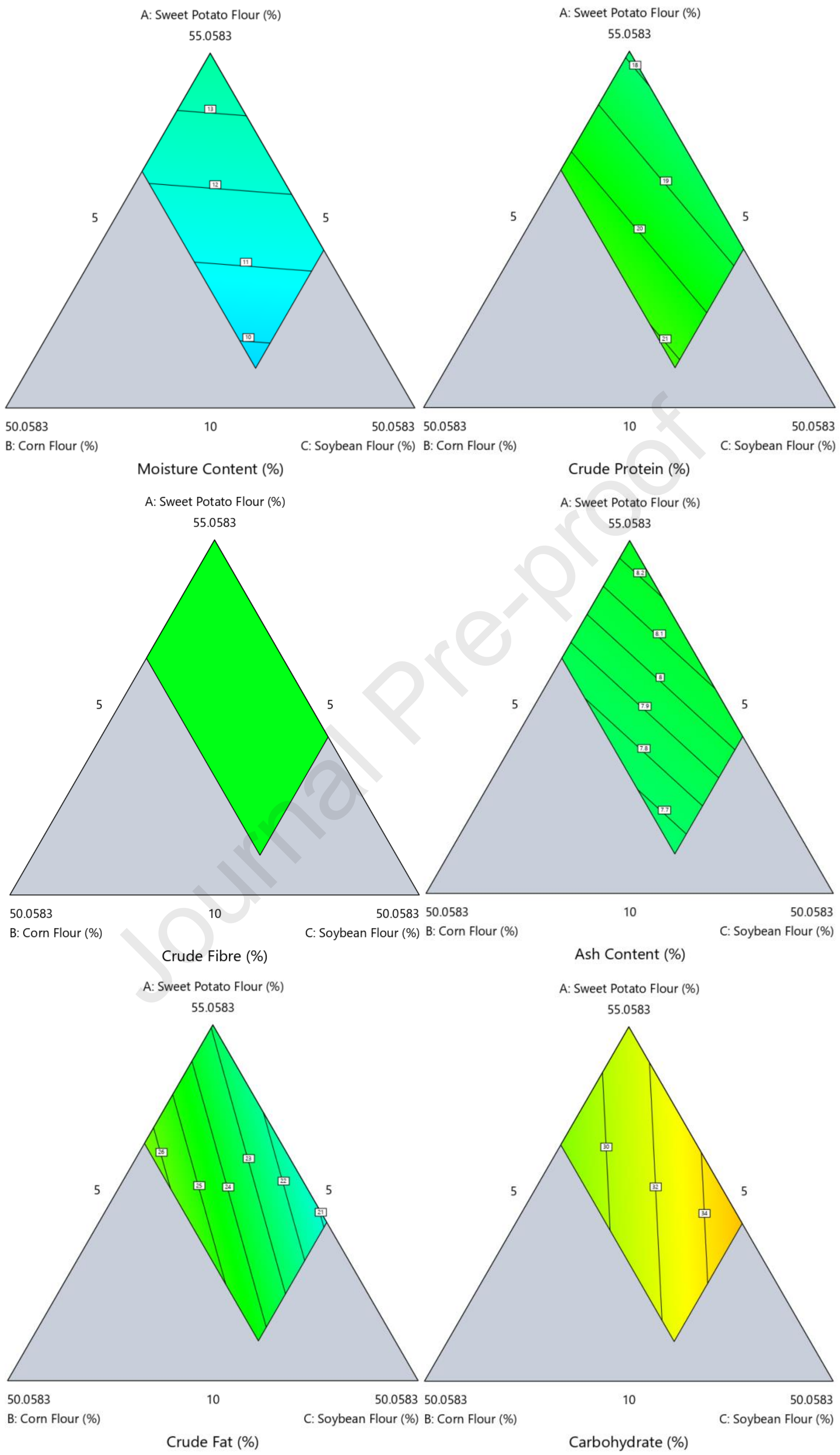
$$y_{Taste} = 5.32385x_1 + 1.32386x_2 + 11.7386x_3 + 1.57472x_4 \tag{13}$$

$$y_{Appearance} = 5.22519x_1 + 2.12404x_2 + 11.051x_3 + 1.42538x_4 \tag{14}$$

$$y_{Flavour} = 4.31318x_1 + 1.04484x_2 + 11.3674x_3 + 2.69392x_4 \tag{15}$$

$$y_{Overall\ Acceptability} = 4.66919x_1 + 0.819455x_2 + 10.7792x_3 + 2.27657x_4 \tag{16}$$

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: Sweet Potato Flour (%)
55.0583
5
5
50.0583
B: Corn Flour (%)
10
50.0583
C: Soybean Flour (%)
Moisture Content (%)
Crude Protein (%)
Crude Fibre (%)
Ash Content (%)
Crude Fat (%)
Carbohydrate (%)

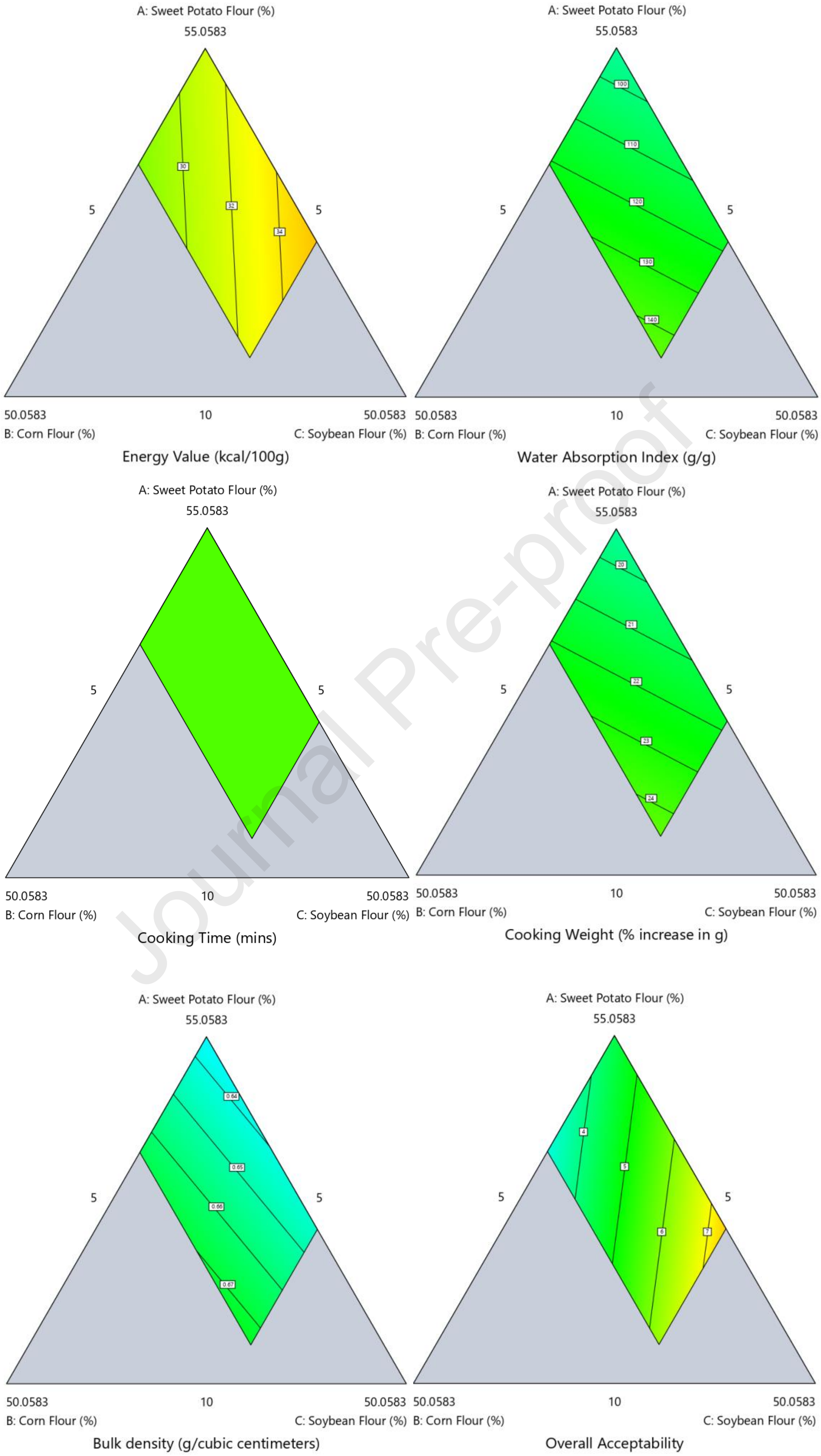
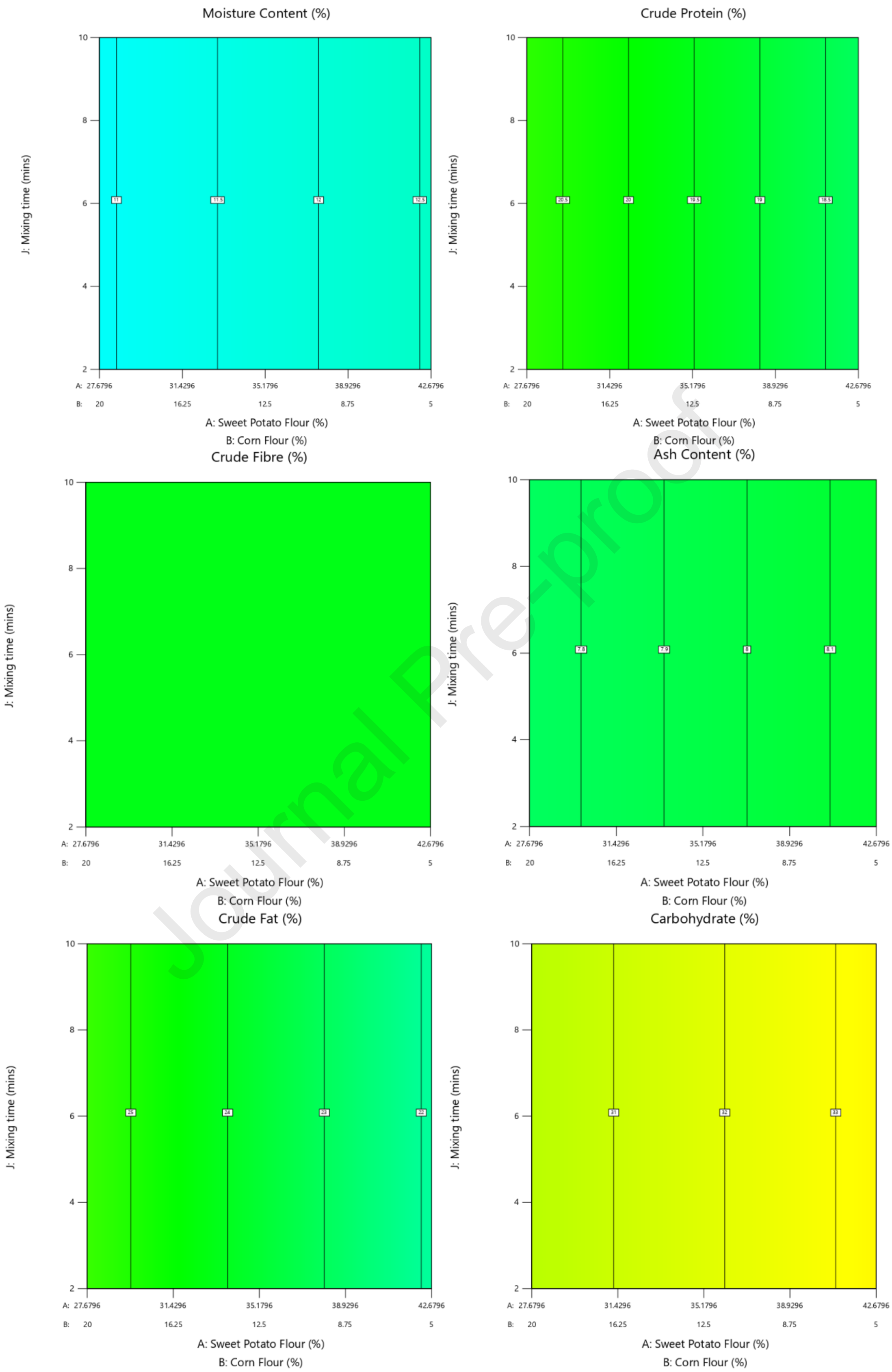


Figure 1. *The Quality Parameters Contour Plots for the Formulated Noodles*


Moisture Content (%)
J: Mixing time (mins)
A: Sweet Potato Flour (%)
B: Corn Flour (%)
Crude Protein (%)
J: Mixing time (mins)
A: Sweet Potato Flour (%)
B: Corn Flour (%)
Crude Fibre (%)
J: Mixing time (mins)
A: Sweet Potato Flour (%)
B: Corn Flour (%)
Ash Content (%)
J: Mixing time (mins)
A: Sweet Potato Flour (%)
B: Corn Flour (%)
Crude Fat (%)
J: Mixing time (mins)
A: Sweet Potato Flour (%)
B: Corn Flour (%)
Carbohydrate (%)
J: Mixing time (mins)
A: Sweet Potato Flour (%)
B: Corn Flour (%)

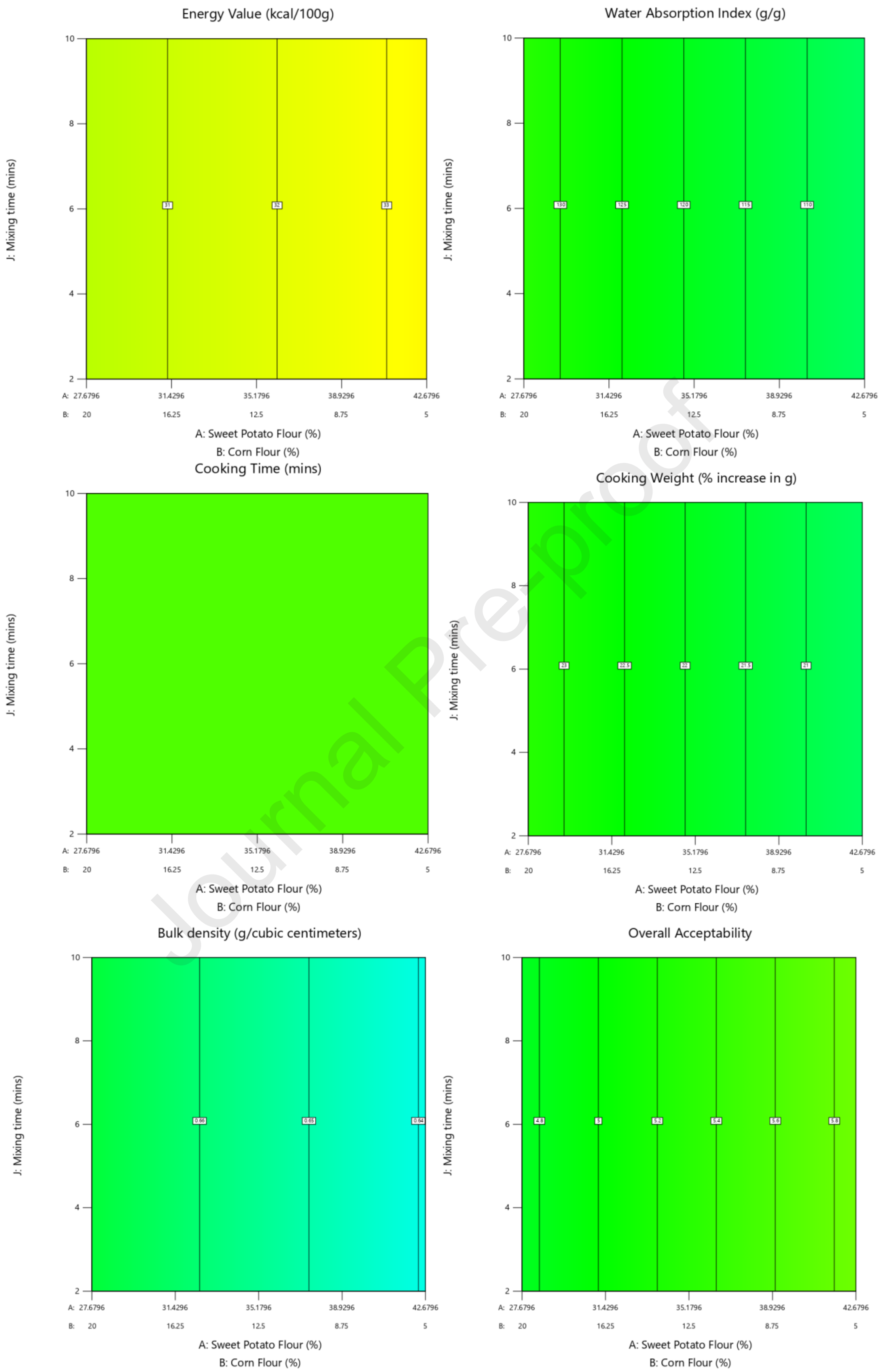
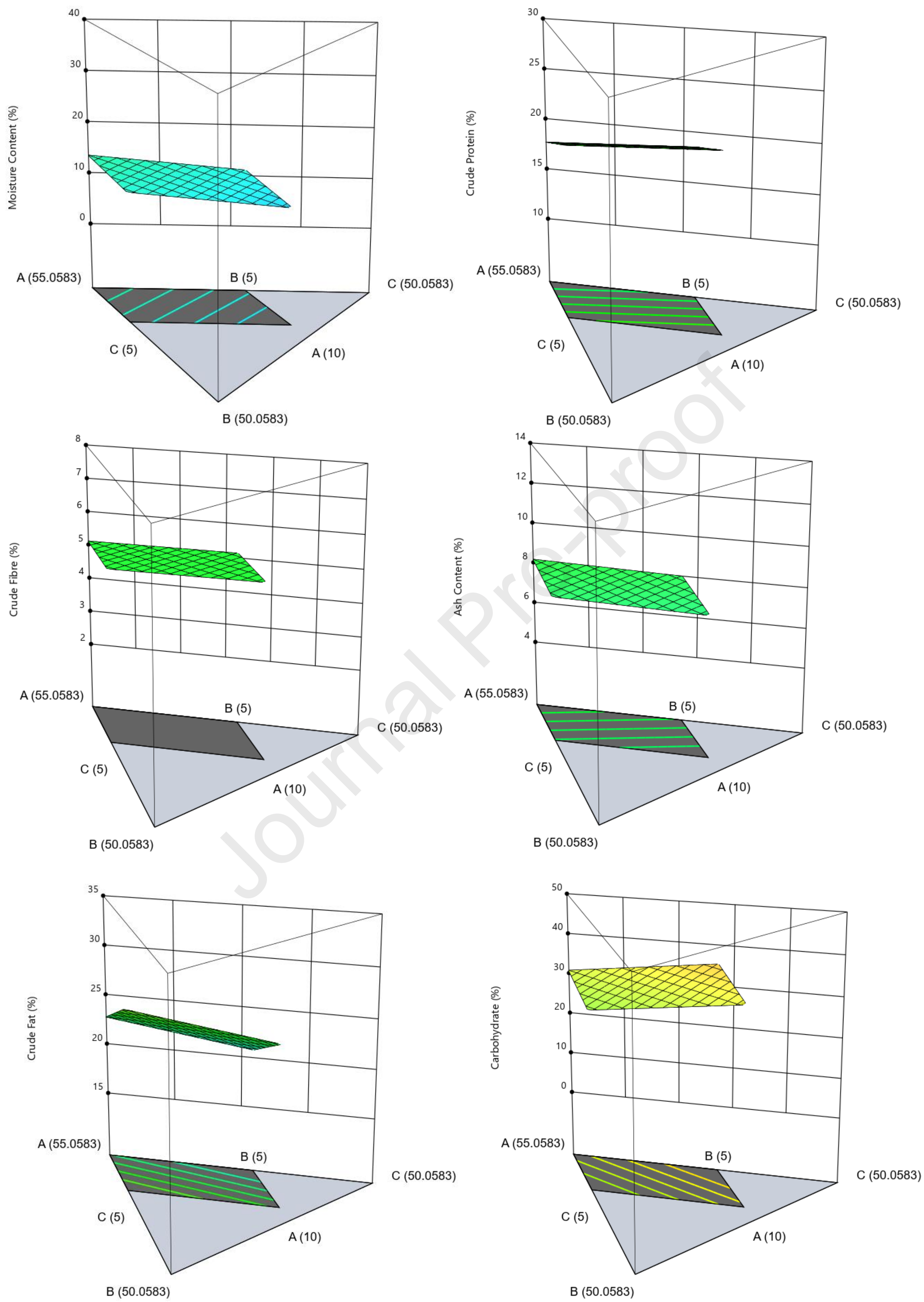


Figure 2. *The Quality Parameters Mix-Process Plots for the Formulated Noodles*


Moisture Content (%)
0
10
20
30
40
A (55.0583)
B (5)
C (50.0583)
C (5)
A (10)
B (50.0583)
Crude Protein (%)
10
15
20
25
30
A (55.0583)
B (5)
C (50.0583)
C (5)
A (10)
B (50.0583)
Crude Fibre (%)
2
3
4
5
6
7
8
A (55.0583)
B (5)
C (50.0583)
C (5)
A (10)
B (50.0583)
Ash Content (%)
4
6
8
10
12
14
A (55.0583)
B (5)
C (50.0583)
C (5)
A (10)
B (50.0583)
Crude Fat (%)
15
20
25
30
35
A (55.0583)
B (5)
C (50.0583)
C (5)
A (10)
B (50.0583)
Carbohydrate (%)
0
10
20
30
40
50
A (55.0583)
B (5)
C (50.0583)
C (5)
A (10)
B (50.0583)

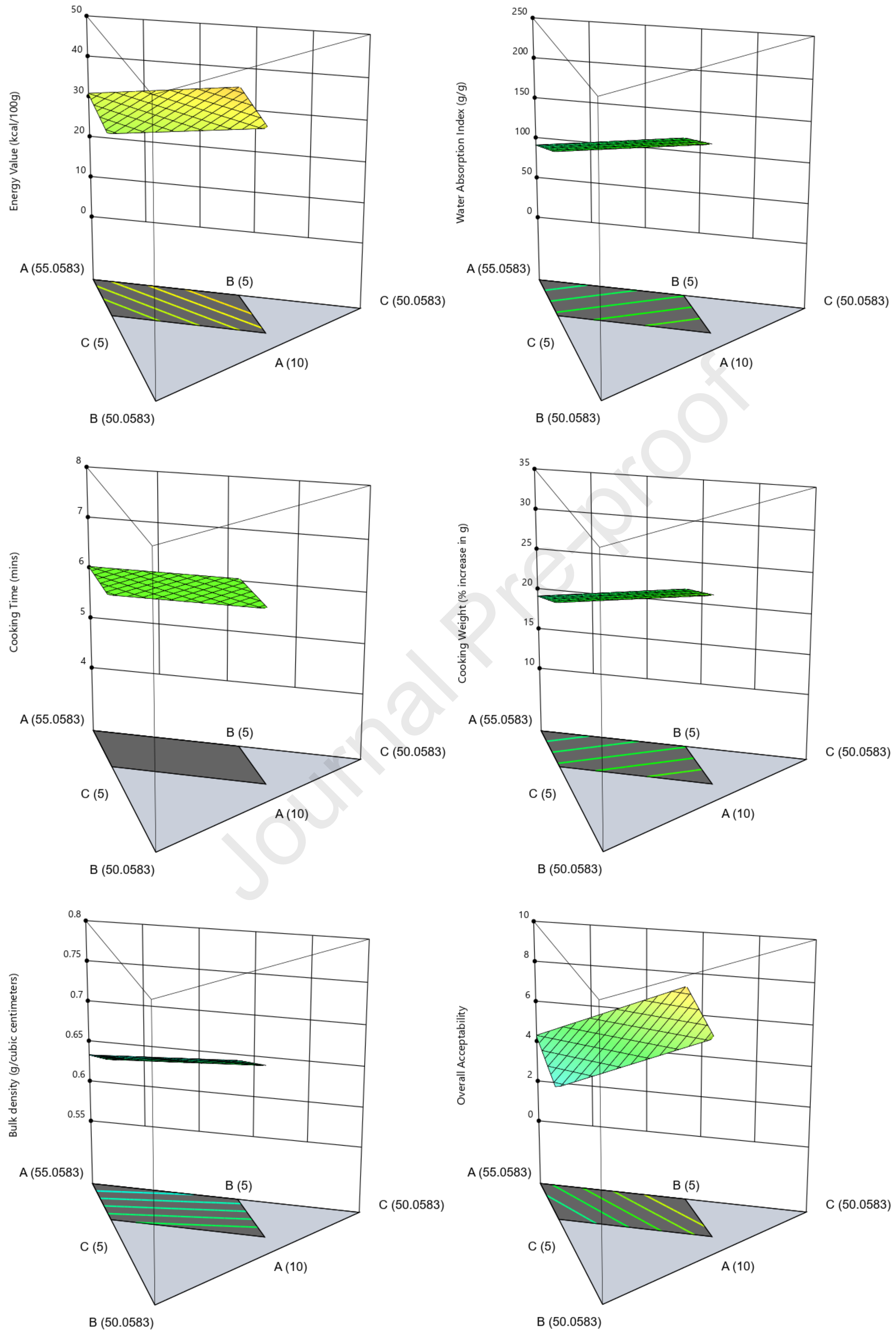
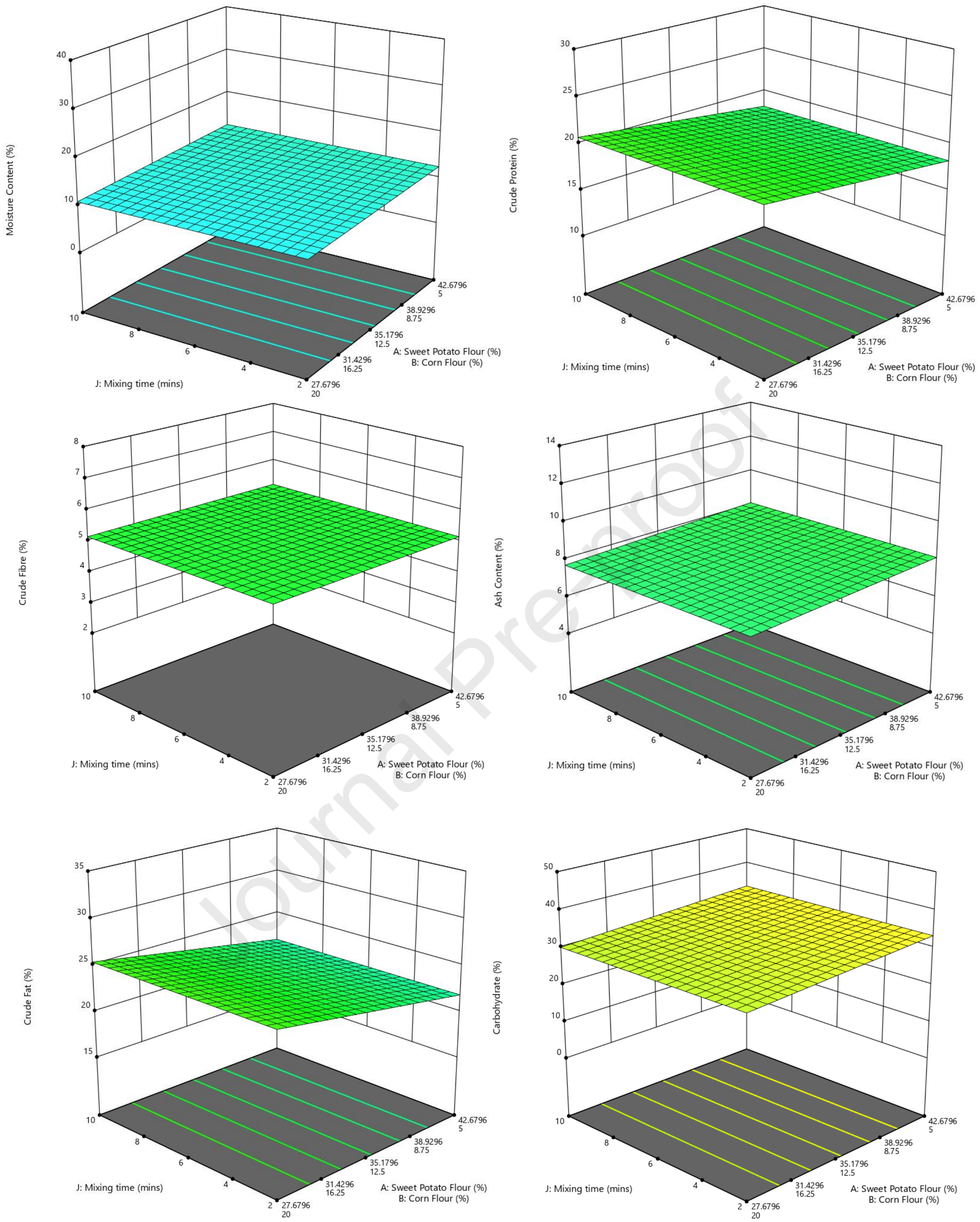


Figure 3. *The Quality Parameters 3-D Surface Plots for the Formulated Noodles*



Moisture Content (%)
40
30
20
10
0
J: Mixing time (mins)
10
8
6
4
2
A: Sweet Potato Flour (%)
B: Corn Flour (%)
27.6796
20
31.4296
16.25
35.1796
12.5
38.9296
8.75
42.6796
5
Crude Protein (%)
30
25
20
15
10
Crude Fibre (%)
8
7
6
5
4
3
2
Ash Content (%)
14
12
10
8
6
4
Crude Fat (%)
35
30
25
20
15
Carbohydrate (%)
50
40
30
20
10
0

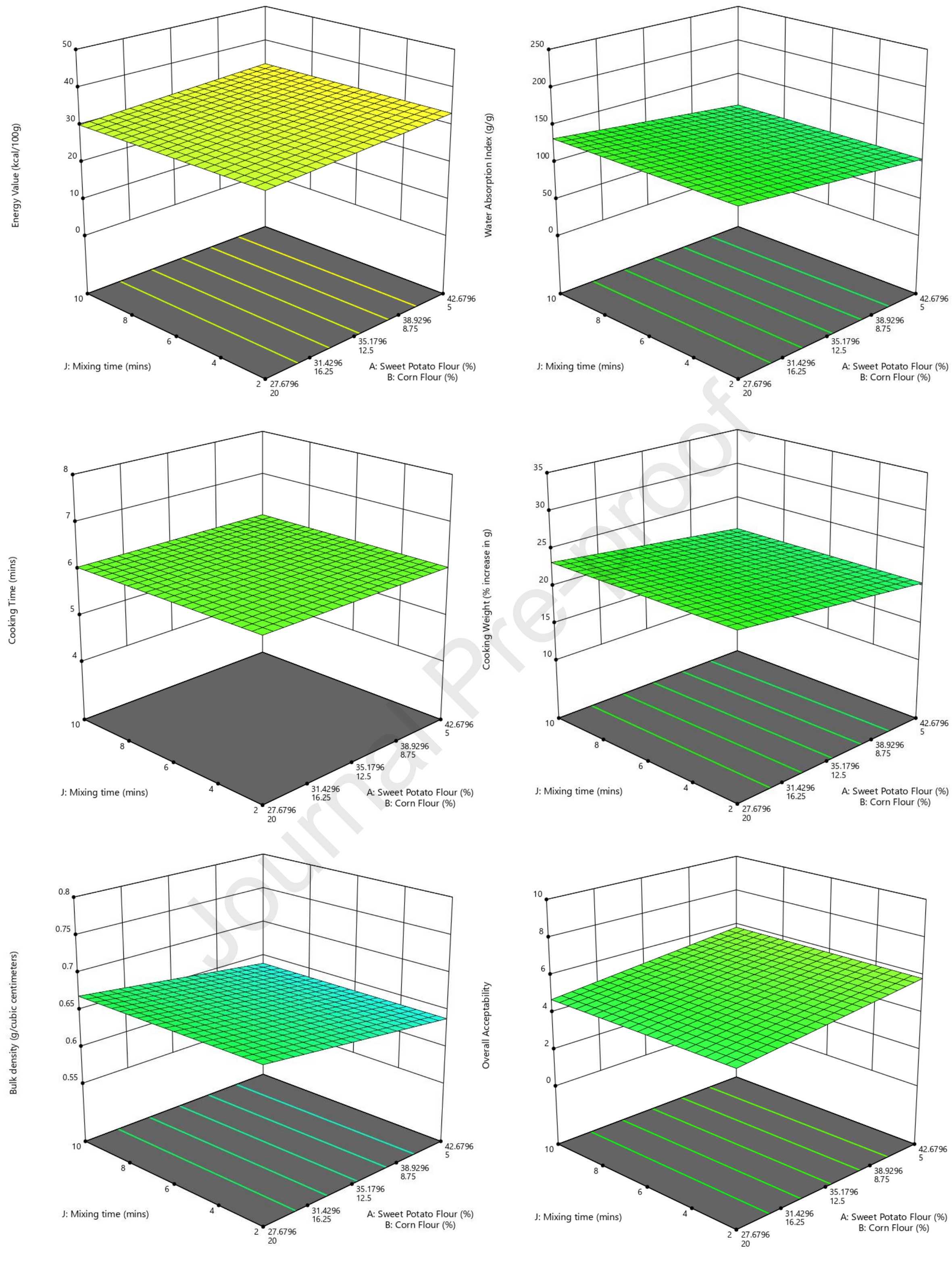


Figure 4. The Quality Parameters 3-D Surface Mix-Process Plots for the Formulated Noodles

3.3. Optimization Constraints/Settings

The summary of the optimization constraints employed for the formulated noodles are presented in Table 5.

Table 5. *Optimization constraints for the Formulated Noodles*

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance

Sweet Potato Flour	is in range	10	61	1	1	3
Corn Flour	is in range	5	20	1	1	3
Soybean Flour	is target = 30	20	30	1	10	5
Water	is in range	25	37	1	1	3
Mixing time	is in range	2	10	1	1	3
Frying time	is in range	1	3	1	1	3
Frying Temperature	is target = 140	140	140	1	5	5
Moisture Content	is target = 14	2.81	14	1	10	5
Crude Protein	is target = 29.4	10.5	29.4	1	10	5
Crude Fibre	is in range	2.57	8	1	1	3
Ash Content	is in range	4.11	13	1	1	3
Crude Fat	is in range	16	33	1	1	3
Carbohydrate	minimize	2.02	43.45	1	1	3
Energy Value	is target = 43.45	2.02	43.45	1	10	5
Water Absorption Index	is target = 38	20	230	1	5	3
Cooking Time	is in range	4.15	7.45	1	1	3
Cooking Weight	is in range	12	33	1	1	3
Bulk density	is in range	0.59	0.77	1	1	3
Texture	is in range	1	9	1	1	3
Taste	is in range	1	9	1	1	3
Appearance	is in range	1	9	1	1	3
Flavour	is in range	0	9	1	1	3
Overall Acceptability	maximize	1	9	1	1	3

3.4. Results of Numerical Optimization of the Formulated Noodles

Optimal production conditions were obtained, based on set optimization goals and individual quality desirability indices; using numerical optimization, via desirability function technique. fifty-two desirability formulation conditions (component proportions) were found and summarized in Table 6, with the quality properties of the optimal formulation for the formulated noodles presented in Tables 7 and 8.

Table 6. *Optimal formulation conditions for the Formulated Noodles*

No	x_1	x_2	x_3	x_4	c_1	c_2	c_3	c_4	z_1	z_2	z_3	D_i	
1	**23.228**	**8.815**	**27.508**	**36.449**	***2.500***	***0.500***	***0.500***	***0.500***	***8.169***	***2.502***	***144.031***	**0.518**	**Selected**
2	27.033	6.205	27.303	35.459	*2.500*	*0.500*	*0.500*	*0.500*	*2.145*	*2.244*	*155.709*	0.516	
3	23.024	9.714	30.000	33.262	*2.500*	*0.500*	*0.500*	*0.500*	*2.321*	*1.077*	*140.000*	0.503	
…. .	……… ….	…… …..	…… ……	…… …..	…… …..	…… …	……… ..	…… ..	…… ….	…… …..	……… ….	…… ….	
50	27.904	12.812	20.568	34.716	*2.500*	*0.500*	*0.500*	*0.500*	*3.613*	*1.406*	*159.236*	0.320	
51	29.700	17.982	22.617	25.702	*2.500*	*0.500*	*0.500*	*0.500*	*8.365*	*1.571*	*157.543*	0.318	
52	41.342	6.902	20.654	27.102	*2.500*	*0.500*	*0.500*	*0.500*	*5.606*	*1.597*	*146.702*	0.294	

$x_1 = Sweet\ Potato\ Flour\ (\%)$, $x_2 = Corn\ Flour\ (\%)$, $x_3 = Soybean\ Flour\ (\%)$, $x_4 = Water\ (\%)$, $c_1 = Salt\ (\%)$,

c_2 = Sodium carbonate (%), c_3 = Guar gum (%), c_4 = Soy Lecithin (%), z_1 = Mixing time (mins),
z_2 = Frying time (mins), z_3 = Frying Temperature (deg C)

***Table** 7. The quality properties of the optimal formulated noodles*

No	y_{mc}	y_{cp}	y_{cf}	y_{ac}	y_{cf}	y_{cho}	y_{ev}	y_{wai}	D_i	
1	**13.654**	**19.131**	**5.171**	**7.798**	**21.818**	**32.231**	**32.231**	**109.275**	**0.518**	**Selected**
2	13.506	18.699	5.171	7.902	21.242	33.116	33.116	106.617	0.516	
3	11.843	19.405	5.171	7.847	21.909	33.705	33.705	120.942	0.503	
…	………	………	……	……	………	………	………	…………	………	
..	…	….	…	…….	….	……	….	…..	….	
49	9.383	19.570	5.171	8.064	23.241	34.413	34.413	132.265	0.325	
50	13.116	19.611	5.171	7.798	23.384	30.856	30.856	113.912	0.320	
51	8.205	20.671	5.171	7.906	24.677	33.607	33.607	146.832	0.318	
52	10.256	18.726	5.171	8.189	22.175	35.018	35.018	121.185	0.294	

y_{mc} = Moisture Content (%), y_{cp} = Crude Protein (%), y_{cf} = Crude Fibre (%),
y_{ac} = Ash Content (%), y_{cf} = Crude Fat (%), y_{cho} = Carbohydrate (%), ,
y_{ev} = Energy Value (kcal / 100g) y_{wai} = Water Absorption Index (g / g), D_i = Overall Desirability Index

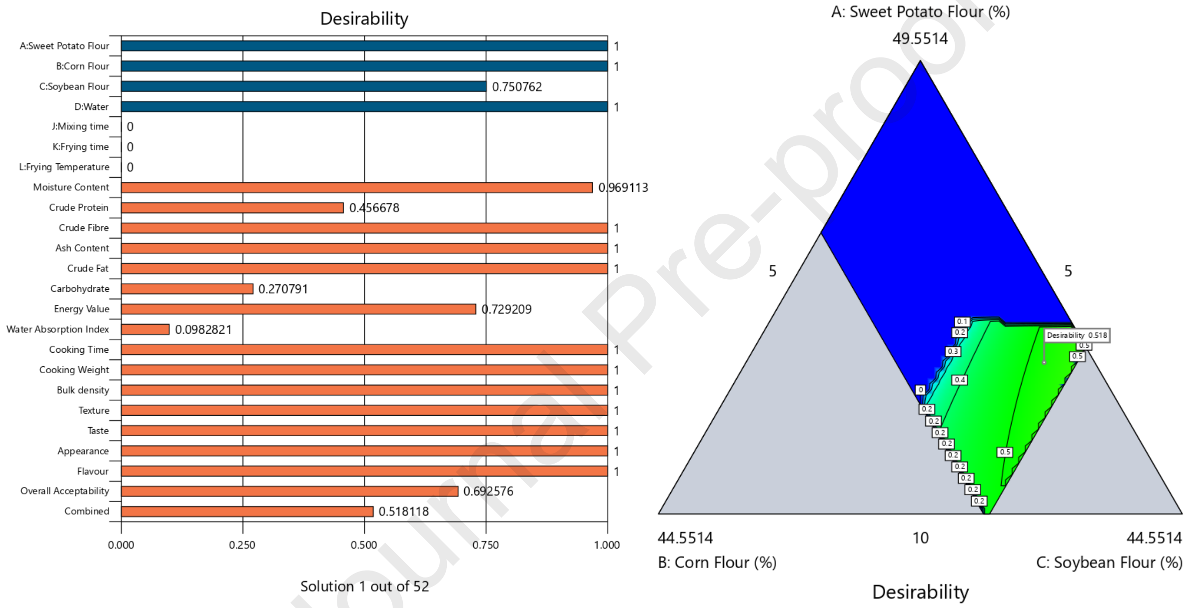
***Table 8.** The quality properties of the optimal formulated noodles*

No	y_{ct}	y_{cw}	y_{bd}	y_{tex}	y_{tast}	y_{apea}	y_{flav}	y_{oa}	D_i	
1	**6.058**	**20.928**	**0.645**	**7.038**	**7.014**	**6.711**	**6.818**	**6.541**	**0.518**	**Selected**
2	6.058	20.662	0.641	7.215	7.266	6.920	6.989	6.760	0.516	
3	6.058	22.094	0.651	7.471	7.491	7.179	7.207	6.921	0.503	
…	………	………	………	……	……	……	………	………	………	
.	…..	…..	…..	…….	…….	……	…..	…..	…..	
50	6.058	21.391	0.653	6.079	5.955	5.805	5.657	5.489	0.320	
51	6.058	24.683	0.673	6.557	6.470	6.396	5.896	5.767	0.318	
52	6.058	22.118	0.648	6.853	6.989	6.741	6.290	6.302	0.294	

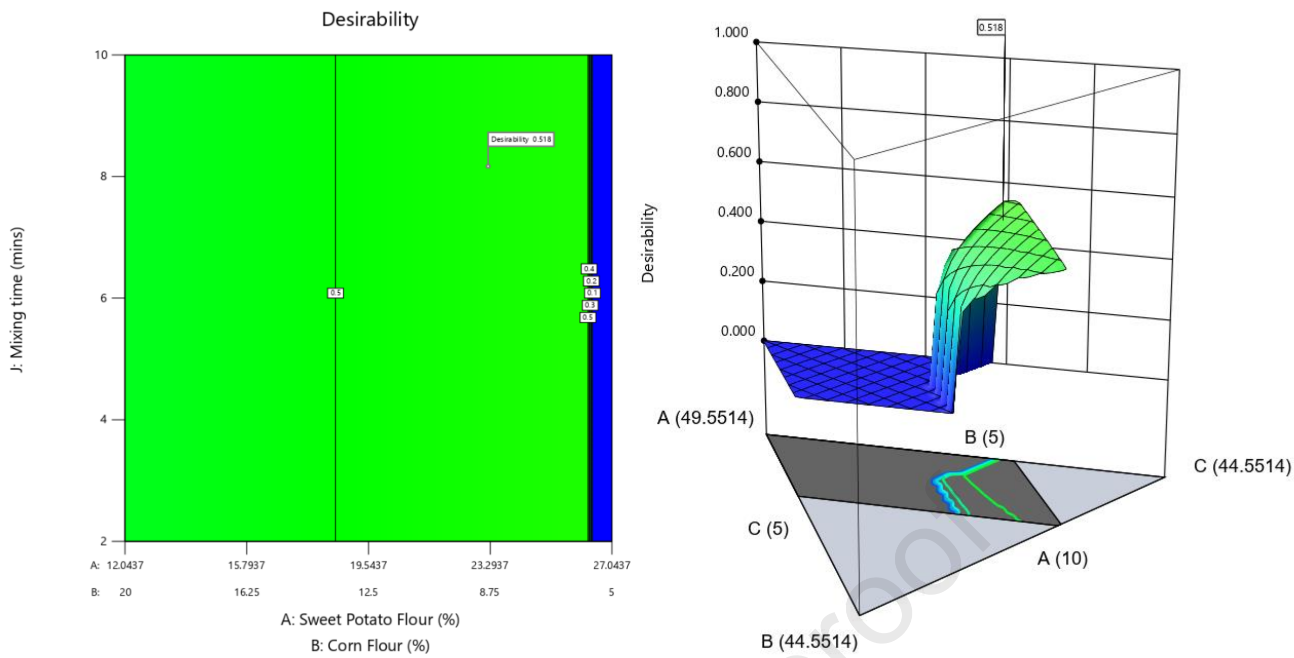
y_{ct} = Cooking Time (mins), y_{cw} = Cooking Weight (% increase in g),
y_{bd} = Bulk density (g / cubic centimeters), y_{tex} = Texture, y_{tast} = Taste, y_{apea} = Appearance,
y_{flav} = Flavour, y_{oa} = Overall Acceptability, D_i = Overall Desirability Index

The numerical solution desirability bar graph and desirability contour plot for the optimal formulated noodles 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. The graphical optimization contour and mix-process overlay plots gives the summary or details of the optimal conditions and quality properties of the optimal noodle. Exploiting the desirability function technique, the formulation that produced formulated noodles of the highest desirability index of 0.518 was 23.228% sweet potato flour, 8.815% corn flour, 27.508% soybean flour, 36.449% water, 2.500% salt, 0.500% sodium carbonate, 0.500% guar gum, 0.500% soy lecithin; with 8.169min mixing time, 2.5min frying time, and 1440C frying temperature. The quality properties of this optimal noodle were 13.654% moisture content, 19.131% crude protein, 5.171% crude fibre, 7.798% ash content, 21.818% crude fat, 32.231% carbohydrate, 32.231 kcal/100g energy value, 109.275 g/g water absorption index, 6min cooking time, 20.928 (% increase in g) cooking weight, 0.645 (g/cubic centimeters) bulk density, and overall acceptability of 6.54, based on 9-point hedonic scale.

In a study, four flour blends of wheat, soybean and carrot pomace flour in ratios of 100:0:0, 80:15:5, 70:20:10, 60:25:15, respectively, were used to produce instant fried noodles. It was reported that incorporation of soybean flour and carrot pomace flour improved the nutritional quality and sensory attributes of the instant fried noodles. Sensory analysis showed that noodles prepared from substitution of wheat with 15% soybean flour and 5% carrot pomace flour had the highest rating in taste, color, aroma, texture and overall acceptability. However, sensory characteristics like smell, taste, appearance influences food acceptability more than the nutritive value.[16]. In a study, the influence of various supplements (extruded maize, maize, defatted soy flour and maize/soy flour blends, lecithin and wheat straw) on the noodle's quality was examined. Common wheat flour were supplemented with 1% lecithin powder, 20% extruded maize flour, 20% maize flour, 10% defatted soy flour, 20% defatted soy and maize flour blend (1:1), and 7.5% wheat straw. Noodles made with extruded maize, maize flour and wheat straw supplements had the highest total sensory score. The addition of defatted soy flour in the noodles production recorded an improvement in the quantity and nutritional quality [17]. In a study, the quality and physicochemical properties of noodles made from blends of chayotextle flour and wheat semolina were investigated. The results showed that the inclusion of chayotextle flour increased both the hardness and adhesiveness of the noodles, and there was a 10% increase in cohesiveness and elasticity when using this particular flour [18].



Figures 5: The numerical solution desirability bar graph and desirability contour plot for the optimal formulated noodles



Figures 6: The numerical solution desirability mix-process and 3-D surface plots for the optimal noodles

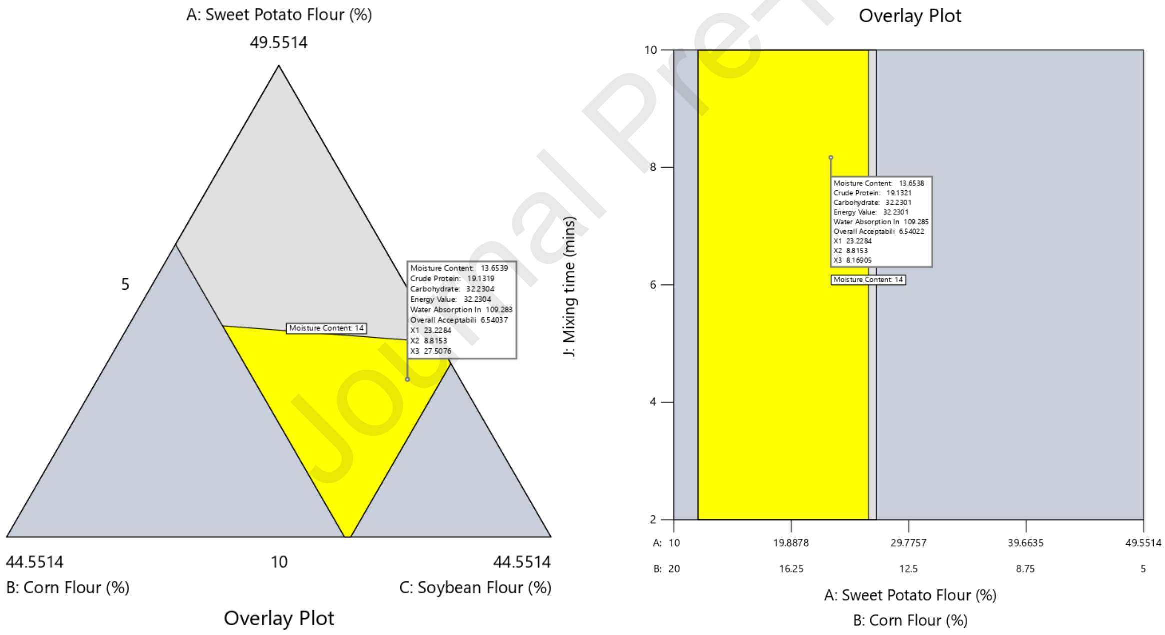


Figure 7. The *graphical optimization contour and mix-process overlay plots for the optimal noodles*

4. Conclusion

Wheat flour commonly used in making traditional noodles is rich in starch but poor in protein, vitamins, minerals, and fibre. This study encourages exploitation of underutilized local food resources in the production of noodles. There are many flours which can be used as base materials for the formulation of composite flours. There is the need for concerted researches on formulating noodles from blends of different unique local food ingredients. Products made from non-wheat flour or from composite flour are the latest trend in producing noodles and baked goods. Currently, composite flour formulation concept in which flours with high nutritional, functional and sensory properties derived from cereals, roots, tubers, and legumes (with or without the addition of wheat flour) are blended for noodles production has evolved to enhance nutritional quality of noodles. The concept is aimed at improving the overall quality properties of noodles. Today foods are not intended to only satisfy hunger but also to improve physical and mental well-being of humans by providing necessary nutrients for and to prevent nutrition-related diseases. Composite flour noodles are gluten-free and can be formulated to meet the dietary needs of different categories of consumers or target populations. This is another phase which this research is aimed at achieving, though not treated in in this presentation. Now a day's noodles are being considered to be most efficacious means of delivering supplementary nutritional on to weaker and vulnerable sections suffering from calories malnutrition.

Efforts are been made to promote the use of composite flour in noodles productions, thereby decreasing the demand for imported wheat, improving the nutritional content of cookies, and also enhancing indigenous crop utilization. Protein-rich noodles are gaining popularity in countries where protein energy malnutrition is prevalent. Composite flour noodles can serve as good vehicle or source of protein, energy, minerals, and vitamins for the majority of the population. Using composite products technology, noodles were developed, characterized and optimized, from blends of sweet potato flour, corn flour, soybean flour, and other minor ingredients, via a constrained, randomized, combined, D-optimal mixture-process experimental design. 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. The methodology is a quality by design, systematic approach to food development that is based on science and quality management. It begins with predefined objectives and emphasizes product and process understanding as well as process control. The emphasis is multivariable experimentation, design of experiments, process modeling, optimization, and simulation. The approach begins with quality target product profile, which is a prospective summary of the quality characteristics of the food product that ensures the desired quality, and then works backward through the food product and food formulation processes; establishing a holistic understanding of which attributes are linked to consumers' dietary requirements and functional relationships of these attributes. The approach is a multidimensional combination and interaction of input variables (e.g., ingredients proportions) and process parameters that have been demonstrated to provide assurance of quality. A new product should be adequately designed before any serious product development is undertaken.

Conflict of Interests

The authors declare that they have no competing interests.

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References

[1] Yadav, B. S., Yadav, R. B., Kumari, M., & Khatkar, B. S. (2014). Studies on suitability of wheat flour blends with sweet potato, colocasia and water chestnut flours for noodle making. LWT-Food Science and Technology, 57, 352–358. doi:10.1016/j.lwt.2013.12.042

[2] World Instant Noodle Association. (2013). WINA expanding market: National trends in instant noodles demand. Retrieved from http://instantnoodles.org/noodles/expanding marketon25/12/2013

[3] Uchenna Uzo, Louis Nzegwu, (2018) "Indomie Noodles in Africa: lessons on digital and cultural branding", Emerald Emerging Markets Case Studies, Vol. 8 Issue: 1, pp.1-18, https://doi.org/10.1108/EEMCS-03-2017-0048

[4] Onigbogi, I. O., Sanni, L. O., Hou, G., & Shittu, T. A. (2014). Development of cassava flour supplemented-wheat flour instant noodles. Proceedings of the 33rd Conference and Annual General Meetings of the Nigerian Institute of Food Science and Technology. 13–15th October, Lagos, Nigeria.

[5] Olalekan J. Adebowale, Hafeez A. Salaam, Olakunle M. Komolafe, T. A. Adebiyi & Idayat O. Ilesanmi (2016): Quality Characteristics of Noodles Produced from Wheat Flour and Modified Starch of African Breadfruit (Artocarpus altilis) Blends, Journal of Culinary Science & Technology, DOI: 10.1080/15428052.2016.1204973

[6] Omeire, G.C., Umeji, O.F. and Obasi, N.E 2014. Acceptability of Noodles Produced from Blends of Wheat, Acha and Soybean Composite Flours. Nigerian Food Journal; Official Journal of Nigerian Institute of Food Science and Technology; Vol. 32 No. 1, pages 31 – 37, 2014. www.nifst.org

[7] Afifah N and Ratnawati L. (2021). Quality assessment of dry noodles made from blend of mocaf flour, rice flour and corn flour. IOP Conf. Series: Earth and Environmental Science 101 (2017) 012021 doi:10.1088/17551315/101/1/012021

[8] Habibat Adedotun, Abdul-Rasaq A. Adebowale, Ibiyemi O. Olayiwola, Taofik A. Shittu & Lateef O. Sanni (2015) Production and Quality Evaluation of Noodles from Sweet Potato Starch, Journal of Culinary Science & Technology, 13:1, 79-93, DOI: 10.1080/15428052.2014.952479

[9] Yu-Chan Huang amd Hsi-Mei Lai. (2009). Noodle quality affected by different cereal starches. Journal of Food Engineering 97 (2010) 135–143. doi: 10.1016/j.jfoodeng.2009.10.002

[10] Bahnassey, Y., Khan, K. and Harrold, R. 1986. Fortification of spaghetti with edible legumes. I. Physicochemical, antinutritional, amino acid and mineral composition. Cereal Chem. 63: 210 – 215. https://scirp.org/reference/referencespapers.aspx?referenceid=410113

[11] Hasmadi, M., Siti Faridah, A., Salwa, I., Matanjun, P., Abdul Hamid, M. and Rameli, A. S. 2014. The effect of seaweed composite flour on the textural properties of dough and bread. J Appl Phycol (2014):1057–1062. DOI 10.1007/s10811-013-0082-8.

[12] Myers, Raymond H. and Montgomery, Douglas C, 1995. Response surface methodology: process and product optimization using designed experiments. John Wiley & Sons, Inc., Hoboken, New Jersey. Pp 557-567.

[13] Cornell, John A., 2002. Experiments with mixtures: designs, models, and the analysis of mixture data. John Wiley & Sons, Inc., New York. Pp 2-20.

[14] Wendell, F. Smith., 2005. Experimental design for formulation. ASA-SIAM Series on Statistics and Applied Probability, SIAM, Philadelphia, ASA, Alexandria, VA. Pp 15-23

[15] Cornell, John A., 2011. A primer on experiments with mixtures. John Wiley & Sons, Inc., Hoboken, New Jersey. Pp 2, 6-13

[16] Tiony Mercy Chepkosgei and Irene Orina. 2021. Quality and sensory properties of instant fried noodles made with soybean and carrot pomace flour. African Journal of Food Science. Vol. 15(3) pp. 92-99, March 2021 DOI: 10.5897/AJFS2020.2019 Article Number: E29065966228. http://www.academicjournals.org/AJFS.

[17] Ugarčić-Hardi Ž., Jukić M., Koceva Komlenić D., Sabo M., Hardi J. (2007): Quality parameters ofnoodles made with various supplements. Czech J. Food Sci., 25: 151–157.

[18] Lizbeth González Victoriano, Norma Güemes Vera1, Sergio Soto Simental, Juan Pablo Hernández, Aurora Quintero Lira, Javier Piloni Martini. (2021). Quality properties of doughs and noodles using chayotextle (Sechiem edule) flours. Food Sci. Technol, Campinas, 41(1): 158-166, DOI: https://doi.org/10.1590/fst.30219

Highlights

- This study optimized the production of noodles.
- A four-component constrained D-optimal mixture-process design, was employed.
- The numerical optimization yielded an overall desirability index of 0.518.

Declaration of Interest Statement

The author declares no conflict of interest. The author alone is responsible for the content and writing of the manuscript.