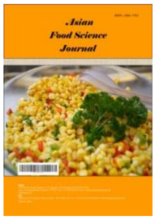

Asian Food Science Journal

20(4): 1-21, 2021; Article no.AFSJ.66597
ISSN: 2581-7752

Optimisation of Rice-Kidney Beans Composite Flours Incorporated with Fermented and Unfermented Sorghum Flours for the Production of Ready-to-Eat Extruded Snacks

Olugbenga Olufemi Awolu[1*] and Adeyanmola Oluwaseyi Akintade[2]

[1]Department of Food Science and Technology, Federal University of Technology, Akure, Nigeria.
[2]Department of Food Science and Technology, Olusegun Agagu University of Science and Technology, Okitipupa, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Author OOA designed the research, supervised, performed statistical analyses, wrote the protocol and wrote the first draft of the manuscript. Author AOA managed literature searches and took part in writing the manuscript. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AFSJ/2021/v20i430284
Editor(s):
(1) Dr. Amjad Iqbal, Abdul Wali Khan University Mardan, Pakistan.
Reviewers:
(1) Abdulkadir Ndabokun Aliyu, National Cereal Research Institute Badeggi, Nigeria.
(2) Carmen Cuadrado, INIA, Spain.
Complete Peer review History: http://www.sdiarticle4.com/review-history/66597

Original Research Article

Received 09 January 2021
Accepted 12 March 2021
Published 20 March 2021

ABSTRACT

Aims: Rice-based ready-to-eat extruded snack was developed by incorporating the rice flour with kidney bean, fermented surgum and unfermented sorghum flours with the sole aim of accessing the effect of the addition of the kidney bean and sorghum on the nutritional quality of the extruded snack developed.
Methodology: Rice-dried kidney bean composite flours were supplemented with fermented and unfermented sorghum grains were optimized using optimal design model of response surface methodology; the dependent variables were the proximate and mineral compositions. The extrusion process was also optimized using central composite design of response surface methodology. The sensory evaluations of the extrudates were carried out.
Results: The result of the product optimization of the composite flours gave the R-squared and adjusted R-squared of the ash, crude fibre and crude protein to be between 0.9961 and 0.9987. R-

**Corresponding author: Email: ooawolu@futa.edu.ng;*

squared and adjusted R-squared close to unity is an indicated of statistical model that is fit, and hence, show that the independent variables support the dependent variables strongly. So, we can deduce that the independent variables strongly supported the ash, crude fibre and crude protein contents. The extrusion results showed that screw speed was the most potent factor required for the extrusion process, followed by temperature. Sample 19 having independent variables of 21.7% screw speed, 80°C temperature and 105 rpm resulted in extruded snack with the highest overall sensory acceptability.

Conclusion: Acceptable snacks with over 70% sensory qualities were developed. Addition of fermented sorghum flour resulted in composite flour with protein content were well above 100%.

Keywords: Extruded snack; fermented sorghum flour; optimization; protein content; response surface methodology; rice flour.

1. INTRODUCTION

Developments in functional foods production continues to attract research interests. There is a shift from nutritionally-rich foods to foods that are both nutritionally-rich and health-promoting [1,2] This shift might not be unconnected to increase in several diseases associated with stress and production of free radicals in the living systems. Another development in healthy food baked products is the reduction or total removal of gluten from the foods. Gluten-free products as rightly called are meant to address consumers who are gluten intolerant, resulting in celiac diseases. Production of gluten-free foods products and development of functional foods have promoted the utilization of several other raw materials aside wheat. Several researches have been carried out on utilization of non-wheat food materials for the production of health foods. Some of the non-wheat materials that have been utilized include several cereals, psudo cereals, legumes, tubers, oil seeds [3,4].

Baked food products are one of the most promising food products for the actualization of nutraceuticals. This is basically because of the easy possibilities of utilizing raw materials with healthy components such as antioxidant properties in addition to their rich nutritional properties. This development of utilizing several raw materials (composite flours) to developed nutraceuticals and nutritionally-rich foods are being utilized in the production of bread, snacks, cookies and others that can be regarded as nutraceuticals.

Red kidney bean (*Phaseolus Vulgaris L.*) contains high amounts of dietary fibre, starch, vitamins, minerals as well as an extensive array of phytochemicals. However, the most important component of its nutritional significance is its high protein content which is 2-3 times that of cereal grains [5]. Due to its high protein content, red kidney beans are used as supplements in the human diet and are also used in the production of snacks in their composited forms [6]. Several researches on the incorporation of legumes for the enhancement of the nutritional and functional qualities of baked and other food products have been carried out [7].

Sorghum (*Sorghum bicolour L. Moench*) grains has been found to contain about 68 – 75% starch, in addition to its rich antioxidants, fibre, iron and protein contents [8]. The antioxidants components are phenolic compounds and anthocyanins which help to reduce inflammation and lower free radical damage.

Rice (*Oryzae sativa*) is widely used for the production of baked products, and it is a good alternative to wheat in preparing gluten-free foods [9]. In addition to being a rich source of energy, it has high digestibility, a good source of vitamin B1, B2 and B3, minerals (calcium, magnesium and phosphorus) and other trace elements like iron, zinc and manganese [10].

Extrusion is a HTST process which involves simultaneous thermal and pressure treatment along with mechanical shearing, resulting in changes such as gelatinization of starch, denaturation of protein and at times, complete cooking of the extrudate [11] to obtain ready to eat products [12]. Extrusion brings variability into snacks, hence, it has great potentials among snack consumers [13].

The present study optimized the physico-chemical composition of the rice, sorghum and kidney beans composite flour. The pasting characteristics and in-vitro antioxidant activities of the optimized composite flour were evaluated. The samples with the best physicochemical composition, pasting characteristics and in-vitro antioxidant activities were extruded. The sensory assessment of the extruded snack was also carried out to evaluate its acceptability.

2. MATERIALS AND METHODS

2.1 Materials

Rice, Sorghum, Kidney-bean and wheat grains were obtained from Oja-Oba, Akure, Ondo State, Nigeria. Locally fabricated food extruder fabricated by NASOD Engineering Ltd, Ogun State, Nigeria was sourced in the Food Processing Laboratory of the Federal University of Abeokuta (FUNAAB) Nigeria. All reagents used were of analytical grade.

2.2 Processing of Raw Food Materials into Flours

Local rice grains obtained were winnowed to remove extraneous materials. It was then washed in distilled water until properly cleaned, and subsequently sun-dried to to an acceptable moisture content required for milling. The rice was milled into fine flour using an attrition mill, and then sieved through a 212 µm sieve size to obtain fine flour [14].

Sorghum grain were processed into flour according to the method described by [15]. The sorghum was sorted to remove debris and other extraneous matters. It was then cleaned in distilled water and sun-dried to reduce the moisture content to an acceptable level before milling using a hammer mill. The flour was then sieved through a 212 µm sieve to obtain the fine flour. The sorghum was divided into fermented and unfermented samples.

Kidney beans flour was prepared by using the method of [16] and modified by [17]. Exactly 250 g kidney beans seeds were thoroughly washed, soaked in water for 30 min, manually dehulled, boiled at 100°C for 30 min, oven-dried (in a thermostated oven, Model MC-1959 K, China) at 65°C for 6 h, milled using locally fabricated attrition mill and made to pass through 212 µm sieve. It was subsequently stored in a sealed plastic container at room temperature.

2.3 Experimental Design for Composite Flour Formulation using Response Surface Methodology

The experimental design for the blends of rice, sorghum and kidney beans flours was carried out using optimal mixture design of response surface methodology (Design expert 8.3.0.1 trial version). The independent variables were rice flour (A), kidney bean flour (B), unfermented sorghum flour (C) and fermented sorghum flour (D). Xanthan gum was added to the composite flours at 0.5% of total weight. The samples were then blended together using a laboratory mixer. The composite flour samples were stored in air tight containers and were analyzed for Proximate, Minerals, Functional, Pasting properties, Antioxidant and Anti-nutritional composition. Wheat flour was used as a control sample.

2.4 Proximate Determination of Composite Flours

Proximate compositions, that is, moisture content, ash, crude fibre, crude fat and crude protein contents of experimental food samples were determined using the standard methods [18]. Carbohydrate content was determined by difference.

2.5 Minerals Composition Determination of Composite Flours

The mineral compositions of calcium (Ca), and zinc (Zn) were determined using Atomic Absorption Spectrophotometer (AAS Model SP9). Sodium (Na) and potassium (K) were determined using flame emission photometer (Sherwood Flame Photometer 410, Sherwood Scientific Ltd. Cambridge, UK) with NaCl and KCl as the standards [18].

2.6 Extrusion Processing

This was carried out according to [12] procedure using locally fabricated food extruder fabricated by NASOD Engineering Ltd, Ogun State, Nigeria and sourced from the Department of Food Science and Technology, Federal University of Agriculture, Abeokuta, Nigeria. The configurations of the extruder are 304:18.5 L/D ratios, 18 mm screw diameter, 1.74 KW Power and 304 mm barrel diameter. Optimizing the extrusion processes, the variables were moisture content, A, (15-29 g/100g), temperature, B, (63-97^{o}C), and screw speed, C, (70-120 rpm), while the responses were throughput, lateral expansion and residence time.

2.7 Sensory Evaluation of Extruded Snacks

The extruded snack was subjected to sensory test using 10 semi-trained panelists, where evaluation using [19] was done on the basis of appearance, taste, texture, mouth-feel and overall acceptability using a 9-point hedonic scale (9-like extremely, 8-like very much, 7-like moderately, 6-like slightly, 5-neither like nor dislike, 4-dislike slightly, 3-dislike moderately, 2-dislike very much and 1-dislike extremely).

2.8 Statistical Analysis

All data were analyzed using SPSS version 20.0 and RSM Design Expert 8.3.0.1 design expert trial version. The mean and standard error of means (SEM) of the triplicate analyses were calculated. The analysis of variance (ANOVA) was performed to determine significant differences between the means, while the means were separated using the New Duncan Multiple Range Test (NDMRT).

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of the Optimised Composite Flours

The result of the proximate composition of the flour blends is presented in Table 1. Sample run 21 is the control consisting 100% wheat flour. The moisture contents of all the samples are lesser than the recommended value of 10 g/100 g recommended for flour samples [20]. Moisture contents lesser than 10 g/100 g guarantees better shelf life of the food materials [21].

The ash content of the composited flour blends ranges between 1.04 g / 100 g to 1.70 g / 100 g. Ash content is a useful indication of the amount of minerals present in the flour which can be attributed to a specific number of functions in the body [22]. The analysis of variance (ANOVA) result for ash content showed the model was special cubic, and the model terms (linear mixture, AB, AC, BC, CD, ABC, ACD and BCD) were significant ($P \leq 0.05$). The R-squared and Adjusted R-squared values were 0.9987 and 0.9958, respectively. High R-squared and Adjusted R-squared indicated that the raw materials support the ash contents. In addition, the contour plot showing the effect of the composite flour on the ash content Figs. 1a,1b,1c) clearly indicated that both fermented and unfermented sorghum had almost the same effect on the ash content. The effect of the sorghum on the ash content was however the highest.

The crude fibre content of the composited flour blend ranges from 4.23 g/100 g to 6.33 g /100 g. Dietary fibre have been reported to aid the rate of digestion and absorption of nutrients and chemicals [23]. Also, soluble fibre supplements may be beneficial for alleviating symptoms of irritable bowel syndrome, such as diarrhea or constipation and abdominal discomfort [24] and are effective in reducing total blood cholesterol [25]. The analysis of variance (ANOVA) result for crude fibre content showed the model was special cubic, and model terms (linear mixture, AB, AC, BC, CD, ABC, ACD and BCD) were significant ($P \leq 0.05$). The R-squared and Adjusted R-squared values were 0.9957 and 0.9864 respectively and close to 1.000, indicating a good model. The contour plots Figs. 2a,2b,2c showed that unfermented sorghum had the highest contribution to the crude fibre.

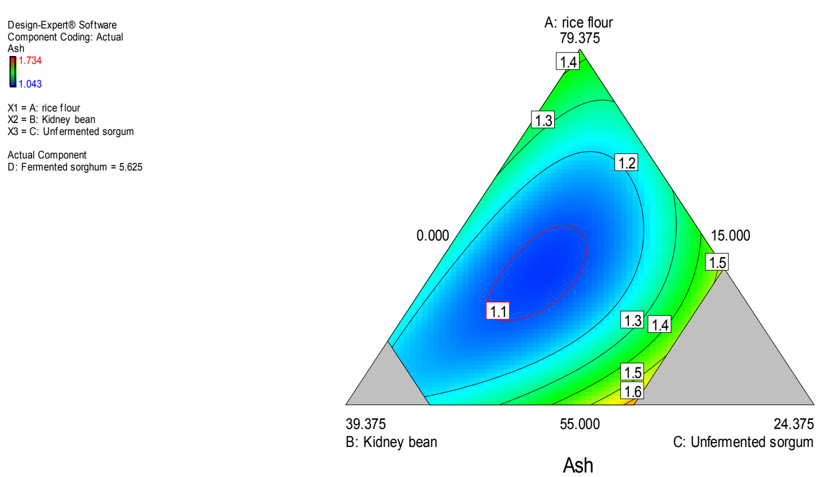

Fig. 1a. Contour plot showing the effects of the composite flour on ash content

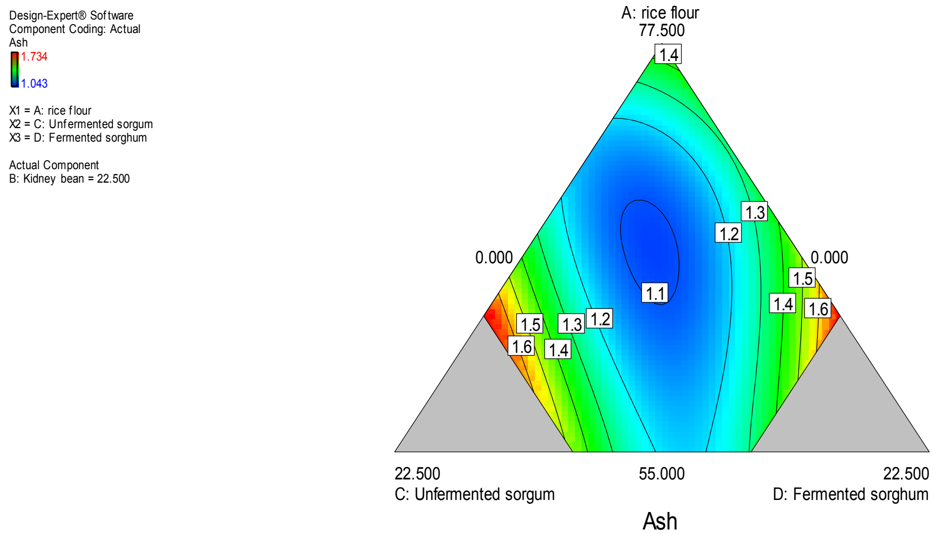

Fig. 1b. Contour plot showing the effects of the composite flour on ash content

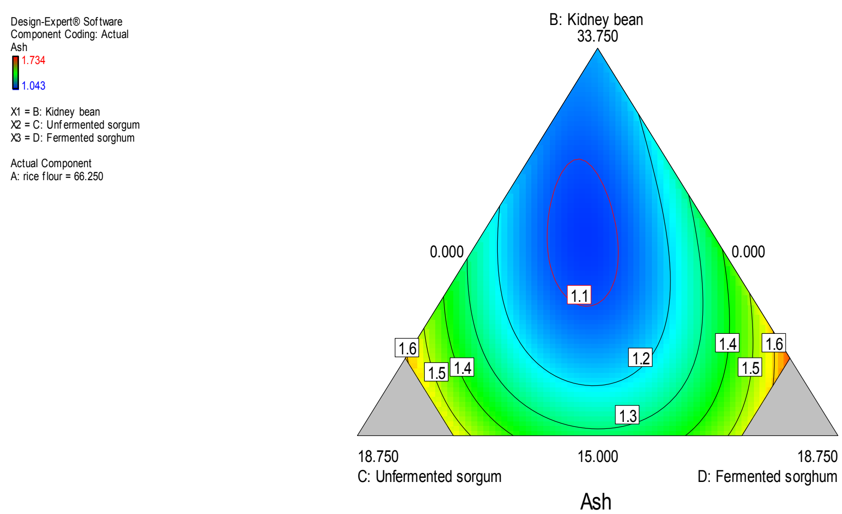

Fig. 1c. Contour plot showing the effects of the composite flour on ash content

The fat content of the composited flour blends ranged from 1.395 g/100 g to 2.030 g/100 g. A high fat content will affect the keeping quality of the product in an oxidative rancidity process [12]. The amount of fat in the composited flour blend is low enough to enhance the keeping quality of the extruded snack. Addition of fat during production of cookies and other baked products from the raw composite flours will further improve the energy content resulting from the lipids.

The protein content in the composited flour blends ranged from 9.010 g/100 g to 10.272 g/100 g. The contour plots Figs. 3a,3b,3c showed that kidney beans contributed most to the protein contents, and closely followed by rice flours. The most important component of nutritional significance of kidney beans is their high protein content which is 2-3 times that of cereal grains [5]. The analysis of variance (ANOVA) result for protein content of the composited flour blend showed the model was special cubic, and model terms (linear mixture, AB, AC, BC, CD, ABC, ACD, and BCD) were significant ($P \leq 0.05$). The R-squared and Adjusted R-squared values were 0.9959 and 0.9869, respectively, which showed that the model was good.

The carbohydrate content of the composited blends ranged from 72.84 g/100 g to 77.22 g/100 g. Rice is a good source of starch and will therefore, enhance the energy content of the products.

Table 1. Proximate composition of composite flour

Samples formulation (%)					Proximate composition of blends (g/ 100g)					
Run	**RF**	**KBF**	**USF**	**FSF**	**Moisture**	**Ash**	**Fibre**	**Fat**	**Protein**	**Carbohydrate**
1	63.01	35.00	0.98	1.01	7.65	1.04	5.43	1.83	9.71	74.34
2	64.95	25.33	9.62	0.11	7.42	1.29	5.02	1.73	9.49	75.05
3	55.00	35.00	10.00	0.00	6.63	1.70	4.63	1.95	9.02	76.09
4	55.00	15.00	15.00	15.00	6.45	1.15	5.97	1.90	10.19	74.34
5	70.00	15.00	15.00	0.00	7.16	1.55	6.31	2.03	9.98	72.97
6	61.95	16.29	14.99	6.77	7.31	1.48	6.33	1.95	9.36	73.58
7	55.00	35.00	0.00	10.00	6.30	1.69	4.95	1.86	10.24	74.97
8	72.37	27.63	0.00	0.00	6.22	1.38	4.32	1.87	9.480	75.40
9	77.40	15.00	0.19	7.41	6.17	1.45	5.41	1.40	9.89	75.69
10	70.01	15.00	7.79	7.20	6.89	1.28	5.80	1.44	9.19	75.40
11	55.00	35.00	0.00	10.00	6.35	1.69	5.135	1.85	10.27	74.94
12	55.00	25.21	4.79	15.00	7.14	1.55	4.39	1.52	9.98	75.44
13	62.91	22.09	0.00	15.00	6.93	1.73	5.21	1.63	9.89	74.61
14	70.00	15.00	15.00	0.00	7.21	1.55	6.32	2.03	9.98	72.84
15	70.00	15.00	0.00	15.00	6.23	1.70	4.47	1.61	9.63	76.38
16	85.00	15.00	0.00	0.00	6.08	1.50	4.23	1.82	9.45	76.94
17	55.00	15.00	15.00	15.00	6.46	1.15	5.97	1.90	10.19	74.36
18	85.00	15.00	0.00	0.00	6.08	1.48	4.23	1.84	9.39	77.22
19	55.00	25.18	15.00	4.82	6.33	1.70	4.62	1.74	9.54	74.33
20	55.00	35.00	10.00	0.00	6.65	1.69	4.62	1.95	8.96	75.97
21	0.00	0.00	0.00	0.00	6.58	1.50	5.00	1.65	9.54	75.74

Values are mean and are significantly different across the column at (p≤0.05)
Key: RF: Rice flour; KBF: Kidney bean flour; USF: Unfermented sorghum flour; FSF: Fermented Sorghum Flour

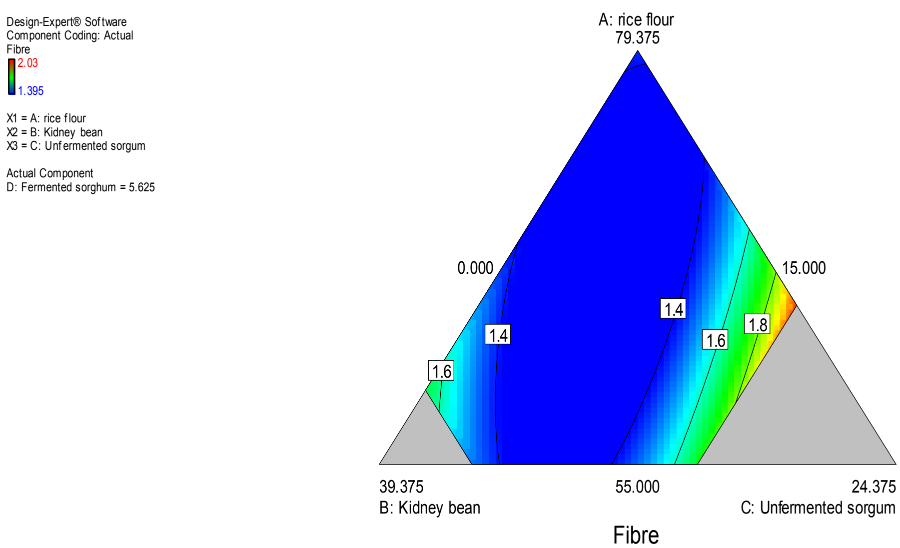

Fig. 2a. Contour plot showing the effects of the composite flour on fibre content

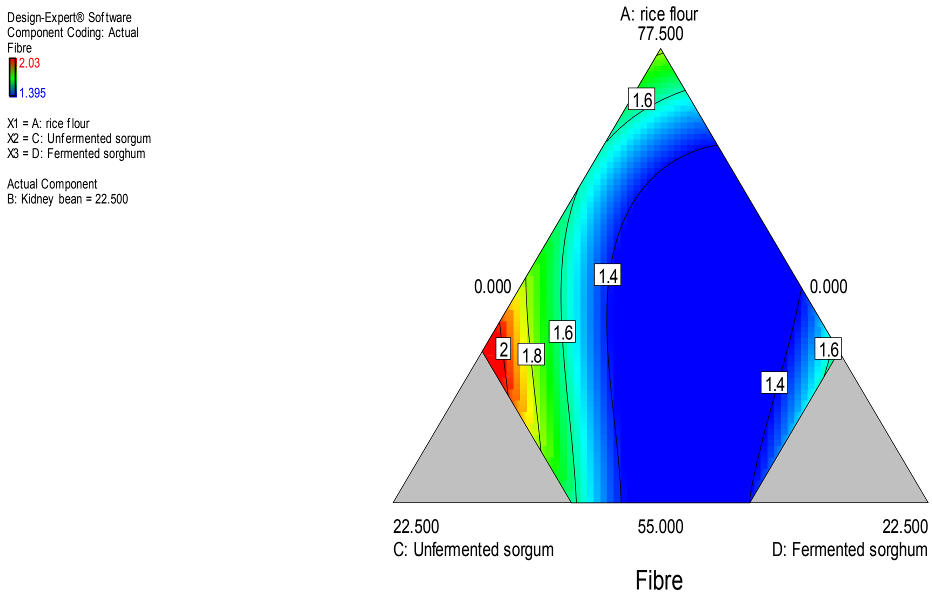

Fig. 2b. Contour plot showing the effects of the composite flour on fibre content

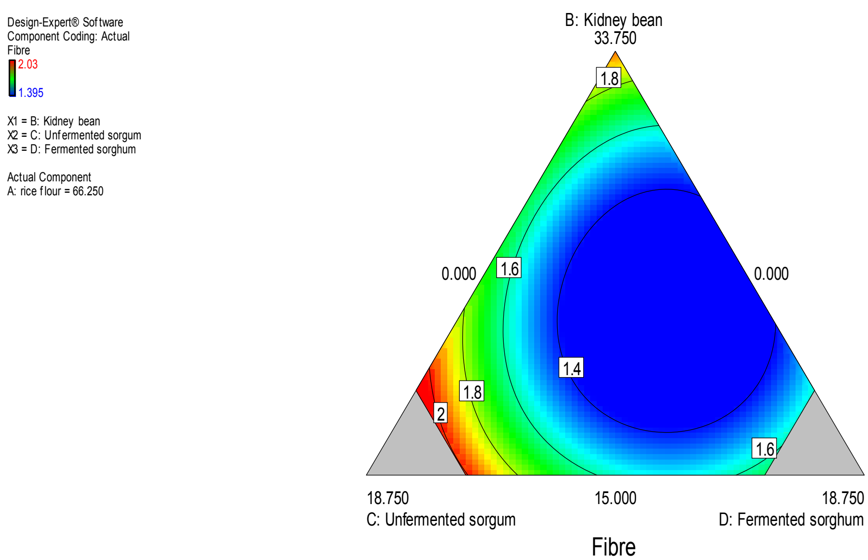

Fig. 2c. Contour plot showing the effects of the composite flour on fibre content

3.2 Minerals Compositions of the Optimized Composite Flours

The result of the mineral compositions of the flour blends is presented in Table 2. The samples contain high proportions of both Potassium and Magnesium and little proportions of Sodium, Calcium and Zinc. Minerals are important in the diet as they perform functions such as regulating the body, maintaining the internal pressure of the body. Potassium is especially known for its ability to maintain osmotic balance of the body fluids, pH of the body, to regulate muscle and nerve irritability, control glucose absorption, and to enhance normal retention of protein during growth [26].

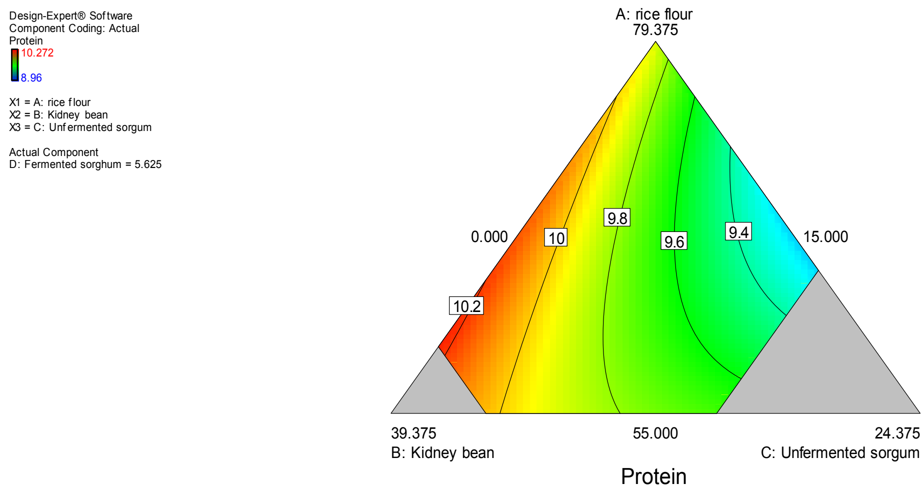

Fig. 3a: Contour plot showing the effects of the composite flour on protein content

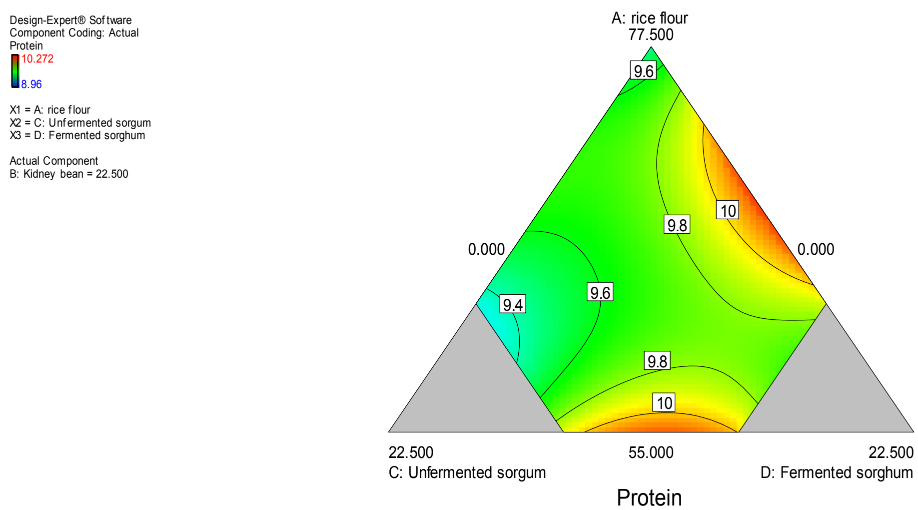

Fig. 3b. Contour plot showing the effects of the composite flour on protein content

Magnesium is especially useful for healthy bones, proper nervous system functioning and energy metabolism. The Na/K ratio of all the composited flour blend is less than 1, which could suggest that the snacks would be suitable for maintaining high blood pressure and reducing risks of cardiovascular diseases. The results for the analysis of variance (ANOVA) for calcium showed that the R-squared and Adjusted R-squared values were 0.8745 and 0.6027 respectively. The R-squared and Adjusted R-squared values could suggest that the raw materials had fair support for calcium contents. However, the R-squared and adjusted R-squared values for magnesium contents were 0.9675 and 0.8969 respectively; which were better than the values for calcium contents. The magnesium contents were actually the second highest after potassium content. Fig. 4 showed that kidney beans contributed highest to the magnesium content, followed by unfermented sorghum flour.

The results of ANOVA for zinc showed that the R-squared and Adjusted R-squared values were 0.9854 and 0.9537 respectively. The contour plot Fig. 5 showed that kidney bean flour was the best source of zinc.

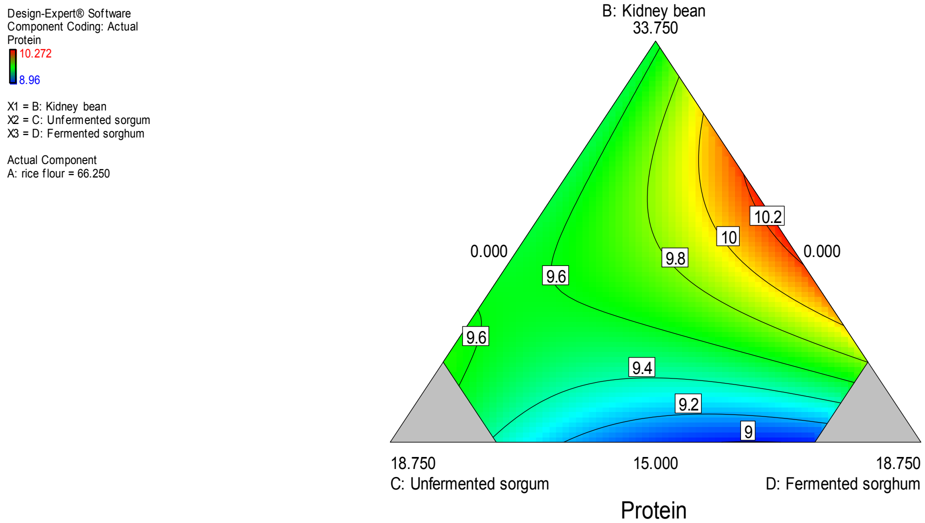

Fig. 3c. Contour plot showing the effects of the composite flour on protein content

Table 2. Mineral composition of composite flour

Samples formulation (%)					Mineral composition of blends (ppm)					
Run	**RF**	**KBF**	**USF**	**FSF**	**Ca**	**Mg**	**Zn**	**Na**	**K**	**Na/K**
1	63.01	35.00	0.98	1.01	2.12	4.98	1.86	2.52	6.75	0.37
2	64.95	25.33	9.62	0.11	2.43	4.87	1.67	2.86	6.97	0.41
3	55.00	35.00	10.00	0.00	2.11	5.02	2.02	2.65	6.39	0.41
4	55.00	15.00	15.00	15.00	2.51	4.91	1.43	2.55	6.45	0.40
5	70.00	15.00	15.00	0.00	2.62	4.84	1.34	2.62	6.23	0.42
6	61.95	16.29	14.99	6.77	2.38	4.93	1.51	2.73	6.33	0.43
7	55.00	35.00	0.00	10.00	2.71	4.88	1.86	2.19	6.78	0.32
8	72.37	27.63	0.00	0.00	2.53	4.65	1.62	2.28	6.64	0.34
9	77.40	15.00	0.19	7.41	2.46	4.68	1.38	2.44	6.82	0.36
10	70.01	15.00	7.79	7.20	2.55	4.85	1.73	2.53	6.34	0.4
11	55.00	35.00	0.00	10.00	2.80	4.78	1.92	2.17	6.69	0.32
12	55.00	25.21	4.79	15.00	2.44	4.89	1.51	2.41	6.54	0.37
13	62.91	22.09	0.00	15.00	2.48	4.57	1.22	2.34	6.55	0.36
14	70.00	15.00	15.00	0.00	2.66	4.90	1.37	2.68	6.19	0.43
15	70.00	15.00	0.00	15.00	2.56	4.74	1.13	2.76	6.67	0.41
16	85.00	15.00	0.00	0.00	2.36	4.28	1.22	2.81	6.57	0.43
17	55.00	15.00	15.00	15.00	2.55	4.87	1.61	2.61	6.42	0.41
18	85.00	15.00	0.00	0.00	2.29	4.33	1.25	2.84	6.48	0.44
19	55.00	25.18	15.00	4.82	2.70	4.81	1.52	2.58	6.30	0.41
20	55.00	35.00	10.00	0.00	2.13	5.11	2.10	2.69	6.41	0.42
21	0.00	0.00	0.00	0.00	2.63	4.82	1.34	2.71	6.81	0.37

Values are mean and are significantly different across the column at (p≤0.05)
Key: RF: Rice flour; KBF: Kidney bean flour; USF: Unfermented sorghum flour; FSF: Fermented Sorghum Flour; Ca: Calcium; Mg: Magnesium; Zn: Zinc; Na: Sodium; K: Potassium

Figs. 6a,6b and 6c showed that the sodium contents were minimal in the absence of kidney beans. Rice flour supported low sodium content such that fermented flour had almost no contribution to sodium content Fig. 6b. Sodium is useful for the generation of nerve impulses and for maintenance of electrolytes balance and fluid balance, for heart activities and certain metabolic functions.

Table 3. Sample blending formulation/ratio and extrusion parameters of composite flour

Run	Moisture (g/100 g)	Temperature (°C)	Screw Speed (rpm)	Throughput (g/s)	Lateral Expansion (%)	Residence Time (s)
1	2.12	4.98	1.86	2.52	6.75	0.37
2	2.43	4.87	1.67	2.86	6.97	0.41
3	2.11	5.02	2.02	2.65	6.39	0.41
4	2.51	4.91	1.43	2.55	6.45	0.40
5	2.62	4.84	1.34	2.62	6.23	0.42
6	2.38	4.93	1.51	2.73	6.33	0.43
7	2.71	4.88	1.86	2.19	6.78	0.32
8	2.53	4.65	1.62	2.28	6.64	0.34
9	2.46	4.68	1.38	2.44	6.82	0.36
10	2.55	4.85	1.73	2.53	6.34	0.4
11	2.80	4.78	1.92	2.17	6.69	0.32
12	2.44	4.89	1.51	2.41	6.54	0.37
13	2.48	4.57	1.22	2.34	6.55	0.36
14	2.66	4.90	1.37	2.68	6.19	0.43
15	2.56	4.74	1.13	2.76	6.67	0.41
16	2.36	4.28	1.22	2.81	6.57	0.43
17	2.55	4.87	1.61	2.61	6.42	0.41
18	2.29	4.33	1.25	2.84	6.48	0.44
19	2.70	4.81	1.52	2.58	6.30	0.41
20	2.13	5.11	2.10	2.69	6.41	0.42
21	2.63	4.82	1.34	2.71	6.81	0.37

Values are mean and are significantly different across the column at (p≤0.05)
Key: RF: Rice flour; KBF: Kidney bean flour; USF: Unfermented sorghum flour; FSF: Fermented

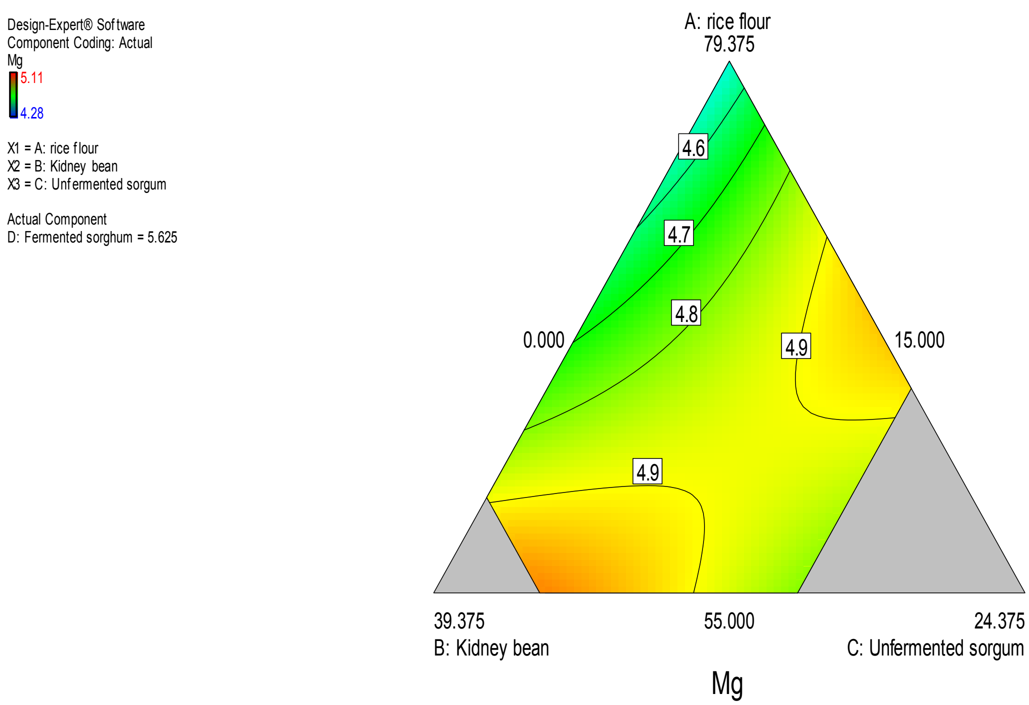

Fig. 4. Contour plot showing the effects of the composite flour on magnesium content

The contour plot showing the effects of the composite flour on potassium are shown in the Fig. 7a,b,c. The result showed that unfermented sorghum and kidney beans flour combination resulted in the highest potassium contents Fig. 7c flowed by unfermented sorghum and rice flour Fig. 7b. The R-squared and Adjusted R-squared values for potassium contents were 0.9893 and 0.9661 respectively, which signaled a very good model.

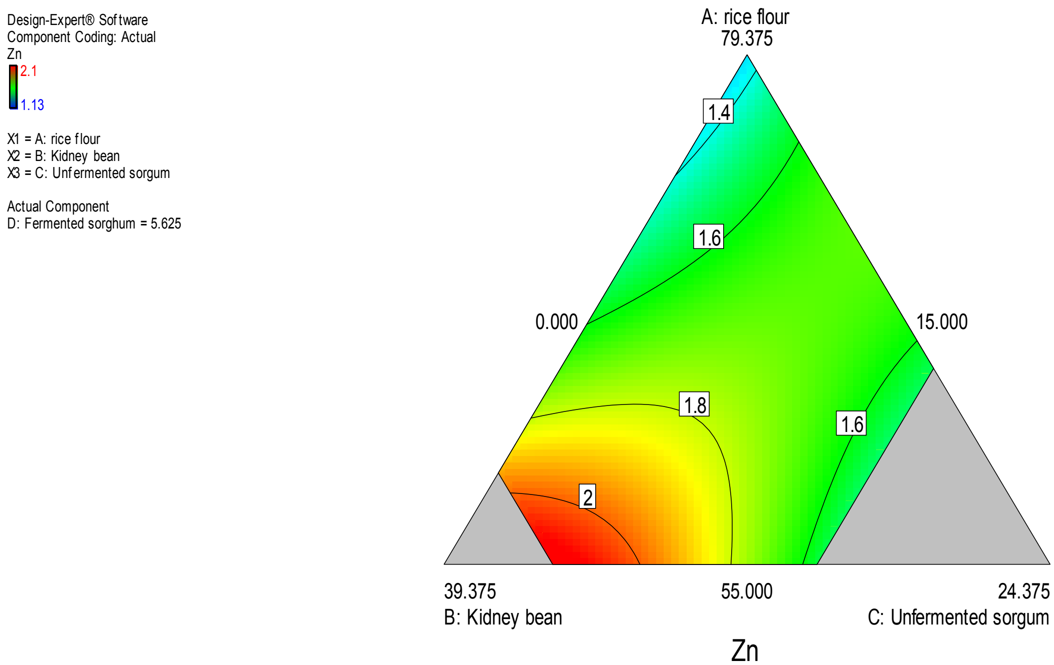

Fig. 5. Contour plot showing the effects of the composite flour on zinc content

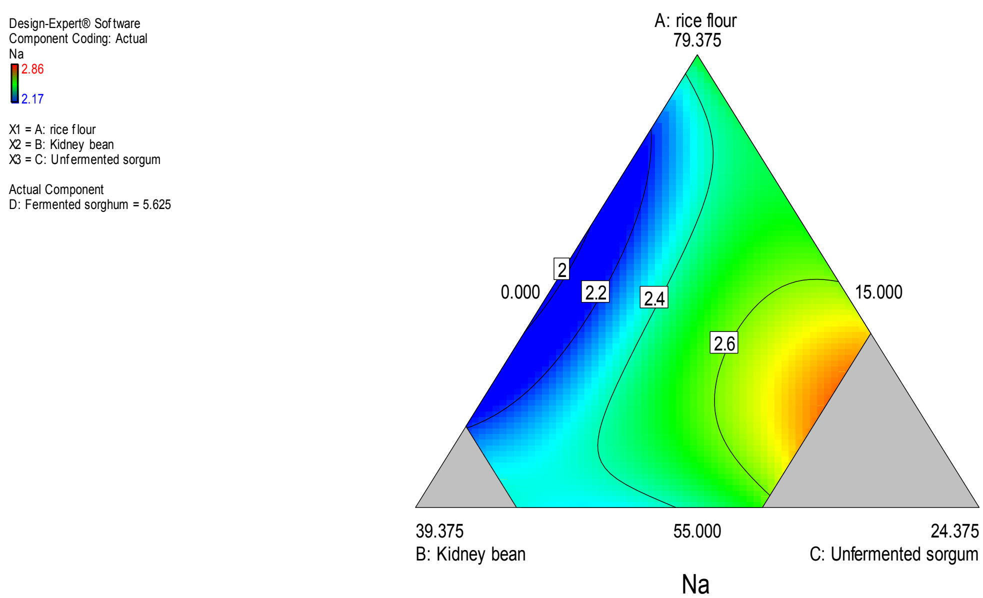

Fig. 6a. Contour plot showing the effects of the composite flour on sodium content

The Na/k ratio were lesser than one for all the samples. This could indicate that the products from the composite flours would be beneficial for consumers with cardiovascular diseases such as high blood pressure.

3.3 Effects of Extrusion Variable Conditions on the Responses

The highest throughput was obtained at the highest screw speed and lowest water content Fig. 8a. Overall, screw speed had the most positive effect on the throughput compared to other parameters considered Fig. 8a, 8b and 8c. Nest to screw speed was the temperature. Moisture had the least positive effect on the throughput. The contour plots showing the effect of the variables on throughput are shown in the Figs. 8a,8b and 8c. The final equation representing the effect of the variables on throughput is shown in the equation below:

$$Throughput = 1.16 - 0.12A - 0.010B + 0.11C - 0.044AB + 0.10AC - 3.750 \times 10^{-3}BC + 0.098A^2 - 0.063B^2 + 0.17C^2$$

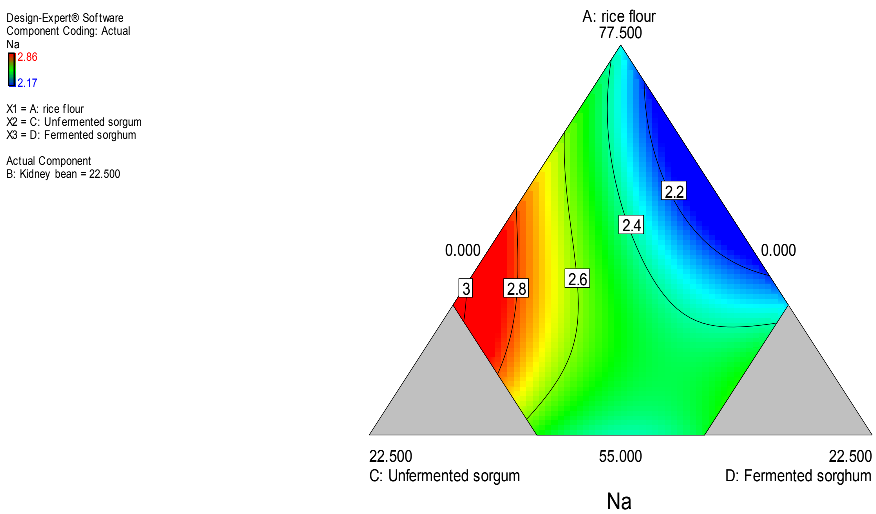

Fig. 6b. Contour plot showing the effects of the composite flour on sodium content

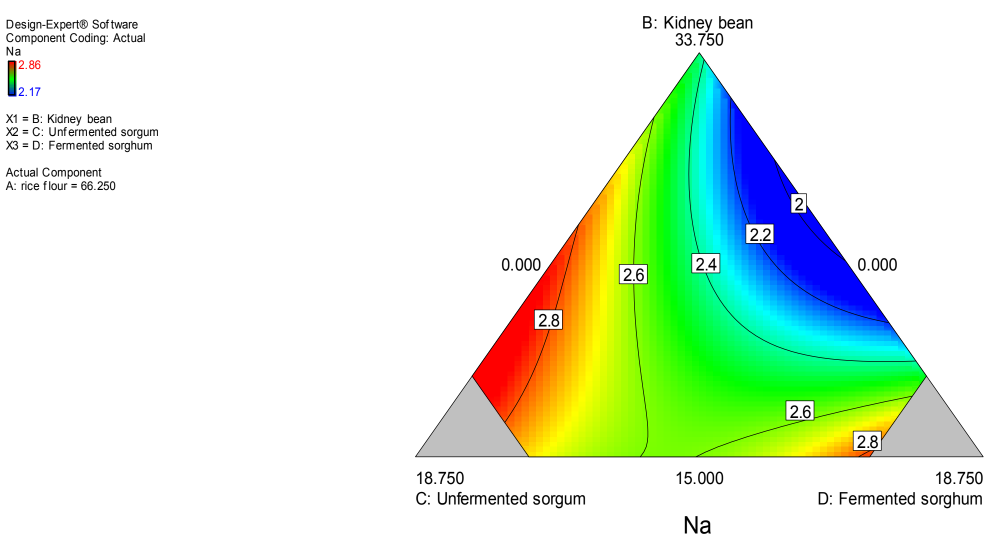

Fig. 6c. Contour plot showing the effects of the composite flour on sodium content

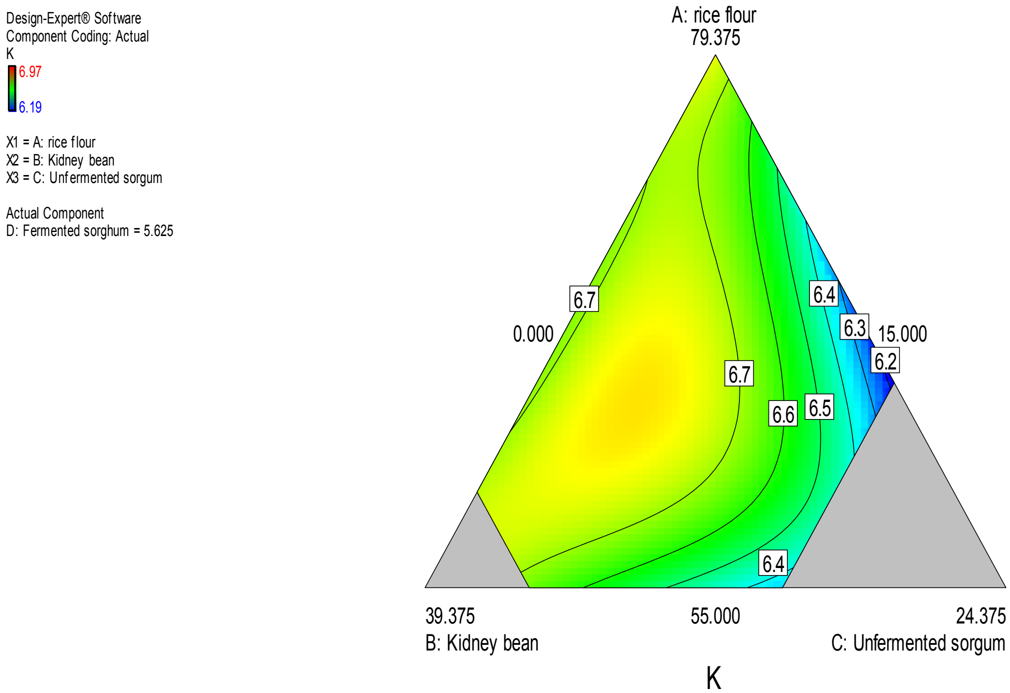

Fig. 7a. Contour plot showing the effects of the composite flour on potassium content

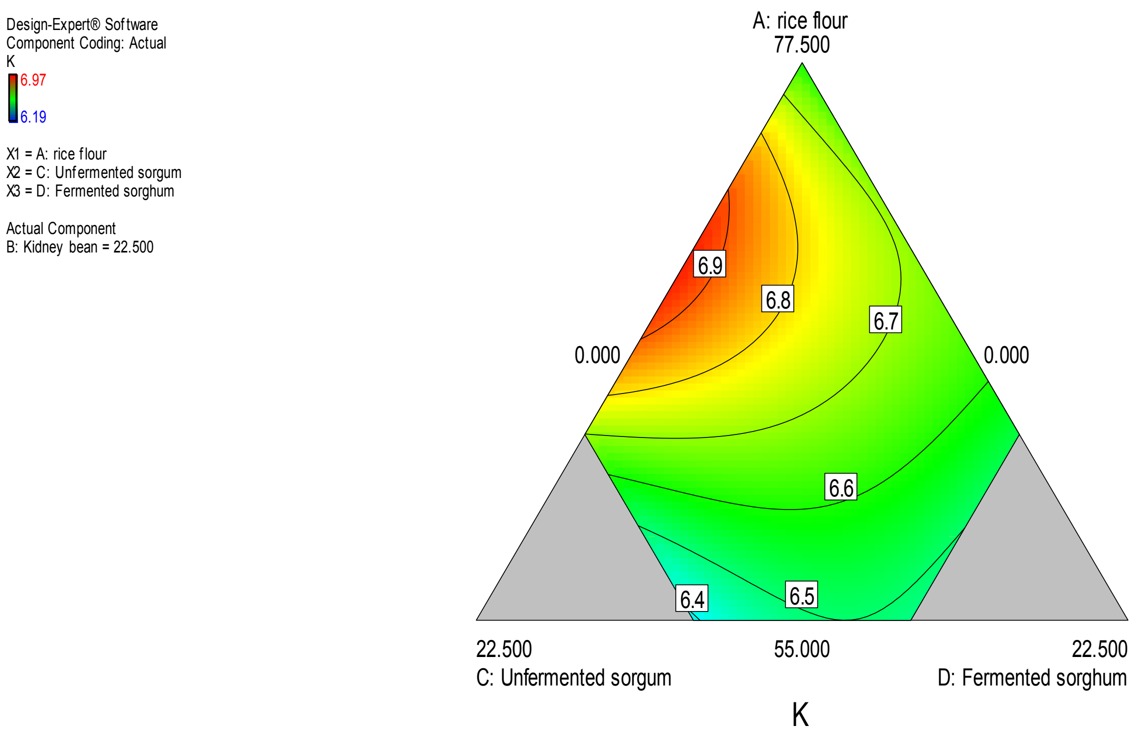

Fig. 7b. Contour plot showing the effects of the composite flour on potassium content

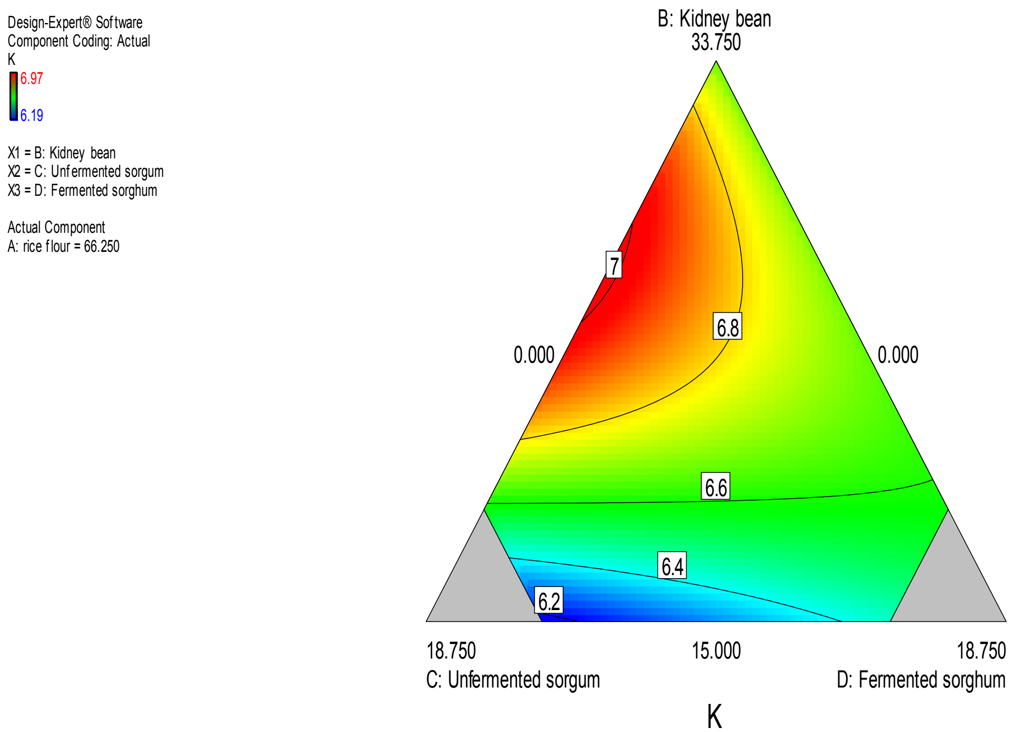

Fig. 7c. Contour plot showing the effects of the composite flour on potassium content

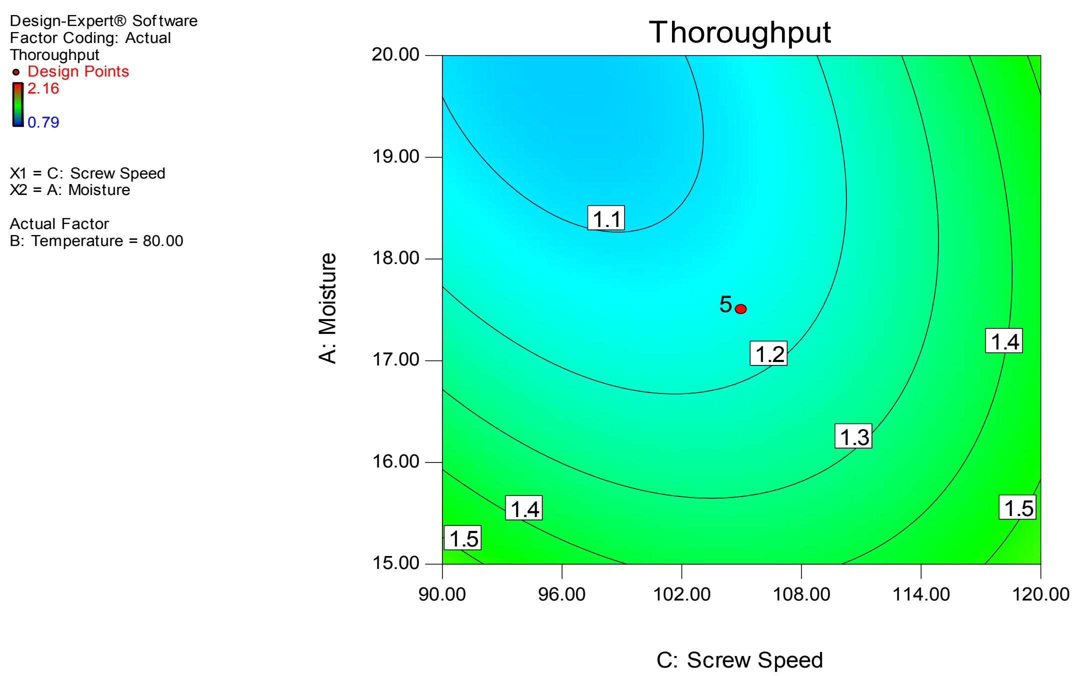

Fig. 8a. Contour plot showing the effects of the composite flour on throughput

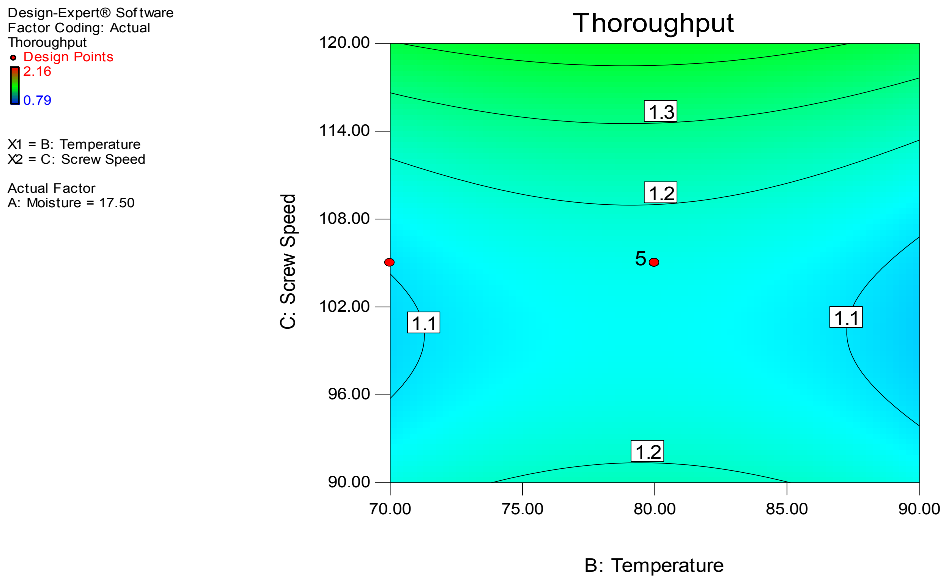

Fig. 8b. Contour plot showing the effects of the composite flour on throughput

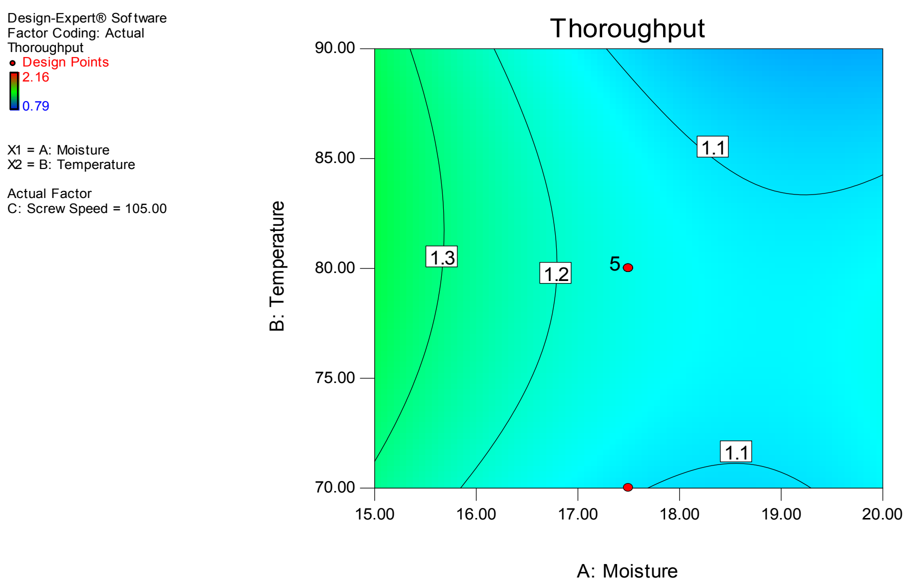

Fig. 8c. Contour plot showing the effects of the composite flour on throughput

The lateral expansion of the extrudates was positively affected by the temperature and screw speed Figs 9a,b and c. High screw speed could also generate heat which indicates heat is a bacic factor that affects lateral expansion. The final equation representing the effect of the variables on lateral expansion is shown in the equation below:

$$\begin{aligned}\mathit{Lateral\ expansion} &= 0.087 - 0.013A + 6.155\ x\ 10^{-3}B \\ &+ 7.256\ x\ 10^{-3}C - 6.250\ x\ 10^{-4}AB \\ &- 3.125\ x\ 10^{-3}AC - 0.013BC + 5.495\ x\ 10^{-5}A^2 \\ &+ 0.015B^2 + 3.590\ x\ 10^{-3}C^2\end{aligned}$$

The residence time was lower at high screw speed Figs. 10a,b,c and d. Moisture and temperature seemed not to be strong factor to be considered for residence time.

In general, the screw speed was the strongest factor that affects all the dependent variables.

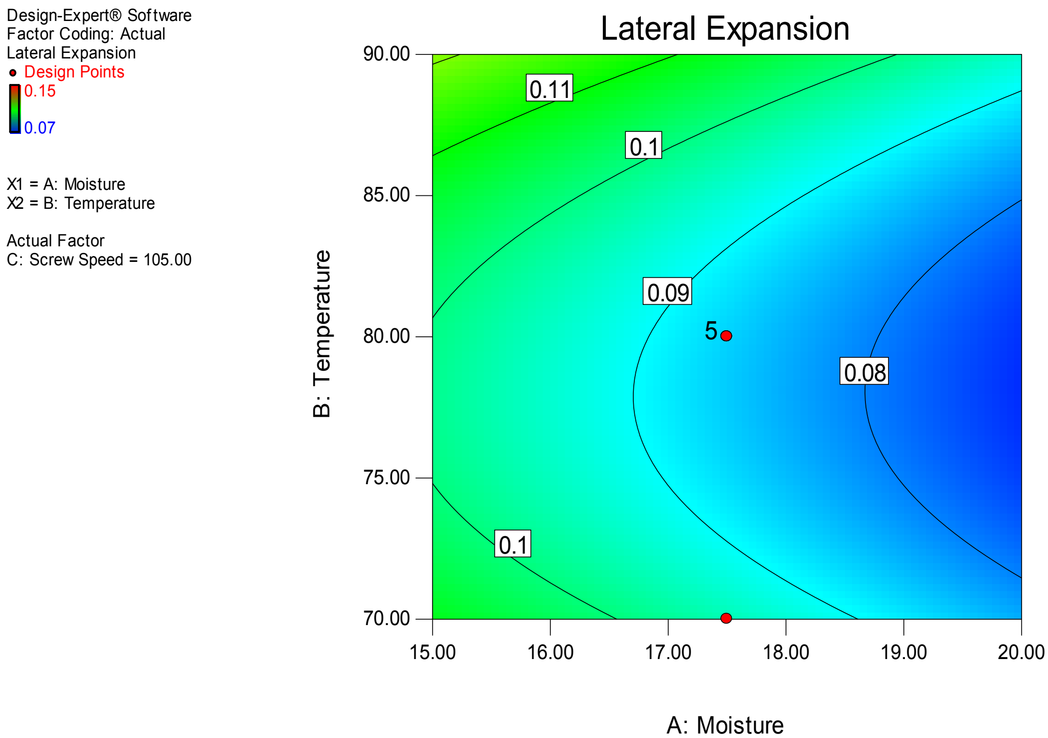

Fig. 9a. Contour plot showing the effects of the composite flour on lateral expansion

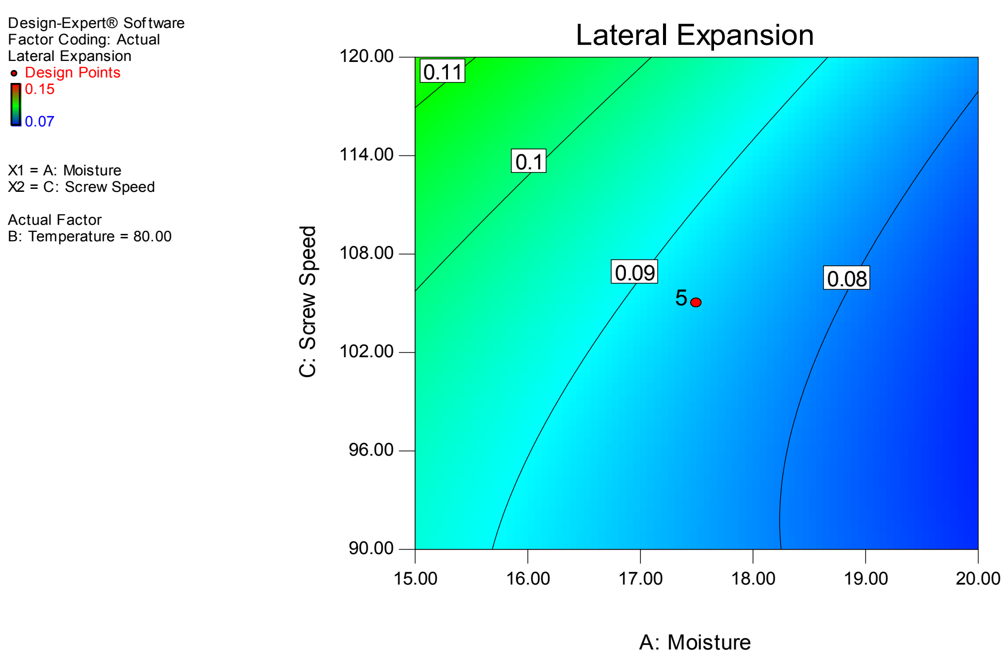

Fig. 9b. Contour plot showing the effects of the composite flour on lateral expansion

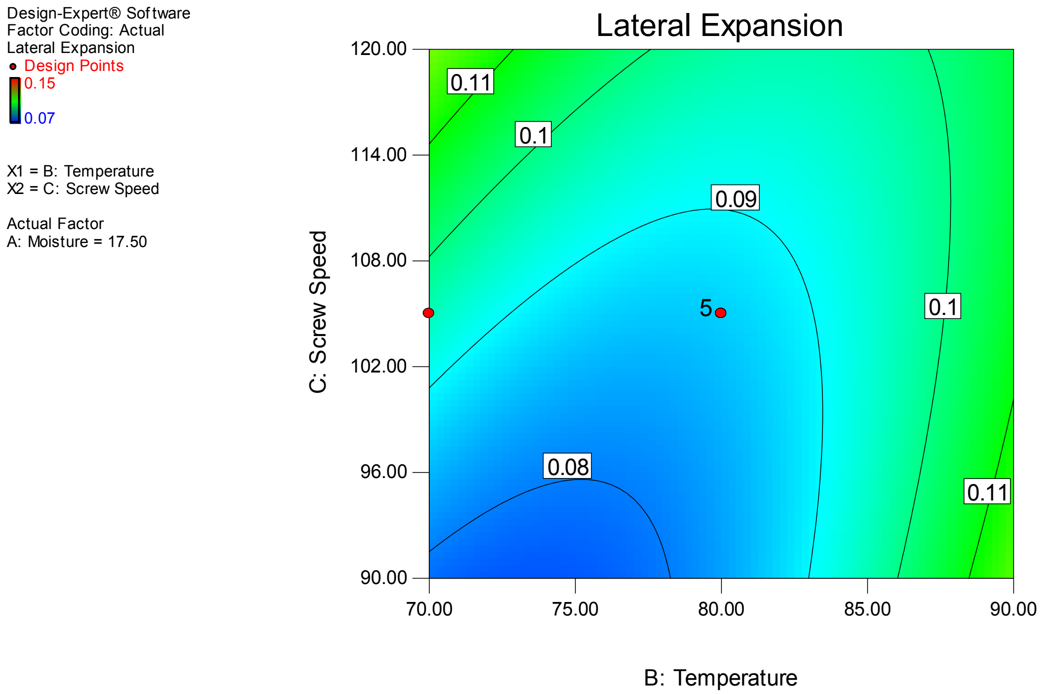

Fig. 9c. Contour plot showing the effects of the composite flour on lateral expansion

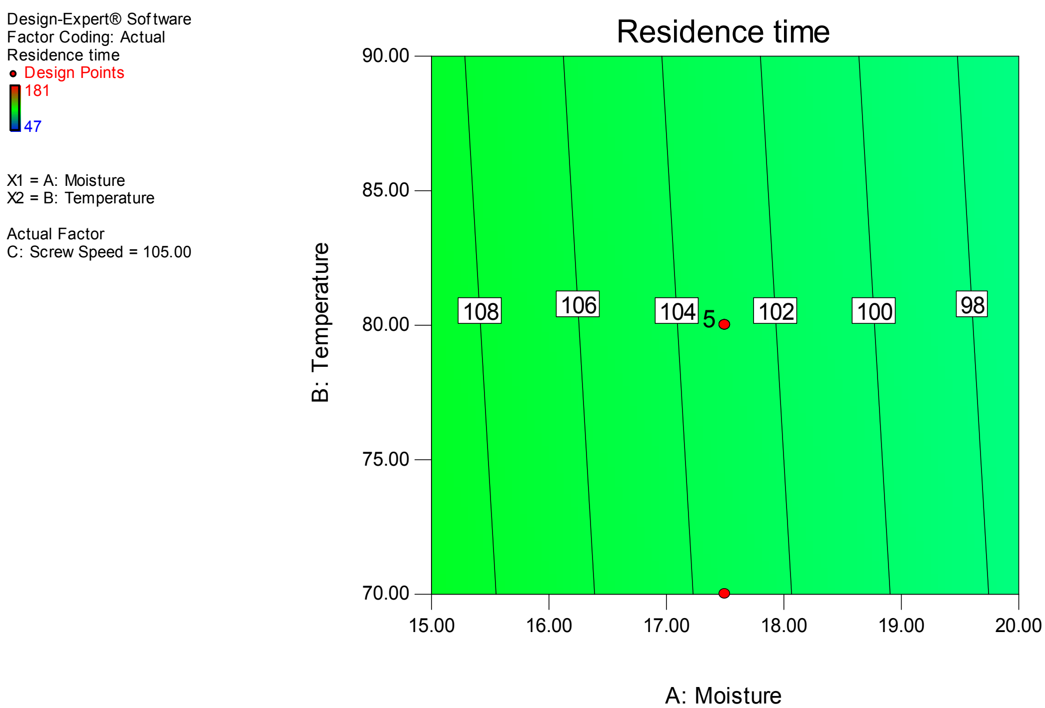

Fig. 10a. Contour plot showing the effects of the composite flour on residence time

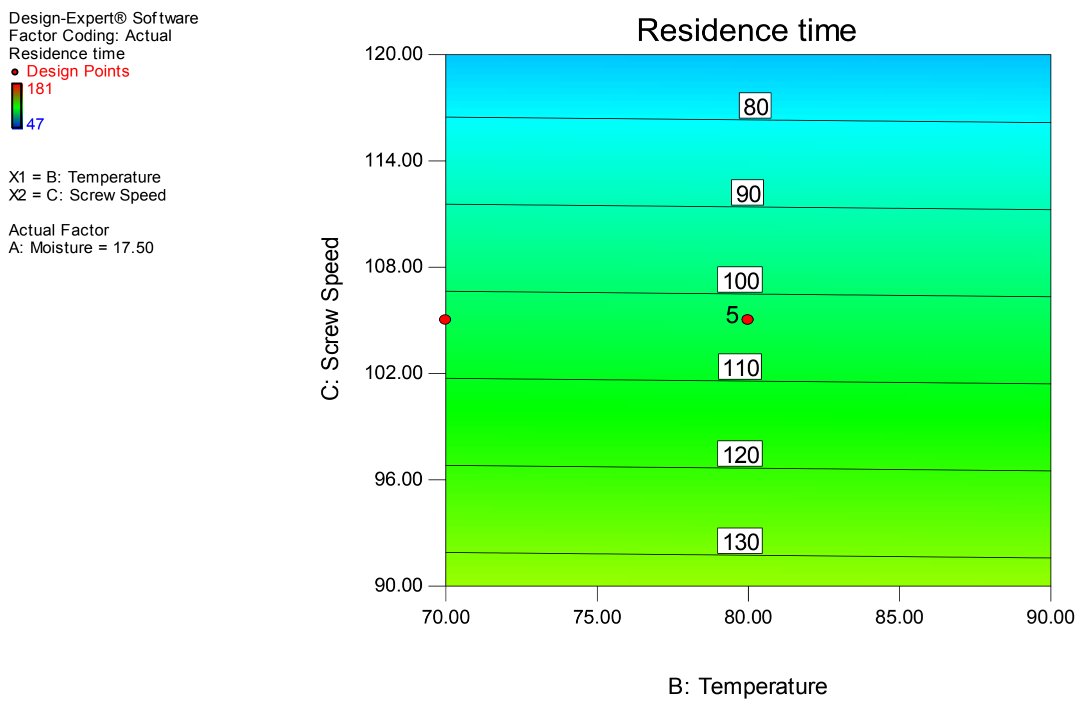

Fig. 10b. Contour plot showing the effects of the composite flour on residence time

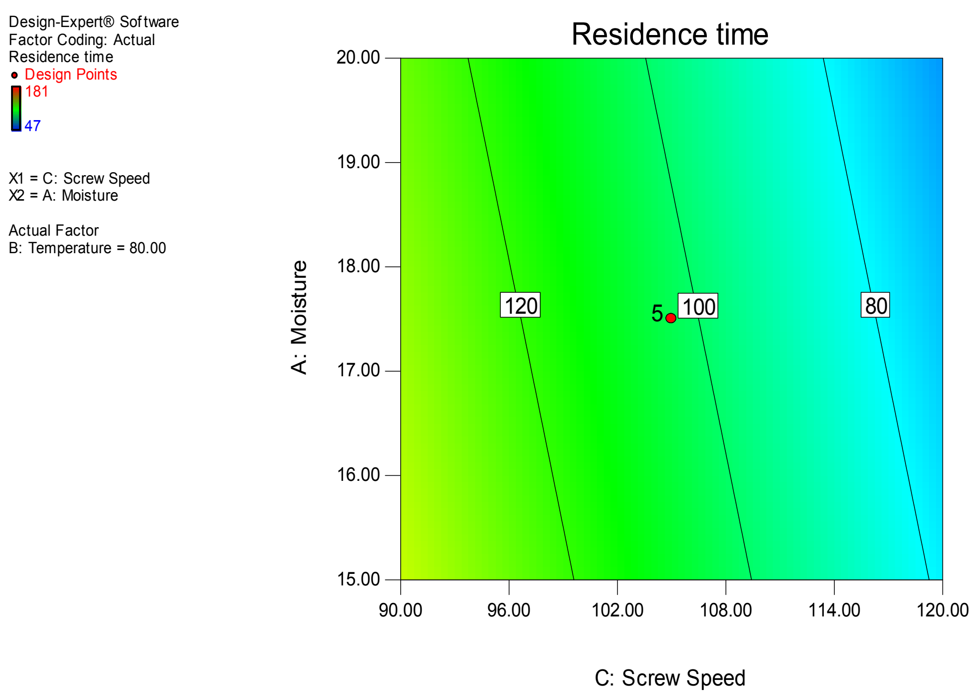

Fig. 10c. Contour plot showing the effects of the composite flour on residence time

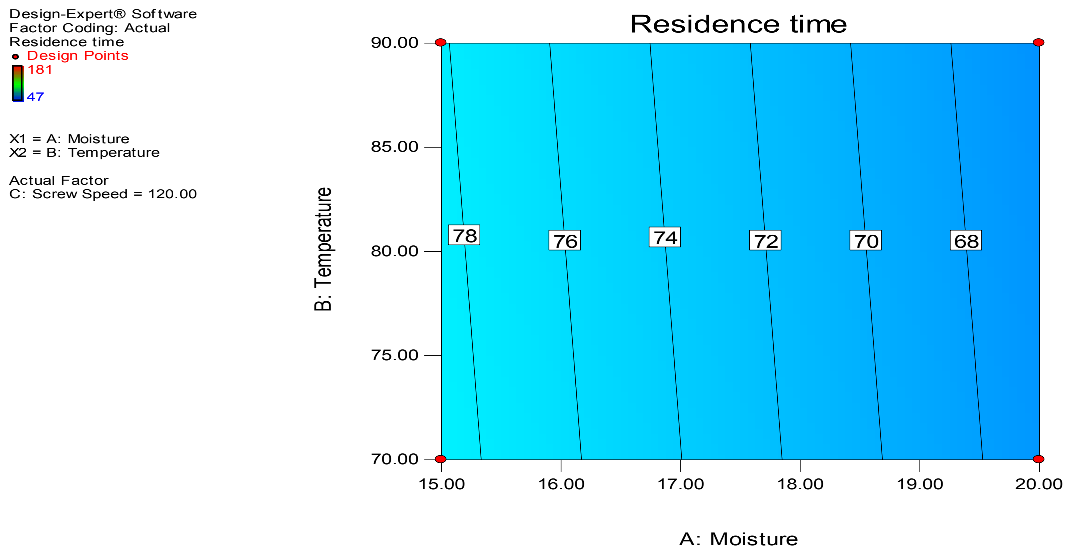

Fig. 10d. Contour plot showing the effects of the composite flour on residence time

3.4 Sensory Evaluation of the Extruded Snacks

The results of the sensory evaluation were presented in Table 4. Sample 19 had the highest consumer acceptability in terms of appearance, and also had the highest overall acceptability. The screw speed of the single screw extruder also contributes to the appearance of the snacks as a slow to moderate screw speed allow for adequate cooking for a considerable length of time. The attractive colour of sample 19 may be attributed to the moisture content of the composite flour during the extrusion process.

Table 4. Sample blending formulation/ratio and sensory attributes of extruded snacks

Run	%Moisture g/100 g	Temperature (^{0}C)	Screw speed(rpm)	Throughput (g/s)	Lateral expansion(%)	Residence time (s)
1	15	90	90	1.75	0.13	134
2	15	79	120	1.41	0.13	52
3	15	70	90	1.52	0.13	181
4	15	90	120	1.27	0.15	73
5	17.5	63.18	105	1.07	0.07	128
6	17.5	96.82	105	0.9	0.08	127
7	17.5	80	105	0.9	0.08	127
8	17.5	70	105	0.79	0.07	125
9	17.5	80	105	1.23	0.13	124
10	17.5	80	105	1.32	0.075	128
11	17.5	80	79.77	1.04	0.07	142
12	17.5	80	105	1.20	0.1	79
13	17.5	80	105	1.10	0.08	128
14	17.5	80	105	1.10	0.08	128
15	20	70	120	1.36	0.09	76
16	20	90	120	1.40	0.11	47
17	20	70	90	1.41	0.07	85
18	20	90	90	1.11	0.11	132
19	21.70	80	105	1.09	0.12	73
20	13.30	80	105	1.68	0.09	78

Values are mean and are significantly different across the column at ($p \leq 0.05$)
Key: RF: Rice flour; KBF: Kidney bean flour; USF: Unfermented sorghum flour; FSF: Fermented

From the results, it can be said that increase in moisture content yielded snacks with better appearance and colour compared to samples having lower moisture content. As the moisture increases, the taste of the samples also improved which is a useful indication that moisture enhances adequate mix ability of ingredients and cooking of the extruded snacks. The results for the texture shows the correlation between the screw speed and screw temperature during extrusion cooking; high temperature cooking with high screw speed resulted in a more uniform and good textured product that when cooking is done under high temperature and low screw speed.

In general, most of the samples were generally acceptable while few others were not. Panelists show very high interest in sample 19 compared to the other samples. From the sensory evaluation, it was seen that sample 19 was the most preferred and generally.

4. CONCLUSION

The composite flours from rice with kidney beans supplemented with fermented and unfermented sorghum resulted had high acceptable ash, crude fibre and protein contents. Samples with fermented sorghum had the highest protein contents of over 10%. The use of response surface methodology gave insights into independent variables with significant ($p \leq 0.05$) effect on dependent variables such as the protein, ash and crude fibre contents. Screw speed was the most potent independent variables for the production of the extruded snacks, and the sensory acceptability of some of the snacks were over 70%.

DISCLAIMER

The products used for this research are commonly and predominantly used products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

ACKNOWLEDGEMENTS

Adewale Adebayo and Fanifosi Funmilayo are hereby acknowledged for the vital roles in making this study a reality.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Oluwasina OO, Demehin BF, Awolu OO, Igbe FO. Optimization of starch-based candy supplemented with date palm (*Phoenix dactylifera*) and tamarind (*Tamarindus indica* L.). Arabian Journal of Chemistry. 2020;13(11):8039-8050.
2. Awolu OO, Okedele GO, Ojewumi ME, Oseyemi FG. Functional jam production from blends of banana, pineapple and watermelon pulp. International Journal of Food Science and Biotechnology. 2018; 3(1):7-14.
3. Akinjayeju O, Fagbemi TN, Ijarotimi OS, Awolu OO. Optimization and evaluation of some physicochemical and nutritional properties of cereal-based soya-fortified flours for dough meal. J. Adv. in Food Sci. and Technol. 2019;6(1):40-59.
4. Awolu OO, Olokunsusi EY. Optimisation and evaluation of the effect of bambara groundnut addition on the nutritional quality and functional properties of amaranth grain-based composite flour. Acta Universitatis Cibiniensis. Series E: Food Technology. 2017;21(2):43-52.
5. Mindi S, Aluko RE. Physiochemical and functional properties of kidney bean albumin and globulin protein fractions. Food Resources International. 2012;48:299-306.
6. Horax R, Hettiarachchy NS, Chen P, Jalauddin M. Preparation and characterization of protein isolate from cowpea (*Vigna unguiculata L. Walp*). Journal of Food Science. 2004;69:114–118.
7. Awolu OO, Omoba OS, Olawoye O, Dairo M. Optimization of production and quality evaluation of maize-based snack supplemented with soybean and tiger-nut (*Cyperus esculenta*) flour. Food Science and Nutrition. 2017;5(1):3-13.
8. Pelembe LAM, Erasmus C, Taylor JRN. Development of a protein-rich composite sorghum-cowpea instant porridge by extrusion cooking process. Lebensmittel - Wissenschaft and Technologie. 2002;35: 120-127.
9. Awolu OO, Magoh AO, Ojewumi ME. Development and evaluation of extruded

ready-to-eat snack from optimized rice, kersting's groundnut and lemon pomace composite flours. Journal of Food Science and Technology. 2020;57(1):86-95.
10. Yousaf M. Study on some physico-chemical characteristics affecting cooking and eating qualities of some Pakistani rice varieties, M.Sc. Thesis Department of Food Technology, University of Agriculture Faisalabad, Pakistan; 1992.
11. Singh S, Gamlath S, Wakeling L. Nutritional aspects of food extrusion: A review. International Journal of Food Science and Technology. 2007;42:916-929.
12. Awolu OO, Oluwaferanmi PM, Fafowora OI, Oseyemi GF. Optimization of the extrusion process for the production of ready-to-eat snack from rice, cassava and kersting's groundnut composite flours. LWT Food Science and Technology. 2015;64(1):18-24.
13. Priyanka K, Aparna K, Lakshmi DN. Development and evaluation of rte (ready to eat) extruded snack using egg albumin powder and cheese powder. Agricultural Engineer International*:* CIGR Journal. 2012;14(4):179-187.
14. Awolu OO, Osigwe MA. Nutritional and antioxidant potential of rice flour enriched with kersting's groundnut (*Kerstingiella geocarpa*) and lemon pomace. International Journal of Food Studies. 2019;8(1):30-40.
15. Osungbaro TO, Jimoh D, Osundeyi E. Functional and pasting properties of composite cassava-sorghum flour meals. Agriculture and Biology Journal of North America. 2010;1(4):715-720.
16. Giami SY, Bekeham DA. Proximate composition and functional properties of raw and processed full fat fluted pumpkin (*Telferia occidentalis*) seed flour. Journal of Science Food and Agriculture. 1992;59:32.
17. Awolu OO. Optimization of the functional characteristics, pasting and rheological properties of pearl millet-based composite flour. Heliyon. 2017;3(2):e00240.
18. AOAC. Association of official analytical chemist. Official methods of analysis of the analytical chemist international, 18th ed. Gathersburg, MD USA; 2018.
19. Iwe MO. Organoleptic assessment of extruded blends of soy and sweet potato flour by response surface analysis. Plants Foods for Human Nutrition. 2001;60:1-14.
20. Ihekoronye AI, Ngoddy PO. Integrated food science and technology for the tropics, 1st ed. Mc Millan Publishers, London. 1985;261–291.
21. Sanni OL, Adebowale AA, Filani TA, Oyewole OB, Westby A. Quality of flash and rotary dryer dried fufu flour. Journal of Food Agriculture and Environment*.* 2006;4:74–78.
22. Baah F, Maziya-Dixon B, Robert A, Oduro I. Nutritional and biochemical composition of *D. alata* (*Dioscorea spp.*) tubers. Journal of Food, Agriculture and Environment. 2009;7(2):373-378.
23. Eastwood M, Kritchevsky D. Dietary fibre: How did we get where we are?. Annual Review in Nutrition. 2005;25:1-8.
24. Friedman G. Nutritional therapy of irritable bowel syndrome. Gastroenterology and Clinical of North America. 1989;18(3):513-524.
25. Anderson JW, Allgood LD, Lawrence A, Altringer LA, Jerdack GR, Hengehold DA, Morel JG. Cholesterol-lowering effects of psyllium intake adjunctive to diet therapy in men and women with hypercholesterolemia: Meta-analysis of 8 controlled trials. American Journal of Clinical Nutrition. 1999;71(2):472-479
26. Omoba OS, Awolu OO, Olagunju, AI, Akomolafe AO. Optimization of plantain-brewers spent grain biscuitusing response surface methodology. Journal of Science Resources Rep. 2013;2:665–681.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/66597