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Formulation, Nutritional Evaluation and Consumer Acceptability of High Energy and Protein Dense Complimentary Foods from Millet and Soybeans

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Authors' contributions

This work was carried out in collaboration between authors NMB and ND. Author NMB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author ND managed the analyses of the study and literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

This study was designed to formulate complementary foods from millet and soybean blends with the aim to provide high energy and proteineous food for vulnerable populations. Single screw extruder was used for the extrusion of the millet-soybeans composite blends and response surface methodology in a central composite rotatable design were adopted for the design of the process variables that could produce optimum complementary foods with high protein, calorie values and physical attributes. Results indicated that during extrusion, the colour of the extrudates varied between 17.67 and 54.81. The expansion index of the formulations ranges between 121.10 to 149.84. However, the results of proximate composition reported that moisture content ranges from 0.18% to 0.35%. The protein content increased from 23.81±1.21 to 28.87±0.16 suggesting proportional increase in protein when millet was blended with soybeans. The fat content varied

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between 0.08% and 0.10%. With respect to the carbohydrate and calorie values, the highest values were 89.56% and 494.53 kcal/100 g which was found in sample extruded at temperature of 100℃ with 25% soybeans composition and 8% feed moisture content while the least values were observed in samples extruded at 140℃ with 25% soybean s composition and 8% feed moisture content for carbohydrates (81.06%) and for calories (432 kcal). The result of pasting characteristics showed effect on the variation observed in the peak viscosity of different extruded products. Peak viscosity for the extrudates varied from 113.83 to 228.68. The consumer's acceptability of the extrudates after reconstituting into gruel with warm water, milk and sugar showed that all the samples were generally acceptable.

Keywords: Millet; soybeansl complementary food; composite blends; response surface methodology.

1. INTRODUCTION

Protein–energy malnutrition (PEM) is still a major public health issue in developing countries and mostly associated with 50–60% of under-five mortality [1,2]. In its effort to address the situation in Nigeria, the National Policy on food and nutrition was launched in 2002 and was revised in 2014 to reposition the country to address malnutrition and hunger from more comprehensive perspective than was earlier envisaged in the 1990s when the policy was first formulated [3]. The improvement of local food staples and utilization of locally produced staple crops in the development of high energy foods rich in micronutrients has been a subject of research over the years to meet the protein and energy need of vulnerable populations [4]. This has shown high economic advantage when composite flour made from cereals and legumes are used to develop such food products.

Extrusion cooking technology is central to improving the nutrition and aesthetic values of agricultural commodities, especially cereals-legumes blends which are used to enhance food and nutrition security and sustainable development. Food extrusion cooking is a high-temperature short-time (HTST) process which reduces microbial contamination, inactivates enzymes, and facilitates the elimination of anti-nutritional factors, resulting in products that are in a dry state and do not require refrigeration for storage. Such extruded products are better for a tropical nation especially, Nigeria where infrastructure for a cold supply chain is inadequate [5]. But the adoption of extrusion for the development of food products depends on how well the process parameters both for the extruder and raw materials are adjusted and conditioned [6]. The main objective of this work is to formulate, evaluate and optimize process variables that will produce high energy nutritious foods from millet and soybeans as a strategy to combat protein-energy malnutrition in Nigeria.

2. METHODOLOGY

Millet samples were purchased from the modern (New) market Bida, Niger State, while soybean was obtained from the Soybean Research Program of the National Cereals Research Institute, Badeggi, Nigeria. Samples (or They) were manually cleaned and packaged in a paper bags under ambient temperature (30±2℃) in a cardboard. All chemical/reagents used were purchase from local chemical store in Minna, Niger State and are of analytical grade.

2.1 Processing of Millet and Soybean Flours

The millet grains were milled into flour using locally fabricated attrition mill and sieved. The sieved flour was then packaged in plastic containers and stored until required for extrusion. Ten kilograms (10kg) of soybean was soaked in hot water for 60min and then washed several time in tap water to remove the seed coat. Washing water was drained off and the seed dried to about 14% moisture content. The dried seeds were then milled using an attrition mill (Galenkamp, England) and sieved to pass through a 2 mm sieve mesh. The sieved flour was then packaged for further use.

2.2 Composite Flour Formulation

Based on the central composite design in a response surface methodology (Table 1), 20 formulations were generated containing between 11.59 and 28.41% (w/w) soybean flour. The moisture content of the formulations was adjusted to fall between 5.61 and 17.39% (w/w) by sprinkling with calculated amount of water after the determination of initial moisture content and mixing thoroughly before extrusion.

2.3 Experimental Design

Response Surface Methodology (RSM) and Central Composite Design (CCD) were used to study the production process and optimization of process parameters for the production of extruded foods using extrusion cooking technology [6]. The methodology was based on five levels of three extruder variables (barrel temperature (A) = 86.36 – 153.64℃), feed moisture content (B) = 5.61-17.39% w/w and millet-soybean composition, (C) =11.59 – 28.41). The operating ranges of the three independent variables were established after several preliminary trials and reported range for similar products (Table 1). Data generated were subjected to analysis of variance,(ANOVA). Significant differences were accepted at 5% probability (p=0.05).

2.4 Physico-chemical Analysis

Monilta Colour Reader CR-10 (Minolta Co. Ltd., Tokyo, Japan) was used to measure colour indices of the extruded foods. Colour of sample is represented by L*, a*, and b*. The L* value gives a measure of product lightness, a chromatic colour from absolute black (0) to absolute white (100); a* value represents mixed red-to-green colour of samples and ranges from negative value on the red side to positive on the green side (a+ = 0-100 for red and a- = 0-(-100) for green); and b* value represents mixed blue-to-yellow colour of samples ranging from negative to positive value (b+ = 0 - 100) for yellow and b- = 0-(-100) for blue. Protein, fat, ash, dietary fibre, and moisture were determined according to AOAC method [7]. The carbohydrate was calculated by difference method, while energy value (kcal/100 g) was calculated as reported by FAO [8].

2.4.1 Sectional expansion index (SEI)

Sectional expansion index was determined by dividing the cross sectional area (mean of five measurements) of the extrudates by the cross-sectional area of the die nozzle [9]. The ratio of diameter of extrudates and the diameter of die was used to express the expansion of extrudates [10].

Table 1. Experimental design

Runs	Coded variables			Non-coded variables		
	A	B	C	A (^{o}C)	B (w/w)	C (w/w)
1	-1	-1	-1	100.00	15.00	8.00
2	1	-1	-1	140.00	15.00	8.00
3	-1	1	-1	100.00	25.00	8.00
4	1	1	-1	140.00	25.00	8.00
5	-1	-1	1	100.00	15.00	24.00
6	1	-1	1	140.00	15.00	24.00
7	-1	1	1	100.00	25.00	24.00
8	1	1	1	140.00	25.00	24.00
9	-1.68	0	0	86.36	20.00	16.00
10	1.68	0	0	153.64	20.00	16.00
11	0	-1.68	0	120.00	11.60	16.00
12	0	1.68	0	120.00	28.40	16.00
13	0	0	-1.68	120.00	20.00	2.600
14	0	0	1.68	120.00	20.00	29.50
15	0	0	0	120.00	20.00	16.00
16	0	0	0	120.00	20.00	16.00
17	0	0	0	120.00	20.00	16.00
18	0	0	0	120.00	20.00	16.00
19	0	0	0	120.00	20.00	16.00
20	0	0	0	120.00	20.00	16.00

2.5 Pasting Characteristics

The pasting characteristics were determined using a Brabender viskograph- E(Brabender OHG, Duisberg, Germany) [11]. The slurries were heated to 95℃ from 50℃ at a rate of 1.5℃/minute, and held for 15 min before cooling back to 50℃ at the same rate and finally held at 50℃ for another 15 min. Gelatinization temperature (GT), maximum or peak viscosity (PV), minimum viscosity (MV), final viscosity (FV), breakdown viscosity (BDV), and setback viscosity (SBV) were measured. The BDV was calculated as PV minus TV (Temperature viscosity), while setback viscosity (SV) determined by subtracting PV from FV. Peak time (PT) (the time at which peak viscosity was recorded) and the Pasting temperature (PT ℃) (the temperature at which starch granules begin to swell and gelatinize due to water uptake). The viscosity was expressed in terms of Rapid Visco Units (RVU), which is equivalent to 10 centipoises [12].

2.6 Sensory Evaluation

One hundred gram of pulverized extruded porridge will be added to 500 ml of water in a plastic cup each for the best selected extruded porridge samples. The panelists were asked to indicate their opinion on four sensory attributes, namely the colour, flavour, texture and the overall acceptability using Hedonic scale rating of 9 = liked extremely to 1 = disliked extremely. Acceptability scores using the mean of the observations was recorded.

2.7 Statistical Analysis

Data obtained from Experimental design matrix (CCD) was subjected to regression analysis using response surface regression procedure of MINITAB 14.13. Statistical software (Manitab Inc. USA) was used to optimize the product responses [13].

3. RESULTS AND DISCUSSION

3.1 Proximate Composition

The results of proximate composition (moisture, protein, lipid, ash, carbohydrate and caloric value) of five highly rated samples are presented in Table 2. The moisture content varied between 0.18% and 0.35%. The highest moisture content was recorded in sample corresponding to barrel temperature 100℃, moisture 20% and feed composition 16% and the least value in sample extruded at 120℃ barrel temperature, 20% moisture and 16% soybeans addition, however there was a significant reduction in moisture content which is dependent on the extrusion temperature that determine the speed of the extruder and not on the amount of moisture of raw material or blend composition. In addition, the higher the screws speed, the rate at which the extrusion temperature will also be affected. These results suggested that the product had low moisture enough to have an extended shelf life. It has also been reported in the literature that in a dry food systems with moisture content between 6% and 10%, there is a prolong shelf life stability, and above this range, the shelf life stability of the products could be hindered by both chemical and microbiological agents [14]. The protein content of the extrudates increased from 23.81% to 28.87% when temperature fall from 140℃ to 120℃, 15 to 20% of feed moisture and 8 to 16% blend composition suggesting proportional significant increase in protein when cereals was blended with legumes. [15] revealed that protein content increase from 11.23% to 16.23% when millet was fortified with soybeans using extrusion cooking. Protein content of foods are determinant as nitrogen multiply by a factor (Nx6.25), and apparent protein content is not influenced by extrusion temperature as nitrogen is not affected by heat [16,17]. The fat content varied between 0.08±0.01 and 0.10±0.00. The highest value was observed in sample extruded at 100℃ barrel temperature, 15% moisture and 8% feed blend composition. The little changes in fat content may be due to the possible raising concentration of non-fat compounds established by Millard reaction or caramelization which are insoluble in organic solvent [18]. The reduction in fat content indicated that this quality indices requires to be added from other sources into the diet of the consumers of this product, most especially if it is going to be used as food formulation. [19] reported that the requirement for good complementary formulations should be 6%. Both cereals and some legumes are low in fat content, in addition, the extruder processing condition such as barrel temperature and screw speed remove the little fat present in the raw materials through several reactions including complex formation with amylose and protein, oxidation, lipid binding due to interactions with starch and protein's cis and trans isomerization of unsaturated fatty acids and degradation of fat splitting enzymes. All these reactions resulted in fat loss. The ash content of the extruded foods ranged between 1.13% and 1.87%, with the highest value observed in sample corresponding to 140℃ barrel temperature, 25% moisture and 8% of blend compositions and the least value were studied at 100℃ barrel temperature, 25% moisture and 8% soybeans. There was significant increase in the ash content of complementary food as the concentration of soybeans increased. [20], reported increase in ash content when legumes concentration was increased in cereals extruded samples. Regarding the carbohydrate and calorie values of the complementary food, the highest values was recorded in samples C for both carbohydrates (89.56%) and calories (494.53±0.08 kcal/100 g) at (153.6℃ barrel temperature, 20% moisture and 16% blend composition) while the least values were observed in samples D (81.06%) for carbohydrates at (120℃ barrel temperature, 15% moisture and 24% soybeans) and Sample E (432±0.08) for calories at (100℃ barrel temperature, 15% moisture and 24% blend composition) respectively.

3.2 Product Colour

Colour in food products is an important physical quality of foods that attract consumer. Therefore, any changes in colour of food product could be an indication of nutrients degradation during heat processing [5]. Colour in foods produced through extrusion is a trigger force in the acceptance of the food products by the consumers; it also plays an important role in visual recognition and assessment of the surface and sub-surface properties of the foods [21]. It was observed that during extrusion, the colour of the finished products varied between 17.67 and 54.81 which was extruded at 140°C barrel temperature, 15% (w/w) feed moisture level and 8% (w/w) feed legume composition. However, the highest value recorded for yellowness was an indication of traversing of the colour from brown to yellow colour. The colour of the product therefore is golden in colour.

3.3 Expansion Index

The results of expansion index ranges between 121.10 and 149.8. The highest expansion found in extrusion parameters of 120℃ barrel temperature, 20% (w/w) feed moisture and 2.6% (w/w) soybeans composition, while the lowest level was recorded at higher temperature of 140℃ barrel temperature, 15% (w/w) feed moisture and 8% (w/w) feed soybeans composition (Table 3). Extrusion cooking of cereal based raw materials to produce extrudates such as expanded-puffed snacks and ready-to-eat cereals, porridges, among one of the most important quality attributes is the ability of the materials to expand significantly at the die. During extrusion exercise, the extrudates reaches its maximum expansion as it is formed into a definite shape at the die. This expansion phenomenon is fundamentally important property describing the product quality and directly correlated with degree of cook. Until the extruded products expansion index meet some certain specifications, the product will not be acceptable.

3.4 Consumer Preference Analysis

The results of consumer preference showed that below 24% feed composition and 15% feed moisture content, colour rating of extrudates was below 5.61±0.13. On the other hand, increasing the moisture content with increased level of soybeans at the same barrel temperature resulted in increased colour rating of extruded samples. Maximal colour rating (6.98±0.65) was recorded at 29.5% feed composition, 20% feed moisture content at 120℃ barrel temperature. These results were earlier reported by [22-24]. [25] also explained this phenomenon as the activity of the amino groups in soy protein triggering off maillard reactions with the melt carbohydrate of cereals. The result of the taste of extrudates ranges from 6.79±0.21 and 6.16±0.11. Increasing the concentration of soybeans in turn increased the taste rating of the extruded products. However, the result of aroma ranges from 6.46±0.11 and 5.41±0.21. There was significant increase in aroma as the level of soybeans increased. The highest values for aroma was recorded at 29.5% feed composition, 20% feed moisture content at 120℃ barrel temperature. This result is agreement with [26] who reported a similar trend of results for cereal/legumes flour blends. They also reported that the taste of the samples closely resembled those of aroma, noting that taste and aroma interaction are physiologically and physically connected and depending on the respondents, identities could be confused. These observations are reflected in the results obtained from this study. Results from this work show that the highest contributor to aroma and taste of extrudates was the Feed Composition, and of lesser consequence, the Barrel Temperature and Feed Moisture Content. Further, [26] explained that lower values for taste and aroma might be due to the non-full development and release of adequate heterocyclic with diverse aromas, due to low shear effect. Other results of consumer preferences (Such as texture, consistency and overall acceptability) followed similar trend of results.

Table 2. Proximate composition of highly extruded products

Samples	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	CHO (%)	Energy (Kcal/g)
Sample A	0.35±0.01[a]	24.90±1.01[b]	1.13±0.01[c]	0.08±0.01[a]	87.44±0.03[a]	464.08±0.06[ab]
Sample B	0.29±0.03[ab]	25.16±0.07[ab]	1.22±0.04[b]	0.10±0.00[a]	88.29±0.02[a]	464.70±1.01[ab]
Sample C	0.26±0.05[ab]	28.87±0.16[a]	1.22±0.05[b]	0.09±0.04[a]	89.56±0.01[a]	494.53±0.08[a]
Sample D	0.18±0.04[b]	23.81±1.21[b]	1.87±0.04[a]	0.08±0.06[a]	81.06±0.02[b]	452.86±0.03[b]
Sample E	0.26±0.02[ab]	25.49±0.59[ab]	1.46±0.02[ab]	0.08±0.03[a]	82.71±0.01[ab]	432.52±0.08[c]

Values are mean of three determinations. Values in the same column followed by different superscripts are significantly different at 5% level of probability.

Table 3. Design layout and mean experimental results for color and expansion indices of millet-soybeans composite flour extruded instant porridge

Runs	Independent variables in coded forms			Non coded variables in natural forms			CIE Colour value			EI
	X_1	X_2	X_3	BRT	FMC	FBC	L*	a*	b*	
1	-1	-1	-1	100.00	15.00	8.00	20.31	4.90	36.01	137.81
2	1	-1	-1	140.00	15.00	8.00	17.67	10.20	43.60	121.10
3	-1	1	-1	100.00	25.00	8.00	18.12	13.50	51.00	145.68
4	1	1	-1	140.00	25.00	8.00	33.21	11.30	52.10	140.85
5	-1	-1	1	100.00	15.00	24.00	25.52	11.75	43.70	140.66
6	1	-1	1	140.00	15.00	24.00	21.33	12.64	36.49	139.86
7	-1	1	1	100.00	25.00	24.00	26.73	12.20	47.17	141.66
8	1	1	1	140.00	25.00	24.00	25.43	14.10	43.13	142.74
9	-1.68	0	0	86.4	20.00	16.00	26.94	12.63	55.00	138.84
10	1.68	0	0	153.6	20.00	16.00	20.38	15.35	58.80	141.51
11	0	-1.68	0	120.00	11.6	16.00	27.14	21.61	43.70	138.90
12	0	1.68	0	120.00	28.4	16.00	27.65	11.10	36.55	139.54
13	0	0	-1.68	120.00	20.00	2.600	36.43	11.02	44.87	149.84
14	0	0	1.68	120.00	20.00	29.50	35.36	10.07	54.81	143.82
15	0	0	0	120.00	20.00	16.00	38.35	11.36	53.12	143.56
16	0	0	0	120.00	20.00	16.00	38.35	11.36	53.12	143.56
17	0	0	0	120.00	20.00	16.00	38.35	11.36	53.12	143.56
18	0	0	0	120.00	20.00	16.00	38.35	11.36	53.12	143.56
19	0	0	0	120.00	20.00	16.00	38.35	11.36	53.12	143.56
20	0	0	0	120.00	20.00	16.00	38.35	11.36	53.12	143.56

L is the luminance or lightness component, which ranges from 0 to 100, a* (from green to red), and b* (from blue to yellow) are the two chromatic components, which range from -120 to +120, X_1 = Barrel temperature, X_2 = Feed moisture content, X_3 = Feed blend composition, BRT = Barrel temperature (℃), FMC = Feed moisture content (g/100 g), FBC = Feed blend composition (g/100 g), EI = Expansion index*

Table 4. Consumer preference analysis of porridge made from extruded millet and soybean

Samples	Taste	Texture	Smell	Colour	Consistency	Overall acceptability
Sample A	6.16±0.11[c]	6.15±0.12[c]	5.41±0.21[c]	6.26±0.15[ab]	6.56±0.06[c]	6.11±0.03[c]
Sample B	6.61±0.12[ab]	6.44±0.12[b]	6.46±0.11[a]	5.61±0.13[c]	7.08±0.25[ab]	6.78±0.08[a]
Sample C	6.23±0.17[bc]	6.76±0.18[a]	5.89±0.18[bc]	6.70±0.15[a]	7.33±0.21[a]	6.98±0.22[a]
Sample D	6.79±0.21[a]	6.46±0.06[b]	6.49±0.26[a]	6.08±0.24[b]	6.78±0.07[b]	6.33±0.23[ab]
Sample E	6.51±0.05[ab]	6.59±0.05[ab]	6.31±0.35[ab]	6.98±0.65[a]	6.99±0.23[b]	6.12±0.33[c]

Values are mean of three determinations. Values in the same column followed by different superscripts are significantly different at 5% level of probability

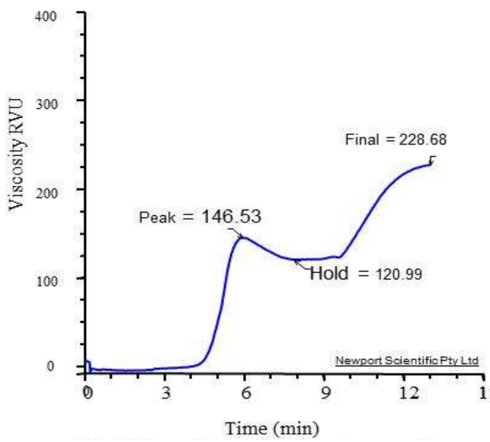

Fig. 1a. Pasting characteristics of extruded millet and soybean

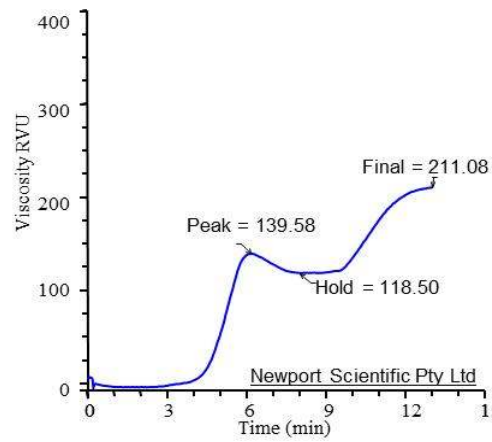

Fig. 1b. Pasting characteristics of extruded millet and soybeans

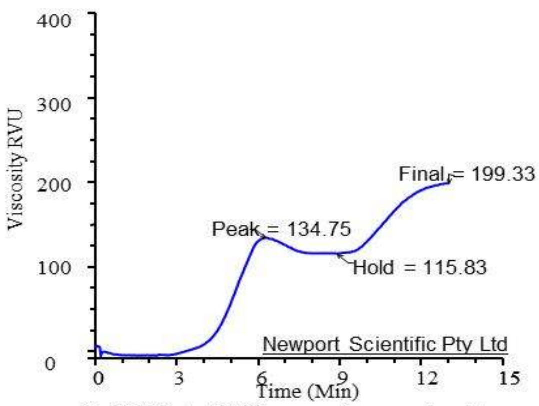

Fig. 1c. Pasting characteristics of extruded millet and soybeans

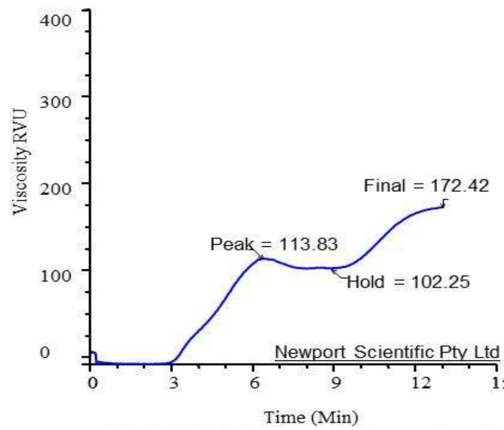

Fig. 1d. Pasting characteristics of extruded millet and soybeans

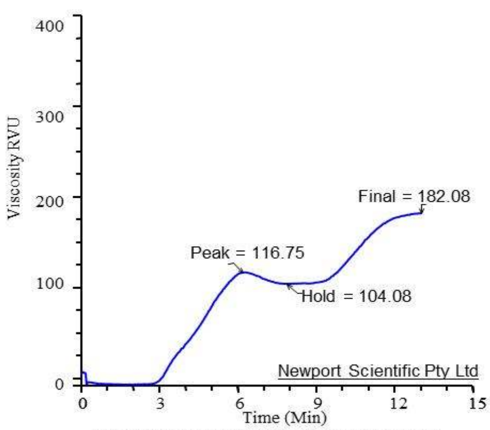

Fig. 1e. Pasting characteristics of extruded millet and soybeans

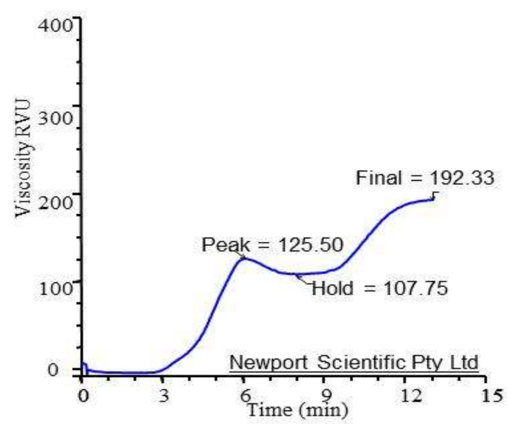

Fig. 1f. Pasting characteristics of extruded millet and soybeans

Fig. 1a-f. Pasting behaviour of extruded products using preparation in warm water

3.5 Pasting Characteristics

The results of pasting characteristics of complementary foods developed from millet-soybean blend were presented in Fig. 1 a, b, c, d, e and f respectively. This characteristic response was generally common to all the extrudates tested for pasting characteristics. Viscosity increased gradually when the paste was heated under mechanical force, reaching peak viscosity after heating at 120℃ without any form of cold swell, showing less starch destruction and cooking of the extrudates starch during extrusion. The lack of cold swell might be attributed to amylose lipid-complex, which inhibits starch for hydration [27]. The results revealed that there was an effect of formulation on the variation observed in the peak viscosity of different extruded products. Peak viscosity for the extrudates varied from 113.83–228.68 indicating significant quantity of starch in millet extrudates compared to other cereals extruded samples. This result is in agreement with [28] who reported difference for peak viscosity of extruded corn starch. There is an effect between peak viscosities of millet extrudates with 20% soy content. However, with 29.5% soy addition, peak viscosity decreased significantly. This effect might be as a result of protein which could influence viscosity development during cooking [28,29]. In addition to [30], it was reported that the level of starch and presence of protein in extruded samples have a great effect on the degree of swelling. However, high soy flour blends attained peak viscosity quicker than low soy blends. This trend was contrary in millet extrudates. The similar trend of viscosity was also observed in high soy samples, which might be an indication of minimal starch damage linked to lower starch content and protein shielding effect on starch in the samples.

4. CONCLUSION

In this current study attempt have been made to formulate a complementary food that will be of higher nutritive value and easily affordable. The results showed that acceptable convenient and low cost complementary food could be produced from Millet and soybean extrudates. It is recommended that the instant complementary food could be used by both infants and adult consumption. However, complementary food should also be taken with water or milk and less quantity of sugar or honey. Finally, Soybeans composition could be added to millet without developing any objectionable taste and flavour.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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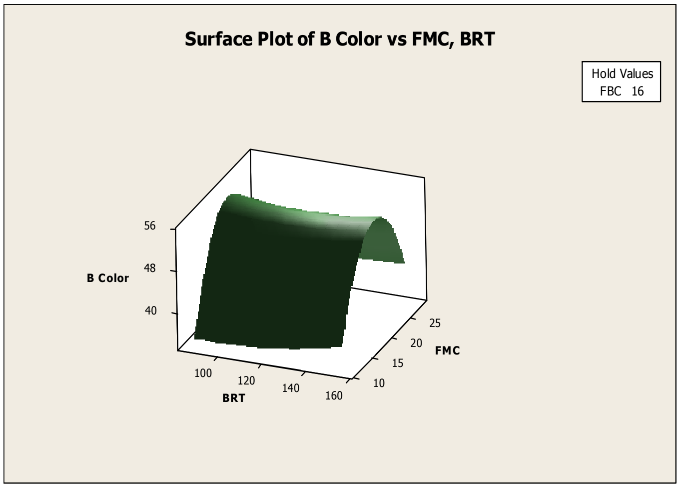
APPENDIX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BRT
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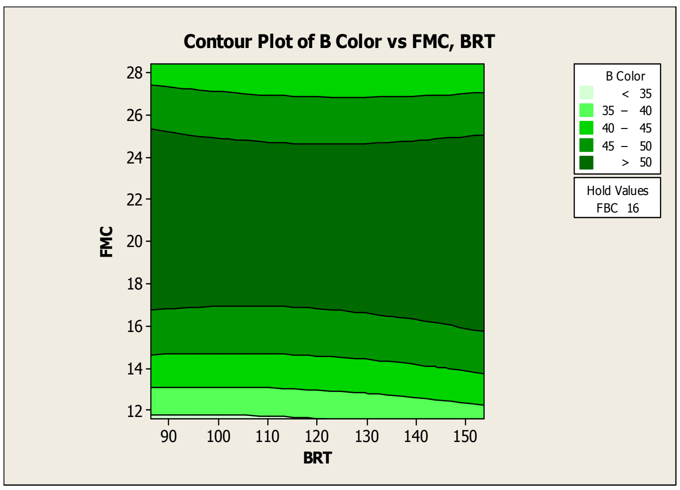
15
20
25
FMC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40 – 45
45 – 50
> 50
Hold Values
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100
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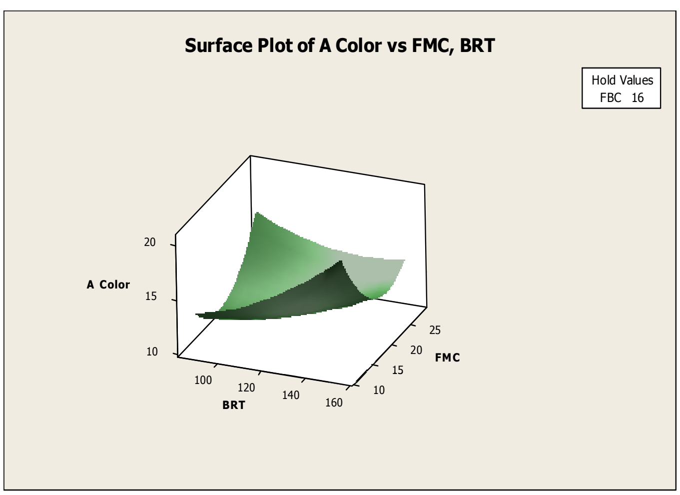
130
140
150
BRT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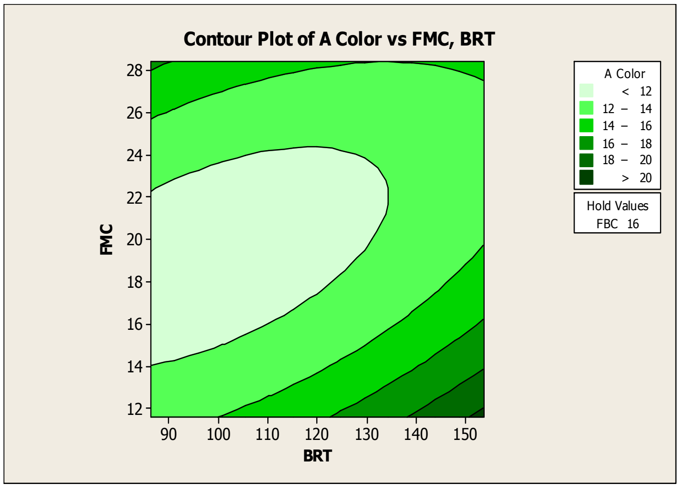
FMC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14 – 16
16 – 18
18 – 20
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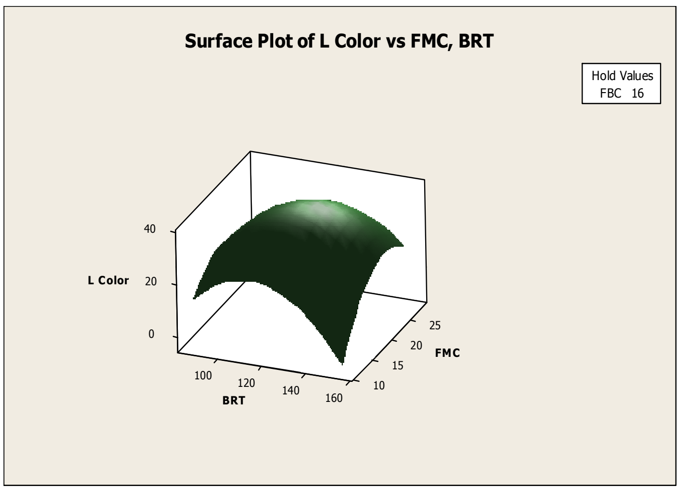
12
90 100 110 120 130 140 150
BRT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20
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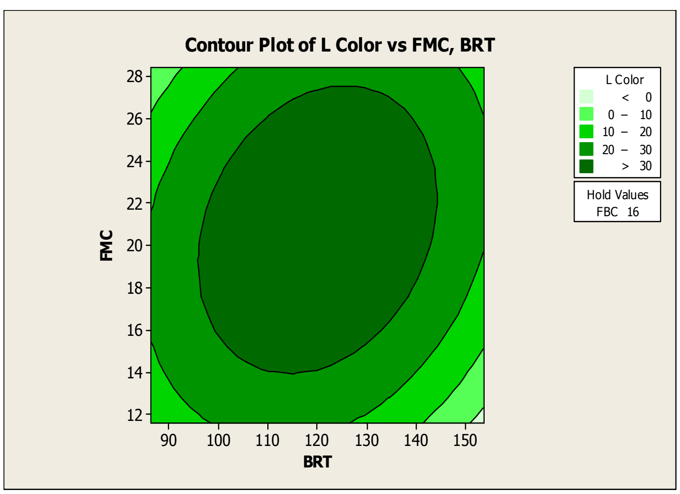
BRT
10 15 20 25
FMC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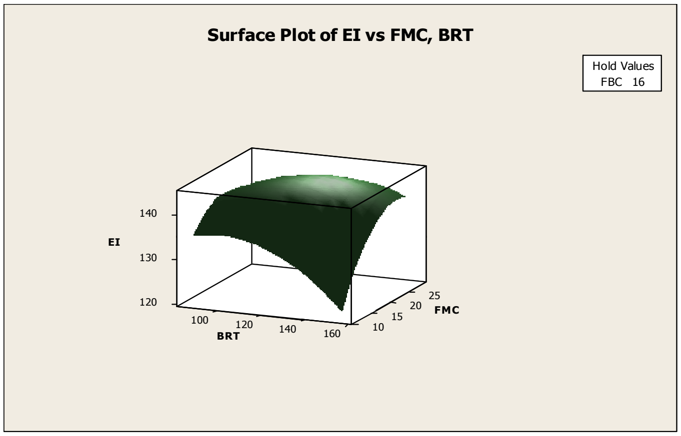

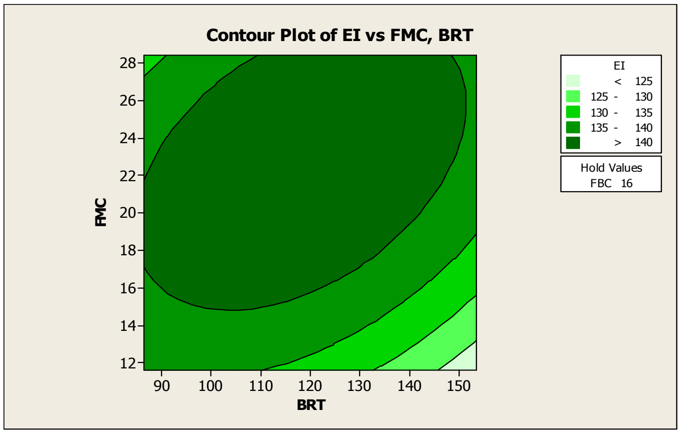

Mathematical models of Complementary food produced from millet-soybeans

L*colour {-250.396+3.43343(BRT)+5.48270(FMC)+3.18333(FBC)-0.0155682(BRT*BRT)-0.196270(FMC*FMC) -0.0289658(FBC*FBC)+ 0.0255250(BRT*FMC) -0.0138594(BRT*FBC)-0.0257500(FMC*FBC)}

A* colour {11.2437-0.0440309(BRT)-0.726257(FMC)+1.00201(FBC)+0.00103528(BRT*BRT)+ 0.0500107(FMC*FMC)-0.0125606(FBC*FBC) -0.00811250(BRT*FMC)-2.42188E-04(BRT*FBC) -0.0243438(FMC*FBC)}

B* colour {-92.4784+0.120809(BRT)+10.3711(FMC)+3.80694(FBC)+0.000939441(BRT*BRT)-0.222203(FMC*FMC) -0.0331299(FBC*FBC)-0.00415000(BRT*FMB)-0.0155781(BRT*FBC)-0.0418125(FMC*FBC)}

Expansion Index {89.6824+0.443810(BRT)+3.13218(FMC)-0.717729(FBC)-0.00467482(BRT*BRT)-0.0883029(FMC*FMC)+0.00754640(FBC*FBC)+ 0.0172000(BRT*FMC)+ 0.0170469(BRT*FBC)-0.0741875(FMC*FBC)}

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