

Research Article

Use of D-Optimal Mixture Design in Optimizing the Quality Characteristics of Refined Wheat-Soybean-Oyster Meat Powder Composite Flour

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Abstract

The use of composite flours for domestic and industrial applications in baked and confectionery products has been seen as one of the ways for achieving sustainable food and nutrition security especially in developing countries of the world, however, its utilization might be limited by the quality characteristics of the resulting composite flour samples. In this research study, D-optimal design mixture was used to investigate the simultaneous effects of varying compositional percentage of refined wheat flour, soybeans flour and oyster meat powder on some proximate and pasting properties of composite flour. A total of 14 combinations were generated using Design Expert software. The properties of the composite flour measured showed a significant ($p < 0.05$) influence on the composite flour samples. The ranges of values for the properties are moisture content - 8.31 - 12.25%, fat content - 1.46 - 9.41%, protein content - 11.34 - 20.28%; while peak, breakdown and setback viscosities range from 418 - 1025cP, 220 - 515cP and 240 - 690cP respectively. The proximate properties of fat and protein contents increased with increase in soybean and oyster meat flour inclusion while moisture content decreased with increase in soybean and oyster meat flour inclusion. The pasting properties of peak, breakdown and setback viscosities were also significantly ($p < 0.05$) affected by varying percentage composition with the properties decreasing with increase in percentage soybean flour and oyster meat powder inclusion. The numerical optimization showed that the best combination of the individual flour were 72.00% refined wheat flour, 20.00% soybeans flour and 8.00% oyster meat powder with a desirability value of 0.719.

Keywords

Composite Flour, Proximate Properties, Pasting Properties, Optimization

1. Introduction

Composite flour is a novel blend of two or more flours and additional ingredients intended to partially or completely replace refined wheat flour in culinary applications [1, 2]. Its utilization in food industry remains an important tool for enhancing sustainable growth and development of the

industry as it serves the tripodal purpose of reducing the cost of importation of refined wheat flour, enhancing the utilization of local/underutilized crop and improving the nutritional value of food products [3, 4]. However, many of the nutrients in the refined wheat flour were lost or degraded

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Received: 30 September 2025; **Accepted:** 15 October 2025; **Published:** 26 November 2025



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during milling and other processing activities, which impacts the nutritional value of the raw wheat [5-7].

Recently, the use of different types of flour to create composite flour has become popular as a way of improving the quality of flour as individual components of composite flours would greatly affect the functional qualities and nutritional makeup of the final flours and the subsequent food applications [8, 9].

Though wheat provides a good source of calories and some nutrients, it lacks sufficient amounts of the important amino acids - lysine and threonine, which results in lower-quality protein when compared to proteins from milk, soybeans, peas, and lupin [10, 11].

One of the most significant oilseed and protein crops in the world is soybeans. They are rich in all essential amino acids, containing between 30 and 45% protein and isoflavones which have been found to be powerful cancer-preventive agents. They have been identified to lower the risk of a number of malignancies and help prevent cardiovascular disease; hence, soybeans have been referred to as "the protein hope of the future" [12, 13].

Authors have suggested and shown that combining legume proteins like soybean with lysine-poor staples is a good way of increasing the protein nutritional content of the final products [14-16]. The high-protein soybean composite flour would serve as an effective nutritional carrier for vulnerable groups - pregnant and nursing mothers, young children [12]. However, soybeans like other plant-based proteins are also deficient in one or two of the essential amino acids (sulfur-containing amino acid like methionine), leading to their label as "incomplete protein packages" [17].

Animal proteins contain indispensable or essential amino acids (histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine) that are highly digestible by the body; and many people believe that animal proteins are "complete protein packages" because they include all nine essential amino acids [18].

An important source of underutilized animal protein is the meat of oysters (*Crassostrea gasar*), which are marine animals belonging to the Ostreidae family. They are among the most popular and extensively grown seafood in the world. Nutritionally, oyster meat is low in fats, the polyunsaturated fatty acids (PUFAs) are predominant among the total lipids, rich in protein (with lysine as the most abundant essential amino acid), vitamins and essential micronutrients (such as calcium, magnesium, potassium, phosphorus etc) which makes them food source for eradicating "hidden hunger" [19-21].

Therefore, developing a composite flour by combining refined wheat flour, soybean flour and oyster meat powder would result in a flour with sufficient and balanced nutritional attributes that, when employed in food applications, can positively impact the nutritional status of the consumers. Nevertheless, the functionality of the final composite flour would be impacted by the combinations of these flours. This

forms the objective for this work which is to determine how the combination of different flours affects some quality characteristics of the final composite flour.

2. Materials and Methods

2.1. Materials

Refined wheat flour was purchased from BUA IRS Flour Mills in Port Harcourt, Rivers State, Nigeria and wholesome soybeans grains were purchased from new layout market in Port Harcourt, Rivers State, Nigeria. Raw oysters in their shells were purchased from Okrika market square in Okrika Island, Rivers State, Nigeria. The grains were kept in air-tight, moisture-proof container after purchase while raw oyster were packed in ziplock bag and stored in refrigeration before usage (within the 24 hour).

2.2. Methods

2.2.1. Preparation of Soybean Flour

Soybean flour was produced from raw soybean grains using modified method of Ndife [22]. The soybeans were sorted and cleaned of all contaminants and spoiled seeds. The soybeans were then washed, oven-dried, roasted, winnowed, and milled in an attrition mill. Soybean flour (full fat) was sieved to 0.25 mm particle size, the soybean flour was then cooled at room temperature for six hours and then packed in air and water tight cellophane bag and stored (Figure 1).

2.2.2. Preparation of Oyster Meat Powder

Oyster meat powder was prepared using the method of Orunaboka [16]. Raw Oysters were obtained from the market. Prior to its sales in the market, the oyster were harvested from the mangrove tree root to which they were attached, they were scrubbed and washed with warm water to remove mud, seawater and all contaminants then rinsed with cold fresh water (pre-sales/post-harvest activities by the market women). The meat was shucked from the shell with knife and oven-dried at 60 °C for 7 hrs. Dried oyster meat was ground and sieved to 0.25 mm particle size then packaged and stored (Figure 2).

2.2.3. Experimental Design and Data Analysis

A D-optimal mixture design using Design-Expert software version 6.0.8 was used to investigate the effect of blending ratios on some proximate (moisture, fat and protein) and pasting properties (peak, breakdown and setback viscosities) characteristics of composite flours.

The component proportions of the flour formulation as previously established from preliminary experiments carried out in the laboratory were subject to multiple-components constraints. The range for the constraints for the 3

independent variables were Refined wheat flour, (RWF - x_1), Soybean flour (SBF- x_2) and Oyster meat powder (OMP - x_3) were $70 \leq x_1 \leq 100$, $0 \leq x_2 \leq 22$, and $0 \leq x_3 \leq 8$, respectively (Table 1).

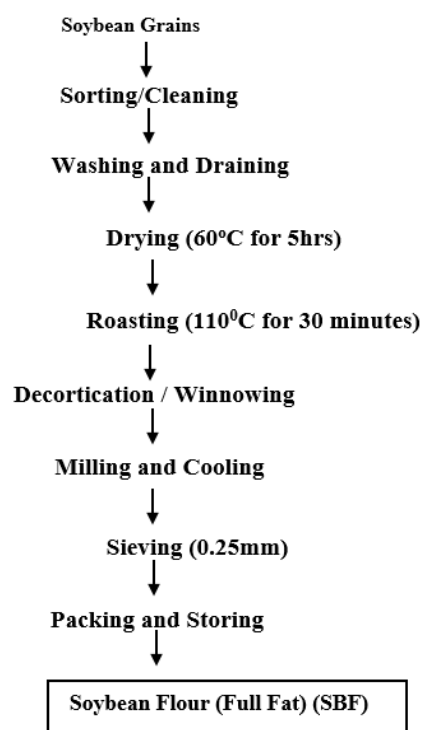


Figure 1. Preparation of Soybean Flour (SBF).

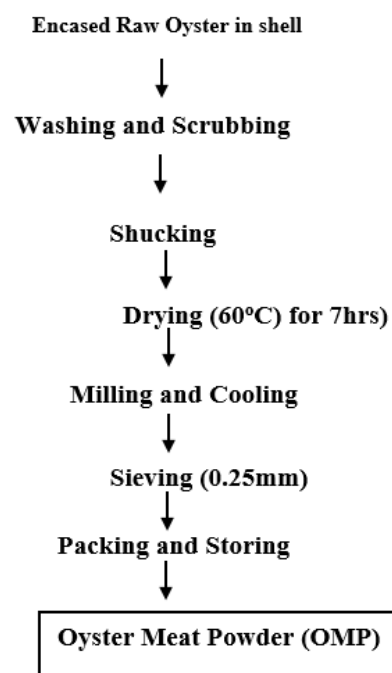


Figure 2. Preparation of Oyster Meat Powder (OMP).

Table 1. Ranges for the 3 independent variables - Refined Wheat Flour, Soybean Flour and Oyster Meat Powder.

Code	Parameter	Low level	High level
RWF	Refined Wheat Flour	70	100
SBF	Soybean Flour	0	22
OMP	Oyster Meat Powder	0	8

A D-optimal design matrix consisting of 14 experimental runs with 4 replications was chosen to evaluate the combined effect of the 3 independent variables (Table 2). The dependent variables - Moisture Content (Y_1), Fat Content (Y_2), Protein Content (Y_3), Peak Viscosity (Y_4), Breakdown Viscosity (Y_5) and Setback Viscosity (Y_6) were selected as responses for representing the main parameters of flour because of their pertinent qualities in determining the functionality of the flour.

The significance of effect and regression coefficients of models was verified by the ANOVA test, analyzing the f and p value ($p < 0.05$), the smallest standard error, the smallest mean, and the sum of the predicted deviations, and maximizing the R^2 and the adjusted R^2 . The highest polynomial orders with significant additional terms were selected.

$$Y = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + \beta_{123} X_1 X_2 X_3$$

Where: Y = the predicted variable; $X_{1,2,3}$ = the proportion of the three flours in the mixture

β 's = the coefficients of the linear, quadratic, and cubic terms of the model

The significance of all terms was judged statistically by a probability (p) at 0.05 and the interaction effects of variables on the mixture were determined using a 3-dimension contour plots.

2.3. Analyses

2.3.1. Moisture, Protein and Fat Content Analysis of Samples

The moisture content, crude protein and fat contents of the samples were determined by standard methods of AOAC [23].

2.3.2. Pasting Properties Determination of Samples

The pasting properties of composite flour samples were determined using the method of Falade and Olugbuyi [24] with the aid of a Rapid Visco Analyzer (Model RVA 4500, Perten Instruments, and Australia) equipped with a 1,000 cmg sensitivity cartridge. Composite flour sample (3.5 g) was weighed into a dried empty canister and 25 ml of distilled water was added. The mixture was thoroughly stirred and the canister was fitted into the RVA as

recommended. The slurry was heated from 50 to 95 °C at a rate of 1.5 °C/min, held at this temperature for 15 min, cooled to 50 °C. The pasting profile indices of the samples were read

with the aid of Thermocline for Windows Software connected to a computer.

Table 2. Percentage Composition of Refined Wheat-Soybean-Oyster Meat in Composite Flour.

Exp.Run	Sample Code	X ₁ - RWF	X ₂ - SBF	X ₃ - OMP
1*	RWC1	78.00	22.00	0.00
2*	RWC 2	100.00	0.00	0.00
3	RWC 3	90.50	5.50	4.00
4	RWC 4	74.00	22.00	4.00
5	RWC5	78.00	22.00	0.00
6	RWC6	89.00	11.00	0.00
7	RWC7	81.00	11.00	8.00
8*	RWC8	100.00	0.00	0.00
9	RWC9	70.00	22.00	8.00
10*	RWC10	92.00	0.00	8.00
11	RWC11	92.00	0.00	8.00
12	RWC12	100.00	0.00	8.00
13	RWC13	92.50	5.50	2.00
14	RWC14	74.00	22.00	4.00

*Duplicated Runs.

2.3.3. Fitting for the Best Model

The best model for predicting quality characteristics of composite flour samples is the regression model that has a low standard deviation, a low predicted sum of squares, and high R^2 values [25]. Therefore, the results of ANOVA showed that quadratic model was best fitted for the moisture protein content, fat protein content, protein content, while cubic model was best fitted for peak, breakdown and setback viscosities responses. The R^2 value obtained from quadratic and cubic models was found to be greater than 0.85, indicating a great fitting model.

2.3.4. Optimization

The numerical optimization used to determine the optimal combination of the mix proportions by setting a response goal. The desirability function was used to numerically optimize the blend proportions. For X attributes, the overall desirability D based on the desirability value (d_i) of each attribute is given by:

$$D = (d_1 \times d_2 \times d_3 \times \dots \times d_x)^{1/x}$$

3. Results and Discussion

In Table 3, the composite flour samples' mean values for the dependent variables showed that the ranges for the moisture, fat, and protein contents were 8.31 to 12.25%, 1.46 to 9.41%, and 11.34 to 20.28%, respectively. The ranges were 418.00 to 1025 (cP), 220 to 515 (cP), and 240 to 690 (cP) for peak, breakdown, and setback viscosities.

3.1. Moisture, Fat and Protein Contents of Flour Samples

The flour combinations significantly ($p < 0.05$) influenced the moisture content of the samples. Figure 3 presents the relationship between the individual components of the flour blend and the moisture content. Increased substitution of refined wheat flour with soybean flour and oyster meat powder resulted in significant reduction in the moisture contents of refined wheat composite flours this might be attributed to the higher total dry solids, fat content and high emulsifying properties contained in the soybean flour [26, 27].

The moisture content of the composite flour samples are within the stipulated CODEX moisture content range for

flours (15.5% maximum) [28]. Generally, lower moisture content of flour would enhance shelf stability during storage by preventing the growth of moulds and subsequent biochemical reactions [29, 30].

Figure 4 shows the relationship between fat content and the effect of different components of flour blend samples. The inclusion of soybean flour and oyster meat powder in the composite flour resulted in significant ($p < 0.05$) increases in

the fat contents of composite flours.

Other research on the effects of soybean flour inclusion on food products [16, 31, 32] supports this increase in the composite flours fat content. This may be explained by the fact that soybeans are one of the main sources of edible oils in the globe [33, 34]. Given that fats are known to improve flavor and provide vital fatty acids, the sample's increased fat content may be an added benefit [35].

Table 3. Mean Value of Quality Characteristic of Refined Wheat-Soybean-Oyster Meat Composite Flour.

Runs	Variables			Responses					
Codes	X ₁	X ₂	X ₃	Y ₁	Y ₂	Y ₃	Y ₄	Y ₅	Y ₆
RWC ₁	78.00	22.00	0.00	9.80	7.96	16.87	570	310	280
RWC ₂	100.00	0.00	0.00	12.20	1.44	11.48	1020	510	690
RWC ₃	90.50	5.50	4.00	10.83	5.53	14.19	670	410	430
RWC ₄	74.00	22.00	4.00	9.14	8.62	18.60	460	260	240
RWC ₅	81.50	16.50	2.00	10.01	7.39	17.68	580	350	330
RWC ₆	70.00	22.00	8.00	8.31	9.38	20.28	420	222	242
RWC ₇	92.00	0.00	8.00	11.30	4.42	14.99	747	440	450
RWC ₈	100.00	0.00	0.00	12.25	1.46	11.34	1025	515	680
RWC ₉	92.00	0.00	8.00	11.39	4.40	14.95	740	430	450
RWC ₁₀	78.00	22.00	0.00	9.91	7.99	16.83	560	310	280
RWC ₁₁	85.00	11.00	4.00	10.54	6.14	15.94	660	390	380
RWC ₁₂	89.00	11.00	0.00	10.70	5.31	15.50	550	300	275
RWC ₁₃	77.50	16.50	6.00	9.60	7.31	17.74	550	300	275
RWC ₁₄	70.00	22.00	8.00	8.40	9.41	20.15	418	220	240

Where:

(X₁) = Refined Wheat Flour, (X₂) = Soybean Flour, (X₃) Oyster Meat Powder, (Y₁) = Moisture Content, (Y₂) = Fat Content, (Y₃) = Protein Content, (Y₄) = Peak Viscosity, (Y₅) = Breakdown Viscosity and (Y₆) = Setback Viscosity

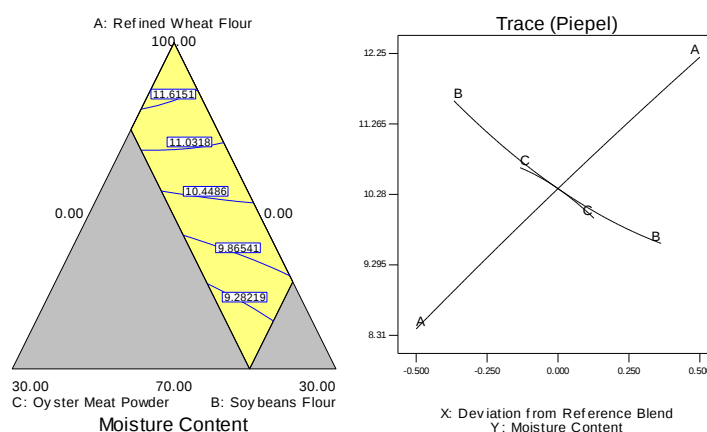


Figure 3. Contour plots and Trace plot curves of variation in composite (A: Refined wheat, B: Soybeans, C: Oyster meat powder) flour on the moisture content composite flour.

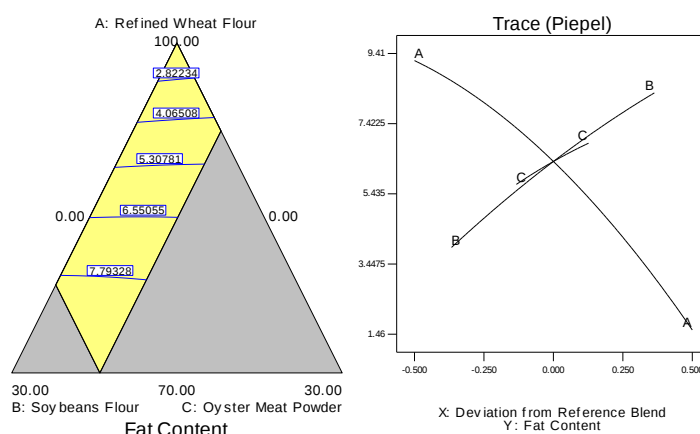


Figure 4. Contour plots and Trace plot curves of variation in composite (A: Refined wheat, B: Soybeans, C: Oyster meat powder) flour on the fat content of composite flour.

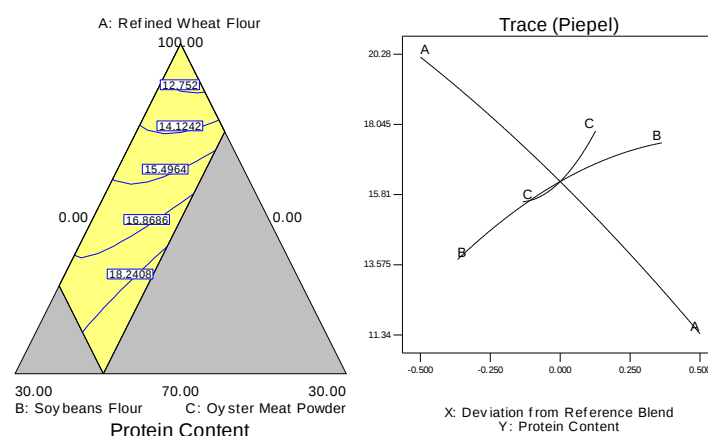


Figure 5. Contour plots and Trace plot curves of variation in composite (A: Refined wheat, B: Soybeans, C: Oyster meat powder) flour on the protein content of composite flour.

Figure 5 illustrates how the protein content of the composite flour samples is affected significantly ($p < 0.05$) by varying percentages of soybean flour and oyster meat powder inclusion. The higher the percentage of soybean flour and oyster meat powder in the flour samples, the higher the protein content. This could be because soybeans are a high-protein legume crop that complements lysine-limited cereal protein well [36, 37]. Cereal-legumes composite flours have been reported to have high protein content [38, 39].

The increase in protein and fat content of the composite flours was anticipated since soybeans flour and oyster meat powder have them present resulting in synergistic effects of increase in protein and fat complementation [40]. Generally, higher protein content in dough is recognized to improve texture and quality of baked foods [41].

The increase in the percentage protein and fat contents of the composite flour served as the foundation for the blend formulation since it was anticipated that the finished product would have a higher protein and fat content among other nutrients.

3.2. Peak, Breakdown and Setback Viscosity of the Flour Samples

The pasting properties of samples are used in assessing the suitability of its application as a functional ingredient in food and other industrial products [42]. Varying the percentage composition of the individual components of the composite flour samples had a significant ($p < 0.05$) effect on the peak viscosity of the composite samples. The interaction between the individual components of the composite flours and the peak viscosity of the sample is as presented in Figure 6. Peak viscosity is indicative of the viscous load likely to be encountered during mixing [43]. The peak viscosity of the sample decreases with increase in of soybean and oyster meat powder.

This might be attributed to the dilution and/or disruption of the gluten matrix of the refine wheat flour leading to the weakening of the gluten matrix of the dough; additionally, the lower starch content of the oyster meat and soybean flours results in a low gelatinization and swelling index of the flour

samples. Lower peak viscosity in flour has been identified to improving the confectionary making qualities of composite flours [44].

Figure 7 shows the interaction between the components of the composite flours and the breakdown viscosity of the samples. Breakdown viscosity is the measure of the tendency of swollen starch granules to rupture when held at high temperatures and continuous shearing. It is indicative of paste stability of the flour samples [45, 46]. Significant ($p < 0.05$) difference was observed on the variation of the components of the composite flour samples and breakdown viscosity of the composite samples with the breakdown viscosity decreasing

with increasing level of both soybeans flour and oyster meat powder substitution meaning that the composite would not breakdown on heating.

The interaction between the components of the composite flours and the setback viscosity of the samples is as presented in Figure 8. Setback value measures the stability of the paste after cooking. It is the cooling phase of the mixture during pasting in which a re-association between the starch molecules occurs to a greater or lesser degree. It therefore affects retrogression or re-ordering of the starch molecules as well as synergism and weeping [42].

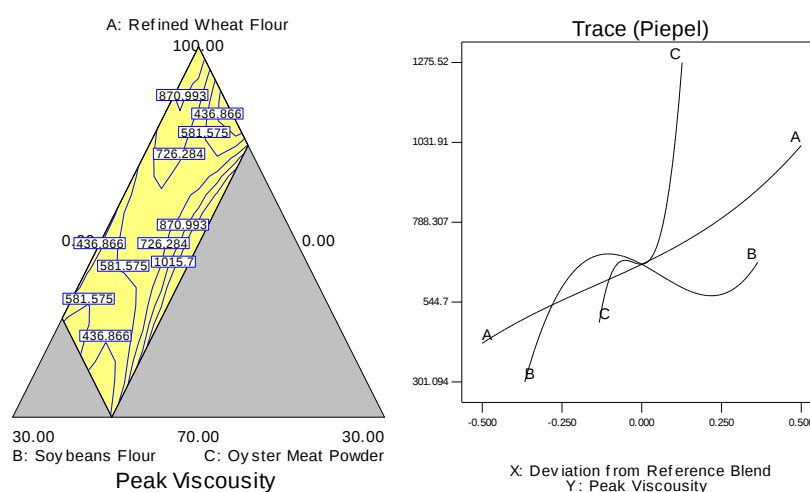


Figure 6. Contour plots and Trace plot curves of variation in composite (A: Refined wheat, B: Soybeans, C: Oyster meat powder) flour on the Peak viscosity of composite flour.

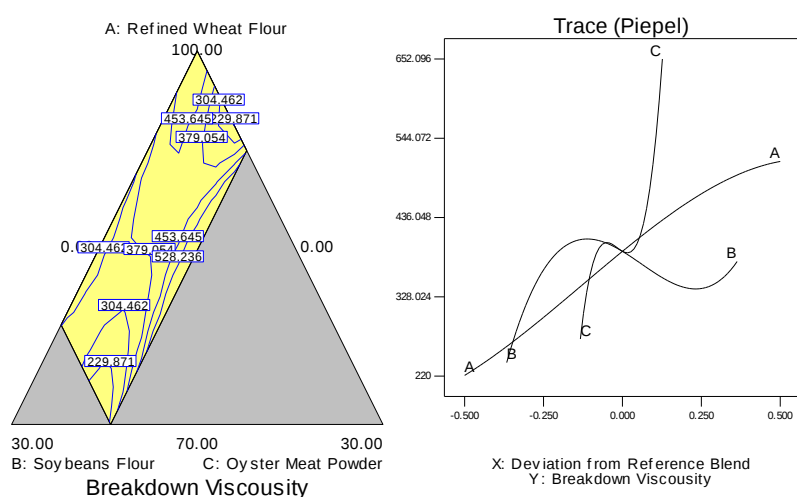


Figure 7. Contour plots and Trace plot curves of variation in composite (A: Refined wheat, B: Soybeans, C: Oyster meat powder) flour on the Breakdown viscosity of composite flour.

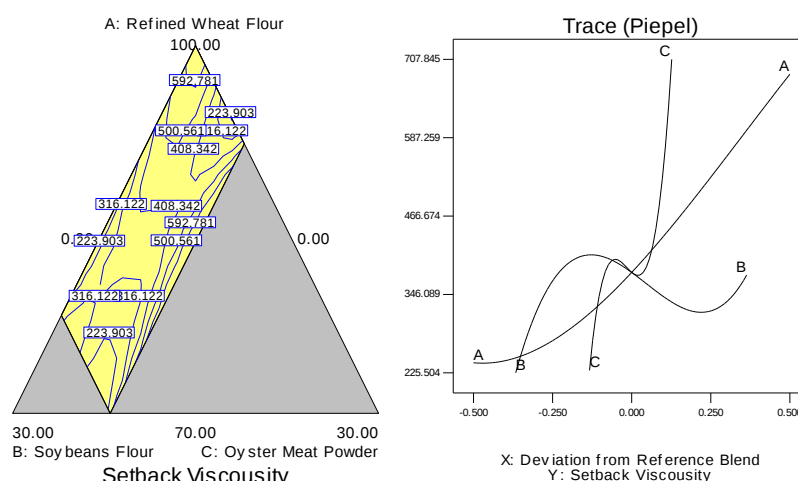


Figure 8. Contour plots and Trace plot curves of variation in composite (A: Refined wheat, B: Soybeans, C: Oyster meat powder) flour on the Setback Viscosity of composite flour.

There were significant ($p < 0.05$) difference in the observed variation in the components of the composite flour samples and setback viscosity of the composite samples. The setback viscosity of the composite flour samples decreases with increases in the percentage level of both soybeans flour and oyster meat powder substitution. This might be associated with the lower starch content of the both soybean and oyster meat powder with increasing substitution. This is an indicative of high stability as higher setback value is associated with syneresis.

3.3. ANOVA and Regression Coefficients of the Models for the Measured Parameters for Refined Wheat- Soybeans-Oyster Meat Composite Flours

Tables 4 and 5 present the ANOVA and the Regression coefficients for the refined wheat- Soybeans-Oyster meat composite flours respectively. For the proximate (moisture, fat and protein contents) only the linear mixture model terms was significant ($p < 0.05$); while for the pasting properties of peak, breakdown and setback viscosities, both the linear and all the interactive model terms were significant ($p < 0.05$) (Table 4).

The regression coefficients of the models (Table 5) revealed a significant difference ($p < 0.05$) across the measured parameters of the composite flours. Moisture, fat and protein contents were best fitted with quadratic models while peak, breakdown and setback viscosities were best fitted with cubic models.

Table 5 revealed the variation in the models with respect to the individual component of the flour samples. The magnitude of the coded coefficients indicated that oyster meat powder appeared to have the least contribution to the moisture content of the composite samples followed by soybeans flour. The R^2 (0.9911) and adjusted R^2 (0.9855) were in reasonable

agreement.

For fat content, the linear blend coefficients significantly ($p < 0.05$) affected the composite flours samples where soybeans flour is the dominant positive effect followed by oyster meat powder as indicated by the magnitude of the coefficients. The R^2 (0.9867) and adjusted R^2 (0.9784) agreed reasonably. Also, protein content revealed a significant ($p < 0.05$) linear blend coefficient variation on the composite samples with oyster meat powder have the dominant effect followed by soybean flour. The R^2 (0.9779) and adjusted R^2 (0.9662) of the models were very close.

For the viscosities models, the linear, mixture and quadratic coefficients significantly ($p < 0.05$) affected the variation in composite flours. Their R^2 (0.9998, 0.9995 and 0.9998) and adjusted R^2 (0.9994, 0.9993 and 0.9994) respectively for peak, breakdown and set back viscosities best described the models.

3.4. Process Optimization of Refined Wheat Composite Flour

Using numerical optimization, the criteria and goals for the optimization of responses for refined wheat composite flour samples is as shown in Table 6 where protein content, water absorption capacity, dough stability and peak viscosity were maximize and moisture content and setback viscosity were minimize.

Table 7 presents the predicted variables and response values for the selected composite flour. The composite flour sample would contain 72.00% refined wheat flour, 20.00% soybeans flour and 8.00% oyster meat powder would produce composite flour sample with the following characteristics: moisture content - 8.61 (%), fat content - 8.92%, protein content - 19.99 (%), peak viscosity - 623.77 (cP), breakdown viscosity - 323.59 (cP) and setback viscosity - 354.10 (cP) with desirability of 0.719.

Table 4. ANOVA for quality characteristics of refined wheat flour-soybeans flour-oyster meat powder composite flour.

Source	Moisture ^a (%)	Fat ^a (%)	Protein ^a (%)	Peak Viscosity ^b (cP)	Breakdown Viscosity ^b (cP)	Setback Viscosity ^b (cP)
Model (SS)	20.000	86.64	96.22	4.765E+005	1.217E+005	3.007E+005
Linear Mixture (SS)	19.94*	84.65*	94.27*	4.114E+005*	1.103E+005*	2.454E+005*
AB (SS)	0.046	0.28	1.09	3820.69*	756.93*	1722.23*
AC (SS)	0.016	0.018	0.47	3909.46*	1160.11*	2036.59*
BC (SS)	1.131E-003	4.349E-004	0.40	3761.02*	1098.80*	1899.76*
ABC (SS)				3899.93*	1157.31*	2013.24*
AB (A-B)				1102.55*	208.74*	289.61*
AC (A-C)				4138.85*	1361.01*	2413.58*
BC (B-C)				3588.41*	1092.83*	1889.88*
Model F-Value	177.66*	118.66*	75.29*	2379.34*	838.75*	2570.15*
Lack of Fit F-Value	11.73*	1061.10*	202.48*	-	-	-
<i>p</i> -Value (Prob>F)	< 0.0001*	< 0.0001*	< 0.0001*	< 0.0001*	< 0.0001*	< 0.0001*
Std Dev	0.15	0.38	0.51	4.72	4.02	3.61

*Significance at $p < 0.05$. ^a = Fitted with quadratic model; ^b = Fitted by cubic model.

Table 5. Predictive model equations for quality characteristics of refined wheat flour-soybeans flour-oyster meat powder composite flour.

Responses	Regression Model (Final Equation in Terms of Pseudo Component)	Type of Model	R ²	Adj. R ²	Adeq Precision
Moisture Content	12.20*A+9.32*B+4.86*C-1.33*A*B+5.63*A*C+1.40*B*C	Quadratic	0.9911	0.9855	38.674
Fat Content	1.58*A+9.43*B+7.95*C+3.28*A*B+5.99*A*C+0.87*B*C	Quadratic	0.9867	0.9784	30.496
Protein Content	11.38*A+17.58*B+46.65*C+6.46*A*B-30.45*A*C-26.30*B*C	Quadratic	0.9779	0.9662	26.617
Peak Viscosity	1022.50*A+1748.88*B+1.314E+005*C-3865.91*A*B-2.196E+005*A*C-2.251E+005*B*C+2.107E+005*A*B*C+2566.12*A*B*(A-B)+86642.58*A*C*(A-C)+ 88964.63 *B*C*(B-C)	Cubic	0.9998	0.9994	151.383
Breakdown Viscosity	512.50*A+834.17*B+70959.61*C-1720.72*A*B-1.196E+005*A*C-1.217E +005 *B*C+1.148E+005*A*B*C+1116.55*A*B*(A-B)+49684.57*A*C*(A-C)+ 49095.66*B*C*(B-C)	Cubic	0.9995	0.9993	85.892
Setback Viscosity	685.00*A+988.53*B+93413.75*C-2595.53*A*B-1.585E+005*A*C-1.600E+ 005 *B*C+1.514E+005*A*B*C+1315.18*A*B*(A-B)+66164.06*A*C*(A-C)+ 64562.99*B* C*(B-C)	Cubic	0.9998	0.9994	146.033

Table 6. Criteria and goals for the numerical optimization of responses for refine wheat flour composite sample.

Categories	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
Refined Wheat Flour	is in range	70	100	1	1	3
Soybeans Flour	is in range	0	22	1	1	3
Oyster Meat Powder	is in range	0	8	1	1	3
Moisture Content	Minimize	8.31	12.25	1	1	3
Fat Content	Maximize	1.46	9.41	1	1	3
Protein Content	Maximize	11.34	20.28	1	1	3
Peak Viscosity	Maximize	418	1025	1	1	3
Breakdown Viscosity	Minimize	220	515	1	1	3
Setback Viscosity	Minimize	240	690	1	1	3

Table 7. Solution for the numerical optimization of responses for refine wheat flour composite sample.

No	Refined Wheat Flour (%)	Soybean Flour (%)	Oyster Meat Powder (%)	Moisture Content (%)	Fat Content (%)	Protein Content (%)	Peak Viscosity (cP)	Breakdown Viscosity (cP)	Setback Viscosity (cP)	Desirability
1	72.00	20.00	8.00	8.608	8.922	19.989	623.773	323.592	354.101	0.719
2	75.45	22.00	2.55	9.391	8.533	17.794	581.491	329.478	323.015	0.633
3	77.73	22.00	0.27	9.788	8.036	17.222	606.036	314.313	314.313	0.614

4. Conclusion

In the present work, D-optimal mixture design (DMD) was used to optimization the production of composite flour from refined wheat flour, soybean flour and oyster meat powder. The blend proportions significantly (<0.05) affected the measured properties (proximate and pasting properties) of the composite flour. The fat and protein content of the samples increased with increase inclusion of both soybean and oyster meat flour while the moisture content decreases.

Higher inclusion of soybeans and oyster meat flours increased the peak viscosity of the composite flour samples while breakdown and setback viscosity decreases with increased inclusion.

The models obtained can be used to predict quality characteristics of the composite flour based on measured parameters. The numerical optimization revealed that best results were obtained at 72.88% refined wheat flour, 19.12% soybean flour and 8.00% oyster meat powder with a desirability value of 0.759.

Abbreviations

RWF	Refined Wheat Flour
SBF	Soybean Flour
OMP	Oyster Meat Powder

Author Contributions

Wilson Tamunotonye Orunaboka: Conceptualization, Formal Analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing

Sulaimon Babatunde Kosoko: Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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