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FORMULATING POULTRY FEEDS FROM FOOD PROCESSING BY-PRODUCTS

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Abstract
This study was undertaken to formulate poultry feeds (chick mash, growers mash and layers mash) from food processing by-products using mixture design experimental methodology. The proximate composition of the formulated feeds were also determined and compared with the recommended nutrient level of layers feed. Models for the proximate composition of the formulated feeds were also developed. The results of analyses for the formulated samples of chicks, growers and layers mashes showed that the crude protein, the crude fibre, the moisture, the fat, the ash, and the carbohydrate contents, ranged respectively from 16.1% to 17.89%, 4% to 6.25%, 9.34% to 11.9%, 2.9% to 6.1%, 3.54% to 6.23%, and 55.3% to 60.98%. The respectively recommended values for chick mash, growers mash and layers mash are: 18%, 16%, 15% (crude protein); 6.25%, 4.56%, 5.94% (crude fibre); 9.45%, 9.65%, 7.98% (moisture content); 3.25%, 3.84%, 4.1% (fat); 4.29%, 6.02%, 5.39% (ash); and 57.98%, 59.48%, 61.28% (carbohydrate). The study showed that the proximate compositions of the formulated feeds are in close agreement with recommendations on nutrient levels for poultry feeds.

Keywords: Formulation, mixture design, models, optimization, poultry feeds, proximate compositions

1. Introduction

Nigeria hosts more than 45% of the poultry in the West African sub region and its poultry population is estimated at 140 – 160 million (FAO, 2006). This figure accounts for 71.38% of the total livestock kept in the country and supplies 17% of animal protein need of the population (Oji and Chukwuma, 2007; Afolabi, 2007).

The Nigerian poultry industry in particular has been rapidly expanding in recent years and is therefore one of the most commercialized subsectors of Nigerian agriculture (NCERD, 2000; Okonkwo and Akubo, 2001; Adene and Oguntade, 2006; Ocholi *et al.,* 2006). In 2013 the livestock population in Nigeria was estimated at 137,678,508, and the poultry industry was estimated to be worth ₦80 billion (USDA, 2013).

The popularity of poultry production can be explained by the fact that poultry has many advantages over other livestock (Ojo, 2003; Aboki *et al.,* 2013). Although poultry production is becoming the fastest growing agribusiness sector in sub-Saharan Africa, it faces problems of feed-food competition (Mammo, 2012). Feed, which is said to be the most important input for profitable poultry production, has continued to be a problem to most poultry farmers. The availability of low-priced, high-quality feeds is critical if poultry production is to remain competitive and continue to grow to meet the demand for animal protein (Umeh and Odo, 2002; Okonkwo and Akubuo, 2001).

1.1 Poultry Feeds Formulation

Globally, maize (corn) is the most commonly used energy source, and soybean meal is a common plant protein source. Other grains such as millet and sorghum are also widely used in some countries. The main animal protein ingredients are fishmeal and meat meal. Almost all developing countries are net importers of these ingredients; the poultry feed industries in Africa depend on imports, which are a drain on their foreign exchange reserves. The demand on grains for human consumption has caused severe grain supply problems in the poultry feed industries.

A number of studies have shown that feed costs constitute one the highest variable costs in the poultry production process (Umeh et al., 2002; Effiong and Onyenweaku, 2006; Tijjani *et al.*, 2012; Ohajianya *et al.,* 2013; Esiobu et al., 2014; Nmadu *et al.* 2014). In recent years, there has been a rapid increase in the price of feed. This constraint makes it difficult for farmers to purchase the quantity of feeds needed for efficient poultry production. Shortage and high cost of feed have forced many large scale operators out of the business (Okonkwo and Akubo, 2001).

Meeting the requirements for the four traditional feed ingredients – maize, soybean meal, fish meal and meat meal – is becoming difficult. There is a wide gap between local supply and demand for these traditional ingredients, thus providing a compelling reason for innovation and exploration of readily available alternative feedstuffs. Optimization of feed formulation is one of the powerful means of addressing relatively low poultry production. However, the level of innovation adoption among poultry producers in Nigeria is still quite low (Ladele, 2002).

Paradoxically, the solution for this problem could come from the food processing industries, through their major by-products which have been shown to be good sources of available amino acids and energy (UNEP. 2009). Worldwide, feed millers are showing keen interest in agricultural waste and food processing by-products as alternative feedstuffs because of their cost-effectiveness and ready availability (UNEP, 2009).

1.2 Food Processing Wastes for Animal Feeds

The food industry processing plants produces large amounts of waste that are good sources of dietary fibre and phytochemicals for animal feeds. In most households and locations, several by-products from cereal milling and processing are available for animal feeding, including bran, hulls and screenings. These can be valuable sources of energy. In areas where there are fishing and meat processing operations, there is good potential for using offal for poultry feeding, in either fresh form or after processing. Scrap fish and fish wastes or residues (heads and offal) can be dried and processed into a meal. Efficient utilization of these by-products will have direct impact on the economy and environmental pollution of the country. Non-utilization or underutilization of these by-products will not only lead to loss of potential revenues but also lead to the added and increasing cost of disposal of these products.

Mixture design, which is employed in this study, is a special class of response surface experiments in which the product under investigation is made up of several components or ingredients. Response surface methodology (RSM) is a statistically technique used for the design of experiments and optimization of a complex systems. It is an efficient and effective tool for product formulation and optimization (Raymond, *et al*., 2009).

This study is aimed at formulating poultry feed (i.e. chick mash, growers mash and layers mash) from by-products of processed yellow corn, rice, and soybean.

2. Methodology

2.1 Materials

By-products of processed yellow corn, rice, and soybean were sourced from the local agro-processing unit of Kure Ultra-Modern Market, Minna. Bone meal, fish meal, salt, and vitamin premix were also prepared/sourced locally from the same market.

2.2 Methods

2.2.1 Raw material preparation

Fresh yellow corn bran, rice bran, and soybean meal samples were preserved by oven-drying at 60^{o}C for 12 hours. Then, the samples were kilned to 6% moisture content, grounded into grits using a laboratory milling machine, packed in sealed polyethylene bags and stored at room temperature until they were required for use.

2.2.2 Experimental design

The design constraints and formulation equation used are as follows:

$$
\begin{array}{ccc}
\text{Low} & \text{Constraint} & \text{High} \\
20\% \leq & x_1 \text{ (rice bran)} & \leq 25\% \\
55\% \leq & x_2 \text{ (yellow corn bran)} & \leq 60\% \\
10\% \leq & x_3 \text{ (soya bean meal)} & \leq 15\% \\
5\% \leq & x_4 \text{ (fish meal)} & \leq 10\%
\end{array}
$$

$$x_1 + x_2 + x_3 + x_4 = 95\% \quad (1)$$

These components represent ninety-five weight-percent of the total formulation. The other materials (held constant) made up the difference: 5% weight-percent of the feed.

A simplex-lattice mixture design, augmented with axial check blends and the overall centroid, was used (Raymond, et al., 2009). The vertices and overall centroid were replicated. The component levels for the augmented design are presented in Table 1.

The formulated feeds were subjected to proximate analyses. The properties determined were: crude protein (%), crude fibre (%), moisture content (%), fat content (%), ash content (%), and carbohydrate (%). These were determined using the method described by the Association of Official Analytical Chemists (A.O.A.C, 2000). The results were then analyzed statistically using the Design Expert Software version 7.0.

Table 1: A simplex-lattice mixture design

Run	x_1 (%)	x_2 (%)	x_3 (%)	x_4 (%)
1	20.000	60.000	10.000	5.000
2	25.000	55.000	10.000	5.000
3	20.000	60.000	10.000	5.000
4	20.000	57.500	10.000	7.500
5	20.000	55.000	15.000	5.000
6	20.000	57.500	12.500	5.000
7	23.125	55.625	10.625	5.625
8	20.625	55.625	13.125	5.625
9	20.000	55.000	10.000	10.000
10	20.000	55.000	12.500	7.500
11	20.625	58.125	10.625	5.625
12	25.000	55.000	10.000	5.000
13	20.625	55.625	10.625	8.125
14	22.500	55.000	10.000	7.500
15	25.000	55.000	10.000	5.000
16	21.250	56.250	11.250	6.250
17	20.000	55.000	15.000	5.000
18	22.500	55.000	12.500	5.000
19	22.500	57.500	10.000	5.200

x_1 = Rice bran, x_2 = Yellow corn bran, x_3 = Soya bean meal, x_4 = Fishmeal.

3. Results and Discussion

The average proximate compositions of the formulated feeds are shown in the Table 2.

Table 2: Proximate Compositions/Responses of the formulated feeds

Run	CP (%)	CF (%)	MC (%)	FC (%)	ASH (%)	CHO (%)
1	16.52	4.30	11.60	3.20	5.90	58.48
2	16.10	4.00	10.90	2.90	5.40	60.70
3	16.50	4.30	11.60	3.20	5.95	58.50
4	16.75	5.20	11.10	3.39	5.51	60.75
5	17.01	4.28	10.54	4.31	5.57	58.29
6	16.89	4.31	11.01	3.97	6.10	57.72
7	16.31	5.10	11.25	3.15	4.97	59.22
8	16.35	4.89	9.34	4.01	4.43	60.98
9	17.89	4.43	10.55	6.10	3.54	57.49
10	17.10	4.34	10.15	5.33	5.02	58.06
11	16.96	6.25	11.46	5.15	4.88	55.30
12	16.87	4.55	11.29	3.87	4.59	58.83
13	16.53	5.95	10.57	3.92	6.23	56.80
14	17.05	6.02	10.97	3.90	4.98	57.08
15	16.10	4.15	10.33	3.49	5.55	60.38
16	16.35	4.49	11.90	4.22	4.47	58.57
17	17.01	6.11	11.80	4.01	4.29	56.78
18	16.55	5.25	11.23	5.43	6.02	55.52
19	16.23	5.90	11.59	3.87	5.39	57.02

CP = Crude Protein, CF = Crude Fibre, MC = Moisture Content,
FC = Fat Content, ASH = Ash Content, CHO = Carbohydrate

Crude protein content of the formulated feeds ranged from 16.1% to 17.89% compared to the recommended values of 18%, 16% and 15% (NAP, 1994), respectively, for chick mash, growers mash and layers mash. The crude fibre content of the formulated samples ranged from 4% to 6.25% compared to the recommended values of 6.25%, 4.56% and 5.94%, respectively, for chick mash, growers mash and layers mash. The moisture content of the formulated feeds ranged from 9.34% to 11.9% compared to the recommended values of 9.45%, 9.65% and 7.98%, respectively, for chick mash, growers mash and layers mash (NAP, 1994). The fat content of the formulated feed samples ranged from 2.9% to 6.1% compared to the recommended values of 3.25%, 3.84% and 4.1%, respectively, for chick mash, growers mash and layers mash. The ash content of the formulated feed samples ranged from 3.54% to 6.23% compared to the recommended values of 4.29%, 6.02% and 5.39%, respectively, for chick mash, growers mash and layers mash. The carbohydrate content of the formulated samples ranged from 55.3% to 60.98% compared to the recommended carbohydrate values of 57.98%, 59.48% and 61.28%, respectively, for chick mash, growers mash and layers mash. The analysis of variance (ANOVA) for the crude protein is presented in Table 3.

Table 3: ANOVA for Crude Protein

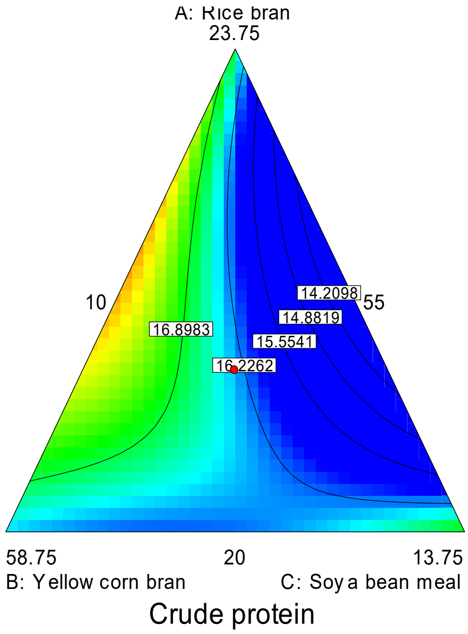
Source	SS	DF	MS	F-Value	Prob > F	
Model	3.09	13	0.24	3.00	0.1162	
L/Mix	1.79	3	0.60	7.53	0.0266	Significant
x_1x_2	0.093	1	0.093	1.18	0.3277	
x_1x_3	0.015	1	0.015	0.19	0.6809	
x_1x_4	4.204E-003	1	4.204E-003	0.053	0.8269	
x_2x_3	0.013	1	0.013	0.17	0.6991	
x_2x_4	0.15	1	0.15	1.88	0.2292	
x_3x_4	0.090	1	0.090	1.13	0.3359	
$x_1x_2x_3$	0.21	1	0.21	2.65	0.1644	
$x_1x_2x_4$	0.062	1	0.062	0.79	0.4161	
$x_1x_3x_4$	0.52	1	0.52	6.60	0.0501	
$x_2x_3x_4$	0.013	1	0.013	0.16	0.7027	
Residual	0.40	5	0.079			
L/ Fit	5.121E-004	1	5.121E-004	5.180E-003	0.9461	
Pure Error	0.40	4	0.099			
Cor Total	3.48	18				

Std. Dev.	0.28	R-Squared	0.8864
Mean	16.69	Adj R-Squared	0.5909
C.V. %	1.69	Pred R-Squared	0.5658
PRESS	1.51	Adeq Precision	6.878

The "Model F-value" of 3.00 implies the model is not significant relative to the noise. There is a 11.62 % chance that a "Model F-value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. However, the Linear Mixture Components are significant model terms ($p < 0.05$). Values greater than 0.1000 indicate the model terms are not significant (Raymond, et al., 2009).
The "Lack of Fit F-value" of 0.01 implies the Lack of Fit is not significant relative to the pure error. There is a 94.61% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good - it can be fitted with the model. The "Pred R-Squared" of 0.5658 is in reasonable agreement with the "Adj R-Squared" of 0.5909.

Equation 2 is the crude protein fitted model in terms of L-Pseudo components. The crude protein contour and 3 - D surface plots are presented in Figures 2 and 3. The analysis of variance (ANOVA) for the crude fibre is presented in Table 4.

$$y_{CP} = \left.\begin{matrix} 16.36x_1 + 16.51x_2 + 17.01x_3 + 17.89x_4 - 2.39x_1x_2 - 054x_1x_3 - 0.30x_1x_4 + 0.51x_2x_3 \\ -1.81x_2x_4 - 1.40x_3x_4 + 53.38x_1x_2x_3 - 37.19x_1x_2x_4 - 91.34x_1x_3x_4 - 1432x_2x_3x_4 \end{matrix}\right\} \quad (2)$$



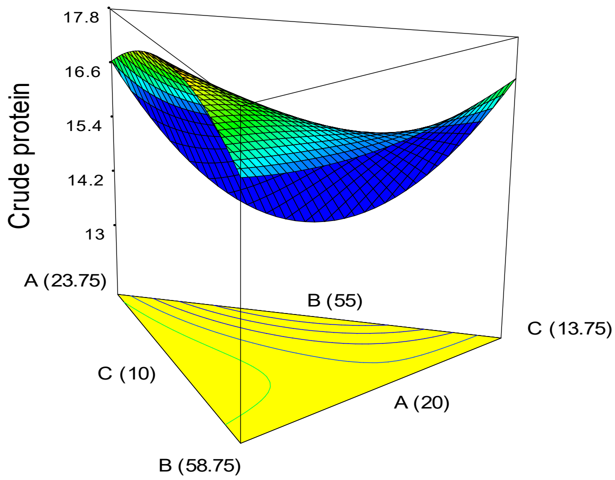


Figure 1: Crude Protein Contour Plot

Figure 2: Crude Protein 3- D Surface Plot

Table 4: ANOVA for Crude Fibre

Source	SS	DF	MS	F-Value	Prob > F
Model	5.99	9	0.67	1.32	0.3418
Linear Mixture	0.35	3	0.12	0.23	0.8717
x_1x_2	1.89	1	1.89	3.75	0.0847
x_1x_3	0.083	1	0.083	0.17	0.6934
x_1x_4	1.98	1	1.98	3.93	0.0786
x_2x_3	0.15	1	0.15	0.31	0.5932
x_2x_4	0.73	1	0.73	1.45	0.2594
x_3x_4	0.25	1	0.25	0.50	0.4967
Residual	4.53	9	0.50		
Lack of Fit	2.69	5	0.54	1.17	0.4512
Pure Error	1.84	4	0.46		
Cor Total	10.52	18			

Std. Dev.	0.71	R-Squared	0.5695
Mean	4.94	Adj R-Squared	0.1390
C.V. %	14.37	Pred R-Squared	-1.9286
PRESS	30.81	Adeq Precision	3.373

The "Model F-value" of 1.32 implies the model is not significant relative to the noise. There is a 34.18 % chance that a "Model F-value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case there are no significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

The "Lack of Fit F-value" of 1.17 implies the Lack of Fit is not significant relative to the pure error. There is a 45.12% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good (Raymond, et al., 2009).

A negative "Pred R-Squared" implies that the overall mean is a better predictor of crude fibre response than the current model. Equation 3 is the crude fibre fitted model in terms of L-Pseudo components. The crude fibre contour and 3 - D surface plots are presented in Figures 3 and 4.

$$y_{CF} = 4.20x_1 + 4.43x_2 + 5.19x_3 + 4.59x_4 + 6.06x_1x_2 + 1.19x_1x_3 + 6.16x_1x_4 - 1.65x_2x_3 + 3.80x_2x_4 - 2.22x_3x_4 \quad (3)$$

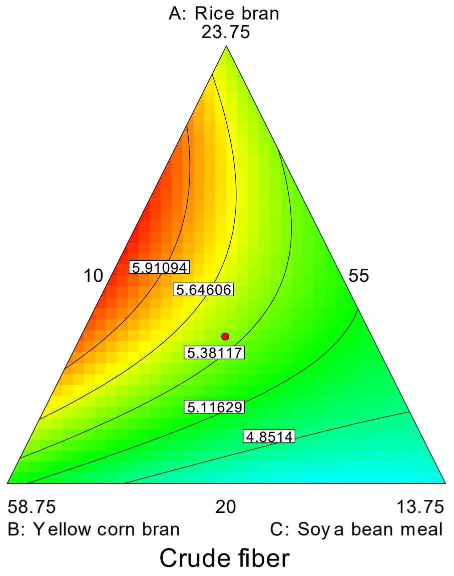


Figure 3: Crude Fibre Contour Plot

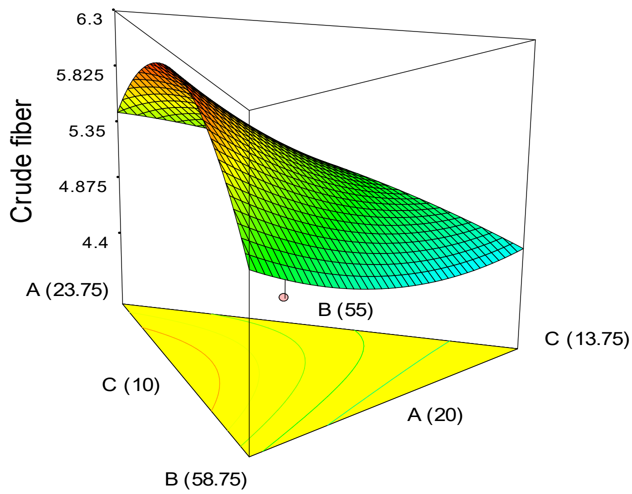


Figure 4: Crude Fibre 3- D Surface Plot

The analysis of variance (ANOVA) for the moisture content is presented in Table 5.

The "Model F-value" of 1.79 implies the model is not significant relative to the noise. There is a 19.17 % chance that a "Model F-value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case there are no significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

The "Lack of Fit F-value" of 1.22 implies the Lack of Fit is not significant relative to the pure error. There is a 45.95% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good. A negative "Pred R-Squared" implies that the overall mean is a better predictor of moisture content than the current model. Equation 4 is the moisture content fitted model in terms of L-Pseudo components. The moisture content contour and 3 - D surface plots are presented in Figures 5 and 6.

$$y_M = 11.04x_1 + 11.68x_2 + 10.74x_3 + 10.46x_4 \quad (4)$$

Table 5: ANOVA for Moisture Content

Source	SS	DF	MS	F-Value	Prob > F
Model	1.97	3	0.66	1.79	0.1917
L/ Mixture	1.97	3	0.66	1.79	0.1917
Residual	5 .50	15	0.37		
Lack of Fit	4. 24	11	0.39	1.22	0.4595
Pure Error	1.26	4	0.32		
Cor Total	7.47	18			

Std. Dev.	0.61	R-Squared	0.2639
Mean	11.01	Adj R-Squared	0.1167
C.V. %	5.50	Pred R-Squared	-0.1214
PRESS	8.38	Adeq Precision	4.426

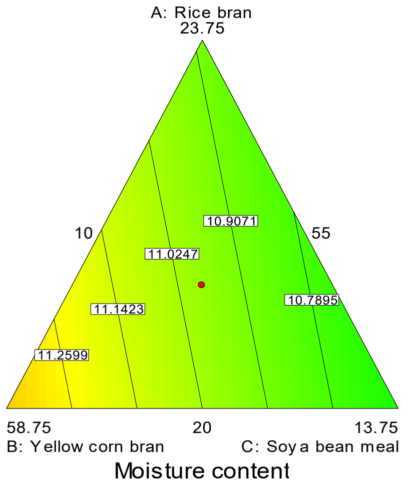


Figure 5: Moisture Contour Plot

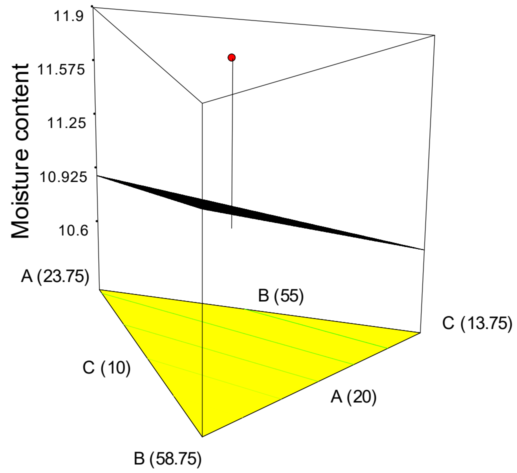


Figure 6: Moisture 3- D Surface Plot

The analysis of variance (ANOVA) for the fat content is presented in Table 6. The Model F-value of 8.67 implies the model is significant. There is only a 1.33% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case Linear Mixture Components, AC, BD, ACD are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. Equation 5 is the fat content fitted model in terms of L-Pseudo components. The fat content contour and 3 - D surface plots are presented in Figures 7 and 8.

$$y_{Fat} = \left.\begin{array}{l} 3.42x_1+3.19x_2+4.16x_3+6.09x_4-0.22x_1x_2+6.51x_1x_3-3.50x_1x_4+1.11x_2x_3 \\ -5.09x_2x_4+0.76x_3x_4+73.81x_1x_2x_3+72.18x_1x_2x_4-239.84x_1x_3x_4+86.30x_2x_3x_4 \end{array}\right\} \quad (5)$$

The "Lack of Fit F-value" of 0.38 implies the Lack of Fit is not significant relative to the pure error. There is a 56.95% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good. A negative "Pred R-Squared" implies that the overall mean is a better predictor of fat content than the current model.

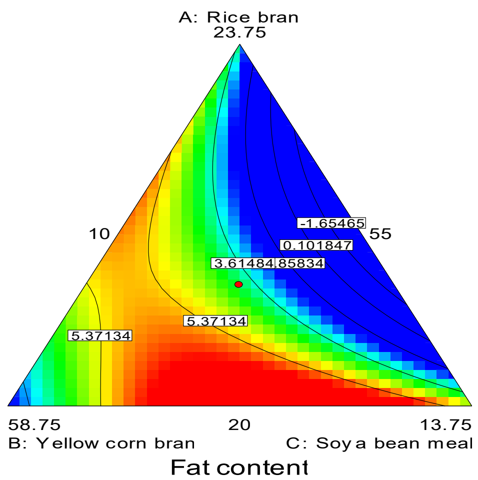


Figure 7: Fat Contour Plot

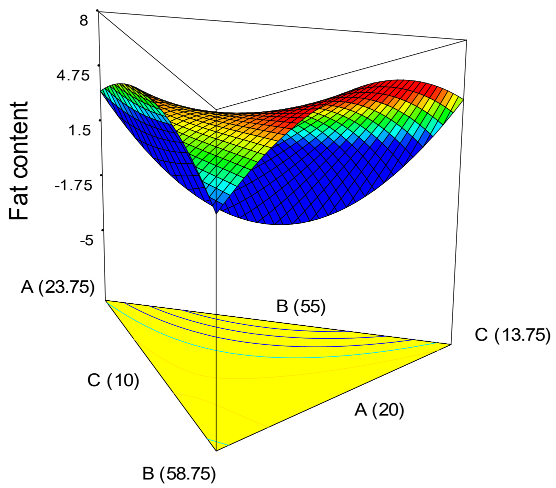


Figure 8: Fat 3- D Surface Plot

Table 6: ANOVA for Fat Content

Source	SS	DF	MS	F-Value	Prob > F
Model	12.91	13	0.99	8.67	0.0133
L/Mix.	5.37	3	1.79	15.63	0.0057
x_1x_2	7.896E-004	1	7.896E-004	6.892E-003	0.9371
x_1x_3	2.20	1	2.20	19.16	0.0072
x_1x_4	0.57	1	0.57	5.02	0.0752
x_2x_3	0.062	1	0.062	0.54	0.4962
x_2x_4	1.18	1	1.18	10.31	0.0237
x_3x_4	0.026	1	0.026	0.23	0.6516
$x_1x_2x_3$	0.40	1	0.40	3.50	0.1201
$x_1x_2x_4$	0.23	1	0.23	2.04	0.2121
$x_1x_3x_4$	3.60	1	3.60	31.46	0.0025
$x_2x_3x_4$	0.47	1	0.47	4.10	0.0987
Residual	0.57	5	0.11		
Lack of Fit	0.050	1	0.050	0.38	0.5695
Pure Error	0.52	4	0.13		
Cor Total	13.48	18			

Std. Dev.	0.34	R-Squared	0.9575
Mean	4.07	Adj R-Squared	0.8470
C.V. %	8.31	Pred R-Squared	-3.6169
PRESS	62.24	Adeq Precision	9.959

The analysis of variance (ANOVA) for the ash content is presented in Table 7. The Model F-value of 1.99 implies the model is not significant relative to the noise. There is a 22.99 % chance that a Model F-value this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case ABC are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

The "Lack of Fit F-value" of 0.46 implies the Lack of Fit is not significant relative to the pure error. There is a 53.33% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good. A negative "Pred R-Squared" implies that the overall mean is a better predictor of your response than the current model.

Equation 6 is the ash content fitted model in terms of L-Pseudo components. The ash content contour and 3 - D surface plots are presented in Figures 9 and 10.

$$y_{Ash} = \left. \begin{array}{l} 5.19x_1+5.92x_2+4.93x_3+3.56x_4-4.85x_1x_2+3.96x_1x_3+2.58x_1x_4+2.78x_2x_3 \\ +3.20x_2x_4+3.21x_3x_4-210.53x_1x_2x_3+108.64x_1x_2x_4+51.34x_1x_3x_4-3.65x_2x_3x_4 \end{array} \right\} \quad (6)$$

Table 7: ANOVA for Ash Content

Source	SS	DF	MS	F-Value	Prob > F
Model	7.83	13	0.60	1.99	0.2299
Linear Mixture	2.31	3	0.77	2.55	0.1691
x_1x_2	0.38	1	0.38	1.27	0.3116
x_1x_3	0.81	1	0.81	2.69	0.1620
x_1x_4	0.31	1	0.31	1.04	0.3555
x_2x_3	0.39	1	0.39	1.28	0.3088
x_2x_4	0.47	1	0.47	1.55	0.2687
x_3x_4	0.47	1	0.47	1.55	0.2682
$x_1x_2x_3$	3.27	1	3.27	10.81	0.0218
$x_1x_2x_4$	0.53	1	0.53	1.76	0.2424
$x_1x_3x_4$	0.17	1	0.17	0.55	0.4930
$x_2x_3x_4$	8.398E-004	1	8.398E-004	2.779E-003	0.9600
Residual	1.51	5	0.30		
Lack of Fit	0.16	1	0.16	0.46	0.5333
Pure Error	1.35	4	0.34		
Cor Total	9.35	18			

Std. Dev.	0.55	R-Squared	0.8383
Mean	5.20	Adj R-Squared	0.4180
C.V. %	10.57	Pred R-Squared	-19.9271
PRESS	195.57	Adeq Precision	5.443

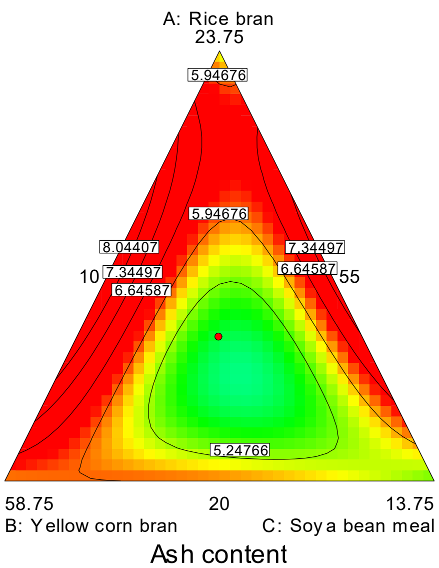


Figure 9: Ash Contour Plot

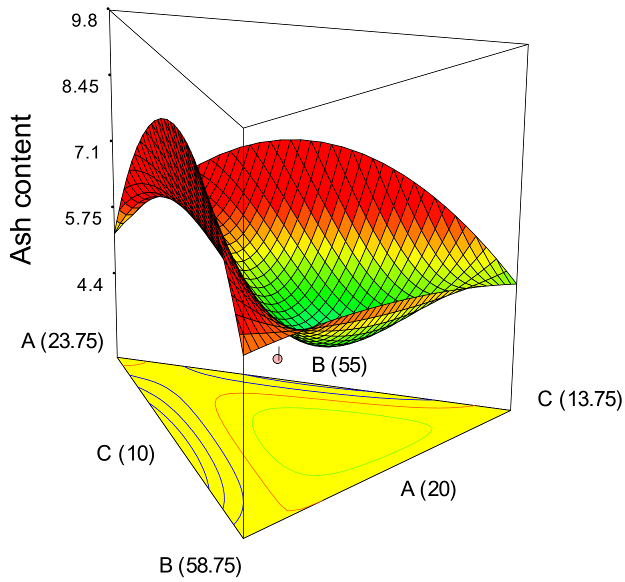


Figure 10: Ash 3- D Surface Plot

The analysis of variance (ANOVA) for the carbohydrate is presented in Table 8. The Model F-value of 5.06 implies the model is significant. There is only a 4.22% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case AC, BD, ABD, ACD are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

Table 8: ANOVA for Carbohydrate

Source	SS	DF	MS	F-Value	Prob > F	
Model	46.40	13	3.57	5.06	0.0422	Significant
L/ Mix	4.32	3	1.44	2.04	0.2269	
x_1x_2	1.81	1	1.81	2.56	0.1702	
x_1x_3	8.88	1	8.88	12.59	0.0164	
x_1x_4	2.15	1	2.15	3.04	0.1416	
x_2x_3	0.086	1	0.086	0.12	0.7408	
x_2x_4	5.41	1	5.41	7.67	0.0394	
x_3x_4	0.20	1	0.20	0.28	0.6195	
$x_1x_2x_3$	1.40	1	1.40	1.98	0.2183	
$x_1x_2x_4$	12.65	1	12.65	17.93	0.0082	
$x_1x_3x_4$	16.05	1	16.05	22.75	0.0050	
$x_2x_3x_4$	1.17	1	1.17	1.65	0.2548	
Residual	3.53	5	0.71			
Lack of Fit	0.39	1	0.39	0.49	0.5215	
Pure Error	3.14	4	0.79			
Cor Total	49.93	18				

Std. Dev.	0.84	R-Squared	0.9294
Mean	58.24	Adj R-Squared	0.7457
C.V. %	1.44	Pred R-Squared	-8.6125
PRESS	479.95	Adeq Precision	7.850

The "Lack of Fit F-value" of 0.49 implies the Lack of Fit is not significant relative to the pure error. There is a 52.15% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good.

Equation 7 is the carbohydrate fitted model in terms of L-Pseudo components. The carbohydrate contour and 3 - D surface plots are presented in Figures 11 and 12.

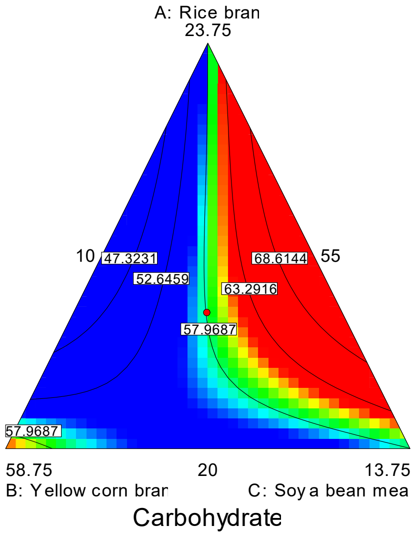


Figure 11: Carbohydrate Contour Plot

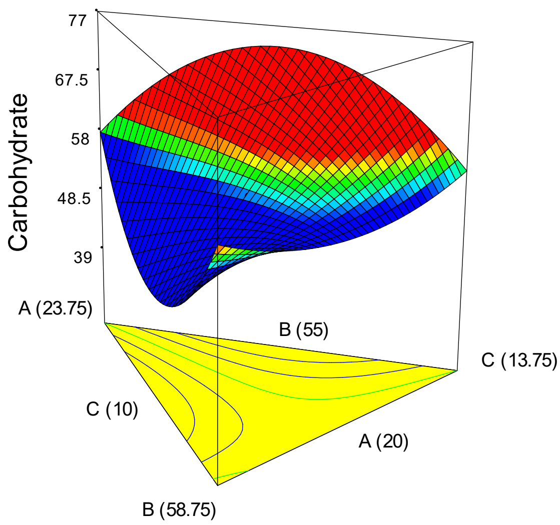


Figure 12: Carbohydrate 3- D Surface Plot

$$y_{CHO} = \left. \begin{array}{l} 59.96x_1 + 58.47x_2 + 57.53x_3 + 57.46x_4 + 10.55x_1x_2 - 13.08x_1x_3 - 6.76x_1x_4 - 1.31x_2x_3 \\ + 10.89x_2x_4 + 2.08x_3x_4 + 137.71x_1x_2x_3 - 530.42x_1x_2x_4 + 506.10x_1x_3x_4 - 135.97x_2x_3x_4 \end{array} \right\} \quad (7)$$

There are several methods that have been employed in poultry feeds formulation. Some of these methods include the pearson square method, the simultaneous equation method, the trial-and-error method, the two –by-two matrix method, and linear programming method. All these methods have their individual limitations. For instance, the pearson square method uses only two feed ingredients. the trial-and-error method takes more time before one will arrive at a fairly satisfactory result (Talat, 2004; Jerry, 2004). In this work, a simplex-lattice mixture design with nineteen replicated experimental runs was employed. The formulated feeds conformed with the proximate composition recommended by the National research council, 1994 (NRC) for poultry feeds.

5.0 Conclusion

From this study, poultry feeds (chick mash, growers mash and layers mash) were formulated from food processing by-products using mixture design experimental methodology. The proximate compositions of the formulated feeds were also determined and compared with the recommended nutritional requirements for feeds. Models for the proximate compositions of the formulated feeds were developed.

The study showed that the proximate compositions of the formulated feeds are in close agreement with the recommended nutrient level of layers and hence could be used to substitute or reduce importation of feed. It also showed that mixture design experimental methodology is a useful tool for the formulation and modelling.

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