Poultry Feed Synthesis and Characterization from Cake of Castor Seed and By-Products of Cassava Root

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Research Article

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ABSTRACT

The world population is rapidly increasing rapidly increasing world population is demanding more food. Addressing this demand requires growth in agricultural outputs including eatable animals (livestock, poultry, and fish) and, their products. However, these animals by themselves need food, which is usually competing with human food. Besides, some animals and human foods are industrially competitive, Which makes feeds less available and costly. As a result, the cost of animals and animal products is drastically increasing. Thus, to address these trade-offs either optimize the consumption of the feeds or looking for alternative feeds is required for poultry feeding. This study focuses on Poultry feed synthesis and characterization from castor seed and cassava root cakes. Cake left after solvent extraction was detoxified with a chemical method (lime treatment 10 gm/kg cake) followed by a physical method (autoclaving at 15 psi for 30 min) and the ricin level was quantified with UV spectroscopy. The cassava cake was prepared by extracting the starch from fresh cassava root through sedimentation and filtration process and the cyanide content of the cassava root was determined by UV spectroscopy. The result showed that insignificant ricin was found in castor cake and the cyanide content of the cassava root was 10 mg/kg. The poultry feed was synthesized by mixing each raw material according to poultry feed preparation FAO standards. Proximate analysis of the feed was Moisture content, 10%, carbohydrate 59.1%, crude protein 21%, fat content 2.2%, ash content 4.5%, fiber content 3.4%. The prepared feed was checked for palatability on broiler chickens and their average daily gains were calculated. For optimization, the average daily gain was taken as a response with three level factors: Castor cake, cassava cake, and maize dosages. Response Surface Methodology (RSM) in combination with Box Behnken design was used to optimize the operating parameters. The optimization result showed that 25% castor cake, 40% cassava by-productss and 10% maize were the optimum condition which gave 76.83 gm an average daily gain.

Keywords: Detoxification; Ricin; Cyanide content; Average daily gain, Palatability.

INTRODUCTION

The economy of Ethiopia is mainly based on mixed agriculture (crop and livestock production together) [1]. The poultry sector is one of the most subsectors of the rural area's economy. The productions give society a source of food and money. According to the statistical agency, Ethiopia has 49 million poultry [2]. The poultry industry uses a largely traditional production system, where the production rate is low and the supply system is mainly based on yard scavenging. This traditional system has failed to meet the needs of society as the country's population has been increasing annually [3]. This brings the poultry sector to a modern production system to meet the needs of society. Modern poultry production uses a balanced diet in poultry feed. However, balanced diets consist of various conventional food sources such as corn, wheat, and various seeds which are expensive and competitive for humans. As the population increases daily, nutritionists are finding other unconventional feed sources for partial or complete feed replacement. Thus, the unconventional food sources Castor bean meal (castor cake) and cassava by-products are the major sources of protein and carbohydrates respectively [4].

Castor cake obtained after castor bean extraction accounts for about half the weight of castor and is one of the more unconventional sources of protein for poultry feed [5]. It is used as a protein supplement due to its high crude protein content compared to traditional sources. However, it is restricted in poultry feed due to anti-nutritional factors such as ricin [6]. In the old days, the anti-nutrition factor carried castor cake as a fertilizer. This is because the cake treat is more expensive than other food sources. Recently, the protein crop source has become competitive with humans and has become more expensive for its use as poultry feed. By applying various detoxification methods such as physical, chemical, and biological, inexpensive compared to the cost of crops, castor cake can be used as a protein supplement in poultry feed.

Over many decades, the continuous increase in the cost of conventional energy sources, caused by insufficient supply and competition between humans, animals, and various industries, has led to the need to find suitable, readily available, and low-cost energy sources for poultry production worldwide [7]. One such alternative which constitutes the main by-product of the tubers used for the production of industrial starch. Starch production has produced large quantities of pulp and small tuber waste, which are difficult to transform into starch [8]. It accounts for up to 13% of cassava's weight (Hahn, Reynolds, and Egbunike). However, the levels of cyanogenic glycosides limit the uses of the by-products directly to poultry feed. It requires treatment to reduce the toxicity. Various processing methods like soaking in water, proper sun drying boiling, and fermentation reduce the cyanidelevel (Hahn, Reynolds, and Egbunike).

After processing the raw materials of the poultry feed, the correct formulation of the feed is a critical point. Poultry feed formulation contains various ingredients in the correct proportions needed to provide the correct amounts of nutrients needed for a given stage of production. The formulated feed should be palatable, not because of severe digestive upset or toxic effects. To increase palatability, corn was mixed with both feedstocks. Feeding this feed to poultry increases the average daily gain.

MATERIALS AND METHODS

Raw materials and chemicals

Castor seed and cassava root were the main raw materials used for the experiment. The castor seed was used in the preparations of protein supplementation and the cassava was used in the supplementations of the carbohydrate content of the feed. Several chemicals such as ethanol, calcium hydroxide, potassium bromide, sodium hydroxide, sulphuric acid, hydrochloric acid, phenolphthalein, potassium cyanide, and distilled water were used.

Equipment and instruments

For this experiment, the following equipment and instruments were used. A muffle furnace, laboratory oven, beaker, volumetric flask, conical flask, measuring cylinder, desiccator, balances, grinder, mortar and pestle, titration unit, crucibles, magnetic stirrer, mixer, centrifuge, rotary evaporator, UV spectrophotometer was used.

Methodology

The methodology used for this research was a general method. In the treatment and preparation of the raw materials, synthesis, and characterization of raw materials and the feedstuff different procedures were performed. The details of the

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procedures were given in the following section.

Raw material preparation

Castor seed preparation: The castor beans must undergo some steps of processing before the extraction procedure. The castor seed was bought from Debre Berhan town. Firstly, the purchased castor seed was cleaned manually to remove impurities present in them. It was sun-dried for one-day to keep the moisture content within the standards for oil extraction, it was oven dried at 60°C for 2 hours. The dried seed was deshelled to remove the upper cove. Finally, the deshelled seed was ground using mortar and pestle to reduce its size.

Castor oil extraction

The solvent extraction method as described by Akpan et al was adopted for the extraction of the oil and ethanol was used as a solvent.100 g of the sample was placed in the thimble and inserted in the center of the soxhlet extractor. 300 ml of normal ethanol was poured into a round bottom flask. The soxhlet washeated at 78°C and as the solvent boiled, the vapor rises until the condenser was at the top of the extractor. The condensate solvent then drips into the thimble, which contains the castor sample to be extracted. The extracted product then seeps through the thimble's pores and flows back down into the round bottom flask. The extraction was preceded until 3 hrs repeatedly. After that, the castor cake was removed from the tube and dried in the oven. The castor cake was weighed again to determine the amount of oil that had already been extracted. The mixture of the solvent and the extracted oil was separated by using a rotary evaporator (Figures 1 and 2). The yield of the oil was calculated using equation 1 as follows.

$$\text{Yield (\%)} = \text{Weight of oil})/(\text{Weight of the seed}) \times 100\% \qquad (1)$$

Figure 1. Solvent extraction.

Detoxification of castor cake: The detoxification process was done according to the method. One kg of the cake was treated with 10 g lime and, autoclaved the sample at 15 psi for 30 min. The treated castor cake was oven dried at 60°C for two hrs. The cake was stored in a dry place.

Figure 2. A) Untreated and, B) Treated castor cake.

Preparation of cassava by-products: Cassava by-products were present during the processing of cassava into valuable starch. In the first step, cassava root was collected from Arba Minch town. 1 kg of fresh roots was selected from the harvested cassava, then peeled, washed, and soaked in water for 20 min to reduce the cyanogen level. The root was then sliced to a small diameter thickness using a manual slicer. The sliced sample was ground using a juice extractor machine. The juice was filtered using a filter cloth. The starch slurry was repeatedly washed with distilled water until the supernatant became translucent. The pulp and the peels were sun-dried for 4 hr followed by oven drying at 60 degrees Celsius for 2 hrs. Finally the by-products were milled and stored in a dry place for further process (Figure 3).

Figure 3. Cassava processing A) fresh cassava root B) cassava peel C) cassaa starch D) cassava pulp (cake) E) cassava peel powder.

Characterization of raw materials

Determination of cyanide content in cassava by UV spectroscopy: Ten gram of cassava meal was mixed with 50 ml of water in a stoppered Erlenmeyer flask and allowed to stand for 24 h to extract residual cyano glucosides in the samples. The mixture was then filtered to obtain the soluble extract containing cyano glucosides. KCN standard solutions were used to determine the concentration of free cyanide (in HCN equivalent) in the sample filtrate. The absorbance of the sample solution was similarly measured at a wavelength of 510 nm against a KCN solution blank. The cyanide levels of the test samples were evaluated using the standard calibration curve.

Quantification of ricin by UV spectrophotometer: The amount of ricin in castor cake was done according to the method proposed by Journal [9]. 1 gm of the detoxified cake was dissolved with 5 ml of dilute H_2SO_4 (at pH 3.8). The dissolved sample was centrifuged at 4000 rpm the absorbance of the supernatant was measured by UV752 visible spectrophotometer at wavelength 279 a nm using a quartz cell. The system was calibrated with the Bovine Serum Albumin (BSA) standard. The concentrations of the ricin in sample the were termined using beer Lambert law with the molar absorption coefficient of ricin 93,900 L mol^{-1} cm^{-1}.

$$A = \varepsilon L c \qquad (2)$$

Where,

A is the amount of light absorbed for a particular wavelength by the sample,
ε is the molar extinction coefficient
L is the distance covered by the light through the solution
C is the concentration of the absorbing species

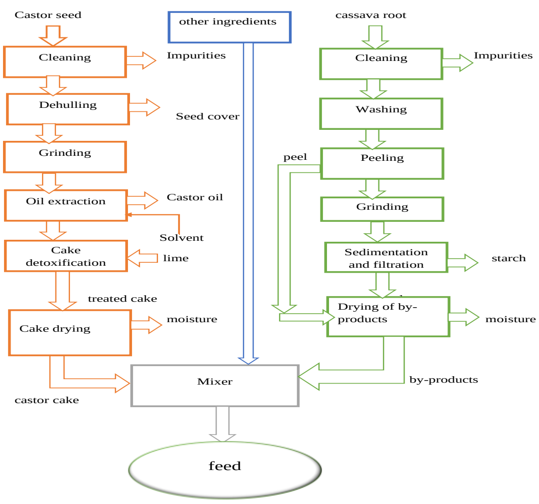
Proximate analysis: For the proximate analysis of raw material and feeds, The Association of Official Analytical Chemists recommended methods (AOAC) were used. Proximate parameters (carbohydrate, fats, protein, fiber, and ash) of the raw material and the prepared feed were determined according to the method proposed. The nitrogen content of the samples was determined by the Kjeldahl method. 6.25 factor was used to convert it to crude protein multiplied by the nitrogen value obtained. The weight difference methods were used to determine moisture and ash content levels while the crude fat of the feed was determined by the Soxhlet method using petroleum ether as solvent. The carbohydrate content was determined by calculation using the following method:

$$\%\ \text{Total carbohydrate}=(100-\%(\text{Protein}+\text{Fat}+\text{Moisture}+\text{Ash}+\text{Fiber}))$$

Mixing of the ingredients

After raw material preparation, the next step was mixing the ingredients within a given standard. According to the standards of poultry feed nutrition requirements reported by Ravinadan, the prepared raw materials were measured using an analytical balance [10]. Different amounts of the ingredients were used for different experimental runs. The weighted samples were added to a mixer. The mixture was well mixed to keep the homogeneity of the feed. The sample was oven dried for 2 hr at 60°C to keep the moisture content (Figure 4).

Figure 4. General experimental framework of the experiment.



Experimental Design (DOE) for average daily gain

Design Expert 7.0.0 software was used to arrive at a suitable predictive model and optimal production conditions for poultry feed. To determine optimal settings of the operating parameters that result in an optimal response, the response surface method in combination with the Box-Behnken Design (BBD) was chosen. The Box-Behnken design was preferred for this study due to the reduction in the number of experiments required. This design consisted of seventeen randomized experiments with five central replicates to minimize errors. To maximize the correct weight, the variables castor cake, cassava cake, and amount of maize were varied as shown in Table 1.

Table 1. Three levels and three-factor used in the experimental design.

Factors	Factor coding	Unit	Coded level		
			-1	0	1
Castor cake	A	Wt%	15	20	15
Cassava cake	B	Wt%	20	30	40
Maize	C	Wt%	10	15	20

Palatability test

The palatability of the feed was done using the single bowl method proposed by Aldrich et al [11]. 50 gm of the prepared feed, and 50 gm pure maize were fed to a single broiler chicken as shown in figure 5 below. The feed left after the feeding of the chicken was measured. The feed palatability was calculated by subtracting the final weight from the initial weight of the feed (Figure 5).

Figure 5. Single-bowl palatability test.

Average daily gain

A total of 16 kg of feed was prepared from the prepared raw materials (castor cake, cassava by products, and maize) for 17 different compositions with constant amounts of other ingredients.17 different broiler chickens aged 4 weeks were bought from Debre Berhan town. The chickens were coded with different colors on their legs to identify the experimental run. The initial weight of each chicken was measured. The different prepared feed was given to each chicken for 28 days.

The weight of each chicken was measured daily. The daily gain of the chickens was calculated by subtracting the initial weight from the final weight. The average daily gain was calculated by using equation 3 given below.

$$\text{Average daily gain} \rule{6cm}{0.4pt} \quad (3)$$

RESULTS AND DISCUSSION

Raw material preparation

After deshelling, its upper cover, 736 g castor seed was obtained from 1 kg which was 73.60% of the original castor seed used. The moisture content of the prepared castor seed was measured as 7%. The result of the moisture content of the castor seed was within the range of 5%-12% of the standard used in the oil extraction process.

Oil extraction

The dried castor seed was used for extracting the oil, and about 273.8 g of oil was obtained from 736 g of castor seed after the rotary evaporation of solvent and oil. The percentage of oil was calculated based on equation 1. The result was about 37.2% of the mass of the castor seed used. This result falls within the range of the percentage oil content up to 40% of castor seed as reported by Bera [12]. A total of 462.2 g cake was obtained from 736 g castor seed. It indicates that castor seed has a great potential for poultry feed after detoxification of the ake.

Quantification of ricin concentration in castor cake: The amount of ricin found in castor cake sample was evaluated according to equation 2. During the absorbance measurement, the UV vis spectroscopy gives a result of 0.18 absorbances. Based on the beer Lamber law the concentration found in the cake was $1.6*10^{-7}$ L/mol. The result showed that ricin was almost not found in the sample. It indicates that the selected method eliminated the toxin of the seed, and it was efficient to detoxify ricin from castor cake as reported by Bera. In addition to UV result, no mortality of broiler chickens observed during feeding of the meal. It indicates that the ricin toxicity was completely eliminated from the cake as small amounts of ricin dosage kill animals reported by Akande et al [13].

Cassava by-products: From one kg of fresh cassava root, the results obtained were presented in Table 2 below.

Table 2. Results of cassava cake preparation.

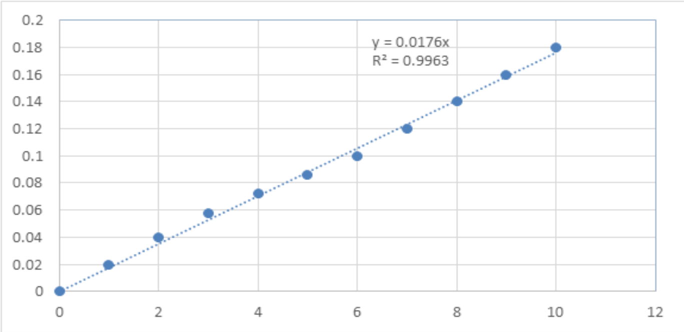
Amount used	Peel found	Starch found	Pulp found
1 kg cassava root	130 gm	215 gm	158 gm

As shown in the above Table 2 the amounts of the peel and cassava pulp obtained were in the range reported by Gani [14]. The amounts of cassava starch obtained were the ranges of cassava starch composition to 20%-31% carbohydrate reported by Morgan et al. This result showed that cassava processing has large amounts of by-products. Therefore, processing cassava root gives a large number of by-products that could be used as a carbohydrate supplement in poultry feed formulation.

Raw material characterization

UV spectroscopy analysis of cyanide content in cassava by-product: The standard calibration curve of absorbance against KCN concentration (as HCN equivalent) shown in Figure 6 below.

Figure 6. Calibration curve for potassium cyanide.



The cyanide content of the test samples was evaluated from the calibration curve. During the absorbance measurement, the UV vis spectroscopy gives a result of 0.148 absorbances. Based on the calibration curve the result shows that cassava root has a cyanide level of 8.71 ppm. The cyanide level of 5 to 10 PPM in cassava products falls within the acceptable limits of 10 mg HCN equivalent/kg dry weight reported for safe cassava products. Therefore, sun drying flowed by soaking in water before processing cassava reduces the cyanide level.

Proximate analysis of raw materials

The determinations of the proximate constituents were necessary for the nutritional level of poultry feeds frequently consumed in the poultry sector. The proximate result for the final product was presented in Table 3 below.

Table 3. Proximate analysis of raw material.

Proximate property	Proximate value		Unit
	Castor cake	Cassava cake	
Moisture content	9.1	10.4	Percentage
Carbohydrate	5.5	71.2	Percentage
Crude protein	32.5	3.2	Percentage
Fat content	24.3	1.2	Percentage
Ash content	8.3	4.34	Percentage
Fiber content	20.3	9.6	Percentage

As shown in the table above the proximate analysis of castor cake was in the range reported by Akande et al. The cassava by-product was also in the range reported by Oladimeji et al. [15]. The raw material proximate results how input for the preparations of poultry feed.

Proximate analysis of the final product: The proximate analysis of the final product was presented in Table 4 below.

Table 4. Proximate analysis of the final product.

Proximate property	Proximate value	Unit
Moisture content	10	Percentage
Carbohydrate	59.1	Percentage
Crude protein	21.01	Percentage
Fat content	2.2	Percentage
Ash content	4.5	Percentage
Fiber content	3.4	Percentage

The Moisture Content (MC) of feed determines the amount of water in the feed samples. Too much amount of moisture content in feeds affects the physical and chemical properties of the feed which relate to its freshens, suitability for storage of the feed over a long period, and mold formation which affects the health of the poultry. The result in Table 4 above indicates that the prepared poultry feed has an acceptable moisture content of 10% the standard of poultry feed moisture content reported by Ofori et al [16].

Carbohydrates are an essential dietary source of energy for poultry. It makes up the largest nutrient in the poultry diet it gives a high level of energy production. Improper carbohydrate level affects energy production, which affects the digestion system, body weight loss, and health problem [17]. The conventional method in the above Table 4 showed that the prepared poultry feed has a carbohydrate source of 59.1% which indicates the prepared poultry feed is a good source of carbohydrates in poultry feed.

An optimum amount of protein in poultry could be used for egg production, carcass growth, and feather development. While the improper balance of protein in the diet can cause improper egg size, and weight loss and affects the work of kidneys. As shown in above Table 4 the prepared poultry feed has 21% which was the best result according to the standard of protein requirements for poultry.

The level of fat in the blend affects palatability and the overall physical quality of the feed whether in the mash or pelleted diets. All fats should be blended from a strictly controlled range of sustainable ingredients to produce a consistent fatty acid profile, giving good digestibility and handling characteristics. as shown in the above Table 4 the prepared poultry feed has a fat content of 2.2% which is an optimum fat content according to the standards required for fat for poultry.

The ash component of the feed describes the inorganic content of the feed mainly minerals. These critical nutrients are required in specific amounts in poultry diets strong bone, blood clotting, enzyme activation, and egg shell formations. To improve the quality of feed a suitable level of ash content is required in poultry feed. As shown in the table above the prepared poultry feed has an ash content of 4.5% which fits the standards required for ash for poultry.

The fiber content in feeds affects the digestion system. To keep the digestion system to normal way optimum fiber content is required for feeds. As shown in the above Table 4 the prepared poultry feed has a fiber content of 3.4 % which was the standard of fiber requirements for poultry as stated by Ofori et al.

Feed palatability

From 50 grams of feed 42 grams of the feed, 49 gram maize was consumed by the broiler chickens accounts about 84% of the prepared feed and 98% of the pure maize. This indicates that maize has more palatable than the compound feed. The result also showed adding small amount of maize in the feed increases the palatability of the feed.

Experimental design and model fitting for average daily gain

The average daily gain was calculated by measuring the weight of the chicken and dividing it by the number of feeding days according to equation 3. The average gain values are reported in Table 5. The response (actualaveragedailygain) was used to develop a mathematical model that correlates the actual average daily gain with the predicted gain in the model. Average daily gain produced at various process parameters (actual gain) calculated as equation 3 and the predicted values of average daily gain and ANOVA were presented in Tables 5 and 6, respectively.

Table 5. Experimental and predicted data for ADG obtained from Box-Behnken design.

Run	A	B	C	Response; ADG (gram)		Residual
				Experimental	Predicted	
1	20	20	10	62.4	62.11	0.2875
2	25	40	15	84.6	83.95	0.65
3	20	30	15	66.7	67.3	-0.6
4	25	30	10	65.3	65.76	-0.4625
5	20	40	10	72.3	72.49	-0.1875
6	20	30	15	67.2	67.3	-0.1
7	20	30	15	67.8	67.3	-0.5

8	15	40	15	72.7	72.88	-0.175
9	15	30	20	66.8	66.34	0.4625
10	20	40	20	85.5	85.79	-0.2875
11	15	20	15	60.2	60.85	-0.65
12	20	30	15	67.2	67.3	-0.1
13	20	20	20	62.6	62.41	0.1875
14	20	30	15	67.6	67.3	0.3
15	15	30	10	60.6	60.24	0.3625
16	25	20	15	62.4	62.23	0.175
17	25	30	20	72.9	73.26	-0.3625

Analysis of variance (ANOVA)

Table 6. ANOVA for quadratic model.

Source	Sum of squares	df	Mean square	F-value	p-value	
Model	858.67	9	95.41	261.65	<0.0001	Significant
A	77.5	1	77.5	212.54	<0.0001	
B	569.53	1	569.53	1561.89	<0.0001	
C	92.48	1	92.48	253.62	<0.0001	
AB	23.52	1	23.52	64.51	<0.0001	
AC	0.49	1	0.49	1.34	0.2844	
BC	42.25	1	42.25	115.87	<0.0001	
A^2	2.78	1	2.78	7.62	0.0281	
B^2	51.21	1	51.21	140.44	<0.0001	
C^2	0.0322	1	0.0322	0.0884	0.7748	
Residual	2.55	7	0.3646			
Lack of fit	1.83	3	0.6108	3.39	0.1343	Not significant
Pure error	0.72	4	0.18			
Core total	861.22	16				

Based on the p-value (<0.0001) of the pre-defined model, the quadratic model has been significant and selected for average daily gain using castor cake, cassava cake, and maize as a basic process parameter for the production of poultry feed. The statistical analysis of the ANOVA was given in Table 6. From the ANOVA of the response surface quadratic model for average daily gain, the Model F-value of 261.65 and Prob >F of F less than 0.0500 indicated that the model terms were significant. In this case, A, B, C, AB, BC, A^2, and B^2 are significant model terms.

The model term indicated that the castor cake, cassava cake, maize, the interactions of castor and cassava, cassava and maize, and their quadratic terms of castor cake and cassava affect the average daily gain significantly. However, the interaction term of castor cake and maize, and the quadratic term of maize were found to be insignificant because their values were greater than 0.1000. The observed p-value of the variable was less than 0.0001. This indicates that the variables were significant in determining the model. The variation between the model prediction and the extra points compared with the pure error to test the lack of fit. In the statistical output, the lack of fit should NOT be significant. A small F-value and high p-value (greater than 0.1) are good in this test. It was observed that the "Lack of Fit F-value of 3.39 and p-value of 0.1343" implies the Lack of Fit was not significant relative to the pure error. This indicated that the model desirably represents the actual relationships of process parameters, which were well within the selected ranges. Non-significant lack of fit was good because I want the model to fit. There was a 13.43% chance that a Lack of Fit F-value this large could occur due to noise.

Model equation development: The model equation that correlates the response variable with process variables, in terms of coded factors was given in equation 4. The quadratic model was selected to predict average daily gain. Design expert software has been suggested to select a quadratic model in the analysis because the highest values of R^2, adjusted R^2, and predicted R^2 were obtained and the model was not aliased as shown below in Table 7. The final equation in terms of coded factors was given in equation 4 below.

$$ADG=67.30+3.11A+8.44B+3.40C+2.42AB+0.3500AC+3.25BC-0.8125A^2+3.49B^2-0.0875C^2 \quad (4)$$

Where,

A=Amount of castor cake

B=Amount of cassava cake

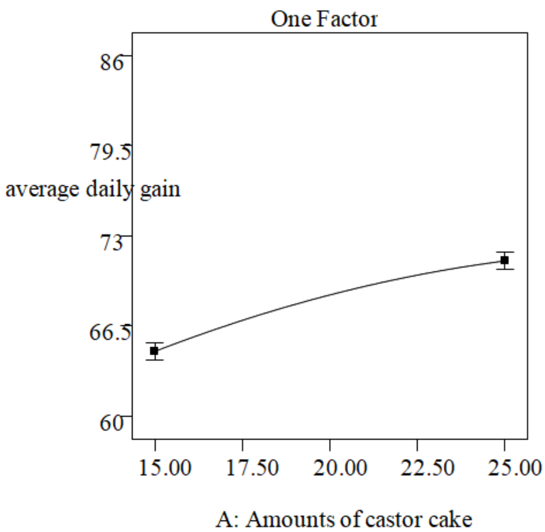
Table 7. Fit summary for response.

Source	Sequential p-value	Lack of fit p-value	Adjusted R^2	Predicted R^2	
Linear	<0.0001	0.0004	0.8261	0.7133	
2FI	0.0418	0.001	0.897	0.7071	
Quadratic	<0.0001	0.1343	0.9932	0.9646	Suggested
Cubic	0.1343		0.9967		Aliased

Individual effects of operating parameters on average daily gain

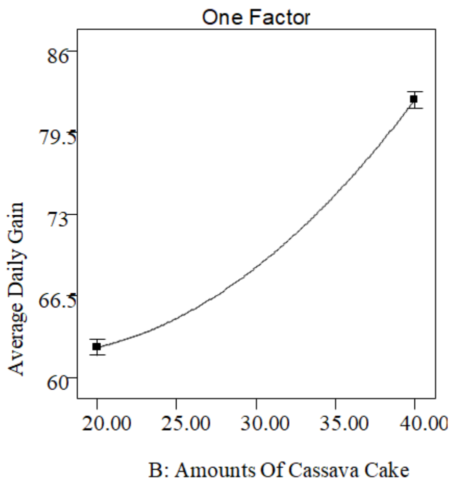
Effect of castor cake: In this study, the effects of castor cake on average daily gain were investigated at constant amounts of cassava cake and maize. With the increase in castor cake from 15% to 25% inclusion in the feed, no health effect was observed during the feeding period and, the average daily gain increased sharply as shown in Figure 7. The result showed that the inclusion of lime treated followed by autoclaving 15 for 30 min castor cake had no adverse effect on the health and, the average daily gain. This was because the method used eliminated the ricin toxic found in castor cake as reported by Anandan et al [18]. Therefore, during the synthesis of poultry feed up to 21% of castor cake could sub substitute the protein requirements.

Figure 7. Effect of castor cake on average daily gain.



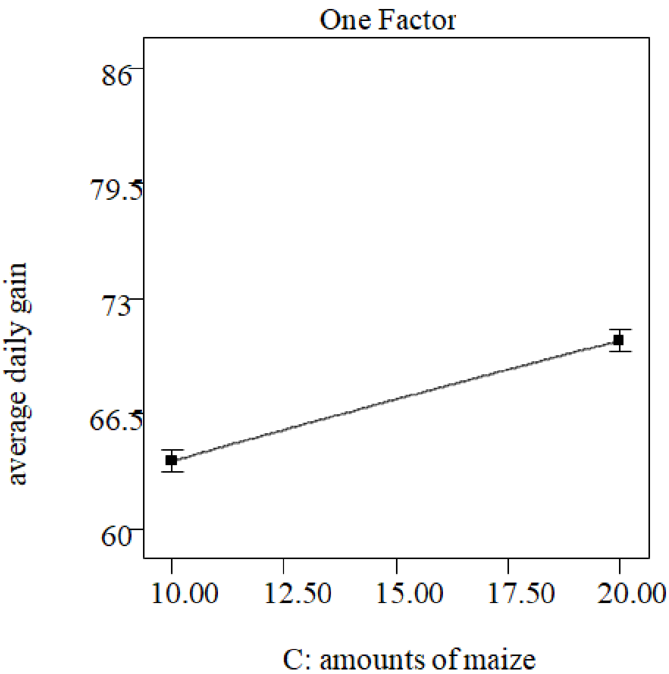
Effect of cassava cake: In this study, the effects of cassava cake on average daily gain were investigated at constant amounts of castor cake and maize. With the increase in cassava cake from 20% to 40% inclusion in the feed, the average daily gain was increased as shown in Figure 8. This result indicates that reduced cyanide level cassava by-products substitute the carbohydrate requirements from maize as reported by Diarra et al. The result also showed that cassava cake could be used up to 40% without a negative effect on health and average daily gain, as no health problem was observed during the feeding period.

Figure 8: Effect of cassava cake on average daily gain.



Effect of maize: In this study, the effects of the amount of maize on average daily gain were investigated at constant amounts of cassava cake and maize. With the increase in maize from 10% to 20% inclusion in the feed, the average daily gain was increased as shown in Figure 9. This result indicates that the inclusion of a high amount of maize in the diet increases the average daily gain of the broiler chickens. This was because of increasing maize and increased palatability of feed.

Figure 9. Effect of maize on average daily gain.



Interaction effect of process parameters on averaged daily gain

Figure 10 shows the response surface plots developed as a function of amounts of castor cake and cassava cake, while the amounts of maize were kept constant at 20%. Proper addition of carbohydrates and protein in poultry feed, gives optimum daily gain. It was seen that the average daily gain depended on both of the amounts of the inputs. The average daily gains increase with increasing the amounts of cassava cake from 20%-40%. However, as the amounts of castor cake increased from 15%-25% the average daily gain was increased and became smooth constant above 21% inclusion. The observation showed that optimum average daily gain was found within the ranges of cassava cake up to 40% and amounts of castor cake upto 21% during the feeding of broilers.

Figure 10. Response surface plots of the effect of castor cake and cassava cake on ADG at a fixed amount of maize.

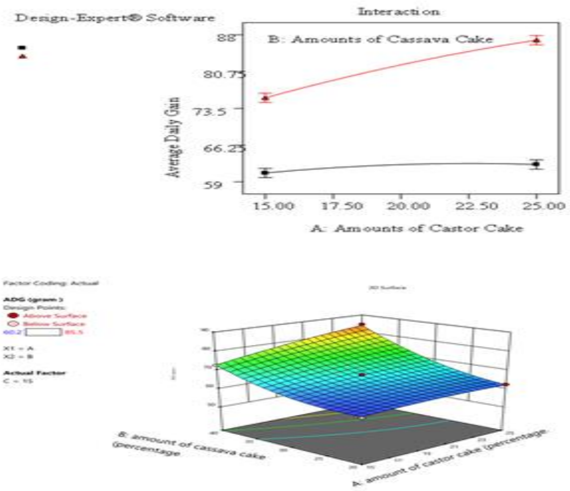
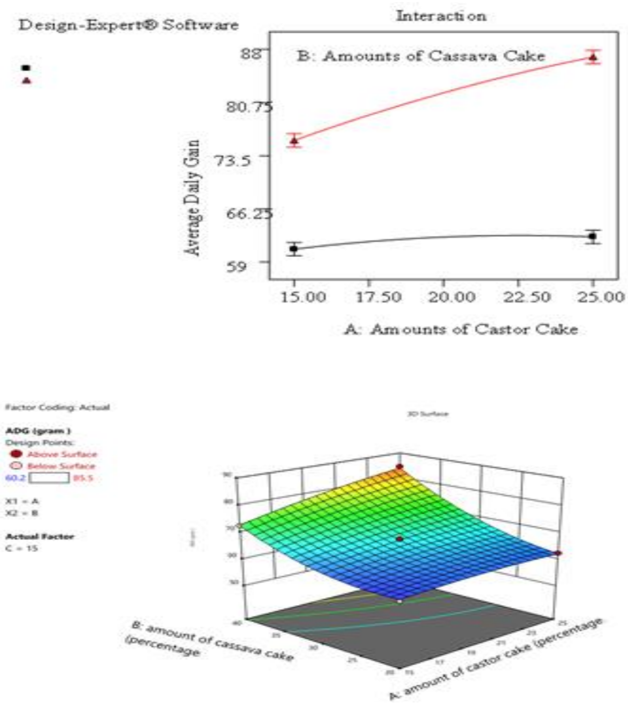


Figure 11 shows the response surface plots developed as a function of amounts of cassava cake and amounts of maize, while the amounts of castor cake were kept constant at 25%. It was seen that the average daily gain depended on both of the amounts. The average daily gains increase with increasing the amounts of maize from 10%-20% and amounts of cassava cake from 20%-40%. The observation showed that average daily gain was more dependent on the amounts of maize and cassava cake since as the amounts of the maize increased the palatability of the feed also increased.

Figure 11. Response surface plots of the effect of cassava cake and maize on ADG at a fixed amount of castor cake.



Optimization of process variables on average daily gain using RSM

Response Surface Methodology (RSM) is a collection of statistical and mathematical techniques useful for developing, improving, and optimizing processes. In Response Surface Methodology (RSM), the process variables were optimized to maximize the average daily gain at optimum material cost and time. The optimum conditions for the three variables, *i.e.*, castor cake, cassava cake, and maize were determined using the numerical optimization feature of the design expert software. Optimization of the process was conducted by setting the parameters and responses with their high and low values listed in Table 8 to identify the optimum condition. The optimum conditions obtained were then evaluated by the composite desirability, which has a value from 0 to 1, to determine the degree of satisfaction of the optimum conditions for the ultimate goal of response. Based on the predicted parameters, three experiments were conducted in the laboratory to validate the optimum conditions, 76.26 gm per day was obtained, and the results are closely related to the d data obtained from optimization analysis using desirability functions that were 76.86 gm per day (Table 9 and Figure 12).

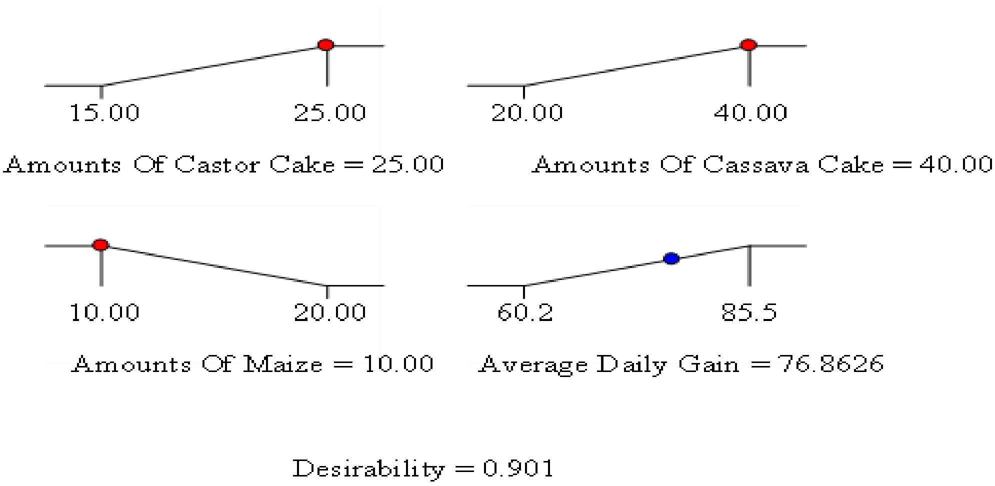
Table 8. Numerical optimizations of process parameters using RSM.

Name	Goal	Lower limit	Upper limit	Lower weight	Upper weight	Importance
A	Maximization	15	25	1	1	3
B	Maximization	20	40	1	1	3
C	Minimization	10	20	1	1	3
ADG	Maximization	60.2	85.5	1	1	3

Table 9. Results of optimization.

No	Amount of castor cake	Amount of cassava cake	Amount of maize	ADG		Desirability	
				Predicted	Actual		
1	25	40	10	76.863	76.26	0.901	Selected

Figure 12. Operating condition of optimization for ADG.



CONCLUSION

In this study, non-competitive to human food and industrial input, cost-effective nutrients were prepared from the seeds of castor and the roots of cassava for the supplementation of protein and carbohydrate in poultry feed respectively. Based on the detailed inspections of using response surface methodology coupled box Behnken design method, the optimal operating parameters for poultry feed preparation for an average daily gain of 76.86 gm per day were castor cake 25%, cassava cake 40%, and maize 10%. The relationship between the predicted and experimental gain indicates the value was in a reasonable argument and the data fit well with the model by giving a good estimation of response for the system in the range studied. The model can be considerable, with all three independent variables affecting the gain and the R^2 of the model was found to be 0.9970.

Generally, the poultry feed preparation from castor and cassava cake mixed with maize was economically feasible. It indicates that the cakes could be used as supplementations of protein and carbohydrate sources of nutrient requirements for poultry.

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