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Nutritional and economic value of local poultry feeds, formulated by design of experimental (DOE) method

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ABSTRACT

A prospective study was conducted on feeds for local poultry in Burkina Faso. The objective of this study was to contribute to the improvement of the nutritional and economic quality of feeds for local poultry. Design of experimental (DOE) method was used to formulate ten feeds with mainly local raw materials and an evaluation of their nutritional and economic value has been carried out. Classical analytical methods were used to determine the macro elements. Chromatography and flame spectrometry were used to determine amino acids and minerals respectively. The results showed mass proportions (g/100 g DM) between 18.32±0.06 and 20.46±0.00 for proteins, 4.86±0.10 and 5.70±0.03 for lipids, 36.81±0.07 and 40.36±0.04 for total carbohydrates, between 10.28±0.09 and 12.34±0.12 for ash, between 7.03±0.09 and 7.79±0.00 for cellulose, 1.67±0.74 and 3.86±0.06 for calcium, 1.16±0.07 and 2.10±0.04 for phosphorus. Methionine contents ranged from 0.36±0.04 to 0.47±0.02, lysine from 0.78±0.07 to 0.94±0.00, and threonine from 0.68±0.02 to 0.83±0.03. The rations cost varied from 203.40 to 238.98 FCFA/kg with an average value of 213.77 FCFA/kg. The results obtained constitute new information in the breeding of local chicken in Burkina Faso. They will allow poultry farmers to make their activity more profitable.

Keywords*:* Nutritional and economic value, Formulation, poultry feed, design of experimental (DOE) method.

INTRODUCTION

A large proportion of Burkina Faso's population engages in livestock production, which accounts for about 10-20% of GDP and is the second largest contributor to agricultural value added, after cotton (FAO, 2018).

Poultry farming provides livelihoods for about 1.6 million poultry farmers, mostly women in rural areas (Ayssiwede et al., 2013; FAO, 2018). With about 6% contribution to agricultural GDP, poultry farming is a crucial link in the Burkinabe economy (FAO, 2018).

Poultry farming in Burkina Faso is dominated by the local breed of poultry, which represents more than 98% of the national poultry population (FAO, 2019). The local

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chicken is an important source of income for farmers (FAO, 2018), and is also used in several ritual sacrifices and religious ceremonies such as weddings and baptisms (Hofman 2000; Sonaiya and Swan 2004; Kondombo 2005). Despite this numerical, economic and social importance, local poultry breeds experience low productivity due to insufficient quality and quantity of feed and high mortality due to poor husbandry conditions (FAO, 2019). As feed can represent up to 70% of the variable costs of poultry production (Oladokun and Johnson, 2012), the formulation of high nutritional value feed rations for local poultry remains a permanent quest to raise the level of productivity and improve the profitability of this sector.

Thus, the present work aimed at proposing to the poultry farmers of this breed, feed formulations from local raw materials by the method of design of experiments in order to improve the profitability of their activity.

MATERIALS AND METHODS

Biological material

The biological material was composed of samples of ground maize grain, ground cottonseed cake, ground soybean cake, wheat bran, rice bran, fish meal, oyster shell, and dicalcium phosphate, iodized salt and concentrated-mineral-vitamin-nitrogen (CMVA). These raw materials were selected on the basis of their biochemical composition, their availability on the local market, their cost and their threshold of incorporation in the food ration described by the bibliography.

Food rations formulation

The formulation of feeds was carried out by the design of experiments method, especially the mixing design. For this purpose, ten raw materials were selected as the factors of the study. These are ground yellow corn grain, ground cottonseed meal, ground soybean meal, wheat bran, rice bran, fish meal, oyster shell, dicalcium phosphate, salt and CMVA. The levels of these factors were determined by the method developed by John CORNELL (1941) and taking into account the recommended incorporation thresholds as described by Ngom (2004). The method consisted in varying the proportion of the constituents so that the sum is equal to one hundred. The range of variation chosen for each constituent is presented in Table 1.

Formulation matrix

The formulation or experiment matrix is a set of mathematical combinations of modalities selected for testing (Goupy and Creighton, 2006). In this study, each combination constitutes a food rations formulation. The matrix was constructed with the Minitab software version 18.1 according to the method developed by Henri SCHEFFE (1958) using the Simplex Lattice Design with a mesh size m = 1. A series of ten feed formulas was generated by the software. The top level of each constituent was combined with the bottom level of the other nine (9) constituents. Table 2 represents the set of ten formulas generated by the design of experiments method.

Determination of the biochemical composition and cost of formulated feeds

Two 500 g samples of each formulated feed were taken and the main constituents were determined by standard methods. Protein was determined by the Kjeldahl method according to AOAC 979.09 (AOAC, 1999). This method consists in mineralizing the protein nitrogen into ammonium and then determining it by acidimetry. The determination of lipids was done by Soxhlet extraction according to AOAC. 960.39 (AOAC, 1999) with hexane as solvent. The carbohydrate content was determined by the spectrophotometric method of Montreuil and Spik (1969). The method consists of adding 0.2 g of crushed material of each raw material to 2 ml of orcinol solution and 7 ml of 60% H_2SO_4 solution. The mixture was incubated in a boiling water bath for 20 min and the solutions are placed in the dark for 45 min and then at room temperature for 10 min. The optical density was read at 510 nm.

The carbohydrate content was determined using a D-glucose standard curve. Ash was determined according to AOAC method 923.03 (AOAC, 1999) by incinerating 5 g of the sample in an oven at 550°C for 4 hours. The determination of crude cellulose content was done by the method developed by Aubry (2012). According to this method, the residue is separated by filtration in a glass crucible, washed, dried, weighed, and then calcined at 500°C and reweighed. The weight loss from calcination represents the crude cellulose of the sample.

Minerals (calcium and phosphorus) were determined after mineralization of the sample according to the method developed by Houba et al. (1980). The profile and content of amino acids were determined by reverse phase HPLC, using the Pico-Tag system described by Bindlingmeyer et al. (1984). The theoretical energy value was determined by using Atwater coefficients. The cost of the rations was estimated by summing the products of the raw material prices by their proportion in the ration

Statistical analysis

The biochemical composition resulting from the analyses was presented as mean ± standard deviation. The results were processed with the "XLSTAT version 7.5.2" software by analysis of variances (ANOVA) at the 5% significance level.

RESULTS

The nutrient composition of the formulated feeds was reported in Tables 3 and 4. Protein content ranged from 18.32± 0.06 (F9) to 20.46± 0.01% (w/w) (F3). Three feeds (F2, F3, and F6) had the highest protein contents of 20.33±0.04, 20.46±0.01, and 20.28±0.02% (m/m) respectively. The protein content of F8, F9 and F10 were relatively low. Fat content ranged from 4.86±0.10 (F10) to 5.70±0.04% (m/m) (F5). F1, F5, and F6 had significantly high fat contents compared to the other feeds. The carbohydrate content ranged from 36.81± 0.07(F10) to 40.39±0.04% (m/m) (F1). F1 and F5 feeds were relatively richer in carbohydrates, with contents of 40.39±0.04 and 39.35±0.04% (m/m), respectively. The ash content of the feeds ranged from 10.28±0.09 (F10) to 12.34±0.12 (F8) % (m/m). F7 and F8 feeds had the highest ash contents with 11.98±0.06 and 12.34±0.12% (m/m) respectively. Cellulose content ranged from 7.03±0.09 (F10) to 7.79±0.00% (m/m) (F2). F2 and F4 were the feeds with the highest fiber content of 7.79±0.00 and 7.76±0.01% (m/m), respectively. Phosphorus content ranged from 1.16±0.07 (F10) to 2.10±0.04% (m/m) (F8), and feed F8 contained the most phosphorus with a content of 2.10±0.04% (m/m). Calcium content ranged from 1.67±0.07 (F10) to 3.86±0.06% (m/m). Feed F7 and F8 had the highest calcium concentrations with contents of 3.86±0.06 and 3.40±0.01% (m/m) respectively.

Finally, the food rations had variable amino acid contents. Thus, lysine, methionine and threonine contents ranged from 0.78±0.07 (F9) to 0.94±0.00 (F6) % (m/m), from 0.36±0.04 (F7) to 0.47±0.02% (m/m) (F6) and 0.68±0.02 (F10) to 0.83±0.03% (m/m (F2)) respectively. F2, F3, and F6 food rations were the richest in these essential amino acids. The energy values of the feeds ranged from 264.42±1.23(F10) to 284.90±0.72 kcal/100 g. The energetic food rations were F1, F5 with respective caloric values of 283.79±0.12 and 284.90±0.72 kcal/100 g. Statistical analysis of variance of the data of biochemical composition of feeds showed a significant difference ($P<0.05$) between the formulated feeds.

The formulation cost of the rations varied from 203.40 to 238.98 FCFA/kg with an average value of 213.77 FCFA/kg (Table 2). Ration R8 was the most expensive (238.98 FCFA/kg), followed by R10 (234.23 FCFA/kg). The formulation cost of R5 ration was the cheapest (203.4 FCFA/kg) followed by R9 ration (205.29 FCFA/kg).

Table 1: Experimental field.

Factors (Raw materials)	Lower Limit (g/100 g)	Upper limit (g/100 g)	Purchase cost (FCFA/kg)
Ground corn grain	40	44,75	130
Crushed cotton cake	5	9,75	125
Crushed Soybean cake	15	19,79	300
Wheat bran	5	9,75	98
Rice bran	10	14,75	51
Fish meal	10	14,75	300
Oyster shell	2,5	7,25	100
Bicalcium Phosphate	2,5	7,25	800
Iodized Salt	0,25	5	90
Mineral-Vitamin-Azote Concentrate (MVAC)	5	9,75	700

Table 2: Experimental formulation matrix and formula costs.

Formula code	Ground corn grain (g/100g)	Crushed cotton cake (g/100 g)	Crushed Soybean cake (g/100 g)	Wheat bran (g/100 g)	Rice bran (g/100 g)	Fish meal (g/100 g)	Oyster shell (g/100 g)	Bicalcium Phosphate (g/100 g)	Iodized Salt (g/100 g)	MVAC é(g/100 g)	Cost-formula FCFA/kg
F1	44,75	5	15	5	10	10	2,5	2,5	0,25	5	207,15
F2	40	9,75	15	5	10	10	2,5	2,5	0,25	5	206,91
F3	40	5	19,75	5	10	10	2,5	2,5	0,25	5	215,23

F4	40	5	15	9,75	10	10	2,5	2,5	0,25	5	205,63
F5	40	5	15	5	14,75	10	2,5	2,5	0,25	5	203,5
F6	40	5	15	5	10	14,75	2,5	2,5	0,25	5	215,23
F7	40	5	15	5	10	10	7,25	2,5	0,25	5	205,73
F8	40	5	15	5	10	10	2,5	7,25	0,25	5	238,98
F9	40	5	15	5	10	10	2,5	2,5	5	5	205,25
F10	40	5	15	5	10	10	2,5	2,5	0,25	9,75	234,23
Moyenne											213,77

Table 3: *Biochemical composition and energy value of food rations (g/100, m/m).

Formula code	Crude protein	Fatty matter	Carbohydrate	Ashes	Energy value
F1	18,8225±0,04^{d}	5,21±0,02^{c}	40,39±0,04^{a}	10,45±0,03^{ef}	283,79±0,12^{a}
F2	20,33±0,04^{b}	5,09±0,03c^{d}	37,08±0,04^{d}	10,59±0,14^{de}	275,31±0,07^{bc}
F3	20,465±0,01^{a}	5,04±0,01^{d}	37,12±0,01^{d}	10,56±0,15^{de}	275,78±0,24^{bc}
F4	19,095±0,03^{c}	5,12±0,03^{cd}	37,93±0,03^{c}	10,63±0,02^{de}	274,28±0,60^{c}
F5	19,035±0,03^{c}	5,70±0,04^{a}	39,35±0,04^{b}	10,80±0,01^{d}	284,90±0,72^{a}
F6	20,28±0,02^{b}	5,37±0,02^{b}	36,87±0,02^{e}	11,43±0,03^{c}	276,99±0,36^{b}

F7	18,41±0,06[e]	4,97±0,06[de]	36,90±0,06[e]	11,98±0,06[b]	266,06±1,08[d]
F8	18,37±0,01[e]	4,96±0,04[de]	36,84±0,02[e]	12,34±0,12[a]	265,58±0,40[d]
F9	18,32±0,06[e]	4,97±0,05[de]	36,92±0,09[e]	10,37±0,01[ef]	265,72±0,60[d]
F10	18,35±0,01[e]	4,86±0,10[e]	36,81±0,07[e]	10,28±0,09[f]	264,42±1,23[d]

* Values reported in the same column with different superscript letters are significantly different at the P<0.0001 threshold.

Table 4: *Content of Cellulose, Calcium, Phosphorus and some amino acids in food rations (%, m/m).

Formula code	Crude cellulose	Phosphorus	Calcium	Lysine	Methionine	Thréonine
F1	7,58±0,01[ab]	1,26±0,04[c]	2,21±0,02[b]	0,87±0,04[a]	0,42±0,03[a]	0,75±0,05[ab]
F2	7,79±0,00[a]	1,25±0,02[c]	2,21±0,01[b]	0,88±0,02[a]	0,43±0,02[a]	0,83±0,03[a]
F3	7,36±0,02b[c]	1,25±0,01[c]	2,22±0,01[b]	0,93±0,00[a]	0,43±0,01[a]	0,81±0,02[ab]
F4	7,76±0,01[a]	1,20±0,02[c]	2,17±0,03[b]	0,87±0,01[a]	0,38±0,03[a]	0,76±0,04[ab]
F5	7,26±0,30[c]	1,27±0,02[c]	2,23±0,04[b]	0,89±0,04[a]	0,40±0,00[a]	0,77±0,04[ab]
F6	7,10±0,00[c]	1,41±0,02[b]	2,49±0,01[b]	0,94±0,00[a]	0,47±0,02[a]	0,82±0,03[ab]
F7	7,11±0,02[c]	1,22±0,00[c]	3,86±0,06[a]	0,87±0,06[a]	0,36±0,04[a]	0,75±0,01[ab]
F8	7,13±0,04[c]	2,10±0,04[a]	3,40±0,01[a]	0,81±0,02[a]	0,42±0,04[a]	0,72±0,01[ab]
F9	7,05±0,06[c]	1,18±0,04[c]	2,15±0,06[b]	0,78±0,07[a]	0,37±0,02[a]	0,71±0,03[ab]
F10	7,03±0,09[c]	1,16±0,07[c]	1,67±0,74[b]	0,78±0,07[a]	0,36±0,04[a]	0,68±0,02[b]

* Means in the same column with different superscript letters are significantly different at the P<0.0001 threshold.

DISCUSSION

Protein contents of all feeds were well above the values 13.7 and 14.8% found by (Hien and Coulibaly, 2017) in experimental chicken feeds. They were also higher than the values of 17.8% and 16.2% found by Bastianeli et al. (2009) respectively in broiler and layer feeds in France. Protein contents of F2, F3 and F6 feeds were similar to the values 20.13±0.54, 20.64±0.46 and 20.33±0.58 g/100 g found by Ayssiwede et al. (2012) in experimental rations in Senegal. However, protein contents of the ten formulated feeds were lower than the values 24.79 and 23.39% of the experimental rations respectively formulated by Bayala et al. (2016) and Diomande et al. (2018). Protein content of all feeds covers the recommended protein requirement (18%) for pullet feeding. This constitutes a quality of the formulated feeds because a correct protein level in a feed translates into a better feed intake and better zootechnical performance (INRA, 2015).

Lipid contents of the ten feeds were lower than the values 6.1%, 6.88% and 6.2% of the feeds formulated respectively by Bastianeli et al. (2009), Ayssiwede et al. (2012), Ouattara et al. (2015). These contents were within the range of 4-7% lipid content recommended by INRA (2015). The relatively low contents of feed are an advantage because a feed too rich in lipid limits digestion in chicks (INRA, 2015). Fats increase the energy concentration of the feed (from 2 to 10%) and therefore decrease the feed conversion ratio. It also facilitates the incorporation of protein-rich and energy-poor materials but increases the need for vitamins E and B2 (Nir, 2003).

The food rations presented carbohydrate contents higher than the value 33.1% of the food rations analyzed by Bastianeli et al. (2009) in France. This is significant because carbohydrates are the main source of energy for basic metabolism and provide the spontaneous energy necessary for the functioning of the nervous system (Sguera, 2008). Some carbohydrates participate in the construction of fundamental structures of the organism such as cartilage, nucleic acids, mucus, glycoproteins, immunoglobulins, etc. (Sguera, 2008). Because they are rapidly digested, carbohydrates release their energy faster than proteins and fats. However, a food ration too rich in carbohydrates is not systematically a food ration with a high energy value because, some carbohydrates are digestible and others are fibers for monogastric (Ponka et al., 2017).

Ash contents of the feeds were slightly higher than the values 7.06% and 7.10% of the feeds formulated by Ayssiwede et al. (2012) and Bayala et al. (2016) respectively, but were lower than the value 12.6% of the feed formulated by Ouattara et al. (2015). The F6, F7 and F8 feeds have higher ash contents compared to the other feeds. This difference in content can be attributed to the nature of the oyster shell and fish meal used in the feed formulation. A high ash content also means a high content of mineral salts, which are essential for the proper functioning of the body and the growth of poultry.

Crude cellulose contents of the feeds were well above the 3% and 4.93% values of the feeds respectively formulated by Ouattara et al. (2015) and Ayssiwede et al. (2012). However, the ash contents of the feeds were similar to the value (7%) recommended by INRA (2015).

Food rations F7 and F8 had the highest calcium concentrations while phosphorus was highly concentrated in feed F8. These levels were higher than the calcium and phosphorus levels of the feeds formulated by Hien and Coulibaly (2017), Abasse et al. (2017) and the value recommended by INRA (2015). However, the other food rations (F1, F2, F3, F4, F5, F6, F9 and F10) had calcium and phosphorus contents slightly lower than the value recommended by INRA (2015).

Energy concentration of a food ration for poultry should cover the needs of maintenance, growth and production estimated at 2700 to 2900 kcal/kg (Blum, 1989). Compared to this recommendation, only food rations F7, F8, F9 and F10 had a slightly lower energy value. The energy values of all feeds were higher than those of feeds formulated by Bastianeli et al. (2009) and Ouattara et al. (2015), but remain lower than those of feeds formulated by Bayala et al. (2016) and Abasse et al. (2017). The high energy value of some formulated feeds may be related to their high lipid content. However, in animal nutrition, a feed is termed energy-rich when it contains a significant carbohydrate content (Ponka et al., 2017). Diets for poultry are mainly composed of a mixture of several ingredients such as cereals, soybean meal, animal product derivatives (fish meal, bones, shells, etc.), fats, vitamin premixes and minerals. All of these feeds provide the energy and nutrients needed for growth, reproduction, and animal welfare (Ponka et al., 2017).

The average cost (213.77 FCFA/kg) of the formulas was lower than the costs (219.05 FCFA/kg) and (302 FCFA/kg) of the feeds formulated by Guembo et al. (2021) and Ouattara et al. (2015) respectively. This average cost was also lower than the national market price for poultry feeds which varies between 240 and 300 FCFA/kg (Ouattara et al., 2015). This decrease could be explained by the rational use of raw materials in the formulation through the design of experiments method.

Conclusion

This study showed the nutritional richness of feeds formulated from local raw materials by the methodology of experimental designs produced in Burkina Faso. Indeed, it was found that feeds F2, F3 and F6 have the highest contents of protein, calcium and phosphorus as well as essential amino acids (lysine, methionine and threonine). The F1 feed was the richest in carbohydrates while the F7 and F8 feeds were the richest in minerals. The study has thus highlighted the interest of using the design of experimental method in the formulation of poultry feeds in Burkina Faso. The dissemination of the results obtained to poultry farmers will enable them to improve the yields and profitability of their activity.

COMPETING INTERESTS

The authors declare that there is no competing.

AUTHORS' CONTRIBUTIONS

IK and CP designed and conducted the study and participated in the collection, analysis and interpretation of the data. IK wrote the manuscript. IK, CP, MKS, BD, MHD made critical revisions to the article. The final manuscript was approved by MHD. All authors read and approved the final manuscript.

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