ON-FARM ASSESSMENT OF TWO NUTRITIONAL STRATEGIES ON PRODUCTION EFFICIENCY AND NUTRIENT EXCRETION IN BROILER PRODUCTION IN NIGERIA

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ABSTRACT

This study was carried out to assess the effect of two nutritional strategies on production efficiency and nutrient excretion in commercial broiler production in Nigeria. The study was carried out at Dovetech Farms Consult, Nigeria, in conjunction with Obafemi Awolowo University, Ile-Ife, Nigeria. Twelve thousand one-day-old Abor Acre broilers obtained in six batches of two thousand each were used for the study. Each batch was raised separately and in succession in the same house with an area of 280 m2. Experimental treatments were composed of two feed types. The first three batches were fed with conventional low-nutrient feed while the last three batches were raised on high-nutrient feed. Feed intake and body weight were monitored daily and weekly, respectively. Twenty birds from each batch were placed in the metabolic cages to determine nutrient digestibility and excretion of N, Ca and P. The Two-Sample T-test method was used to analyze the data. The two nutritional strategies supported the growth of broilers differently ($p<0.05$). Birds on high and low-nutrient feeds reached 1.9 kg body weight in 37 and 47 days, respectively. There was higher ($p<0.05$) daily feed intake, body weight gain, and better feed conversion in high-nutrient feed than low-nutrient feed. Broiler performance efficiency factor (BPEF) and Broiler farm economy index (BFEI) were both superior in high-nutrient feed while feed cost per kg weight gained did not differ ($p>0.05$) in both feeding strategies. Feed digestibility was better in high-nutrient feed but no significant difference ($p>0.05$) was observed in the excretion of all nutrients assessed. High-nutrient feed was more efficient and did not constitute any significant threat to the environment in terms of nutrient excretion over the conventional low-nutrient feed.

Keywords: Broilers, digestibility, excretion, feed types, production efficiency

INTRODUCTION

Poultry is the most commercialized agricultural sub-sector in Nigeria with about 196 million chicken population (FAOSTAT, 2019), and the industry stands at 4.2 billion USD net worth (The Cable Magazine, 2019). The sector contributes 6-8% to real GDP annually, and about 30% to the agricultural GDP, making it the largest producer of poultry eggs and fourth-largest poultry meat producer in Africa (FAOSTAT, 2019). The consumption of poultry meat, however, is still relatively low compared to other countries. It is estimated that on average Nigerians eat 1.9 kg of chicken per capita in a year, 32.98 kg in South Africa, and 7.67 kg in Ghana (NEA, 2020). This presents a unique opportunity for investments in many aspects of the poultry production value chains, and hence the Nigerian poultry sector is pivotally positioned to stimulate Africa-wide industry development and growth based on its expected contribution and experience.

The modern poultry industry has evolved in developing different types of feed with different nutrient profiles, particularly for broilers. There are two categories of feed available for broilers at the commercial level, the high and low-nutrient feed types designed to finish broilers at 2 kg average weight between 5 and 8 weeks of age, respectively. Many brands of these feeds exist within the country and have different name tags such as 'special', 'super', 'professional', '3 in 1' etc. These two categories of feed are used by farmers based on targets and economic capability or returns. The high-nutrient type is essentially high in price and many farmers operating at small- to medium-scale levels will not consider it as an option. They would rather opt for the conventional low-nutrient type while many farmers at large-scale levels often go for the high-nutrient feed type. The downside to this trend in growth and development of the industry is that poultry waste may become a significant environmental issue, particularly in regions where waste management is not properly handled. Poultry excreta contains significant N, Ca, P, Cu, Mn, and Zn levels, which contribute to environmental pollution, particularly in water bodies (Paterson, 2002). These excess elements can leach through soils, potentially contaminating groundwater supplies. Nitrate leaching has been considered a major N pollution concern in livestock and poultry farms.

Furthermore, manure can be a major source of methane and N oxides which contributes to the accumulation of greenhouse gas. Greenhouse gas emissions are key drivers of global warming and atmospheric pollution. However, according to a review by Hristov *et al*., 2013, and Forabosco *et al*., 2017, chickens emit 7% less harmful gas (methane) than other livestock. Similarly, due to recent improvements, broilers are better at absorbing the nutrients from feed, hence they excrete less waste and environmental pollutants. Aviagen data shows that the improvements achieved in FCR over the past 15 years have resulted in a 20% reduction in nitrate and phosphate excretion. Despite all these, responsible poultry production should minimize every potential pollutant. Apart from the green gas emission, the major environmental burden of broiler production includes eutrophication (ammonia emission water pollution) and soil acidification; volatilization of ammonia can also cause acid rain which leads to forest dieback in some countries.

Some research findings have indicated possible advantages of a low crude protein feeding strategy to reduce faecal nitrogen excretion and consequently reduce the environmental nitrogen loads (Hernández *et al*., 2012; Kamran *et al*., 2008; Such *et al*., 2021). According to estimates from European Feed Manufacturers' Federation, total poultry feed production in 2019 in EU-28 countries was 55999 (000MT), and if on average, 0.5% CP is reduced in total poultry feed production, it carries a potential of reducing estimated N excretion by 2799 (000MT). However, the recent trend in the use of high and low-nutrient feed with fortification with enzymes, and pre- and pro-biotics in broiler enterprise is on an alarming level, possibly because of the accrued benefits and higher return on investment. Yet, little attention is paid to nutrient excretion factors from feeding broilers with low or high-nutrient feed on a commercial scale.

Tripartite dynamics are critical to the sustainable production of broilers on a global stage, comprising, the need for greater efficiency to satisfy the growing demand for high-quality protein, the rising campaign to protect animal welfare, and the collective effort in preserving the earth against green gas emissions and environmental pollution. These factors need more and continued research for the safe sustainability of the industry. With these in mind, this study was designed to evaluate the production efficiency and environmental impact of feeding broilers with two nutritional strategies of high and low-nutrient feed types.

MATERIALS AND METHODS

Experimental Location

The study was carried out partly at Dovetech Farms Consult, a commercial poultry farm in Ikoyi- Ile, Ogbomoso, Oyo State, and partly at the Central Research Laboratory of Obafemi Awolowo University, Ile-Ife between March 2021 and February 2022. The climatic conditions during the rearing period were as indicated in Table 1.

Table 1: Climatic conditions during the rearing for each batch of broilers

	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan
Min. Temp., ºC	24.1	24.1	23.6	22.6	21.9	21.5	21.9	22.3	22.9	23.3	23.4
Max. Temp., ºC	35	33.3	31.4	29.2	28	27.5	28.5	29.8	32.5	34.5	34.8
Ave. Temp., ºC	28.3	27.5	26.4	25	24.1	23.8	24.2	25	26.4	27	27.4
Humidity, %	62	73	79	83	84	85	85	83	75	55	55.3
Rainy days, d	5	9	14	16	19	18	18	13	2	0	0
Av. sun hour, hr	8	7	5.6	4.4	4.2	3.7	4.2	5.2	7	7.2	7

Source: Online weather forecast

Experimental Birds and Management

Twelve-thousand-day-old Arbor Acre broiler chicks were obtained in six batches of two thousand per batch from a reputable commercial hatchery in Oyo State, Nigeria. Each batch was raised separately and in succession in the same house with an area of 280 m^2 such that each bird had 0.14 m^2 rearing space. A period of 15 days was observed as the interval for cleaning and getting the house ready for the next batch. A section of the building was used to brood the chicks for about 10-14 days using a charcoal heating system. The birds were raised in a full litter open-sided house system where feed and water were supplied *ad-libitum* throughout the growing period. Routine vaccination and medication schedules were observed. Wood shaving litter material was used and was changed weekly.

Source and Composition of Experimental Diets

One of the commonly used feed brands in the country was adopted for the study. The feed types were sourced directly from the company located in Ibadan, Nigeria. The low-nutrient feed type had starter and finisher phases while the high-nutrient feed type came as a single feed. The first three batches were fed with conventional low-nutrient feed and were finished at 49 days of age per batch while the last three batches were raised on high-nutrient feed, often tagged as ‘super’, ‘premium’, or ‘professional’ feed, and were finished at 39 days of age when the birds’ average weight was about 1.9 kg. The nutrient composition of the two feed types is indicated in Table 2.

Data Collection

Data on feed intake were monitored daily while body weight gained was measured weekly. One hundred birds randomly selected from ten different points in the house were used to determine the average weight gain of the population. The feed conversion ratio (FCR) was calculated as the ratio of feed intake to body weight gained. Mortality was recorded as the number of dead birds at the end of the cycle for each batch. The broiler performance efficiency factor and broiler farm economy index were calculated with the formulae provided below. The cost of feed and FCR were used to determine the cost of production efficiency for each batch. The experiment was arranged and analyzed with the Two-Sample T-test method using the SAS (1998) computer software package.

The following formulas according to Murugan and Ragavan, 2017 were used:

$$Broiler\ Performance\ Efficiency\ Factor\ (BPEF) = \frac{Live\ weight(kg)}{Feed\ Efficiency} \times 100$$

$$Broiler\ Farm\ Economy\ Index\ (BFEI) = \frac{Live\ weight\ (kg) \times\ Livability}{(Feed\ efficiency \times\ growing\ period\ (days))}$$

For nutrient excretion, twenty birds of the average weight of the flock were selected from each batch in the last week of the growing and kept in metabolic cages individually. One hundred and forty grams (140 g) of feed was supplied daily to each bird and the droppings were collected and weighed daily for four consecutive days. Trays lined with aluminum foil papers were placed under the cage for excreta collection. Excreta was labeled, weighed, and oven-dried for subsequent analyses. Samples of both the feed and the excreta from each batch were weighed, bulked, prepared, and analyzed for the selected nutrients. ProxiMate^{TM}, a near-infrared spectrophotometer at IITA was used to analyze the samples for proximate composition, amino acid profile, mineral profile, fatty acid composition, and metabolizable energy.

RESULTS

Nutrient profile of the experimental feed

Tables 2 and 3 showed the stipulated (manufacturer) and determined nutrient composition of the experimental feeds. The proximate compositions determined were within the values stipulated by the manufacturer of the feed. However, the amino acid contents particularly methionine, lysine, tryptophan, threonine, and arginine were slightly lower than the values indicated for broiler chickens.

Table 2: Stipulated nutrient composition of experimental feed

Nutrients, %	Low-nutrient Feed		High-nutrient Feed
	Starter	Finisher	
Moisture	8.5	7.9	8.0
Protein	21	19	23
Fat	4.5	4.3	5.5
Crude Fibre	4.0	4.2	3.0
Ca	1.0	1.0	1.2
Available P	0.4	0.4	0.5
Methionine	0.50	10.50	0.56
Lysine	1.2	1.2	1.3
Metabolizable Energy, kcal/kg	2800	2850	3050

Table 3: Determined nutrient composition of the experimental feeds

Nutrient	Low-nutrient feed	High-nutrient Feed
Proximate Composition, %		
Dry Matter	91.75	90.32
ASH	7.03	6.26
Ether Extract	3.38	2.95
Crude Fibre	6.17	5.51
Crude Protein	19.48	23.05
Metabolizable Energy (MJ/Kg)	11.92	12.80
Amino Acid Profile		
Aspartic Acid	1.36	1.69
Serine	0.62	0.80
Glutamin Acid	1.46	2.52
Glycine	1.46	0.92
Arginine	0.51	1.04
Threonine	0.65	0.62
Alanine	1.03	1.16
Proline	0.93	1.19
Cystine	0.28	0.31
Tyrosine	0.64	0.59
Methionine	0.33	0.37
Lysine	0.82	8.47
Isoleucine	0.57	0.59
Leucine	0.87	1.19
Phenylalanine	0.59	0.68
Tryptophane	0.11	0.18
Fatty Acid Profile		
Omega-3	353.98	204.14
Trans-Fat	37.80	24.97
MUFA	4,201.20	3,064.53
PUFA	992.14	1,964.21
Mineral Profile		
Copper	9.10	6.60
Zinc	52.58	61.18
Phosphorus	7,069.15	6,832.15
Sodium	3,574.27	1,911.17
Potassium	5,652.30	5,706.07
Magnesium	5,061.17	3,792.25
Calcium	2,851.40	2,250.18

Production attributes of broilers raised on two feed types

Tables 4 and 5 show performance attributes obtained with birds fed the two nutrient concentrations. The weight range varied between 1.1 kg to 2.7 kg in both nutritional strategies. However, the variation in weight was wider in low-nutrient feed compared to the high-nutrient feed. Birds on low-nutrient feed attained an average weight of 1.9 kg in

49 days while their counterpart on high-nutrient feed attained similar weight within 39 days. Feed consumption patterns showed higher (p<0.05) daily feed intake in birds placed on a high-nutrient profile over the low-nutrient group. The total feed intake pattern, however, showed that greater (p<0.05) feed consumption was observed with birds on the low-nutrient profile to attain similar weight with their high-nutrient counterpart. Hence, the feed conversion ratio was significantly (p<0.05) improved on high-nutrient feed than on low-nutrient feed. Mortality and morbidity patterns were similar (p>0.05) in all six batches and across the two nutritional strategies. The values of the Broiler performance efficiency factor (BPEF) and Broiler farm economy index (BFEI) obtained were significantly different (p< 0.05) between the two feed types. For the high-nutrient feed, the BPEF and BFEI values were a little above the recommended values of 100 and 2, respectively while that of low-nutrient feed fell below the recommended values. The cost of feed was significantly different (p<0.05). There was undoubtedly a higher cost of feeding in high-nutrient feed than the regular diets. One tonnage of high-nutrient feed costs as much as 12% higher than the low-nutrient feed. However, feed cost per kilogram of body weight gained did not differ (p>0.05) in both feeding strategies.

Table 4: An overview of stock performance traits of the six batches of broilers

Parameters	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5	Batch 6
Age at finishing, d	47.00	47.00	47.00	38.00	37.00	37.00
Stock	2000.00	2000.00	2000.00	2000.00	2000.00	2000.00
Weight at DOC, g	41.00	39.00	40.00	41.00	40.80	40.00
Final body Weight range, g	1200-2600	1100-2550	1200-2600	1300-2700	1300-2600	1200-2600
Total feed intake, g	3827	3915	3940	3421	3490	3480
Feed conversion ratio	2.01	2.10	2.06	1.80	1.83	1.82
Livability, %	95.00	93.00	93.00	95.00	94.00	94.00

NB: DOC- day-old chicks

Table 5: Performance characteristics of broilers fed low and high-nutrient diets

Response	Low-nutrient feed	High-nutrient feed	Prob.
Initial wt at DOC, g	40.00±0.06	40.50±0.04	2.53
Ave. final body wt, g	1890.00±23	1903.00±31	0.021
Total feed intake, g/b	3894.05±45	3464.00±39	0.032
Ave. daily feed intake, g/b	79.47±2.80	88.82±3.71	0.025
Feed conversion ratio	2.06±0.03	1.82±0.04	0.022
Livability, %	93.67	95.67	
Broiler performance efficiency factor	92.01±2.55	105± 2.34	0.05
Broiler farm economy index	1.75± 0.03	2.56± 0.05	0.02
Feed cost/kg, ₦	266.00±13	300.00±11	0.001
Feed cost per kg Body weight, ₦	547.60±32	546.00±21	1.71

Nutrient digestibility and excretion

The results of nutrient excretion by broilers subjected to the two nutritional strategies are indicated in Table 6. The nitrogen excretion followed the nitrogen intake pattern. There was no significant difference in N excretion ($p>0.05$) between the two protein feed types, although a numerical increase was observed with high-nutrient feed. Similar patterns were observed for Ca and P intake and excretion alike. It appears the higher the intake the higher the excretion but the difference in excretion was not significantly different between the two nutritional strategies. Feed digestibility was significantly higher ($p<0.05$) in high-nutrient feed, which was translated to a better feed conversion ratio. Magnesium excretion was significantly increased in broilers fed low-nutrient feed but may not pose any significant threat to the environment as the mineral was not indicated among those that pollute the ecosystem.

Table 6: Feed digestibility and nutrient excretion of broilers fed low and high-nutrient diets, %

Feed digestibility DM	70.60±4.03	77.51±4.11	0.005
Faecal output, g/b/d	63.90±2.12	65.7±3.33	5.70
N excretion	2.31±0.04	2.77±0.05	0.75
Ca excretion	0.85±0.06	0.91±0.02	0.07
P excretion	0.41±0.01	0.53±0.01	0.40
K excretion	0.22±0.04	0.19±0.06	0.35
Mg excretion	0.30±0.009	0.17±0.03	0.002
Na excretion	0.11±0.01	0.10±0.02	0.50

DISCUSSION

Production attributes of broilers raised on two feed types

Since the use of a low-crude-protein diet supplemented with essential amino acids is considered an economical feeding strategy and has gained commercial recognition to improve protein utilization and minimize environmental pollution (Attia *et al.,* 2020; 2022), some commercial feed manufacturers need to review the amino acid profile of their feeds in line with recent recommendations. In this study, the high-nutrient feed appears to bridge gaps in the bodyweight range to support better uniformity of the flock. This is very important in broiler enterprise because it offers more guarantee for the marketing of birds not just on time but also at the same time to enable farmers to prepare for subsequent batches. A difference of ten days gap was observed between the two feeding strategies. This has an extensive implication; first, on the number of cycles a farmer can turn over per year, then on the mortality rate, because the more the birds stay on the farm the more the tendency to be predisposed to diseases. Similarly, the cost of medication and labour is expected to rise as a result of increased rearing time.

The feed consumption intake pattern showed that the high-nutrient feed enhanced daily feed intake. Since birds tend to consume feed to satisfy their energy requirement, more calories in high-nutrient feed were expected to lower the consumption rate compared to low-nutrient feed type, however, this was not the case. This suggests that the high-nutrient feed possibly contains factors that enhance palatability and higher intake of the feed despite its higher calories. It is also possible that the birds were eating to meet the nutrient requirements for a higher growth rate brought about by the high-density nutrient feed. This also probably explains in part, the reason for superseding performance in body weight gain of birds on high-nutrient feed over their low-nutrient counterpart.

Since values of BPEF and BFEI for high-nutrient feed exceeded recommended standard values of 100 and 2, respectively, these indicate a better and more desirable performance of the flock. Although lower values were obtained in low-nutrient feed, the BFEI value did not fall below 1.3 which marks out a flock as poor performing one (Murugan and Ragavan, 2017). These factors are also pointers that the nutrient profiles of both feeds reliably supported the birds and that they were raised under good management practices. Regardless of nutrient concentration, the health of the birds was not jeopardized.

Lower cost of production observed, in numeric terms, with high-nutrient feed type was also considered an advantage to maximize profitability. In other words, the cost of feed should not be the only determining factor in the choice of feed type rather, its efficiency in terms of feed conversion and environmental impact

The quantity of manure produced may be influenced by many factors such as age, diet, and health of the birds as observed by Williams *et al.* (1999). Since the population of the birds was homogeneous and was raised under near similar conditions as indicated in Table 1, one can assume that changes in metabolism were primarily caused by the nutritional factor. Excreta produced by a mature bird sums up to about 64 g per day. Values of excreta voided were not significantly different ($p>0.05$) between the two strategies. This value is closer to 80 g for meat chickens reported by Williams *et al*., (1999). This value can be used as an extrapolation for an estimate of total excreta throughout the cycle of production. Estimates of the litter produced by 1000 broilers range from 1.1 to 2.4 tonnes (Williams, *et al*., 1999; Velthof *et al*., 2015). However, it should be noted that more excreta will likely accrue from low-nutrient feed types because of the longer period of days the birds had to spend before culling. In other words, the overall excreta production is expected to be higher in low-nutrient feed as was observed for the feed. An increase in the volume of excreta is expected to contribute to the deterioration of environmental conditions in terms of the microbiological challenge and possible threat to climate. This suggests clearly that the professional high-nutrient feed did not constitute a serious threat to the environment despite an increase of about 4% and 200 kcal in the average protein and energy contents, respectively, between the two feeding strategies.

Although the exact content of the feeds in terms of the presence of special enzymes and other additives could not be ascertained, similar excretion of N may largely be influenced by variations in the efficiency of nitrogen utilization in the feed. This result shows a similar pattern to the findings of Kamran *et al*. (2016), that despite reducing dietary CP, the birds maintained their N intake resulting in similar N excretion and litter composition among various treatments. However, Such *et al*. (2021) revealed that 2% protein decrease in grower and finisher broiler diets did not affect the production traits but can decrease the N excretion of birds significantly. Reports by Graña *et al*. (2013) showed that for every unit of dietary crude protein reduction, there was about 10.3% less N excretion. In this study, only about a 4.15% reduction was observed in nitrogen excretion on low-nutrient feed. Similar results were obtained by De Faria and Sakamoto (2008), who observed a 9.9% N excretion reduction when feeds based on the ideal protein concepts were used whereas Ferket *et al.* (2002) reported 8.5% less N excretion for each unit of dietary crude protein reduction. From different batches raised in this study, there was no substantial variation in N excretion as earlier demonstrated by Coufal *et al.* (2006) that season is one of the most important factors contributing to the variability of N loss from broilers raised consecutively for eighteen cycles. Briukhanov *et al*. (2021) underscored the essential role of systemic measures for nitrogen use efficiency by increasing animal productivity and reducing mineral fertilization for low-emission manure practice.

Phosphorus is another essential nutrient in poultry production with an economic impact on the environment and the failure to provide adequate quantity has a negative effect. There was a numerical high value of P excretion in birds placed on the high-nutrient feed but the value was not statistically different ($p>0.05$) between the two nutrient concentrations. The study conducted by Waldroup (1999) firmly recommended the choice of P supplements of maximum biological value, the practice of exogenous phytase enzymes, and cautious selection of dietary P levels to minimize excessive amounts of P excreted in the excreta. The possible practice of these feeding strategies by producers of the high-nutrient feed type might have contributed to the efficient utilization and or moderate excretion of this element in this study. The report of Gomide *et al*. (2011) shared a similar view with the present findings. Similarly, the report of Miles and Sistani (2002) indicated that the impact of P on the environment can be reduced by maintaining the performance and economic viability of broiler production.

Feed digestibility was significantly higher ($p<0.05$) in high-nutrient feed which was translated to a better feed conversion ratio. While some authors have advocated for a low-nutrient feeding strategy in a way to curb excessive nutrient excretion, this study has demonstrated that high-nutrient feed as with the case of the professional feed type used in this study demonstrated superior digestibility over its low-nutrient counterpart. The excellent digestibility prevented excessive daily excretion of nutrients. The possible presence of feed digestion enhancers such as enzymes in the high-nutrient feed may contribute partly to its higher digestibility observed. Hence, nutrient concentration particularly, the protein content below the requirement of chicken may not deliver any significant benefit in terms of nutrient excretion. The exception may be in the case of fortification with the desired amino acid or enzyme as demonstrated by the report of Gomide *et al.* (2011) that manipulation of the diets reducing the crude protein, calcium, and available phosphorus levels, supplemented with phytase and amino acids was efficient in reducing the pollutant power of broiler excrements in the growing and retirement phases of production. Similar results were obtained by Graña *et al*. (2013) that phytase supplementation reduced phosphorus, calcium, and manganese excretion and improved phosphorus retention. It should also be noted that elemental excretions may be reduced by avoiding the overfeeding of specific elements or using nutritional approaches to improve element utilization by the animals.

CONCLUSION

Feeding broilers with the low and high-nutrient feed types supported growth differently. The high-nutrient feed showed higher daily feed intake and better feed conversion. Turnover on investment was quicker in high-nutrient feed, which in turn allowed two additional cycles of production per annum with reduced risk of mortality.

Despite variations in nutrient density, excretion factors were not significantly affected by the two feed types. High-nutrient feed was considered efficient and did not constitute any significant threat to the environment over conventional low-nutrient feed. This information can also be used to estimate manure turnover produced under these two nutritional strategies for environmentally responsible production.

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