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Determination of Optimum Tryptophan Requirement of Broiler Chickens Reared in the Cool Season under Tropical Environment

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Abstract
A study was conducted in a completely randomized design to determine the response of broiler chickens fed graded dietary levels of tryptophan. A total of two hundred and eighty five mixed sex day old broilers (Arbor Acre) were used in this experiment. Daily temperature ranged from 14^{o}C - 20^{o}C during the period of the study. Five broiler starter diets were formulated such that diet 1 (basal diet) had dietary tryptophan content of 0.15%; diets 2 to 5 contained graded levels of supplemental tryptophan at 0.04% intervals giving total dietary tryptophan levels of 0.19, 0.23, 0.27 and 0.31 - percent levels respectively while for the finisher, diet 1 (basal diet) had dietary tryptophan content of 0.13%; diets 2 to 5 contained graded levels of supplemental tryptophan at 0.04% intervals giving total dietary tryptophan levels of 0.17 0.21, 0.25 and 0.29 - percent levels respectively . The experiment lasted 28 days (0 to 28days) for the starter and another 28 days (28- 56 days) for the finisher phase. Results showed that dietary treatments had significant (P<0.05) effects on final body weight, weight gain, average daily weight gain, feed intake and feed conversion ratio. An appropriate fit was obtained by polynomial models for bird performance data, since this model was significant (P<0.05) by regression analysis of variance. The equation obtained from regression analysis in this study was reliable for obtaining an optimal digestible tryptophan level in the analyzed variables. It can be inferred that the 0.24% and 0.23% digestible tryptophan levels estimated from polynomial regression equation indicated an improvement in weight gain for the starter and finisher phases, respectively. Chicks fed 0.23% and 0.27% dietary tryptophan had similar results in terms of apparent digestible crude protein, ether extract, ash and nitrogen free extract. It was concluded that dietary tryptophan requirements during the cool season for the starter was 0.24%.
Key words: *broiler, tryptophan, growth performance, nutrient digestibility, tropical environment.*

INTRODUCTION

Dietary amino acids are essential components for optimal growth, feed efficiency and reproduction of animals. In poultry production, cost of meats is mainly associated with the need to supply dietary energy, dietary protein and dietary amino acids. However, amongst the feed stuffs, protein and amino acids are generally considered as one of the major cost components of poultry diets (Onimisi *et al.*, 2008). Thus, maximizing the efficiency of protein and amino acid utilization are very crucial for the reduction of feed costs, reduction of nitrogen gas and the production of lean meat. In practice it is very difficult, if not impossible; to formulate diets with natural feed ingredients that will provide all the amino acids needed by broiler chickens in adequate quantities. The optimal use of synthetic amino acids in animal diets is important not only on nutrition and economic aspects, but also on environmental aspects. It is well known that synthetic amino acids enhance the digestibility of amino acids; as well they promote high lean meat production (NRC 1994). Tryptophan is an essential amino acid in poultry and is required for a wide variety of metabolic activities. It also, it serves as a precursor of melatonin, tryptamine and co-enzymes (NAD and NADP) as well as meeting the major requirement for nicotinic acid (Sterling *et al.*, 2006). Tryptophan which is the third or fourth limiting amino acid in poultry is a precursor of serotonin, which plays an important role in feed intake, weight gain, animal performance, feed conversion ratio. Its levels influence growth performance, feed intake and carcass composition (Corzo *et al.*, 2005). Although, growth performance and carcass characteristics of chickens during tryptophan supplementation experiment have been well studied in the temperate regions, few studies clearly clarify whether these changes are due to the supplemental tryptophan or increased feed consumption owing to high tryptophan intake (Wei *et al*., 2011). The level of tryptophan recommended for broiler chickens reared in the temperate regions by the NRC (1994) from 0 to 3 weeks and 3 to 7 weeks were 0.20% and 0.18% respectively. Rack *et al.* (2009) reported decreased performance of broiler chickens fed Dl- methionine in late fall likely because of cold ambient temperature. Duarte *et al*. (2009) reported that 0.2255% of digestible tryptophan numerically improves feed conversion, and the level of 0.1919% estimated by the quadratic equation improves carcass yield, corresponding to a digestible tryptophan: digestible lysine rate of 21.00% for feed conversion and 17.00% for carcass yield. Therefore, the objective of this present study was to determining the optimum tryptophan requirements for broiler chickens reared in the cool season under tropical environment. This will enable the modern broiler chickens in the tropical environment to fully express its genetic potential and possibly to permit further reduction of dietary protein levels.

MATERIALS AND METHODS

Experimental site

The experiment was carried out at the Poultry Unit of Kogi State Ministry of Agriculture, Kabba, located within the Southern Guinea Savannah Zone on latitude $7^0 5'$N, longitude $6^0 4'$E and altitude of 640m above sea level. It has annual rainfall of 1500mm and rain starts between late April and early May to mid October. The dry season begins around the middle of November, with cold weather that ends in February. This is followed by relatively hot-dry weather between March and April just before the rain begins. The minimum daily temperature is from 14 to 24^{o}C during the cold season while the maximum daily temperature is from 19 to 36^{0}C during the hot season. The mean relative humidity during dry and wet seasons is 21% and 72%, respectively Kabba College of Agriculture Metrological Section, Ahmadu Bello University. (2015).

Birds and experimental diets

The mixed sex broiler chicks (Arbor Acre) used in this experiment was obtained from a commercial hatchery with good records of birds' performance. Five broiler starter and finisher diets were formulated. Diet 1 was formulated without synthetic tryptophan but had dietary tryptophan of 0.15% which was practically below (0.20%) the NRC (1994) tryptophan requirement while diets 2, 3, 4 and 5 contained graded levels of supplemental tryptophan at: 0.04, 0.08, 0.12 and 0.16% to give total dietary levels of tryptophan of 0.19, 0.23, 0.27, and 0.31% for broiler starter chickens, respectively (Table 1). For the finisher phase diet 1 was formulated without synthetic tryptophan but had dietary tryptophan of 0.13% which was practically below (0.18%) the NRC (1994) tryptophan requirement while diets 2, 3, 4 and 5 contained graded levels of supplemental tryptophan at: 0.04, 0.08, 0.12 and 0.16% to give total dietary levels of tryptophan of 0.17, 0.21, 0.25, and 0.29% for broiler finisher chickens, respectively (Table 2). The diets were formulated to be isocaloric and isonitrogenous . The nutritional recommendations of crude protein, metabolizable energy, calcium, available phosphorus and digestible amino acids used in the experimental diets were established by NRC (1994) for broiler chickens reared from 0 to 28days and 28-56 days of age. The synthetic tryptophan used was purchased from Ajinomoto Eurolysine S. A. S, from France under Licence from Ajinomoto. Inc. Japan. All the diets were chemically analyzed according to the standard of AOAC (1990) methods for their proximate composition (Table 3 and 4).

Experimental design and management of birds

A total of two hundred and eighty five day old broiler chicks were used in this study. The mean weights of birds for all the pens were made to be approximately equal. There were five dietary treatments with three replicates having 19 birds per replicate for the starter phase and 18 birds per replicate for the finisher phase. The experiment was a completely randomized design. The broilers were housed in pens under the deep litter system of (45 cm × 36 cm × 36 cm). The room temperature was maintained at 30 to 35°C from d 1-7, and then gradually reduced 2°C per week until a final temperature of 25°C was reached. Relative humidity was maintained at 55% to 60%. Chicks were exposed to 22 h of light and 2 h of darkness from d 1-8 and 16 h of light and 8 h darkness from d 9-58. The maximum temperatures varied from 29^{0}C to 45^{0}C. The litter was made from wood shavings and the amount placed in each box was 2.2 kg of dry matter/bird housed, so that all treatments had the same initial amount of material used as litter, at a height of 6 cm. The chicks were vaccinated in the hatchery against Marek's disease, Gumboro and Bouba disease, followed by vaccination at 5 and 21 days against Gumboro disease, and on the 8th day against Newcastle disease. Mash feed and water were supplied *ad libitum.*

Nutrient Digestibility Trial

A nutrient digestibility trial was carried out at the end of the starter phase (4 weeks) of the experiment, using metabolic cages. This was done by randomly selecting 3 birds of approximately equal weight from the each replicate. The birds were placed in alternated cages, with polythene bags attached beneath the cages. The birds were fed with the control diet for 7 days of adjustment period and fasted for 24 hours with only water given. Forty gram of experimental diets was allocated to each bird by 8:00am daily. Faecal samples were collected daily, separated from feeds and other extraneous materials, weighed, bulk together and kept in a deep freezer. At the end of the 6th day the birds were not fed. The remaining faeces were then collected by 8.00am on the 7th day. The total samples were thawed and weighed after it has been thoroughly mixed together and oven dried for 72 hours at 65^{0}C. The dried samples were then weighed and ground, after which samples were taken for proximate analysis along with the sample of the feed fed at the Department of Animal Science Laboratory, Ahmadu Bello University, Zaria. Nutrient retention was determined for crude protein, crude fibre, ether extract, ash, and nitrogen free extract.

$$\text{Nutrient Retention} = \frac{\text{Nutrient intake} - \text{Nutrient output}}{\text{Nutrient intake}} \times 100$$

Parameters measured

The final body weight and feed intake were measured weekly. From the primary data collected for feed intake and weight gain, data for feed conversion ratio was generated. Mortality record was recorded as it occurred.

Statistical analyses:

All data obtained were statistically analyzed using the General Linear Models (GLM) procedure of SAS (2001) for the analysis of variance. Duncan's multiple range tests were used to determine differences among treatment means. Means were considered different at P<0.05. The growth response estimates, of broiler chickens to varying levels of tryptophan was determined by regression analysis. To determine optimum tryptophan requirement, polynomial regression model was used.

General Linear Model

$Y_{ij} = \mu + K_i + e_{ij}$

Y_{ij}= Observation of the ith level of tryptophan as shown by broilers performance

μ= Overall mean

K_i =ith effect of tryptophan

e_{ij} = Random error

RESULTS AND DISCUSSION

In the study, dietary tryptophan had significant (P<0.05) effects on final weight, weight gain, average daily weight gain, total feed intake, average feed intake and feed conversion ratio (Table 5). Chicks fed dietary tryptophan at 0.23% had better performances in terms of final body weight, weight gain and average daily weight gain compared to chicks fed other tryptophan levels (Table 5 and Figure 1). This observation is contrary to the NRC (1994) and (Rostagno *et al*., 1995) recommendation of 0.20% tryptophan for the starter phase period. Weight gain was observed to be increasing as the levels of tryptophan increased but it decreased at 0.27% dietary tryptophan. This result is in agreement with the reports of (Harm and Russell, 2000; Fatufe and Rodehutscord, 2005; Emadi *et al*., 2010; Yu *et al*., 2010), who reported an increase in body weight gain in broiler chickens which received the high concentrations of dietary tryptophan compared with those which received low concentrations. This may be due to the phenomenon of amino acid balance. The increase in body weight gain may be partly due to the increased feed intake as the dietary tryptophan increased. An appropriate fit was obtained by polynomial models for bird performance data, since this model was significant (P<0.05) by regression analysis of variance. The equation obtained from regression analysis in this study was reliable for obtaining an optimal digestible tryptophan level in the analyzed variables. Given the significant (P<0.05) effect of digestible tryptophan levels on these variables, the means were compared by the Duncan test at 5% of probability. It can be inferred that the 0.24% digestible tryptophan level estimated from polynomial regression equation indicated an improvement in weight gain (Figure 2). This value (0.24%) disagreed with the 0.20% tryptophan suggested by NRC (1994) and Rostagno *et al*. (2005) for broilers from 0 to 28 days of age. The optimum value of 0.24% dietary tryptophan also disagreed with the findings of (Harm and Russell, 2000) who reported that no more than 0.18% tryptophan is needed by starting broiler chickens, regardless of genotype. Chicks fed diet without supplemental tryptophan but with dietary tryptophan level of 0.15% had higher feed consumption rate compared to those receiving higher dietary concentrations of tryptophan. This result is contrary to the findings of (Yu *et al*., 2010; Mozhdeh *et al*., 2010), who reported reduced feed intake of broiler chicks, fed the lowest concentration of tryptophan. This may be partially explained by the fact that chicks were searching for the missing nutrients which precisely is the tryptophan. Generally, it was observed that chicks fed supplemental tryptophan fortified diets had higher feed consumption (1569.20g – 1687.99g) than the feed consumption rates reported by NRC (1994) of 1085g for male and 965g for female). The reasons for this may be due to the function of tryptophan as a precursor of neurotransmitter serotonin which is formed in the brain and influence feed intake (Xi *et al*., 2009, Zarate *et al.,* 2003). The energy levels of the diets, the fibre level, environmental temperature and breed of chickens may also enhance the increased feed consumption observed in chicks fed diet supplemented with tryptophan. . In this study, tryptophan deficient diet had the highest feed conversion ratio (1.79). This result was similar to the findings of (Rostagno *et al.* 1995; Mozdeh *et al*., 2010) who reported increase in feed conversion ratio and a gradual decrease in feed conversion ratio as the levels of dietary tryptophan increased. However, this result is contrary to the findings of (Duarte *et al*., 2013), who reported that digestible tryptophan levels did not influence feed conversion ratio. The increase in feed conversion ratio observed in the chicks fed basal diet containing 0.15% dietary tryptophan might be considered to be due to the deficiency of some critical amino acids. Hence, the efficiency of protein utilization is decreased. Dietary tryptophan up to the highest level tested did not affect the mortality rate of broiler chicks. Dietary tryptophan levels had significant (P<0.05) influence on the apparent dry matter, crude protein, ether extract, ash and NFE digestibilities of chicks fed graded levels of dietary tryptophan (Table 6). Chicks fed 0.23% dietary tryptophan had the best value for the apparent dry matter digestibility. This result disagreed with the report of (Faria Filho *et al*., 2007), who reported that the apparent dry matter digestibility was not affect by inclusion of tryptophan in chick's diet. Chicks fed high concentrations of dietary tryptophan were observed to have higher values for apparent crude protein digestibility compared to chicks fed the control diet without supplemental tryptophan. This result is similar to the findings of (Ratriyanto *et al*., 2012), who reported that chickens fed high concentration of tryptophan, recorded the highest value for apparent CP digestibility indicating more efficient nutrient degradation and absorption as evident in the increased weight observed in this study. The high value for apparent EE digestibility of Chicks fed 0.23% dietary tryptophan is similar to the findings of (Dean *et al*., 2006), who reported that chickens fed high concentration of tryptophan recorded the highest value for apparent EE digestibility indicating more efficient nutrient degradation and absorption of ether extract. Dietary treatment had effect on apparent NFE digestibility, the highest value was observed in chicks fed 0.27. This result is similar to the study conducted by (El-Husseiny *et al*., 2007), who reported an increase in the apparent NFE digestibility as the levels of tryptophan increased. It was observed generally in this study that chicks fed diets with high concentrations of supplemental tryptophan had the best apparent nutrient digestibility values. This indicated an efficient nutrient utilization by the chicks across the treatments.

Table 7 shows the performance of broiler finisher chickens fed graded dietary levels of tryptophan, (0.13%, 0.17%, 0.21%, 0.25% and 0.29%) , respectively. Dietary treatments had significant effects on final body weights, weight gains, average daily gain, feed intake, and feed conversion ratio. Dietary treatments however had no significant effects on mortality rate. Chickens fed 0.21% and 0.25% tryptophan diets had the best performance in terms of weight gain, daily weight gain and feed conversion ratio. A steady increase in weight gain was observed as the levels of dietary tryptophan increased from 0.13 – 0.21% after which weight gain decline were observed at 0.29% dietary tryptophan level. This result disagrees with the 0.18% suggested by NRC (1994) and Rostagno *et al.* (2007) for broilers between 22 to 42 days of age. A polynomial regression equation showed that at 0.23% dietary tryptophan the optimum weight gain was attained (Figure 3). Chickens fed 0.13% dietary tryptophan had the lowest weight gain and average daily weight gain. The observed low body weight for the chickens fed 0.13% dietary tryptophan could be related to possible stress-induced insufficiency of dietary tryptophan and amino acid imbalance. Birds fed Diet1 without supplemental tryptophan but with *insitu* dietary tryptophan of 0.13% had significantly higher feed consumption compared to those receiving tryptophan supplemented diets. This result is contrary to the findings of Harms and Russel (2000), Mozhdeh *et al.* (2010) and Corzo *et al.* (2005a), who reported reduced feed intake for broiler chickens, fed the low concentration of dietary tryptophan. This may be due to the fact that birds fed diets deficient in any nutrient consume more to meet their requirements for gain. In this study, tryptophan deficient diet had the poorest feed conversion ratio of 2.90 which is similar to the findings of Mozhdeh *et al.* (2010), Rostagno *et al.* (2007). These authors reported increase high feed conversion ratio for lower dietary tryptophan and a gradual decrease in feed conversion ratio as the levels of dietary tryptophan increased. The high feed conversion ratio observed in the chicks fed 0.13% dietary tryptophan might be the result of the fed low tryptophan or difference in amino acid digestibility of diets. This result is in contrast to the findings of Karina *et al.* (2013), who reported that digestible tryptophan levels did not influence feed conversion ratio. The results of the nutrient digestibilities of broiler finisher chickens fed graded dietary levels of tryptophan during the cool season is shown in Table 8. Dietary treatments had significant effect on the apparent NFE digestibility of chickens. Dietary treatments did not have any significant effects on the apparent CP, CF, EE and ash. This result disagreed with the findings of Faria Filho *et al.* (2007), who reported a significant effect of levels of tryptophan on apparent digestibilities of CP, CF, EE and ash for broiler chickens. Chickens fed 0.17% dietary tryptophan had the highest value for apparent NFE digestibility, although it was observed that the values obtained across all the treatments were not high. The low values obtained might be as a result of natural variability of these ingredients due to ingredient quality and processing that can affect digestibility.

CONCLUSION

The overall conclusion of this study is that no more than 0.24% and 0.23% dietary tryptophan was needed by starting and finishing broiler chickens for improved growth and efficient nutrient utilization in the tropical environment. More research needs to be done on the requirements for individual amino acids other than methionine and lysine which are the most commonly used synthetic essential amino acids in the tropical environment.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Table 1: Composition of broiler starter diets containing graded supplemental levels of tryptophan during the cool season (0 - 4 Weeks)

	Treatments				
Ingredient (kg)	**1**	**2**	**3**	**4**	**5**
	Try 0.00%	**Try 0.04%**	**Try 0.08%**	**Try 0.12%**	**Try 0.16%**
Maize	50.66	50.66	50.66	50.66	50.66
Groundnut cake	25.00	25.00	25.00	25.00	25.00
Soya cake	12.59	12.59	12.59	12.59	12.59
Fish meal	3.00	3.00	3.00	3.00	3.00
Palm oil	3.69	3.69	3.69	3.69	3.69
Limestone	0.90	0.90	0.90	0.90	0.90
Bone meal	2.75	2.75	2.75	2.75	2.75
Common salt	0.30	0.30	0.30	0.30	0.30
Premix **	0.30	0.30	0.30	0.30	0.30
Lysine	0.32	0.32	0.32	0.32	0.32
Methionine	0.21	0.21	0.21	0.21	0.21
Tryptophan	0.00	0.04	0.08	0.12	0.16
Threonine	0.25	0.25	0.25	0.25	0.25
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Calculated Analysis					
ME (Kcal/kg)	3008	3008	3008	3008	3008
Crude protein (%)	23.00	23.00	23.00	23.00	23.00
Ether extract (%)	8.11	8.11	8.11	8.11	8.11
Crude fibre (%)	3.70	3.70	3.70	3.70	3.70
Calcium (%)	1.28	1.28	1.28	1.28	1.28
Lysine (%)	1.26	1.26	1.26	1.26	1.26
Methionine (%)	0.56	0.56	0.56	0.56	0.56
Available P (%)	0.57	0.57	0.57	0.57	0.57
TSAA (%)	0.90	0.90	0.90	0.90	0.90
Tryptophan (%)	0.15	0.19	0.23	0.27	0.31
Threonine (%)	0.95	0.95	0.95	0.95	0.95
Glycine (%)	1.69	1.69	1.69	1.69	1.69
Arginine (%)	1.69	1.69	1.69	1.69	1.69
Phenylalanine (%)	1.07	1.07	1.07	1.07	1.07
Leucine (%)	1.85	1.85	1.85	1.85	1.85
Isoleucine (%)	0.99	0.99	0.99	0.99	0.99
Valine (%)	1.05	1.05	1.05	1.05	1.05

Total sulfur amino acid =TSSA, Try = Tryptophan; P=Phosphorus; ME=Metabolizable energy;**Biomix Premix Supplied per kg of diet: Vit. A, 10,000iu; Vit.D_3, 2000 iu; Vit E, 23mg;Vit.K, 2mg: Vit.B1,1.8; Vit. B_2, 5.5mg; Niacin, 27.5mg; Pantothenic acid, 7.5mg; Vit. B_{12}, 0.015mg: Folic acid, 0.75mg; Biotin, 0.06mg; Choline Chloride, 300mg; Cobalt, 0.2mg; Copper, 3mg; Iodine, 1 mg; Iron, 20 mg; Manganese, 40 mg; Selenium, 0.2 mg; Zinc, 30mg; Antioxidant, 1.25mg.

Table 2: Composition of Broiler Finisher Diets Containing Graded Supplemental Levels of Tryptophan During the Cool Season (5- 8 Weeks)

	Treatments				
	1	**2**	**3**	**4**	**5**
Ingredient (kg)	**Try 0.00%**	**Try 0.04%**	**Try 0.08%**	**Try 0.12%**	**Try 0.16%**
Maize	56.33	56.33	56.33	56.33	56.33
Groundnut cake	22.00	22.00	22.00	22.00	22.00
Soya cake	10.00	10.00	10.00	10.00	10.00
Fish meal	3.00	3.00	3.00	3.00	3.00
Palm oil	3.50	3.50	3.50	3.50	3.50
Limestone	1.00	1.00	1.00	1.00	1.00
Bone meal	2.80	2.80	2.80	2.80	2.80
Common salt	0.30	0.30	0.30	0.30	0.30
Premix **	0.30	0.30	0.30	0.30	0.30
Lysine	0.30	0.30	0.30	0.30	0.30
Methionine	0.21	0.21	0.21	0.21	0.21
Tryptophan	0.00	0.04	0.08	0.12	0.16
Threonine	0.29	0.29	0.29	0.29	0.29
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Calculated Analysis					
ME (Kcal/kg)	3056	3056	3056	3056	3056
Crude protein (%)	21.00	21.00	21.00	21.00	21.00
Ether extract (%)	7.79	7.79	7.79	7.79	7.79
Crude fibre (%)	3.43	3.43	3.43	3.43	3.43
Calcium (%)	1.32	1.32	1.32	1.32	1.32
Lysine (%)	1.14	1.14	1.14	1.14	1.14
Methionine (%)	0.54	0.54	0.54	0.54	0.54
Available P (%)	0.57	0.57	0.57	0.57	0.57
TSAA (%)	0.85	0.85	0.85	0.85	0.85
Tryptophan (%)	0.13	0.17	0.21	0.25	0.29
Threonine (%)	0.88	0.88	0.88	0.88	0.88
Glycine (%)	1.52	1.52	1.52	1.52	1.52
Arginine (%)	1.51	1.51	1.51	1.51	1.51
Phenylalanine (%)	0.98	0.98	0.98	0.98	0.98
Leucine (%)	1.72	1.72	1.72	1.72	1.72
Isoleucine (%)	0.90	0.90	0.90	0.90	0.90
Valine (%)	0.96	0.96	0.96	0.96	0.96

Total sulfur amino acid =TSSA, Try= Tryptophan; P=Phosphorus; ME=Metabolizable energy;**Biomix Premix Supplied per kg of diet: Vit. A, 10,000iu; Vit.D_3, 2000iu; Vit E, 23mg;Vit. K, 2mg: Vit.B1,1.8; Vit. B_2, 5.5mg; Niacin, 27.5mg; Pantothenic acid, 7.5mg; Vit. B_{12}, 0.015mg: Folic acid, 0.75mg; Biotin, 0.06mg; Choline Chloride, 300mg; Cobalt, 0.2mg; Copper, 3mg; Iodine, 1mg; Iron, 20mg; Manganese, 40mg; Selenium, 0.2mg; Zinc, 30mg; Antioxidant, 1.25mg.

Table 3: Proximate Composition of Broiler Chicks Diets Containing Dietary Levels of Tryptophan (0 – 4 weeks)

	Treatments				
Parameters (%)	0.15	0.19	0.23	0.27	0.31
Dry matter	93.01	89.01	93.44	91.01	89.91
Crude protein	22.92	23.01	22.86	21.96	21.41
Crude fibre	4.01	3.82	3.68	3.62	3.71
Ether extract	7.99	8.21	8.01	7.89	7.86
Ash	8.55	7.39	8.05	8.50	8.24
Nitrogen free extract	56.56	57.87	57.40	56.96	57.35

Table 4: Proximate Composition of Broiler Finisher Chickens Diets Fed Under the Cool Season (5 – 8 weeks)

	Treatments				
Parameters (%)	0.13	0.17	0.21	0.25	0.29
Dry matter	84.51	90.85	92.91	89.41	91.89
Crude protein	20.01	20.94	20.05	19.89	19.99
Crude fibre	3.05	3.89	3.20	3.48	3.38
Ether extract	6.98	7.24	6.99	7.34	7.80
Ash	7.81	7.69	8.33	7.14	7.63
Nitrogen free extract	62.15	60.28	61.43	62.15	61.30

Table 5. Performance of broiler starter chicks fed graded dietary levels of tryptophan (0- 4 Weeks).

	Treatments					
Parameters	Tryptophan Levels%					SEM
	0.15	0.19	0.23	0.27	0.31	
Initial weight (g)	52.06	52.07	52.09	52.05	52.06	0.02
Final weight(g)	1073.47^{c}	1177.97^{ab}	1215.78^{a}	1179.83^{ab}	1159.65^{b}	14.84
Weight gain (g)	1021.00^{c}	1125.97^{ab}	1163.69^{a}	1127.77^{ab}	1106.59^{b}	14.88
Average daily gain (g)	36.48^{c}	40.21^{ab}	41.56^{a}	40.28^{ab}	39.52^{b}	0.53
Feed Intake (g)	1783.39^{a}	1569.20^{b}	1682.46^{ab}	1587.72^{b}	1687.91^{ab}	57.82
Feed Intake (g/birds/day)	63.69^{a}	56.04^{b}	60.09^{ab}	56.70^{b}	60.28^{ab}	2.06
FCR	1.74^{b}	1.39^{a}	1.44^{a}	1.41^{a}	1.53^{a}	0.05
Mortality (%)	3.51	1.75	0.00	0.00	3.52	1.92

a, b, c= Means with different superscript on the same row differ significantly ($p<0.05$)
SEM = Standard error of means
Try = Tryptophan
FCR = Feed conversion ratio

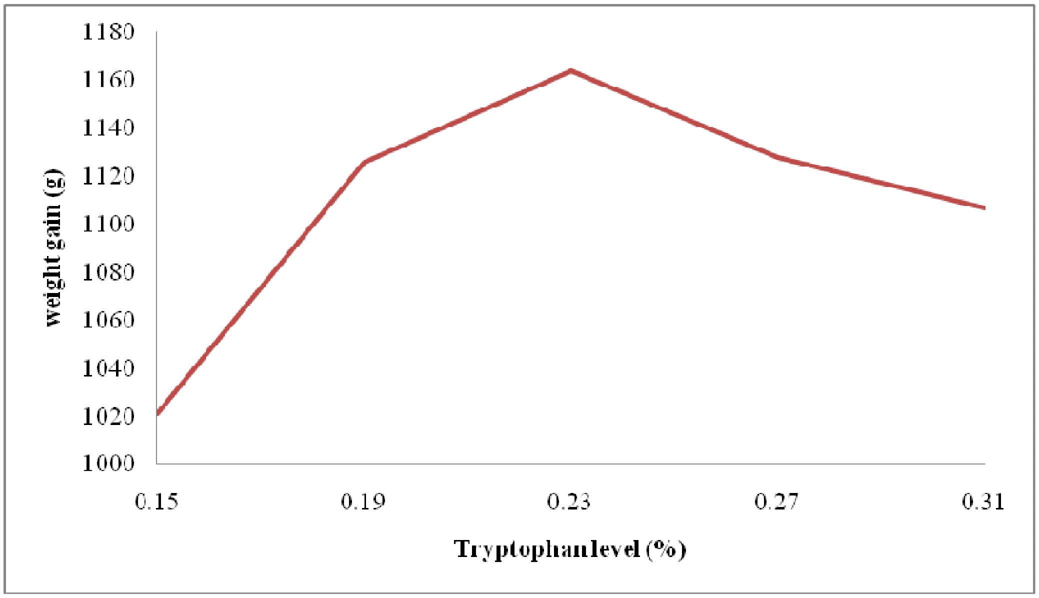

Figure 1: A graph showing highest dietary tryptophan level to maximize weight gain for broiler chicks reared in the cool season under tropical environment. (0 -4 weeks).

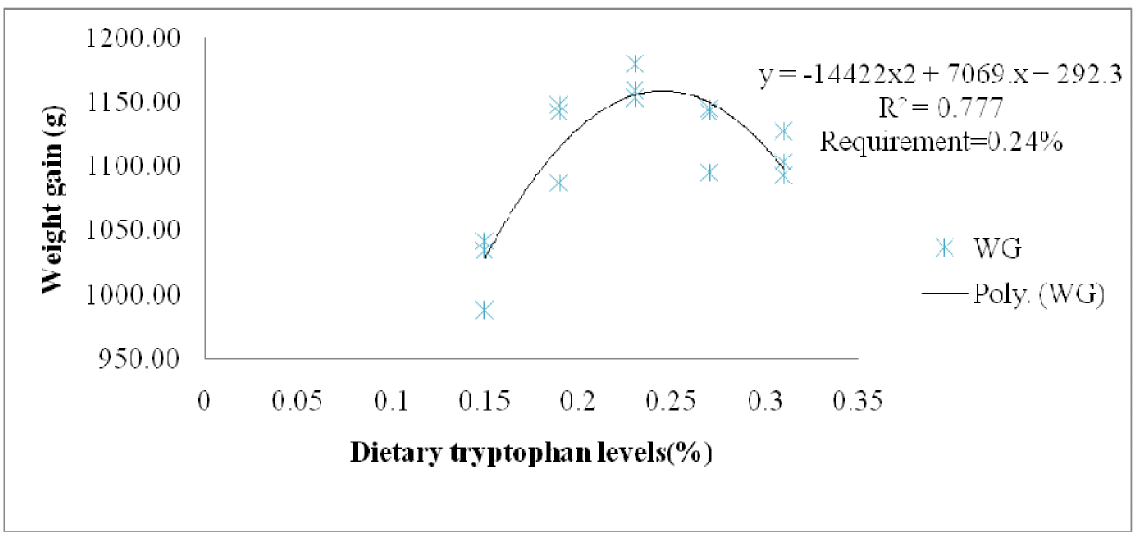

Figure 2: A polynomial regression showing the optimum dietary tryptophan level to maximize weight gain for broiler chicks reared in the cool season under tropical environment. (0 -4 weeks).

Table 6: Nutrient Digestibility of Broiler Starter Chicks fed Graded Dietary Levels of Tryptophan (0-4 weeks)

	Tryptophan Levels (%)					
Parameters (%)	0.15	0.19	0.23	0.27	0.31	SEM
Dry matter	81.88^{c}	85.50^{b}	87.55^{a}	85.56^{b}	84.28^{b}	0.90
Crude protein	74.20^{c}	84.93^{a}	82.49^{a}	84.08^{a}	80.59^{b}	2.51
Crude fibre	77.75^{ab}	77.57^{b}	73.37^{c}	72.71^{c}	80.68^{a}	6.92
Ether extract	81.39^{b}	84.33^{ab}	89.01^{a}	86.94^{ab}	87.15^{ab}	2.20
Ash	74.48^{c}	79.13^{b}	87.62^{a}	87.10^{a}	80.38^{b}	4.17
NFE	64.46^{b}	67.05^{ab}	70.28^{ab}	72.05^{a}	69.44^{ab}	1.80

a, b,c= Means with different superscript on the same row differ significantly (P<0.05)
SEM = Standard error of means
NFE = Nitrogen free extract

Table 7: Performance of Broiler Finisher Chickens fed Graded Dietary Level Tryptophan During the Cool Season (5 – 8 Weeks)

	Tryptophan Levels%					
Parameters	0.13	0.17	0.21	0.25	0.29	SEM
Initial weight (g)	1420.73	1420.70	1421.42	1420.76	1421.16	0.29
Final weight(g)	2993.97^{c}	3161.67^{b}	3378.95^{a}	3364.91^{a}	3243.51^{ab}	51.89
Weight Gain (g)	1575.00^{b}	1741.00^{ab}	1957.50^{a}	1944.20^{a}	1535.90^{b}	106.07
Ave daily gain (g)	74.92^{b}	82.90^{ab}	93.22^{a}	92.58^{a}	73.12^{b}	5.05
Feed Intake (g)	4559.45^{a}	4414.03^{ab}	4352.63^{b}	4523.69^{ab}	4378.95^{ab}	59.87
Feed Intake (g/b/d)	217.12^{a}	210.19^{ab}	207.27^{b}	215.42^{ab}	208.52^{ab}	2.85
FCR	2.90^{b}	2.54^{a}	2.23^{a}	2.32^{a}	2.99^{b}	0.23
Feedcost/kg Gain(₦)	61.59^{a}	59.12^{a}	58.69^{a}	55.59^{a}	82.45^{b}	6.24
Mortality (%)	1.75	0.00	1.75	0.00	0.00	1.11

a, b, c= Means with different superscript on the same row differ significantly (P<0.05)
SEM = Standard Error of Means
Try = Tryptophan
FCR = Feed conversion ratio

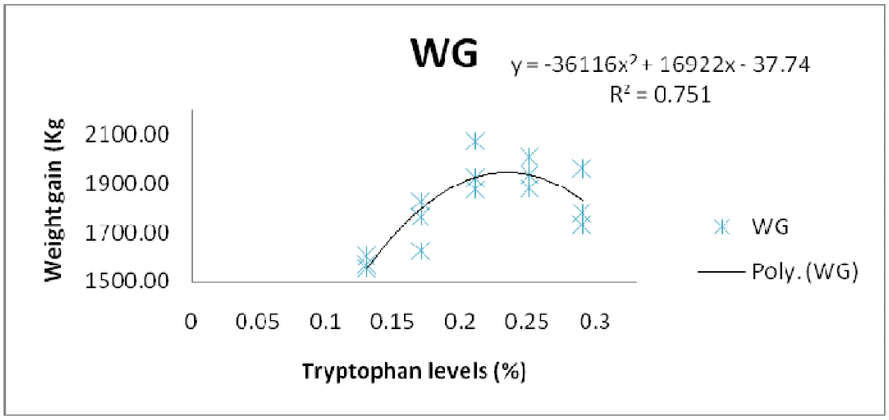

Figure 3: Optimum dietary tryptophan level to maximize weight gain for broiler finisher chickens during the cool season under tropical environment (5-8 weeks).

Table 8. Nutrient Digestibility of Broiler Finisher Chickens fed Graded Dietary Levels of Tryptophan During the Cool Season (5 – 8 Weeks)

	Tryptophan Levels (%)					
Parameters (%)	0.13	0.17	0.21	0.25	0.29	SEM
Dry matter	80.22	86.32	84.06	86.78	87.69	5.67
Crude protein	72.76	75.09	74.71	74.48	72.37	2.68
Crude fibre	67.43	75.09	74.71	74.48	72.37	5.67
Ether extract	69.77	77.03	79.78	82.35	84.73	4.51
Ash	74.60	84.83	86.04	75.91	84.62	3.67
NFE	64.77^{b}	71.90^{a}	67.98^{ab}	$65.9b^{a}$	68.62^{ab}	1.64

a, b= Means with different superscript on the same row differ significantly (P<0.05)
SEM = Standard Error of Means
NFE = Nitrogen free extract