academicJournals

Vol. 9(4), pp. 223-229, April, 2015
DOI: 10.5897/AJFS2014.1220
Article Number: DA2726C51603
ISSN 1996-0794

http://www.academicjournals.org/AJFS

African Journal of Food Science

Full Length Research Paper

Particulating broiler feeds into forms and sizes for nutritional and economic benefits (part 1)

Fasuyi A. O.* and Odunayo O. T.

Department of Animal Production and Health Sciences, Faculty of Agricultural Sciences, Ekiti State University, Ado-Ekiti, P.M.B. 5363, Ekiti State, Nigeria.

Received 20 October, 2014; Accepted 26 February, 2015

A study was conducted to examine the nutritional and economic effects of using mash, crumbs and pellet diets for broiler starter birds using Arbor Acre broilers chickens. The study examines the starter phase (0-28 days) of 288 Arbor Acre broiler chickens fed mash, 2 mm pellet size diet and feed crumbs. All diets had identical nutrients composition and the study was conducted under similar environmental conditions and management practices. Data on growth performance, nitrogen utilization, carcass and visceral organs characteristics, hematology and serum biochemistry were collected and evaluated. Economic analyses were also conducted. Early growth performances were more evidently manifested (P<0.05) in chicks fed 2 mm pellet diets where the weight gain was highest at 46.93±4.19 g/bird/day and the feed conversion ratio (FCR) was also lowest for the same set of birds at 1.85±0.14. Most other examined organs and carcasses indicated better and significant values for chicks on 2 mm pellet diet. These diets also enhanced most carcass and organs characteristics. Hematological and blood biochemistry indices were not adversely affected. There was an overall better net return per bird for birds on 2 mm diets in broiler starter.

Key words: Pellet feeds, Arbor Acre, performance, biometry.

INTRODUCTION

Successful broiler development is dependent on optimal feed intake throughout the growing period. Optimal feed intake is dependent on a number of factors such as environmental temperature and diet nutrient density. The physical feed quality is considered to have a very significant impact on broiler growth (Jafarnejad et al., 2010). Growth is emphatically dependent upon feed intake, which in turn is influenced by feed form. The most logical reasons for pelleting are that the heat generated in conditioning and pelleting makes the feedstuffs more digestible by breaking down the starches (Ghazi et al., 2012). By combining moisture, heat and pressure on feed ingredients, a degree of gelatinization is produced which allows animals and poultry to better utilize the nutrients in these ingredients. Reasons for the enhanced performance may be due to increased digestibility, decreased ingredient segregation, reduction of energy during prehension, and increased palatability (McKinney and

*Corresponding author. E-mail: fasuyi.ayodeji@eksu.edu.ng.

Teeter, 2004). Pelleting of feed also provides the benefits of increasing the bulk density of feed; improving feed flow ability; and providing opportunities to reduce feed formula costs through the use of alternative feed ingredients (Ghazi et al., 2012).

However, disadvantages associated with pelleting feeds include the increase in the cost of the feed due to the pelleting process; the excessive heat generated during the pelleting process may decrease the availability of the amino acids such as lysine and destroy some vitamins.

Although several studies have investigated and reported the effect of feeding different forms of feed (mash, pellet and crumble) on the productive performance of broiler, there has been a dearth of reports on the actual comparison of broiler performances on three diets of equal nutrient compositions but with varying physical types and forms. The present study has been carried out for comparison among broiler birds raised on the three feed types of equal nutrient compositions (mash, pellet and crumble feeds) using their growth rate, feed efficiency and other productive characters and to determine the most economic and suitable forms of feed in view of the productive performance of broilers.

MATERIALS AND METHODS

Experimental site and preparation

The study was carried out at the Poultry Research Unit of the Teaching and Research Farm of Ekiti State University Ado-Ekiti. The experimental site was properly cleaned and disinfected.

Experimental design

The experiment was carried out using the completely randomized design. The experiment had 3 dietary treatments with 4 replicates consisting of 20 birds each making a total of 288 birds in this study. There were three experimental diets in this experiment. Diet 1 (mash feed) was the control diet. Diet 2 consisted of 2 mm pellet feed while diet 3 consisted of crumbled feed.

Experimental animals and management

A total of 288 Arbor Acre day old chicks were sexed using the method described by Laseinde and Oluyemi (1997) for the first experiment. The chicks were randomly selected into each treatment such that equal numbers of male and female (equal sex ratio) of uniform batch weights make up each of the three treatments. The birds were raised on conventional deep litter system, where they were supplied with feed and clean water *ad-libitum*. The following veterinary routines were observed from day old:

i. Intraocular vaccination against Newcastle disease at day one.
ii. Neoceryl (Antibiotics) for a period of 4 days from 3 days of age.
iii. Coccidiostat for the treatment/control of coccidiosis and chronic respiratory diseases.
iv. Gumboro vaccine at two weeks of age.
v. Lasota vaccine (New castle booster) administered in a day at the age of about three weeks.

Experimental diets

Three forms of broiler starter diets were used at this phase of the experiment (mash, 2 mm pellet and crumbs). All experimental diets were isocaloric and isonitrogenous (Table 1) compounded with the same quantities of ingredients. Particle sized screen was achieved by using a hammer mill with small sizes of screen openings. The fine mash was prepared by mixing corn and soybean meal that was grounded through a screen, and then blended with all other ingredients to yield a final mash diet. Manufactured experimental feeds were made into pellets using diesel flat die feed pellet mill with customized sizes of 2.0/3.0/4.0/6.0/8.0 mm. Power rating is 8-55 HP and has a capacity of 70-1000 kg/h. Crumbling of pellet feed was achieved by a further coarse milling of the already pellet diet into crumbs.

Data collection

The weights of the experimental birds were taken every 3 days to record the weight gain. Feed consumption was recorded on daily basis and these data were used to generate other data such as feed conversion ratio and protein efficiency ratio. Nitrogen digestibility trial was carried out for each study to determine the nitrogen retention and utilization. Carcass and relative organs characteristics were recorded after slaughter at the termination of the experiment. Haematological parameters such as haemoglobin concentration, HBC; packed cell volume, PCV; red blood cell, RBC; erythrocyte sedimentation rates, ESR; mean corpuscular volume, MCV; mean corpuscular haemoglobin, MCH and mean corpuscular haemoglobin concentration, MCHC were determined for the two studies. Biochemical components such as total serum protein, albumin, globulin and albumin/globulin ratio were also determined for the two studies. Cost benefit analysis was done using simple economic indices such as feed cost, cost of feed/intake of bird, total revenue and total net returns.

Carcass, muscle and organ measurements

The measurement of the carcass traits (dressed weight %, eviscerated weight %, thigh, drumstick, shank, chest, back, neck, wing, belly fat and head) were taken before dissecting out the organs. The organs measured were the liver, kidneys, lungs, pancreas, heart, spleen, bursa of fabricus and gizzard. The following muscles: inner chest muscle (*Supracoracoideus*) outer chest muscle (*Pectoralis major*) and thigh (*Iliotibialis*) were carefully dissected out from their points of origin and insertion. All the carcass traits, except the dressed and eviscerated weights, were expressed as percentages of the live weight while the organs and muscles were expressed in g kg^{-1} body weight, while the length and breadth of the muscles were expressed in cm kg^{-1} body weight.

Estimation of nitrogen retention, nitrogen digestibility and protein efficiency ratio

Total faeces voided during the last 5 days were collected, weighed, dried at 65-70°C in an air circulating oven for 72 h and preserved while the corresponding feed consumed was also recorded for nitrogen studies. The nitrogen contents of the samples were determined by the method of AOAC (2010) and nitrogen retained was calculated as the algebraic difference between feed nitrogen and fecal nitrogen (on dry matter basis) for the period.

Blood sampling

Blood from two slaughtered birds from each treatment were allowed

Table 1. Composition of the experimental diets (0-28 days).

Ingredient	Dietary treatments		
	1 (Mash)	2 (Pellet)	3 (Crumble)
Maize (9% CP)	50.2	50.2	50.2
Soya bean meal (45% CP)	33.5	33.5	33.5
Palm kernel cake (18.8% CP)	10.0	10.0	10.0
Fish meal (68% CP)	2.0	2.0	2.0
Bone meal	2.50	2.50	2.50
Oyster shell	0.50	0.50	0.50
Salt	0.50	0.50	0.50
DL-methionine	0.15	0.15	0.15
L-lysine	0.15	0.15	0.15
Premix	0.50	0.50	0.50
Total calculated:	100	100	100
Crude protein,%	22.9	22.9	22.9
Me (kcal/kg)	2980.5	2980.5	2980.5
Crude fibre,%	3.3	3.3	3.3
Ether extract,% Analysed:	8.1	8.1	8.1
Ash,%	8.79	10.33	8.30
Moisture content,%	14.77	16.15	16.24
Crude protein,%	21.64	21.87	20.78
Ether extract,%	3.68	3.71	3.64
Crude fibre,%	3.61	3.59	3.66

% CP, percentage crude protein; broilers vitamin premix supplied the following vitamins and trace elements per kg of diet: vit A 7812.50IU; vit D 1562.50 IU; vit E 25 mg; vit K 1.25 mg; vit B1 1.88 mg; vit B2 3.44 mg; niacin 34.38 mg; calcium pantothenate 7.19 mg; vit B 36 .13 mg; vit B 102 0.016 mg; choline chloride 312.50 mg: folic acid 0.62 mg; biotin 0.05; Mn 75 mg; Fe 62.5 mg: Zn 50 mg; Cu 5.31 mg; iodine 0.94 mg; Co 0.19 mg; Se 0.07 mg and antioxidant 75 mg.

to flow freely into labeled bottles one of which contained a speck of EDTA while the other without EDTA was processed for serum. The serum was kept deep frozen prior to analysis. The packed cell volume (PCV%) was estimated in heparinized capillary tubes in an haematocrit micro centrifuge for 5 min while the total red blood cell (RBC) count was determined using normal saline as the diluting fluid. The haemoglobin concentration (Hbc) was estimated using cyanomethaemoglobin method while the mean corpuscular haemoglobin concentration (MCHC), mean corpuscular haemoglobin (MCH) and the mean corpuscular volume (MCV) were calculated.

Economic analysis

The cost of birds, feed and medication incurred during the two phases of the experiment were collected from the income and expenditure statements. Revenue generated from the sale of the birds was recorded. The cost per kilogram gain, total profit and returns to naira invested were also calculated.

Statistical analysis

All recorded and calculated data were statistically analyzed with the standard procedures of analysis of variance (One Way ANOVA) technique by a computer using Minitab statistical computer software package (2005 version). Results were expressed as mean ± standard deviation of two measurements.

RESULTS

Average growth performance

Performance characteristics of broiler chicks fed mash, 2 mm pellet diet and crumble diet are presented in Table 2. The feed intake (FI) value obtained for birds on mash diet (diet 1) had the highest value of 81.4 ± 0.29 g/bird/day and was significantly different ($P<0.05$) from the lowest value obtained for birds fed 2 mm pellet diet (diet 2) at 79.4± 0.92 g/bird/day. The highest weight gain value was recorded for birds placed on pellets (diet 2) at 46.9±4.17 g/bird/day although similar ($P>0.05$) to those on crumbles (diet 3).

The least and optimum feed conversion ratio was obtained for birds placed on pellets (diet 2) at 1.85±0.14 g/day and this valu-e was significantly different ($P<0.05$) from those placed on mash and crumbles. The highest and significantly different ($P<0.05$) protein efficiency ratio value of 2.69±0.2 was obtained for birds placed on pellets (diet 2).

Table 2. Average growth performance of broilers fed various feed forms (0-28 days).

Parameter	Dietary treatment		
	1 (Control/mash)	2 (Pellet)	3 (Crumble)
Average daily feed intake (g/bird/day)	81.4±0.29[a]	79.4±0.92[b]	80.8±0.76[ab]
Average daily weight gain (g/bird/day)	37.5±3.44[a]	46.9±4.19[b]	40.8±0.99[ab]
Feed conversion ratio (FCR)	2.35±0.08[a]	1.85±0.14[b]	2.15±0.08[a]
Protein efficiency ratio (PER)	2.10±0.2[a]	2.69±0.2[b]	2.44±0.08[c]

Means within a row with different superscript are significantly different (P<0.05).

Table 3. Nitrogen utilization of broilers fed various feed forms (0-28 days).

Parameter	Dietary treatment		
	1 (Control/mash)	2 (Pellet)	3 (Crumble)
Nitrogen intake (g)	3.43±0.04[a]	3.46±0.3[b]	3.28±0.34[a]
Faecal nitrogen (g)	0.92±0.01[a]	1.39±0.1[a]	1.14±0.2[a]
Nitrogen retention (g)	0.62±0.34[a]	1.31±0.49[a]	0.61±0.20[a]
Apparent nitrogen digestibility (%)	17.82±9.84[a]	37.44±14.19[a]	18.27±6.03[a]

Means within a row with different superscript are significantly different (P<0.05).

Table 4. Carcass characteristics of broilers fed various feed forms (0-28 days).

Parameter	Dietary treatment		
	1 (Control/mash)	2 (Pellet)	3 (Crumble)
Live weight, g	1059.0±50.0[a]	1453.0±30.5[b]	1401.0±42.1[b]
Carcass weight, g	960.0±45.2[a]	1282.0±50.0[b]	1275.0±35.2[b]
Dressing Percentage, %	90.7±0.5[a]	88.2±0.15[b]	91.0±0.10[a]
Head, g	39.0±9.5[a]	39.0±0.5[a]	37.0±0.6[b]
Wings, g	78.0±0.5[a]	124.0±0.5[b]	104.0±0.5[c]
Neck, g	51.0±0.5[a]	71.0±0.5[b]	69.0±0.5[c]
Thigh, g	102.0±0.5[a]	145.0±0.5[b]	132.0±0.5[c]
Drumstick, g	89.0±0.5[a]	135.0±0.5[b]	127.0±0.5[c]
Breast Muscle, g	238.0±0.5[a]	354±0.5[b]	286±0.5[c]
Back, g	88.00±0.5[a]	135.0±0.5[b]	110.0±0.5[c]
Shank, g	49.0± 0.15[a]	59.0±0.5[a]	66.0±0.2[b]

Means within a row with different superscript are significantly different (P<0.05).

Nitrogen utilization

Nitrogen utilization for birds at the starter phase is shown in Table 3. All the values obtained for nitrogen utilization (nitrogen intake, faecal nitrogen, nitrogen retention and apparent nitrogen digestibility) were similar (P>0.05) in all experimental diets. However, birds on the pellets (diet 2) had the highest numerical value for nitrogen retention of 1.31 ± 0.49.

Carcass characteristics

Carcass characteristics of broiler chicks fed mash, 2 mm pellet and crumble diets are presented in Table 4. Live weight value was highest for birds placed on diet 2 (pellet) at 1453.0±30.5 g which was similar to those placed on crumbles (diet 3) at 1401.0±42.1 g. These values were significantly higher (P<0.05) than those placed on the diet 1 (mash) with the lowest value of

Table 5. Relative organs weights broiler chicks fed various feed forms (0-28 days).

Parameter	Dietary treatment		
	1 (Control/mash)	2 (Pellet)	3 (Crumble)
Liver	29 ±0.5^{a}	21 ± 0.5^{b}	34 ± 0.5^{c}
Kidney	6.0 ± 0.5^{ab}	5.0 ± 0.5^{a}	7.0 ± 0.5^{b}
Heart	4.0 ± 0.5^{ab}	7.0 ± 0.5^{b}	6.0 ± 0.5^{b}
Spleen	1.0 ± 0.5	1.0 ± 0.5	2.0 ± 0.5
Gizzard	25 ± 0.5	26.0 ± 0.5	26.0 ± 0.5
Lungs	7.0 ±0.5^{a}	7.0 ± 0.5^{a}	9.0 ± 0.5^{b}
Intestine	84 ± 0.5^{a}	79 ± 0.5^{b}	133 ± 0.5^{c}
Bursa of fabricius	7.0±0.5^{a}	10.0± 0.5^{b}	8.0± 0.5^{c}

Means within a row with different superscript are significantly different (P<0.05).

1059±50.0 g.

Highest carcass weight was also obtained for birds on the pellet diet (diet 2) at 1282±50.0 g which was similar (P>0.05) to those on crumble diet (diet 3) at 1275±35.1 g and significantly different (P<0.05) from the lowest value obtained for birds on mash diets (diet 1) at 960±45.2 g.

There were similarities (P>0.05) in dressing percentage values obtained for birds placed on mash diet (diet 1) and crumble diets (diet 3) at 90.7±0.5 and 91.0±0.15 g, respectively and were significantly different (P<0.05) from those placed on pellet diets (diet 2) with the lowest value of 88.23±0.10 g. Carcass characteristics value of birds significantly varied (P<0.05) across the experimental diets. However, the highest values were obtained mostly for birds on pellet diets (diet 2).

Visceral organs characteristics

Relative organs of broiler chicks fed mash, 2 mm pellet and crumble diets are presented in Table 5. Except for spleen and gizzard, all other visceral organs were significantly lower (P<0.05) in measured weights for birds on mash (diet 1).

Other carcass characteristics such as head, wings, neck, thigh, drumstick, breast muscle, back and shank had significantly higher or similar values for broiler starter birds on 2 mm pellet diets and broiler finisher birds at 4 mm pellet diets. There is no doubt that these particulate feed form and sizes augur well for the two phases of broiler production in terms of growth and muscle development.

Most visceral organs such as liver, heart, kidney, lungs, proventriculus, crop, intestine and pancreas showed similarity of growth at broiler starter and finisher phases, indicating similar organ development.

Haematological and serum biochemical parameters

Table 6 shows the haematological and serum biochemistry of broiler birds at starter phase placed on the different feed forms. There were no significant differences (P<0.05) among the haematological para-meters examined for birds at this phase.

Economic analysis (cost benefit analysis)

The cost implication indices for the broiler starting phase are shown in Table 7. The costs of diets were calculated using the prevailing current prices of the feed ingredients. The cost of the diets were calculated with the basic assumption that labour and other overhead costs were similar for all diets prepared and did not need to be considered in the calculation.

The cost of finished feed (diets) expectedly revealed that the pelleted feed (diet 2) was the most expensive at N68.5 per kg of feed while the mash had the lowest cost of N58.0. Even though the highest cost of production of N470.42 was recorded for birds on the pellet diets, the total net return per bird was also highest at N470.1 for birds on the pellet diet.

It is evidently clear that 2 mm pellet diets at broiler starter phase of broiler production generated more total net returns per bird and would be more profitable for the purpose of commercial broiler production.

DISCUSSION

Average growth performance

Generally, growth performance results for this experiment showed that optimal performances were achieved in the pellet diets. It is commonly accepted that pelleting poultry rations increases weight gain and improves feed efficiency. These improvements have been attributed to the higher density, improved starch digestibility resulting from chemical changes during pelleting, increased

Table 6. Haematological and biochemical profile of broilers fed various feed forms (0-28 days).

Parameter	Dietary treatment		
	1 (Control/mash)	2 (Pellet)	3 (Crumble)
Hbc (g/dl)	5.45±0.34	6.01±0.42	6.01±0.45
PCV (%)	23 .00±0.45	24.00±0.65	24.00±0.52
RBC x 10^6 (mm^3)	1.42±0.42	1.54±0.43	1.63±0.54
ESRs ($mm^{3/}$l)	4.00±0.43	3.14±0.50	4.01±0.43
MCV x 10^{-6} (µl)	0.10±0.71	0.12±0.43	0.11±0.32
MCH x 10^{-6} (µg)	4.45±0.22	4.34±0.45	4.29±0.54
MCHC (g/dl)	41.50±0.40	40.16±0.41	36.94±0.63
Serum biochemical parameters (g/100 ml)			
Total serum protein	16.42±0.43	17.01±0.78	17.51±0.43
Albumin	15.67±0.45	15.06±0.56	15.56±0.56
Globulin	8.72±0.42	8.41±0.41	8.56±0.32
Albumin/globulin ratio	1.80±0.30	1.79±0.31	1.81±0.51

Means within a row with different superscript are significantly different (P<0.05).

Table 7. Economic analysis of the broilers fed various feed forms (0-28 day of age).

Parameter	Dietary treatment		
	1 (Control/mash)	2 (Pellet)	3 (Crumble)
Total feed intake (kg/bird)	1.53	1.61	1.57
Feed cost per Kg of diet (N/kg)	58	68.5	63.25
Cost of feed intake / bird (N/bird)	177.5	220.42	198.96
Cost of Day old chicks (N/bird)	250	250	250
Total Cost of production/bird (N/bird)	427.5	470.42	448.96
Av. body wt. at 28^{th} day old (kg/bird)	1.19	1.27	1.21
Cost of 1kg of poultry meat (N/kg)	750	750	750
Total Revenue/bird (N/bird)	892.5	952.5	906.5
Total net returns/bird (N/bird)	465	470.08	457.54

nutrient intake, changes in physical form, reduced feed wastage and decreased energy spent for eating (Jensen, 2000; Ghazi et al., 2012). The present study is consistent with previous findings that pelleting complete diets improved weight gain, feed conversion (Douglas et al., 1990) and feed intake (Nir et al., 1995) in broilers. Protein efficiency ratio (PER) is an important protein quality index (Fasuyi, 2006). The high PER value of birds on pellets indicated that protein was most efficiently utilized in birds on the pelleted diets in spite of the fact that all diets were formulated isonitrogenous with the same quantity and quality of ingredients.

Nitrogen utilization

The fact that nitrogen retention values were similar for experimental birds on all feed types and sizes indicated that feed forms and sizes in broiler starter may have little or no remarkable effect as long as adequate intake of the feed and nitrogen is ensured.

Carcass characteristics

Most carcass characteristics examined had significantly higher values for birds on the pellet diets indicating that there was ample benefit in the consumption of pellet diets over the other diets which translated into better carcass formation and muscle development. This is supported by previous studies (Oluyemi and Roberts, 1979; Rodehutscord et al., 2004).

Visceral organs characteristics

The uniformity in the growth rate and muscle development

compared favourably with previous standard growth pattern and muscle development of birds of the same age and strain (Oluyemi and Roberts, 1979; Rodehutscord et al., 2004).

Haematological and serum biochemical parameters

The similarity in all blood parameters examined for broiler starter birds indicated that feed forms had no marked effect on the birds at that stage of production and may not be predisposed to any health hazards as a result of the feed forms. The erythrocyte sedimentation rates (ESRs) of broiler starter birds were similar and compared with ESRs obtained for healthy birds in literature (Oluyemi and Roberts, 1979; Rodehutscord et al., 2004).

The variations in total serum protein (TSP), albumin, globulin and albumin/globulin ratio could be have been influenced by the dietary treatments. Total serum protein (TSP) is indirect indices for measuring the nutritional protein adequacy.

Economic analysis (cost benefit analysis)

It is obvious that birds on the pellet diets had the highest and most profitable commercial value as the total net return per bird was most favourable for commercial broiler starter production. About 7% increase in revenue generated from the production of broilers on pellet feeds compared to mash have been previously reported (Banerjee, 1987).

Conclusion

The present study reveals that pelleting broiler poultry at the starter phase of broiler production had nutritional advantage as it attracted better feed intake, increased growth rate and better feed efficiency. Pellet feeds also enhanced carcass and other organs characteristics of broiler starter. Hematological and blood biochemistry indices were not adversely affected. Expectedly, the cost of pelleting broiler feeds initially attracted extra cost of broiler production but eventually culminated into a better total net return per bird which translated into higher profitability for birds reared on pellet diets at broiler starter phase of production.

Conflict of interests

The authors did not declare any conflict of interest.

REFERENCES

AOAC (2010). Association of official analytical chemists. Official methods of analysis 6th ed. Washington D.C.

Banerjee GC (1987). Animal husbandry, 8th Edition, Oxford and IBN Publishers, Oxford.

Fasuyi AO (2006). Nutritional potentials of some tropical vegetable leaf meals: Chemical characterisation and functional properties. Afr. J. Biotechnol. 5(1):049-053.

Ghazi AMZ, Gameel A, Al-Maktari, Mohamed MA (2012). A comparative effect of mash and pellet feed on broiler performance and ascites at high altitude (field study). Glob. Vet. 9(2):154-159.

Jafarnejad S, Farkhoy M, Sadegh M, Bahonar AR (2010). Effect of crumble-pellet and mash diets with different levels of dietary protein and energy on the performance of broilers at the end of the third week. Vet. Med. Int. 2010:328123

Jensen LS (2000). Influence of pelleting on the nutritional needs of poultry. Asian-Australas. J. Anim. Sci. 13:35-46.

Laseinde EAO, Oluyemi JA (1997). Sexual dimorphism in the growth pattern of broiler under different dietary and housing conditions. Nig. J. Anim. Prod. 24:1-6.

McKinney LJ, Teeter RG (2004). Predicting effective caloric value of Nonnutritive factors: I. Pellet quality and II. Prediction of consequential formulation dead zones. Poult. Sci. 83:1165-1174

Minitab Computer Software Package (2005). One-way analysis of variance (ANOVA). 2005 Version Developed by Minitab Inc. (www.minitab.com)

Nir I, Hillel R, Ptichi I, Shefet G (1995). Effect of particle size on performance of grinding and pelleting interactions. Poult. Sci. 74:771-783.

Oluyemi JA, Roberts FA (1979). Poultry production in warm wet climates. Macmillan Tropical Agriculture, Horticulture and Applied Ecology Series.

Rodehutscord M, Kapcius M, Timmler R, Dieckmann A (2004). Linear regression approach to study amino acid digestibility in broiler chickens. Braz. Poult. Sci. 45:85-92.