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Pelletized Feed of Different Particle Sizes: Effects on Performance, Carcass Characteristics and Intestinal Morphology of Two Strains of Broiler Chicken

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ABSTRACT

This study was conducted to determine the effects of feeding pelletized feeds of different particle sizes on the performance, carcass characteristics and intestinal morphology of two strains of broiler chickens. A total of one hundred and eighty (180) birds consisting of 90 birds each of Marshal MY and Hubbard strains of broiler chicken were used in the experiment. They were brooded for 14 days and thereafter divided into two treatment groups, namely, fed with feed of different particle sizes of 1 and 2mm. These were further divided into 3 replicates of 15 chicks and the experimental period was 42 days. The performance of the chicks was monitored weekly. At week eight, 3 birds per replicate were randomly selected, weighed, slaughtered via neck slit, defeathered, singed and eviscerated for carcass evaluation. The intestinal morphometry and histomorphometry of the birds were analysed. Data collected were arranged in a 2 x 2 factorial layout and subjected to 2-way Analysis of Variance. Significant ($P<0.05$) differences were observed in the final weight, weight gain and protein efficiency ratio with Hubbard strain having better values than Marshal. Mortality ($P<0.05$) was lower in the birds fed with feed particle size of 2 mm. In addition, significantly ($P<0.05$) higher values were obtained in the head, drum stick, shank and keel of birds fed with feed with particle size of 2mm. Meanwhile, the highest ($P<0.05$) villus height was recorded

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for Hubbard fed 2mm feed particle size while Marshal had the least value. Hence, pelletized feed of 2mm particle size was recommended for broiler production.

Keywords: Particle size, pelletized feed, performance, carcass characteristic, intestinal morphology, Hubbard strain, Marshal strain

INTRODUCTION

In poultry production, whole grain feeding is associated with increased gut development leading to a more muscular gizzard and less recurrence of proventricular dilation (Jones & Taylor, 2001). However, reducing grain particle size has been shown to increase hammer mill energy and production rate. A review of the past literature (Reece *et al.,* 1986a; Lott *et al.,* 1992) revealed inconsistencies in the recommended grain particle size for optimal poultry performance. However, the authors reported improved broiler performance when corn particle size decreased from 1289 to 987µm and from 1173 to 710µm, respectively. Further decrease from 900 to 300µm has also been reported by Healy (1992) to improve performance in the feed efficiency.

Particle size encompasses both the size of the various feed ingredients used in poultry diets as well as the consistency of the particle size. It is noteworthy that ingredient texture impacts on two areas of the poultry industry. Firstly, it impacts directly on the bird itself and the manner in which it utilizes the nutrients in its diet. The issue is further complicated by the fact that the manner in which materials are digested differs between ingredients. Secondly, it impacts on the manner in which ingredients are handled and processed in the feed mill.

Particle size is established by the geometric mean diameter (GMD). However, the complete information on particle size must include a measure of dispersion. This measure is the geometric standard deviation (GSD), which establishes the range of variation among the different particle sizes (Nir *et al*., 1994). Both these measures are described by ASEA (1983), but sadly they are seldom reported in literature as they independently affect broiler growth and performance. The average particle size of the sample is then determined by standard formula and given as geometric mean diameter (GMD), expressed as microns (µ). Particle size uniformity is described by geometric standard deviation (GSD), a small GSD representing higher uniformity.

Relatively, a study (Morel & Cottam, 2007) was conducted on the effects of feed form (pellet or mash) on the intestinal morphology in broilers' overall performance. The improved villus height and villus crypt depth for various segments of birds fed pelletized diets were in agreement with enhanced growth performance and increased metabolizability of nutrients. Extension of the villus enlarges total luminal villus absorptive area and subsequently results in adequate digestive enzyme action and higher transport of nutrients at the villus surface. In addition, the higher villus crypt depth in the broilers fed pellet diets is an indication for a decreased turnover rate of the intestinal mucosa. Meanwhile, a slower turnover rate

of the intestinal epithelium results in a lower maintenance requirement which leads to a higher growth rate of the animal. Thus, changes in intestinal morphology influence nutrient metabolizability and performance. Feed millers in Nigeria produce mash feeds which have ≤ 0.5 mm feed particle size (Personal Communication). However, Nir (1994) reported that feeding large particle corn may produce beneficial effects similar to whole grain feeding though the digestion and utilization of the feed particle sizes by birds would vary due to the texture of the feed and this will affect the birds' performance. The author further stated that feed particle size and the form in which it is presented are of great importance in assessing the overall productivity of broiler. For broiler to be highly productive, a good level of feeding is needed. The efficiency of feed utilization is a function of the feed particle size and the form of presentation which is directly related to the performance of broiler. The paucity of information on the effects of feed particle size of pelletized feeds on the performance of broiler chickens necessitates this research.

MATERIALS AND METHODS

Experimental Site

The experiment was carried out at the poultry unit of the Teaching and Research Farm, University of Agriculture, Abeokuta (UNAAB), Ogun State, Nigeria. The area is situated in the south-western part of Nigeria which is a derived savannah zone with an annual mean temperature of 34.70^{0}C and a relative humidity of 82%. It is in the region 70 m above the sea level of latitude 7^{0}5' to 7^{0}8'N and longitude 3^{0}11.2'E (University of Agriculture, Abeokuta, Meteorological Station).

Experimental Birds and Management

A total of 180 (90 each of Marshal MY and Hubbard strains) chicks were used in the experiment. The 180 chicks were brooded for two weeks (14 days). Thereafter, they were divided into two treatment groups of 1 and 2mm pelletized feed particle sizes consisting of 45 chicks each which were further divided into 3 replicates of 15 chicks each and maintained for 42 days. The chicks were fed the dietary mix shown in Table 1, with pelletized feed particle sizes of 1 and 2mm *ad libitum*. Fresh water was also given to the chicks *ad libitum*.

Experimental Diet Mix

The macro feed ingredients (maize, soybean, wheat offal and ground nut cake) were milled and mixed together. The macro feed ingredients were sieved using 1 mm mesh and the particles that passed through the mesh were considered as the feed particle size ≤ 1 mm, whereas the feed that remained on the mesh were then sieved through 2mm mesh to get ≤ 2 mm particle size feed. The micro feed ingredients (ground bone meal, fish meal, ground oyster shell, vitamin and mineral premix, salt, lysine and methionine) were then equally divided into the two treatment groups and then mixed thoroughly with the already sieved macro feed ingredients of 1 and 2 mm feed particle sizes, respectively. The feeds

were then pelletized. Pelletizing was done using water as a binding agent in a pellet mill, where the feeds were conditioned and thermally treated in the fitted conditioners of a pellet mill.

Performance Characteristics

Data were taken weekly on the performance of the chicks: feed intake and weight gain. The data on feed which included gain, protein intake, protein efficiency ratio and mortality were also calculated. The protein intake was calculated by multiplying the percentage protein content of the feed by the actual intake while the protein efficiency ratio was the ratio of the weight gain to the protein intake.

Carcass Characteristics Determination

At the 8th week, 3 birds whose weights were close to the average replicate weight were selected per replicate, weighed, slaughtered, defeathered, singed and eviscerated. The dressed weights were determined. Cut-up parts such as head, neck, shank, thigh, drumstick, back and breast were weighed. The organs such as liver, gizzard and heart were also removed and weighed. These parts

TABLE 1
Composition of the experimental diet (g/kg)

Ingredient	Composition	
Maize	450.0	
Soybean meal	150.0	
Wheat offal	215.0	
Groundnut cake	125.0	
Fish meal	10.0	
Bone meal	25.0	
Oyster shell	15.0	
*Vitamin and mineral premix	2.5	
Salt	2.5	
Lysine	2.5	
Methionine	2.5	
Total	**1000.0**	
Determined Analysis (g/kg)	1mm pellet size	2mm pellet size
Dry matter	918.7	925.6
Crude protein	242.6	238.7
Crude fibre	35.9	37.4
Ether extract	34.8	35.1
Ash	450.6	461.7
Nitrogen-free extract	236.1	227.0
Gross energy (KJ/kg)	11.92	11.92

*Premix contained the following: (Univit. 15 Roche) 1500I.U., Vit. A; 1500I.U., Vit. D; 3000I.U., Vit. E; 3.0g, Vit. K; 2.5g, Vit. B_2; 0.3g, Vit. B_6; 8.0mg, Vit. B_{12}; 8.0g, Nicotinic acid; 3.0g, Ca-Pantothenate; 5.0mg, Fe; 10.0g, Al; 0.2g, Cu; 3.5mg, Zn; 0.15mg, I; 0.02g, Co; 0.01g Se.

were expressed as the percentage of the live weight. In addition, the weight of the empty gizzards, and length small intestines were also taken using a top-loading scale and a measuring tape, respectively.

Small Intestine Sampling and Specimen Preparation for Light Microscope

At the end of the experiment, 2 chicken from each replicate were randomly selected and killed by decapitation under light diethyl ether anaesthesia. Thereafter, the entire intestines were removed and placed immediately into a mixture of 3% glutaraldehyde and 4% paraformaldehyde fixative solution in 0.1M cacodylate buffer (pH7.4). The midpoint of the bile duct and Meckel's diverticulum (jejunum) and the midpoint between Meckel's diverticulum and the ileo-caecal junction (ileum) were cut and prepared for light and scanning electron microscopy, as enunciated by Shamoto and Yamauchi (2000). The segments (2 to 3 cm in length) were washed with 0.1M phosphate buffered saline (pH7.4), fixed in Bouin's solution for 6 hours and dehydrated in a graded ethanol series. Each segment was embedded in paraffin wax using a standard technique. The values of the villus area were calculated from the villus height, basal width and apical width according to the method described by Iji *et al.* (2001). The average villus area from the two birds was expressed as a mean villus area for one treatment group.

Intestinal Histomorphometry

The slides were examined under the microscope and using a calibrated eye piece graticule (Graticule Ltd. Tonbridge Kent, England). The following measurements were taken: Villus Height (VH), lamina propria depth (LPD), Apical Width (AW) and Basal Width of the villi (BW). Only those villi attached to the lamina propria and with defined tips were measured. The lamina propria measurement extended from the base of the villus to the muscular mucosa. A total of six measurements were taken for each of the parameters via each sample of the intestinal segment. The mean of the measurements for each parameter was later statistically evaluated.

Proximate Analysis

The proximate analysis of the two diets of 1 and 2mm particle sizes were determined according to the methods of AOAC (1995). The moisture content was determined by oven-drying 2 grams of each diet for 26 hours at 60^0C to constant weight. The gross energy of the feeds was determined using Adiabatic Bomb® calorimetric method.

Statistical Design and Analysis

The data collected were subjected to 2-way analysis of variance using SAS (1999) in a 2 x 2 factorial arrangement. Significant ($p < 0.05$) means among the variables were separated using Duncan's Multiple Range Test as contained in the SAS (1999) package. The model used was:

$$Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + \varepsilon_{ijk}$$

Where,
Y_{ijk} = individual observation
μ = overall mean
A_i = effect of Factor A
(Particle size: i = 1mm, 2mm)
B_j = effect of Factor B
(strain: j = Marshal, Hubbard)
$(AB)_{ij}$ = effect of interaction AB
(Particle size*strain)
ε_{ijk} = Experimental error

RESULTS

In the main effects of strain and feed particle sizes on the performance and carcass characteristics of broiler chickens (Table 2), significant ($P<0.05$) differences were observed in the final weight, weight gain and protein efficiency ratio. The Hubbard strain had a higher final weight, weight gain and a better protein efficiency ratio (1.56) than that of Marshal. In the feed particle size, significant ($P< 0.05$) difference was observed only in the mortality with the feed particle size of 2mm having a lower mortality of 1.67% as compared to 4.00% which was recorded for the birds on 1mm feed particle size. Significant ($P<0.05$) differences were also observed in the head, neck, wing, shank and large intestine. The Hubbard strain had higher head (2.84 %), neck (5.84 %) wing (9.99 %) and shank (5.27 %) than the Marshal strain of broiler chicken. Similarly, the Marshal strain recorded a better large intestine (14.90 cm) than the Hubbard strain. In the feed particle size, significant ($P<0.05$) differences were observed in the head, drum stick, and large intestine with feed particle size of 2 mm recording a higher value of 2.70 %, 11.29 %, and 14.47 cm for the head, drumstick, and large intestine, respectively.

The effects of the interaction between strain and particle size on the performance and carcass characteristics of the broiler chicken are shown in Table 3. Significant ($P<0.05$) differences were recorded in the protein efficiency ratio and mortality. The Hubbard strain on the 2mm feed particle size had the best protein efficiency ratio of 1.56 while the least value (1.38) was recorded in the Marshal strain on the feed particle size of 1mm. The highest percentage mortality of 4.67 was recorded in the Marshal strain on the 1mm feed particle size, while the Hubbard strain on the 2mm feed particle size had the least value of 1.33. Significant ($P<0.05$) results were found in the dressed percentage, head, neck, thigh, drumstick, shank, keel, large intestine and caeca. The Hubbard strain on 2mm feed particle size recorded the highest value of dressing percentage (89.77%), head (3.03%), neck (5.73%), thigh (11.20%), drumstick (12.18%), shank (5.87%), keel (20.61%), large intestine (13.47cm) and ceaca (16.33cm).

The main effects of the strain and feed particle size on the morphology of ileum and jejunum in broiler chicken are shown in Table 4. Significant ($P<0.05$) difference was observed in the lamina propria depth with Marshal strain recording a higher value of 249.17µm compared to the Hubbard strain. However, feed particle size had no significant ($P>0.05$) effect on the parameters considered, except for the

TABLE 2
The main effect of strain (±SE) and feed particle size (±SE) on the performance and carcass characteristics of broiler chicken

Parameters	Strain		Feed particle size	
	Marshal	Hubbard	1mm	2mm
Performance Characteristics				
Initial weight (kg)	0.23 ± 0.008	0.22 ± 0.003	0.22 ± 0.005	0.23 ± 0.006
Final weight (kg)	1.55 ± 0.03[b]	1.69 ± 0.05[a]	1.60 ± 0.05	1.64 ± 0.05
Weight gain (g/b/d)	31.47 ± 0.72[b]	34.80 ± 1.17[a]	32.82 ± 1.14	33.45 ± 1.28
Feed intake (g)	93.20 ± 1.99	97.69 ± 1.29	95.19 ± 2.09	95.90 ± 1.80
Feed: gain	2.97 ± 0.02	2.82 ± 0.07	2.91 ± 0.05	2.87 ± 0.07
Protein intake (g)	22.61 ± 0.48	22.34 ± 0.29	22.41 ± 0.33	22.54 ± 0.42
Protein efficiency ratio	1.39 ± 0.012[b]	1.56 ± 0.03[a]	1.47 ± 0.04	1.48 ± 0.033
Mortality (%)	3.33 ± 0.71	2.33 ± 0.61	4.00 ± 0.58[a]	1.67 ± 0.05[b]
Carcass Characteristics				
Live weight (kg)	1.85 ± 0.04	1.86 ± 0.08	1.78 ± 0.05	1.93 ±0.06
Dressed weight %	83.35 ± 2.02	83.38 ± 3.05	81.86 ± 2.58	84.86 ± 2.41
Cut-up parts[1]				
Head	2.42 ± 0.05[b]	2.84 ± 0.15[a]	2.55 ± 0.06[b]	2.70 ± 0.19[a]
Neck	4.88 ± 0.13[b]	5.84 ± 0.10[a]	5.41 ± 0.25	5.30 ± 0.23
Wing	8.39 ± 0.05[b]	9.99 ± 0.67[a]	9.32 ± 0.74	9.06 ± 0.38
Thigh	10.49 ± 0.27	10.54 ± 0.35	10.45 ± 0.29	10.58 ± 0.34
Drumstick	10.17 ± 0.42	11.01 ± 0.53	9.90 ± 0.19[b]	11.29 ± 0.55[a]
Liver	2.34 ± 0.15	2.12 ± 0.20	2.19 ± 0.21	2.27 ± 0.15
Shank	4.46 ± 0.21[b]	5.27 ± 0.31[a]	4.58 ± 0.13	5.15 ± 0.40
Keel	20.98 ± 0.88	18.82 ± 0.91	18.98 ± 1.10	20.81 ± 0.74
Back	14.05 ± 1.06	13.21 ± 0.55	13.23 ± 0.53	14.04 ± 1.07
Organs[2]				
Heart	0.54 ± 0.05	0.48 ± 0.03	0.51 ± 0.05	0.51 ± 0.03
Gizzard	2.06 ± 0.10	2.27 ± 0.16	2.27 ± 0.17	2.07 ± 0.09
Kidney	0.50 ± 0.05	0.43 ± 0.01	0.50 ± 0.04	0.44 ± 0.04
Intestinal tract (cm)				
Small intestine	127.40 ± 8.00	134.97 ± 8.00	131.53 ± 8.00	130.83 ± 8.00
Large intestine	14.90 ± 0.37[a]	13.00 ± 0.37[b]	13.43 ± 0.37[b]	14.47 ± 0.37[a]
Caeca	17.17± 0.39	16.17± 0.39	16.17± 0.39	17.17± 0.39

[a,b:] Means in the same row by factor with different superscripts differ significantly ($P<0.05$)
[1,2] Values expressed as percentages of the live weight

TABLE 3
The effects of the interaction between strain and particle size (±SE) on performance and carcass characteristics of broiler chickens

Strain	Marshal		Hubbard	
Feed particle size	1mm	2mm	1mm	2mm
Parameters				
Performance characteristics				
Initial weight (kg)	0.22 ± 0.01	0.24 ± 0.01	0.23 ± 0.003	0.22 ± 0.005
Final weight (kg)	1.51 ± 0.04	1.60 ± 0.04	1.70 ± 0.04	1.67 ± 0.10
Weight gain (g/b/d)	30.64 ± 1.03	32.30 ± 0.89	35.00 ± 0.84	34.60 ± 2.46
Feed intake (g)	91.56 ± 2.31	94.84 ± 3.45	98.81 ± 1.87	96.56 ± 1.91
Feed gain (g)	3.00 ± 0.04	2.94 ± 0.03	2.82 ± 0.07	2.81 ± 0.14
Protein intake	22.22 ± 0.56	23.00 ± 0.83	22.60 ± 0.43	22.08 ± 0.44
Protein efficiency ratio	1.38 ± 0.02^{b}	1.40 ± 0.01^{b}	1.55 ± 0.04^{ab}	1.56 ± 0.08^{a}
Mortality	4.67 ± 0.66^{c}	2.00 ± 0.58^{bc}	3.33 ± 0.88^{ab}	1.33 ± 0.33^{a}
Carcass characteristics				
Live weight (kg)	1.78 ± 0.06	1.92 ± 0.03	1.77 ± 0.09	1.95 ± 0.13
Dressing percentage	86.74 ± 2.91^{a}	79.97 ± 0.66^{b}	76.99 ± 1.07^{b}	89.77 ± 2.17^{a}
Cut-up part[1]				
Head	2.46 ± 0.06^{b}	2.37 ± 0.06^{b}	2.64 ± 0.08^{ab}	3.03 ± 0.25^{a}
Neck	4.89 ± 0.17^{b}	4.86 ± 0.23^{b}	5.94 ± 0.12^{a}	5.73 ± 0.17^{a}
Wing	8.45 ± 0.10	8.33 ± 0.02	10.19 ± 0.42	9.78 ± 0.42
Thigh	11.01 ± 0.29^{a}	9.96 ± 0.11^{b}	9.89 ± 0.10^{b}	11.20 ± 0.42^{a}
Drumstick	9.95 ± 0.39^{b}	10.40 ± 0.83^{b}	9.85 ± 0.17^{b}	12.18 ± 0.19^{a}
Liver	2.53 ± 0.28	2.14 ± 0.02	1.84 ± 0.18	2.39 ± 0.32
Shank	4.49 ± 0.22^{b}	4.43 ± 0.41^{b}	4.67 ± 0.15^{b}	5.87 ± 0.32^{a}
Keel	20.93 ± 1.38^{a}	21.02 ± 1.41^{a}	17.03 ± 0.54^{b}	20.61 ± 0.82^{ab}
Back	14.19 ± 0.55	13.90 ± 2.31	12.26 ± 0.39	14.17 ± 0.65
Organs[2]				
Heart	0.58 ± 0.08	0.50 ± 0.06	0.43 ± 0.05	0.53 ± 0.02
Gizzard	2.17 ± 0.12	1.95 ± 0.14	2.36 ± 0.34	2.18 ± 0.06
Kidney	0.53 ± 0.07	0.47 ± 0.10	0.04 ± 0.02	0.41 ± 0.00
Intestinal tract (cm)				
Small intestine	140.30 ± 11.31	114.50 ± 11.31	122.77 ± 11.31	147.17 ± 11.31
Large intestine	14.33 ± 0.52^{ab}	15.37 ± 0.52^{a}	12.53 ± 0.52^{c}	13.47 ± 0.52^{bc}
Caeca	16.33 ± 0.55^{ab}	18.00 ± 0.55^{a}	16.00 ± 0.55^{b}	16.33 ± 0.55^{ab}

$^{a,b,c:}$ Means in the same row with different superscripts differ significantly ($P<0.05$)
^{1,2}:values expressed as percentages of live weight

TABLE 4
The main effect of strain (±SE) and feed particle size (±SE) on the morphology of ileum and jejunum in broiler chicken

Parameters	Strain		Feed particle size	
	Marshal	Hubbard	1mm	2mm
Ileum morphology				
Apical width (µm)	70.83 ± 8.44	60.00 ± 6.85	78.33 ± 7.05[a]	52.50 ± 6.64[b]
Basal width (µm)	189.58 ± 56.26	105.83 ± 10.25	107.92 ± 9.48	187.50 ± 56.66
Villus height (µm)	480.00 ± 74.10	547.50 ± 65.24	507.50 ± 78.60	520.00 ± 61.39
Lamina depth (µm)	249.17 ± 23.78[a]	215.83 ± 20.17[b]	241.67 ± 24.46	233.33 ± 20.24
Jejunum morphology				
Apical width (µm)	64.17 ± 12.34	55.83 ± 8.21	71.67 ± 11.27	48.33 ± 8.42
Basal width (µm)	99.17 ± 11.45	81.67 ± 9.20	95.83 ± 12.22	85.00 ± 8.66
Villus height (µm)	504.17 ± 80.18	539.17 ± 68.90	548.33 ±82.92	495.00 ± 65.02
Lamina propria depth (µm)	268.33 ± 34.06	245.83 ± 18.73	258.33 ± 27.60	255.83 ± 27.78

[a,b]: Means in the same row by factor with different superscripts differ significantly (P<0.05)

apical width. Meanwhile, no significant (P>0.05) differences were recorded in all the parameters measured. Strains (Marshal MY and Hubbard) and feed particle size (1 and 2mm) gave similar result by factors.

The effects of the interaction between strain and feed particle size on the morphology of ileum and jejunum in the broiler chicken (Table 5) showed significant (P<0.05) differences in the basal width, villus height and lamina propria depth. The Marshal strain fed with 1mm feed particle size recorded the highest basal width of 272.50 µm, while the Hubbard strain fed with 2mm feed particle size had the least value of 91.66 µm. The highest value for the villus height (645.00 µm) was recorded in the Hubbard strain fed with 2mm feed particle size with the Marshal strain fed with 1mm feed particle size having the least value of 345.00µm. The Marshal strain fed with 2mm feed particle size had the highest value of 271.67µm in the lamina propria depth and the least value of 163.33 µm was recorded for the Hubbard strain fed with 1mm feed particle size. In the jejunum, no significant (P>0.05) differences detected in all the parameters measured except in the lamina propria depth with the Marshal strain fed with 2mm feed particle size recorded the highest value (350.00µm) as compared to the least value (186.67µm) recorded in the same strain fed with 1mm feed particle size.

Fig.1 shows the intestinal histomorphometry of the ileum of Marshal MY fed with feed in the particle size 1mm. It was observed that ileum is normal with good architectural display of villi. The villi were elongated proportionately and well defined. In Fig.2, the intestinal histomorphometry of the ileum of Marshal MY fed with feed in the particle size of 2mm showed abnormalities of the ileum. The villi were greatly atrophied with pieces scattered in

TABLE 5
The effect of the interaction between strain and feed particle size (±SE) on the morphology of ileum and jejunum in broiler chicken

Strain	Marshal		Hubbard	
Feed particle size	1mm	2mm	1mm	2mm
Parameters				
Ileum morphology				
Apical width (µm)	70.00 ± 15.06	71.67 ± 9.46	61.67 ± 11.67	58.33 ± 8.33
Basal width (µm)	272.50 ± 104.03^{a}	106.67 ± 18.73^{ab}	120.00 ± 15.06^{ab}	91.66 ± 12.49^{b}
Villus height (µm)	345.00 ± 28.49^{b}	615.00 ± 126.72^{ab}	450.00 ± 100.83^{ab}	645.00 ± 68.98^{a}
Lamina propria depth (µm)	226.67 ± 31.38^{ab}	271.67 ± 36.09^{a}	163.33 ± 17.64^{b}	268.33 ± 19.40^{a}
Jejunum morphology				
Apical width (µm)	70.00 ± 21.14	58.33 ± 14.47	45.00 ± 12.32	66.67 ± 9.89
Basal width (µm)	103.33 ± 17.64	95.00 ± 16.07	78.33 ± 16.00	85.00 ± 10.57
Villus height (µm)	391.67 ± 24.82	616.67 ± 150.37	393.33 ± 95.28	685.00 ± 57.49
Lamina propria depth (µm)	186.67 ± 27.78^{b}	350.00 ± 40.83^{a}	250.00 ± 27.45^{b}	241.67 ± 27.98^{b}

^{a,b}: Means in the same row with different superscripts differ significantly (P<0.05)

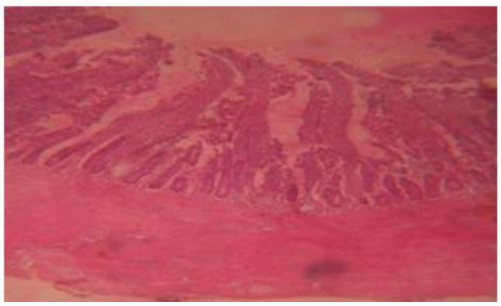

Fig.1: Intestinal Histomorphometry of the ileum of Marshal MY Broiler Chicken fed 1mm pelletized feed particle size (Magnification X10)

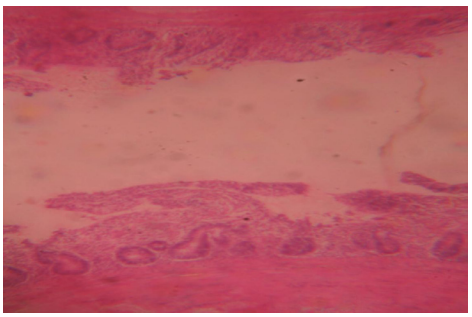

Fig.2: Intestinal Histomorphometry of the ileum of Marshal MY Broiler Chicken fed 2mm pelletized feed particle size (Magnification X10)

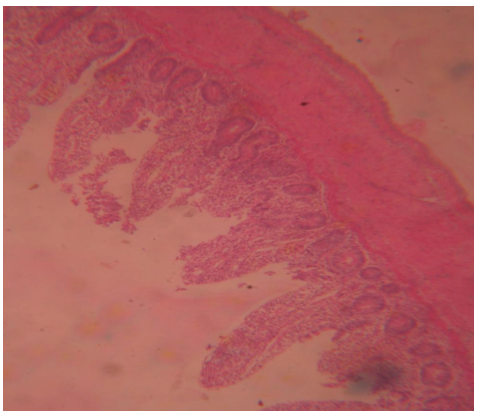

Fig.3: Intestinal Histomorphometry of Hubbard Broiler Chicken fed 1mm pelletized feed particle size (Magnification X10)

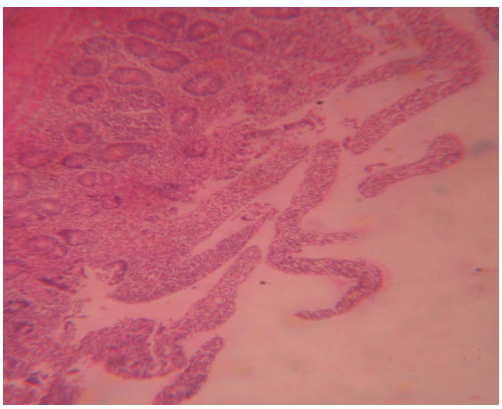

Fig.4: Intestinal Histomorphometry of Hubbard Broiler Chicken fed 2mm pelletized feed particle size (Magnification X10)

the lumen of the intestine. The intestinal histomorphometry of the ileum of Hubbard fed with feed in the particle size of 1mm shown in Fig.3 revealed that the ileum was degenerated as the villi were stumpy and not properly formed while in Fig.4, the intestinal histomorphometry of the ileum of Hubbard fed with feed om tje particle size of 2mm was normal with well-developed villi. This figure shows the best features among all the observed figures.

DISCUSSION

The results obtained in the present study corroborated the reports of Mehaffey *et al*. (2006) who evaluated five most commercially used strains by the poultry industry in Europe and found no significant differences in the initial live body weights among broiler strains at various ages. However, there was a significant difference in the average final body weight among the strains considered, thereby corroborating the findings in the present study. The results contradicted the reports of Goliomytis *et al.* (2003) and Korver *et al.* (2004) who found that there were no significant differences between the commercial broiler strains for their final body weights at 42 days of age. The fact that the final body weight was increased in the birds fed with 2mm-sized pellets compared to 1-mm-sized pellets in the present study suggested that the 2mm pellet size is appropriate, as also reported by Cerrate *et al.* (2008).

The overall feed intakes for both the Marshal and Hubbard birds are similar. This result is also similar to those reported by Korver *et al.* (2004) whereby the overall feed intake is similar for 3 strains of broilers, but is in contrast with the findings of Abdullah *et al.* (2010) who reported that there was a significant difference in the overall feed intake between the strains, with no differences between the Hubbard and Lohman. Stickland (1995) reported that within a strain, muscle fibres increase as the average daily gain and feed conversion rate increase. It was observed that as the birds grew older and larger, they consumed more feed to meet the increasing requirement for maintenance, growth and fat deposition.

It must be recognized that not only the size of the feed particles but also the uniformity of the particles size are relevant in determining the influence of the particle size on bird's performance. Both the particle size and shape did influence the birds' performance (Axe, 1995). In addition, the birds in this study could distinguish the differences in the feed particle size by mechanoreceptors located in the beak (Gentle, 1979).

The findings of Nir *et al.* (1995) gave sustained interest in studying the effects of the particle size in the pelleted feeds on the basis that the pellets dissolve in the crop after consumption and hence, the effect of the feed particle size might be maintained even after pelleting. Reece *et al.* (1986a) found no effect on performance using maize of differing particle sizes to formulate broiler starter diets in crumble form. Similarly, Svihus *et al.* (2004a) showed no difference in any of the performance parameter when the broilers were fed pelleted feeds made

from wheat that was ground in hammer and roller mills to a range of particle sizes, and concluded that pelleting evened out the differences in particle size distribution. In addition to these findings, Cabrera (1994) found no effect of the feed particle size (1,000-400μ) on the growth performance of broiler chicks fed complex (added tallow, meat and bone meal and feather meal) diet fed in a crumb form. On the contrary, this study showed that feed form (pellets) had an impact on the performance, with pelleting improving the growth rate and particle size enhancing better protein efficiency (Engberg *et al.,* 2002; Skinner-Noble *et al.,* 2005; Greenwood *et al.,* 2005; Lemme *et al.,* 2006). Though the results of this study showed no significant effects of the feed particle sizes on the weight gain, feed intake and feed gain ratio, the results are supported by the findings of Van Biljon (2005), Galobart and Moran (2005) and Salari *et al.* (2006)) who reported that the form of diet and/or particle size had no significant effect on the weight gain, dry matter intake and feed gain. Meanwhile, Kilburn and Edwards (2001) also reported improvements in feed per gain when the diet included medium ground corn (GMD, 0.87 mm) compared to that made from very coarse corn (GMD, 2.90 mm). Reece *et al.* (1985, 1986a,b), however, found that the corn particle size (GMD, 0.68 vs. 1.29 mm) had no effect on the performance of the broilers fed crumbled or pelleted diets.

The significant difference obtained in the protein efficiency ratio with birds fed 2mm feed particle size having a higher ratio than those fed on 1 mm feed particle size could be attributable to the improvement in the feed efficiency in birds fed diets with higher particle size. Further to this, a greater proportion of coarse particulate matter resulted in a longer residence time within the gizzard, leading to enhanced digestion and thus better protein efficiency. Moreover, a greater proportion of coarse particulate matter stimulated greater gizzard activity, leading to more efficient grinding with production of greater quantities of finer particles that are more readily digested. Coarse particles may however slow the passage rate of digestion to the gizzard (Nir *et al.,* 1994a), increasing the exposure time of nutrients to digestive enzymes in the proventriculus, which in turn may improve energy utilization and nutrient digestibility (Carre, 2000). Furthermore, it has been reported that a lower pH of gizzard contents may increase pepsin activity (Gabriel *et al.,* 2003) and improve protein digestion.

Birds fed with 1mm of feed particle size recorded significantly high percentage mortality when compared to birds fed with 2mm of feed particle size. This was similar to the report by Scott (2002) who found that feed form did not affect mortality but that feeding a high-density ration resulted in a higher incidence of sudden death syndrome (SDS) compared with broilers fed a low-density ration.

Nir *et al.* (1994) suggested that the average daily feed consumption in hens is related to the particle size. In more specific, coarse particle size with denser feed bulk density promotes more feed consumption.

On the other hand, finer feed particle size decreases feed consumption due to dustiness problems (Patrick & Schaible, 1980). Hetland *et al.* (2002) reported increased feed intake when feeding diets with high inclusions of whole cereals. This is similar to the findings of this study as the birds fed with 2mm of feed particle size consumed more feed than those fed with 1mm of feed particle size.

The differences obtained in the weight gain are similar to the findings of Abdullah *et al.* (2010) who reported a significant difference in the overall average daily gain (ADG) between strains. Similarly, Korver *et al.* (2004) reported that the overall ADG (from week 1 to week 6) of 3 strains of broilers was significantly different. The result of feed gain between strains is similar to the findings of Abdullah *et al.* (2010) who reported that there was no significant difference in the overall feed conversion ratio (FCR) between the strains. In addition, Waibel *et al.* (1992) reported that if fines were fed to poultry, losses in feed conversion and rate of gain were observed. In addition, increasing the level of fines or grinding pellets has been shown to adversely affect the feed conversion (Plavnik *et al.,* 1997). However, these results contradict with the findings of Elisabeth *et al.* (1998) and Korver *et al.* (2004) who reported that the overall FCR of different strains of broiler is significantly different.

The results on the carcass evaluation contradicted the findings of Karima and Fathy, (2005) who reported that the differences in live body between breeds were found to be significant and that the proportion of meat in the valuable parts of the carcass was influenced less by diet and more by slaughter weight. Meanwhile, feed particle sizes had significant effect on the head, drumstick and large intestine length. This is similar to the findings of Ebrahimi *et al.* (2010) who reported that feed particle size had no effect on the weights of carcass, chest, femur, liver, gizzard and heart.

Past literature (see Lott *et al.,* 1992; Kilburn & Edwards, 2001) which suggested that broilers might not be able to efficiently utilize large corn particles due to underdeveloped gastrointestinal tracts contradict the findings of the present study. It, however, a showed similar finding with that of Nir *et al.* (1994a) who reported that a mash diet with large particles is better suited to the chicken's intestinal tract than a mash diet with small particles only. The authors also reported that the content weight of the gizzard was significantly less for diets containing small particles as compared with large ones, suggesting a decreased particle retention time. This contradicted the findings of this present study, as no difference was found in the gizzard weight in the two feed particle sizes.

Annison (1993) showed that the physical effect of feed such as size and fibre composition could improve the digestibility of nutrients and very fine grinded grains have had harmful effects on health and activity of broiler chicks. Feed processing, as reported in many scientific resources, could affect broiler ileum and caecum contents microflora, growth and efficiency in feed

utilization (Kenny & Kemp, 2003). These findings are corroborated by the results of the present study which has shown that the ileum morphology of the Hubbard strain on the 2 mm feed particle size had the highest villus height and a statistically similar lamina propria depth with the Marshal strain on the 2 mm feed particle size. However, the Marshal strain on 1 mm feed particle size had the highest basal height while the lowest was obtained in the Hubbard strain on 2 mm feed particle size. In addition, the jejunum morphology showed the Marshal strain on 2 mm feed particle size having the highest lamina propria depth and the lowest in the same strain on 1 mm feed particle size. This finding is in consonance with the reports of Choi *et al.* (1986) and Nir *et al.* (1994b) who revealed an increase in the broilers' digestive tract weight and in the height of jejunum and ileum through increasing the particle sizes of diet.

RECOMMENDATION

Based on the findings of the present study, it could be recommended that:

- Pelletized feed of 2mm particle size should be adopted for broiler production from day 14.

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