Feed Forms of Different Particle Sizes: Effects on Growth Performance, Carcass Characteristics, and Intestinal Villus Morphology of Cockerel Chickens.

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ABSTRACT

This study determined the effect of feed forms of different particle sizes on growth performance, carcass characteristics and intestinal villus morphology of cockerel chickens. A total of 180 day old cockerel chickens were divided into 4 treatment groups of crumbs and pellets with 1mm and 2 mm feed particle sizes, subdivided into 3 replicates and subjected to Completely Randomized Design in a 2x2 factorial experimental layout. The birds were brooded for 14 days and thereafter maintained for 98 days experimental period. In the performance, significant (P<0.05) effects were obtained in the protein intake (g /bird/day) and protein efficiency ratio between birds fed 1 mm and 2 mm feed particle sizes, respectively. Similarly, the interaction gave the best (P<0.05) protein efficiency ratio (1.64) in birds fed 1 mm particle-sized pellets. Villus height of jejunum had higher values in crumbs of 1 mm (985.00 µm), 2 mm (805.00 µm) feed particle sizes and pellets of 1 mm particle sizes than crumbs of 2 mm feed particle sizes (135.00 µm). It was recommended that pelletized feed up to 2 mm particle size should be adopted for cockerel production.

(Keywords: growth performance, villus, pellets, crumbs, cockerel chickens, livestock)

INTRODUCTION

The effects of particle size on feed quality and quality of poultry have been researched in a number of studies (Behnke, 1994; Behnke and Beyer, 2004, Aderibigbe *et al.,* 2013). Particle size increases the surface area of the grain, thus allowing for greater interaction with digestive enzymes. It also improves the ease of handling and the mixing characteristics. In poultry diets, the effects of feed particle size appear to be confounded with complexity of the diet as well as further processing such as pelleting or crumblizing. The reduction in particle size of grain feeds involves disruption of the outer seed coat and fracture of the endosperm. Finer reduction increases the number and size of particles, and hence the overall surface area per unit volume, which may allow greater access to digestive enzymes and increase digestive efficiency (Goodband *et al.*, 2002). Koch (1996) opined earlier that particle size reduction ensured a generally greater ease of handling and ease of mixing of ingredients.

The feeding of a coarser grain size is relevant from the viewpoint of energy expenditure. The grinding of whole grain for broiler feeds constitutes the second greatest energy expenditure after pelleting (Reece *et al*., 1986). However, coarse grinding is said to reduce pellet quality, although there is no objective evidence for this claim. This counter-intuitive effect may result from the positive effect of feed particle size on gizzard development. Promotion of gizzard development is a nutritional strategy, which can be achieved by manipulating feed particle size (Engberg *et al*., 2004) since a well-developed gizzard is associated with improvement of gut motility (Ferket, 2000) and may prevent pathogenic bacteria from entering the small intestine (Bjerrum *et al*., 2005) thus, reducing the risk of coccidiosis and other enteric diseases (Engberg *et al*., 2004; Bjerrum *et al*., 2005). Systematic investigations on the relationships of feed particle size and diet uniformity with bird performance, gut health and pellet quality are warranted if efficiency is to be optimized in respect of the energy expenditure of grinding (Amerah *et al*., 2007).

Recently, the crumble form of feed has become popular in poultry production due to its convenience of feeding. Choi *et al.* (1986) reported that chicks fed the crumbled starter diet consumed more feed. Reece *et al.* (1984) observed that best feed conversion was obtained with a feeding of high energy and high protein crumble form of feed. Pellet system of feeding is really a modification of the mash system. It consists of mechanically pressing the mash into hard dry pellets or "artificial grains". It is generally accepted that the feeding of pellets improves bird growth rate with an increased feed intake when compared to mash (Nir *et al*., 1994). The enhanced performance may be due to increased digestibility, decreased ingredient segregation, reduction of energy during prehension and increased palatability (Behnke, 1998). Briggs *et al.* (1999) also stated that feeding pelletized rations is not enough to ensure enhanced performance of poultry, the quality of pellets must be taken into account.

It is noteworthy that in spite of the aforementioned, research emphasis within the last three decades has been on fast weight gain without considering factors like climatic conditions, eating habits, availability of raw materials for feed manufacturing, feed forms, levels of farm inputs and knowledge in poultry rearing at farm level; yet, these factors influence the rearing of birds. This research work is thereby aimed at investigating the effects of different sizes of crumbs and pellets on performance, intestinal villus morphology and carcass characteristics of cockerel chickens in order to optimize the use of the feed for the birds.

MATERIALS AND METHODS

The experiment was carried out at the poultry unit of the Teaching and Research Farm Directorate, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria. This area is situated in the rainforest vegetation zone of South-western Nigeria on Latitude 7°13´49.46´´N, Longitude 3° 26´ 11.98´´ E and altitude of 98m above sea level. The climate is humid with a mean annual rainfall of 1003mm annual mean temperature and humidity ranges from 31.9 to 34.8^{0}C and 79.7 to 90.1%, respectively.

A total of 180 day-old cockerel chicks were used in the experiment. The chicks were purchased from a reputable hatchery in the Ogun State, Nigeria. The chicks were brooded for two weeks and thereafter, divided into four treatment groups of 1 mm and 2 mm particle sizes of pelletized and crumbled feeds consisting of 45 chicks each which were sub-divided into 3 replicates of 15 chicks each for pelletized and crumbled feed particle sizes and then maintained for 98days. The chicks were fed chicks mash dietary mix shown in Table 1. This dietary mix was given to the chicks in mash form at brooding stage. Both feeds and fresh clean water were given to the chicks *ad libitum*.

Table 1: Composition (%) of Experimental Diet for Cockerel Chickens.

Ingredient	Chicks mash	Growers' mash
Maize	45.00	45.70
Fishmeal (72% CP)	2.00	
Soybean meal	11.70	8.00
Wheat offal	18.00	26.60
Groundnut cake	9.60	-
Palm kernel cake	8.00	11.00
Bone meal	2.00	2.00
Oyster shell	3.00	6.00
Salt (NaCl)	0.25	0.25
*Vit./trace min. premix	0.25	
**Vit./trace min. premix		0.25
Lysine	0.10	0.10
Methionine	0.10	0.10
Total	100.00	100.00
Determined analysis (%)		
Dry matter	89.10	88.90
Crude protein	19.70	14.40
Ash	21.41	27.87
Crude fibre	4.10	4.30
Ether extract	3.60	3.60
Nitrogen-free extract	51.19	49.83
ME (MJ/kg)	11.49	10.90

*Vit./mineral premix contained: B_1, 1g; B_2, 6g; B_{12}, 0.02g; K_3, 3g, biotin, 0.05g; folic acid, 1.5g; choline chloride, 250g; nicotinic acid, 30g; Ca-pantothenate, 15g; Co, 0.4g; Cu, 8g; Fe, 32g; I, 0.8g; Zn, 40g; Mn, 64g; Se, 0.16g, BHT, 5g

**1 kg of vit/mineral contained: vit. A, 10 000 000 iu; vit. D_3, 200 000 iu; vit. E, 12 500 iu; vit. K, 1.30 g; vit B_1, 1.30 g; vit. B_2, 4.00 g; Dicalcium-pantothenate, 1.30 g; vit. B_6, 1.30 g; vit. B_{12}, 0.01 g; nicotinic acid, 15. 00 g; folic acid, 0.05 g; biotin, 0.02 g; Co, 0.20 g; Cu, 5.00 g; Fe, 25.00 g; I, 0.06 g; Mn, 48.00 g; Se, 0.10 g; Zn, 45.00 g; choline chloride, 200.00 g; BHT, 50.00 g.

The diet was processed into four different diets consisting of crumbs and pellets of 1 mm and 2 mm particle sizes. The macro feed ingredients (maize, soybean, wheat offal and palm kernel cake) were milled and sieved using 1 mm and 2 mm sieves. The macro feed particles that passed through 1 mm sieve were considered to be feed of particle size ≤ 1 mm, while the macro feed particles that passed through 2 mm mesh were considered to be feed of particle size ≤ 2 mm.

The micro feed ingredients (ground bone meal, fish meal, ground oyster shell, vitamin, lysine, methionine, vitamin/trace mineral premix and salt) were then added equally into the sieved macro feed ingredients of four diet groups consisting of two 1 mm and 2 mm feed particle sizes, respectively.

The four diets were pelletized and two (1 mm and 2 mm particle sizes) of the pellets were converted to crumbs. Pelletizing was done using a pellet mill in which the feed was conditioned and thermally treated in the fitted conditioners of a pellet mill. The two crumbled diets were prepared by crushing two of the pelleted feeds of particle sizes of 1 mm and 2 mm to a consistency coarser than mash form. The proximate compositions of dietary mix of 1 mm and 2 mm particle sizes were determined in accordance with AOAC (2005) standards. Moisture was determined by drying about 2 g of each sample at 102 ^{o}C for 16h. Ash was determined at 525 ^{o}C. Total lipids were analyzed by extraction with petroleum ether.

Carcass Characteristics Determination

At the 16th week of age, two birds that were of average weight per replicate were selected from the experimental birds, weighed, slaughtered by cervical dislocation and eviscerated for carcass evaluation.

The dressed weights were determined and expressed as a percentage of the live weight. Cut-up parts such as head, neck, shank, thigh, drumstick, back and breast were weighed. The organs such as liver, gizzard, kidney and heart were removed and weighed using a top-loading scale. These parts were expressed as percentages of the live weight.

Digestive Tract and Small Intestinal Morphometry

Also, at the 16th week of age, two birds from each replicate, with body weights that were average weights of each replicate, were slaughtered by cervical dislocation. These birds were used for the microscopic study of intestinal morphology. The body live weight and weight of digestive tract segments from the crop to caeca of each bird were determined by weighing of wet tissue. The length of each intestinal segment was determined with a flexible tape on a glass surface to prevent inadvertent stretching (Lentle *et al*., 1998). Thus, the length (±0.1 mm) of the duodenum (from the pyloric junction to the distal-most point of insertion of the duodenal mesentery), the length of the jejunum (from the distal-most point of insertion of the duodenal mesentery to the junction with Meckel's diverticulum), the length of the ileum (from the junction with Meckel's diverticulum to the ileocecal junction) and the sum of the lengths from the ostium to the tip of each caecum were determined. After division and freezing of each of these components from any adhering mesentery, their full and empty weights (±0.1 g) were determined, along with those of the crop, proventriculus, and gizzard.

For intestinal morphological examinations, sections from the middle of the duodenum and jejunum (about 5 cm in length) were excised and flushed with ice-cold saline and immediately placed in Bouin's fluid. Samples were transferred into 70% ethanol after 24 hour. Each fixed sample will then be embedded in wax and sectioned at a thickness of 7 µmm, stained with alcian blue and hematoxy-lineosin, and examined by light microscopy. Four intestinal segments were fixed in each slide, and the slides were viewed on a Zeiss Axiophotomicroscope (Carl Zeiss, Oberkochen, Germany). Visual measurements of villus height and crypt depth were made on 10 villi at 100x and 200x magnifications with imaging software (Image Pro Plus, Version 4.1.0.9, Media Cybernetics, Silver Spring, MD).

The variables measured were villus height (the distance from the apex of the villus to the junction of the villus and crypt), crypt depth (the distance from the junction to the basement membrane of the epithelial cell at the bottom of the crypt), and the total extent of the mucosal layer (the distance from the apex of the villus to the basement membrane of the epithelial cell at the bottom of the crypt). The slides of villus from the small intestine sampled 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 (BW) of the villi. 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 as described by Yamauchi and Ishiki (1991). The mean of the measurements for each parameter was statistically evaluated.

Statistical Analysis

The data collected were arranged in a 2 x 2 factorial experimental layout and then subjected to One-way Analysis of Variance (SAS, 2003). Significant (P<0.05) differences among the variable means were separated using Duncan's Multiple Range Test as contained in the same SAS (2003) software package.

RESULTS AND DISCUSSION

Proximate Composition of Experimental Diets

Table 2 shows the proximate composition of the experimental diets for 1mm feed particle size and 2mm feed particle size. Dry matter content of 1mm feed particle size had value of 89.00 % while 2 mm feed particle sizes had value of 89.70 %. The crude protein content of the 1mm particle size feed had value of 15.57 % while 2mm feed particle size had value of 16.06 %. The 1mm particle size feed had a value of 3.31 % crude fat while 2mm feed particle size had a value of 3.18 %. The crude fibre of 1mm feed particle size showed a lower value of 5.74 % compared to that of 2 mm particle size which had a crude fibre value of 5.91 %. Ash of 1mm feed particle size had value of 14.13 % while 2mm feed particle size had a value of 14.36 %. The nitrogen-free extract of 1mm feed particle size having a value of 50.25 % while 2 mm feed particle sizes had a value of 50.19 %.

Table 2: Proximate Composition of Experimental Diets.

Particle size Parameters (%)	**1mm**	**2mm**
Dry matter	89.00	89.70
Crude protein	15.57	16.06
Crude fat	3.31	3.18
Crude Fibre	5.74	5.91
Ash	14.13	14.36
Nitrogen-free extract	50.25	50.19

Effects of Feed Forms and Particle Size on the Growth Performance of Cockerel Chickens

Table 3 shows the main effect of feed form and particle size on growth performance of cockerel chickens. All the parameters considered were not significantly (P>0.05) affected by the feed form. Significant (P<0.05) effect were obtained in the protein intake (g /bird/day) and protein efficiency ratio among birds fed 1mm feed particle size and 2mm feed particle size. Birds fed 1mm feed particle size had a lower protein intake (8.19g/day) than birds fed 2mm feed particle size (9.53 g/day) while protein efficiency ratio was better in birds fed 1mm feed particle size (1.60) than birds fed 2mm feed particle size (1.39). These statistically similar values in feed intake and protein intake in the feed forms (pellets and crumbs) thereby contradicted the findings of Choi *et al*. (1986) who reported that chicks fed the crumbled starter diet consumed more feed. These results may be due to its (crumbs) convenience in feeding.

The effect of particle size on feed intake corroborated the findings of Reece *et al.* (1986) who found no effect on performance using maize of differing particle sizes to formulate bird diets in crumble forms. However, Nir *et al.* (1994a) suggested that average daily feed intake in birds was related to the particle size. Coarse particle size with denser feed bulk density promoted more feed consumption. It was also similar to the findings of Cabrera (1994) who found no effect of feed particle size on growth performance of chicks fed a complex diet fed in a crumblized form.

Table 3: Main Effect of Feed Forms and Particle Sizes on Growth Performance of Cockerel Chicken.

Parameters	Feed forms		SEM	Particle sizes		SEM
	Pellets	Crumbs		1mm	2mm	
Initial weight (g/b)	185.00	183.33	2.64	183.33	185.00	2.55
Final weight (g/b)	1460.00	1486.67	34.04	1463.33	1483.33	33.43
Weight gain(g/b)	13.01	13.30	0.36	13.06	13.25	0.35
Feed intake (g/b/d)	55.61	59.96	1.76	56.20	59.37	1.91
Feed conversion ratio	4.28	4.50	0.10	4.31	4.48	0.10
Protein intake (g/b/d)	8.52	9.20	0.40	8.19[b]	9.53[a]	0.30
Protein efficiency ratio	1.53	1.45	0.05	1.60[a]	1.39[b]	0.03
Mortality (%)	7.79	11.11	3.56	7.77	11.11	3.56

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

Table 4: Effect of Interaction between Feed Forms and Particle Sizes on Growth Performance of Cockerel Chickens.

Feed forms	Pellets		Crumbs		SEM
Particle sizes	1mm	2mm	1mm	2mm	
Parameters					
Initial weight (g/b)	183.33	186.67	183.33	183.33	3.86
Final weight (g/b)	1473.33	1446.67	1453.30	1520.00	49.09
Weight gain(g/b)	13.16	12.86	12.96	13.64	0.52
Feed intake (g/b/d)	55.14	56.09	57.27	62.66	3.47
Feed conversion ratio	4.19	4.37	4.42	4.57	0.13
Protein intake(g/b/d)	8.03[b]	9.01[ab]	8.34[b]	10.06[a]	0.37
Protein efficiency ratio	1.64[a]	1.42[bc]	1.55[ab]	1.36[c]	0.05
Mortality (%)	8.89	6.67	6.67	15.57	4.91

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

The effects of interaction between feed form and particle size on the growth performance of cockerel chickens are shown in Table 4. Significant (P< 0.05) differences were obtained in the protein intake and protein efficiency ratio between birds fed pellet (1mm and 2mm particle size) and birds fed crumbs (1mm and 2mm particle size). Protein efficiency ratio was best (1.64) in birds fed 1mm particle sized pellet and poorest (1.36) in birds fed 2mm particle-sized crumbs. It however gave no effect on the fed intake and weight gain. These might be due to the structural integrity of pellets as reported in the findings of vanBiljon (2005); Galobart and Moran (2005) and Salari *et al*. (2006) that the form of diet and/or particle size had no significant effect on the weight gain, intake and feed gain ratio. In addition, the findings of Aderibigbe *et al.* (2013) who worked on pelletized feeds of different particle sizes for broiler chickens corroborated this result.

On the other hands, Jahan *et al*. (2006) who worked on broiler chicken reported significantly highest body weight gain in the crumble group throughout the experiment period. However, the present study contradicted the authors' findings and this could be attributable to the difference in the species of poultry used. The mortality percent did not differ significantly between pellets- or crumbs-fed birds. These results suggest that physical form of feed and feed particle sizes had no deleterious effect on health condition of birds and it is supported by the findings of Deaton (1992) who observed no significant difference in mortality between feed forms.

Effects of Feed Forms and Particle Size on Carcass Characteristics of Cockerel Chickens

Table 5 shows the main effects of feed form and particle size on the carcass characteristics of cockerels chicken. In the feed forms, all the parameters considered were not significantly (P>0.05) different except in the weight of crop which gave a higher (0.96) value in crumbs than 0.71 obtained in pellet feed. Also, in the feed particle sizes all the parameters considered were not significantly (P>0.05) different. In the carcass evaluation, feed forms and feed particle sizes showed no significant difference in the live weight and dressing percentage. The carcass yield values, based on the carcass weight were similar in all treatments except for the shanks. Effect of feed particle size on carcass yield supported the findings of Ebrahimi *et al.* (2010) who reported that feed particle size had no effect on the carcass parts; chest, femur, liver, gizzard and heart.

All the parameters considered on effect of interaction of feed forms and particle sizes of carcass characteristics of cockerel chicken at the end of 16th week (Table 6) were not significantly (P>0.05) affected by the treatment except in crop (P<0.05) which gave a higher value of 1.11 % in 2 mm feed-particle sized crumbs than 0.82 obtained in 1mm feed particle sized crumbs. However, the live weight (P>0.05) ranged from 1216.67 to 1283.00g with the highest from crumbs of 1mm feed particle size and lowest from pellets of 1mm feed particle size. The dressing percentage (P>0.05) ranged from 74.17 to 76.30 % with the highest from crumbs of 1mm feed particle size and lowest from crumbs of 2mm feed particle size.

Effects of Feed Forms and Particle Size on Intestinal Villus Morphology of Cockerel Chickens

Table 7 shows the main effect of feed form and particle size on the intestinal morphology of cockerel chickens. The effects of feed forms on all the parameters considered were not significantly (P>0.05) different except in the villus height of jejunum which gave a higher value (895.00 µm) in crumbs than 497.50 µm obtained in pellet feed. Significant (P<0.05) differences were obtained in the villus height of duodenum and jejunum in birds that were fed 1mm feed particle size and 2mm feed particle size. Birds fed 1mm feed particle size had a lower villus height (370.00 µm) for duodenum than birds fed 2mm feed particle size (700.00 µm) while villus height for jejunum had higher value in birds fed 1mm feed particle size (922.50 µm) than birds fed 2mm feed particle size (470.00 µm).

Table 5: Main Effect of Feed Forms and Particle Sizes on Carcass Characteristics of Cockerel Chickens.

Parameters	Feed forms			Particle sizes		
	Pellet	**Crumbs**	**SEM**	**1mm**	**2mm**	**SEM**
Live weight (g/b)	1233.33	1258.00	78.44	1250.00	1241.67	78.26
Dressing %	75.23	75.23	1.52	75.92	74.54	1.54
Cut-up parts[1]						
Head	3.52	3.47	2.43	3.47	3.52	0.22
Legs	5.43	5.17	0.20	5.38	5.22	0.16
Thighs	10.93	10.48	0.51	10.52	10.88	0.44
Wings	7.72	8.64	0.50	8.56	7.80	0.49
Drumstick	9.34	9.40	0.22	9.55	9.19	0.20
Back	11.37	12.24	0.25	11.63	11.97	0.34
Neck	6.45	6.61	0.20	6.50	6.56	0.20
Breast	11.73	12.88	0.45	12.37	12.23	0.50
Organs[2]						
Crop	0.71[b]	0.96[a]	0.06	0.76	0.92	0.08
Heart	0.49	0.50	0.04	0.49	0.50	0.04
Proventriculus	0.47	0.46	0.03	0.48	0.46	0.03
Spleen	0.12	0.13	0.01	0.13	0.13	0.01
Liver	1.55	1.62	0.07	1.64	1.54	0.07
Kidney	0.41	0.48	0.05	0.47	0.42	0.05
Lungs	0.65	0.73	0.08	0.68	0.70	0.08
EmptyGizzard	3.14	2.82	0.30	2.90	3.05	0.30

a,b: Means in the row by factor with different superscripts differ significantly (P<0.05)
1,2: Expressed as percentages of the live weight.

Table 6: Effect of Interaction between Feed Forms and Particle Sizes on Carcass Characteristics of Cockerel Chickens.

Feed forms	Pellets		Crumbs		SEM
Particle sizes	1mm	2mm	1mm	2mm	
Parameters					
Live weight (g/b)	1216.67	1250.00	1283.00	1233.33	112.88
Dressing percentage	75.55	74.90	76.30	74.17	2.27
Cut-up parts[1]					
Head	3.52	3.53	3.43	3.52	1.14
Legs	5.75	5.12	5.01	5.32	0.24
Thighs	11.30	10.55	9.75	11.22	0.55
Wings	8.62	6.81	8.49	8.78	0.57
Drumsticks	9.39	9.29	9.70	9.10	0.29
Back	11.37	11.36	11.90	12.59	0.36
Neck	6.35	6.55	6.66	6.57	0.28
Breast	12.16	11.29	12.59	13.17	0.32
Organs[2]					
Crop	0.69^{b}	0.74^{as}	0.82^{b}	1.11^{a}	0.07
Heart	0.48	0.51	0.51	0.49	0.05
Proventriculus	0.48	0.47	0.48	0.44	0.04
Empty Gizzard	2.96	3.31	2.83	2.80	0.45
Spleen	0.13	0.11	0.12	0.14	0.02
Liver	1.48^{b}	1.62^{ab}	1.79^{a}	1.46^{b}	0.05
Kidney	0.41	0.41	0.53	0.43	0.04
Lungs	0.62	0.69	0.75	0.71	0.12

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

Table 7: Main Effect of Feed Forms and Particle Sizes on Intestinal Morphology of Cockerel Chickens.

Parameters	Feed form			Particle size		
	Pellet	Crumbs	SEM	1mm	2mm	SEM
Duodenum (µm)						
Villus height	510.00	560.00	125.36	370.00^{b}	700.00^{a}	72.36
Lamina propria depth	555.00	110.00	124.58	540.00	125.00	128.73
Basal width	75.00	195.00	32.21	95.00	175.00	35.70
Apical width	42.50	80.00	12.80	42.50	80.00	12.80
Jejunum (µm)						
Villus height	497.50^{b}	895.00^{a}	136.99	922.50^{a}	470.00^{b}	131.33
Lamina propria depth	577.50	162.50	126.00	185.00	555.00	131.89
Basal width	55.00	77.50	11.49	77.50	55.00	12.07
Apical width	32.55	40.00	8.55	45.00	27.50	6.45
Ileum (µm)						
Villus height	235.00	447.50	86.3	372.50	310.00	112.11
Lamina propria depth	320.00	247.50	76.69	212.50	355.00	61.65
Basal width	80.00	150.00	36.79	90.00	140.00	39.125
Apical width	45.00	60.00	11.97	55.00	50.00	11.805

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

These results showed that feed processing, as reported by Kenny and Kemp (2003) can affect ileum and caecum contents of microflora, growth and efficiency in feed utilization of birds. In addition, the results corroborated the findings of Macari and Maiorka (2000) and Loddi (2003), who described differences in villus height found in the intestinal mucosa of birds. The results of these present study showed that the ileum morphology of cockerels on feed forms and feed particle size were not significantly influenced by all the parameters.

Table 8: Effect of Interaction between Feed Forms and Particle Sizes on Intestinal Morphology of Cockerel Chickens.

Feed forms	Pellets		Crumbs		SEM
Particle sizes	1mm	2mm	1mm	2mm	
Parameters					
Duodenum(µm)					
Villus height	220.00^{d}	800.00^{a}	520.00^{c}	600.00^{b}	5.00
Lamina propria depth	960.00^{a}	150.00^{b}	120.00^{b}	100.00^{b}	10.00
Basal width	90.00^{b}	60.00^{c}	100.00^{b}	290.00^{a}	17.5
Apical width	45.00^{b}	40.00^{b}	40.00^{b}	120.00^{a}	1.25
Jejunum (µm)					
Villus height	860.00^{a}	135.00^{b}	985.00^{a}	805.00^{a}	56.00
Lamina propria depth	205.00^{b}	950.00^{a}	165.00^{b}	160.00^{b}	75.00
Basal width	55.00	55.00	100.00	55.00	13.75
Apical width	35.00	30.00	55.00	25.00	8.75
Ileum (µm)					
Villus height	335.00^{b}	135.00^{c}	410.00^{a}	485.00^{a}	121.25
Lamina propria depth	190.00^{c}	450.00^{a}	235.00^{b}	260.00^{b}	78.75
Basal width	50.00^{b}	110.00^{a}	130.00^{a}	170.00^{a}	50.00
Apical width	35.00	55.00	75.00	45.00	15.00

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

All the parameters measured on effects of interaction between feed forms and particle sizes on intestinal villus morphology of cockerel chickens (Table 8) were significantly (P<0.05) affected by the treatment except Basal width and Apical width of jejunum as well as Apical width of ileum. Villus height of duodenum gave a higher value in pellets (800.00 µm) and crumbs (600.00µm) of 2mm feed particle size than values obtained in pellets (220.00 µm) and crumbs (520.00 µm)of 1mm feed particle size. Lamina depth of duodenum gave a higher (960.00 µm) value in 1mm feed particle-sized pellets than 150.00µm obtained in 2mm feed particle-sized pellets which had higher values than crumbs of 1mm (120.00 µm) and 2mm feed particle size (100.00 µm). Basal width of duodenum gave a higher value (290.00 µm) in 2mm feed particle sized crumbs than 60.00 µm obtained in 2mm feed particle-sizes pellets. Apical width of duodenum gave a higher value (120.00 µm) in 2mm feed particle-sized crumbs than 45.00, 40.00, and 40.00 µm obtained in pellets (1mm and 2mm feed particle sizes) and crumbs of 1mm feed particle size, respectively. The results are in consonance with the findings of Nir *et al.* (1994b) and Choi *et al.* (1986) who reported an increase in bird's digestive tract weight and in height of jejunum and ileum through increasing particle sizes of diet.

CONCLUSION

The protein utilization of the birds on 2 mm feed particle sizes was better than that obtained for birds on 1mm feed particle size.

The jejunum morphology showed that crumbs of 1 mm feed particle sizes increased villus height. Also, pelletized feed of 2 mm feed particle size improved villus height of duodenum and lamina propriae depth of both jejunum and ileum.

REFERENCES

1. Aderibigbe, O.B., O.M. Sogunle, L.T. Egbeyale, S.S. Abiola, A.O. Ladokun, and O.L. Ajayi. 2013. "Pelletized Feed of Different Particle Sizes: Effect on Performance, Carcass Characteristics and Intestinal Morphology of Two Strains of Broiler Chickens". *Pertanika Journal of Tropical Agricultural Science*. 36(2):127-144.

2. Amerah, A.M., V. Ravindran, R.G. Lentle, and D.G. Thomas. 2007. "Feed Particle Size: Implications on the Digestion and Performance of Poultry". *World's Poultry Science Journal*. 63:439–451. Web of Science.

3. AOAC. 2005. *Official Method of Analysis of Association of Official Analytical Chemists International (18th ed.)*. AOAC: Washington, DC.

4. Behnke, K.C. and R.S. Beyer. 2004. "Effect of Feed Processing on Broiler Performance". Kansas State University, Manhattan, KS.

5. Behnke, K.C. 1994. "Factors Affecting Pellet Quality". University of Maryland, College Park, MD.

6. Behnke, K.C. 1998. "Why Pellet?". In: *Proceedings of Kansas State University/American Feed Industry Association Pellet Conference*. Manhattan, KS.

7. Bjerrum, L., K. Pedersen, and R.M. Engberg. 2005. "The Influence of Whole Wheat Feeding on Salmonella Infection and Gut Flora Composition in Broilers". *Avian Diseases*. 49:9 – 15.

8. Briggs, J.L., D.E. Maier, B.A. Watkins, and K.C. Behnke. 1999. "Effect of Ingredients and Processing Parameters on Pellet Quality". *Poultry Science*. 78(10):1464–1471.

9. Cabrera, M.R. 1994. "Effects of Sorghum Genotype and Particle Size on Milling Characteristics and Performance of Finishing Pigs, Broiler Chicks, and Laying Hens". M.Sc. Thesis, Kansas State University: Manhattan, KS.

10. Choi, J.H., B.S. So, K.S. Ryu, and S.L. Kang. 1986. "Effects of Pelleted or Crumbled Diets on the Performance and the Development of the Digestive Organs of Broilers". *Poultry Science*. 65(3):594–597.

11. Embrahimi, R., M. Bojar Pour, and S. Mokhtar Zadeh. 2010. "Effects of Feed Particle Size on the Performance and Carcass Characteristics of Broilers". *Journal of Animal and Veterinary Advances*. 9(10): 1482 – 1484.

12. Engberg, R. M., M.S. Hedemann, S. Steenfeldt, and B.B. Jensen. 2004. "Influence of Whole Wheat and Xylanase on Broiler Performance and Microbial Composition and Activity in the Digestive Tract". *Poultry Science*. 83:925–938.

13. Ferket, P. 2000. "Feeding Whole Grains to Poultry Improves Gut Health". *Feedstuffs*. 72:12–14.

14. Galobart, J. and E.T. Moran, Jr. 2005. "Influence of Stocking Density and Feed Pellet Quality on Heat Stressed Broilers from 6 to 8 weeks of Age". *International Journal of Poultry Science*. 4: 55-59.

15. Goodband, R.D., M.D. Tokach, and J.L. Nelssen. 2002. "The Effects of Diet Particle Size on Animal's Performance". MF-2050 Feed Manufacturing. Dept. Grain Science Industry: Kansas State University, Manhattan, KS.

16. Howlider, M.A.R. and S.P. Rose. 1992. "The Response of Growing Male and Female Broiler Chickens Kept at Different Temperatures to Dietary Energy Concentration and Feed Form". *Animal Feed Science Technology*. 39:71-78..

17. Jahan, M.S., M. Asaduzzaman, and A.K. Sarkar. 2006. "Performance of Broiler Fed on Mash, Pellet and Crumble". *International Journal of Poultry Science*. 5(3):265– 270.

18. Koch, K. 1996. "Hammermills and Rollermills". MF-2048 Feed Manufacturing, Department of Grain Science Industry, Kansas State University: Manhattan, KS.

19. Lentle, R.G., K.J. Stafford, M.A. Potter, B.P. Springett, and S. Haslett. 1998. "Factors Affecting the Volume and Macrostructure of Gastrointestinal Compartments in the Tammar Wallaby (*Macropus eugenii* Desmarest). *Austria. Journal of Zoology*. 46:529– 545.

20. Loddi, M.M. 2003: "Probióticos, prebióticos e acidificante orgânico em dietas para frangos de corte [tese]". *Jaboticabal*. FCAV, UNESP.

21. Macari, M. and A. Maiorka. 2000: "Função gastrintestinal e seu impacto no rendimento avícola". In: *Anais da Conferência Apinco de Ciência e Tecnologia Avícolas*. Campinas: FACTA. 2:161-174.

22. Nir, I., Y. Twina, E. Grossman, and Z. Nitsan. 1994a. "Quantitative effects of Pelleting on Performance, Gastrointestinal Tract, and Behaviour of Meat-Type Chickens". *British Poultry Science*. 35(4):589–602.

23. Nir, I., R. Hillel, G. Shefet, and Z. Nitsan. 1994b. "Effect of Grain Particle Size on Performance. 2. Grain Texture Interactions". *Poultry Science*. 73(6):781–791.6.

24. Nir, I. and I. Ptichi. 2001. "Feed Particle Size and Hardness: Influence on Performance, Nutritional, Behavioral and Metabolic Aspects". 157–186. In: *Proc. 1st World Feed Conf., Utrecht, the Netherlands*. Wageningen Press: Wageningen, The Netherlands.

25. Radecki, S.V. and M.T. Yokoyama. 1991. "Intestinal Bacteria and Their Influence on Swine Nutrition". In: Miller, E. R., Duane, E. U.., Lewis, A. J. eds. *Swine Nutrition*. Butterworth-Heinemann: Boston, MA. 439-447.

26. Reece, F.N., B.D. Lott, and J.W. Deaton. 1984. "The Effects of Feed Form, Protein Profile, Energy Level and Gender on Broiler Performance in Warm Environments". *Poultry Science*. 63:1906-1911.

27. Reece, F.N., B.D. Lott, and J.W. Deaton. 1985. "The Effects of Feed Form, Grinding Method,

Energy Level, and Gender on Broiler Performance in a Moderate (21°C) Environment". *Poultry Science*. 64:1834–1839.

28. Reece, F.N., B.D. Lott, and J.W. Deaton. 1986. "Effects of Environmental Temperature and Corn Particle Size on Response of Broilers to Pelleted Feed". *Poultry Science*. 65:636– 641.

29. Salari, S., H. Kermanshahi, and H.N. Moghaddam. 2006. "Effect of Sodium Bentonite and Comparison of Pellet vs. Mash on Performance of Broiler Chickens". *International Journal of Poultry Science*. 5:31-34.

30. SAS. 2003. "SAS User Guide for Personal Computers, Statistical Programme release 9.01 Windows Version 4.10.22222". SAS Institute Inc.: Cary, NC.

31. vanBiljon, J.N. 2005. "The Effect of Feed Processing and Feed Texture on Body Weight, Feed Conversion and Mortality in Male Broiler". University of Pretoria, Pretoria, South Africa.

32. Yamauchi, K.E. and Y. Ishiki. 1991. "Scanning Electron Microscopic Observations on the Intestinal Villi in Growing White Leghorn and Broiler Chickens from 1 to 30 Days of Age". *British Poultry Science*. 32:67-78.

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