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Performance, Gut Size and Ileal Digesta Viscosity of Broiler Chickens Fed with a Whole Wheat Added Diet and the Diets with Different Wheat Particle Sizes[1]

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Abstract: To evaluate the effect of various particle sizes of wheat grain in meat-type birds, the performance and gut response of birds to 4 starter diets containing 30% and 4 finisher diets containing 50% wheat grain of different particle sizes passed through 4, 5, 6 and 7 mm sieves were compared with the responses of birds to whole wheat addition in a starter and a finisher diet at the same rates. The dietary treatments were as follows: fine texture (F) for wheat sieved by 4 mm, medium texture 1 (M1) for 5 mm sieved wheat, medium texture 2 (M2) for 6 mm sieved wheat, coarse texture (C) for 7 mm sieved wheat and whole (W) for whole wheat. All diets were isocaloric and isonitrogenous, and all other main dietary ingredients except wheat were ground to pass 5 mm sieve. The performance parameters were feed intake, weight gain and feed conversion ratio from 0 to 42 d. *In vivo* viscosity of ileal digesta, fresh lengths and weights of whole digestive tract and the amount of abdominal fat were also determined for all treatments. The results revealed that the best performance was obtained from the C diets, the F diet resulted in the lowest performance and those resulting from the M1, M2 and W were intermediate. However, the worsened performance induced by F and W starter diets of 30% wheat up to 21 d old was statistically become insignificant at later ages with finishing diets of 50% in comparison with the M1, M2 and C diets, suggesting that particle size of wheat grain lead to significant changes in bird's performance at early starting and growing periods, but not during the finishing periods even though the rate of wheat in the diet was increased from 30 to 50%. The diet of fine wheat particle resulted in significantly higher ileal digesta viscosity than the coarse and whole wheat added diets at both 21 d and 42 d old. It is most likely that increased digesta viscosity and changes in gut size can induce significant changes in the performance of broiler chickens, especially when the birds were young. In short, feeding broiler chickens with fine texture of wheat grain at early growing periods is not suggested due to the increased ileal viscosity and depressed performance although the negative effects of fine texture of wheat grain were overcome during finishing period even with 50% wheat additions. Medium and coarse texture of wheat grain remained to be the most preferred form of cereal grains although the whole grain is of great importance when no cost is considered for grinding.

Key words: Particle size, whole wheat, digesta viscosity, gut size, broiler chickens

Introduction

Of cereal grains, wheat has been generally preferred as main dietary ingredient in broiler diets by European and Canadian feed manufacturers, in contrast to their counterparts in USA. This is most likely to due to the high production of wheat grain in Europe and Canada. However, the nutritional value of wheat in terms of the utilization of metabolizable energy (ME) by poultry is lower than corn. Therefore, nutritionists have long been emphasized on the optimization of performance and reduction of feed costs by various dietary manipulations, such as enzyme supplementation, pelleting, whole grain feeding or diet dilution at various growth stages in broiler chickens fed with diets based on wheat grain.

Enzyme supplementation has been used as the main dietary vehicle to increase the nutrient utilization of wheat by broiler chickens. Therefore, great improvements in wheat AME (apparent metabolizable energy) value and nutrient digestibility, and reduction in adverse effects of wheat non-starch polysaccharides (NSP) were obtained from enzyme supplementation in broiler production (Petterson and Aman, 1988; Choct and Annison, 1992; Friesen *et al.*, 1992; Francesch *et al.*, 1994; Philip *et al.*, 1995; Ritz *et al.*, 1995ab; Choct *et al.*, 1996; Bedford, 1996).

Pelleting is the most preferred form of diet for broiler chickens for grower and finisher diets due to the increased feed intake (FI) and weight gain (WG), and improved feed conversion ratio (FCR) (Calet, 1965; Slinger, 1973). On the other hand, Nir *et al.* (1995) stated that the effect of

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grinding was additive to that of pelleting: the diets produced with roller mill ground grain other than that of hammer mill caused improved performance when broilers were fed with a mash diet or crumbles to 4 wk of age, then pellets to 7 wk of age. Therefore, particle size (Nir *et al.,* 1994ab) and grinding method, hammer mill versus roller mill (Nir *et al.*, 1995), greatly influence the performance parameters.

Birds were found to differentiate between two feeds, different in nutrient composition, to meet their nutrient requirements and grow optimally when these feeds were offered in two separate feeders (Shariatmadari and Forbes, 1993).

Having regarded this ability of birds, diet dilution, whole grain feeding and/or choice feeding were used as efficient means of reducing feed costs affected by grinding since the fineness of grind increased the cost of grinding, and pelleting followed by grinding is an energy costing process (McEllhiney, 1985). When the manipulations of diet dilution were examined in detail (Leeson *et al.,* 1996ab), it can be seen that these attempts were done for the sake of reducing the body fatness in birds just before the slaughtering. On the other hand, diet dilution with oats hulls and sand, starting from 35 to 49 d, caused reduced weight gain at 42 d, but then this was compensated, suggesting that birds can grow quite well on low energy diet but a period of 7 d is necessary to adjust their feed intake. The growth rate of broiler chickens did not differ when they were fed with the diets differed in energy content from 2700 to 3300 kcal/kg ME although body fatness was greatly changed. Offering the above different diets in a free-choice trial provided birds to precisely control the feed intake. However, the application of diet dilution in meat-type broilers is not commonly practiced in commercial scale, but it is most importantly used to reduce body fatness during the last week of whole production.

Whole grain feeding seems to remain an effective method of reducing the grinding costs in the broiler production, most dominantly practiced in Scandinavian countries. Peterson (1997) suggested that broiler chickens could grow optimally with whole wheat feeding with which whole grain can be included in broiler starter diet at the rate of 5% from 7 d without any adjustment on the nutrient composition of diet, and then increased by an appropriate quantity for every 10 days to reach a 35% inclusion at 42 d. The careful inclusion of whole wheat to both starter and finisher diets is of significant importance to ensure that the performance of birds is maintained at optimal levels. More recently, Yasar (2003) studied the high rates of whole-wheat inclusions of different wheat varieties compared with ground counterparts in broiler chickens. The results revealed that birds can control feed intake with 10, 20 and 30% whole wheat added diets by 28 d old unless they are not fed with 50% whole wheat, and grow optimally unless they are not fed with > 30% whole wheat added diet from 28 d of age. However, it is likely that the depressed performance by the inclusion rates of < 30% is due to the early administration of the whole wheat. The differences between varieties and physical forms (ground versus whole) were insignificant in bird performance. It was stated that enzyme supplementation did not alter the bird performance with either whole or ground wheat. In all above studies, the effect of whole grain feeding was evaluated with the effect of only a single particle size of ground wheat. The comparison of the effect of whole wheat with the different particle sizes of ground counterparts will be of great importance in broiler production.

Reece *et al.* (1986) reported that the size of screen used for grinding cereal grains directly influence the rate of grinding, indicating less energy needed for larger screens. They stated that when the screen openings were increased from 4.76 to 6.38 mm the rate of grinding was increased by 27%. Nir *et al.* (1994b) studied the effect of grain particle size (coarse, medium and fine). The wheat grain of medium particle size was found to induce greater performance than wheat grains of coarse or fine particle size. The gizzard weight and content positively correlated to the particle size. The greater feed intake was observed with medium and coarse grains than fine ground grains in the first 2 hours of re-feeding after overnight deprivation of feed.

Thus, there have been no comparisons between the different particle sizes of wheat and whole wheat in term of bird performance since the particle size of cereal grains included in the broiler diets were previously reported to influence the performance (Hamilton and Proudfoot, 1995; Nir *et al.*, 1994b) and the development of gastrointestinal tract (Nir *et al.,* 1994a and 1995).

The present study was conducted to test the hypothesis that different sizes of wheat particle including whole-ungrounded form affect the performance and gut size of broiler chickens.

Materials and Methods

In the experiment, 210 male commercial broiler chicks of one-day old (Avian strain) were kept in cages for 42 days. The room temperature was maintained at around 33 °C on the arrival, then reduced by 4 °C every week to reach 22 °C by 21 d of age, thereafter set at 22 °C till 42 d of age. The temperature and humidity were together automatically controlled in the room throughout the experiment. Two hundred and 10 chicks were divided into 5 groups, each with 42 birds. One of the five groups was randomly assigned with 6 cages, each cage with 7 birds. The starter and finisher diets were formulated to include 30 and 50% whole-wheat grain, respectively, and ground wheat grains by hammer mill to pass different sieve sizes. The particle sizes of wheat were whole wheat (W), fine texture (F) for wheat sieved by 4 mm, medium texture 1 (M1) for 5 mm sieved wheat, medium texture 2

Table 1: Nutrient composition of broiler diets containing different particle sizes of wheat

Ingredients, g/kg	Starting diet	Finishing diet
Corn	380	200
Wheat	300	500
Soybean meal	210	190
Fish meal	70	50
Corn oil	15.4	35.4
Limestone	15	10
Salt	2.5	2.5
DCP	1.5	6.5
Vitamin premix[1]	2.5	2.5
Mineral premix[2]	2.5	2.5
DL-methionine	0.6	0.6
Total	1000	1000
Nutrient Analysis		
Dry Matter, g/kg	893.1	878.3
Crude Protein, g/kg	232.7	203.3
Metabolizable Energy, (kcal/kg)	3096.11	3230.93
Crude cellulose, g/kg	29.9	39.5
Crude fat, g/kg	58.5	61.26
Starch, g/kg	329.3	335.3

[1]Provided per kilogram of diet; 4.800 IU Vit A (retinyl palmitate); 600.000 IU Vit D_3 (cholecalciferol); 12.000 mg Vit E (dl-α-tocopherol acetate); 2.000 mg Vit K_3, 1.200 mg Vit B_1, 2.400 mg Vit B_2, 2.000 mg Vit B_6, 12 mg Vit B_{12}, 16.000 mg Nicotinamid, 4.000 mg Calcium-D-Pantothenate, 300 mg Folic acid, 30 mg D-Biotin, 150.000 mg Choline chloride, 4.000 mg Antioxidant. [2]Provided per kilogram of diet; 80.000 mg Mn; 80.000 mg Fe; 60.000 mg Zn; 8.000 mg Cu; 500 mg I; 200 mg Co; and 150 mg Se.

(M2) for 6 mm sieved wheat, coarse texture (C) for 7 mm sieved wheat. To produce F, M1, M2 and C particles, wheat was ground using hammer mill that was attached with 4, 5, 6 and 7 mm sieves. The composition of diets was given in Table1. The diets were formulated to be isonitrogenous and isocaloric. The other feed ingredients in all diets were ground using hammer mill to pass only 5 mm sieve. All the ingredients were homogeneously mixed with a feed mixer equipped with hammer mill (Topkoclar makina sanayii, Sandikli, Afyon, Turkey). All the diets were prepared in mash form. The starter diets were fed to birds from 1 to 21 d old, and the finisher diets from 22 to 42 d old.

Three samples of each batch of complete diets after the homogenous mixing were taken for the measurement of particle size distributions. This was determined by passing the known weights of each sample through a series of laboratory sieves (4.76, 2, 1 and 0.5 mm screens) and weighting the amount of samples collected on each screen and on the pan under the 0.5 mm screen.

Birds kept in-group cages were fed and watered *ad libitum*. No restriction was made on lighting. FIs of bird in groups and BWs of each bird identified with wing number were recorded at the end of each week for the periods of 0 to 7 d old, 7 to 14 d old, 14 to 21 d old, 21 to 28 d old, 28 to 35 d old and 35 to 42 d old. At 21 and 42 days of age, 6 birds at each period for one of five treatment groups, one bird from each cage (totally 6 cages), were killed to measure digesta viscosity of ileum, abdominal fat, total weights and lengths of whole digestive tract. As previously described by Yasar and Forbes (1999), digesta from ileum of each bird was poured into 5 ml tubes, centrifuged and the supernatant was taken into Brookfield digital viscometer, cone-plate type. The viscosity was measured at room temperature at 50 rpm (round per minute).

The experimental design was a complete randomized model where there were 5 treatment groups, each with 6 replicates. The analysis of variance, ANOVA, was employed for the data of each specified week. The significant differences between the treatment means were separated by Duncan's multiply comparison test (Duncan, 1955) under the Statistical Computer Program of SPSS for Windows, 1996.

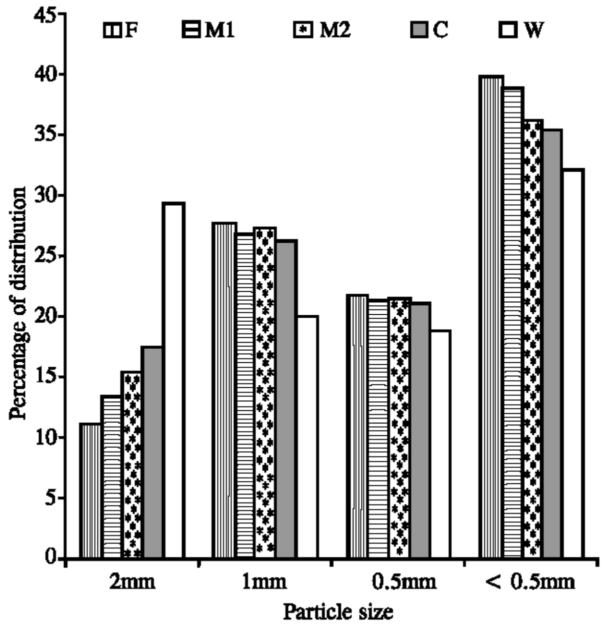

Fig.1: Particle size distribution of diets with Fine (F), Medium 1 (M1), Medium 2 (M2) and Coarse (C) ground wheat, and the diet of whole wheat (W).

Results

Data of particle size distributions of both starter and finisher diets were pooled and presented in Fig.1 since there was no statistical difference between the starter and finisher diets. From Fig.1, it can be seen that the percentage of particles for 2 mm or greater sizes was increased with increasing the coarseness of diet. On the other hand, the percentage of >2 mm particle size was higher for the W diet, 29.06%, than those of F, M1, M2 and C, 11.12, 13.34, 15.26 and 17.36%, respectively. In

Table 2: Feed intake (g per bird per week) of broiler chickens fed with diets based on wheat grain of different particle sizes.

Treatments[1]	0-7 d	7 to 14 d	14 to 21 d	21 to 28 d	28 to 35 d	35 to 42 d
F	120.28[a]	292.21[a]	594.28[a]	825.20[a]	835.84[a]	1190.00[a]
M1	121.14[a]	332.19[b]	597.21[ab]	850.32[a]	854.65[a]	1215.00[a]
M2	125.95[ab]	320.68[b]	594.32[a]	866.37[a]	857.82[a]	1210.50[a]
C	122.33[a]	324.38[b]	619.43[ab]	821.22[a]	836.91[a]	1220.00[a]
W	143.67[b]	325.65[b]	629.31[b]	938.59[b]	890.45[a]	1260.00[a]
Significance of main effects (ANOVA)	*	*	*	*	NS	NS
SEM (Pooled)	8.23	12.76	16.58	34.56	36.75	41.6

[1]F, M1, M2 and C for the diets based on ground wheat grain passed through 4, 5, 6 and 7 mm sieve, respectively; and W for whole wheat-based diet. [a, b,c] Indicate significant differences ($P < 0.05$) between the means of experimental groups. * =Significance level at $P < 0.05$, NS= not significant.

Table 3: Body weight and weight gain of broiler chickens fed with diets based on wheat grain of different particle sizes.

	Body weight gain (g per bird per week)					
Treatments[1]	7 d	14 d	21 d	28 d	35 d	42 d
F	126.25[ab]	319.42[a]	705.15[a]	1100.00[a]	1490.00[a]	2010.00[a]
M1	125.76[ab]	349.67[ab]	740.95[a]	1170.53[ab]	1560.87[ab]	2110.14[ab]
M2	122.83[a]	340.60[ab]	733.69[a]	1173.56[ab]	1584.36[ab]	2150.23[ab]
C	132.07[b]	361.92[b]	785.95[a]	1230.54[b]	1614.00[b]	2175.00[b]
W	132.10[b]	331.12[a]	711.21[a]	1156.25[ab]	1548.25[ab]	2094.00[ab]
Significance of main effects (ANOVA)	**	NS	*	*	*	*
SEM (Pooled)	4.43	14.25	40.33	52.28	58.41	60.21
Treatments[1]	Body weight gain (g per bird per week)					
	0-7 d	7 to 14 d	14 to 21 d	21 to 28 d	28 to 35 d	35 to 42 d
F	82.40[ab]	193.17[a]	385.73[a]	394.85[a]	390.00[a]	520.00[a]
M1	85.05[ab]	223.90[cb]	391.28[a]	429.58[b]	390.34[a]	549.27[a]
M2	81.45[a]	217.77[b]	393.09[a]	439.87[b]	410.80[a]	565.87[a]
C	90.45[b]	229.85[cb]	424.03[b]	444.59[b]	383.46[a]	561.00[a]
W	91.62[b]	199.02[ab]	380.09[a]	445.04[b]	392.00[a]	545.75[a]
Significance of main effects (ANOVA)	**	*	*	*	NS	NS
SEM (Pooled)	4.22	9.61	14.58	16.78	19.21	22.45

[1]F, M1, M2 and C for the diets based on ground wheat grain passed through 4, 5, 6 and 7 mm sieve, respectively; and W for whole wheat-based diet. [a, b,c] indicate significant differences ($P < 0.05$) between the means of experimental groups. * and ** = significance levels at $P < 0.05$ and $P < 0.01$, respectively, NS= not significant.

contrast, the increased percentage of particles of < 0.5 mm was seen to associate with the increased diet fineness. In other word, the percentages of < 0.5 mm size particle fractions for the F, M1, M2 and C diets, 39.83, 38.80, 36.16 and 35.42%, respectively, were higher than that of the W diet, 32.22%. In addition, the percentage distribution of particles between 0.5 mm and < 2mm sizes was remained unchanged, ranging from 47.2 to %49.0, between the diets of F, M1, M2 and C, whereas the corresponded percentage was low for the W diet (38.71%).

Until the 28 d old, FI was significantly ($P<0.05$) increased with the W diet, compared with the F, M1, M2 and C diets (Table 2). The lowest FI was observed with only the F diet. There were significant differences in FI of broiler chickens fed on experimental diets until the day of 28 whereas these differences were not meaningful thereafter. However, similar pattern of feed intake was observed with the diets of M1, M2 and C, except that the W diet appeared to induce increased FI and the F diet reduced FI up to 28 d old. From the 28 to 42 d old, the birds tended to consume similar amount of feed when they were fed the diets of F, M1, M2, C and W since no significant differences were seen in FI between these dietary treatments (Table 2).

During the first week of the starter period, birds fed with the diets of F and M1 and M2 gained low weight, compared to the diets of C and W (Table 3). From 7 to 28 d old, WG was reduced with the F diet whereas highest weight gain was observed with M1, M2 and C diets, and the effect of W diet was moderate. Similar to FI, there were no significant differences in WG between the

Table 4: Feed conversion ratio of broiler chickens fed with diets based on wheat grain of different particle sizes

	Feed Conversion Ratio (feed/gain per week)					
Treatments*	0-7 d	7 to 14 d	14 to 21 d	21 to 28 d	28 to 35 d	35 to 42 d
F	1.46[ab]	1.51[ab]	1.54[ab]	2.09[a]	2.14[a]	2.29[a]
M1	1.42[ab]	1.48[a]	1.53[ab]	1.98[ab]	2.19[a]	2.21[a]
M2	1.55[b]	1.47[a]	1.51[ab]	1.97[ab]	2.09[a]	2.14[a]
C	1.35[a]	1.41[a]	1.46[a]	1.85[b]	2.18[a]	2.17[a]
Whole	1.57[b]	1.64[b]	1.66[b]	2.11[a]	2.27[a]	2.31[a]
Significance of main effects (ANOVA)[1]	*	*	*	*	NS	NS
SEM (Pooled)	0.07	0.06	0.09	0.08	0.09	0.08

*F, M1, M2 and C for the diets based on ground wheat grain passed through 4, 5, 6 and 7 mm sieve, respectively; and W for whole wheat-based diet. [a, b,c] Indicate significant differences (P<0.05) between the means of experimental groups. [1]Significance levels at P<0.05, NS = not significant.

Table 5: Ileal digesta viscosity (cPs), whole gut length (g/b), whole gut weight (g/b), relative gut length (g/b/100 g body weight) relative gut weight (g/b/100 g body weight) and abdominal fat (g/b) at 21 d old-broiler chickens fed with diets based on wheat grain of different particle sizes

Treatments*	Ileal viscosity	Whole gut length	Whole gut weight	Relative gut length	Relative gut weight	Abdominal fat
F	18.3[a]	114.5[a]	85.4[a]	16.2[ab]	12.1[a]	--
M1	9.1[b]	112.5[a]	94.6[b]	15.2[a]	12.7[ab]	--
M2	7.5[b]	134.5[b]	93.8[b]	18.3[bc]	12.8[ab]	--
C	7.3[b]	132.2[b]	98.2[b]	16.8[ab]	12.5[ab]	--
W	7.4[b]	139.8[b]	96.5[b]	19.6[c]	13.6[b]	--
Significance of main effects (ANOVA)[1]	*	*	*	NS	NS	--
SEM	1.1	2.5	1.7	1.2	0.6	--

*F, M1, M2 and C for the diets based on ground wheat grain passed through 4, 5, 6 and 7 mm sieve, respectively; and W for whole wheat-based diet. [a, b,c] Indicate significant differences (P < 0.05) between the means of experimental groups. [1]Significance levels at P < 0.05 NS not significant. --, Not Determined.

experimental treatments during the periods between 28 and 42 d old. However, F diet produced lowest WG throughout the experimental periods.

There were significant differences in FCR between the experimental treatments during the periods of 7 to 14, 7 to 14, 14 to 21 and 21 to 28 d old (Table 4). The significantly worsened FCR was seen with the diets of F and W from day 0 to day 28 in comparison to the diets of M1, M2 and C with which an optimum or improved FCR was obtained. However, the worsened FCR was compensated for the diets of F and W thereafter since there were no statistical differences in FCR of broiler chickens fed with all experimental diets from 28 to 42 d old (Table 4).

Both at 21and 42 d old, ileal viscosity values were significantly ($P < 0.05$) differed between the experimental treatments (Table 5 and 6). Birds fed with the F diet produced significantly ($P < 0.05$) higher ileal viscosity than the birds fed with the M1, M2, C and W diets whereas no significant differences observed between the diets of M1, M2, C and W. F diet produced significantly ($P < 0.05$) shorter gut length during either periods (21 and 42 d old) whereas there was a significantly lighter gut weight at 21 old and heavier gut weight at 42 old than M1, M2, C and W diets. No significant differences in total gut length and weight were observed between the M1, M2, C and W treatments at both periods. When the total gut weights were related to 100 g body weights, the similar pattern was observed between the treatments at 21 d old whereas, at 42 d old, the relative weight values (g per 100 g body weight) were not significantly differed between the experimental treatments. Similarly, no significant differences were seen in the amount of abdominal fat between the treatments at only 42 d old.

Discussion

FIs of broiler chickens were altered by various feed particle sizes at the present study. The diet containing fine wheat particle, F diet, caused depressed FI, particularly during the early growing periods (0 to 21 d old) at a 30% wheat addition. FI of birds fed with F diet was remarkably low throughout the experiment while FI did not significantly differ between all diets during the finishing periods where wheat level of the diets was 50%. Lowered FI was seen to be associated with the worsened FCR, reduced WG and more importantly a significant

Table 6: Ileal digesta viscosity (cPs), whole gut length (g/b), whole gut weight (g/b), relative gut length (g/b/100 g body weight) relative gut weight (g/b/100 g body weight) and abdominal fat (g/b) at 42 d old-broiler chickens fed with diets based on wheat grain of different particle sizes.

Treatments*	Ileal viscosity	Whole gut length	Whole gut weight	Relative gut length	Relative gut weight	Abdominal fat
F	11.6[a]	210.4[a]	198.7[a]	10.5[a]	9.9[a]	35.5[a]
M1	6.2[b]	215.3[ab]	181.6[b]	10.2[a]	8.6[a]	37.7[a]
M2	5.5[b]	214.7[ab]	185.4[b]	9.9[a]	8.6[a]	34.3[a]
C	4.9[b]	222.6[b]	179.6[b]	10.2[a]	8.3[a]	36.6[a]
W	5.0[b]	220.5[b]	181.3[b]	10.5[a]	8.7[a]	33.4[a]
Significance of main effects (ANOVA)[1]	*	*	*	NS	NS	NS
SEM	0.6	3.4	2.8	0.8	0.6	3.1

*F, M1, M2 and C for the diets based on ground wheat grain passed through 4, 5, 6 and 7 mm sieve, respectively; and W for whole wheat-based diet. [a, b,c] Indicate significant differences ($P<0.05$) between the means of experimental groups. [1]Significance levels at $P<0.05$ NS not significant.

increase in ileal digesta viscosity when the birds were fed with the diet containing fine wheat particles at 21 d old. It is most likely that depressed performance by F diet was due to the possible reduction in feed passage rate throughout the gastrointestinal tract. Increased digesta viscosity may, therefore, play important role to slow down the passage rate of digesta within the gut. Although the passage rate was not determined in the present case, Van Der Klis *et al.* (1993) and Almiral and Garcia (1994) previously found that increased digesta viscosity induced by viscous gel forming dietary compounds reduced the rate of digestion and passage of digesta throughout the gut and may depress FI similar in the case of F diet.

Feeding broiler with wheat based-diets introduces an appreciable amount of non-starch polysaccharides (NSP) (Annison, 1991), and the antinutritional effects of NSP have been attributed to increased viscosity of intestinal contents (Pawlik *et al.,* 1990; Bedford, 1993; Philip *et al.,* 1995; Yasar and Forbes, 1999 and 2000; Yasar, 2003) and reduced digestibility of nutrients (Leong *et al.*, 1962; Fengler *et al.,* 1988; Choct and Annison, 1992; Friesen *et al.,* 1992; Yasar and Forbes, 1998). In the present case, it was, therefore, believed that the release of NSP from the wheat grain into the lumen of intestine may be greater for the F diet than M1, M2, C and W diets due to the increased degradation of fine wheat particles, thereby forming a highly viscous digesta which is mostly responsible for the reduced passage rate of digesta and depressed performance. In some other cases where there was no association of feed particle size with digesta viscosity, coarse particle compared to fine ones generally caused an increase in total transit time associated with increased FI. It was also reported that coarse grinding should be positive for protein digestibility. This effect is explained by a better control of intestinal transit time by gizzard emptying under the influence of coarse grounded feeds (Carre, 2000). These results agreed with the present results: FI was decreased with fine texture of wheat diet up to 21 d old, and similarly ileal digesta viscosity was high whereas FI was high with medium and coarse texture of wheat diet and ileal digesta viscosity was low. Furthermore, the changes in WG and FCR by various textures of wheat diets were in agreement with the changes in FI and digesta viscosity in the present case. During the finishing periods, insignificant differences in the performance of broilers fed with experimental diets of 50% wheat is due to the developed gastrointestinal systems of the growing birds, allowing the optimal utilization of dietary ingredients and overcoming the detrimental effects of wheat NSPs. This was also previously reported by Yasar and Forbes, 1999 and 2000: when birds get older the antinutritional effects of wheat NSP were overcome by a greater development of digestive tract where the increased digesta viscosity with the younger birds were drastically reduced.

In contrast to the effect of F diets on performance, the performance of broiler chickens on the diets of medium wheat particle size, M1 diet were observed to be at optimal levels, whereas the increased coarseness of diets, M2 and C diet, produced the greater performance in terms of feed intake, weight gain and FCR. These results agreed with the previously published results (Nir *et al.*, 1994b) in which broiler chickens performed best with the medium or coarse particle sizes of wheat diets. Similarly, Proudfoot and Hulan (1989) stated that the birds fed with very coarse mash diets were significantly ($P<0.01$) heavier than those received fine mash diets. It can be speculated that grinding cereal grains to result in very fine particles could not preferred for feeding the broiler chickens, causing not only depressed weight gain, increased digesta viscosity and worsened FCR in particular during the starting and early growing periods in the present case, but also decreased the grinding rate by 27% in a previous case (Reece *et al.,* 1986). On the other hand, grinding wheat grain using large-sized sieves can also cause savings on the energy costs; hence increased the grinding rate during the feed grinding (Reece *et al.,* 1986). Although the present circumstances can not give an opportunity for the use of suitable equipment at the feed mill unit to measure the grinding rate during the preparation of experimental diets, it is strongly believed that grinding wheat grain using 6 or 7 mm sieve sizes to prepare the M2 and C diets could have been cost less energy compared to the F diet for which 4 mm sieve size was used. When the ileal digesta viscosity values were examined in detail for the diets of F or C, it is obvious to see that digesta viscosity was significantly ($P < 0.05$) higher for the F diet than C diet, indicating that the antinutritive effect of grain NSP was less pronounced for the coarse diet rather than the fine diet. The later can to be due to the fact that the more fine grinding wheat the more release of grain NSP into the gut, thereby causing lowered passage rate of feed. The effect of increased amount of grain NSP within the digestive tract on bird performance and the physiochemical feature of digesta, such as viscosity and digesta passage rate, was formerly discussed in detail. Therefore, it can be concluded from the present results that wheat NSP exert its deleterious effects through a mechanism by which intestinal digesta viscosity increased and the performance of bird depressed.

The effect of whole wheat added diet, W, on bird performance was an increased feed intake throughout the experimental period. However, the increased feed intake did not associate with improved FCR or the greater weight gain, especially when compared with the coarse diet, C, in the present case. One could speculate that the increased feed intake by whole wheat added diet can be due to the low availability of metabolizable energy (ME) of whole wheat compared to ground wheat. Salah Uddin *et al.* (1996) had found no significant evidence, indicating that whole grain wheat had a different apparent ME from ground wheat. On the other hand, the weigh gain of broiler chickens fed with W diet was seen to be greater than those fed with F diet whereas similar FCR was obtained from these diets. In fact, the preparation of ungrounded, whole, wheat based-diet was less costly in terms of saving energy, and the final profit is apparently higher than the ground wheat-based diets. The effect of W diet in term of weigh gain was intermediate, similar to that of M1 diet throughout the experiment.

In the present experiment, although the performance of broiler chickens significantly differed between the wheat diets from 0 to 28 d old, the differences in bird performance were insignificant during the periods of 28 to 42 d old. This clearly indicated that the birds were given sufficient time to adapt these diets to overcome the depressed effects of fine mash diet or whole wheat added diet during the periods of 28 to 42 d old, and this was supported by the similar gut responses (relative to body weight) of birds to these diets in terms gut weight and length at 42 d old. Similarly, the significant differences in gut size (relative to body weight) between the dietary diets at 21 d old were associated with the similar patters of bird performance. Similar amount of abdominal fat and gut sizes at the end of experiment also indicated that, during the finishing periods, birds had almost similar nutrient utilization and similar responses in term of performance, gut size and abdominal fat to the experimental diets. There was a good evidence from the previous works that birds are able to overcome the antinutritional effect of increased viscosity by wheat grain as the birds get older since digesta viscosity was significantly lowered in birds older than 28 d old (Yasar and Forbes, 1999 and 2000). Therefore, the low ileal viscosity values determined at 42 d old compared to those values at 21 d old is explained by the reducing effect of bird age.

Although birds appeared to lose weight with the diluted diets for a specified period, the growth can be compensated if the birds were given a 7 days of period (Leeson *et al.*, 1996a). In the present case, the depressed growth by the F diet, even its nutrient composition similar to that of other counterparts, was compensated during the periods from 28 to 42 d old.

From the results of the present experiment, it can be concluded that the diets based on fine wheat particle can cause depressed performance in broiler chickens from day 0 to day 28 during which ileal digesta viscosity was increased, thereafter the growth was nearly compensated by day 42 during which the gut size was also restored. It is also believed that the viscosity of gut contents remains to be strong evidence as an indication of antinutritional effect of wheat grain. Feeding broiler with medium or coarse wheat grain based diets resulted in improved performance as the grinding cost also reduced, and the effect of whole wheat feeding was of great significant when no cost is considered for grinding, compared to the fine particle wheat grain based diet.

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