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Performance of Broiler Chickens on Commercial Diets Mixed with Whole or Ground Wheat of Different Varieties

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Abstract: To study the effects of mixing commercial diets with whole wheat on bird performance with respect to growing ages, each of four whole or ground wheat varieties was mixed with commercial diets at the presence or absence of enzyme at the following rates: 10% from 7 to 14 d of age, 20% from 14 to 21 d of age, 30% from 21 to 28 d of age, and 50% from 28 to 35 d of age. A control group of broiler chickens was fed only with commercial diets throughout. Birds performed well with the diets mixed with 10 and 20% wheat whether ground or whole. Feed intake of birds significantly ($P < 0.05$) depressed only by the diets mixed with 50% of both whole and ground wheat. Weight gain and feed conversion ratio significantly ($P < 0.05$) reduced with the diets mixed with 30 and 50% whole and ground wheat. There were no significant effects of wheat variety, wheat form and enzyme addition on the bird performance. Enzyme did not improve the performance of birds fed with the diets containing whole or ground wheat although there was a significant reduction in the digesta viscosity. Gut length was significantly longer in the birds fed on all the diets mixed with ground or whole wheat than the birds of control diets. It is concluded that birds can control feed intake unless they are not fed with the 50% wheat mixed diet until 28 d of age and grow optimally unless they are not fed with the 30% wheat mixed diet from 21 to 28 d of age. Furthermore, it is suggested that the fortification with some essential nutrients is necessary at early growing ages when mixing the diets with whole/ground wheat at high rates of $< 30\%$.

Key words: Broiler chickens, whole wheat, wheat variety, enzyme, viscosity

Introduction

Nutritionists have long focused on the changes in dietary factors to minimize body fatness and to increase lean tissue whereas geneticists try to select today's commercial broilers for rapid growth rate. Feed restriction, diet dilution and semi or free-choice feeding are the main dietary manipulations being recently tested with fast growing broiler chickens to optimize growth rate and feed efficiency, and most importantly to reduce the feed costs.

It has been previously reported that chickens have an ability to meet their nutrient requirements and grow optimally when given a choice of two diets different in nutrient composition (Shariatmadari and Forbes, 1993). Many semi-choice or free-choice trials were conducted to examine the changes in performance of broilers fed with the diets mixed with whole or ground wheat in order to reduce the feed costs.

By knowing the ability of chickens for a precise control of feed intake, a mixture of whole wheat in broiler diets can be used an alternative vehicle to reduce feed cost in the broiler industry. A whole wheat feeding program is generally practiced by the Scandinavian and Canadian poultry producers (Peterson, 1997; Classen and Bennett, 1997). The concentration of whole wheat in a complete commercial mixture is set at 5% at 7 d of age and then increased by 5% each week to reach a 35% mixing rate at the end of 42 d of age. Due to the low mixing rates of whole wheat in total feed mixture, this practice was found to have no negative impact on growth rate or feed efficiency, whereas whole wheat feeding reduced total feed cost and increased gross margin depending on the price relationship between whole wheat and feed mixture (Peterson, 1997). However, no experiments are yet reported to monitor the bird performance under the feeding of high mixing rates of whole or ground wheat in commercial diets and to determine how the feeding behaviour of birds is formed when such dietary modifications are practiced.

Offering diets in different energy contents only, 2.700, 2.900, 3.100 or 3.300 kcal/kg ME (Metabolizable Energy), to broiler chickens on *ad libitum* basis, was found to have no effects on growth rate, but there was a reduction in carcass fatness. However, when these diets were given in restricted quantities the growth rate was reduced. On the other hand, offering all the above diets in a free choice feeding experiment caused a precise control of feed intake, although lowering dietary energy content tended to reduce carcass fat deposition (Leeson *et al.*, 1996b).

Leeson *et al*. (1996a) reported that diluting commercial broiler diets from 35 to 49 d of age with oats hulls and sand, which lead to the diets deficient in energy content, caused a significant reduction in body weight at 42 d of age, although the growth was compensated thereafter. Birds seemed to maintain energy intake, but there was increased feed intake with energy deficient diet. On the

Table 1: Nutrient composition of broiler diets mixed with whole or ground wheat varieties

Dietary Ingredients, g/kg	Starter	Grower	Finisher
Corn	517.78	492.25	550.74
Wheat	----	60.0	50
Corn protein supplement	----	84.5	55.16
Soybean	180.0	246.1	183.50
Soybean meal	241.6	74.83	99.83
Fish meal	19.83	3.33	-----
Tallow	5.43	-----	20
Limestone	8.45	9.45	9.55
Salt	2.73	2.91	5.0
DCP	18.33	19.48	19.13
Vitamin premix[1]	2.00	2.00	2.0
Mineral premix[2]	1.00	1.00	1.0
L-lysine	----	2.3	2.03
DL-methionine	2.85	1.85	2.06
Total	1000	1000	1000
Nutrient Analysis			
Dry Matter, g/kg	886.0	884.3	890.8
Crude Protein, g/kg	244.7	236.0	207.4
Metabolisable Energy, kcal/kg)	3054	3159	3200
Crude cellulose, g/kg	29.9	39.5	33.87
Crude fat, g/kg	60.87	59.2	61.3
Starch, g/kg	391.3	429.3	379.5

[1]Containing 4.800 IU Vit A (retinyl palmitate); 600.000 IU Vit D_3 (cholecalciferol); 12.000 mg Vit E (dl-"-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 Nicotinamide, 4.000 mg Calcium-D-Pantothenate, 300 mg Folic acid, 30 mg D-Biotin, 150.000 mg Choline chloride, 4.000 mg Antioxidant.[2]Containing 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.

other hand, a linear decrease in carcass weight and breast meat yield was observed with birds fed both protein and energy deficient diets. These results suggested that birds can grow quite well on low energy diet but a period of 7 d is necessary to adjust their feed intake (Leeson *et al.*, 1996a).

Wheat has been traditionally used in broiler diets as main source of dietary energy, especially in European Countries. However, wheat can have variable nutritional values, depending on geographical area of grown (Willingham *et al.*, 1960), harvest conditions and harvesting time and different varieties of wheat being cultivated (Willingham *et al.*, 1960; Bedford, 1996). Nutritional variability in wheat grains have been long explained with their different AME (Apparent Metabolizable Energy) values, due to the diluting effect of wheat fibre on bird performance (Aman and Hesselman, 1984). However, dietary fibre *per se* was not responsible for the variation in overall bird performance related with the diets diluted by fibre (Savory and Gentle, 1976a,b). Bedford (1996) has also reported remarkable nutritional variability between different wheat varieties associated with their differing NSP (nonstarch polysaccharide) contents; most of its negative effects such as depressed performance in association with increased viscosity of gut content can be overcome by dietary enzyme supplementation (Bedford, 1995).

Furthermore, it can be thought the some varieties of wheat may have higher nutritional value than the other wheat varieties in whole wheat mixing trials. Therefore, It is proposed that the response of birds during various growing stages to the diets mixed with whole wheat at increasing rates can be affected by different varieties of wheat to which enzymes are added or not.

The objective of the present experiment was, therefore:

1. to determine the nutritive values of four Turkish wheat varieties for broiler chickens in a whole wheat feeding trial,
2. to investigate the effects of both ground and whole wheat at high mixing rates with three commercially practiced diets for different growing stages (starter, grower and finisher)
3. to test the supplementation of diets containing whole or ground wheat grain with exogenous feed enzyme.

Materials and Methods

Three hundred and six, one-d old chicks (Avian strain) were kindly provided by Banvit Poultry Integrator, Bandirma, Turkey. They were kept in cages placed in a room where temperature was around 33 ºC on the arrival. Temperature was then reduced by 4 ºC every week to reach 22 ºC by 21 d of age, thereafter maintained at

Table 2: Feeding program of whole/ground wheat varieties mixed with broiler diets

Periods	7 to 14 d of age	14 to 21 d of age	21 to 28 d of age	28 to 35 d of age
Variety	Starter	Starter	Grower	Finisher
Cumhuriyet	10% wheat + 90% starter	20% wheat + 80% starter	30% wheat + 70% grower	50% wheat +50% finisher
Panda	10% wheat + 90% starter	20% wheat + 80% starter	30% wheat + 70% grower	50% wheat +50% finisher
Gerek	10% wheat + 90% starter	20% wheat + 80% starter	30% wheat + 70% grower	50% wheat +50% finisher
Galio	10% wheat + 90% starter	20% wheat + 80% starter	30% wheat + 70% grower	50% wheat +50% finisher
Control group	100% starter	100% starter	100% grower	100 finisher

around 22 ºC until 35 d of age. The temperature and humidity were together automatically controlled in the room throughout the experiment. The one-d old chicks were fed *ad libitum* with a commercial starter diet up to 7 d of age. The experiment was started at 7 d of age and terminated at 35 d of age. The experiment was designed to have a totally 17 experimental groups, 1 control group and 16 treatment groups, each with 3 cages of replicate, resulting totally in 51 experimental cages (units). All the chicks at 7 d of age were weighed and separated into 51 individual cages with similar body weight (154.25 ± 5.64), each with 6 birds up to 21 d of age. Three birds from each cage were killed for the measurement of digesta viscosity and the gut size at 21 d of age. The experiment was continued with the other remaining 3 birds in each cage from 21 to 35 d of age. During the experiment, there was a constant lighting in the room.

The birds of control group were *ad libitum* fed with a commercial starter diet from 7 to 21 d of age, a commercial grower diet from 21 to 28 d of age and a commercial finisher diet from 28 to 35 d of age. Abalioglu Feed Integrator, Denizli, Turkey, kindly provided the commercial diets. The nutrient composition of control diets is given in Table 1.

The other 16 treatment groups comprised of 4 wheat varieties, each with 2 wheat forms (whole versus ground) to which enzyme inclusion was made at the rate of 0 or 1 g/kg. Four wheat varieties (Golia, Gerek, Cumhuriyet and Panda) were obtained from Hediye Feed Mill, Isparta, Turkey. The half quantity of each wheat variety was ground in a hammer mill to pass a 2.0 mm sieve, the other half was left as whole grain.

Ground or whole grains of each of the four wheat varieties were mixed with the control commercial diets in a mixer at the rates of 10, 20, 30 and 50% and fed to birds for the periods between 7 and 14 d of age, 14 and 21 d of age, 21 and 28 d of age and 28 and 35 d of age, respectively (Table 2). All treatment diets, except the control diet, were added with 0 or 1 g/kg feed enzymes. Feed enzyme was kindly provided by Kartal Kimya, Istanbul, Turkey. It was stated that the feed enzyme was Avizyme 1302 (Finnfeeds International) with the activities of 5000 U/g endo-1,4 beta-xylanase (EC 3•2•1•8) and 1600 U/g protease (EC 3•4•21•62).

Feed intakes of birds in all experimental groups were daily recorded at 9.00 hours. The remaining feed was discarded from the feeders to which fresh feed was supplied every day. Body weights of birds in the groups were weekly recorded. Feed conversion ratio (FCR) was calculated by dividing the amount of feed consumed during a period of 7 day with the weight gained during that specified period.

Three birds from each replicated cage at 21 d of age were killed to collect digesta samples from the ileum of their digestive tract. The content of the ileum was milked into 10-ml centrifuge tube for centrifugation. The supernatant of the ìleal content was taken to Brookfield digital viscometer, cone-plate type, to measure the viscosity of digesta at room temperature (22 ºC). The lengths and weights of whole digestive tract were also measured for all birds killed at 21 d of age.

The data from the experimental groups were analyzed separately for every week of the experiment using GLM ANOVA (General Linear Model) under the Statistical Computer Program of SPSS for Windows, 1996. Duncan's Multiply Range Test was used to find the differences between the means of experimental groups (Duncan, 1955).

Results

Feed Intake (FI), Weight Gain (WG) and Feed Conversion Ratio (FCR): The results of FI presented in Table 3 clearly showed that young growing birds of 7 to 21 d of age consumed similar amount of feed with the diets mixed with wheat grain at the rates of 10 or 20%, whether wheat grain was ground or whole. Birds fed with the diets mixed with the varieties of Gerek and Panda at the rates of 30 % (21 to 28 d of age) or 50% (28 to 35 d of age), respectively had significantly increased FI, compared to the other wheat varieties. The effects of wheat form (whole versus ground), enzyme inclusion and the effects of 2 and 3 way interactions on FI were not found to be statistically significant ($P > 0.05$) during the each week of experiment (Table 3).

Broiler chickens fed on the diets mixed with four different wheat varieties at the rates of 10, 20, 30 and 50% with

Table 3: Daily feed intake, g/day/bird, (Means with SEM, the pooled standard error of mean) of broiler chickens fed with the diets mixed with whole or ground wheat at different rates

Variety/form/enzyme	Inclusion rates	10% Wheat (7 to 14 d)	20% Wheat (14 to 21 d)	30% Wheat (21 to 28 d)	50% Wheat (28 to 34 d)
Galio	Mean	48.07^{x}	82.08^{x}	89.29^{xy}	124.25^{xy}
Cumhuriyet		46.50^{x}	76.22^{x}	89.82^{xy}	126.34^{xy}
Panda		45.10^{x}	76.79^{x}	82.11^{x}	135.76^{y}
Gerek		47.70^{x}	82.08^{x}	92.27^{y}	122.02^{x}
	SEM	1.33	2.60	2.83	4.95
Whole	Mean	46.98^{x}	79.37^{x}	88.08^{x}	124.76^{x}
Ground		46.70^{x}	79.21^{x}	88.66^{x}	129.40^{x}
	SEM	0.94	1.84	2.00	3.50
Enzyme (-)	Mean	47.04^{x}	80.50^{x}	87.57^{x}	126.83^{x}
Enzyme (+)		46.64^{x}	78.08^{x}	89.17^{x}	127.35^{x}
	SEM	0.94	1.84	2.00	3.50
Significance (P)	Variety	0.399	0.226	0.088	0.236
	Wheat form	0.837	0.950	0.838	0.352
	Enzyme	0.931	0.236	0.219	0.688
	2 and 3 way interactions	NS	NS	NS	NS

^{x,y} Different letters in the same column show significant (P < 0.05) differences between the means of treatment groups.

Table 4: Average weight gain, g/day/bird, (Mean ± SEM, standard error of mean) of broiler chickens fed with diets mixed with wheat at different rates during the experiment

Variety/form/enzyme	10% Wheat (7 to 14 d)	20% Wheat (14 to 21 d)	30% Wheat (21 to 28 d)	50% Wheat (28 to 34 d)
Galio	31.00^{x}	45.91^{x}	34.70^{x}	35.27^{x}
Cumhuriyet	29.77^{x}	41.79^{x}	34.47^{x}	38.39^{x}
Panda	28.91^{x}	44.49^{x}	32.75^{x}	36.56^{x}
Gerek	30.58^{x}	46.09^{x}	33.85^{x}	34.48^{x}
SEM	1.11	1.78	1.78	1.88
Whole	30.17^{x}	44.56^{x}	32.96^{x}	33.77^{x}
Ground	29.96^{x}	44.58^{x}	34.92^{x}	38.58^{y}
SEM	0.74	1.26	1.26	1.33
Enzyme (-)	30.16^{x}	45.73^{x}	33.58^{x}	35.25^{x}
Enzyme (+)	29.97^{x}	43.41^{x}	34.31^{x}	37.10^{x}
SEM	0.74	1.26	1.26	1.33
Significance (P)Variety	0.524	0.311	0.869	0.490
Wheat form	0.852	0.987	0.280	0.016
Enzyme	0.857	0.202	0.684	0.333
2 and 3 way interactions	NS	NS	NS	Ns

^{x,y}Different letters in the same column show significant (P < 0.05) differences between the means of treatment groups.

regard to growing ages 7 to 14, 14 to 21, 21 to 28 and 28 to 35 d of age, respectively, gained similar live weight (Table 4) and had similar FCR (feed/gain) (Table 5), irrespective of physical form of wheat form and whether enzyme added or not WG and FCR of broiler chickens were not significantly (P > 0.05) affected by the wheat form and enzyme supplementation as overall (Table 4 and 5), except that birds of 28 to 35 d of age had a significantly lowered WG and worsened FCR with the 50% whole wheat added diet compared with the same diet of ground wheat. Similar to FI, two and three way interactions between variety, form and enzyme were not statistically significant on WG and FCE in the present experiment.

From Table 6, it can be seen that there were no statistical (P > 0.05) differences between FI of broiler chickens fed with either a commercial diet or the diets with ground or whole wheat varieties at the rates of 10, 20 and 30% for the periods of 7 to 14 (week 1), 14 to 21 (week 2) and 21 to 28 d of age (week 3), respectively. However, FI of broiler chickens was significantly (P < 0.05) depressed when the commercial diet was mixed with 50% wheat whether ground or whole from the age of 28 to 35 d without respect of variety (week 4).

During the periods of 7 to 14 (week 1) and 14 to 21 d of age (week 2), WG values of birds fed with the wheat

Table 5: Average feed conversion efficiency (Mean ± SEM, standard error of mean) of broiler chickens fed with the diets mixed with wheat at different rates during the experiment

Variety/form/enzyme	Inclusion rates/ bird age	10% Wheat (7 to 14 d)	20% Wheat (14 to 21 d)	30% Wheat (21 to 28 d)	50% Wheat (28 to 34 d)
Galio	Mean	1.55^x	1.80^x	2.63^x	3.60^x
Cumhuriyet		1.56^x	1.83^x	2.65^x	3.36^x
Panda		1.57^x	1.74^x	2.54^x	3.80^x
Gerek		1.57^x	1.78^x	2.77^x	3.59^x
	SEM	0.03	0.04	0.11	0.17
Whole	Mean	1.57^x	1.78^x	2.70^x	3.80^x
Ground		1.56^x	1.79^x	2.60^x	3.38^x
	SEM	0.02	0.03	0.07	0.12
Enzyme (-)	Mean	1.57^x	1.77^x	2.65^x	3.67^x
Enzyme (+)		1.56^x	1.81^x	2.64^x	3.50^x
	SEM	0.02	0.03	0.07	0.12
Significance (P)	Variety	0.986	0.456	0.567	0.385
	Wheat form	0.908	0.931	0.352	0.025
	Enzyme	0.936	0.330	0.905	0.345
	2 and 3 way interactions	NS	NS	NS	NS

x,y Different letters in the same column show significant ($P < 0.05$) differences between the means of treatment groups.

Table 6: FI, WG and FCR of broiler chickens fed with a commercial diet or the diets mixed with whole and ground wheat

	7 to 14 d 10%	14 to 21 d 20%	21 to 28 d 30%	28 to 35d 50%
Feed Intake (g/d per bird)Ages				
Control	44.27^x	77.32^x	93.14^x	183.20^x
Whole	46.98^x	77.38^x	88.08^x	124.76^y
Ground	46.70^x	79.21^x	88.66^x	129.43^y
SEM	0.58	1.23	1.40	2.91
Weight Gain (g/d per bird)				
Control	29.10^x	44.94^x	45.49^x	85.19^x
Whole	30.10^x	44.56^x	32.96^y	33.77^y
Ground	29.96^x	44.58^x	34.92^y	38.58^z
SEM	0.43	0.87	0.92	1.85
Feed Conversion Ratio				
Control	1.52^x	1.72^x	2.05^x	2.14^x
Whole	1.57^x	1.78^x	2.70^y	3.80^y
Ground	1.56^x	1.79^x	2.60^y	3.38^z
SEM	0.02	0.04	0.05	0.09

x,y,z Different letters in the same column show significant ($P < 0.05$) differences between the means of treatment groups.

mixed diets at the rates of 10 and 20% whether ground or whole were not significantly ($P > 0.05$) different from that of control birds on the commercial diet. However, increasing the dietary rate of wheat from 20 to 30% during the periods of 21 to 28 d of age, or to 50% during the periods of 28 to 35 d of age, respectively, depressed weight gain, compared to the control diet. The reduction in WG was more pronounced for the diets mixed with whole grain than ground grain (Table 6).

Birds fed with commercial diet had similar FCR with the birds on the diet mixing with wheat at the 10 and 20% rates (Table 6). Birds fed on the diets of ground or whole wheat at the rates of 30% during the periods of 21 to 28 d of age or 50% during the periods of 28 to 35 d of age had a significantly ($P < 0.05$) worsened FCR compared to those fed commercial diets in the experiment.

Digesta Viscosity and Gut Size: At the age of 21 d, intestinal viscosities (cPs) of broiler chickens were statistically ($P < 0.05$) affected by the variety of grain and the enzyme supplementation, but not by the wheat form, whole or ground (Table 7). The lowest intestinal viscosity was obtained from the birds fed with the control diet and those fed with wheat varieties of Galio and Gerek, 4.00,

Table 7: Average intestinal viscosity (Mean ± SEM, standard error of mean) of broiler chickens fed with the diets of whole or ground wheat at the age of 21 d

Wheat Varieties	Control	Galio	Cumhuriyet	Panda	Gerek	SEM
	4.00[a]	4.72[ac]	7.54[b]	7.93[b]	6.41[bc]	0.67
Wheat form		Whole		Ground		SEM
		6.50[a]		6.81[a]		0.48
Enzyme Addition		Absent		Present		SEM
		9.22[a]		4.08[b]		0.48

Significance (P)						
Variety (V)	Wheat form (F)	Enzyme (E)	VxF	VxE	FxE	VxFxE
0.008	0.642	0.001	0.073	0.01	0.622	0.001[a,b]

[a,b]Different letters in the same row show significant (P < 0.05) differences between the means of treatment groups.

Table 8: Whole digestive tract length (cm) and weight (g) (relative to 100 g body weight) of broiler chickens fed with the diets of whole or ground wheat at the age of 21 d. (Mean ± SEM, standard error of mean)

Wheat Varieties	Control	Galio	Cumhuriyet	Panda	Gerek	SEM
Length, cm	97.33[a]	130.41[b]	125.83[b]	128.33[b]	130.75[b]	5.35
Relative weight, g	17.64[a]	16.43[a]	17.47[a]	18.43[a]	17.60[a]	0.58

Wheat form	Whole	Ground	SEM
Length, cm	132.45[a]	125.20[a]	3.78
Relative weight, g	16.94[a]	18.02[a]	0.41

Enzyme Addition	Absent	Present	SEM
Length, cm	125.91[a]	131.75[a]	3.78
Relative weight, g	18.04[a]	16.92[b]	0.41

Significance (P)	Variety (V)	Wheat form (F)	Enzyme (E)	VxF	VxE	FxE	VxFxE
Length, cm	0.910	0.185	0.284	0.115	0.764	0.227	0.136
Relative weight, g	0.133	0.070	0.061	0.512	0.965	0.216	0.320

[a,b] Different letters in the same row show significant (P < 0.05) differences between the means of treatment groups.

4.72 and 6.41 cPs, respectively. Birds fed on the diets with wheat varieties of Cumhuriyet and Panda produced significantly (P < 0.05) high intestinal viscosities, 7.54 and 7.93 cPs, respectively (Table 7).

Birds either fed on the whole or ground wheat mixed diet had similar intestinal viscosity at the age of 21 d, 6.50 versus 6.81 (cPs), respectively (Table 6). However, enzyme addition had an overall reducing effect on the ileal viscosity, 9.22 (cPs) in no enzyme added diet versus 4.08 (cPs) in enzyme added diets.

The whole length and relative weight of digestive tract (g/100g body weight) in broiler chickens were not statistically (P > 0.05) affected by the wheat variety, wheat form and enzyme addition. There were also no significant (P > 0.05) interaction effects on these parameters of gut size (Table 8). However, the whole digestive length of control birds was significantly (P < 0.05) shorter than that of all treatment birds. On the other hand, the birds given the whole wheat mixed diet had numerically longer but lighter digestive tract than those given the ground wheat mixed diet. Enzyme added diets, without respect to wheat form and variety, caused a numerically longer, but lighter digestive tract in broiler chickens than no enzyme added diets (Table 8).

Discussion

The nutritional values of four different wheat varieties in wheat feeding trial were seen to be almost similar because the performance parameters, FI, WG and FCR did not significantly differ from variety to variety. Even though small differences in feed intakes between wheat varieties show similar nutrient composition, the different wheat varieties may have significantly differed NSP contents (Non-starch polysaccharides) with which the performance of birds can be depressed (Bedford and Classen, 1992). Especially, AME values were influenced by different wheat varieties. Only some circumstantial changes in the present case were observed in FI, WG and FCR of birds fed with the diets of wheat varieties, especially at high rates. This may reflect the similar changes in their NSP contents because Bedford (1996) reported significant variability between the NSP contents and the performance of birds fed with different wheat-based diets. The *in vivo* viscosity values of ileal contents, the length and relative weight of whole digestive tract of birds fed with the diets of different wheat varieties reflected similar phyco-chemical behaviour of their NSP, except the *in vivo* viscosity value of Galio variety. Therefore, it can be possible to speculate that all the varieties of wheat grain tested in the present experiment have similar nutritional values for broiler chickens.

Irrespective of varieties, mixing commercial broiler diets either with whole or ground wheat varieties by 10%, from 7 to 14 d of age, and 20%, from 14 to 21 d of age, did not cause depressed FI, WG and FCR compared to the control diet. Peterson (1997) suggested a gradual increase of whole wheat in the total feed mixture by 5% for each week, starting with 5% at 10 d of age and finishing with 35% at 42 d of age. Similarly, Polat *et al*. (1997) suggested at least a 35% mixing rate of whole wheat in the total feed mixture at 42 d of age. However, the present results suggested that birds could normalize the nutrient intakes with 10 and 20% whole or ground wheat up to 21 d of age. These mixing rates, however, lead to no depressed performance and eventually were introduced at the young periods. The birds of the present experiment were offered the wheat mixed diets at younger periods than the birds in the study of Peterson (1997). It can be, therefore, suggested that birds can grow optimally with the diets with 10% wheat from 7 to 14 d of age and with 20% wheat from 14 to 21 d of age.

The birds up to the age of 21 d were fed with the commercial broiler starter diet- mixing with 10 and 20% wheat grains- which have a nutrient composition of 244.7 g/kg CP and 3054 kcal/kg ME without any dietary modifications in the total feed mixture. When the grower commercial diet was mixed with 30% ground or whole wheat, starting from 21 d of age to 28 d of age, WG and FCR depressed significantly whereas FI was still unaffected, compared to the birds of control group. Additionally, all productive parameters of FI, WG and FCR were significantly depressed by 50% dilution rate during the periods of between 28 and 35 d of age. The nutrient composition of the control grower diet and the control finisher diet were, in fact, lower than that of the starter diet. Thus, the level of the difference in nutrient composition, particularly for crude protein (CP), between the commercial diets and the whole or ground wheat was eventually greater during the finishing and growing periods than the starting period. The lowered nutrient composition may have become severe for the birds when considering the increased rates of wheat in the total mixture, especially during the finishing period where the mixing rate was 50%. Therefore, the grower and finisher diets need to be fortified by the appropriate nutrients. Classen and Bennett (1997) reported that much of the lost performance in birds fed on the diets mixed with whole or pelleted wheat in the diet was restored by supplementing the whole wheat mixed diets with the synthetic amino acids of lysine, methionine and threonine. Therefore, if the high mixing rates of wheat are intended to be practiced in poultry production the fortification of such diets with necessary nutrients, especially with amino acids, is of great importance. However, the levels of nutrient supplementation must be identified when it is necessary, and the results of the present study will provide where the nutrient fortification are necessary with regard to both wheat inclusion rates and growing periods.

Leeson *et al*. (1996a) found that birds can have an initial depressed growth rate by only energy deficient diet with no major dilution of protein or amino acids, but they can be adapted rapidly to compensate for it after a short time, a week, by a dramatic increase in the feed intake. However, when both energy and protein were deficient in the diets the older broiler chickens were not able to maintain constant intakes of either energy or protein, similar to the present study in which the performance of bird was greatly reduced by high mixing rates of whole/ground wheat.

The depressed growth rate with 30 and 50% rates can be, therefore, due to the depressing effect of limiting nutrient intakes, particularly for protein, induced by depressed FI. Expectedly, the role of amino acids could be the most pronounced cause of the depressed performance by the 30 and 50% rates in the present case. If the birds progressively had increased their FI by the time, similar to the previous case (Leeson *et al*., 1996a), the initial depressed growth rate and worsened FCE with 30% wheat mix could have been compensated on the following weeks, perhaps with 50% mixing as well.

The birds seemed to normalise nutrient intake up to 30% wheat mixed in the diet, but no normalization seen with 50% mixing. Savory and Gentle (1976a) showed a similar normalization of nutrient intake with 20% dilution with the dietary fibre that was taken for 8 to 10 days although the growth rate was not maintained, unlikely to the present study.

Although Savory and Gentle (1976b) showed no significant effect of dietary fibre *per se* on the utilization of other nutrients, they found a reduction in diet ME by fibre inclusion. Dietary fibre is most importantly associated with the increased rate of feed passage throughout the gut. In the present case, the diets of 50% wheat, even with 30%, may have introduced a great amount of dietary fibre into the gut lumen, suggesting that the rate of feed passage can be increased. However, this was not found to be so in the present experiment because FI did not increase with all wheat rates, indicating a possible lowered passage rate of feed, which was induced by the increased digesta viscosity.

On the other hand, the overall reduction in FI, WG and FCR of birds at the high ratio of wheat in the total mixture, compared with the control birds may be due to the high level of NSP introduction into the lumen of intestine where the nutrient uptake can be limited by the antinutritive effect of NSP (Van Der Klis *et al.*, 1993a,b). These results suggested that high rates of mixing diet with wheat grain, especially during the fast growing periods caused a possible increase in the amount of NSP in the lumen causing to limit the nutrient uptake.

Grinding wheat did not prevent the birds from the depressed growth rate when they are fed with the ground wheat mixed diets at the high rates although the birds of the whole wheat mixed diet gained less and had a worsened FCE than those fed the same diet with ground wheat.

Similarly, performance of broiler chickens was not significantly ($P > 0.05$) affected by enzyme inclusion (Table 2). Although Peterson (1997) found no significant effect of enzyme supplementation on the performance of broilers on whole wheat feeding, enzyme supplementation are generally reported to improve bird performance with diets based on cereals (Petterson and Aman, 1988; Pawlic *et al.*, 1990; Bedford and Classen, 1992). The reduced digesta viscosity in broiler diets based on wheat grains supplemented with enzymes was found to be associated with improved performance by many others (Fengler *et al.*, 1988; Bedford *et al.*, 1991; Almirall and Garcia, 1994). However, in the present case the effect of enzyme on the viscosity did not reflect any improvement in the bird performance. Yasar and Forbes (1999 and 2000) suggested that the high rate of wheat presented in the broiler diets to which enzyme added could cause reduced digesta viscosity, but not any improvement in bird performance.

The present results revealed that there were no significant differences in the nutritive values of different wheat varieties in a whole wheat feeding trial, and enzyme supplementation of the diets of wheat varieties at various mixing rates did not cause significant improvement in performance although the digesta viscosity was lowered by the presence of enzyme in the whole mixture. It can be concluded that the low rates of mixing the diets with wheat can be successfully practiced in poultry but in the case of the high rates of whole or ground wheat mixing $< 30\%$ the fortification of the diets with some essential nutrients will be inevitable. Further trials are on the way to determine the fortification effects of some essential nutrients on the lost performance induced by high wheat mixing rates in broiler chickens.

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