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In Vitro and *in Vivo* Variability in the Nutritional Compositions of Wheat Varieties[1]

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Abstract: The present study involved in the determination of non-starch polysaccharides (NSP) of 15 wheat varieties and their *in vitro* and *in vivo* nutritional characteristics. The determination of *in vitro* viscosity, NSP, acid detergent fibre (ADF), neutral detergent fibre (NDF), crude protein and bushel weight were done for the samples of wheat varieties. There were significant differences between the samples of varieties in respect of these parameters. Especially, high correlations were estimated between the *in vitro* viscosity, NSP, ADF, NDF and bushel weight with regard to wheat varieties: For instance, the increased *in vitro* viscosity of 15 wheat varieties was associated with the increased ADF and NSP and the decreased bushel weight of wheat varieties. All the varieties were classified into 4 different groups according to their contents of NSP, bushel weight and *in vitro* viscosity. An animal digestibility trial was conducted with only one wheat variety from each of the four groups with broiler chickens from 14 d old to 42 d old. These varieties were Gun_{95}, $Cakmak_{79}$, $Gerek_{79}$ and $Kundura_{1149}$. Animals fed with all diets based on wheat varieties consumed significantly higher feed than the animals fed with a control diet based on corn grain. Especially, Gun_{95} and $Cakmak_{79}$ varieties caused to increased feed intake compared with the other two varieties. All wheat based diets lead to significantly low weight gain, worsened feed conversion ratio, longer digestive tract and heavier digestive tract of animals in comparison with their counterpart of control diet. In addition, all wheat-based diets caused increased amount of abdominal fat and reduced carcass yield. On the other hand, there were some significant differences between the diets of wheat varieties in some of the above measured parameters. For instance, the lowest carcass yield was obtained from the $Kundura_{1149}$, $Gerek_{79}$, $Cakmak_{79}$ and Gun_{95}, respectively. Unlikely, the lowest abdominal fat was obtained from Gun_{95}, $Cakmak_{79}$, $Gerek_{79}$ and $Kundura_{1149}$, respectively. There were no significant differences in the digestibility of dry matter and crude protein between the wheat varieties. The NSP digestibility at both 21d old age and 42 d old age were numerically found to be higher for Gun_{95} and $Cakmak_{79}$ varieties only. Some wheat varieties have a greater nutritional potential in both animal and human nutrition.

Key words: Wheat, non-starch polysaccharides, nutrition

Introduction

Cereals and cereal by-products are the main dietary energy sources of the animal and human's diets. Cereal grains are also important dietary sources of cell-wall polysaccharides and cell storage polysaccharides. Van Soest (1982) suggested these polysaccharides as dietary fibre, in particular for ruminant feeds (e.g. forages, hay) with two fractions, soluble- (lipids, sugars, organic acids, starch, non-protein nitrogen and soluble protein) and insoluble-neutral detergent (soluble acid detergent fibre, hemicellulose, fibre-bound protein and insoluble acid detergent fibre, cellulose, lignin, silica). This definition of "dietary fibre" is lately not considered to be valid for the foods and feeds of human and monogastric animals, respectively. It was, then, defined complex carbohydrates as "starches" and "non-starch polysaccharides" (NSP) rather than dietary fibre by British Nutrition Foundation (1990). In monogastric animals and humans, the use of "NSP" to define complex dietary polysaccharides seems to be widespread. The dietary constituents of NSPs are methodologically classified into soluble- and insoluble-NSP. The former commonly include pentosans (arabinan + xylan) and β-glucans of cell wall polysaccharides, and the latter cellulose, hemicellulose and lignin.

Johson and Gee (1981) reported that NSP components of cereals caused significantly lowered uptake of glucose and cholesterol from the intestines, suggesting a reduced risk for heart diseases. Even, insoluble fractions of NSP compounds were claimed to play role in the prevention of colon cancer (Boffa *et al.*, 1992). More detailed information on the health related nutritional effects of NSP components can be found in the review of Harris and Fergusan (1993). Thus, NSP components of cereals seemed to have significant health and nutrition effects in

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human nutrition. Therefore, the nutritional characteristics of various wheat varieties must be taken into consideration within the food industry.

On the other hand, animal digestibility studies have used ME (metabolizable energy) or AME (apparent metabolizable energy) values of cereal based-diets in order to evaluate the nutritive value of wheat grains for monogastric animals. According to Annison (1991), wheat grains contain pentosans, cell wall NSP compounds, at appreciable levels, 50-80 g/kg DM. He demonstrated a negative linearity between AME of wheat and soluble NSP content, suggesting that NSP is responsible for the low ME of certain wheat grains for poultry species. Recently, Bedford (1996) clearly indicated that there is a great variability in ME and FCE between 9 wheat varieties and 16 barley varieties whether hulled or hulless. Furthermore, Annison (1992, 1993) observed that the addition of wheat-isolated pentosans to a diet of broiler chicks caused to significant reduction in nutrient digestibility (particularly starch), weight gain and ME utilization by the animals. Some researchers took one step further to name these negative effects of NSP components as antinutritive for monogastric nutrition. The following effects were also reported in animal studies under the various inclusion rates of wheat NSP in the diets: increased digesta viscosity leading to reduced assimilation and absorption of nutrients (Bedford *et al.*, 1991; Bedford and Classen, 1992, 1993), reduced epithelial cell renewal rate (Johnson *et al.*, 1988; Yasar and Forbes, 1999, 2000), reduced digestibility of nutrient in the gut and significant changes in the size and histo-morphology of epitheal tissue of intestine (Silva and Simithard, 1996; Yasar and Forbes, 1999, 2000). These antinutritive effects of cereal NSP have been shown to be overcome by various dietary treatments, enzyme supplementation and/or water treatment (Yasar and Forbes, 1999, 2000 and 2001).

The objective of the present investigation was to examine the variability in the chemical composition of 15 wheat cultivars grown in Turkey, and to study how this variability affects weight gain and feed conversion in broiler chickens. Intestinal viscosity and NSP digestibility were determined in order to examine a possible negative influence of the NSP content and different fractions of NSP in the wheat. Furthermore, abdominal fat and the size of the gut were measured to study whether high inclusion of the different wheat cultivars in some way influenced abdominal fat and the size of the gut.

Materials and Methods

Wheat varieties, *in vitro* viscosity and analyses of chemical composition: All wheats used were autumn sown wheat varieties, and represented approximately 60% of the wheat types harvested in Turkey in terms of the total production. The officially approved names of wheat varieties used in the present experiment were Besoztaya$_{30}$ (B$_{30}$), Besoztaya$_{5}$ (B$_{5}$), Bome$_{9}$, Gun$_{95}$, Besoztaya$_{22}$ (B$_{22}$), Cumhuriyet$_{1252}$ (C$_{1252}$), Cakmak$_{79}$, MBVD$_{18}$, BDMM$_{19}$, Gerek$_{79}$, Kutluk$_{94}$ and Besoztaya$_{3}$ (B$_{3}$), Kiziltan$_{91}$, Kundura1$_{149}$ and Dagdas$_{94}$. The bushel weights of corresponding wheat varieties were previously measured during the sampling.

The samples of wheat varieties were fine ground (0.5 mm) through a hammer mill for *in vitro* viscosity measurement and various nutrient analyses. All analyses were performed in triplicate.

In vitro viscosity of ground grains was determined according to Silva *et al.* (1983) as follows:

One gram of sample was suspended in a 15 ml of 0.2 M HCl-KCl acidic buffer (pH, 1.5). Samples were then placed in an agitating water bath at 37 °C for 3 h at 200 stroke per minute. Samples with buffer solution were then centrifuged at 900 g for 10 minutes and viscosity of supernatants was measured in a digital, cone-plate viscometer (model LVTD-CP-40, Brookfield Engineering Laboratories, Inc. Massachusetts, USA), at 25 °C at 50 RPM.

Samples of wheat varieties were analyzed for the contents of dry matter, crude protein, ADF, NDF and NSP whereas the samples of animal droppings obtained from the animal digestibility trial were only chemically analyzed for the contents of dry matter, crude protein and total NSP.

Crude protein is usually expressed as nitrogen content of a sample of wheat in terms of its apparent protein content (Nx6.25), assuming that all nitrogen in the wheat grain is present in the form of protein, which contains about 160g/kg nitrogen. The nitrogen content of each sample was measured using the Kjeldahl technique. The weight of nitrogen collected was calculated and thus the proportion of nitrogen in the sample, and this was converted into the proportion of crude protein by multiplying by 6.25 (AOAC, 1984). All samples were dried at 105 °C overnight until to reach a constant weight to determine the dry matter contents.

The dietary fibre components of Acid Detergent Fibre (ADF) and Neutr Detergent Fibre (NDF) were determined according to the method of AOAC (1984). Total NSP and their total constituent sugars were determined by a spectrometrical method according to the procedure of Englyst *et al.* (1994). The method measures dietary fibre as NSP, using an enzymec-chemical method and evolved from the principles detailed in the work of Englyst *et al.* (1994). Starch is hydrolyzed enzymically; NSP is isolated by the precipitation in ethanol and then hydrolyzed by sulphuric acid. The constituent neutral sugars and uranic acids are measured by colorimetry. The method allows separation of the NSP fraction in soluble NSP (S-NSP) and insoluble NSP (I-NSP). Soluble NSP was calculated as:

Soluble NSP = total NSP - insoluble NSP

Performance and digestibility trial : Fifteen wheat varieties were classified into 4 group, each with similar

Table 1: Composition of the experimental diets based on 4 representative wheat varieties and the control diet

Ingredients, g/kg	Control	Gun_{95}	$Cakmak_{79}$	$Gerek_{79}$	$Kundura_{1149}$
Wheat	------	530	530	530	530
Corn	513.1	------	------	------	------
Soybean meal	342.3	299.6	299.6	299.6	299.6
Sunflower meal	35.7	60.2	60.2	60.2	60.2
Fish meal	34.2	34.1	34.1	34.1	34.1
Vegetable oil	40.0	42.3	42.3	42.3	42.3
DCP	10.0	10.0	10.0	10.0	10.0
DL-methionine	3.40	2.50	2.50	2.50	2.50
L-lysine	1.00	1.00	1.00	1.00	1.00
Vitamin premix[1]	2.50	2.50	2.50	2.50	2.50
Mineral premix[2]	1.00	1.00	1.00	1.00	1.00
Anti-Coccidiants	1.00	1.00	1.00	1.00	1.00
Salt	2.50	2.50	2.50	2.50	2.50
Limestone	13.3	13.3	13.3	13.3	13.3
Total	1000	1000	1000	1000	1000
Analyzed nutrients					
Dry matter, g/kg	918.4	920.0	918.2	921.0	919.2
Crude protein, g/kg	220.6	212.0	210.2	213.0	211.2
Total NSP, g/kg	22.76	35.63	39.88	47.41	57.00
Total ash, g/kg	56.20	58.0	59.10	56.70	57.80
Total fat, g/kg	53.60	55.2	54.80	61.50	60.90
Total crude fibre, g/kg	35.0	38.4	37.90	35.20	36.40
Ca, g/kg (calculated)	10.1	9.50	9.70	11.0	11.30
Total P, g/kg (calculated)	6.50	6.40	6.50	6.80	6.70
Metabolizable Energy (calculated), (kcal/kg)	3007	3038	3017	3175	3160

[1]Vitamin Premix included in the following vitamins (in 1 kg feed): 4.800.000 IU Vit A, 600.000 IU Vit D_3, 12.000 mg Vit E, 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]Mineral Premix included in the following minerals (in 1 kg feed): 80.000 mg Mn, 80.000 mg Fe, 60.000 mg Zn, 8.000 mg Cu, 500 mg I, 200 mg Co, 150 mg Se.

Table 2: *In vitro* viscosity (cPs) of 15 wheat varieties

Wheat varieties	Mean	Standard deviation
B_{30}	1.83	0.02
B_5	1.87	0.21
$Bome_9$	1.92	0.13
Gun_{95}	1.93	0.01
B_{22}	2.09	0.01
C_{1252}	2.14	0.08
$Cakmak_{79}$	2.30	0.16
$MBVD_{18}$	2.30	0.11
$BDMM_{19}$	2.32	0.55
$Gerek_{79}$	2.36	0.62
$Kutluk_{94}$	2.40	0.08
B_3	2.50	0.17
$Kiziltan_{91}$	2.53	0.32
$Kundura_{1149}$	2.62	0.26
$Dagdas_{94}$	2.72	0.14

chemical analyses of only *in vitro* viscosity, NSP content and ADF content: A representative wheat variety from each classified group was chosen to formulate experimental diets. The wheat varieties of first group were B_{30}, B_5, $Bome_9$ and Gun_{95}, from which only Gun_{95} was chosen; those of second group were B_{22}, C_{1252}, $Cakmak_{79}$ and $MBVD_{18}$, from which only $Cakmak_{79}$ was chosen; those of third group were $BDMM_{19}$, $Gerek_{79}$, $Kutluk_{94}$ and B_3, from which only $Gerek_{79}$ was chosen and those of last group were $Kiziltan_{91}$, $Kundura_{1149}$ and $Dagdas_{94}$, from which only $Kundura_{1149}$ was chosen. The composition of the experimental diets based on the 4 representative wheat varieties and the composition of the control diet based on corn grain are given in Table 1. Experimental diets were formulated to provide the 4 wheat varieties at only one inclusion level of 530 g/kg. The diets differed only in the wheat cultivar included. Wheat was the only carbohydrate source in the 4 experimental diets, whereas in the control diet only ground corn grain was included as carbohydrate source. The diets were supplemented with essential amino acids, mineral and vitamin premixes to meet the requirements of broiler chickens. The all major dietary ingredients were milled to pass through a 3 mm screen in a hammer mill and mixed with the other ingredients in a small mixer. To avoid any cross-contamination of the different wheats, the hammer mill was cleaned after milling each

Table 3: Bushel weight, crude protein and dry matter content of wheat varieties (Means±standard deviation)

Wheat varieties	Bushel weight kg/hl	Crude protein, %	Dry Matter, %
B_{30}	81.95±0.15	11.45±0.22	88.88±0.02
B_5	78.33±0.19	13.96±0.13	85.27±0.01
$Bome_9$	77.78±1.12	14.11±0.33	85.21±0.03
Gun_{95}	74.79±0.05	10.72±0.27	87±0.01
B_{22}	75.43±0.34	11.58±0.19	88.55±0.01
C_{1252}	74.56±0.54	10.08±0.06	88.34±0.02
$Cakmak_{79}$	75.59±0.12	7.84±0.48	87.74±0.01
$MBVD_{18}$	72.71±1.19	9.03±0.52	87.77±0.005
$BDMM_{19}$	71.24±0.45	11.41±0.26	87.23±0.001
$Gerek_{79}$	66.90±2.65	13.18±0.14	86.87±0.02
$Kutluk_{94}$	66.52±1.32	12.65±0.17	87.14±0.02
B_3	65.37±2.00	12.88±0.05	86.79±0.01
$Kiziltan_{91}$	61.58±1.78	12.32±0.05	86.83±0.01
$Kundura_{1149}$	61.59±1.15	12.45±0.28	86.94±0.01
$Dagdas_{94}$	59.50±2.87	11.96±0.17	88.04±0.01

Table 4: ADF and NDF contents of 15 wheat varieties (Means±standard deviation)

Wheat varieties	ADF, mg/g	NDF, mg/g
B_{30}	26.93±0.65	0.2005±0.0058
B_5	2412±2.16	0.1234±0.0072
$Bome_9$	29.79±2.14	0.1722±0.0313
Gun_{95}	30.84±1.37	0.1677±0.0148
B_{22}	35.46±0.42	0.2038±0.0083
C_{1252}	28.00±0.80	0.1572±0.0039
$Cakmak_{79}$	31.06±1.18	0.1596±0.0062
$MBVD_{18}$	29.73±1.13	0.1548±0.0122
$BDMM_{19}$	26.99±0.10	0.1569±0.0135
$Gerek_{79}$	38.99±3.23	0.1541±0.0115
$Kutluk_{94}$	36.75±0.75	0.1618±0.0138
B_3	37.48±0.37	0.154±0.0120
$Kiziltan_{91}$	43.66±1.52	0.1684±0.0074
$Kundura_{1149}$	42.88±1.41	0.1806±0.0084
$Dagdas_{94}$	43.66±1.52	0.1445±0.0047

cultivar. The diets were provided as mash and fed in the whole experimental period from 14 to 42 d of age. The birds were fed until 14 d of age with the control diet, then the experimental diets and the control diet were fed to birds from 14 to 42 d of age. Feed and water were available *ad libitum.*

Three-tier batteries with raised floors were used in the experiment. Pen dimensions were 30×50×50 cm (height × length × width). Each pen had a 1 cm^2 wire mesh bottom and, for the first 10 to 14 days, a plastic mat with 0.1 cm^2 mesh was placed on the wire bottom. Each pen was equipped with a feeding trough placed outside and two water cups inside the pen. All batteries were placed in the same house provided with forced ventilation. The temperature was controlled and gradually reduced from 33 to 22 °C until day 21, and light was continuous during the whole experimental period. A total of 990 male broiler chickens (Ross 208) were obtained from a local hatchery and were allotted at random to 90 pens in 6 batteries with 11 chickens housed per pen. Since each pen representing one replicate, totally 18 pens within each 11 birds included were randomly assigned for each of 5 diet groups. The chickens were wing-banded, weighed individually at 14-d-old and then each week until 42 d of age. The chickens were inspected daily. Feed intake per pen (corrected for feed wastage) was recorded at the same time and feed conversion was calculated on a pen weight basis. A fecal output collection period based on 24 hours was set for 4 consecutive days from 21 d to 25 d of age and from the 38 to 42 d of age. The droppings were only collected from the 5 representative pens for each treatment group. The samples were analyzed for dry matter, crude protein and total NSP. In fact, digestibility of nutrient can precisely be determined using an indigestive feed marker in the diet. However, we had no opportunity to carry out this. The apparent nutrient retentions or digestibility rather than the precise digestibility of dry matter, crude protein and total NSP was calculated as subtracting the daily output of nutrient in the feaces from the daily intake of each nutrient and dividing by the daily intake of each nutrient again, and finally multiplying by 100. At the end of 42 d of age, 5 birds from each pen were killed to determine the carcass yield, the size of whole digestive tract, the weight of abdominal fat and ileal digesta viscosity. The digesta sample from ileum of each bird was collected, and centrifuged at 9000 g. The supernants were taken to the viscometer and the viscosity was measured at 41 °C (which is the deep body temperature of the animal) and at 50 RPM. The experiment complied with the guidelines of the Turkish Regulations with respect to animal experimentation and care of animals under study.

The statistical analyses of the data were carried out under the SPSS for Windows (1999). The analyses of variance was employed to establish the significance levels of treatment effects using a General Linear Model (GLM) where the differences between the treatment means were

Table 5: Soluble, insoluble and total NSP contents of 15 wheat varieties (Means ± standard deviation)

Wheat varieties	Soluble NSP	Insoluble NSP	Total NSP
B_{30}	12.38	43.88	56.26 ± 0.83
B_5	12.64	42.30	54.93 ± 1.01
$Bome_9$	14.52	43.56	58.08 ± 0.72
Gun_{95}	15.01	47.54	62.55 ± 0.55
B_{22}	14.80	55.65	70.45 ± 0.57
C_{1252}	16.08	48.25	64.33 ± 0.42
$Cakmak_{79}$	18.39	45.04	63.43 ± 0.48
$MBVD_{18}$	16.58	40.61	57.29 ± 0.16
$BDMM_{19}$	18.95	38.47	57.42 ± 0.47
$Gerek_{79}$	28.00	56.85	84.85 ± 1.55
$Kutluk_{94}$	20.72	48.35	69.07 ± 0.38
B_3	29.05	67.77	96.82 ± 0.79
$Kiziltan_{91}$	30.25	74.06	104.31 ± 1.50
$Kundura_{1149}$	32.13	71.52	103.65 ± 0.47
$Dagdas_{94}$	28.13	76.07	104.20 ± 0.66

Table 6: Mean values of feed intakes (g/ bird/period) of broiler chicken fed on 4 experimental and 1 control diets

Treatments	14 - 28 d	28 – 42 d	14 – 42 d
Control	1168[a]	2010.32[a]	3178.32[a]
Gun_{95}	1198[b]	2111.13[b]	3309.13[b]
$Cakmak_{79}$	1211[b]	2090.21[b]	3301.21[b]
$Gerek_{79}$	1226[c]	2043.45[c]	3269.45[c]
$Kundura_{1149}$	1200[b]	2064.00[c]	3264.00[c]
SEM	7.00	8.01	8.45
Significant level, P	0.001	0.001	0.001

SEM, standard error of the differences between the means
[ab]Different letters within each horizontal column indicated that the means of treatments significantly ($P < 0.05$) differed from each other.

separated by the Duncan's Multiple Comparison Test. The data were presented as the mean with SEM (a standart error of differences between the means). The significant level was set at 0.05.

Results

The *in vitro* viscosity data of the 15 wheat varieties were presented in Table 2, and the data on bushel weight, crude protein and dry matter of 15 wheat varieties were in Table 3.

Significant differences were observed between the wheat varieties in the parameters of *in vitro* viscosity, bushel weight, crude protein and dry matter. These differences in *in vitro* chemical composition of wheat varieties imply that wheat varieties can differ in NSP content. In order to examine the relationships between the above parameters, the correlation analysis was performed. No correlations were observed between bushel weight and nutrient compositions (crude protein and dry matter).

Significantly high negative correlation, -0.94, was observed between the bushel weight and *in vitro* viscosity values (Fig. 1). The varieties with high viscosity values, $Dagdas_{94}$, $Kundura_{1149}$ and $Kiziltan_{91}$ and B_3, had a significantly lower bushel weight than that of varieties with low viscosity values, B_{30}, B_5, $Bome_9$ ve Gun_{95}.

The results of ADF and NFD analyses were given in Table 4, from which can be seen that there was a great variability in ADF and a little variability in NDF contents of wheat varieties. The correlation coefficients between the *in vitro* viscosity and ADF and between ADF and bushel weight were +0.82 and -0.89, respectively. In Table 5, soluble, insoluble and total NSP contents of the wheat varieties were presented. In cereal grains, a great proportion of ADF was constituted by NSP, suggesting that ADF can be an indicator for the NSP content of the examined varieties.

There were significantly high variabilities between the wheat varieties in total NSP contents, proportionally reflecting a similar positive or negative variability in *in vitro* viscosity, ADF and bushel weight. The correlation coefficients between total NSP and *invitro* viscosity, between NSP and bushel weight and between total NSP and ADF values were +0.82, -0.90 and 0.93, respectively.

Since total NSP was positively correlated with *in vitro* viscosity and ADF, and negatively correlated with bushel weight total NSP content of wheat varieties can be estimated by these quick and fast *in vitro* measurements, particularly by *in vitro* viscosity and bushel weight parameters (Fig. 2). The regression equation of this relationship was as follows:

WheatNSP = 118.2 - 9.50 *in vitro* viscosity + 1.92 wheat ADF - 1.24 wheat bushel weight (Regression coefficient is 0.95).

As an overall, the examined varieties of wheat grains can be evaluated on the bases of *in vitro* chemical compositions within four groups, each with similar *in vitro* viscosity, bushel weight and the contents of NSP and ADF. As mentioned in the material and methods, one representative wheat variety was chosen from each group, and four broiler diets were based on these 4 wheat varieties and fed to broiler chickens. The data of performance were presented in Table 6 and 7. Broiler chicken fed with diets of 4 wheat varieties consumed significantly ($P < 0.05$) higher feed than the birds given a control diet based on corn grain. Within the wheat varieties, high values of feed intake were observed with the diets of Gun_{95} and $Cakmak_{79}$ whereas low intakes were obtained from the diets of $Gerek_{79}$ and $Kundura_{1149}$ (Table 6).

Wheat based-experimental diets significantly ($P < 0.05$) caused to reductions in live weight gain, compared to the effect of control diet (Table 7). Feed conversion ratios (g

Table 7: Mean values of live weight gain (g/ bird/period) and feed conversion ratios of broiler chicken fed on 4 experimental and 1 control diets

Treatments	14 - 28 d	28 – 42 d	14 - 42 d
Live weight gain			
Control	710.45[a]	1000.3[a]	1653.54[a]
Gun_{95}	650.23[b]	921.89[b]	1536.66[b]
$Cakmak_{79}$	645.65[b]	906.18[bc]	1609.8[c]
$Gerek_{79}$	630.85[c]	879.45[cd]	1505.05[b]
$Kundura_{1149}$	665.56[d]	844.46[d]	1536.84[b]
SEM	5.45	17.50	22.50
Significant level, P	0.01	0.001	0.01
Feed conversion ratios			
Control	1.64[a]	2.01[a]	1.92[a]
Gun_{95}	1.84[b]	2.29[b]	2.15[bd]
$Cakmak_{79}$	1.87[bd]	2.30[b]	2.05[c]
$Gerek_{79}$	1.94[c]	2.32[b]	2.17[b]
$Kundura_{1149}$	1.80[d]	2.44[c]	2.12[d]
SEM	0.02	0.03	0.02
Significant level, P	0.01	0.001	0.01

SEM, standard error of the differences between the means
[ab]Different letters within each horizontal column indicated that the means of treatments significantly ($P < 0.05$) differed from each other.

Table 8: Mean values of carcass yield, total length and weight of whole digestive tract (DT), abdominal fat and *in vivo* ileal viscosity of the 4 experimental and 1 control diets

Treatments	Carcass yield %	Total length of DT, cm	Total weight of DT, gr
Control	71.05[a]	226.65[a]	179.15[a]
Gun_{95}	71.51[a]	240.56[b]	201.71[b]
$Cakmak_{79}$	70.71[ab]	245.09[b]	205.15[b]
$Gerek_{79}$	69.62[b]	241.56[b]	205.25[b]
$Kundura_{1149}$	68.60[b]	248.90[b]	205.09[b]
SEM	0.73	4.32	4.94
Significant level, P	0.463	0.183	0.525
	Abdominal fat, gr		Viscosity, cPs
Control	33.00[a]		4.52[a]
Gun_{95}	42.21[b]		6.31[b]
$Cakmak_{79}$	47.46[c]		6.24[b]
$Gerek_{79}$	49.78[c]		7.81[c]
$Kundura_{1149}$	48.82[c]		8.97[c]
SEM	2.46		0.62
Significant level, P	0.001		0.05

SEM, standard error of the differences between the means
[ab]Different letters within each horizontal column indicated that the means of treatments significantly ($P < 0.05$) differed from each other.

feed intake: g weight gain over a specified period) were also significantly worsened by wheat diets, compared to the control diet. During the period from 14 to 42 d of age, the diet of $Cakmak_{79}$ lead to significantly high live weight gain compared to the diets of other varieties whereas the diets of Gun_{95} and $Kundura_{1149}$ between 14 to 28 d and the diet of Gun_{95} and $Cakmak_{79}$ between 28 to 42 d caused significantly high weight gain, compared to other counterpart diets.

Similarly, there were high values of feed conversion ratios with the diets of $Kundura_{1149}$ from 14 to 28 d, Gun_{95} and $Cakmak_{79}$ from 28 to 42d, and only $Cakmak_{79}$ from 14 to 42 d in comparison to other counterpart diets.

In Table 7, total length and total weight of whole digestive tract were given, from which can be seen that the broiler chickens were observed to have a longer and heavier digestive tract with the experimental diets based on wheat varieties than the diet of control. Furthermore, the carcass yield was seen to be significantly reduced by wheat based-diets compared to the control diet whereas the abdominal fat significantly increased with the wheat diets. *In vivo* viscosity of the digesta of ileum was greatly increased under the influence of wheat diets compared to the control counterpart.

$Kundura_{1149}$, $Gerek_{79}$, $Cakmak_{79}$ and Gun_{95} produced the lowest carcass yield and the highest abdominal fat values, respectively. Amongs to the wheat varieties, $Kundura_{1149}$ produced the highest *in vivo* viscosity, and this was followed by $Gerek_{79}$, $Cakmak_{79}$ and Gun_{95}, respectively (Table 8). However, the difference in *in vivo* viscosity was not proportionally reflected in the differences in feed intake and weight gain.

Apperant nutrient retentions of feed dry matter, crude protein and total NSP were significantly ($P < 0.05$) lower in the birds of wheat based-diets than the birds of control diet (Table 9). The birds of control diet retained similar amount of total NSP with the birds of wheat based-diets when the birds get older (42 d of age). No significant differences were observed in both dry matter and crude matter retention between the diets of different wheat varieties. Of the diets of wheat varieties, total NSP retentions were higher with the diets of Gun_{95} and $Cakmak_{79}$ than the diets of $Gerek_{79}$ and $Kundura_{1149}$.

Discussion

The studied wheat varieties can be classified into 4 groups according to their *in vitro* viscosity, ADF, bushel weight and total NSP contents in the present experiment (Table 10).

The reasons for this kind of classification were discussed as follows: In general, wheat varieties with < 64 kg/hl bushel weight is regarded as feed grade varieties with low nutrional quality, suggesting that the wheat grains with less bushel weight would have a lowered amount of crude protein (Leeson and Summers, 1997) (Table 3). However, this generalisation must not be considered to be so in the food industry since there were no positive or negative relationships between the grain bushel weight and crude protein level in the present study. Therefore, the apparent nutrient analyses of wheat grains such as Weende analyses are not sufficiently enough to provide pricise information

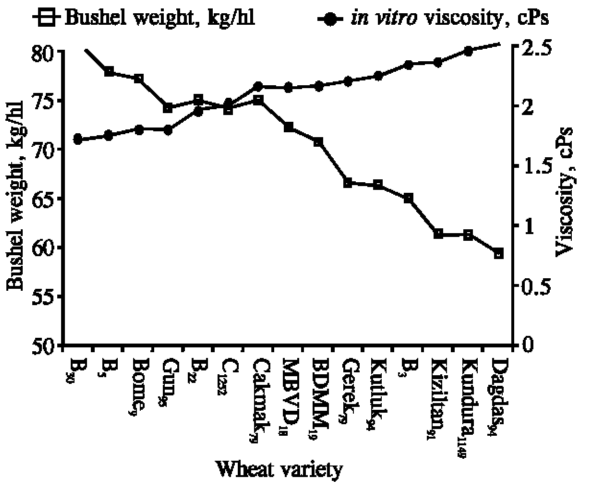

Fig. 1: Correlation (-0.94) between *in vitro* viscosity and bushel weight of wheat varieties.

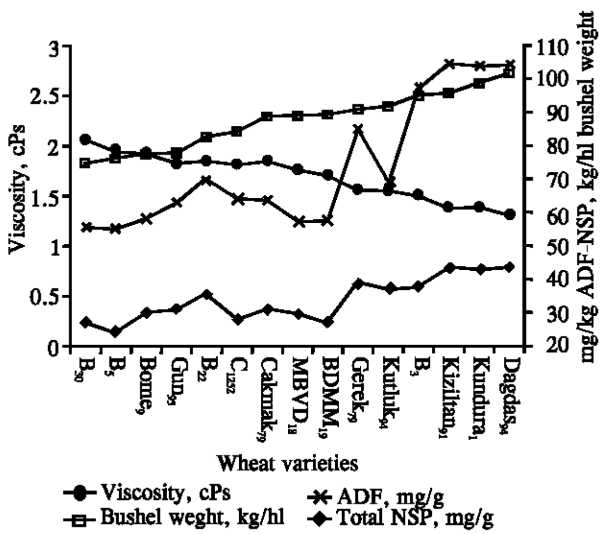

Fig. 2: The relationship between NSP and *in vitro* viscosity, ADF and bushel weight of 15 varieties

of grain quality. Regarding the other remaining chemical analyses there was a strong and meaningful association between the studied partameters of *in vitro* viscosity, bushel weight, ADF and total NSP (Fig. 1 and 2). In fact, there were high correlations between *in vitro* viscosity and NSP, ADF and NSP, and bushel weight and NSP. Since *in vitro* viscosity is a reliable and fast measurement, it can be a good indicator for the grain quality. Previously, Bedford (1993) and Yasar (1998) suggested that *in vitro* viscosity can provide more information on the total NSP contents of various varieties. In other words, the increased *in vitro* viscosity could indicate a high level of NSP of wheat grain, thereby implying low nutritional value for poultry (Bedford, 1993) since poultry species less utilise from the feeds of high viscous. In humans, the effect of high viscous foods resulted from the dietary fibre only can be more beneficial for various health reasons, particularly on the reduction of blood cholesterol level and diminished uptakes of fatty acids and other nutrients (Johson and Gee, 1981; Boffa *et al.*, 1992). In contrast to the study of Bedford (1993) in which only *in vitro* viscosity was evaluated as a good estimate for total NSP content of cereals, the regression analyses showed that *in vitro* viscosity, ADF and bushel weight are the good estimates for the total NSP contents of 15 wheat varieties in the present study.

The contents of total NSP determined in the present experiment were in a great aggrement with the NSP values of wheat grains reported by Choct and Annison, 1990; Boros *et al.*, 1994; Aman and Graham, 1987; Henry, 1985; Henry, 1987).

The use of wheat varieties with high nutritive value is desirable in fast growing animals, especially in meat-type birds. Therefore, feeding quality wheat varieties with low bushel weight and high viscous have been long supplemented with NSP-degrading exogenous enzymes during the feed manufacturing, depending the rate of wheat inclusion (Yasar and Forbes, 1999, 2000). When baking quality wheat grains with low inclusion rates and high nutritive value (low in NSP and viscosity) are considered in animal production the enzyme treatment is not practised. We can, therefore, be classified the above 4 groups of wheat varieties according to the chemical analyses as follows: the groups of 1 and 2 as baking quality wheats and the groups of 3 and 4 as feeding quality wheats.

The data of performance and nutrient retention can support that the present classification of 15 wheat grains is appropriate. In comparison with the effects of the control diet in broiler chicken, there were significant reductions in weight gain and feed conversion ratio in the birds fed with the diets of 4 different wheat grains. This indicated that all the diets of wheat varieties must be supplemented with the exogenous NSP-degrading enzymes in order to overcome the negative effects of NSP from the cereal feeding. It was previously well established that enzyme supplementation and/or water treatment of cereal based-diets at high inclusions had benefial effects in fast growing birds: reduced *in vivo* viscosity, improved weight and feed efficiency and increased ME intakes (Yasar and Forbes, 1999, 2000; Yasar *et al.*, 2000; Van Der Klis *et al.*, 1993a,b; Bedford, 1995). Of the wheat varieties groups, the decreased weight gain and worsened feed conversion ratio were less pronounced for Gun_{95} of the group 1 and $Cakmak_{79}$ of the group 2 than $Gerek_{79}$ of the group 3 and $Kundura_{1149}$ of the group4. This was also supported by the data of carcass yield and *in vivo* viscosities to a greater extend and by the data of nutrient retentions to a lesser extend. Similarly, the baking quality wheats (the groups of 1 and 2) had significantly higher

Table 9: Dry matter, Crude protein and total NSP (%) digestibility of the diets of 4 wheat varieties and the control diet

Treatments	21 d of age			42 d of age		
	DM	CP	NSP	DM	CP	NSP
Control	74.36[a]	67.56[a]	45.98[b]	77.87[a]	70.33[a]	41.23[a]
Gun_{95}	70.21[b]	62.73[b]	37.54[a]	72.33[b]	61.86[b]	42.56[a]
$Cakmak_{79}$	69.45[b]	63.00[b]	36.21[a]	73.21[b]	63.98[b]	43.18[a]
$Gerek_{79}$	65.03[b]	61.79[b]	36.59[a]	69.34[c]	63.23[b]	40.43[a]
$Kundura_{1149}$	66.98[b]	63.39[b]	35.98[a]	64.00[c]	64.14[b]	40.30[a]
SEM	2.21	1.59	0.54	2.32	2.74	1.33
Significant level, P	0.01	0.051	0.233	0.01	0.812	0.123

SEM, standard error of the differences between the means. [ab]Different letters within each horizontal column indicated that the means of treatments significantly ($P < 0.05$) differed from each other.

Table 10: *In vitro* chemical compositions of 15 wheat varieties

Groups	varieties	*in vitro* viscosity, cPs	ADF, mg/g	Bushel weight, kg/hl	Total NSP, mg/g
1	B_{30}	1.83	26.93	81.90	57.31
	B_5	1.87	24.12	78.30	56.00
	$Bome_9$	1.92	29.79	77.70	58.00
	Gun_{95}	1.93	30.84	74.70	62.50
2	B_{22}	2.09	35.46	75.40	69.89
	C_{1252}	2.14	28.00	74.50	64.89
	$Cakmak_{79}$	2.30	31.06	75.50	62.98
	$MBVD_{18}$	2.30	29.73	72.70	57.00
3	$BDMM_{19}$	2.32	26.99	71.20	56.86
	$Gerek_{79}$	2.36	38.99	66.90	85.65
	$Kutluk_{94}$	2.40	36.75	66.50	69.40
4	B_3	2.50	37.48	65.30	96.00
	$Kiziltan_{91}$	2.53	43.66	61.50	106.00
	$Kundura_{1149}$	2.62	42.88	61.50	103.00
	$Dagdas_{94}$	2.72	43.66	59.50	103.50

carcass yield and lower *in vivo* viscosity than the feeding quality wheats (the groups 3 and 4) whereas such differences were less observed in total NSP retentions between the wheat varieties. It can be therefore said that the the wheat varieties of the groups 1 and 2 were higher in the nutritional value than the varieties of the groups 3 and 4 for poultry nutrition. In terms of human nutrition matters, no such differentiation can be made since the wheat varieties did not differ in the dry matter, crude protein and total NSP retentions although there were some numerical differences. Dietary fibre through human daily intake is supposed to be a benefial nutrient for the maintaince of body weight and the mobility of the gut environments (Harris and Fergusan, 1993). The varieties studied in the present experiment can be said to have a potential in human nutrition although more nutritional measurements such as glucose and cholesterol uptake from the intestine must be taken under the different levels of wheat NSP.

In short, the followings can be concluded from the present experiments:

1. *In vitro* chemical characteristics of 15 Turkish wheat varieties were determined and the relationships between the studied parameters were established.
2. The nutritional value of the studied wheat varieties were determined in an animal experiment with the some important physiological and digestibility parameters.
3. There were great variabilities in both *in vitro* and *in vivo* experimental parameters between the wheat varieties. This differentiation between the varieties is of great importance in both feed and food industry.

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