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Effect of grain processing at different barley varieties on nutrient compositions, starch contents and in vitro digestion parameters

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Summary. This study examined how response of treating with heat of twelve different barley varieties on nutrient composition, starch contents, in vitro dry matter digestibility (IVDMD) and in vitro organic matter digestibility (IVOMD). In the study, a total of twelve different barley varieties (Tarm-92, Avcı-2000, Çetin-2002, Özdemir, İnce, Bolayır, Anka-04, Tosunpaşa, Larende, Martı) were used. Processing with heat to all barley varieties were significantly higher contents of DM, OM and neutral detergent fiber (NDF). However, starch contents were significantly lower compared to unprocessing group ($p<0.05$). Treating with heat in term of IVDMD and IVOMD had importantly decreased in some varieties, while no change did in some varieties ($p<0.05$). Of all results, it was thought that treating with heat of barley varieties were important in term of regulating synchronization of energy and protein in rumen of nutrient digestion in ruminant as it increase the cell wall.

Key words: barley variety, barley starch composition, in vitro digestibility

1. Introduction

Barley is an important cereal grain for ruminant in many region of the World. It is also a readily available source of dietary energy (1). Grains containing starch such as barley are a primary source of energy commonly fed to beef and dairy cattle to improve meat or milk productions. Feed grains needs to be processed cattle to increase their accessibility to microbial population in the rumen and the host enzyme in the intestine (1, 2). Therefore, it is important to determine the energy values and nutrient digestibilities of these varieties as well as the differences in the content of barley varieties in term of nutrient composition. On the other hand, it is also very important to know the effects of processing cereals on nutrient contents and digestibility. As a matter of fact, it is reported that heat processing of starch, which is the energy storage of grains, positively affects energy usage and animal performance. The grain processing can be done by the application of various combinations of heat, moisture, time and mechanic actions (2). This study was carried out to investigate the effect of heat processing at 12 different barley varieties on the nutrient composition, starch content, in vitro digestion parameters.

2. Material and method

2.1 Feed Material

The study was carried out in 12 different barley varieties (Tarm-92, Bülbül-89, Avcı-2000, Çetin-2002, Özdemir, Ince, Bolayir, Burakbey, Anka-04, Tosunpaşa, Larende, Marti). Barley varieties were obtained from Field Crops Central Research Instıtute province of Ankara. Approximately 500 g samples

from each varieties were taken and brought to the laboratory. For heat processing to barley varieties, was applied to 105-170 °C heat and 100 bar pressure to the samples (3).

2.2 Chemical Analysis

Barley varieties were grinded in a hammer mill through a 1 mm sieve for analysis. Then, all samples were analyzed to determine dry matter (DM), ash, and crude protein (CP) contents based on the methods described by AOAC (4). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents were analyzed (5). Starch content of samples was determined by the polarimetric method according to ISO (6).

2.3 Determination of in vitro DM, OM Digestion and Energy Contents

ANCOM Daisy II incubator device which provides artifical rumen environment was used in order to determine in vitro DM and OM digestibilities of unprocessing and processing barley varieties. For in vitro incubation, rumen fluid was taken from a two year-old cattle fed barley based on diet. Twelve barley varieties were weighed to F57 filter bag and incubated in DAISY incubator for 24 hours. For this stage, 56 for each treatment, total of 112 filter bags were used; 4 replicates for each barley type and 8 blind were kept in acetone for 3-5 minutes before incubation and then dried at 105°C for 4 hours in the oven. For each barley sample excluding the blinds, 0.5 g was weighed and closed tightly. After incubation, samples were washed in tap water until clear water was removed and dried at 105 °C for 3 hours until constant weight and weighed. Then, the ANCOM method were determined in vitro the true DM, OM digestion and ME (Mcal/kg DM) levels (5) using strainer bag technique (ANCOM 2002 Technology Corp., Fairport, NY). The following equalities were used for in vitro true DM and OM.

Digestibilties;

in vitro true DM digestibilty (%)= 100-(T3-(T1×C1))/(T2×D) ×100

in vitro OM digestibility (%)= 100× (T2×Q)-((T3-T1)×Z/(T2×Q)

T1 : F57 weight of bags

T2 : Weight of feed sample

T3 : Weight of bag and feed sample after in vitro incubation

C1 : Bag weight change correction coefficient due to incubation

Q : Feed organic matter before incubation, %

Z : Feed organic matter after incubation, %

2.4 Statistical Analysis

Data analysis was performed using general linear model (GLM) of SAS 9.4 package program (7). The differences between the averages of heat processing and barley varieties were determined by Duncan test.

3. Results and Discussion

The chemical composition of unprocessed and processed barley varieties are presented in Table 1. There were significantly increased DM, OM with heat treatment for all varieties ($p<0.05$). It was reported that DM content of processed barley grain was reduced due to steaming compared with original whole grain, however, processing had no major impact on nutrient content (8). Also, it was stated that the application of heat to barley in broiler rations did not change the dry matter content (9). Contrary to this result, in present study increased DM and OM content in all barley varieties as the application of heat increased volume weight. Ash content, except for Tarm-92, Bülbül-89, Çetin-2000, Özdemir, Bolayır, Burakbey, and Tosunpaşa was decreased with heat processing within each variety depending on the increase in the amount of DM and OM ($p<0.05$). CP content had different results with heat processing, but CP content increased in general with heat processing among varieties, and CP content in the study was 11.05-15.85%. It has reported that CP content in barley varieties is 11.3-14.4% (10), and in a different study it was found 13.5-16.6% as similar to the value obtained in the study (11). It is thought that the increase in CP content may be caused by carbon bonds between protein and carbohydrate in barley. NDF content was significantly increased in all varieties except for the Burakbey variety with heat processing ($p<0.05$). ADF contents with heat application did not chance except for Çetin-2000, Anka-04, Tosunpaşa variety. It is reported that the ce-

Table 1. Chemical composition (DM%) of untreated or treated barley grain with heat

Variety	Treatment	DM	OM	Ash	CP	NDF	ADF
Tarm-92	Unprocessed	95.00±0.04b	93.19±0.02b	1.81±0.02	12.80±0.08a	28.03±0.34b	4.81±0.32a
	Processed	99.15±0.08a	97.70±0.06a	1.45±0.14	11.61±0.31b	38.26±0.78a	4.67±0.12b
	P<	0.0001	0.0001	0.06	0.02	0.0003	0.709
Bülbül-89	Unprocessed	94.87±0.11b	93.09±0.11b	1.78±0.01	12.03±0.57	29.10±0.55b	4.84±0.14
	Processed	98.70±0.01a	96.99±0.04a	1.71±0.03	12.79±0.24	41.98±0.29a	5.43±0.23
	P<	0.0001	0.0001	0.136	0.287	0.0001	0.100
Avcı-2000	Unprocessed	95.03±0.37b	92.99±0.37b	2.04±0.00a	12.18±0.01	28.76±0.65b	5.57±0.02
	Processed	98.75±0.10a	97.08±0.10a	1.67±0.01b	12.06±0.25	35.91±0.18a	5.18±0.39
	P<	0.001	0.0004	0.0001	0.670	0.0004	0.371
Çetin-2000	Unprocessed	94.60±0.05b	92.69±0.03b	1.91±0.08	11.55±0.12b	28.51±0.79b	5.29±0.03b
	Processed	98.98±0.05a	97.06±0.16a	1.92±0.13	11.99±0.09a	41.98±0.88a	6.71±0.03a
	P<	0.0001	0.0001	0.936	0.043	0.0001	0.0001
Özdemir	Unprocessed	96.05±0.11b	94.27±0.10b	1.78±0.01	13.76±0.53	31.96±2.69b	4.40±0.25
	Processed	99.06±0.02a	97.38±0.09a	1.68±0.07	13.84±0.50	42.35±0.08a	5.58±0.64
	P<	0.0001	0.0001	0.215	0.921	0.02	0.157
Ince	Unprocessed	94.87±0.02b	92.77±0.13b	2.10±0.11a	12.47±0.23b	31.71±0.84b	5.42±0.36
	Processed	98.95±0.05a	97.35±0.08a	1.60±0.03b	14.01±0.25a	45.67±0.28a	4.40±0.18
	P<	0.0001	0.0001	0.010	0.010	0.0001	0.06
Bolayır	Unprocessed	95.94±0.00b	93.89±0.04b	2.05±0.04	13.22±0.47	31.54±1.59	5.44±0.35
	Processed	99.23±0.05a	97.26±0.06a	1.97±0.01	15.04±0.50	43.50±1.04	5.71±0.10
	P<	0.0001	0.0001	0.124	0.06	0.003	0.500
Burakbey	Unprocessed	95.79±0.04b	93.97±0.00b	1.82±0.00	11.05±0.00b	42.41±1.97	4.84±0.12
	Processed	99.32±0.02a	97.40±0.05a	1.92±0.03	13.86±0.45a	37.60±0.12	5.00±0.16
	P<	0.0001	0.0001	0.111	0.003	0.07	0.490
Anka-04	Unprocessed	96.24±0.01b	94.48±0.02b	1.76±0.01a	13.80±0.03b	28.21±0.02b	4.14±0.03b
	Processed	98.99±0.01a	97.28±0.01a	1.71±0.00b	15.86±0.47a	39.84±1.93a	4.79±0.22a
	P<	0.0001	0.0001	0.02	0.012	0.004	0.04
Tosunpaşa	Unprocessed	96.15±0.05b	94.52±0.10b	1.63±0.16	12.50±0.10b	34.74±1.85b	3.65±0.08b
	Processed	99.17±0.04a	97.49±0.03a	1.68±0.01	15.06±0.10a	41.56±0.40a	5.43±0.40a
	P<	0.0001	0.0001	0.750	0.0001	0.021	0.013
Larende	Unprocessed	96.23±0.01b	94.05±0.05b	2.18±0.04a	12.66±0.01b	35.55±2.93b	5.81±0.24
	Processed	99.18±0.07a	97.39±0.05a	1.79±0.12b	14.57±0.43a	45.01±0.14a	5.06±0.19
	P<	0.0001	0.0001	0.04	0.01	0.03	0.07
Martı	Unprocessed	95.78±0.05b	93.11±0.05b	2.68±0.10a	11.73±0.02b	27.98±0.88b	6.49±0.29
	Processed	98.69±0.04a	96.37±0.11a	2.32±0.07b	13.84±0.12a	34.56±0.50a	7.06±0.54
	P<	0.0001	0.0001	0.04	0.0001	0.003	0.401

a, b: Means with the same superscript(s) within each row are significantly different
DM: Dry matter, OM: Organic matter, CP: Crude protein, NDF: Neutral detergent fiber, ADF: Acid detergent fiber
Unprocessed: without heat treated; Processed: heat treated

reals contain bioactive compounds such as phenolic compounds, lignans, and hemicelluloses. The majority of these compounds are concentrated in aleurone and germ layers on the outside of the cereals, and the endosperm layer contains only a small proportion of bioactive compounds (12). The phenolic compounds in cereals such as barley, wheat and corn are considered to be in free form or in the form of conjugates with sugar, sugar alcohols or amines (13). Heat processing of the cereals broke down the cell wall and weakened the bounds between the phenolic compounds and the cell wall (14). Therefore, the physical properties of

β-glucans in barley be changed by thermal, enzymatic and physical processes. It is also stated that an adverse relationship between total β-glucan content and starch content was observed (10). In this study, it is thought to be activated of hemicellulose in the cell wall and so the contents of NDF in barley varieties increased.

Starch is the main energy component used in ruminant feeds due to its presence (15, 16, 17). It is often used to improve rumen fermentation, optimizing digestion of structural carbohydrates and increasing protein flow to the small intestine. It is also reported that the starch content of the diet can positively or negatively affect animal performance and health. A high percentage of starch in diet can trigger rumen acidosis in ruminant, but its appropriate use in the diet has positive effects on methane emissions, and in animal performance (16). It was determined that processing applications for improving the functional properties of bio-molecules such as starch is becoming increasingly important in terms of reducing the microbial load and controlling the activity of the enzyme (18). In this study, the contents of starch with heat processing were significant decreased in all varieties except for Çetin-2000 variety. It found that processed barley varieties ranged from 29.21 to 44.28%, while unprocessed barley varieties ranged from 42.90 to 47.26%. Starch which accounts for 70 to 80% of most grains (17) is greatly affected by genetic factors. It is also determined that starch content of barley grain ranged from 49.6 to 61.9% (19). Application pressure to cereal grains is gelatinized by partially losing the crystalline structure of starch (20) and the hydrogen bonds which hold the starch granules together are weakened and the amylose molecules have become soluble by pressure application and cause gelation (21). It is reported that both the diffusion of water into granules and leaching soluble polysaccharides, amylose leaching depended on the temperature and the type of starch studied. Morever, an inverse correlation between the diffusion of water into granules and amylose content was observed. In other words, the diffusion of water into granules also decreased as the amylose content of starch increased. In a research studied in corn starch, it has been stated that the application of the vapor applied to grain has deteriorated the starch structure of maize, and the structure of the chemical bonds has deteriorated. As a result, amylose and amylopectin bonds are released and described as starch gelatinization (22). For our study, starch contents with heat processing decreased in all varieties except one. it can be expressed that the reduce of starch values in processed barley were deteriorated the starch structure of barley varieties, and starch has been gelatinized.

Table 2. Starch contents of untreated and treated barley varieties, DM%

Variety	Treatment		
	Unprocessed	Processed	P<
Tarm-92	42.90±0.11a	39.55±0.65b	0.007
Bülbül-89	46.30±0.20a	41.00±0.11b	0.0001
Avcı 2000	47.79±0.16a	44.28±0.01b	0.0001
Çetin 2000	44.16±0.27	44.09±0.15	0.839
Özdemir	45.69±0.48a	41.65±0.07b	0.001
Ince	46.02±0.16a	33.32±0.100b	0.0001
Bolayır	40.92±0.14a	31.30±0.12b	0.0001
Burakbey	43.31±0.03a	36.89±0.14b	0.0001
Anka-04	47.26±0.30a	31.47±0.03b	0.0001
Tosunpaşa	47.18±0.14a	32.31±0.07b	0.0001
Larende	46.59±0.03a	29.21±0.11b	0.0001
Martı	43.24±0.10a	41.91±0.16b	0.002

a, b: Means with the same superscript(s) within each row are significantly different

Table 3. In vitro DM, OM digestibility, and ME values of barley varieties

Varieties	**Treatment**	**IVDMD, %**	**IVOMD, %**	**ME,** Mcal/kg
Tarm-92	Unprocessed	63.15±1.14a	69.04±1.08a	2.50±0.04a
	Processed	53.86±1.52b	59.53±1.39b	2.15±0.05b
	P<	0.0027	0.0017	0.017
Bülbül-89	Unprocessed	62.21±2.92	67.63±3.45	2.45±0.12
	Processed	53.98±2.61	59.21±3.26	2.17±0.14
	P<	0.081	0.126	0.190
Avcı-2000	Unprocessed	66.26±2.30	71.66±2.21	2.59±0.08a
	Processed	58.17±3.97	63.83±4.18	2.29±0.16b
	P<	0.128	0.149	0.153
Çetin-2000	Unprocessed	53.46±1.53	59.09±2.07	2.53±0.38
	Processed	53.43±1.34	59.87±1.60	2.16±0.06
	P<	0.999	0.774	0.376
Özdemir	Unprocessed	58.02±1.61a	62.42±1.71a	2.26±0.06
	Processed	46.90±1.72b	48.84±5.21a	1.80±0.21
	P<	0.003	0.048	0.081
Ince	Unprocessed	53.32±2.82	57.30±3.37	2.04±0.15
	Processed	51.70±2.40	57.95±2.76	2.10±0.10
	P<	0.688	0.886	0.750
Bolayır	Unprocessed	63.93±0.85a	69.12±0.96a	2.50±0.03a
	Processed	54.44±1.58b	60.75±1.56b	2.20±0.06b
	P<	0.002	0.004	0.004
Burakbey	Unprocessed	61.83±5.65	66.62±5.76b	2.41±0.21
	Processed	51.95±5.18	56.40±5.54	2.04±0.20
	P<	0.244	0.249	0.249
Anka-04	Unprocessed	62.88±2.01	67.65±1.86	2.45±0.07
	Processed	47.96±4.18	52.92±5.24	1.92±0.19
	P<	0.02	0.04	0.04
Tosunpaşa	Unprocessed	60.66±2.57a	65.23±3.04a	2.36±0.11a
	Processed	46.34±1.76b	51.77±1.94b	1.87±0.07b
	P<	0.004	0.01	0.01
Larende	Unprocessed	66.67±1.39a	71.78±1.49a	2.59±0.05a
	Processed	51.16±0.74b	58.23±1.16b	2.04±0.04b
	P<	0.0001	0.0004	0.0002
Martı	Unprocessed	65.27±3.85a	70.94±3.72a	2.57±0.13
	Processed	49.83±2.17b	54.99±2.93b	1.91±0.18
	P<	0.013	0.015	0.03

a, b: Means with the same superscript(s) within each row are significantly different
IVDMD: in vitro dry matter digestibility; IVOMD: in vitro organic matter digestibility; ME: Metabolic energy

In vitro DM, OM digestibility, and metabolized energy levels in 12 different variety of barley, heat unprocessed and processed was given in Table 3. While DM digestion of barley varieties with heat treatment decreased in some varieties, it did not change in some varieties. But, generally processing heat reduced DM digestibility (Table 3; $p<0.05$), and DM digestion in unprocessed barley varieties ranged from 53.32-66.67%; whereas DM digestion in processed varieties varied between 46.34-58.17%. A comparison between barley varieties did not made, but DM digestion of Avcı-2000 variety for both untreated and treated was higher than other varieties, was lower Tosunpaşa variety ($p<0.05$). This result was valid to OM digestibil-

ity, and OM digestion in unprocessed barley varieties ranged from 57.30-71.78%; whereas OM digestion in processed varieties ranged from 48.84-63.83%. It is reported that the values resulting from incubation of barley, and concluded that in vitro total digestibility of barley was 66.7 to 85.1% (23). Processing barley grain with heat could change the site and extend digestion of nutrient (24). It can be stated that the increasing cell wall levels in barley grain with processing in this study causes a decrease in the total DM and OM digestibility of varieties. Morever, it was stated that there are a number of factors affecting nutrient digestion, including variety, granule size, amylose/amylopectin ratio, presence of starch-lipid and starch-protein complexes (16). In the study, the rate of the insoluble of nutrient was greater for processed barley than for unprocessed barley grains. It was think that lower DM digestibility with heat treated of barley grains related to the solubility of barley varieties. ME contents of barley varieties were decreased heat processing except for Bülbül-89, Avcı-2000, Çetin-2000, Özdemir, İnce and Burakbey varieties. ME contents was observed between 2.04-2.59 Mcal/kg with unprocessed barley, while it was found between 1.80-2.29 Mcal/kg with processed barley, and lower ME level in processed barley varieties was thought to be caused by a lower in vitro OM digestion.

This study demonstrated that processing with heat of barley varieties have higher DM, OM, and NDF contents. Treating barley grain with heat in all barley varieties decreased starch contents and in vitro DM and OM digestibilities. It is thought that starch contents of varities are gelatinized. Generally, it is recommend that processing barley grains can be used to regulate rate of digestion of barley grain in the rumen. Therefore, it is thought that these results of barley varieties are important in term of prevent ruminal asidozis and synchronization of rapidly fermented barley in rumen.

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