Effect of harvesting time and cultivar on barley quality and predict the nutrient composition

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Abstract: The present study was conducted in response to the lack of information of the effects of cultivar and harvesting time on nutritional value of barley grown in Iran. The objective of this study was to determine the detailed chemical composition of barley in different cultivar and harvesting time and then to predict the nutrient composition. Three barley cultivars (Ansar, Abidar and Sahand), were harvested at two stages of growth (ripening of grain GS-91 and forage barley GS-83) and nutrition indices of treatments were determined in the advanced nutrition lab. The results of analysis showed that the effect of harvesting time and cultivar were significant on minerals and crude protein of barley, also the effect of harvesting time was significant on gross energy and crud fat. The highest percentage of minerals was in Sahand cultivar with an average of 7.13%, also the mineral of forage barley (GS-83) was higher than barley in the ripening of grain (GS-91). Sahand cultivar with the mean of 15.3% and GS-83 with a mean of 13.4% had the highest crude protein. The highest amount of gross energy was related to Abidar cultivar at GS-83 with an average of 6416 cal gr^{-1}. The mean of GS-83 with 2.1% of crude fat was more than GS-91 with the mean of 1.5%. The result of linear regression model showed that harvesting time and cultivar were effective parameters in the prediction of crud protein and mineral content, but only harvesting time could be used in the prediction of crud fat and gross energy.

Keywords: barley, harvesting time, cultivar, chemical analysis, regression model

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1 Introduction

Cereals are the most common sources of readily available energy for livestock and comprise up to 60% of the total diet for high yielding dairy cows. Barley (*Hordeum vulgare*) is one of the most important cereals grown in Iran; also it is one of the main sources of feedstock in ruminant diets. Barley possesses many of the attributes necessary for obtaining high, consistent levels of milk produce and for maintaining animal health (Anonymous, 1990). Barley includes high nutrient levels and high overall digestibility. Barley cultivars: Ansar, Abidar and Sahand are commonly grown in Iran. Numerous studies (Jung and Allen, 1995; Ayres et al., 1998; Elizalde et al., 1999; Ferdinandez and Coulman, 2001; Lyon et al., 2001) have shown that nutritional values, yield and quality of forages are affected by harvesting time, forage species, cultivar (Griffin et al., 1994; Lundvall et al., 1994), fertilization (Aumont and Salas, 1996), soil type (Aumont and Salas, 1996), climate (e.g., rainfall, temperature) (Minson and McLeod, 1970; Mathison et al., 1996), planting (e.g., row spacing, planting rate) (Hintz and Albrecht, 1994), and growing conditions (Cox et al., 1994). Kalu et al. (1988) developed the quantitative mean stage weight (MSW) as a maturity index to document maturity effects on alfalfa

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nutritive composition. One of the most important factors affecting the nutritive value of maize silage is the choice of harvest time and the physiological maturity of the crop at harvest. Contradictory effects of the maturity status on the feeding value of maize silage demonstrate the difficulty of determining an optimal harvest time (Johnson et al., 1997; Johnson et al., 1999). The present study was conducted in response to the lack of information on the effects of cultivar and harvesting time at different physiological maturity on nutritional value of barley grown in Iran and also quantifies the effects of harvesting time and cultivar on barley nutrition value as linear regression model. Such information would allow to identify the effective parameters on the nutritional value of barley used for feedstock and provide a proper diet for better ruminant performance.

The objective of the current study was to determine the detailed chemical composition of barley in different cultivar and harvesting time as main factors and predict the nutrient composition from those.

2 Materials and methods

2.1 Barley cultivars and harvesting time

Three barley cultivars (1 = Ansar, 2 = Abidar, 3 = Sahand), grown in 2017 in same fields (n = 3) at Khal'at Pooshan research station of agricultural faculty of university of Tabriz (38°01'N, 46°24'E, 1578 m a.s.l.), Iran. The barley cultivars were harvested at two stages of growth including 1 = ripening of grain that which caryopsis was so hard that difficult to divide by thumb-nail and equal to 91 decimal code for the growth stages (GS-91), 2 = forage barley at early dough stage that which finger nail impression not held on caryopsis and equal to 83 decimal code for the growth stages (GS-83) according to Zadoks et al. (1974). With respect to the Iranian weather condition, stage 1 was at the point of commercial cutting for grain use, stage 2 is approximately 1 month before the point at which the barley would be commercially harvested for grain use. The barley cultivars were chosen as they were the most common for rained barley grown in Iran. Ansar, Abidar and Sahand barley cultivars were initially seeded at a rate of 150 kg ha^{-1} in the fall of 2017. Each field received 61 kg N and 23 kg P, per hectares. No insecticides or herbicides were applied. The barley samples were randomly obtained by hand collection. The fresh-cut barley samples were dried at 55°C (24 h) in a force-aired oven to a constant weight, allowed to cool to ambient temperature and then passing materials1-mrn screen in a Wiley mill (Philadelphia, PA) for chemical analysis.

2.2 Chemical analysis

The material was analyzed for mineral materials (ash), crude protein (CP), crude fat (CF) and gross energy (GE). The ash and CF contents were analyzed according to the procedure of the Association of Official Analytical Chemists (AOAC, 2005). Nitrogen content was determined using the Kjeldahl method (Kjeltec 2300 Autoanalyzer, Foss Tecator AB, Hoganas, Sweden) and CP was calculated as N × 6.25 (AOAC, 2005). Gross energy (GE) was measured using a Parr adiabatic bomb calorimeter (Model 1200, Parr Instrument Co., Moline, IL) (Yu et al., 2003).

2.3 Statistical analysis

The experiments were done at three barley cultivars (Ansar, Abidar, Sahand) and two harvesting time (GS-83 and GS-91) in the form of factorial analysis based on a randomized complete design with three replications. The means of the data were compared with Duncan’s multiple range tests. In order to investigate the relationship between evaluated parameters and nutritional value, the linear regression model was determined. Analyses were performed in SAS 9.2 (SAS Institute, Cary NC, 2008). Excel 2007 was used for drawing charts and tables.

3 Results and discussion

The result of chemical analysis of three barley cultivars (Ansar, Abidar, Sahand) and two harvesting time (GS-83 and GS-91) include mineral materials, gross energy, crude protein and crude fat, which are presented in Table 1.

3.1 Minerals (ash) content

According to Table 1, the effects of cultivar and harvesting time on barley were significant on minerals at 5% probability level, but the interaction between the cultivar and the harvesting time was not significant. The mineral content comparison of three barley cultivars is shown in Figure 1.

Table 1 Variance analysis of independent factors on mineral materials, energy content, crude protein and fat

Sov	DF	Mineral		Gross energy		Crud protein		Crud fat	
		SS	MS	SS	MS	SS	MS	SS	MS
Harvesting time	1	39.33	39.33*	7378586.73	7378586.73**	23.75	23.75**	2	2**
Cultivar	2	43.02	21.51*	448723.6	224361.82^{ns}	117.99	58.99**	0.22	0.11^{ns}
Gs*Cultivar	2	17.81	8.9^{ns}	1387088.71	693544.35**	6.05	3.02^{ns}	0.05	0.025^{ns}
Error	12	61.57	5.13	808368.58	67364.05	19.01	1.58	0.75	0.06
Total	17	161.74		10022767.67		166.82		3.02	

Note: Significant at 1% probability level,* Significant at 5%probability level, ^{ns} not Significant.

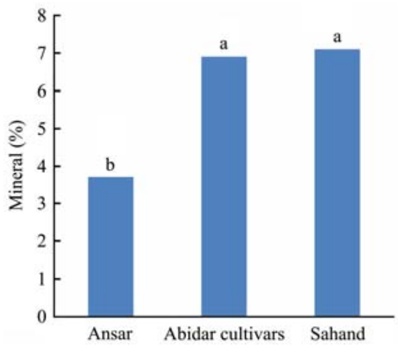

Figure 1 Comparison between different cultivars on mineral content of barley plant

The highest percentage of minerals was in Sahand cultivar with an average of 7.13%, followed by Abidar cultivar with an average of 6.9% and then Ansar with an average of 3.7%. As indicated in Figure 1, the mean difference between Sahand and Abidar cultivar was not significant, but the difference of each of them with Ansar was significant.

Comparison of the minerals at two harvesting time of barley is shown in Figure 2.

As it is shown, the mineral of forage barley harvested at (GS-83) was higher than barley in the ripening of grain (GS-91). These results were consistent with Minson (1990), as the plant matures mineral and trace element contents declined, because of a dilution process and translocation of some minerals to the root system and contrasted with the results of Aumont and Salas (1996).

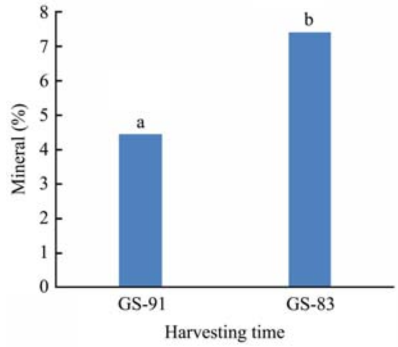

Figure 2 Comparison between different means of harvesting time on mineral content of barley plant

The linear regression model was used for the expression of the chemical composition of barley according to the independent factors variation. The results of variance analysis of linear regression model for mineral material, gross energy, crude protein and crud fat are shown in Table 2.

As shown in Table 2, the linear regression model was significant for the prediction of mineral material in probability level of 5% (p<0.05 as level of significant). The results showed that the model was able to predict the mineral materials with variation of cultivars and harvesting time. The coefficients estimated for this model are presented in Table 3.

Table 2 Variance analysis of linear regression model for mineral material, gross energy, crude protein and crud fat

SOV	Df	Mineral material		Gross energy		Crude protein		Crud fat	
		SS	MS	SS	MS	SS	MS	SS	MS
Model	2	73.66	36.83*	7757597	3878799**	141.68	70.84**	2.21	1.1**
Error	15	88.05	5.86	2265178	151012	25.11	1.67	0.81	0.05
Total	17	161.69		10022775		166.79		3.02	

Note: *= Significant at 5%probability, **= Significant at 1% probability.

Table 3 Coefficients estimated for regression model of mineral materials, gross energy, crud protein and crud fat

Variable	df	Mineral materials		Gross energy		Crude protein		Crude fat	
		EP	P_r>|t|	EP	P_r>|t|	EP	P_r>|t|	EP	P_r>|t|
Intercept	1	–1.88	0.422	3026	0.0001	2.47	0.06	0.57	0.019
Harvesting time	1	2.95	0.02*	1280	0.0001**	2.29	0.0019**	0.66	0.0001**
Cultivar	1	1.69	0.02*	177	0.13^{ns}	3.13	0.0001**	0.13	0.066^{ns}

Note: EP=estimated parameters, *= Significant at 5%probability, **= Significant at 1%probability.

According to Table 3, both of the independent variables had a significant t value and could predict the dependent variables. The linear regression model for ash (%), harvesting time (x_1[2]) and cultivar (x_2[②]) is equal to:

$$ash = -1.88+2.95x_1+1.69x_2$$

Both of harvesting time and cultivar had additive effects. Also, coefficient of harvesting time was more than coefficient of cultivar and so the harvesting time had greater impact on ash. The R^2 for this model was 0.45.

3.2 Gross energy

According to Table 1, the effect of harvesting time was significant on gross energy content of barley at 1% probability level, but the effect of cultivar was not significant. Also, the interaction between cultivar and harvesting time was significant at 1% probability level. Means comparison between harvesting time*Cultivar on gross energy was shown in Figure 3.

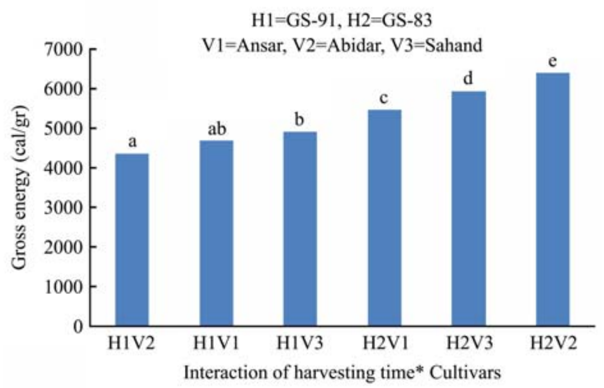

Figure 3 Comparison between different means of harvesting time*Cultivar interaction on gross energy

As shown in Figure 3, the highest amount of gross energy was related to H2V2 (Abidar cultivar at GS-83) with an average of 6416 cal gr^{-1} and its difference with other treatments was significant. After that, the highest amount of energy was related to Sahand, Ansar at GS-83 and then Sahand, Ansar, Abidar cultivars at GS-91 with average 5945, 5466, 4927, 4695, 4364 cal gr^{-1}, respectively. Treatments with the same letters were not significantly different in Figure 3. Yu et al. (2003) showed that there were no differences between alfalfa varieties, but there were significant differences between timothy for all estimated energy values. However, the stage of maturity had significant effects on energy values on alfalfa and timothy as, all energy values significantly declined with maturity.

The linear regression model was significant for the gross energy prediction (Table 2). According to the coefficients estimated for regression presented in Table 3, the harvesting time has a significant t value but the cultivar was not significant to predict the dependent variables. The linear regression model for gross energy (cal gr^{-1}) and harvesting time (x_1) is equal to:

$$GE=3026+1280x_1$$

The harvesting time had additive effect and cultivar had not any effect on gross energy. The R^2 for this model was 0.77.

3.3 Crude protein

Result of variance analysis in Table 1 shows that, the effect of harvesting time and cultivar were significant at 1% probability level on crude protein of barley percentage, but the interaction between cultivar and harvesting time was not significant at 1% probability level. The results were consistent to result of Ferdinandez and Coulman (2001). That would be related to difference between their genetic makeup's (Ferdinandez and Coulman, 2001), environmental conditions (Garza et al., 1965; Coors et al., 1986), morphological differences in leaf/stem ratio (Garza et al., 1965; Kephart et al., 1990), rate of maturation (Garza et al., 1965) or confused (Lyon et al., 2001).

The comparison between means of cultivars on the crude protein content of barley was shown in Figure 4.

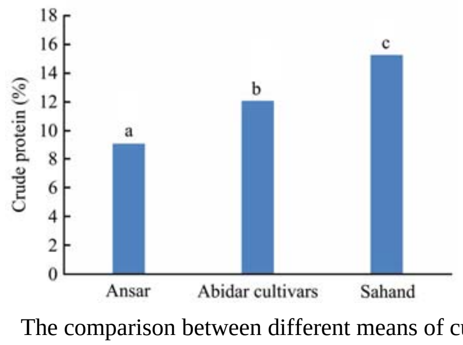

Figure 4 The comparison between different means of cultivars s on the crude protein content of barley

As shown in Figure 4, the differences between means of cultivars were significant and Sahand cultivar with the mean of 15.3% had the highest crude protein and then Abidar and Ansar cultivars with mean of 12.1% and 9.1% respectively. The comparison of the different means of harvesting time on the crude protein of barley plant was shown in Figure 5.

① x_1=1 for GS-91 and 2 for GS-83

② x_2= 1 for Ansar, 2 for Abidar and 3 for Sahand

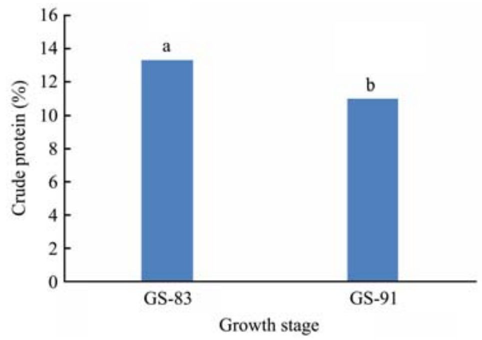

Figure 5 Comparison between different means of harvesting time on the crude protein

Figure 5 showed that, the difference between means of harvesting time were significant and GS-83 with a mean of 13.4% had the highest crude protein content, and the mean of GS-91 was 11.04%. The results of the variance analysis for linear model of crude protein are presented in Table 1. The linear regression model was significant for the crude protein prediction (Table 2). The coefficients estimated for the current model presented in Table 3, showed that the harvesting time and cultivar had a significant t value to predict the dependent variables. The linear regression model for crude protein (%), harvesting time (x_1) and cultivar (x_2) is equal to:

$$CP=2.47+2.29x_1+3.13x_2$$

Both of harvesting time and cultivar had additive effects. But the coefficient of cultivar was more than coefficient of harvesting time and R^2 for this model was 0.84.

3.4 Crude fat

According to Table 1, the effect of harvesting time was significant at 1% level probability on crude fat of barley, but the effect of cultivar and interaction between cultivar and harvesting time was not significant. The comparison between different means of harvesting time on the crude fat percentage was shown in Figure 6.

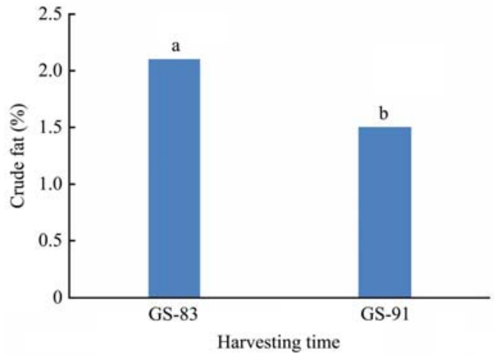

Figure 6 Comparison between different means of harvesting time on the crude fat percentage

As it was shown in the figure, the difference between harvesting time was significant; the mean of GS-83 with 2.1% of crude fat was more than GS-91 with the mean of 1.5%. The regression model was significant for the crude fat prediction (Table 2). The coefficients estimated for this model in Table 3 showed that the harvesting time had a significant t value to predict the dependent variables but the cultivar had not significant t value to predict the dependent variables. The linear regression model for crude fat (%) and harvesting time (x_1) is equal to:

$$CF=0.57+0.66x_1$$

The harvesting time had additive effect and cultivar had no any effect on crud fat. The R^2 for this model was 0.73.

4 Conclusions

The results of chemical analysis of barley cultivars at different harvesting time in the present study were more than those reported in NRC tables that was similar to the previous results (Steenfeldt, 2001). This difference in the amount of chemical compounds is probably due to the cultivation method, genetic variation, stage of life, type and amount of fertilizer and weather conditions. It seems that agronomic, climate and genotypic are effective factors in the occurrence of such differences (Villamide et al., 1997).

Minerals content, crud protein, gross energy and crud fat of barley decreased with maturity stage, thus harvesting at growth stage -83 had the highest quality than growth stage -91. Also cultivar had a significant effect on mineral and crud protein content, thus harvesting time and cultivar were effective parameters in the prediction of crud protein and mineral content. Further, only growth stage could be used in the prediction of crud fat and gross energy.

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