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Research Paper

Effects of growth stage on nutritional value of barley and triticale forages for goats

Los efectos de la etapa de crecimiento sobre el valor nutricional de los forrajes de cebada y triticale para las cabras

HANDE ISIL AKBAĞ

Department of Animal Science, Faculty of Agriculture, Çanakkale Onsekiz Mart University, Çanakkale, Turkey. zootekni.ziraat.comu.edu.tr

Abstract

The nutritional composition and *in vitro* gas production of barley and triticale forages at tillering, stem elongation, and ear emergence stages were studied. The mean crude protein (CP), neutral detergent fiber (NDF) and water-soluble carbohydrate (WSC) content was higher in barley than triticale. The supplementation of wheat grain in *in vitro* incubation had no effect on the gas production of barley and triticale forage. The nutritive value of barley and triticale forages is highly influenced by growth stage and is high during the early stage of growth during tillering and stem elongation. Barley and triticale forages have potential as feed for dairy goats and although barley had a higher CP content, both have adequate ME and CP levels to meet the nutritional requirements of adult goats with 50 kg body weight in early lactation.

Keywords: *In vitro* gas production, supplementation, winter cereal.

Resumen

Se estudió la composición nutricional y la producción de gas *in vitro* de forrajes de cebada y triticale en las etapas de macollaje, elongación del tallo y emergencia de la espiga. El contenido medio de proteína bruta (PC), fibra detergente neutro (FDN) y carbohidratos solubles en agua (CSA) fue mayor en la cebada que en el triticale. La suplementación de grano de trigo en incubación *in vitro* no tuvo efecto sobre la producción de gas del forraje de cebada y triticale. El valor nutritivo de los forrajes de cebada y triticale está altamente influenciado por la etapa de crecimiento y es alto durante la etapa temprana de crecimiento durante el macollamiento y la elongación del tallo. Los forrajes de cebada y triticale tienen potencial como alimento para cabras lecheras y, aunque la cebada tuvo un mayor contenido de PC, ambos tienen niveles adecuados de energía metabolizable y PC para cumplir con los requisitos nutricionales de cabras adultas con 50 kg de peso corporal al inicio de la lactancia.

Palabras clave: Cereal de inverno, producción de gas *in vitro*, suplementación.

Introduction

The success of low-input small ruminant production systems depends largely on the efficient use of year-round available natural resources. Goat production in developing countries is mainly based on extensive natural pastures (shrublands, forest areas and herbaceous vegetation) (Miller and Lu 2019). Annual fluctuations in the production and nutrient supply from natural pastures in tropical and subtropical regions can reduce goat productivity due to an inability to meet their nutritional needs (Cowley and Roschinsky 2019). Forage barley and triticale are drought tolerant and can be grown in marginal lands (Giunta et al. 1993) as cultivated pastures in highland tropical and subtropical regions to supplement natural pastures. Cultivated pastures reduce grazing pressure on natural

Correspondence: Hande Isıl Akbağ, Canakkale Onsekiz Mart University, Faculty of Agriculture, Department of Animal Science, Canakkale, Turkey. Email: hiulku@comu.edu.tr

pastures (Chen et al. 2016) and have an important place in dairy goat production systems (Ruiz et al. 2009). Goats prefer grasses to legumes and forage barley, triticale, wheat, and oat pastures are valuable sources of fodder for dairy goat production (Bonanno et al. 2008).

Grazing season is the principal factor affecting forage nutrient composition, digestibility, dry matter yield and animal intake (Bhaita et al. 2001). Supplementary feeding of grazing dairy goats with concentrate feed generally increases energy intake and milk production on cultivated pastures (Morand-Fehr et al. 2007). Lefrileux et al. (2008) suggested that supplementary feeds should be chosen according to the quality and growth stage of the forages. The success of supplementation for grazing dairy goats mainly depends on the concentrate fermentation characteristics in the rumen (Bonanno et al. 2008).

Few studies are available comparing the nutritional value of barley and triticale at different stages of growth and their rumen fermentation characteristics. We hypothesize that the nutritional value and *in vitro* fermentation characteristics of barley and triticale forages are affected by sampling period and supplementation with wheat grain during *in vitro* incubation. Therefore, the objective of this study was to compare the nutritive value and *in vitro* fermentation characteristics of barley and triticale forages at different growth stages.

Materials and Methods

Study site and forage establishment

The study was performed at the Faculty of Agriculture Animal Production Farm Research and Practice Unit of Çanakkale Onsekiz Mart University, located in Northwest Turkey (40º09' N, 26º26' E). The soil properties were silty loam with 2.57% organic matter (OM), 4.3% lime and a pH value of 7.2. The average daily temperature and precipitation from October to May during the experiment were 11.28 ºC and 65.9 mm respectively.

Barley and triticale plots were seeded at 3 kg seed/ha in October. The plants were grown in rainfed conditions with no irrigation and fertilization. The study was carried out in a completely randomized design with 3 replicates; each replicate had a plot size of 6 m x 4 m.

Sampling methods and chemical analysis of forages

Three forage samples were harvested from barley and triticale at each stage: tillering (T), stem elongation (SE) and ear emergence (EE). Forage samples were harvested using electric shears by cutting a 0.2 m^2 quadrat selected randomly in each plot at a height of 2 cm. Samples were weighed and oven-dried at 40 °C for 48 hours for dry matter (DM) determination and then ground to pass a 1 mm sieve. DM, crude protein (CP) and ash content of the forage samples were analyzed (AOAC 2000). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed with an ANKOM 200 Fiber Analyzer (ANKOM® Technology, NY, USA) (Van Soest et al. 1991). NDF and ADF are expressed without residual ash. Water soluble carbohydrate (WSC) was determined according to Dubois et al. (1956).

In vitro *fermentation characteristics*

Three non-lactating Turkish Saanen goats (35.0 ± 1.0 kg body weight) were selected as donor animals for the rumen fluid. The goats were fed with lucerne hay (90.1 % DM; 15.3 % CP) and concentrate feed (89 % DM; 17.2 % CP), with a forage to concentrate ratio of 60/40, formulated to provide 1.25 times the daily maintenance nutrient requirement according to NRC (2007). The feed was supplied to the donor animals twice a day (08:30 and 16:30 h). Ruminal fluid samples were collected before morning feeding from the rumen cannula and used for the *in vitro* incubations which were conducted in triplicate for each treatment following the procedure of Menke and Steingass (1988). The rumen fluid and buffer solution (1:2, v/v) were mixed under carbon dioxide and 30 ml was drawn into each calibrated glass syringe (100 ml) (Model Fortuna, Häberle, Labortechnik, Germany) which already contained 200 mg of the barley or triticale at tillering, stem elongation or ear emergence stages. To assess the effects of wheat grain on *in vitro* gas production, 40 mg of ground wheat was weighed into the syringes in the same incubation sets. The syringes were incubated at 39 ºC and gas production levels were measured at 4, 8, 12, 24, 48, 72, and 96 h of incubation. The incubations were repeated 3 times at weekly intervals. Blanks containing only rumen fluid and rumen fluid plus the wheat grain were included for correction. Cumulative gas production data were fitted to the model of Ørskov and McDonald (1970), using the Neway program:

$$y = a + b\,(1 - \exp^{-ct})$$

where:

y is presented gas volume (ml) at a time (t);

a is the gas produced from the soluble fraction (ml);

b is the gas produced from an insoluble but fermentable fraction (ml);

a+b is potential gas production (ml); and

c is the rate constant of gas production during incubation (ml/h).

Metabolizable energy (ME) and organic matter digestibility (OMD) of the forages were calculated from the gas production according to Menke et al. (1979):

ME (MJ/kg DM) = 2.20 + 0.136 GP + 0.057 CP

OMD (%) = 14.88 + 0.889 GP + 0.45 CP + 0.0651 A

where:

GP is 24 h net gas production (ml/200 mg);

CP is the crude protein content (%); and

A is ash content (%).

Statistical analysis

The data were analyzed by using the general linear model procedure and the fixed effects were forage type, growth stage and their interactions. The *in vitro* gas production and incubation parameters were analyzed by using the general linear model procedure and the fixed effects were forage type, growth stage, wheat supplementation and their interactions. Tukey's test was used for the post hoc analyses. All statistical analyses were performed using the SAS (2002) software package.

Results

Forage dry matter production and green forage production were similar between barley and triticale (Table 1) and affected by growth stages (P<0.0001). The dry matter production (P=0.2954) and green forage production (P=0.3566) were not affected by forage type x growth stage interaction. Forages provided greater amounts of dry matter at EE stage than at T and SE stages (Table 1).

Chemical composition of forages

The least square means of the chemical composition of barley and triticale at different growth stages and P values are presented in Table 2. Forage type affected the CP, NDF, ADL and WSC contents significantly (P≤0.0059). The DM, CP, ADF, ADL, WSC, and ash contents were significantly changed by growth stages (P<0.0001). Significant forage type x growth stage interactions were observed for the NDF, ADF and WSC.

In vitro *fermentation kinetics*

The gas production profiles of barley and triticale at different growth stages and the effects of wheat supplementation on *in vitro* gas production are given in Figure 1. Forage type significantly affected gas production at 4 and 8 hours of incubation (P<0.0168). Growth stage significantly affected gas production (P<0.05) at 96 h incubation. Forage type x growth stage interaction effects on gas production was significant at 24 hours incubation (P<0.05). Gas production of triticale at 24 hours of incubation was higher (P<0.05) than barley in SE and EE stages, whereas barley had higher gas production than triticale at stage T.

The effects of forage type x growth stage x wheat supplementation interaction on *in vitro* gas production during 96 h incubation are presented in Table 3.

The gas production was significantly changed by wheat supplementation at 4, 24, 48, and 72 hours of *in vitro* incubation (P≤0.0144). For *in vitro* gas production, there were no significant interactions between forage type x wheat supplementation and growth stage x wheat supplementation (P>0.05). The ME and OMD (Table 4) were significantly affected by growth stages (P<0.0001). Forage type, forage type x growth stage interaction, wheat supplementation, forage type x wheat supplementation interaction, growth stage x wheat supplementation interaction, and forage type x growth stage x wheat supplementation interactions were not significant (P>0.05).

Table 1. Least square means of green forage and dry matter yield of barley and triticale.

Forage	GFY	DMY
Barley	27,016.7	6,167.6
Triticale	30,900.0	6,610.5
SEM	3,150.2	704.5
P value	0.4005	0.6674
Growth stages		
TT	12,208.3[b]	2,325.0[c]
SE	31,817.6[a]	6,417.5[b]
EE	42,850.0[a]	10,417.6[a]
SEM	3,858.2	862.9
P value	0.0004	<0.0001

Means with different superscripts in the same column are different (P<0.05); GFY = green forage yield (kg/ha); DMY = dry matter yield (kg DM/ha); T = tillering stage; SE = stem elongation stage; EE = ear emergence stage.

Table 2. Least square means of chemical composition of barley and triticale at different growth stages.

Forage	GS	DM	CP	NDF	ADF	ADL	WSC	Ash
Barley	T	198.89	148.08	529.0[a]	230.5[a]	81.87	193.89[b]	131.66
	SE	203.43	114.88	607.3[b]	231.9[a]	126.94	249.08[a]	114.50
	EE	249.08	89.22	627.3[c]	233.9[a]	170.15	203.43[b]	91.21
Triticale	T	189.21	148.17	531.9[a]	215.4[a]	101.63	162.40[c]	156.03
	SE	199.31	88.94	558.6[a]	238.7[a]	149.41	252.32a	114.01
	EE	256.42	70.09	560.9[b]	270.8[b]	181.28	184.60[b]	89.81
SEM		5.890	5.495	19.007	9.731	5.611	5.544	6.238
P value	FT	0.9217	0.0059	0.0329	0.2523	0.0022	0.0047	0.1671
	GS	<0.0001	<0.0001	0.0778	0.0513	<0.0001	<0.0001	<0.0001
	FTxGS	0.5331	0.0868	0.0263	0.0380	0.5866	0.0260	0.1041

Means with different superscripts in the same column are different (P<0.05); T = tillering stage; SE = stem elongation stage; EE = ear emergence stage; GS = growth stage; DM = dry matter (g/kg); CP = crude protein (g/kg DM); NDF =neutral detergent fiber (g/kg DM); ADF = acid detergent fiber (g/kg DM); ADL = acid detergent lignin (g/kg DM); WSC = water soluble carbohydrate (g/kg DM); FT = forage type; FTxGS = forage type x growth stage interaction.

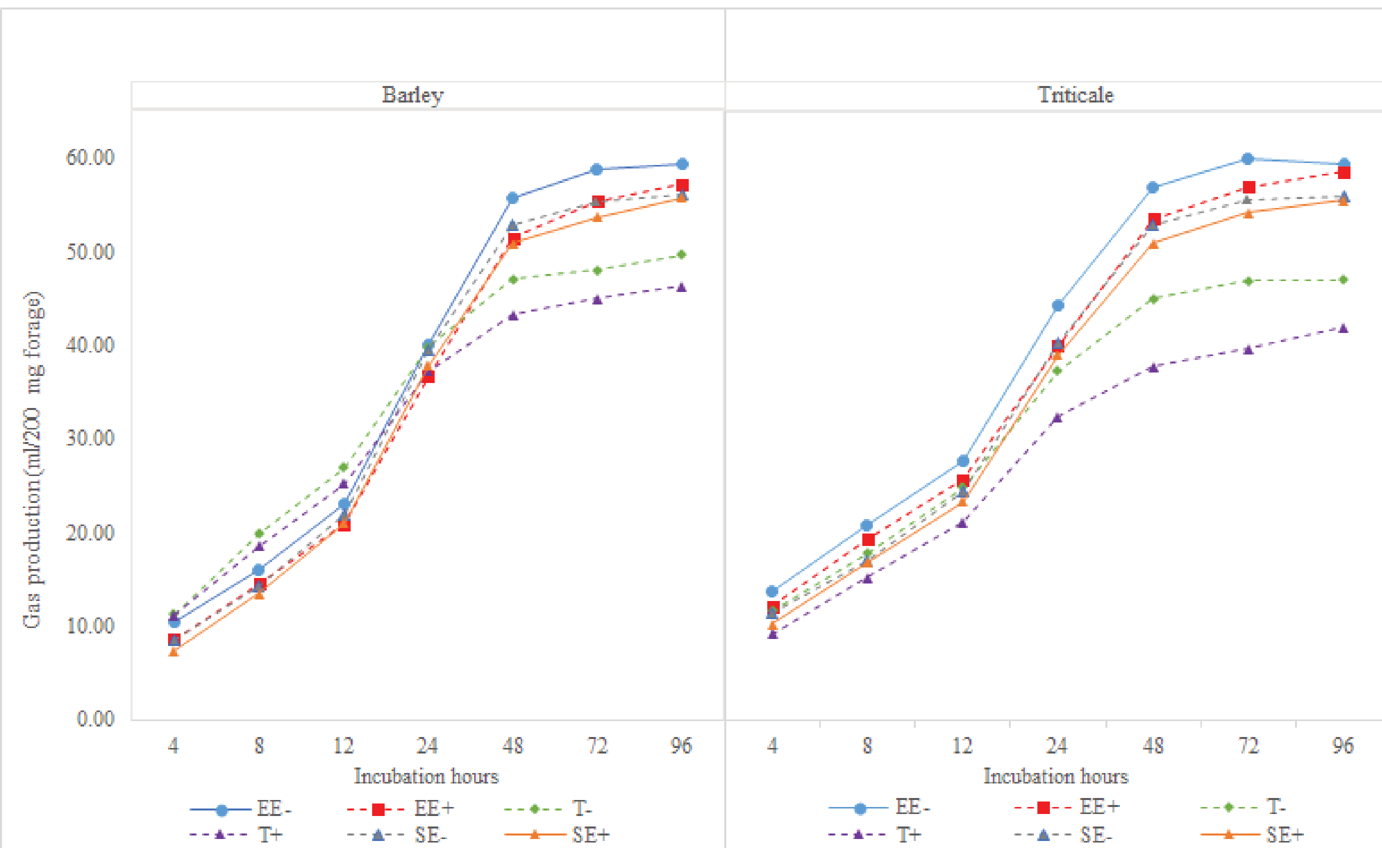

Figure 1. The in vitro gas production curves of barley and triticale supplemented (+) or non-supplemented (-) with wheat at different growth stages (T = tillering stage; SE = stem elongation stage; EE = ear emergence stage).

Table 3. Least square means of *in vitro* gas production (ml) obtained from barley and triticale supplemented (+) and non-supplemented (-) with wheat at different growth stages.

Incubation Hours	Wheat grain	Barley			Triticale			SEM	P
		T	SE	EE	T	SE	EE		
4	-	11.28	8.50	10.39	1169	11.50	13.78	0.949	0.5853
	+	11.19	7.33	8.61	9.22	10.33	12.17		
8	-	19.83	14.22	15.94	17.88	17.06	20.78	1.243	0.8662
	+	18.56	13.44	14.56	15.28	16.83	19.33		
12	-	26.94	22.00	23.06	24.88	24.39	27.78	1.716	0.8956
	+	25.25	21.00	20.94	21.22	23.39	25.78		
24	-	39.83	39.56	40.00	37.31	40.33	44.23	1.700	0.8554
	+	37.25	37.83	36.67	32.39	39.00	40.00		
48	-	47.06	52.89	55.78	45.00	52.83	56.94	1.898	0.7025
	+	43.25	50.94	51.44	37.78	50.94	53.56		
72	-	48.00	55.33	58.83	46.94	55.61	59.89	1.938	0.6416
	+	44.94	53.67	55.39	39.72	54.22	57.00		
96	-	49.67	56.17	59.33	47.06	55.89	59.33	2.173	0.8802
	+	46.31	55.78	57.17	42.00	55.50	58.61		

T = tillering stage; SE = stem elongation stage; EE = ear emergence stage; + = supplemented with wheat grain; - = none supplemented with wheat grain.

Table 4. Least square means of gas production parameters, organic matter digestibility, and metabolizable energy contents obtained from barley and triticale supplemented with wheat (+) and non-supplemented (-) at different growth stages.

Incubation parameters	Wheat grain	Barley			Triticale			SEM	P
		T	SE	EE	T	SE	EE		
OMD	-	65.81	70.42	72.14	63.64	69.12	71.23	0.477	0.8801
	+	62.85	70.07	70.22	59.17	68.79	70.59		
ME	-	9.36	10.29	10.66	9.72	10.46	10.77	0.295	0.8797
	+	8.68	10.24	10.56	9.26	10.41	10.47		
a	-	2.58	4.61	3.97	2.43	4.02	3.43	0.477	0.4589
	+	2.16	4.55	3.32	2.89	3.38	2.89		
b	-	50.44	63.39	62.48	53.97	58.43	59.05	2.058	0.4097
	+	45.96	60.02	61.93	43.36	56.82	57.31		
c	-	0.060	0.044	0.044	0.051	0.047	0.049	0.003	0.900
	+	0.067	0.051	0.044	0.050	0.048	0.048		
a+b	-	50.02	68.00	66.45	56.41	62.45	61.95	2.254	0.5865
	+	48.12	64.57	62.25	46.25	60.20	60.50		

+ = supplemented with wheat grain; - = non supplemented with wheat grain; T = tillering stage; SE = stem elongation stage; EE = ear emergence stage; OMD = organic matter digestibility (%); ME = metabolizable energy (MJ/kg DM); a = gas production from immediately soluble fraction (ml); b = gas production from insoluble fraction (ml); a+b = the potential extent of gas production (ml); c = the gas production rate constant for the insoluble fraction (ml/h).

Discussion

Forage quality is a key factor in animal nutrition. In this study barley and triticale have similar green forage and dry matter production at the 3 growth stages although barley had a higher CP content than triticale, indicating that less barley dry matter would be required to provide equivalent protein supplementation. Geren (2014) and Keles et al. (2016) reported higher dry matter yields for triticale and barley probably due to different climatic and soil conditions. The negative correlation between CP and advancing maturity of wheat and triticale forages has been previously reported (Collar and Aksland 2001) as well as that of triticale and barley at 3 different stages of vegetation (early ear emergence stage, milky stage, and mid-dough stage) (Geren 2014; Keles et al. 2016). The CP content observed in this study corresponded to the findings of Geren (2014), but was lower than that of Keles et al. (2016). The increasing NDF and ADF as the plant ages is also expected, as reported in previous studies (Keles et al. 2016; Salama et al. 2021). Kendall et al. (2009) reported that the outflow rate of feed was decreased when the NDF level of the diet increased from 28% to 32%. The recommended NDF and ADF content of the diet prepared for lactating dairy goats were 41% and 18-20% respectively (Lu et al. 2005). The ADF and NDF determined in this study for barley and triticale were higher than the recommendations of Lu et al. (2005).

As forages mature the leaf:stem ratio decreases and the WSC content will increase in stems (Schnyder 1993). At the early stage of growth, stem tissue is the dominant organ by weight and stem. WSC reserves are the major source for grain filling (Schnyder 1993). WSC is a readily available energy source for rumen microorganisms and it is important for microbial protein synthesis due to energy–protein synchronization (Beaver 1993). WSC reduces ammonia loss from the rumen and increases animal performance (Macrae et al. 1985).

The *in vitro* gas production of triticale was higher than barley at the first 8 hours of incubation. It has been reported that feeds with high CP and NDF content negatively affect *in vitro* gas production (Menke and Steingass 1988; Calabrò et al. 2002). The fact that feeds with high CP and NDF content have lower gas production is associated with negative effects on rumen microbial activity (Rodriguez et al. 2010).

In this study, the ME values of barley and triticale were similar, while ME differed in different growth stages. The ME values determined in this study are in accordance with previous studies reported on barley and triticale (Guney et al. 2016; Keles et al. 2016). The OMD value of barley and triticale in this study progressively increased with advancing growth stage while, Guney et al. (2016) reported that the OMD value of barley progressively decreased with maturity. The OMD and ME values of forages usually decrease with advancing maturity due to the increase in structural carbohydrate content. This increase in structural carbohydrate content may negatively affect digestibility (Kamalak 2010). It is known that non-structural carbohydrate content increases with maturity in winter cereals (Collar and Aksland 2001). This increase in WSC content may lead to enhanced OMD and ME values with advancing growth as determined in this study.

Dairy goat diets are prepared with both forages and concentrates, the amount of concentrate supplementation depending on the nutritional condition of the forages. The interactions among feed ingredients can change the microbial fermentation in the rumen. Associative effects among feed ingredients can be positive or negative (Mould et al. 1983). Zicarelli et al. (2011) argued that supplementation of forages with rapidly digestible carbohydrate sources would enhance feed degradability. In this study supplementation of wheat grain in the incubation did not affect gas production, OMD and ME in barley and triticale forages.

The feeding value of barley and triticale forages at various stages of growth was compared with the requirements for adult dairy goats in an early stage of lactation (50 kg body weight producing 0.88-1.66 kg milk yield/day, with a feed requirement of 1.94 kg DM/day, 104 g CP/day and 3.70 Mcal ME/day according to NRC [2007]). Barley and triticale forages were adequate to meet the daily CP and ME requirements of the goats if they consumed approximately 9 kg/day of barley and triticale green forage regardless of the growth stage to meet early lactation nutrient requirements. Kid mortality is an important problem for goat production in tropical and sub-tropical regions due to seasonal fluctuations in feed supply leading to low milk production and increased pre-weaning kid mortality (Peacock 1996; Orden et al. 2014). Barley and triticale forages are important in these areas for ensuring adequate nutrition of goats because these forages are drought tolerant with high nutritional value.

Conclusions

Barley and triticale forages have potential to be used for feed for dairy goats especially during tillering and stem elongation stages. Although barley had a higher CP content, both have adequate ME and CP levels to meet the nutritional requirements of adult goats with 50 kg body weight and 0.88-1.66 kg milk yield/day in early lactation.

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(Note of the editors: All hyperlinks were verified 3 May 2022).

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