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Digestibility, microbial protein synthesis, rumen and blood parameters in sheep fed diets containing hydroponic barley fodder

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Abstract This experiment was conducted to determine the possibility of replacing part of the barley grain by hydroponic barley fodder (HBF), and evaluating its effect on digestibility, rumen parameters, microbial protein synthesis and blood parameters in sheep. Four male Kermani sheep, 18-month-old (34.7 ± 1 kg live weight) were randomly assigned to a change over 4 × 4 design and fed the experimental diets for 21 d; 16 d for adaptation and 5 d for sample collection. Hydroponic-grown barley fodder replaced barley grain in the experimental diets. The experimental diets were: 1) control diet (without hydroponic barley fodder), 2) diet containing 7% of hydroponic barley fodder, 3) diet containing 14% of hydroponic barley fodder and 4) diet containing 21% of hydroponic barley fodder. Results showed that dry matter intake (DMI), nitrogen intake and retention and digestibility of nutrients increased ($P<0.05$) by increasing the amount of hydroponic barley fodder in experimental diets. Ammonia-nitrogen production changed cubically with increasing level of HBF in the experimental diets ($P<0.05$). In conclusion, the increase in DMI, nutrient digestibility and nitrogen retention suggests that up to 21% of HBF may be fed to sheep. However, an economic analysis is needed before recommendation for practical use at the farm level.

Keywords: feed, forage, germination, grain, nutrients

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Introduction

Growing plants in water or in nutrient solutions without using soil is known as hydroponic fodder or sprouted grains or sprouted fodder (Dung et al, 2010). Hydroponic production systems have been used to produce vegetables for human consumption as well as cereal and legume sprouts for both livestock and human feed. Germination of grain increases the availability and digestibility of nutrients. Reports indicated that sprouts provide a source of rapidly available nutrients due to the action of hydrolytic enzymes releasing readily available amino acids and soluble carbohydrates (Plaza et al., 2003). Soaking and germination cause increased activities of hydrolytic enzymes, improvements in the contents of total proteins, fat, certain essential amino acids, total sugars, B-group vitamins, and a decrease in dry matter, starch and anti-nutrients in sprouting grains (Salunkhe et al., 1984; Peer and Leeson, 1985b; Chavan and Kadam, 1989; Gabrovska et al., 2004).

Dung et al. (2010) reported that no advantage was found when beef animals were given sprouts to replace highly nutritious feeds; however, animals rapidly consumed 6-7 folds green forages possibly due to improved microbial activities. As a result, there was an improvement in efficiency if the forage was added as supplements to diets containing protein deficient hay (Thomas and Reddy, 1962; Tudor et al., 2003). The biological and economic aspects of hydroponic forage culture will depend on sprouting systems, type and quality of the grain, particularly the germination rate, culturing conditions and the management that require further investigation (Fazaeli et al., 2011). Research on availability of hydroponic grown forage as livestock feed, especially in sheep, is very limited needing more research to help determine their optimal levels in livestock diets. Forage limitation and drought are common problems in many parts of Iran. Therefore, nutrient profile, digestibility and conversion ratio of barley fodder production were examined in a hydroponic system. Additionally, feeding value of hydroponic barley and its suitability to replace part of the barley grain in the diet of sheep were investigated.

Materials and methods

Hydroponic barley fodder production

Seeds of barley were washed and soaked in tap water for 18 hours and steeped in water containing 0.5% (v/v) sodium hypochlorite solution for 30 min, and washed before being transferred to perforated plastic trays (50 × 30 × 1 cm) for watering. The seeds were allowed to germinate in a temperature-controlled room (25℃) at 1.5 × 2 m dimensions with continuous lighting for 7 d. They were automatically watered with tap water for 1 min at of 4 h intervals for a period of 7 d. The fresh sprouts were then removed from the trays and allowed to drain the surface water for at least 30 min for to be removed. Dry matter content, crude protein, ether extract, ash in barley grains and the hydroponic fodder were analyzed according to AOAC (2005). Neutral detergent and acid detergent fiber (NDF and ADF) were determined as described by Van Soest et al. (1991).

Experimental diets and animal

The experimental diets were: 1) control diet (barley grain (BG) without hydroponic barley fodder (HBF)), 2) diet containing 7% of BG replaced by HBF, 3) diet containing 14% of BG replaced by HBF and 4) diet containing 21% of BG replaced by HBF (Table 1). All experimental diets contained 40% forage and 60% concentrate. Four rams (34.7 ± 1 kg live weight) were used in 4 × 4 Latin Square design at four 21-days period; 16 days for adaptation to diets and 5 days for sample collection in each period. Sheep were housed separately in metabolic cages for fecal and urinary collection. Diets were offered as total mixed ration (TMR) at 8:30 am and 17:30 pm. Water was freely available.

Blood, fecal, urinary and ruminal fluid sampling

On the last day of each experimental period, blood was collected four hours after morning feeding from the jugular vein in 10 mL syringes and immediately transferred into 10-mL sodium heparinized, evacuated glass tubes and placed on crushed ice. Blood was centrifuged at 3,000 g for 10 min at 4°C, and plasma was harvested and frozen at −20 °C for later analysis. Glucose, total protein, triglycerides, cholesterol and blood urea nitrogen (BUN), were measured using enzymatic procedures and commercial kits according to the manufacturer's instructions (Pars Azmon Co., Tehran, Iran).

Total feces were collected in plastic bags every five days during the experimental period. After collection, the feces were weighed and dried in an oven at 55℃ for 72 h, for dry matter (DM), organic matter (OM), crude protein (CP) and NDF analysis (de Oliveira et al., 2010).

Table 1. Feed ingredients and chemical composition of the experimental diets

	Experimental diets			
Ingredient (% DM)	1	2	3	4
Alfalfa hay	25	25	25	25
Wheat straw	15	15	15	15
Hydroponic barley fodder	0	7	14	21
Ground barley	30	23	16	9
Ground corn	15	14.5	14	16
Soybean meal	4	3	3	2.5
Wheat bran	9	10.5	11	9.5
Vitamin & mineral supplement*	1.5	1.5	1.5	1.5
Salt	0.5	0.5	0.5	0.5
Chemical composition				
DM (%)	76.94	71.53	66.04	66.60
OM (%)	94	93.13	93.17	92.45
ME (Mcal/kg)	2.40	2.39	2.37	2.37
CP (%)	12.22	12.09	12.34	12.19
RDP (%)	8.60	8.60	8.79	8.65
RUP (%)	3.66	3.49	3.55	3.54
EE (%)	2.28	2.37	2.42	2.49
NDF (%)	37.50	39.82	41.77	42.85
ADF (%)	22.59	33.11	23.59	23.79

DM: dry matter, OM: organic matter, ME: metabolizable energy CP: crude protein, RDP: rumen degradable protein, RUP: rumen undegradable protein, EE: ether extract, ADF: acid detergent fiber, NDF: neutral detergent fiber. *Mineral and vitamin supplement contained: Vit A (500000 IU), Vit D_3 (100000 IU), Vit E (100 IU) and minerals (mg): Fe (3000), Cu (300), Mn (300), Ca (2000), Zn (3000), P (90000), Co (100), Na (50000), I (100), Mg (19000) and Se (1).

Daily urine production was collected for 5 d and a 100 mL sample was mixed with 10% (V/V) H_2SO_4 to prevent bacterial degradation of allantoin and volatile N losses. Due to the variability in the urine volume produced by rams, the volume of H_2SO_4 was adjusted to ensure that the pH was maintained below 3.0 (Chen and Gomes, 1992). For determination of the urinary purine derivatives, uric acid, urea nitrogen and creatinine excretion, a 50 mL sub-sample of the diluted urine was stored in a plastic bottle at -20℃.

The quantity of microbial purine absorbed through the small intestine was estimated using the following equation (Chen and Gomez, 1992):

$$Y = 0.84X + (0.150\ BW^{0.75}e^{-0.25x}) \quad (1)$$

where, X is the intestinally-absorbed purine derivatives (PD, exogenous purine), and Y is the excretion of PD in the urine (mmol/d).

At the completion of each period, ruminal fluid samples were aspirated by stomach tube at 0, 2, 4 and 6 h after feeding from all animals. Ruminal pH was determined immediately after ruminal fluid was filtered through four layers of cheesecloth using a pH meter (model AZ8601). A 10-mL was mixed with 0.2 mL of sulfuric acid 50% (Merck) for NH_3-N analysis, and chilled in an ice bath to stop fermentation. The samples were stored at -20℃ until assay.

Statistical analyses

Data on chemical composition were subjected to analysis of variance using the GLM procedure of SAS (2005) as a completely randomized design as $Y_{ij}= \mu + T_i + e_{ij}$ in which, Y_{ij} is the individual observation, μ the general mean, T_i the i^{th} effect of the treatments (HBF and BG) and e_{ij} is the standard error. Mean separation was performed using the least significant difference ($P<0.05$). Data on digestibility, blood parameters, etc. were analyzed using the following model:

$$Y_{ijk} = \mu + T_i + P_j + C_k + e_{ijk} \quad (2)$$

Repeated measure data (ruminal pH and ammonia-N) were analyzed using the following model:

$$Y_{ijk} = \mu + T_i + P_j + C_k + Z_m + ZT_{mi} + e_{ijk} \quad (3)$$

where Y_{ijk} is the dependent variable, μ is the common mean, T_i is the experimental treatment effect, P_j is experimental period effect, C_k is animal effect, Z_m is time effect, ZT_{mi} is interaction of treatment and time and e_{ijk} is the random error. Polynomial contrasts were used to determine linear, quadratic and cubic components of the dietary treatment response.

Results

Chemical composition

Chemical composition of barley grain and HBF are shown in Table 2. Barley grain contained higher ($P<0.05$) DM than HBF (91% vs. 16%). The contents of crude fat, ash, ADF, and NDF in HBF were higher but OM content were lower ($P<0.05$) than in barley grains. No significant difference was found in CP content between HBF and barley grain.

Dry matter intake and nutrient digestibility

The effects of dietary HBF on dry matter intake (DMI) and digestibility of DM, OM, CP, and NDF are summarized in Table 3. Digestibility of DM increased linearly and quadratically ($P<0.05$) by increasing the amount of HBF in the diet. The animals on the control diet (diet without HBF) showed the lowest DM digestibility while the animals which received 21% of HBF had the highest DM digestibility. Digestibility of OM, CP, and NDF were significantly ($P<0.05$) higher in experimental diet containing 21% HBF compared to control and diet cont-

Table 2. Chemical analysis of barley grain and hydroponic barley fodder

Constituents	Barley	Hydroponic barley fodder	SEM*
DM (%)	91.00[a]	16.00[b]	1.00
OM (%)	96.80[a]	95.25[b]	0.23
CP (%)	12.20[b]	14.16[a]	0.25
EE (%)	1.64[b]	2.42[a]	0.10
NDF (%)	22.50[b]	43.68[a]	2.60
ADF (%)	11.40[b]	17.35[a]	0.38
ASH (%)	3.20[b]	4.75[a]	0.23

DM: dry matter, OM: organic matter, CP: crude protein, EE: ether extract, NDF: neutral detergent fiber, ADF: acid detergent fiber exclusive of residual ash.
Means within the same row with differing superscripts are significantly different at $P<0.05$.
*SEM: standard error of the mean.

Table 3. Dry matter intake and nutrient digestibility in sheep fed different levels of hydroponic barley fodder

	Experimental diets				SEM*	Orthogonal contrasts		
	1	2	3	4		linear	quadratic	cubic
DMI (kg/d)	1.23[d]	1.50[c]	1.76[b]	1.98[a]	0.05	0.0001	0.60	0.89
DM digestibility (%)	59.69[c]	67.26[b]	71.83[a]	73.81[a]	0.87	0.0001	0.02	0.92
OM digestibility (%)	62.25[c]	69.10[b]	73.51[a]	74.90[a]	0.81	0.0001	0.01	0.88
CP digestibility (%)	59.41[c]	68.50[b]	73.01[a]	75.32[a]	0.82	0.0001	0.01	0.54
NDF digestibility (%)	26.07[c]	43.03[b]	53.29[a]	57.31[a]	1.51	0.0001	0.01	0.95

DMI: dry matter intake, OM: organic matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, Experimental diets including: 1) control diet (without hydroponic barley fodder), 2) diet containing 7% of hydroponic barley fodder, 3) diet containing 14% of hydroponic barley fodder and 4) diet containing 21% of hydroponic barley fodder.
Means within the same row with differing superscripts are significantly different at P<0.05.
*SEM: standard error of the mean.

aining 7% HBF. Dry matter intake increased linearly by increasing the level of HBF in diets (P<0.05). The highest and lowest values of DMI were recorded for experimental diets containing 21% and control, respectively.

Rumen parameters

Concentrations of NH_3-N and pH in the ruminal fluid are shown in Table 4. Ruminal pH values were not affected by HBF feeding. Ammonia-N production changed cubically by increasing the dietary HBF (P<0.05). The maximum values of ruminal NH_3-N were recorded for experimental diets containing 7 and 21% HBF and the lowest values were for control and diet containing 14% HBF, numerically (P>0.05).

Blood parameters

Blood glucose, crude fat, BUN and total blood plasma protein concentrations were not affected by the diets (Table 5). Blood triglyceride levels were reduced from 14 to 21%, with increasing amount of HBF in the diet, cholesterol concentration increased numerically (P>0.05).

Purine derivatives, microbial protein synthesis and nitrogen retention

Mean values for daily excretion of PD containing allantoin, uric acid, creatinine, total PD in the urine, microbial protein synthesis and nitrogen retention are shown in Table 6. Feeding HBF had no significant effect on urinary purine derivatives and microbial protein synthesis in male sheep. Nevertheless, numerically experimental diets containing 7 and 21% HBF produced the highest content of microbial protein synthesis in the rumen, whereas higher values for uric acid and creatinine excretion in urine were detected in diet containing 14% HBF.

As can be seen in Table 6, N intake increased linearly (P<0.05) by increasing the amount of HBF in the diet.

Table 4. Concentrations of NH_3-N and pH in rumen of sheep fed different levels of hydroponic barley fodder.

	Experimental diets				SEM*	Orthogonal contrasts		
	1	2	3	4		linear	Quadratic	cubic
Total NH3-N (mg/dl rumen liquid)	31.81	36.98	30.93	34.20	3.23	0.10	0.83	0.07
pH	6.70	6.69	6.69	6.75	0.06	0.72	0.22	0.88

Experimental diets including: 1) control diet (without hydroponic barley fodder), 2) diet containing 7% of hydroponic barley fodder, 3) diet containing 14% of hydroponic barley fodder and 4) diet containing 21% of hydroponic barley fodder.
*SEM: standard error of the mean.

Table 5. Blood parameters of sheep fed different levels of hydroponic barley fodder.

	Experimental diets				SEM*	Orthogonal contrasts		
Parameters	1	2	3	4		linear	quadratic	cubic
Glucose (mg/dl)	69.25	71.50	61.25	70.00	5.13	0.74	0.55	0.22
Total protein (mg/dl)	7.20	8.75	8.68	7.77	0.82	0.67	0.19	0.83
Cholesterol (mg/dl)	56.25	56.25	53.25	58.75	1.79	0.59	0.17	0.20
Triglyceride (mg/dl)	26.25	28.75	28.75	21.25	2.75	0.24	0.15	0.88
Urea N (mg/dl)	17.36	17.22	17.94	17.83	0.77	0.51	1.00	0.66

Experimental diets including: 1) control diet (without hydroponic barley fodder), 2) diet containing 7% of hydroponic barley fodder, 3) diet containing 14% of hydroponic barley fodder and 4) diet containing 21% of hydroponic barley fodder.
*SEM: standard error of the mean.

Table 6. Daily excretion of total purine derivatives, allantoin, uric acid, Creatinine, microbial protein synthesis Nitrogen intake, fecal and urine N output and nitrogen retention in sheep fed different levels of hydroponic barley fodder

	Experimental diets				SEM*	Orthogonal contrasts		
	1	2	3	4		linear	quadratic	Cubic
Urine allantoin output (mmol/d)	9.18	10.45	10.20	9.70	1.15	0.82	0.46	0.82
Uric acid (mmol/d)	0.20	0.18	0.21	0.15	0.03	0.42	0.54	0.35
Creatinine (mmol/d)	3.62	4.69	5.02	4.58	0.58	0.27	0.24	0.99
Total purine derivatives (mmol/d)	10.92	12.35	12.07	11.47	1.29	0.82	0.46	0.81
Microbial nitrogen (g/d)	9.32	10.62	10.38	9.85	1.16	0.80	0.46	0.81
Microbial protein (g/d)	58.22	66.41	64.85	61.55	7.25	0.80	0.46	0.81
N intake (g/d)	24.07^{d}	29.05^{c}	34.77^{b}	38.54^{a}	0.99	0.0001	0.56	0.56
Fecal N output (g/d)	9.76	9.16	9.41	9.44	0.36	0.68	0.42	0.54
Urine N output (g/d)	0.36	0.38	0.34	0.35	0.03	0.62	0.86	0.53
Total N excretion (g/d)	10.12	9.54	9.75	9.79	0.36	0.65	0.43	0.58
Nitrogen retention (g/d)	13.95^{d}	19.51^{c}	25.02^{b}	28.75^{a}	0.82	0.0001	0.31	0.65

Experimental diets including: 1) control diet (without hydroponic barley fodder), 2) diet containing 7% of hydroponic barley fodder, 3) diet containing 14% of hydroponic barley fodder and 4) diet containing 21% of hydroponic barley fodder.
Means within the same row with differing superscripts are significantly different at $P<0.05$.
*SEM: standard error of the means.

Animals receiving the control diet recorded the lowest amount of nitrogen intake, while those receiving 21% of HBF had the highest values. Including HBF in the diet up to 21%, did not affect fecal and urine N as well as the total N output. Nitrogen retention increased linearly ($P<0.05$) with increased amount of HBF in the diet. The animals fed with the diet containing 21% HBF retained higher ($P<0.05$) nitrogen than the other treatments; the lowest N retention was observed in control animals. Nitrogen intake was increased by increasing the level of HBF. Total nitrogen excretion rate was not affected, and nitrogen retention increased as nitrogen intake increased.

Discussion

Chemical composition

There was a significant difference between chemical composition of barley grain and HBF. Dry matter losses of 17.8 % and 18% were reported in 6 d sprouting oat seeds and 7 d sprouting barley seeds (Hillier and Perry, 1969; Peer and Leeson, 1985b). Fazaeli et al. (2012) also reported similar results in 7-day old hydroponically sprouted barley grains grown under light, without nutrients. Leaching of material from the seed following soaking as well as degradation and oxidation of substrates from the seed during the sprouting process was reported as a cause of the loss in DM from the original weight of seed (Peer and Leeson, 1985a; Chavan and Kadam, 1989). Chung et al. (1989) found an increase in fiber content from 3.75% in unsprouted barley seeds to 6% in 5-day sprouted barley. An increase in NDF and ADF caused by the sugars is used for cell wall synthesis providing energy for growth (Cuddeford, 1989). This was likely due to the loss in carbohydrates as DM providing energy for the metabolic activities and growth resulting in lower OM and higher ash in HBF (Chavan and Kadam, 1989). Similar findings were reported by Peer and Leeson (1985a) and Fazaeli et al. (2012). Morgan et al. (1992) reported that the ash content of hydroponic fodder increased from day 4 corresponding with the extension of the root, which allows mineral uptake. There are contradictory results on changes in lipid (EE) contents as a result of germination. For example, Kylen and McCready (1975) and Camacho et al. (1992) reported decreases in lipid content of barley sprout with germination while increases were noted by Peer and Leeson (1985b) and Fazaeli et al. (2012). The increase in EE could be due to production of chlorophyll associated with plant growth (Mayer et al., 1975 as cited in Fazaeli et al., 2012).

In cereal grains, Chavan and Kadam (1989) reported that sprouting led to an increase in the content of plant constituents which can increase the associated functions. Barley sprouts were originally used as feed for livestock, and research on sprouts constituents as feed has been developed. Sprouted barley has higher inorganic ingredients such as Ca, Fe, and Zn than other cereals. According to Peer and Leeson, (1985a), 70% increase in essential amino acids contents was found from day 4 to day 7 after seed germination.

Dung et al. (2010) found that CP content of barley grains before and after germination were 13.9 and 15.9%, respectively. However, Snow et al. (2008) reported a higher (16.13%) CP content in HBF. Increased amount of protein in hydroponic fodder from day 4 of sprouting reported by Morgan et al. (1992) could be due to absorption of nitrate that facilitates the metabolism of

nitrogenous compounds from carbohydrate reserves, and may be responsible for increasing the crude protein content. The use of nutrient solution increases the CP content of the hydroponic fodder compared with tap water presumably due to the uptake of nitrogenous compounds contained in hydroponic solutions (Dung et al., 2010).

Cultivation conditions in a hydroponic system could have caused differences in CP contents (Fazaeli, 2012). Most of these increases in nutrients are not true increases, but simply a reflection of the loss in total DM through respiration during germination, mainly in the form of carbohydrates. Therefore, by increasing the duration of sprouting, greater losses in DM and increase in protein content will occur. It has been found that as total carbohydrates decrease, the percentages of other nutrients increase (Lorenz, 1980; Peer and Leeson, 1985b; Chavan and Kadam, 1989; Morgan et al., 1992). The exception is fiber, a major constituent of cell walls, which increases both in percentage and real values with the synthesis of structural carbohydrates, such as cellulose and hemicelluloses (Cuddeford, 1989 as cited in Sneath and McIntosh, 2003).

Dry matter intake and nutrient digestibility

Similar to our results, Dung et al. (2010) and Fayed (2011) also reported increased in DMI with hydroponic barley fodder. It is possible that the release of soluble carbohydrates and N from HBF stimulated microbial growth and colonization, and improved degradation of the low protein forage used in their experiments (Pond et al., 1984).

Unlike the results of the present study, Peer and Leeson (1985a) found in pigs that digestibility of DM of 4-day old HBF was significantly lower in sprouted barley than ground barley, but was superior to that recorded for whole barley. There was no discernable effect on DM, CP and crude fiber digestibility when cattle were fed four levels of hydroponic oat sprouts (0, 0.63, 0.95, 1.26 kg DM) in both low and high-energy diets (Hillier and Perry, 1969). Also, Dung et al. (2010) demonstrated that DM and OM digestibility was not affected by feeding HBF to sheep. A research conducted at Washington State University concluded that digestibility of the sprouted wheat was slightly lower compared with sound wheat (Lardy, 1999). Results obtained in our study were comparable with those reported by Morgan et al. (1992) who found an increase in DM and OM digestibility of 4-day-old sprouts in comparison to barley grains and 8-day-old sprouts. Our findings are in agreement with those of Fayed (2011) where female Barki lambs were fed on diets containing 10-day-old sprouted barley grains on rice straw or sprouted barley grains on dried Tamarix. Ibrahim et al. (2001) also reported the digestibility coefficient of all nutrients increased in sheep as a result of feeding sprouted barley on rice straw.

The germination of seeds to sprouts increases the hydrolysis of nutrient reserves stored in the seed allowing for the release of soluble compounds (Plaza et al., 2003) and consequently leading to increases in nutrient availability in the rumen. The release of soluble carbohydrates and nitrogen from the sprouts most likely can help the proliferation of micro-organisms for a more efficient degradation of diets containing HBF giving rise to higher digestibility values relative to the treatments without HBF supplementation (Fayed, 2011).

Increased DMI in the present study, may be attributed to palatability and high digestibility of the diets containing HBF, corroborated by Dung et al. (2010) and Fayed (2011) findings. However, Fazaeli et al. (2011) reported that including 8-day-old HBF by 22.8% in the diet reduced DMI in male calves.

Rumen parameters

Dung et al. (2010) reported that the lowest rumen pH value and the highest total volatile fatty acid (TVFA) concentration were obtained in sheep fed on diets containing HBF compared to diets without HBF. They also found that total ammonia concentration was higher for fresh HBF supplements than the diets without HBF. Similar results were obtained by Fayed (2011). However, Hafla et al. (2014) hypothesized that the rate of NH_3-N release from herbage NPN was faster than that of water soluble sugars in sprouted barley resulting in NH_3-N accumulation. In the present study, all diets had similar levels of CP and RDP, thus the rate of protein degradation and the ammonia production in the rumen of sheep fed with the experimental diets were almost the same.

Blood parameters

Blood parameters were not affect by treatments. The diets were isocaloric and the rumen pH was not significantly affected, therefore, it seems that propionate production in the rumen as a precursor of glucose via gluconeogenesis in the liver was similar in all treatments. The results of this study were in accordance with the results reported by Kumar et al. (1980) who found a positive correlation between dietary protein and plasma protein concentration. However, Fayed (2011) reported that ewes fed sprouted barley on roughages had significantly

higher values of serum total proteins. This may be due to the high CP content in treated roughages. In this experiment, BUN was not different between treatments in the rumen of sheep fed with experimental diets. We can conclude that the process of converting ammonia to urea in the liver of sheep fed with the experimental diets were similar.

Purine derivatives, microbial protein synthesis and nitrogen retention

Ammonia is the main substrate for microbial protein synthesis. Because ammonia production in the rumen was not affected by the experimental diets, and the experimental diets were iso-nitrogenous and iso-energetic, it seems that nitrogen and energy requirements for microbial protein synthesis were provided by all diets. The rumen microbial outflow did not differ among treatments. Efficient microbial protein synthesis depends on supply of adequate N and readily fermentable carbohydrates as well as other nutrients for uptake and utilization by microbes.

Fayed (2011) reported that production of sprouted barley by utilizing dried Tamarix and rice straw was economical and feeding 10-day-old sprouted barley grains increased N intake and retention in female lambs. In this experiment, the higher nitrogen intake was due to the higher DMI for the diet containing 21% HBF. This finding may be related to higher improvement in CP intake and digestibility in experimental diets containing HBF compared with the control diet. However, supplementing poor quality roughage (oat hay) with freshly sprouted barley and freeze-dried sprouted barley did not affect microbial outflow and N retention in sheep (Dung et al., 2010).

Conclusion

Our results showed that including HBF in diet up to 21%, had no effect on microbial protein synthesis, ammonia-N and blood parameters. However, the increase in DMI, nutrient digestibility and nitrogen retention suggests that it may be possible to feed up to 21% of HBF to sheep. However, an economic analysis is needed before recommendation for practical use at the farm level.

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چکیده این مطالعه با هدف بررسی اثر جایگزینی بخشی از دانه جو موجود در جیره با علف جو آبکشت و همچنین اثر تغذیه آن بر قابلیت هضم، سنتز پروتئین میکروبی، فراسنجه های شکمبه و خون در گوسفند کرمانی انجام گرفت. به این منظور از ۴ رأس بره نر نژاد کرمانی ۱۸ ماهه با میانگین وزنی ۱±۳۴/۷ کیلوگرم استفاده شد. گوسفندان به صورت تصادفی در قالب طرح مربع لاتین ۴×۴ در ۴ دوره ۲۱ روزه، شامل ۱۶ روز دوره عادت پذیری و ۵ روز دوره جمع آوری نمونه ها با جیره‌های آزمایشی تغذیه شدند و در جیره‌های آزمایشی دانه جو با علف جو آبکشت جایگزین شد. جیره‌های آزمایشی شامل: ۱) جیره شاهد (بدون علف جو آبکشت)، ۲) جیره دارای ۷ درصد علف جو آبکشت، ۳) جیره دارای ۱۴ درصد علف جو آبکشت و ۴) جیره دارای ۲۱ درصد علف جو آبکشت بود. نتایج نشان داد با افزایش سطح استفاده از علف جوی آبکشت در جیره، میزان مصرف ماده خشک، قابلیت هضم مواد مغذی، مصرف و ابقای نیتروژن افزایش یافتند ($P<۰/۰۵$). نیتروژن آمونیاکی تولید شده در شکمبه با افزایش سطح استفاده از علف جو آبکشت در جیره به صورت درجه سه تغییر کرد ($P<۰/۰۵$). در نهایت افزایش مصرف ماده خشک، قابلیت هضم مواد مغذی و ابقاء نیتروژن می‌تواند توجیه کننده‌ی استفاده از علف جو آبکشت تا سطح ۲۱٪ در جیره‌های گوسفندان باشد، اگرچه توصیه می شود به منظور ارزیابی دقیق‌تر آنالیز اقتصادی نیز صورت پذیرد.