Effect of Replacing Dietary Corn Silage with Hydroponic Barley Green Fodder on Holstein Dairy Cows Performance

Research Article

H. Fazaeli[1]*, H.A. Golmohammadi[2] and S.N. Tabatatbaei[3]

[1] Department of Animal Science, Animal Science Research Institute of Iran (ASRI), Agricultural Research Education and Extension Organization (AREEO), Karaj, Iran
[2] Department of Animal Science, Isfahan Agricultural and Natural Resources Research and Education Center, Agricultural Research, Education and Extension Organization (AREEO), Isfahan, Iran
[3] Department of Animal Science Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran

Received on: 1 Mar 2020
Revised on: 31 May 2020
Accepted on: 15 Jun 2020
Online Published on: Mar 2021

*Correspondence E-mail: h.fazaeli@areeo.ac.ir

ABSTRACT

The objective of this study was to investigate the effect of inclusion of hydroponic barley green fodder (HBGF) in the diet on the performance of lactating cows. Eight Holstein cows (with daily milk yield of 31.15±2.75 kg and 83.23±12.46 days in milk) were assigned to 1 of 4 diets in a 4 × 4 latin square design. Control diet (I) consisting of 62% concentrates, 20% alfalfa hay, and 18% maize silage (dry matter (DM) basis), where in diets II, III and IV the maize silage was replaced by 20, 40 and 60% HBGF, DM basis, respectively. The green fodder yield was 869 g per kg planted seed (DM basis), showing a loss of 131 g DM. Dry matter intake was 23.20, 22.98, 22.67 and 22.65 kg/d on diets I, II, II and IV, respectively. The dietary HBGF level did not affect the average daily milk yield (27.38, 27.62, 26.41 and 27.22 kg/d), as well as the fat, protein and milk total solid yield. Feed efficiency (milk yield per kg DM intake) was 1.26, 1.27, 1.28 and 1.31 which did not significantly affected by the treatments. Finally, inclusion of HBGF up to 60% of maize silage portion, equal to 10.5% of total diet (DM basis), did not affect the performance of lactating cows when compared with maize silage. However, the biomass yield (DM basis) of hydroponic barley green fodder per kg seed grain was lower than that of the initial grain which would increase the cost of feeding.

KEY WORDS forage, hydroponic, milk yield, productivity.

INTRODUCTION

The dairy farm industry is one of the most important economical sectors of animal production in Iran, nevertheless the industry is challenged with the scarcity of fodder in most part of the year. Therefore, the farmers are continually looking for the ways to provide proper feeds and to lower feed cost and improve profitability (Kamalzadeh *et al.* 2008; Beldman *et al.* 2017). During the last decades there have been some arguments about the green fodder production in hydroponics system to compensate the forage supply for animals, using cereal grains seeds (Tudor *et al.* 2003; Fazaeli *et al.* 2012; Tranel, 2013; Naik *et al.* 2014). The hydroponics green fodder is produced from forage grains, mainly barley and oats, having high germination rate and grown for a short period of time (about one week) in a special chamber that provides the appropriate growing conditions (Al-Ajmi *et al.* 2009; Fazaeli *et al.* 2012). Development of hydroponic planting systems has provided the opportunity for production of fresh forages from cereal grains in controlled growing chambers (Bustos *et al.* 2000; Gunasekaran *et al.* 2019). Depending on the type of grain, the forage mat reaches 15 to 20 cm high where production rate is about 4 to 8 kg of fresh forage equivalent to 0.70 to

0.85 kg of DM per kg seed grain planted (Naik *et al*. 2012; Fazaeli *et al*. 2017; Gunasekaran *et al*. 2019).

A few research has been conducted on the feeding value of sprouted grains and performance of animals fed hydroponically-produced green forage. Raeisi *et al*. (2018) studied the effect of replacing barley grain with hydroponic barley fodder up to 21% in the sheep diet (DM basis) and found that dry matter intake (DMI) and digestibility were increased but rumen pH and NH_3-N, and blood parameters (glucose, total protein, cholesterol, triglyceride and urea) were not affected by the treatments. According to Tawfeeq *et al*. (2018), *in vitro* dry matter and organic matter digestibility of hydroponic green fodder grown for 8 days ranged were 93.53 and 94.23% respectively but the *in vivo* digestibility were 87.14 and 87.94% that were lower than the *in vitro* method. Azila (2001) studied the nutritive value of barley green fodder produced in an 8-day period of hydroponic system and reported that digestibility and energy content were reduced in green fodder (12.5 MJ/kg DM) when compared with barley green (15.9 MJ/kg DM). Fazaeli *et al*. (2012) reported that crude protein (CP), non protein nitrogen (NPN), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), and water soluble carbohydrate (WSC) were increased but organic matter (OM) and non fiber carbohydrate (NFC) decreased in hydroponic green forage compared with the original grain.

Gunasekaran *et al*. (2019) studied the coustomization of low cost hydroponic techniques for fodder maize production and reported that fresh fodder yield ranged from 3.75 to 5.20 kg per kg maize seed during 8-9 days growing period and the green forage contained 9.72 to 23.72% CP, 9.69 to 12.48% CF and 3.30 to 4.71% EE.

Micera *et al*. (2009) reported that addition of hydroponic oat green fodder to the diet did not affect the biochemical and hematological parameters in sheep. Consequently, it was suggested that utilization of hydroponic fodder, might improve the animal welfare and milk production. Dry matter content of hydroponic green fodder ranged from 12 to 16% that could limit the feed intake due to its high moisture content (Fazaeli *et al*. 2012; Naik *et al*. 2012). Hosainy-Abrandabadi *et al*. (2015) reported that DMI and daily gain were decreased in finishing lambs when barley grain was partially replaced by hydroponic barley green fodder in the diet. Fazaeli *et al*. (2011) reported that inclusion of hydroponic barley green fodder in the diet of feedlot calves did not affect the body weight gain, but decreased the dry matter intake and increased the feeding cost. Sulser (2015) evaluated the effect of barley green fodder (produced by a hydroponic system) on the performance of sheep and reported that hydroponic fodder did not offer any advantage over alfalfa hay and cereal grains for the average daily gain, but it increased the total cost of the diet.

Some researchers, however found an advantage when inadequate diets were supplemented with hydroponic green fodder (Marsico *et al*. 2009; Naik *et al*. 2017). Nugroho *et al*. (2015) reported that supplementation of corn silage with hydroponic green maize fodder, increased the DMI, as well as energy and nitrogen consumption. They concluded that it could improve nutrient digestibility and maintain persistency of milk production during late lactation in dairy cows. According to Rajkumar *et al*. (2018), hydroponic maize fodder can be effectively substituted up to 30% of crossbred calves diets without significant variation in the growth performance. Tudor *et al*. (2003) reported an improvement in the performance of steers when fed restricted hay in the diet and included 15.4 kg fresh hydroponic green fodder (about 1.8 kg added DM). However, due to the lack of information on the performance of hydroponically-produced fresh fodder in dairy cattle, this trial was conducted to evaluate the effect of partial substitution of corn silage with barley green forage, produced in a hydroponic system, in the diet of lactating Holstein cows.

MATERIALS AND METHODS

Green forage production

A steel electrically power unit of hydroponic sprouting chamber measuring 4.0 × 3.0 × 2.6 m equipped with automatic sprayer irrigation and ventilation apparatus (Manufactured by Iranian Jahad Engineering Institute) was employed. The chamber was highly insulated and thermostatically controlled. Fluorescent lighting tubes in waterproof electrical devices were arranged on the walls in vertical position in order to get better arrival of light for growing leaves when it provide 1000 to 1500 microwatts/cm^2 during 12 to 14 h of daily light (El-Deeba *et al*. 2009). The system consisted of a growing room, growth troughs and aeration, lighting, cooling, irrigation, supernatant collection and control units, with capacity of 100 polyethylene trays of 70 × 30 cm dimensions.

Commercial grade barley seeds (Valfajr variety) with a relatively high germination rate (about 85%) were screened and soaked in 20% sodium hypochlorite solution to control fungal growth. Then they were washed and soaked in tap water for 20 h, drained and distributed in the growing trays where the density obtained was equivalent to seed rate of 4.5 kg/m^2 (DM) and adequately irrigated to germinate and growth (Fazaeli *et al*. 2012).

In order to provide daily requirement of green fodder, 12 trays were planted every day. Temperature inside the growing chamber was precisely controlled to get a range of working temperature between 18 ˚C to 21 ˚C to prevent growth of unwanted microorganisms such as molds and fungi.

The air circulation of the production room was adjusted to control the relative humidity about 90%. Green fodder mass were harvested every 6-day cycle after sowing. Therefore a period of 6-day was needed to acquire the daily continuously harvesting of the green forage. Therefore, during a period of 12 weeks experiment, 12 trays of prepared green fodder were removed from the growing chamber every day and the fodder mass were removed from each tray, then they were weighted and chopped shred by hand, two hours before mixing with the experimental diets.

The fresh forage batches of trays were individually weighted to determine the fresh yield of green forage. Then all trays were sampled and 6 representative fresh green fodder samples from each period were oven-dried at 70 ˚C for 48 h to determine the DM content and analyzed for crude protein contents, using of kejeldahl method (AOAC, 1990).

The NDf content was determined according to Van Soest *et al.* (1991). The conversion ratio of fresh fodder yield per kg of grain (seed) was calculated (Fazaeli *et al.* 2012). Percentages of dry matter loss were estimated as:

$$(DMS-DMY) / DMS \times 100$$

Where:

DMS: amount of dry matter (of barley grain seed) planted in each tray.

DMY: dry matter yield from green fodder per tray (Fazaeli *et al.* 2012).

Feeding trial

Eight multiparous lactating Holstein dairy cows, with average body weight of 615±39 kg, 83.23±12.46 days in milk (DIM), and average daily milk yield of 31.15±2.75 kg, were selected from the dairy farm of an agro-industrial cooperative, located in Golpayegan. The animals were individually housed in a 3 × 4 m tie-stall barn bedded with wheat straw and had free access to water and rock salt throughout the trial, allowing seven days adaptation to the experimental conditions. Cows were randomly assigned to one of four groups in a double 4 × 4 Latin square design. Animal care and management practices were followed according to the dairy farm.

All cows were weighed at the beginning of the experiment and body weight changes were determined during each period. The feeding trial was accomplished during four experimental periods, each with two weeks of adaptation followed by one week of data collection and sampling. Treatment diets were formulated according to the Nutrient Requirements for dairy cattle of the NRC (2001) and contained similar nutrient concentrations (Table 1). The concentrate ingredients were prepared and mixed weekly, and the roughage and concentrate portions were mixed manually every day and offered *ad-libitum* as a total mixed ration (TMR) three times per day (at 0800, 1300 and 2000 h).

Feeds offered and refusals were recorded and feed intake calculated. Dry matter intake was estimated from feed intake × DM%. Cows were milked three times daily at 07:00, 15:00 and 22:00 h, and milk yield recorded individually at each milking. Milk production was recorded during the third week of each experimental period and used for calculation of the mean daily milk. Daily milk samples were collected from each cow at different milking times from day 17 to 21 of each period, preserved in specific containers, using 6 milligram potassium dichromate per mL of milk sample, and stored at 4 ˚C pending analyses (Monardes *et al.* 1995; Moosavy *et al.* 2017). At the end of the experiment, milk samples were analyzed for fat, protein, lactose, solids-non-fat (SNF) and total solid (TS), using Eco-Milk Analyzer (Foss 605B Milk-Scan; Foss Electric, Hillerød, Denmark) in the Milk Testing Laboratory of Golpayegan Pegah Dairy Plan.

The daily yield of fat, protein, lactose, SNF and TS were computed as the weighted means of milk yields on each recording day and percentages of the milk composition. The 3.5 or 4% fat-corrected milk (FCM) and energy-corrected milk (ECM) were estimated as described by (Britt *et al.* 2003; Erdman, 2009; Krause and Combs, 2003)

The efficiency of feed conversion was calculated for each cow in each period by dividing the mean yield of milk and FCM by the mean DMI over the last week of each period.

Statistical analysis

Data on chemical composition and conversion ratio of the green fodder yield between different weeks were analyzed, using a simple complete randomized design as:

$$Y_{ij} = \mu + T_i + S_j + e_{ij}$$

Where:

Y_{ij}: observation.

μ: overall mean.

s: random effect of sampling.

T: fixet effect of treatment.

e_{ij}: residual error.

Results obtain from nutritional trial were analyzed in a complete 4 × 4 Latin square design, using the PROC MIXED of SAS (2002), with the model sums of squares as:

$$Y_{ijkl} = \mu + S_i + P_j + A_k + A(S) + T_l + e_{ijkl};$$

Where:

Y_{ijkl}: observation.

μ: overall mean.
s: random effect of the square.
P: random effect of period.
A: random effect of animal.
A(S): random effect of the animal within square.
T: fixed effect of treatment.
e_{ijk}: residual error.

For the statistical analyses, the probability of significancy among the treatments and interaction ($P \leq 0.05$) were used to compare the means within and among treatments.

RESULTS AND DISCUSSION

Productivity of barley green fodder

During the fodder growth period, the main visible changes were the increase in root length and thickness.

The green fodder yield per kg barley seed ranged from 5.52 to 5.88 kg, whereas DM yield was 0.776 to 0.813 kg per kg of barley seed (Table 2) in a 6-d growing phase.

There were no significant differences ($P>0.05$) between the growing periods (weeks) for fresh fodder yield or DM basis yield. The crude protein (CP) content ranged from 12.51 to 12.96% DM basis and DM loss ranged from 10.89 to 13.55% of the initial seed. These results are consistent with the previous reports (Naik *et al.* 2012; Fazaeli *et al.* 2017; Gunasekaran *et al.* 2019). The production conversion ratio, per unit of planted seed, based on the amount of fresh fodder produced was 4 to 8 times (Peer and Leeson, 1985; Morgan *et al.* 1992; Fazaeli *et al.* 2012; Naik *et al.* 2014), that affected by several factors, namely type and variety of seed, germination rate, seedling density, lightening, irrigation system and growing lengh (El-Deeba *et al.* 2009; Adjlane *et al.* 2016).

Table 1 Ingredients and chemical composition of the experimental diets[1]

Feed ingredients	**Diets (% DM)**			
	I	II	III	IV
Alfalfa hay	20.00	20.00	20.00	20.00
Corn silage	18.00	14.50	11.0	7.50
Hydroponic barley green fodder (HBGF)	0.00	3.50	7.00	10.50
Barley grain	15.70	15.70	15.70	15.70
Corn grain	12.00	12.00	12.00	12.00
Wheat bran	7.50	7.50	7.50	7.50
Soybean meal	10.30	10.30	10.30	10.30
Canola meal	6.30	6.30	6.30	6.30
Whole cotton seed	4.15	4.15	4.15	4.15
Fish meal	1.50	1.50	1.50	1.50
Fat	1.50	1.50	1.50	1.50
Urea	0.23	0.23	0.23	0.23
Calcium carbonate	0.70	0.70	0.70	0.70
Di-calcium phosphate	0.12	0.12	0.12	0.12
Salt	0.40	0.40	0.40	0.40
Sodium bicarbonate	0.10	0.10	0.10	0.10
Mineral and vitamine premix[2]	1.50	1.50	1.50	1.50
Chemical composition				
Dry matter (%)	62.45	58.72	55.45	52.47
NE_L (Mcal/kg DM)	1.71	1.72	1.73	1.74
Crude protein (%)	17.34	17.51	17.68	17.84
Rumen-degradable protein (RDP) (%)	11.80	11.90	12.11	12.24
Rumen-undegradable protein (RUP) (%)	5.54	5.55	5.57	5.60
Neutral detergent fiber (%)	30.07	29.59	29.10	28.65
Acid detergent fiber (%)	18.26	17.78	17.30	16.80
Non-fiber carbohydrates (%)	41.10	41.50	41.80	42.20
Ca (%)	0.80	0.80	0.80	0.80
P (%)	0.50	0.50	0.50	0.50

[1] The net energy for lactation (NE_L) content of feed ingridients, used in ration formulation, was estimated from NRC (2001) except for the green fodder which was estimated from the report of Fazaeli *et al.* (2012).
[2] Provided (per kg of DM): vitamin A: 500000 IU; vitamin D: 100000 IU; vitamin E: 1000 mg; P: 9000 mg; Ca: 180000 mg; Mn: 2000 mg; Na: 55000 mg; Zn: 2000 mg; Fe: 2000 mg; Cu: 280 mg; Co: 100 mg; Br: 100 mg and Se: 1 mg and Anti-oxidant: 3000 mg.
I: Contrl diet; II: diet contained 3.5% HBGF; III: diet contained 7% HBGF and IV: diet contained 10.5% HBGF.

Table 2 Barley green fodder productivity, during 12 weeks of growth

Week	Fresh yield (kg/kg seed)	DM %	DM yield (kg/kg seed)	DM (kg/kg seed DM)	CP % DM basis	DM loss (%)
1	5.75	14.02	0.80	0.87	12.76	13.32
2	5.82	14.23	0.80	0.87	12.75	10.95
3	5.88	14.15	0.78	0.85	12.96	10.54
4	5.82	13.83	0.78	0.87	12.68	13.45
5	5.77	13.78	0.81	0.88	12.82	14.50
6	5.74	13.69	0.81	0.88	12.57	15.50
7	5.78	13.88	0.80	0.87	12.87	13.74
8	5.83	13.93	0.80	0.87	12.65	12.68
9	5.81	14.13	0.79	0.86	12.83	11.73
10	5.52	14.27	0.78	0.85	12.51	15.30
11	5.88	14.07	0.77	0.84	12.83	11.04
12	5.73	13.83	0.79	0.86	12.94	14.79
Mean	5.78	13.98	0.81	0.87	12.76	13.13
SEM	0.19	0.362	0.01	0.01	0.204	0.971
P-value	0.975	0.237	0.37	0.38	0.887	0.306

DM: dry matter and CP: crude protein.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Lower amount of green forage to seed ratio was reported by Al-Ajmi *et al.* (2009) and Al-Hashimi (2008) who obtained a ratio of 2.76 to 3.0 kg green fodder per kg planted barley seeds. The type and quality of grain, bulk density of seeds per square meter, temperature, humidity, frequency of irrigation, nutritious solution, slowness and position of lights, and growing period (days allowed to grow) are the factors affecting the green fodder productivity (El-Deeba *et al.* 2009; Dung *et al.* 2010; Molla and Birhan, 2010; Fazaeli *et al.* 2012). According to Kumalasari *et al.* (2017), production conversion ratio ranged 2 to 6 folds, based on the kg fresh fodder yield per kg maize seeds in hydroponic system. These authors reported that such variation in productivity was found to be as a result of the environment conditions (light, temperature, humidity and growing period) that were tested as treatments. Nevertheless, dry matter and nutrient productivity are more important than the fresh weight of green fodder (Fazaeli *et al.* 2012).

The increase in the fresh weight of green fodder is due to the absorption of water during germination and vegetative phases in the hydroponic system; however, a negative balances of DM, OM and ME were reported when green fodder was compared with the initial grain (Morgan *et al.* 1992; Fazaeli *et al.* 2012; Tranel, 2013). Saidi and Abo Omar (2015) reported that conversion of barley grains to hydroponic green fodder resulted in about 18% loss in DM. Loss of DM is due to the mobilization and utilization of seed reserves (particularly carbohydrates), as energy source, for metabolic process during germination and preliminary growth (Adjlane *et al.* 2016).

It is not possible to produce higher biomass (DM basis) or metabolizable energy per unit of seed grains, during 6 to 8 days of the growing period, in hydroponic system (Morgan *et al.* 1992).

According to Fazaeli *et al.* (2012), fresh weight of barley green fodder was 4.5 times of the original seed weight after sprouting for 6 days but it had a DM loss of about 19 percent. In another study, Fazaeli *et al.* (2017) reported that fresh weight of barley and maize green fodder was 4.79 to 5.22 times with CP content of 14.29 to 16.31 percent, from 7 to 10 days growing period; however, the DM loss was 23.8 percent of the initial seeds weight. Dung *et al.* (2010) reported that fresh weight of hydroponically-produced barley green fodder increased 3.7 times of the original seed, but the balance of DM was negative (21.9 percent) during 7-day growing period.

Such a decrease in biomass is naturally as a result of physiological changes during the sprouting of seeds, where the stored energy is used and dissipated throughout the germination process and initial growing period (Cuddeford, 1989; Chavan and Kadam, 1989).

Therefore, the multiplication in fresh forage per unit of planted seeds are not true increases in biomass production, hence the values evidently reflect the loss of DM, OM, digestible organic matter obtained, and compensation of ME.

Animal performance

Feed intake

Intakes of dry matter, crude protein and energy are presented in Table 4.

Table 3 Chemical composition of maize silage and hydroponic barley green fodder (HBGF) used in the experiment

Item	DM (%)	OM (%)	CP (%)	NDF (%)	ADF (%)	NFC^1 (%)	NE$_L$ (Mcal/kg DM)
Corn silage	22.14	94.04	8.22	46.10	26.81	36.72	1.38
HBGF	13. 98	96.35	12.76	31.25	14.35	48.14	1.71
SEM	2.54	4.63	1.24	3.37	2.59	3.19	0.18
P-value	0.012	0.38	0.017	0.023	0.010	0.014	0.034

DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; NFC: non-fiber carbohydrates and NE$_L$: net energy for lactation.

The means within the same column with at least one common letter, do not have significant difference (P>0.05).

SEM: standard error of the means.

Table 4 Influence of diets on dry matter intake, milk production, milk composition and feed efficiency

Items	Experimental diets				SEM	P-value
	I	II	III	IV		
Dry matter intake (DMI) (kg/d)	23.20	22.98	22.67	22.65	0.22	0.13
Crude protein intake (kg/d)	4.04	4.02	4.01	4.06	0.02	0.63
Net energy for lactation intake (Mcal/d)	39.79	39.47	39.47	39.22	0.25	0.56
Milk yield (kg/d)	29.17	29.50	28.93	29.73	1.06	0.96
3.5% fat-corrected milk (FCM) yield (kg/d)	27.38	27.62	26.41	27.22	1.17	0.94
4% fat-corrected milk (FCM) yield (kg/d)	24.10	24.31	23.24	23.96	1.12	0.94
Energy corrected milk yield (kg/d)	26.42	26.44	25.15	25.97	1.32	0.93
Milk fat (%)	2.91	2.89	2.69	2.71	0.13	0.53
Milk fat yield (g/d)	828	835	778	803	67.2	0.90
Protein (%)	3.18	3.12	3.08	3.09	0.06	0.63
Milk protein yield (g/d)	932	835	892	922	48.2	0.94
Lactose (%)	4.72	4.80	4.73	4.83	0.06	0.62
Lactose yield (g/d)	1370	1413	1370	1436	61.8	0.83
Total solid (%)	10.57	10.50	10.41	10.47	0.14	0.90
Total solid (g/d)	3060	3070	3013	3110	57.43	0.97
Solid non fat (%)	8.54	8.56	8.56	8.61	0.08	0.94
Feed efficiency^1	1.26	1.27	1.28	1.31	0.03	0.90
Feed efficiency^2	1.18	1.20	1.16	1.21	0.06	0.97

^{1} kg milk/kg DMI.

^{2} kg 3.5 FCM/kg DMI.

I: Contrl diet; II: diet contained 3.5% hydroponic barley green fodder (HBGF); III: diet contained 7% HBGF and IV: diet contained 10.5% HBGF.

The means within the same column with at least one common letter, do not have significant difference (P>0.05).

SEM: standard error of the means.

The average DMI, CP intake and NE$_L$ intake were not significantly different (P>0.05) between the treatments when the cows received diets contained hydroponic barley green fodder, in an amount of 7.20 and 10.80 percent HBGF (equal to 40 and 60 percent of the maize silage portion, DM basis). These results are in accordance with most of the previous studies, where hydroponic green fodder was included in the ruminants diets (Marsico *et al.* 2009; Fazaeli *et al.* 2011; Naik *et al.* 2014; Naik *et al.* 2017), but disagree with Naik *et al.* (2014) and Nugroho *et al.* (2015) where they included hydroponic maize fodder in the diets of lactating cows and reported that DM intake was increased by the animals receiving the diets which contained hydroponic fodder. Such differences could be due to the higher DM content (18.3%) of hydroponic maize fodder than the HBGF (13.98%).

Aditionally, Naik *et al.* (2014) replaced maize green fodder with jowar straw and Nugroho *et al.* (2015) replaced green fodder with napier grass which are less palatable than the maize green fodder but, in our experiment we replaced corn silage (a well known palatable forage) with HBGF.

Naik *et al.* (2014) compared fresh hydroponic maize fodder (HMF) with conventional Napier bajra hybrid green fodder (NBH) in the diet of lactating cows for 68 days and reported that HMF intake was lower (0.59 kg DM/d) than NBH (1.19 kg DM/d); however, total DMI was similar in both groups.

Marsico *et al.* (2009) evaluated the effect of two different levels (1.5 and 3 kg fresh weight) of hydroponic oat green fodder in the diet of milking goat and reported that the feed intake was reduced when green fodder was included in the diet.

In this experiment, HBGF was compared with maize silage where it was expected to obtain improvement in palatability and voluntary intake, in view of the fact that starch content of the grains degraded to simple sugars and some enzymes were active in sprouted green fodder (Dung *et al.* 2010). However, it may be assumed that, very high water content in the green fodder made it bulky, which could have limited the DMI (Fazaeli *et al.* 2011; Hayati *et al.* 2018).

Meanwhile, the palatability of green fodder yield in the hydroponic sprouting system may be affected by the type and quality of the initial grain, particularly the germination rate, culturing conditions and management (Tudor *et al.* 2003; Naik *et al.* 2017). In addition, feeding management and dietary components may affect the green fodder intake. According to Naik *et al.* (2012), when maize green fodder was partially substituted with concentrates and compared with sorghum straw in the diet of lactating cows, DM intake was similar.

The HBGF may contained higher nutrients (particularly energy and crude protein) than that of the maize silage (Table 3). Therefore replacement of maize silage by HBGF in the diet could provide approximately higher concentration of nutrients, where the lactating cows received their requirements with slightly lower DM intake, compared to the control diet. However, it may be inferred that the intake and palatability of hydroponic green forage could be limited when it included in the normal diets of lactating cows, in an intensive feeding system. Fazaeli *et al.* (2011) reported that DM intake was reduced when the hydroponic barley green fodder was included in the diet (up to 22.8% DM basis) of finishing calves. Hosainy-Abrandabadi *et al.* (2015) found that DMI was reduced when HBGF was included up to 15% in the diet of finishing lambs.

In lactating cows, the total DMI is highly influenced by the daily milk yield and milk compositions; nevertheless it could be affected by the physical form, nutrients content and the moisture content of diet. Felton and DeVaries (2010) reported that DMI improved linearly when dry matter content of diet increased (from 44.1 to 50, 8 and 56.3 percent) in lactating cows. In this experiment, control diet was higher in DM (62.45 percent) than those containing HBGF (58.72, 55.42 and 52.47 percent respectively in diets II, II and IV), that was due to the high moisture content (85 percent) of HBGF.

Milk yield and composition

Daily production of milk, 3.5% FCM or 4% FCM did not significantly (P>0.05) differ (Table 4) between the treatments. The similarity in milk yield could be related to the comparable values of the experimental diets. The nutrient levels such as NE_L, CP and NDF were kept approximately the same by including the HBGF in the diets (Table 1), and this result implied that intake of nutrients had the same effect relatively to milk production (Table 4).

These results are in accordance with those of Naik *et al.* (2012) where they reported that milk yield did not differ between dairy cows fed control diet or hydroponic maize fodder diet, in which 2kg of concentrate was replaced by 20 kg hydroponic maize fresh fodder. Additionally, Marsico *et al.* (2009) found that milk yield and compositions were not different, when the hydroponic barley fodder was included in the diet of lactating goats. Chinnman (2015) also reported that milk yield was not affected in lactating buffaloes upon feeding hydroponic maize fodder or control diet. In contrast, Naik *et al.* (2017) found a higher milk production in the cows offered hydroponic maize fodder than those fed control diet. They concluded that such result was due to the higher digestibility and more energetic value of the diet contained hydroponic fodder compared to the control. Adjlane *et al.* (2016) also reported that daily milk production was increased (16.14 *vs.* 13.49 kg) but fat and protein percentages were decreased when they replaced oat hay by hydroponic barley fodder in the diet of dairy cows. In our experiment, all diets (Table 1) contained similar feed ingredients, except for the corn silage that was partially replaced with the HBGF. This substitution did not extremely change the nutrients concentration in the diets; however, net energy for lactation (NE_L), CP, Rumen-degradable protein (RDP) and undegradable protein (UDP) were roughly increased, but NDF and ADF were decreased when the HBGF was included in the diets. This may be explanation for the similarity of milk yield regardless of the slight lower DM intake in the diets III and IV. This finding agrees with the results of Naik *et al.* (2012) and Nugroho *et al.* (2015) where they studied the effects of hydroponic maize green fodder in the diet of lactating cows. In a study on lactating sheep, including of hydroponically growth barley green fodder in the diet, milk yield was not significantly different between the experimental and control diet.

Milk compositions (fat, protein, lactose, SNF and TS) were not affected (P>0.05; Table 4) by the treatments. Similarities in milk composition may be accordance to the correspondence in ruminal fluid pH and fermentation characteristics as explained by (Mutsvangwa *et al.* 2015; Naik *et al.* 2017).

However, the milk fat percentage was relatively low in all treatments in our experiment. It could be related to the roughage portion of the diets (38% of the total DM). However, our results are in accordance with the other authors where they fed lactating cows with low roughage portion diets (Krause and Combs, 2003; Khorvash *et al.* 2012).

Similarity of milk protein, between the treatments, shows that replacing of corn silage by HBGF did not affect the supplying postruminal microbial protein, as demonstrated by Mutsvangwa *et al.* (2015). According to Naik *et al.* (2017), inclusion of hydroponic maize fodder in the diet of lactating cows resulted a comparable milk composition (fat, protein, and lactose) when compared with control diet.

Saidi and Abo Omar (2015) included hydroponic barley fodder in the diet of lactating sheep and reported that milk yield and composition were not different between the control and experimental diets. Comparable results were reported by Hayati *et al.* (2018), where they replaced different percent of barley grain by hydroponic barley fodder in the diet of lactating goats.

In this study, replacement of different portion of maize silage with HBGF in the diet, did not affect the feed efficiency (Table 4), since there were no significant differences between DMI or milk yield when the cows received the control or the experimental diets. These results are agree with those of Naik *et al.* (2012) that reported a similar feed efficiency when fed lactating cows with control diet or diet contained hydroponic fresh fodder. Average body weight of the cows ranged 618.1 to 621.9 kg (Figure 1) throughout the experiment. Inclusion of HBGF in the diets, did not affect the body weight and body weight changes of the lactating cows compared with those fed control diet. These results agree with those reported by De Souza *et al.* (2019) where they studied DMI by Holstein dairy cows based on milk energy, body weight and body weight changes.

The initial body weight of the cows, used in this experiment, was 615±39 kg at the start of the experiment but the final weight was 631±43 kg at the end of the experiment where the cows showed a slight trend of body weight gain ($P<0.01$), during the last two periods of the experiment (Figure 2) that is normal for the lactating cows throughout the mid lactation.

The cows were 83±12 days in milk at the start of the experiment, whereas they were 167±12 days in milk at the end of the experiment. Therefore, increasing trend of body weight is normal in lactating cows from 5th month of lactation period.

Similar trends were observed by Vance *et al.* (2012) where they studied milk production and body weight changes of Holstein-Friesian and Jersey × Holstein-Friesian dairy cows within a medium-input grazing system and a high-input total confinement system.

Furthermore, our results are in agreement with the findings of Nielsen *et al.* (2003), who studied the body weight changes of Holstein cows during transition and lactation periods.

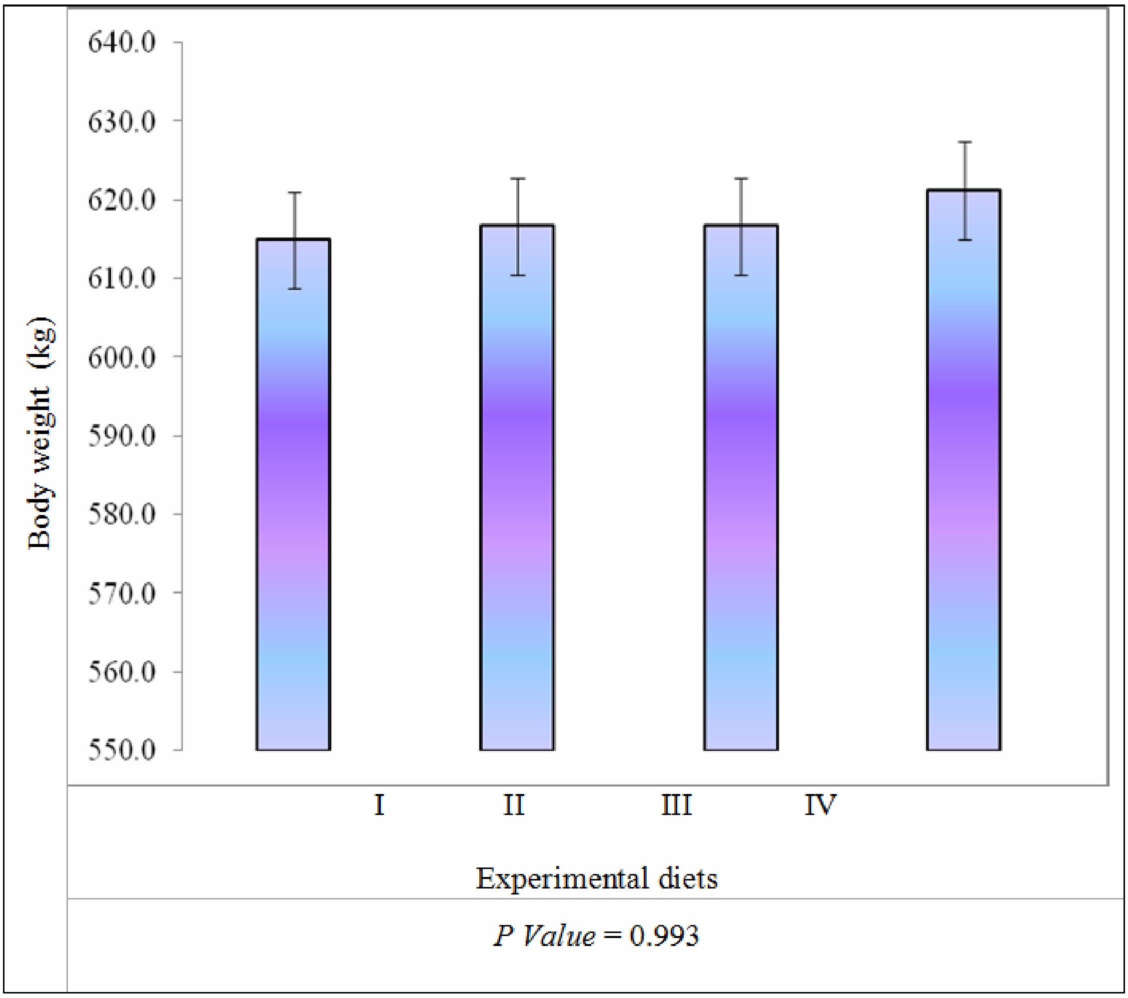

Figure 1 Average body weight of the cows received experimental diets

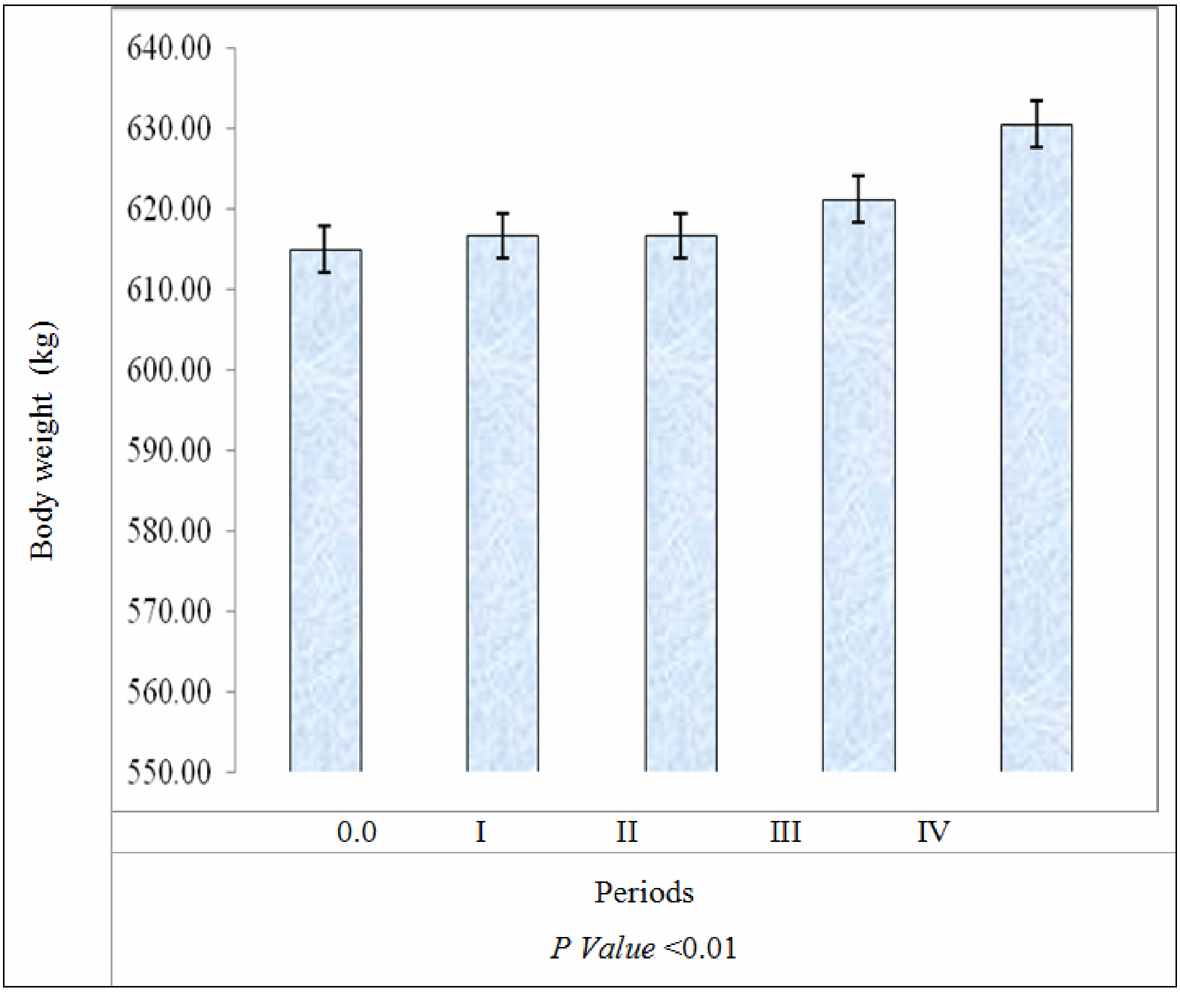

Figure 2 Body weight trend of lactating cows throughout the experimental periods

Regarding the economic aspect, it was considered that hydroponic fodder production was more costly comparing to corn silage due to labour cost, for daily operations such as preparing seeds and planting, controlling the growing conditions, collecting and preparing the fodder for feeding, water and electricity requirements, beside the initial investment. The barley grain used in this system was seed grade whith acceptable germination that costs 1.25 times than the feed grade. However, the final price of HPBG was 1.76 times than the corn silage (DM basis) whereas no advantages were found in dairy cows performance when corn silage replaced with HPBG, but, increase the feed cost. Similar results reported by authors that included hydroponic green fodder in the diet of ruminants (Fazaeli *et al.* 2011; Hayati *et al.* 2018). According to Bakshi *et al.* (2017) initial investment on hydroponic systems and high labour and energy costs in maintaining the desired environment in the system adds substantially to the net cost of hydroponic fodder production.

Therefore negative balance of biomass recovery and the extra cost for converting barley grain to green fodder in hydroponic system for ruminant nutrition is not economic.

CONCLUSION

In this experiment, barley green fodder was produced in a hydroponic chamber for 12 weeks operation and daily harvested green forage included in the diet of lactating cows. The cows were fed with four diets varying in corn silage or hydroponic barley green fodder content, in four periods of 3 week, throughout 12 weeks whole experiment. Milk yield, fat corrected milk, milk composition, feed intake and feed efficiency were similar between the treatments. These finding indicated that barley green fodder produced by hydroponic system could be comparable with the corn silage when it is used up to 60% of maize silage portion in the diet. Even though, the biomass efficiency of green fodder yield (based on DM obtained per kg of barley grain), was negative due to dry matter loss, during germination and short term growth. In addition, daily operation of hydroponic fodder production including cleaning and soaking seeds, draining and distribution of soaked seeds in trays, controlling the growing chamber, harvesting the fodder and preparing for feeding along with electricity and other cost are factors that limit this system of fodder production. Therefore converting of barley grain, as an energetic concentrate feed, to green fodder resulted in lower biomass and energy recovery with increasing the cost of nutrients.

ACKNOWLEDGEMENT

This experiment was supported by the Animal Science Research Institute of Iran, Agricultural Research Center of Isfahan, and Research Station of Golpayegan. The authors thank the management board and the staff of the Dairy Unit of Agricultural Cooperative of Golpayegan for their assistance in feeding trial.

REFERENCES

Adjlane S.K., Serir A.A., Bafdel M. and Benhacine R. (2016). Techno-economic approach to hydroponic forage crops: Use for feeding dairy cattle herd. *J. Appl. Environ. Biol. Sci.* **6,** 83-87.

Al-Ajmi A.A., Salih I., Kadhim I. and Othman Y. (2009). Yield and water use efficiency of barley fodder produced under hydroponic system in GCC countries using tertiary treated sewage effluents. *J. Phytol.* **1(5),** 342-348.

Al-Hashimi M. (2008). Hydroponic green fodder production in the arabian gulf region. MS Thesis. Desert and Arid Zones Programme. Arabian Gulf University. Bahrain.

AOAC. (1990). Official Methods of Analysis. Vol. I. 15th Ed. Association of Official Analytical Chemists, Arlington, VA, USA.

Azila A. (2001). Nutritive value of barley fodder growth in a hydroponics system. MS Thesis. University Putra, Malaysia.

Bakshi M.P.S., Wadhwa M. and Makkar H.P.S. (2017). Hydroponic fodder production: A critical assessment. Available at: https://www.researchgate.net.

Beldman A., van Berkum S., Korstee H. and ZiJlstra J. (2017). Dairy Farming and Dairy Industry in Iran. Wageningen University, Research Report 010. Available at: https://edepot.wur.nl/417175.

Britt J.S., Thomas R.C., Speer N.C. and Hall M.B. (2003). Efficiency of converting nutrient dry matter to milk in Holstein herds. *J. Dairy Sci.* **86,** 3796-3801.

Bustos C.D.E., Gonzalez E.L., Aguilera B.A. and Esptnoza G.J.A. (2000). Forraje hidropónico, una alternativa para la suplementación caprina en el semidesierto queretano. Pp. 383 in Proc. 38th Reunión Nacional de Invest. Pecuaria. Puebla, México.

Chavan J. and Kadam S.S. (1989). Nutritional improvement of cereals by sprouting. *Critic. Rev. Food Sci. Nutr.* **28,** 401-437.

Chinnman H.K. (2015). Effect of feeding rations supplemented with hydroponic maize fodder on nutrient utilization and milk production in lactating Graded Murrah buffaloes. MS Thesis. Sri Venkateswara Veterinary Univ., Tirupati, India.

Cuddeford D. (1989). Hydroponic grass. *In Pract.* **11,** 211-214.

De Souza R.A., Tempelman R.J., Allen M.S. and VandeHaar M.J. (2019). Updating predictions of dry matter intake of lactating dairy cows. *J. Dairy Sci.* **91,** 7948-7960.

Dung D.D., Goodwin I.R. and Nolan J.V. (2010). Nutrient Content and *in sacco* digestibility of barley grain and sprouted barley. *J. Anim. and Vet. Adv.* **19,** 2485-2492.

El-Deeba M.M., El-Awady M.M., Hegazi M.M., Abdel-Azeem F.M. and El-Bourdiny M.M. (2009). Engineering factors affecting hydroponic grass fodder production. Pp. 324-325 in Proc. 16th Ann. Conf. Misr Soc. Agric. Engin. Cairo University, Gisa, Egypt.

Erdman R. (2009). Monitoring Feed Efficacy in Dairy Cows Using Fat Corrected Milk per Unit Dry Matter Intake. Avalble at: http://s3.amazonaws.com/zanran_storage/manc.umd.edu/ContentPages/2529911055.pdf. Accessed Feb. 2019.

Fazaeli H., Golmohammadi H.A., Shoayee A.A., Montajebi N. and Mosharraf S.H. (2011). Performance of feedlot calves fed hydroponics fodder barley. *J. Agric. Sci. Technol.* **13,** 367-375.

Fazaeli H., Golmohammadi H.A., Tabatabayee S.N. and Tabrizi N.A. (2012). Productivity and nutritive value of barley green fodder yield in hydroponic system. *World Appl. Sci. J.* **16,** 531-539.

Fazaeli H., Solaymani S. and Rouzbehan Y. (2017). Nutritive value and performance of cereal green fodder yield in hydroponic system. *Res. Anim. Produc.* **8,** 96-104.

Felton C.A. and DeVaries T.J. (2010). Effect of water addition to a total mixed ration on feed temperature, feed intake, sorting behavior, and milk production of dairy cows. *J. Dairy Sci.* **93(6),** 2651-2660.

Gunasekaran S., Bandeswaran C. and Valli C. (2019). Low-cost hydroponic fodder production technology for sustainable livestock farming during fodder scarcity. *Curr. Sci.* **116,** 526-528.

Hayati S., Valizadeh R., Naserian A.A., Tahmasbi A. and Moosaee A. (2018). Effect of dietary brley grain substitution with hydroponic barley grass on milk yield and some blood metabolites of saanen lactating goats. *Res. Anim. Prod.* **9,** 32-38.

Hosainy-Abrandabadi S.A., Hosainy-Nasab H., Pourmirzayee H.R. and Fazaeli H. (2015). Performance of fattening lambs fed hydroponic barley green fodder. *Anim. Sci. J.* **106,** 157-168.

Kamalzadeh A., Rajabbaigy A.M. and Kiasat A. (2008). Livestock production systems and trends in livestock industry in Iran. *J. Agric. Soc. Sci.* **4,** 183-88.

Khorvash M., Yazdani H., Mahjoubi E., Kousar R. and Ghorbani G. (2012). Effect of protected methionin on the production and reproductive performance of early lactation Holstein cows. *Iranian J. Anim. Sci. Res.* **4,** 122-127.

Krause K.M. and Combs D.K. (2003). Effect of forage particle size, forage source and grain fermentability on performance and ruminal pH in mid lactating cows. *J. Dairy Sci.* **86,** 1382-

1397.

Kumalasari N.R., Permana A.T., Silvia R. and Martina A. (2017). Interaction of fertilizer, light intensity and media on maize growth on semi-hydroponic system for feed production. Pp. 221-223 in Proc. 7th Int. Sem. Trop. Anim. Prod. Yogyacarta, Indonesia.

Marsico G., Micera E., Dimatteo S., Minuti F., Arcangelo Vicenti A. and Zarrilli A. (2009). Evaluation of animal welfare and milk production of goat fed on diet containing hydroponically germinating seeds. *Italian J. Anim. Sci.* **8,** 625-627.

Micera E., Ragni M., Minuti F., Rubino G., Marsico G. and Zarrilli A. (2009). Improvement of sheep welfare and milk production fed on diet containing hydroponically germinating seeds. *Italian J. Anim. Sci.* **8,** 634-636.

Molla A. and Birhan D. (2010). Competition and resource utilization in mixed cropping of barley and durum wheat under different moisture stress levels. *World J. Agric. Sci.* **6,** 713-719.

Monardes H.G., Moore R.K., Corrigan B. and Rioux Y. (1995). Preservation and storage mechanisms for raw milk samples for use in milk-recording schemes. *J. Food Protect.* **59(2),** 151-154.

Moosavy M.H., Mahmoudi M., Ghorbanpour Farkhad E. and Khatibi S.A. (2017). Evaluation of microbial and physicochemical characteristics of raw cow milk delivered to pasteurized milk plants in Tabriz city, Iran. *J. Food Sci.* **28,** 183-196.

Morgan J., Hunter R.R. and O'Haire R. (1992). Limiting factors in hydroponic barley grass production. Pp. 241-26 in Proc. 18th Int. Congr. Soil-less Cult. Hunter′s Rest, South Africa.

Mutsvangwa T., Kiran D. and Abeysekara S. (2015). Effects of feeding canola meal or wheat dried distillers grains with solubles as a major protein source in low- or high-crude protein diets on ruminal fermentation, omasal flow, and production in cows. *J. Dairy Sci.* **99,** 1216-1227.

Naik P.K., Dhuri R.B., Karunakaran M., Swain B.K. and Singh N.P. (2014). Effect of feeding hydroponics maize fodder on digestibility of nutrients and milk production in lactating cows. *Indian J. Anim. Sci.* **84,** 880-883.

Naik P.K., Dhuri R.B., Karunakaran M., Swain B.K. and Singh N.P. (2017). Effect of feeding hydroponics maize fodder replacing maize of concentrate mixture partially on digestibility of nutrients and milk production in lactating cows. *Indian J. Anim. Sci.* **87,** 452-455.

Naik P.K., Dhuri R.B., Swain B.K. and Singh N.P. (2012). Nutrient changes with the growth of hydroponics fodder maize. *Indian J. Nutr.* **29,** 161-163.

Nielsen H.M., Friggens N.C., Løvendahl P., Jensen J. and Ingvartsen K.L. (2003). Influence of breed, parity, and stage of lactation on lactational performance and relationship between body fatness and live weight. *Livest. Prod. Sci.* **79,** 119-133.

NRC. (2001). Nutrient Requirements of Dairy Cattle. 7th Ed. National Academy Press, Washington, DC., USA.

Nugroho H.D., Permana I.G. and Despal G. (2015). Utilization of bioslurry on maize hydroponic fodder as a corn silage supplement on nutrient digestibility and milk production of dairy cows. *Media Petern.* **38,** 70-76.

Peer D.J. and Leeson S. (1985). Nutrient content of hydroponically sprouted barley. *Anim. Feed Sci. Technol.* **13,** 191-202.

Raeisi Z., Tahmasbi R., Dayani O., Ayatollahi Mehrgardi A. and Tavassolian I. (2018). Digestibility, microbial protein synthesis, rumen and blood parameters in sheep fed diets containing hydroponic barley fodder. *Livest. Sci. Technol.* **6,** 9-17.

Rajkumar G., Dipu M.T., Lalu K., Shyama K. and Banakar P.S. (2018). Evaluation of hydroponics fodder as a partial feed substitute in the ration of crossbred calves. *Indian J. Anim. Res.* **52,** 1809-1813.

Saidi A.M.A. and Abo Omar J. (2015). The biological and economical feasibility of feeding barley green fodder to lactating Awassi ewes. *Open J. Anim. Sci.* **5,** 99-105.

SAS Institute. (2002). SAS®/STAT Software, Release 9.1. SAS Institute, Inc., Cary, NC. USA.

Sulser A. (2015). Hydroponic barley fodder feed test on replacement rams and ewes. *J. NACAA.* **8(2),** 1-6.

Tawfeeq J.A., Hassan S.A., Kadori1 H., Shaker R.M. and Hamza Z.R. (2018). Evaluation of feeding hydroponics barley on digestibility and rumen fermentations in Awassi lambs. *Iraqi J Agric. Sci.* **49(4),** 636-645.

Tranel L.F. (2013). Hydroponic Fodder System for Dairy Cattle. Animal Industry Report, AS659. Iowa State University. Available at: http://lib.dr.iastate.edu/ans_air/vol659/iss1/42.

Tudor G., Darcy T., Smith P. and Shallcross F. (2003). The intake and live weight change of droughmaster steers fed hydroponically grown, young sprouted barley fodder (autpgrass). Pp. 55 in Review of Hydroponic Fodder Production for Beef Cattle, Project Report, Western Australia.

Vance E.R., Ferris C.P., Elliott C.T., McGettrick S.A. and Kilpatrick D.J. (2012). Food intake, milk production, and tissue changes of Holstein-Friesian and Jersey × Holstein-Friesian dairy cows within a medium-input grazing system and a high-input total confinement system. *J. Dairy Sci.* **95,** 1527-1544.

Van Soest P.J., Robertson J.B. and Lewis B.A. (1991). Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* **74,** 3583-3597.