EVALUATION OF FEEDING HYDROPONICS BARLEY ON DIGESTIBILITY AND RUMEN FERMENTATIONS IN AWASSI LAMBS

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ABSTRACT

Fifteen Awassi male lambs were randomly distributed to five groups and fed *ad libitum* roughages: hydroponics barley and/or green alfalfa with different levels, 0: 100, 25: 75, 50: 50, 75: 25 and 100: 0% as roughage experimental diets T_1, T_2, T_3, T_4, T_5 to study *in-vitro* and apparent digestibility, rumen fermentations and total rumen bacteria using completely randomized design. Initial weight of replicates were 21.73 kg ± 4.17 kg and 3-4 months old. Concentrate fed at 3% of live body weight based on dry matter basis. Results showed: No differences for *in-vitro* digestibility, while there were significant increases ($p<0.05$) for total digestible nutrients (TDN) 88.24%, apparent digestibility for dry matter (DM) 87.13%, organic matter (OM) 87.94%, crude protein (CP) 95.87%, nitrogen free extract (NFE) 87.88% and metabolisable energy (Me) 88.78% with feeding 100% hydroponic barley (T_5). Rumen fermentations: pH, Ammonia and volatile fatty acids didn't differ between treatments in the end of experiment. Total count of rumen bacteria did not differ in the beginning and middle of experiment, while, significant decreased in treatments T_4 and T_5 2.600 and 1.733 cfu\ ml × 10^7 in contrast with T_1 (control) 4.566 cfu\ ml × 10^7 because of increasing dilution and flow rate of rumen liquor. In conclusion, there is a possibility using hydroponic fodder technology in arid and semi-arid areas, where green feeds are difficult to provide.

Key words: Hydroponics, Barley, Fodder, Digestibility, Rumen fermentations.

تقييم تغذية مستنبت الشعير على معامل الهضم ومتغيرات التخمر في الكرش للحملان العواسية

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المستخلص

وزعت عشوائياً خمسة عشر حملاً عواسياً ذكراً على خمس مجموعات وغذيت علف خشن بشكل حر: مستنبت الشعير مع/ أو الجت الأخضر بمستويات مختلفة: 0: 100، 25: 75، 50: 50، 75: 25، 100: 0٪ كاعلاف خشنة تجريبية هي T_1 ، T_2، T_3، T_4، T_5 لدراسة معامل الهضم المختبري والحقلي، متغيرات التخمر في الكرش والعدد الكلي للبكتريا باستخدام التصميم العشوائي الكامل. معدل الوزن الابتدائي 21.73 كغم ± 4.17 كغم وعمر 3–4 أشهر. قدّم العلف المركز بنسبة 3٪ من وزن الجسم الحي على أساس المادة الجافة. أظهرت النتائج عدم وجود اختلافات في معامل الهضم المختبري، في حين كانت هناك زيادة معنوية ($p<0.05$) في مجموع العناصر الغذائية المهضومة 88.24%، ومعامل الهضم الظاهري للمادة الجافة 87.13%، والمادة العضوية 87.94%، والبروتين الخام 95.87%، والمستخلص الخالي من النتروجين 87.88% والطاقة المتأيضة 88.78% عند تغذية مستنبت الشعير بنسبة 100% (T_5)، متغيرات التخمر في الكرش: درجة الحموضة، الأمونيا والأحماض الدهنية الطيارة لم تختلف معنويا بين المعاملات عند تقديرها في نهاية التجربة. ولم يختلف العدد الكلي لبكتيريا الكرش في بداية ووسط التجربة، في حين انخفضت معنويا ($p<0.05$) في المعاملة الرابعة والخامسة حيث كانت 2.600 و 1.733 خلية وحدة مستعمرة مل × 10^7 مقارنة مع معاملة المقارنة 4.566 خلية وحدة مستعمرة مل × 10^7، نستنتج من هذه الدراسة انه يمكن استخدام تكنولوجيا مستنبت الشعير في المناطق الجافة وشبه الجافة حيث يصعب توفير الأعلاف الخضراء.

كلمات مفتاحية: الزراعة المائية، الشعير، الاعلاف، معامل الهضم، متغيرات التخمر في الكرش.

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INTRODUCTION

The expansion of cities, growth population and increase in the demand of meat accompanied low rainfall, decreasing feeds and higher costs of productions. To meet all these challenges, the adoption of a hydroponic systems is one of the solution to provide green fodders protected from natural weather changes (8) within a short period (26). It's a viable technology in low rangeland or rare water (14; 21) to produce green fresh fodder throughout the year and reduce the costs of feeding (4). Decreasing water during the past two decades have led to need of conserving water stocks. Hydroponics need 1.5 – 2L of water to produce 1 kg of green feed compared with 73L of water to produce green fodder of barley or alfalfa in nature (5) which about 2-3% of water used under field conditions to produce the same amount of fodder, need large areas of lands, a long season and many labor, while, hydroponic green fodder needs short period, continuous production throughout the year, as well as ability to control of plants environment and produce products free of pollution with high nutritional value (27). Barley is one of the most important crops and the third largest crop after wheat and rice production (12). In Iraq, the production of green fodder deserves attention and study, It's palatable without wastage. The current study was designed to evaluate the effects of feeding hydroponic barley on digestibility of nutrients and rumen fermentations in Awassi lambs.

MATERIALS AND METHODS

Production of hydroponics barley fodder: Hydroponics barley fodder was produced in a hydroponics chamber measuring about 20ft × 15ft × 15ft with automatic sprayer irrigation of tap water and daily production 20-25kg fresh hydroponics barley. Seeds of barley were soaked in tap water for 24h. then distributed in the greenhouse trays 30×70cm with a high of seeds 1.5 cm, sprayed with tap water three times a day for three minutes each one, 19 to 22ºc and 30-35 % humidity, 24 hours of lighting (4). Inside green house, the plants are allowed to grow for 7 days and then on eighth day, they are harvested with height 20-27cm and fed to lambs.

Experimental animals

Fifteen Awassi male lambs (Avg. BW 21.73± 4.17kg; aged 3- 4 months) were divided randomly into five groups with *ad libitum* roughage individual feeding to evaluate the substitution of hydroponic barley with green alfalfa at 0, 25, 50, 75, 100% as roughages. Concentrated ration were feeding at 3% of body weight as DM basis consisted of 10% soybeans, 38% barley, 15% corn, 35% wheat bran, 2% minerals and vitamins. All feeds analyzed as A.O.A.C. (1) (Table 1).

Digestion trial

At the end of adaptation period (15 days), a digestion trial was conducted on all experimental animals for 7days. Each day, after 24h. of morning feeding, faeces were collected, weight it and took 10% as a sampled then throw the residues. Recorded the residues of roughages and concentrate feeds for each lamb to determine daily intake.

In-vitro **digestibility** was determined according to Tilley and Terry (29).

Table 1. Chemical composition of roughages treatment and concentrated ration on DM basis (%).

Treat.	DM	Ash	CF	CP	EE	OM	NFE	*ME (MJ/Kg as DM)
T_1	23.36	8.38	20.76	18.19	2.59	91.62	50.08	11.03
T_2	26.69	8.26	21.37	18.3	3.16	91.74	48.89	11.08
T_3	26.16	6.59	21.61	18.31	4.67	93.4	48.8	11.55
T_4	25.62	5.03	22.2	18.88	2.31	94.97	51.57	11.31
T_5	22.94	3.36	23.24	19.15	3.81	96.64	50.44	11.70
Concentrate	93.01	5.1	6.48	16.95	2.32	94.9	69.15	12.75

***(MJ / Kg of dry matter) = 0.012 × CP + 0.031 × EE + 0.005 × CF + 0.014 × NFE… (20)**

T_1=100% green alfalfa, T_2=75% green alfalfa and 25% hydroponic barley, T_3= 50% green alfalfa and 50% hydroponic barley, T_4= 25% green alfalfa and 75% hydroponic barley, T_5= 100% hydroponic barley.

Rumen fermentations

Rumen liquor was withdrawn from all experimental animals at beginning, middle and end of experiment, before morning feeding by inserting a stomach tube (rubber tube) gently through the mouth into animal's rumen, then the rumen liquor is pulled by a plastic syringe from the other end, ruminal pH was measured immediately using pH meter, then filter with cheese cloth and kept in sterilized plastic tubes, take a sample to estimate total bacteria count as Nickerson and Sinskey (22), then add 0.5ml of HCL (1M) to stop fermentation, labeled and kept in deep freeze until use to determine NH3-N as AOAC (1) and total volatile fatty acids (TVFA's) according to Warner (30). After collection process, provides feed to animals.

Statistical analysis

All data were analyzed statistically by completely randomized design (CRD) using ANOVA procedure of SAS (25). Duncan's multiple range tests was used to determine the significance of differences between treatments means (9).

RESULTS AND DISCUSSION

***In-vitro* Digestibility:** *In-vitro* digestibility for substituting hydroponic barley with green alfalfa was shown in Table 2, dry matter and organic matter digestibility between treatments were no differences. Dry matter digestibility was 90.73, 91.2, 92.6, 93.53, 95.13%, while organic matter digestibility was 91.3, 92.13, 94.2, 94.23, 96.2% for T_1, T_2, T_3, T_4 and T_5 respectively. Increasing nitrogen free extract% (NFE), organic matter % and decreasing ash in hydroponic barley lead to high digestibility (17). Abdullah (2) refers to 80 -100 % digestibility of dry matter for hydroponic. Although *in-vitro* digestibility is an indicator of apparent digestion, but it is very different in controlled conditions, rumen area, amount and availability of nutrients, accumulation of metabolic products, counts of bacteria and nutrients flow rate, which leads to lower results of field digestion laboratory, Fazaeli et al. (14) reported an increase in their content of free amino acids and non-protein nitrogen, which led to a high *in-vitro* digestibility.

In vivo digestibility

In vivo digestibility (%) of total daily intake for various rations observed in table (3), significant increasing ($p < 0.05$) in TDN 88.24%, apparent digestibility for dry matter 87.13%, OM 87.94%, CP 95.87%, NFE 87.88% and Me 88.78% with feeding 100% hydroponic barley (T_5) in contrasted with 100% green alfalfa (T_1): TDN 76.48 %, apparent digestibility for dry matter 80.05%, OM 81.78%, CP 92.75%, NFE 81.47% and Me 82.71%. Hydroponic barley contains tenderness plants with higher digestibility, highly non structured carbohydrates or nitrogen free extract (NFE) and low proportion of ash lead to increase digestibility of nutrients with increasing hydroponic barley in treatments. The digestibility of hydroponic barley fodder was 98% (2), because of extremely high in protein and metabolisable energy, which is highly digestible for fattening lambs (13), Fazeeli et al. (14) and Graze (16) reported to same results in increased the dry matter digestibility of hydroponic barley in contrasted with barley grains. Fysken (15) obtained 80% in digestibility of hydroponic barley, while Hafla et al. (18) referred to an increase in apparent and true dry matter digestibility of roughages feeding with hydroponic barley in contrasted without hydroponic. Dung et al. (10) referred to no significant differences between barley grain and hydroponic barley in Merino sheep.

Table 2. Effect of substituting hydroponic barley with green alfalfa on *in-vitro* dry matter and organic matter digestibility (%) ± SE

	In-vitro Digestibility %	
Treat.	**Dry matter**	**Organic matter**
T_1	**90.73±1.35**	**91.30 ±0.47**
T_2	**91.20 ±1.47**	**92.13 ±1.12**
T_3	**92. 60±2.21**	**94.20 ±1.47**
T_4	**93.53 ±0.28**	**94.23 ±1.58**
T_5	**95.13 ±1.15**	**96.20 ±1.09**
Sign.	**NS**	**NS**

NS= Non signi, T_1=100% green alfalfa, T_2=75% green alfalfa and 25% hydroponic barley, T_3= 50% green alfalfa and 50% hydroponic barley, T_4= 25% green alfalfa and 75% hydroponic barley, T_5= 100% hydroponic barley.

Table 3. Effect of substituting hydroponic barley with green alfalfa on TDN%, apparent digestibility (%) of dry matter, nutrients and energy for total daily feed intake ± SE.

Treat.	TDN %	Apparent Digestibility (%) DM	OM	CP	EE	CF	NFE	ME
T_1	76.48 ±0.106c	80.05 ±0.326d	81.78 ±0.370 c	92.75 ±0.501b	80.64 ±3.066 a	68.52 ±1.833 a	81.47 ±0.652b	82.71 ±0.634c
T_2	77.58 ±1.727c	81.95 ±1.085 dc	83.05 ±1.178bc	94.83 ±0.307 a	82.51 ±3.387 a	61.44 ±8.836 a	84.45 ±0.39ba	84.88 ±0.315bc
T_3	83.18 ±0.881b	84.37 ±0.457 bc	85.73 ±0.636ba	94.95 ±0.175 a	84.54 ±1.552 a	67.20 ±5.793 a	87.215 ±2.058 a	87.26 ±1.021ba
T_4	83.22 ±1.28b	84.96 ±0.706 ba	86.46 ±0.807a	95.16 ±0.495 a	82.91 ±3.262 a	71.40 ±2.462 a	87.324 ±0.721a	87.59 ±0.536a
T_5	88.24 ±1.960a	87.139 ±1.224 a	87.94 ±1.183 a	95.87 ±0.900 a	87.03 ±2.063 a	77.58 ±2.986 a	87.88 ±1.344a	88.78 ±1.135a
Sign.	*	*	*	*	NS.	NS.	*	*

Means in the same column with different letter are significantly at 0.05. NS= Non signi., TDN= total digestible nutrients, DM= dry matter, OM= organic matter, CP= crude protein, EE= ether extract, CF= crude fiber, NFE= nitrogen free extract, ME= metabolizable energy. T_1=100% green alfalfa, T_2=75% green alfalfa and 25% hydroponic barley, T_3= 50% green alfalfa and 50% hydroponic barley, T_4= 25% green alfalfa and 75% hydroponic barley, T_5= 100% hydroponic barley.

% TDN = % digested crude protein + % digested crude fiber + % digested nitrogen-free extract + (2.25× % digested ether extract), % digested ingredient = % digestibility of ingredient × ratio ingredient in food × 100

Rumen fermentations

Rumen Ph: The effect of substituted hydroponic barley with green alfalfa on rumen pH was shown in table (4). In the beginning of experiment, pH value of rumen liquor decreased significantly ($p<0.05$) for treatments T_3 (6.376) and T_4 (6.670) in contrast T_1 (7.170) and T_2 (7.293). While, treatments in the middle of experiment differed significantly ($p<0.05$): 7.47, 7.61, 8.02, 7.80 and 6.34 for T_1, T_2, T_3, T_4, T_5 respectively. In the end of experiment, there were no significant differences between the pH values of rumen liquor. The decrease of pH rumen liquor may be due to the hydroponic barley roots layer which contains barley grains consisted of 55-75% starch (23), that leads to increase fermented carbohydrates to short chain fatty acids and decreased the rumen pH (24). The adaptation of rumen environment to hydroponic fodder and increasing saliva production as a result of roughages chewing, there were no significant differences for rumen pH between treatments of after 77 days of consumption. Green fodder and roughage feeds maintain rumen pH normally or tend to increase ruminal pH, low production of short chain fatty acids, as well as increase saliva production (28). American Agriculturalist (6) referred to neutral or moderation of rumen pH with hydroponic feeding compared with barley grain. Hydroponic barley reduction the fermentation of starches in barley grains and controlling the pH rumen liquor (16), Hafla et al. (18) confirmed higher pH of rumen liquor with hydroponic fodder compared to feed barley grain and roughages. Low acidity of rumen to pH 5 for more than 2 - 6 hours as a result of eating large amounts of grains with highly fermentable carbohydrate led to rumen acidosis (19).

Table 4. Effect of substituted hydroponic barley with green alfalfa on rumen pH ± SE.

Treat.	rumen pH value Beginning of Experiment	Middle of Experiment	End of Experiment
T_1	7.170±0.320 a	7.476±0.178 b	7.090±0.277
T_2	7.293±0.328 a	7.616±0.109 ba	7.286±0.199
T_3	6.376±0.274 b	8.020±0.116 a	7.040±0.146
T_4	6.670±0.138 b	7.800±0.051 ba	6.936±0.118
T_5	7.070±0.151 ab	6.340±0.130 c	7.306±0.268
Sign.	*	*	NS.

Means in the same column with different letter are significantly at 0.05, NS= Non signi., T_1=100% green alfalfa, T_2=75% green alfalfa and 25% hydroponic barley, T_3= 50% green alfalfa and 50% hydroponic barley, T_4= 25% green alfalfa and 75% hydroponic barley, T_5= 100% hydroponic barley.

Ammonia rumen liquor

substituted hydroponic fodder with green alfalfa on ammonia-nitrogen (NH3-N) concentrations didn't differ significantly all over the period of experiment (table 5) although the digestibility was higher. The same results found (2) that *ad libitum* feeding of hydroponic barley resulted to 98% digestibility and low levels of rumen ammonia-nitrogen, Al-Kinani (3) refereed to low ammonia concentration with high consuming of digestible energy, or starch-rich diets (11), 80% of rumen microbial protein used rumen ammonia synchronized with VFA for reproduction and growth (7).

Total VFA concentrations: The values of short chain fatty acids or volatile fatty acids (VFA's) reported in table 6, showed significant increase ($p<0.05$) in the beginning of experiment with using 50% hydroponic barley (T_3) (1.416 mg/100ml) in contrast with 100% green alfalfa (T_1) or control (0.833 mg/100ml), with no differences later in the middle and end of the experiment. The values of VFA reported in this study were similar to those of Abdullah (2) when used ad- libitum feeding for hydroponic barley with 98% digestibility and did not produce high levels of volatile fatty acids, that indicating the rapid utilization of VFA for maintenance and production. Hafla et al. (18) showed a low concentration of rumen volatile fatty acids in ruminants fed hydroponic barley in contrast with intake the barley grain and roughages.

Table 5. Effect of substituted hydroponic barley with green alfalfa on rumen ammonia- N concentrations (mg /100ml) ± SE.

	rumen ammonia- N concentrations (mg /100ml)		
Treat.	Beginning of Experiment	Middle of Experiment	End of Experiment
T_1	14.0±0.00	11.666±1.1667	12.833±1.166
T_2	11.666±1.1666	12.833±1.166	12.833±1.166
T_3	12.833±1.1666	14.000±2.020	12.833±1.166
T_4	12.833±1.1666	10.500±0.00	12.833±1.166
T_5	11.666±1.1666	12.833±1.166	12.833±1.166
Sign.	NS.	NS.	NS.

Means in the same column with different letter are significantly at 0.05, NS= Non signi., T_1=100% green alfalfa, T_2=75% green alfalfa and 25% hydroponic barley, T_3= 50% green alfalfa and 50% hydroponic barley, T_4= 25% green alfalfa and 75% hydroponic barley, T_5= 100% hydroponic barley.

Table 6. Effect of substituted hydroponic barley with green alfalfa on total rumen VFA concentrations (mg /100ml) ± SE.

	Total rumen VFA concentrations (mg /100ml)		
Treat.	Beginning of Experiment	Middle of Experiment	End of Experiment
T_1	0.833±0.083 b	1.083±0.083	1.00 ± 0.144
T_2	1.083±0.1666 ba	1.00 ± 0.144	1.333±0.220
T_3	1.416±0.083 a	1.416±0.083	1.333±0.083
T_4	1.00 ± 0.144 b	1.166±0.220	1.083±0.220
T_5	0.833±0.083 b	1.083±0.083	1.083±0.083
Sign.	*	NS.	NS.

Means in the same column with different letter are significantly at 0.05, NS= Non signi., T_1=100% green alfalfa, T_2=75% green alfalfa and 25% hydroponic barley, T_3= 50% green alfalfa and 50% hydroponic barley, T_4= 25% green alfalfa and 75% hydroponic barley, T_5= 100% hydroponic barley.

Total count of rumen bacteria

The total count of rumen bacteria did not differ as a result of given hydroponic barley comparing with green alfalfa in the beginning and middle of experiment (table 7). While, significant decreased in treatments T_4 and T_5 2.600 and 1.733 cfu \ ml × 10^7 respectively in contrast with T_1 (control) 4.566 cfu \ ml × 10^7. The decrease in number of bacteria with increasing proportion of hydroponic barley may be to reduction of hydroponic dry matter content (14) which increase dilution of rumen

liquor and the rate of feed pass then reduce number of bacteria, While, Hafla et al. (18) reported that addition of hydroponic barley to ruminants led to higher digestibility due to increase in numbers of rumen bacteria and efficiency of digestibility.

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Table 7. Effect of substituted hydroponic barley with green alfalfa on total count of rumen bacteria ± SE.

	Total count of rumen bacteria		
Treat.	Beginning of Experiment (cfu/ ml * 10^5)	Middle of Experiment (cfu/ ml * 10^7)	End of Experiment (cfu/ ml * 10^7)
T_1	2.033±1.125	2.233±0.0835	4.566±0.635 a
T_2	2.466±0.290	3.433± 0.581	3.700±0.351 ba
T_3	6.733±2.781	2.966±0.371	3.033±0.819 cba
T_4	4.533±2.258	2.733±0.290	2.600 ±0.305 bc
T_5	4.366±2.302	3.166±0.088	1.733±0.484 c
Sign.	NS.	NS.	*

Means in the same column with different letter are significantly at 0.05, NS= Non signi., T_1=100% green alfalfa, T_2=75% green alfalfa and 25% hydroponic barley, T_3= 50% green alfalfa and 50% hydroponic barley, T_4= 25% green alfalfa and 75% hydroponic barley, T_5= 100% hydroponic barley.

REFERENCES

1. A.O.A.C. 2005. Association of Official Chemists, Official Methods of Analysis, 14thedn. Washington, D.C., U.S.A.

2. Abdullah, A. 2001. Nutritive Value of Barley Fodder Grown in a Hydroponics System. Ph.D. Dissertation, University Putra Malaysia. pp: 233.

3. Al- kinani, J.K.A. 2014. Evaluation of Different Levels of Bakeries By-products in Awassi Lamb's Performance. MSc. Thesis, Agriculture College, Univ. of Baghdad. pp:91.

4. Al-Karaki, G.N., and M.Al-Hashimi. 2012.Green fodder production and water use efficiency of some forage crops under hydroponic conditions. ISRN Agronomy :924672.
http://dx.doi.org/10.54o2/2012/924672.

5. Al-Karaki,G.N., and N.Al-Momani. 2011. Evalution of some barley cultivars for green fodder production and Water use efficiency under hydroponics conditions.Jordan Journal of Agricultural Sciences 7(3): 448-457.

6. American Agricultur list. 2013. Be fussy about barley seed for dairy fodder. http://farmprogress.com/story-fussy-barley-seed-dairy-fodder-9-100629.

7. Bach, A., S. Calsamiglia, and M. D. Stern. 2005. Nitrogen metabolism in the rumen. J. Dairy Sci. 88(E. Suppl.): E9–E21.

8. Douglas, I. and T.P. Curran. 2013. Assessing the viability of hydroponic grown fodder in Irish agriculture. In Biosystems Engineering Research Review (Ed. E. Cummins and T. Curran). University College Dublin 56-58.

9. Duncan, D. B. 1955. Multiple Range and Multiple Test. Biometrics. 11: 1 – 42.

10. Dung.D.D, I.R.Godwin and J.V.Nolan .2010. Nutrient content and in sacco degradation of hydroponic barley sprouts grown using nutrient solution or tap water. J. of Animal and Veterinary Advances 9(18):2432-2436.

11. Fanchone, A., P. Nozière, J. Portelli, B. Duriot, V. Largeau, and M. Doreau. 2013. Effects of nitrogen underfeeding and energy source on nitrogen ruminal metabolism, digestion, and nitrogen partitioning in dairy cows. J. Anim. Sci. 91:895-906.

12. FAO. 2009. Major Food and Agricultural Commodities and Producers - Countries by Commodity. pp: 189.

13. Fayed, A.M. 2011. Comparative study and feed evaluation of sprouted barley grains on rice straw versus tamarix mannifera on performance of growing Barki lambs in Sinai. Journal of American Science, 7(1):954-961.

14. Fazaeli, H., H. A. Golmohoemmeedi, S.N. Tabatabayee and M. Asghari – Tabrizi. 2012. Productivity and nutritive value of barley green fodder yield in hydroponic system.World Applied Sci . J. 16(4):531-539.
15. Fysken, J. 2014. Adams Dairy sprouts new barley fodder venture. Agri-View, Madison, WI. 31(5):17-28.
16. Graze. 2013. Fodder interest sprouting all over. Graze Magazine 1 Jan 2013. http://www.grazeonline.com/fodderinterest.
17. Guiroy, P.J., D.G.Fox, D.H. Beemann, and D.J. Ketchen. 2000. Performance and meat quality of beef steers fed corn-based or bread by-product-based diets. J. Anim. Sci., 78:784-790.
18. Hafla, A.N., K.J. Soder, A.F. Brito, M.D. Rubano, and C.J. Dell. 2014. Effect of sprouted barley grain supplementation of an herbage-based or haylage-based diet on ruminal fermentation and methane output in continuous culture. Journal of dairy science 97(12): 7856-7869.
19. Krause, K.M. and G.R. Oetzel. 2006. Understanding and preventing subacute ruminal acidosis in dairy herds: A Review, Anim. Feed Sci. Technol., 126: 215–236.
20. MAFF. 1975. U.K. Tables of Nutritive Value and Chemical Composition of Feed Ingredients. Rowett Research Services Ltd., Aberdeen, AB2 9SB, UK.: pp51-58.
21. Naik, P.K., B.K. Swain, and N.P. Singh. 2015. Review: production and utilization of hydroponics fodder. Indian J. Anim. Nutr. 2015. 32 (1): 1-9.
22. Nickerson, J. T., and A.J. Sinsky. 1977. Microbiology of Foods and Food Processing 3rd. ed. Elsvir, New York, USA. pp:189.
23. Nikkhah, A. 2011. Optimizing barley grain use by dairy cows: a betterment of current perceptions, in progress in food science and technology, New York: Nova Science Publishers Inc. 1: 165–178.
24. Nikkhah, A. 2012. Postmodern management of starchy grains for ruminants: A barley grain perspective. Russian Agricultural Sciences, 38(1), pp 14–21.
25. SAS. 2012. Statistical analysis system,users guide.statistical. version 9.1th ed.SAS .Inst.Inc.Cary .N.C.USA.
26. Shipard, I. 2005. How can I grow and use sprouts as living food?" Stewart publishing. pp: 285.
27. Sinsinwar, S. and K. Teja .2012. Development of Accost Effective, Energy Sustainably Hydroponic Fodder Production Device. Agri. Engineering Interns. III,Kharagpur. pp: 335.
28. Sousa, D.O., B.D.Mesquita, A.V. Pires, M.H. Santana, and L.F. Silva. 2017. Effects of fibre digestibility and level of roughage on performance and rumen fermentation of finishing beef cattle. Tropical Animal Health and Production, 49(7): 1503–1510.
29. Tilley, J. M. A. and R. A.Terry. 1963. A two stage technique for in- vitro digestion of forage crops. J. Br. Grassld. Sci., 18: 104-111.
30. Warner, A.C.J., 1964. Production of volatile fatty acids in the rumen. Methods of measurements. Nut. Abst. Rev. 34, 339–345.