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Study on comparative biomass yield, nutritional quality and economics of hydroponic sprout produced from different grains

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Abstract

This study was conducted to know the biomass yield, nutritional qualities and production costs of hydroponic sprout of maize, wheat and oats compared to their whole grains as feed. Weighed amount of seeds were soaked in water for 12, 24 and 2 hours, respectively followed by wrapping in cotton cloths for 48 h for maize and wheat, and 24 h for oats to germinate.Then germinated seeds were spread on plastic trays fitted in hydroponic racks for 7 days. At harvest, fresh yield was found 2.74, 3.5 and 2.5 kg for maize, wheat and oats, respectively from each kilogram of respective seed (p<0.01). The DM concentrations in maize (857.0 *vs* 764.6 g/kg; p<0.05) and oat sprout (911.5 *vs* 453.0 g/kg; P<0.01) were decreased, while not changed (P>0.05) in wheat sprout (900.7 *vs* 872.0 g/kg) compared to their respective grain. In contrary, concentration of CP was significantly increased in wheat (126.1 *vs* 183.3 g/kg DM; P<0.05) and oat sprout (158.8 *vs* 201.7 g/kg DM; P<0.01) and numerically in maize sprout (61.2 *vs* 81.3 g/kg DM) compared to respective grain. Similarly, concentrations of ADF and NDF was increased (P<0.01) in all sprouts from their respective grains. Contents of Vitamin E and soluble sugar (SS) both were increased in wheat (1.1 *vs* 2.3 & 443.7 *vs* 477.0 mg/100g, respectively in grain *vs* sprout; P<0.01) and oat sprout (11.0 *vs* 13.4 & 351.5 *vs* 356.2 mg/100g, respectively in grain *vs* sprout; P<0.01), while in maizeonly vitamin-E was increased (3.51 *vs* 8.1 mg/100g, respectively in grain vssprout; P<0.01), but SS was decreased (489.4 *vs* 462.5 mg/100g, respectively in grain vssprout; P<0.01). Maize sprout was found yeast and mold-free, but both of them (7.16 & 7.0 log10 CFU/g) were grown in wheat sprout, while only yeast in low concentration (5.74 log10 CFU/g) was found in oat sprout. The production cost of DM was found 1.5, 1.7 and 2.6 times higher in maize, wheat and oat sprout, respectively compared to grain. Further study including animal feeding trial is needed to confirm the benefits of producing hydroponic sprout instead of using grain as concentrate.

Keywords: Hydroponic sprouts, fodder, nutrient composition.

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Introduction

The increased livestock production has resulted in an increased demand for feeds and forage supply, where about 70% cost involvement with it's feed supply attributing the forage and concentrates quality. Along with, the poor quality roughage e.g. rice straw comprises 90% of the cattle feed

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(Tareque and Saadullah, 1988) and grains comprises 50% of the total concentrate supply that bears high cost in the ruminant production. Besides, farmers in Bangladesh are interested in rearing crossbred animal. Therefore, quality improvement of existing feed resources and feeding green forage is essential for the increased productivity of animals (Naik *et al*., 2015). Though the major constraints in production of green fodder by dairy farmers include unavailability of land for fodder cultivation due to small land holding size, more labor requirement and increasing labor cost for cultivation, more growth time, requirement of manure and fertilizer, uncertain rainfall, scarcity of water or saline water, fencing to prevent fodder crops from wild animals, natural calamities etc. (Naik *et al*., 2014).

To face all these challenges and problems, hydroponics technology, is a method of growing plants without soil, is coming up as an alternative to grow fodder for farm animals (Sneath and McIntosh, 2003). Where, different types of fodder crops viz. barley (Reddy *et al*., 1988), oats, wheat (Snow *et al*., 2008); sorghum, alfalfa, cowpea (AI-Karaki and AI-Hashimi, 2012) maize (Naik *et al*., 2012a) can be produced by hydroponics technology. Sprouting of grains could be one of the major modifications by which, grains can enriched with some biologically active substances like anti-oxidants (e.g., vitamin -E) and activated enzymes. In addition with the increment of biomass yield, a desirable nutritional change may be occurred during sprouting, due to the breakdown of complex compounds into a more simple form, transformation into essential constituents and breakdown of nutritionally undesirable constituents (Chavan and Kadam, 1989). Sprouting of grains also affected the enzyme activity, increased total protein and changes in amino acid profile, increased sugars, crude fibre, certain vitamins and minerals, but decreased starch and loss of total dry matter (Lorenz, 1980).

Besides, this technology may be especially important in the regions, where forage production is limited (Fazaeli *et al*., 2012) and the grain feeding is not well practiced. Development of this hydroponic sprouting system has enabled the production of fresh forage round the year from oats, barley, wheat and other grain (Rodriguez-Muela *et al*., 2004). Though, under tropical agroclimatic conditions maize, wheat and oat was suggested to be the best for hydroponic fodder production due to grain availability, fast growing nature and good biomass yield.

However, limited research has been conducted on the feeding value of hydroponics fodder and the results are not consistent. Many researchers showed improved results in animal production (Tudor et al., 2003) while some researchers noticed no additional advantage in including hydroponic fodder in animal diets (Fazaeli *et al.*, 2012). In addition with, some degree of research work has been deliberated yet to calculate the cost-benefit analysis of sprouting compared with original grain. Hence, the present study was carried with the objectives to investigate the biomass yield and nutritional quality of hydroponic sprout of maize, wheat and oat grains with their production cost and benefit analysis.

Materials and Methods

Hydroponic unit

The hydroponic maize, wheat and oat grains were sprouted in normal room temperature at Nutrition and Feed Biotechnology Laboratory, Biotechnology Division, Bangladesh Livestock Research Institute, Savar, Dhaka. The hydroponic racks in a dimension of 35ft long, 6ft width and 6ft height was made by using stainless steel having three shelves with capacity of 30 numbers (3 stairs x 2 rows x 5 no's) of plastic trays equipped with irrigation system. The plastic trays having size in 3ft long and 2ft wide with holes at the base were allowed to drainage of excess water from irrigation.

Experiential procedure

The maize, wheat and oat grains were collected from local market, cleaned from dust and particles and then, sun dried for an hour.Weighed amount of grains (450g wheat, 500g maize and 210g oats) were soaked into water for 12, 24 and 2 hours, respectively. The amount of grains were differed due to differences in growth volume of different sprout and as the trays were of similar size, while soaking time was varied due to differences in water absorption capacity of different grains in a particular time period. Soaked grains were then wrapped in cotton cloth and kept for germination for 48h for wheat and maize and 24h for oat in a dark environment. The germinated grains were dipped in 8% hydrogen peroxide (H_2O_2) solution for reducing the chance of contamination and then spread on plastic trays to grow sprouts. Water was sprayed regularly in the tray. After, eight days sprouts were harvested and fresh biomass yield was measured. Samples were collected for analyses of proximate composition, vitamin-E and soluble sugar determination and microbial growth.

Microbial enumeration

For counting yeast and mold, 20 grams of fresh sprout was added with 180 ml saline water and vigorously homogenized in a laboratory blender (JAIPAN, INDIA) for 30 second and the resulted extract was screened with three layers of cheese cloth. The filtered then considered as the first dilution. Ten fold serial dilutions of suspension were prepared and 100µl aliquots of three consecutive dilutions (10^{-4} to 10^{-6}) were plated in duplicate onto potato dextrose agar (PDA; Difco, Sparks, MD21152, USA) yeasts and molds. The PDA agar plates were placed in a digital incubator (Daihan Scientific, Korea) at 37^{o}C for 24h. Visible colonies were counted from the plates at appropriate dilutions and the number of colony forming units (CFU) was expressed per gram of sprouts.

Laboratory analysis

Fresh sprouts of different grain (10g) were oven-dried at 105^{o}C for 24 h to determine the dry matter, DM (Labnics, LNO-250, USA). About 500 g of sprouts of different grain were dried at 60^{o}C for 48 h (Memmart, Germany), ground by a Willy mill and sieved through 1.0 mm screen to use for chemical analysis. Standard Kjeldahl procedure and Soxhlet method (AOAC, 2005) were used to determine the crude protein (CP) and ether extract (EE) contents, respectively. Crude ash concentration was determined with a muffle furnace at 550^{0}C for 3 h. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined following the method of Van Soest *et al*. (1991).

Cost analysis

The cost analysis was done according to

Sneath and McIntosh (2003). Fixed costs involved in present study included the cost of hydroponic chamber, shelves, trays, cloths, bowl, buckets, sprayer, balance etc. While variable costs involved price of grains (seed grade for hydroponic, while animal feed grade for grain only), chemical disinfectants (hydrozen peroxide), labor cost and depreciation cost on fixed cost. The fixed cost with chamber construction was calculated as total BDT 50,000 with 5% depreciation cost over 10 years. The seed grade grains and feed grade grains of maize, wheat and oat were 52 and 45, 50 and 35, and 65 and 55tk./kg, respectively, while labor cost were considered as 450 tk./person/day in this study.

Statistical analysis

Data were analyzed in paired sample t-test using SPSS 20.00 software for comparing between sprout and their respective grain.

Results and Discussion

Biomass yield

Fresh yield of maize, wheat and oat sprouts at 8^{th} day of harvesting are presented in Table 1. Results hown that fresh biomass yield was significantly ($p<0.01$) increased in hydroponic sprout compared to their corresponding grains. Similar results in green forage to seed ratio was reported by Al-Ajmi *et al.* (2009) who obtained a ratio of 2.76 to 3 kg green fodder per kg of barley seed. Research experiments conducted with barley (Morgan *et al.*, 1992) and maize (Naik, 2012b) seed, were obtained fresh yield of 2.8-8 folds in 6-8 days with dry matter (DM) content of 8-19.7% and of 3.5-6.0 folds in 7-8 days with DM content of 10.3-18.5% which was much more similar with the present findings. In this study, comparison was only made between sprout and grains not among the fodder species. However, results showed the production conversion ratios of fresh biomass yield from per unit of seed were ranged from 2.57 to 3.50 folds. The fresh yield of the hydroponics fodder are mainly influenced by the type of crops (Sneath and McIntosh, 2003), days of harvesting (Dung *et al.*, 2010a), degree of drainage of free water prior to weighing (Molla and Brihan, 2010), type and quality of seed, seed rate (Fazaeli *et al.*, 2011), irrigation frequencies, nutrient solution used, light, growing period (Naik, 2012b; Islam *et al.*, 2016), which described in the present study with variable findings.

Nutritional characteristics

Nutritional characteristics of hydroponic sprouts in comparison to their corresponding grains were described in Table 1. It was observed that DM contents were reduced significantly ($p<0.05$) in all three sprouts from their respective grains. Each kilogram of fresh maize, wheat and oat grains contained 857.04, 900.71 and 911.48 g DM, respectively, while sprout contained 764.62, 872.73 and 453.0 g/kg DM, respectively. It was calculated that on average DM was reduced at a rate of 11.0, 3.0 and 50.0%, respectively in maize, wheat and oat sprout. Similarly, OM contents were also reduced ($p<0.05$) in all three sprouts compared to their grains. In contrast, ash contents were decreased significantly in maize (9.89 vs13.21 g/kg; $p<0.05$) and oat (9.69 *vs* 18.97 g/kg; $p<0.01$), but numerically in wheat (18.88 *vs* 23.43 g/kg; $p>0.05$). The underlying reason for reducing DM and OM and concomitant increase in ash may due to catabolism of starch to soluble sugar for supporting metabolism and energy requirement of growing plants for respiration and cell wall synthesis (Naik *et al.*, 2015). Earlier studies also suggested DM loss (7-47%) in sprouting process compared to grains (Chung *et al.*, 1989). Studies with barley (Morgan *et al.*, 1992 and Thadchanamoorthy *et al.*, 2012) and maize (Naik, 2012b and Dung *et al.*, 2010) seeds showed 21.9 to 60.98 % loss in DM from grains after sprouting for a period of 7 to 10 days.

Contents of CP in grain *vs* sprout were found 61.24 *vs* 81.34, 126.13 *vs* 183.3 and 158.5 *vs* 201.67 g/kg seed, respectively in maize, wheat and oats and the difference (grain vssprout) is significant in the case of wheat (P<0.05) and oat (P<0.01). This represent 24.7, 31.2 and 21.3% increase in sprout of maize, wheat and oat, respectively. The increased CP in hydroponic sprout may attributed to the proportional change of other nutrients in seed DM, mainly reduction of carbohydrates through respiration during germination and plant growth (Naik *et al.*, 2015 and Dung *et al.*, 2010). In agreement with the present study, Flynn *et al.* (1986) reported increase in CP content upto 48% on 8th days of sprouting. Similarly, Snow *et al.* (2008) reported 16.13% increase in CP contents in hydroponic barley fodder. Naik *et al.* (2014) and Thadchanamoorthy *et al.* (2012) studied with maize and showed an18.18 and 49.87% increase in CP compared to the grain after sprouting for a period of 7 and 10 days, respectively.

The ether extract (EE) content was not change statistically in maize (42.41 *vs* 49.57 g/kg; p>0.01), while a significant increase was observed in wheat (33.82 *vs* 48.22 g/kg; p<0.05) and oats (15.53 *vs* 21.69 g/kg;

Table 1.Biomass yield and nutrient content of hydroponic sprout of maize, wheat and oat grains

Parameters	Fresh wt. (Kg)	DM	Ash	OM	CP	EE	ADF	NDF	Vit-E	SS
		(g/kg)							mg/100g	
Maize										
Grain	1000	857.04	9.89	847.12	61.24	42.41	70.77	158.39	3.51	489.40
Sprout	2736	764.62	13.21	751.62	81.34	49.57	196.87	333.66	8.09	462.50
SEM		10.27	0.58	9.64	5.94	4.34	5.87	8.19	0.02	0.15
P-value		<0.05	<0.05	<0.01	>0.05	>0.05	<0.01	<0.01	<0.01	<0.01
Wheat										
Grain	1000	900.71	18.88	882.08	126.13	33.82	42.21	146.27	1.07	443.70
Sprout	3500	872.73	23.43	863.77	183.30	48.22	396.94	448.12	2.34	477.00
SEM		7.28	1.54	1.27	6.50	2.42	19.69	11.44	0.02	1.09
P-value		>0.05	>0.05	<0.01	<0.05	<0.05	<0.01	<0.01	<0.01	<0.01
Oat										
Grain	1000	911.48	9.69	900.46	158.80	15.53	164.87	285.02	11.03	351.54
Sprout	2573	453.00	18.97	434.02	201.67	21.69	243.03	594.70	13.42	356.20
SEM		10.04	1.38	9.61	2.79	1.31	3.35	16.26	0.02	0.21
P-value		<0.01	<0.05	<0.01	<0.01	<0.05	<0.01	<0.01	<0.01	<0.01

SEM, Standard error of mean; SS, Soluble sugar p<0.05) due to sprouting. Increase in the structural lipids and production of chlorophyll associated with the plant growth might be the underlying reason for this. Similar to this study Naik *et al*. (2012b) also reported an increased EE content in hydroponic maize fodder compared to grain. The contents of acid detergent fibre (ADF) in maize, wheat and oat grains were found 70.77, 42.21 and 164.87 g/kg, respectively, which were increased significantly (P<0.01) to 196.87, 396.94 and 243.03 g/kg in their sprout, respectively. Similarly, neutral detergent fibre (NDF) concentrations were also increased (p<0.01) in sprout of maize (333.66 g/kg), wheat (448.12 g/kg) and oat (594.7 g/kg) compared to their grains (158.39, 146.27 and 285.02 g/kg, respectively). The increase in ADF and NDF (cell wall content) due to sprouting may be attributed to the increase in number and size of cell walls for the synthesis of structural carbohydrates in growth process. Akbag *et al.* (2014) also reported increased ADF and NDF in barley sprouts compared to their grains. The ash contents in sprout were increased with a concomitant decrease in OM contents irrespective of fodder species in this study (Table 1). Morgan *et al* (1992) and Akbag *et al*. (2014) reported similar results and they explained the increase in ash with decrease in OM in sprouts because of root development, which allowed mineral uptake. Again, utilization of energy and other nutrients during plant growth lead to decrease in OM and as a result proportionate increased in ash contents.

The contents of Vitamin-E were increased (p<0.01) in sprouts (8.09, 2.34 and 13.42 mg/100g in maize, wheat and oat sprout, respectively) compared to their grains (3.51, 1.07 and 11.04 mg/100g in maize, wheat and oat grain, respectively (Table 1). Similarly, soluble sugar (SS) contents were increased (P<0.01) in wheat and oat sprouts (477.0 and 356.2 mg/100g, respectively) compared their grains (443.7 and 351.5 mg/100g, respectively). In contrary, soluble sugar was decreased (P<0.01) in maize sprout (462.5 mg/100g) compared to its grain (489.4 mg/100g). It is well known that germinating seed contained increased amount of Vitamin-E (natural antioxidant) and in agreement with the present study Cuddeford (1989) found 62.4% Vitamin E (Alpha-tocopherol) in barley sprout compared to 7.4% in barley grain. The reason for increasing soluble sugar in wheat and oat may be due to the breakdown of complex nutrients into simpler form during sprouting process. It was stated that at sprouting of cereal grains amylase and maltase activity results in gradual decrease in starch with a concomitant increase in reducing and non-reducing sugars (Chavan and Kadam, 1989). However, the reason for decrease in SS in maize is not clear. It may happen that the rate of sugar utilization during plant growth was much higher than the rate of degradation of starch to simple sugar in maize.

Microbial count

As in sprouting process, seeds were in highly moist environment from germination to final harvest, it is vulnerable for yeast and mold growth. Therefore, yeast and mold concentration in harvested sprout were counted (Table 2). Both the organisms were found only in wheat sprout at 7.16 $\log_{10}$ CFU/g and 7.00 $\log_{10}$ CFU/g yeast and mold, respectively. Oat sprout contained only yeast at 5.74 $\log_{10}$ CFU/g but no mold growth was observed. However, their growth was not apparent on sprout at harvest. This might be natural presence or concentrations below the toxic level. In contrary, neither yeast nor mold was grown in maize sprout. Some earlier reports described the root deterioration of hydroponic sprout due to fungi and yeast contamination (Saini *et al.*, 2011 and Capper, 1988).

Cost analysis

Table 3 showed the comparative production cost of hydroponic sprout *vs* feeding grain instead. The cost analysis was done based on a hydroponic production system of capacity of 100 kg seed converting to sprout daily. Factors considered for calculation of hydroponic sprout production cost including fixed cost and variable costs expressed in daily basis that includes all types of cost excluding water and electricity cost. Seed cost (for 100 kg) for producing hydroponic sprout was accounted for 5200, 5000 and 6500 Tk for maize, wheat and oats, respectively based on present retail market price. If a farmer fed animals the same amount of (100 kg) seed (grain) as concentrate he/she will need to expend 4500, 3500 and 5500 Tk daily for maize, wheat and oats, respectively. The lower price in grain feeding as concentrate was due to the fact that it was feed grade grain, while in hydroponic system seed grade grain was used. The disinfection of seeds, using labour and depreciation costs are only included in the case of hydroponic system, not applicable for grain feeding. Therefore, the total daily costs of hydroponic sprout production using 100 kg seed were 6146.4, 5946.4 and 7446.4 Tk/day for maize, wheat and oat, respectively. On the other hand total daily costs comprised only grain cost those were 4500, 3500 and 5500 Tk/day for maize, wheat and oats, respectively. Considering the production cost of DM and CP, it was found that to harvest 1 kg of them, the cost will be 1.5, 1.7 and 2.6 times higher for DM and 1.15, 1.22 and 2.06 times higher for CP production from hydroponic sprout compared to feeding grain directly.

Table 2. Yeast and mold concentration in hydroponic sprouts

Hydroponic sprout	Microbial growth ($\log_{10}$ CFU/g)	
	Yeast	Mold
Maize	*n.d*	*n.d*
Wheat	7.16	7.00
Oat	5.74	*n.d*

n.d, Not detected.

Conclusion

Based on the findings it can be concluded that, the production of hydroponic sprout or so called hydroponic fodder resulted a loss of dry matter but improved nutrient compositions as expressed by increments in, crude protein, vitamin E, soluble sugar and fibre contents. On the other hand, production cost analysis does not support the idea to

Table 3. Comparative cost analysis for producing sprout

Parameters	Maize		Wheat		Oat	
	Grain	Sprout	Grain	Sprout	Grain	Sprout
a. Fixed cost (chamber construction, tray, utensils etc.), Tk	-	50000.0	-	50000.0	-	50000.0
b. Variable costs (based on100 kg grain/seeds used daily for feed/sprout production)						
1. Grain/Seed cost, Tk	4500	5200	3500	5000	5500	6500
2. Labor cost (2 labor @ 450 Taka/day)	-	900	-	900	-	900
3. Disinfectant cost, Tk	-	45	-	45	-	45
4. Depreciation cost* (at 5% over 10 years), Tk	-	1.4	-	1.4	-	1.4
c. Total cost, Tk/day	4500.0	6146.4	3500.0	5946.4	5500.0	7446.4
d. Total cost for fresh biomass production, Tk/kg	45.0	22.3	35.0	17.0	55.0	29.0
e. Total cost for DM production, Tk/kgDM	52.5	80.6	39.0	65.0	60.4	158.5
f. Cost ratio for DM (Sprout/grain)	1.0	1.5	1.0	1.7	1.0	2.6
g. Total cost for CP production,Tk/kg CP	85.80	98.30	30.23	36.98	38.02	78.41
h. Cost ratio for CP (Sprout/grain)	1.0	1.15	1.0	1.22	1.0	2.06

*The depreciation cost was considered only 5% depending on the nature of infrastructure.

produce and feed hydroponic sprout/ so-called hydroponic fodder instead of feeding grains directly as concentrate feed. However, if the improved nutritional composition assists to boost animal production to oversee the extra cost then it may be beneficial, which was beyond the present study. Further study is needed scope of the animal feeding trial for getting firm conclusion on cost-benefit of hydroponic sprout over grain as feed to the animal.

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References

Al-Karaki, G. N. and Al-Hashimi, M. 2012. Green Fodder Production and Water Use Efficiency of Some Forage Crops under Hydroponic Conditions. International Scholarly Research Network. ISRN Agronomy. 2012: 1–5.

Al Ajmi, A., Salih, A. A., Kadim, I. and Othman, Y. 2009. Chemical constituents and heavy metals contents of barley fodder produced under hydroponic system in GCC countries using tertiary treated sewage effluents, J. Phytol. 1 (5): 342-348.

Akbağ, H. I., Türkmen, Q. S., Baytekin, H. and Yurtman, I. Y. 2014. Effects of harvesting time on nutritional value of hydroponic barley production.Türk Tarımve DoğaBilimleri. 7(7): 1761-1765.

Chavan, J. and Kadam, S. S. 1989. Nutritional improvement of cereals by sprouting. Critical

Rev. Food Sci. Nutri. 28(5): 401-437.

Cuddeford, D. 1989. Hydroponic grass. In Practice. 11(5): 211-214.

Capper, A. L. 1988.Fungal contamination of hydroponic forage. Anim. Feed Sci. Tech. 20:163-169.

Chung, T. Y., Nwokolo, E. N. and Sim, J. S. 1989. Compositional and digestibility changes in sprouted barley and canola grains. Plant Foods for Human Nutrition. 39(3): 267- 78.

Dung, D. D., Godwin, I. R. and Nolan, J. V. 2010. Nutrient content and in sacco degradability of barley grain and sprouted barley. J. Anim. Vet. Adv. 9(19): 2485-2492

Fazaeli, H., Golmohammadi, H. A., Tabatabayee, S. N. and Asghari-Tabrizi, M. 2012. Productivity and nutritive value of barley green fodder yield in hydroponic system. World Appli. Sci. J. 16(4): 531-539.

Flynn, V. and O'Kiely, P. 1986. Input / output data for the ACRON germination unit.

Islam, R., Jalal, N. and Akbar, M. A, 2016. Effect of seed rate and water level on production and chemical analysis of hydroponic fodder. European Academic Research. Vol. IV, Issue 8: 6724-6753.

Lorenz, K.1980. Cereal sprouts: composition, nutritive value, food applications. Critical Reviews in Food Science and Nutrition. 13(4): 353-385.

Morgan, J., Hunte, R. R. and O'Haire, R. 1992. Limiting factors in hydroponic barley grass production. In the proceeding of the 8th International congress on soil less culture. 241-261.

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. Agr. Sci. 6(6): 713-719.

Naik, P. K., Dhuri, R. B., Swain, B. K. and Singh, N. P. 2012a. Nutrient changes with the growth of hydroponicsfodder maize. Indian J. Anim. Nutr. 29: 161-163.

Naik, P. K., Dhuri, R. B., Swain, B. K. and Singh, N. P. 2012b. Cost of production of hydroponics fodder maize. In: Proc. of 8th Biennial Animal Nutrition Association Conference on 'Animal Nutrition Research Strategiesfor Food Security', November 28-30, 2012, Bikaner, Rajasthan, India.

Naik, P. K., Dhuri, R. B., Karunakaran, M., Swain, B. K. and Singh, N. P. 2014. Effect of feeding hydroponics maizefodder on digestibility of nutrients and milkproduction in lactating cows. Indian J. Anim. Sci. 84 (8): 880-883.

Naik, P. K., Swain, B. K. and Singh, N. P. 2015. Hydroponics:Its feasibility as an alternative to cultivated forages. In: Proc. 9th Biennial Animal Nutrition Association Conference on 'Eco-responsive Feeding and Nutrition: Linking Livestock and Livelihood' held at Guwahati, India, January 22-24, 2015. 74-87.

Reddy, M. R., Reddy, D. N. and Reddy, G. V. K. 1991. Supplementation of barley fodder to paddy straw based rations of lactating crossbred cows. Indian J. Anim. Nutri. 8(4): 274-277.

Rodriguez-Muela, C., Rodriguez, H. E., Ruiz, O., Flores, A., Grado, J. A. and Arzola, C. 2004. Use of green fodder produced in hydroponic system as supplement for lactating cows during dry season. In: Proc. Am. Soc. Anim. Science. 271-274.

Saini, K., Kalyani, S., Surekha, M. and Reddy, S .M. 2011. Temperature as a factor in the elaboration of mycotoxins by two fungi in groundnut fodder. Int. J. Biotechnol. Mol. Biol. Res. 5:90-92.

Snow, A. M., Ghaly, A. E. and Snow, A. 2008. A comparative assessment of hydroponically grown cereal crops for the purification of aquaculture waste water and the production of fish feed. American J. Agri. and Biol. Sci. 3 (1): 364-78.

Sneath, R. and McIntosh, F. 2003. Review of Hydroponic Fodder Production for Beef Cattle. Queensland Government, Department of Primary Industries, Dalby, Queensland.

Tareque, A. M. M. and Saadullah, M. 1988. Feed availability, requirements for animals and current pattern of feed utilization in Bangladesh. In: Non-Conventional Feed resources and Fibrous Agricultural Residues. Int. Dev. Res. Centre and Indian Council of Agril.Res., New Delhi, India.116-130.

Thadchanamoorthy, S., Jayawardena, V.P. and Pramalal, 2012. Evaluation of hydroponically Grown Maize as a Feed Source for Rabbits. Proceedings of 22nd Annual Students Research Session, Department of Animal Science. P: 22-28.

Tudor, G., Darcy, T., Smith, P. and Shallcross, F. 2003. The intake and live weight change of drought master steers fed hydroponically grown, young sprouted barley fodder (Autograss). Department of Agriculture Western Australia.

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.