J Bangladesh Agril Univ 18(3): 629–635, 2020 https://doi.org/10.5455/JBAU.98462

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Partial Replacement of Conventional Concentrate Mixture with Hydroponic Maize and Its Effect on Milk Production and Quality of Crossbred Cow

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ARTICLE INFO

Article history
Received: 12 Jul 2020
Accepted: 21 Aug 2020
Published online: 25 Sep 2020

Keywords
Concentrate mixture, Maize hydroponic, Milk yield, Feed efficiency, Milk constituents

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ABSTRACT

This study was conducted to evaluate the influence of partial replacement of concentrate mixture (CM) by hydroponic maize fodder (HMF) on the performance of crossbred cow. Six Holstein-Friesian crossbred (HFX) lactating cows were selected and divided into two groups, control (n = 3) and hydroponic (n = 3). Both the control and hydroponic cows received 37.0 kg/head/day German grass (*Echinochloa crus-galli*). In control group, 4.0 kg CM was supplied daily to each cow and 25% of CM was replaced by HMF (6.1 kg/h/d) in the hydroponic group. The dry matter intake and body weight between control and hydroponic groups were found similar (P > 0.05). During the study period, about 21% higher (P < 0.001) milk was obtained in the hydroponic group compared to the control group. Compared to initial day of the study, average of 28 days milk yield was found 11% more in hydroponic group, whereas, milk production of control group was declined. Feed conversion efficiency was found higher (P < 0.001) in hydroponic group than that of the control group (1.25 *vs.* 1.63 kg DMI/kg milk yield and 0.76 *vs.* 0.97 kg TDNI/kg milk yield). Total solids (P < 0.001), fat (P = 0.004) and ash (P = 0.008) contents of milk were found higher in hydroponic group compared to the control group but other milk compositional parameters remains similar between two dietary groups. In conclusion, feeding of hydroponic maize fodder to HFX cows has positive impacts in boosting up the milk production, feed efficiency and milk composition.

Introduction

Dairying is one of the major components of animal agriculture in Bangladesh and growing fast but faces a good deal of challenges as well, especially due to high input and low output prices that lead to lower profitability (Uddin *et al.,* 2010). Bangladesh is densely populated country with limited land resources and according to BBS (2014), 83% of the total cultivable land is used for cultivation of cereal crops, 0.10% for cultivation of fodder crops and rest for other crops. Moreover, every year 1% of cultivable land are being reduced (BBS, 2016) due to continuous pressure of rising human population. Recently, it has emerged an acute problem for dairy animals rearing in Bangladesh due to crisis of land for fodder production and grazing.

Poor quality roughage- rice straw alone contributes ≈ 87% of the total roughage feed of the animal (Khan *et al.,* 2009) and simultaneously less nutritive agricultural byproducts widely being used as concentrate source for dairy ration in Bangladesh (Dutta and Sharma, 2004). Such types of feeds and fodder are continuously hindering the sustainable animal production through poor productive and reproductive responses of the animals. According to Hammon *et al.* (2006) and McArt *et al.* (2013), cattle performances are being negatively affected in tropical areas due to unavailability of forage and their low quality. This situation can be improved by concentrate supplementation which is not available to the farmers at the affordable prices (Khan *et al.,* 2009). In recent years, the cost of concentrate ingredients has increased many folds due to huge competition between monogastric (human and poultry) and ruminants, and its availability is not sufficient throughout the year. Moreover, the ruminant animals cannot always be lived on concentrate (cereal grains and byproducts) like that of monogastric animals (Girma and Gebremariam, 2018). Due to the above constraints in the conventional method of fodder cultivation and realizing gap between demand and supply of the green fodder, hydroponics technology

Cite This Article
Bari, M.S., Islam, M.N., Islam, M.M., Siddiki, M.S.R., Habib, M.R., Islam, M.A. 2020. Partial Replacement of Conventional Concentrate Mixture with Hydroponic Maize and Its Effect on Milk Production and Quality of Crossbred Cow. *Journal of Bangladesh Agricultural University*, 18(3): 629–635. https://doi.org/10.5455/JBAU.98462

is coming up as an alternative to grow fodder in a small house within a short time for farm animals (Sneath and Mclntosh, 2003; Singh, 2011; Naik *et al.,* 2012). This technology of green fodder production is especially important in the regions where green fodder production is limited (Omar *et al.,* 2012; Mohsen *et al.,* 2015).

Hydroponic cultivation is an eco-friendly protocol of growing fodder and, hydroponically grown grains augment up to 50% faster and produce higher yields of fodder with better nutritional quality (Kide *et al.,* 2015). Sprouting of grain in hydroponic system improves the nutritional quality through conversion of complex compounds into simpler and essential form, and such germination process limiting anti-nutritional factors in cereal grains (Chavan *et al.,* 1989). Hydroponically produced green fodder are rich source of crude protein, metabolizable energy with higher nutrient digestibility (El-Morsy, 2013). According to Shipard (2005), germination eliminates the phytic acid effect through production of phytase enzyme and, enhances the content and activation process of plant enzymes. Quality of protein in hydroponic fodder improved by protease enzymes that convert complex compounds into amino acids, small peptides, albumin and globulin (Chavan *et al.,* 1989; Shewry *et al.*, 1995). Sugar and essential fatty acids content also increased due to better amylolytic and lipolytic activity during germination and sprouting. Increasing of such nutrients reduces acidosis problems through stabilization of rumen pH without the constant input of starch (Chavan *et al.,* 1989; Macleod & White, 1962). Minerals and vitamins (A, E, C and B-complex) contents increased remarkably in hydroponically-sprouted grain (Lorenz *et al.,* 1980). Besides nutritive value, hydroponic fodders are highly palatable, digestible, nutritious and free from contaminants like chemical fertilizer, pesticide, insecticides, herbicides fungicide, growth promoter, hormone etc. (Jensen and Malter, 1995; Al-Karaki and Al-Hashmi, 2008).

In the current decades, hydroponic fodder production would be an effective solution for reducing green fodder and concentrate feed scarcity. As feed cost involves 50-60% of the total cost of livestock production (de Freitas *et al.,* 2019) hence, hydroponic technology become more economic in animal farming system (Naik *et al.,* 2015). It leads to reduced dependency on concentrates which is conducive for dairy cows (Girma & Gebremariam, 2018). That is why adoption of hydroponic/sprouting technology could be a better option for the rapid production of succulent fodder for dairy animal feeding. Few research works have already been carried out regarding the feeding effects of hydroponic fodder by replacing traditional roughages in dairy animals around the world. These are- traditional roughage was replaced by hydroponic barley fodder (HBF) in Algeria (Agius *et al.,* 2019), oat hay replaced by HBF (Adjlanea, 2016), hybrid Napier grass was replaced by HBF in India (Reddy *et al*, 1988), maize silage replaced with HBF (Grigor'ev *et al.,* 1986), Napier bajra fodder replaced with hydroponic maize fodder (Naik *et al.,* 2014) and found positive impact on productive and reproductive responses. Satisfactory performances of animals also found through supplementation of hydroponic fodder with basal diet in dairy ration (Šidagis, 2014; Zahera *et al.,* 2015). Though few research works of hydroponic fodder were conducted on dairy animals but no research work came into attention to the authors regarding the feasibility of replacing concentrate mixture with hydroponic maize fodder (*Zea mays*) on HFX lactating cows performances. We can assume that our research work can open a new window of hydroponic maize fodder with the partial replacement of concentrate mixture on milking cow feeding system. Therefore, changes in dry matter intake, body weight, feed conversion efficiency, milk yield and composition of HFX dairy cows were assayed to elucidate the response of partial concentrate mixture replacement with hydroponic maize fodder.

Materials and Methods

Cultivation of hydroponic fodder

Hydroponic maize fodder (*Zea mays*) was cultivated in a low-cost type hydroponic sprouting room (Naik and Singh, 2013) and per day production aptitude was 50 kg fresh fodder. Maize seed were collected from the local market, Mymensingh-2200, Bangladesh. After collection, seeds were sun dried to reduce its moisture level at 13-14%. Seeds were soaked for 24 hours in fresh water, and hanged for 1 hour in a perforated bucket. Then the seeds were incubated in a gunny bag for 48 hours. This was followed by spreading both the germinated (82%) and non-germinated seeds on a sterilized aluminum tray (30×12×1.5 inch^3/tray). Manual sprinklers was used to irrigate the maize grains at 3 hours intervals, and continued from day 0 to 7th day. The hydroponic fodder was collected at 8th day morning and fed to the cows. From 1 kg of maize grain approximately 6.1 kg of fresh hydroponic fodder was produced.

Animal management and diets

Animal management procedures were carried out at the Research Dairy Farm, Department of Dairy Science, Bangladesh Agricultural University (BAU), Mymensingh-2202, Bangladesh (24^{o}43'46.5''N, 90^{o}25'22.8"E) in winter season. Six Holstein-Friesian crossbred (50% HFX) lactating cows with 334.00 kg (±15) body weight, 50 days (±15) in milk and 7.00 kg (±0.50) daily milk yield were selected for this study. Cows were randomly allocated into two equal groups, control (n = 3) and hydroponic (n = 3). The study was carried out for 35 days of which first 7 days were for adjustment period. Cows were kept in stanchion barn (double rowed, face-out system) and had provision to clean water for 24 hours. All the cows were de-wormed by a broad-spectrum anthelmintic (Levanid bolus, The ACME Laboratories Limited, Veterinary Division, Dhaka, Bangladesh).

Current study was conducted using German grass (*Echinochloa crus-galli*), hydroponic maize fodder (HMF) and concentrate mixture. A mixture of 61.50, 21.0, 15.0, 2.0 and 0.50% of wheat bran, rice polish, mustard oil cake, common salt and di-calcium phosphate (DCP PLUS, Opsonin Pharma Limited, Agrovet Division, Barisal, Bangladesh), respectively constitutes the concentrate mixture. Based on the intake during the pre-trial period, 3.2 % (of the body weight) dry matter (DM) was offered to each cow. German grass (37 kg/h/d) was used as basal diet in both groups. In addition, 4.0 kg CM was supplied daily to the control cows, whereas 3.0 kg CM and 6.1 kg hydroponic fodder obtained from 1 kg maize grain (resulted in 25% of the CM replacement by HMF) was provided in hydroponic group. This fixed amount of German grass and concentrate mixtures were supplied to the HFX cows based on the existing farm feeding practices of BAU Dairy Farm. Considering the DM content, German grass, CM and hydroponic fodder ratios were approximately 66 : 34 : 0 and 64 : 27 : 9 in control and hydroponic group, respectively. CM was supplied at 07:30 am (half of the total amount) and 11:30 am (rest of the total amount). HMF was offered once in the morning after CM feeding. The required amount of German grass was supplied once daily at 12.30 pm and fresh drinking water was made available for 24 hours. The major nutrient content (such as DM, CP, EE, CF and ash) of the individual feed items was analyzed according to AOAC (2005) at Animal Science laboratory, Department of Animal Science, BAU, Mymensingh-2202, Bangladesh. Ingredients and chemical composition of the diets are given in Table 1.

Estimation of dry matter intake, body weight and feed conversion efficiency

Individual daily dry matter intake was estimated from the daily feed supplied and feeding orts. Body weight of the cows was measured through weighing balance (Zhunsheng scale, Motor car brand, China) at the beginning of the experiment and at the end of the experiment. The feed conversion efficiency was calculated following these formulas- FCE_{DMI} = DMI (kg)/milk yield (kg) and FCE_{TDNI} = total digestible nutrient intake (TDNI) (kg)/milk yield (kg).

Measurement of milk yield and analysis of milk quality

Individual daily milk yield was measured using weighing balance (RFL electric balance, LA-111×100, SS straight, 100 kg, Bangladesh) from onset of the feeding trial to end of the study period. Manual milking was done and milk yield was calculated by summing up the morning and afternoon milk. Milk yield in start day and final day of the experiment was used in calculation of initial and final milk yield. Average milk yield was calculated considering the daily milk yield of the whole experimental period. Morning milk samples (300 mL) from each cow were collected for the assessment of milk compositional content from start day to each successive week of the study period. Gross constituents of milk (contents of total solids, fat, solids-not-fat, protein, lactose and ash) were analyzed by automated milk analyzer (Lactoscan SLP, MILKOTONIC Ltd., Bulgaria 6000. Stara Zagora) at Dairy Chemistry and Technology laboratory, Department of Dairy Science, BAU, Mymensingh-2202, Bangladesh. Specific gravity in milk was assayed by gravity method using Quevenne lactometer and acidity percentage was determined through titration method using 0.1 M NaOH solution and phenolphthalein indicator.

Statistical analysis

One way analysis of variance was done to compare the effects of the control and experimental diets using the Minitab 17 (Minitab Limited, Brandon Court, Coventry, UK). A probability of $P<0.05$ was used to determine significant differences among the means.

Results and Discussion

Effects on dry matter intake and body weight

The concerned data on DMI and BW of HFX cows are presented in Table 2. Result revealed that partial replacement of concentrate mixture (CM) with hydroponic maize fodder (HMF) did not cause any statistical variation ($P = 0.115$) in the DMI of cows. About 1% low DMI was found in cows received HMF than that of the control cows and when considering DMI per 100 kg BW this variation was 4%. The lower DM content of ration in hydroponic group (Table 1) may explain this variation. Lower DMI in dairy cattle due to high moisture content of hydroponic fodder was also indicated by Abd Rahim *et al.* (2015). Similarly, Heins *et al.* (2016) reported that DMI of cattle was decreased due to feeding of hydroponic barley fodder. Fazaeli *et al.* (2011) reported that high water content in hydroponic fodder lead the animals to limited DMI. Naik *et al.* (2017) found 3% reduced DMI through partial replacement of maize grain in CM with HMF. In another study, Naik *et al.* (2014) found 9% reduced DMI in HMF feeding instead of conventional Napier bajra hybrid green fodder. These findings are in line with our present experimental result. Average BW of HFX cows did not differ ($P = 0.759$) between control and hydroponic groups. It might be due to reaching maximum growing stage of cows and literally proved that growth of the animals did not increase in significant trend after reaching certain age (Wiltbank *et al.,* 1966) which is also indicated by James (2011).

Effects on milk yield and feed conversion efficiency

Figure 1 and Table 2 shows the milk production and feed conversion efficiency (FCE) of HFX cows fed control and hydroponic diets. The hydroponic maize fed cow gave ≈1.50 kg (21%) more milk than that of the control diet fed cow (P < 0.001), although the initial daily milk yield was similar (P = 0.483) (Fig. 1). When considering final day milk yield this difference is ≈1.70 kg (P = 0.040). Compared to start day of the study, it was noted that average milk production was 11% increase in the hydroponic group but production of control group was decreased (3%) during the experimental period (Fig. 1). Findings of this study indicated that partial replacement of CM with HMF has positive impact on milk production of HFX cows. This finding is highly collaborated with Reddy *et al.* (1988); Naik *et al.* (2014) and Naik *et al.* (2017), who claimed that the milk yield is improved by 8-14% by feeding hydroponic fodder. This additional milk might be owe to the higher DCP and TDN content of the ration with hydroponic fodder and it's better nutrient digestibility (Naik *et al.,* 2014; Naik *et al.,* 2015; Helal, 2015). According to Farghaly *et al.* (2019), hydroponically sprouted fodder are rich in nutrient content which have better digestibility, ruminal enzyme activities as well as fermentation. This result is also supported by Grigor'ev *et al.* (1986) who found 9% higher milk yield through replacing 50% of the maize silage with 18 kg of hydroponic barley fodder. Adjlanea *et al.* (2016) reported that supplementation of 10 kg hydroponic barley fodder significantly increased milk yield (2.65 L/d) in dairy cow. In another study, Šidagis *et al.* (2014) concluded that malt sprouts caused 12.5% increased milk yield in cow. These improvements might be due to improved nutrient quality of hydroponic fodder through sprouting (Salo, 2019).

Hydroponic maize fodders fed cows were found more efficient in utilization of feed than that of the control cows. Control diet fed cow consume 0.4 kg more DM to produce 1 kg milk compared to the HMF group (P < 0.001; Table 2). Cows that received HMF as partial replacement of CM consume 21% less TDN (P < 0.001) to produce each kg of milk than that of the control cows (Table 2). This is in agreement with Naik *et al.* (2017) who found better FCE (7% reduction in DM and TDN consumption to produce one kg milk) by replacing maize grain of CM with HMF. However, the used concentrate mixture and roughage type are different from the present study. In another study, Naik *et al.* (2014) reported that DM and TDN consumption to produce one kg milk was reduced by 11 and 5%, respectively due to the replacement of conventional Napier bajra fodder with hydroponic maize fodder. According to Reddy *et al.* (1988), about 11.6% less DM required for producing 1 kg of milk through feeding of hydroponic barley fodder. These findings are in line with the results of the current study. Finney (1983) stated that hydroponic sprouts are rich source of nutrients and contain a grass juice factor that improves the animal performances. Several research works also carried out in field condition of India through reducing the CM level with increasing hydroponic fodder in diet and found distinguished changes in animal production (Naik *et al.,* 2013; Naik *et al.,* 2017).

Effects on milk compositional quality

The response of replacing the concentrate mixture partially by HMF in the quality of milk is presented in Table 2. Results revealed that among the milk constituents, only total solids, milk fat and ash content was found significantly (P < 0.01) higher in cows of hydroponic group than that of the control group. About 2 gm higher total solids were found in the milk of hydroponic group compared to the control group that may be due to increase of protein, fat, minerals contents. This is in line with the finding of Reddy *et al.* (1991) who found slight increase of total solids content in milk through feeding of hydroponic barley fodder in replace of 25 or 50% CM in the diet. Naik *et al*. (2014) also evident that 1% total solids increased in milk through replacement of conventional Napier bajra fodder with hydroponic maize fodder.

Milk fat content was found 4% higher (P = 0.004) in hydroponic group than that of the control group and that may be due to increase of DMI from roughage source by the cows (Table 1). According to O'Brien and Guinee (1998), increasing DMI from the grass (roughage) source is responsible for increasing fat content in milk. This might be the reason that replacing the concentrate mixture by hydroponic fodder caused higher milk fat. Similarly, Agius *et al.* (2019) found 14% more fat in milk due to replacing the traditional roughage with hydroponic barley fodder in diet of HFX cows. Findings of this present study are in line with Reddy *et al.* (1988) and they found 10.5% more milk fat content in milk of artificially grown barley fodder fed Holstein crossbred cows. In the same way malt sprouts supplementation increases 0.4% fat in milk of lactating cow (Šidagis *et al.,* 2014).

Protein, lactose and solids-not-fat (SNF) content of milk remains statistically similar (P > 0.05) between cows fed control and hydroponic diets but numerically higher in hydroponic group compared to the control group. This is in agreement with the results of Naik *et al.* (2014) and Naik *et al.* (2017). In another study, Abd Rahim *et al.*

(2015) also found numerically higher (P > 0.05) SNF, protein and lactose in the milk of hydroponic fed Awassi ewes while examining the feeding effects of hydroponic barley fodder compared to the control fed. Malt sprouts supplementation had non-significant influence on milk protein content in lactating cows (Šidagis *et al.,* 2014). Feeding of hydroponic barley fodder by replacing 66% oat hay had no influence on SNF, protein and lactose (Adjlanea *et al.,* 2016). In another study Reddy *et al.* (1991) also did not find any significant difference in SNF percent in crossbred cows fed machine grown barley fodder. Feeding of hydroponic maize fodder as partial replacement of CM had significant (P = 0.008) impact on ash content in milk and found 4% higher ash content in hydroponic group than that of the control group. It may be due to higher content of minerals in hydroponic fodder (Lorenz *et al.,* 1980). According to Shipard (2005), minerals present in hydroponic fodder are more available due to the action of phytase enzyme and inhibit the negative effects of phytic acid for mineral utilization. Specific gravity and acidity contents of milk remain similar (P > 0.05) between control and HMF groups but numerical values were within normal physiological range for HFX cow milk as reported by Islam *et al.* (2008).

Table 1. Ingredient and chemical composition of the ration in control and hydroponic groups

	Dietary groups	
	Control	Hydroponic
Ingredient composition (g kg^{-1} DM)		
German grass	664.00	642.00
Hydroponic maize fodder	-	92.80
Wheat bran	207.50	163.70
Rice polish	71.00	56.00
Mustard oil Cake	48.50	38.20
Common salt	7.30	5.70
DCP[1]	1.80	1.40
Chemical composition (g kg^{-1} DM)		
Dry matter (g kg^{-1} fresh matter)	258.24	245.41
Crude protein	110.37	110.95
Ether extract	49.93	36.73
Crude fiber	249.58	242.11
Ash	106.72	102.01
Nitrogen-free-extract	484.31	501.02
TDN (%)	59.59	60.32
Metabolizable energy (MJ kg^{-1} DM)†	9.22	9.36
Net energy (MJ kg^{-1} DM)‡‡	8.57	8.70
Net energy (Mcal kg^{-1} DM)‡‡	2.01	2.04

[1]DCP PLUS (Opsonin Pharma Limited, Agrovet division, Barisal, Bangladesh) contained per kilogram: di calcium phosphate 900 g, magnesium sulphate 20 g, sodium chloride 60 g, trace elements e.g. Ferrous, manganese, iodine, copper, zinc and cobalt etc. 20 g; † Metabolizable energy (ME) values were estimated according to the equation of Kearl (1982), ME (MJ kg^{-1} DM) = [− 0.45 + (0.04453 × %TDN)] × 4.184; TDN is estimated according to the following equations: TDN for roughages (% of DM) = − 17.2649 + (1.2120 × %CP) + (0.8352 × %NFE) + (2.4637 × %EE) + (0.4475 × %CF); TDN for concentrate (% of DM) = 40.3227 + (0.5398 × %CP) + (0.4448 × %NFE) + (1.4218 × %EE) − (0.7007 × %CF); ‡‡ Net energy (NE) = ME x 0.93 and, 1 MJ = 0.234 Mcal.

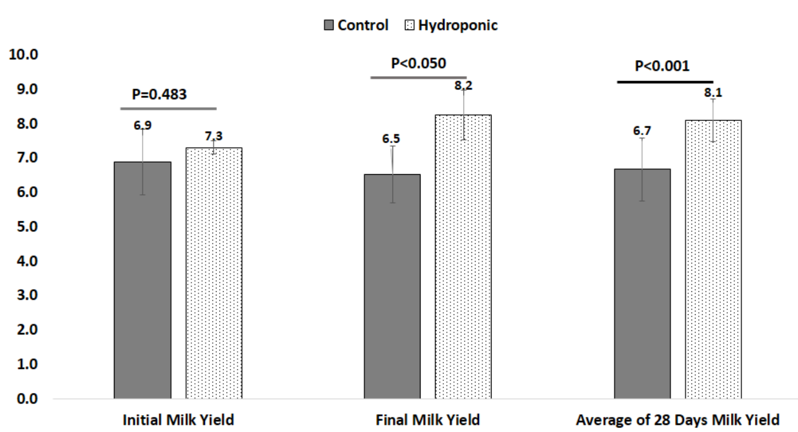

Figure 1. Comparison of initial, final and average milk yield of control and hydroponic fed cows

Table 2. Influence of partial replacement of concentrate mixture by HMF on DMI, body weight, FCE and milk attributes

Parameters	Diets (mean ± SD)		p-value
	Control (n = 3)	Hydroponic (n = 3)	
Average DMI (kg $d^{-1}cow^{-1}$)	10.69 ± 0.19	10.06 ± 0.17	0. 115
Average DMI/100 kg BW (kg)	3.18 ± 0.15	3.03 ± 0.02	0.180
Average BW (kg cow^{-1})	343.0 ± 19.3	339.0 ± 8.54	0.759
Feed conversion efficiency (FCE)			
Kg DMI/kg milk yield	1.63 ± 0.28	1.25 ± 0.11	<0.001
Kg TDNI/kg milk yield	0.97 ± 0.17	0.76 ± 0.07	<0.001
Physical and chemical attributes of milk			
Specific gravity	1.03 ± 0.00	1.03 ± 0.00	0.508
Acidity (%)	0.16 ± 0.00	0.16 ± 0.00	0.069
Chemical constituents (g kg^{-1})			
Total solids	127.62 ± 0.88	129.66 ± 1.01	<0.001
Fat	42.88 ± 0.65	44.46 ± 1.60	0.004
Solids-not-fat	84.74 ± 1.51	85.10 ± 1.41	0.554
Protein	32.04 ± 0.68	32.08 ± 0.45	0.889
Lactose	46.19 ± 0.89	46.35 ± 0.90	0.668
Ash	6.54 ± 0.15	6.81 ± 0.14	0.008

DMI, dry matter intake; TDNI, total digestible nutrients intake; HMF, hydroponic maize fodder; FCE, Feed Conversion Efficiency

Conclusion

It can be concluded that partial replacement of concentrates mixture by hydroponic maize fodder increased Holstein-Friesian crossbred cow's milk yield. Total solids, fat and ash content in milk increased as well with improved feed conversion efficiency in the hydroponic fodder fed cows as compared with control group. However, data on a large sample and long duration is needed to elucidate the effects more evidently which might be future perspective of the present work. The results of this study may be useful to dairy farmers, who seek to partially replace the concentrate mixture with their lactating animals by hydroponic maize fodder. Especially to mitigate the unavailability of the land or seasonal fluctuation of the green grass and concentrate feed ingredients.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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