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# Effects of feeding maize hydroponic fodder on growth performance, nitrogen balance, nutrient digestibility, hematology, and blood metabolites of water buffalo calves

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## Abstract

**Background:** A hydroponic feeding system enables more effective utilization of the entire plant than typical grazing, which only consumes the plant's shoot.

**Aim:** This study evaluated the effects of feeding maize hydroponic fodder on growth performance, nitrogen balance, nutrient digestibility, hematology, and blood metabolites of buffalo calves.

**Methods:** Twelve water buffalo calves, weighing an average of 112 $\pm$ 1.18 kg and between 8 and 10 months old, were divided into three treatments, each with four calves. Each group received one of the treatment diets: T1: the basal diet (BD) at 100%; T2: the BD plus hydroponic feed meal (HFM) at 80%: 20%; and T3: the BD plus HFM at 60%: 40%. For 100 days, each animal was fed *ad libitum*; the first ten days were used for nutritional adaptation, and the final ten days were used for collection. In addition to their BD, each animal received 200 g/day of a normal concentrate mixture to meet their maintenance needs. The BD included Green Hay (Lucerne) 80% and Wheat straw 20%. Each animal's daily feed consumption was noted. Calves were weighed biweekly to track growth. Upon completion of the experiment, blood samples were obtained.

**Results:** The amount of dry matter (DM) consumed by ruminants fed diets, including hydroponic fodder, was considerably higher ($p < 0.05$). Similar trends were seen in crude protein (CP), acid detergent fiber, and neutral detergent fiber intake. Ingesting of CP was highest in animals fed T3. Animals fed diets comprising BD 60% + HFM 40% had the highest levels of DM and CP digestibility. Animals fed the T3 diet (BD 60% + HFM 40%) showed the best feed conversion values ($p < 0.05$). Blood metabolites like blood urea nitrogen, creatinine, and glucose showed non-significant variations in all experimental animals. In hematology, a similar trend was seen.

**Conclusion:** Therefore, it can be said that supplementing the diet with more HFM helped growing buffalo calves gain weight, have a lower feed consumption ratio, and digest their food more efficiently.

**Keywords:** Animals, Buffalo calves, Growth, Hydroponic fodder, Maize.

## Introduction

Green fodder is a crucial part of livestock diet and greatly impacts how well they produce and reproduce and how healthy they are. Nevertheless, due to greater urbanization or manufacturing, there is now less pasture area accessible, which makes it challenging to provide the animals with the green feed they require. Investigating all available feed supplies for animal production is necessary because a lack of high-quality green fodder harms livestock health (Safwat, 2014).

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The hydroponic fodder sector has received significant global attention recently, which has rekindled interest among academics and cattle owners alike (Naik, 2014; Prakash, 2017).

Hydroponics is a technique for growing plants without soil using only a small amount of water. It is simpler to gather and hence requires less labor. Greek word hydroponics translates to "water working" (where "hydro" stands for "water" and "Ponic" for "working"). One kilogram of grain can be placed in a hydroponic system to produce 4–8 kg of fresh green sprouts without regard to the weather or the time of year. Within 8–9 days, the roots of hydroponic fodder can develop into a mat and reach a height of 25–28 cm (Diver, 2006; Rajkumar *et al*., 2018). Growing plants in water or a nutrient-rich solution without using soil, hydroponics fodder, sprouted grains, or sprouted fodder produced (Dung *et al*., 2010). According to Haddad *et al*. (2009), and Naik and Singh (2013), using hydroponics technology, up to 1,000 kg of maize feed may be generated daily from a 45–50 m$^2$ space, which is equivalent to 25 acres of arable land used to create the same amount of feed using traditional methods.

Beta-carotene, Vitamin A, E, and C, and Lysine, an important amino acid, are all abundant in hydroponically grown feed. According to Rajkumar *et al*. (2018), giving calves hydroponically grown maize fodder increases their dry matter (DM) intake, weight gain, and cost per kilogram of body weight gained. The growth performance and nutritional digestibility of goats fed hydroponically grown maize and barley fodder are improved (Kide *et al*., 2015; Dadhich *et al*., 2019).

Using hydroponic technology, several feed crops can be cultivated in a hygienic setting free of pesticides, including insecticides, herbicides, fungicides, and synthetic growth promoters (Al-Hashmi, 2008; Al-Karaki and Al-Momani, 2011). Its high chlorophyll content boosts animal efficiency and eliminates antinutritional elements such as phytate (Naik *et al*., 2015; Girma and Gebremariam, 2018). Hydroponic fodder benefits animals' health, mortality, conception rate, and abortion and is devoid of antibiotics, hormones, pesticides, and herbicides (Naik, 2014). The hydroponic fodder enhances the DM intake and lowers the cost per kg of body weight gain (Rajkumar *et al*., 2018). It also reduces heat stress and increases birth rates (Farghaly *et al*., 2019).

According to Rani *et al*. (2019) and Jediya *et al*. (2021), found that hydroponically grown maize fodder may substitute up to 75% of the crude protein (CP) in a concentrated mixture and has a positive impact on the calves' growth and nutritional intake. Additionally, Sharma *et al*. (2023) demonstrated that hydroponics fodder might replace 75% of the CP in a concentrated mixture and positively impact Gir cows' ability to utilize nutrients. Also, according to Arif *et al*. (2023), feeding animals with hydroponic fodder could increase growth and productivity while bridging a feed supply gap in dry and semi-arid regions where most feeds are imported and resources for both land and water are limited.

There are few reports on the nutritional value of hydroponic feed meal (HFM) for buffalo calves (Naik *et al*., 2015). Therefore, a trial regarding the evaluation of the growth performance of buffalo calves fed HFM was conducted.

## Materials and Methods

***Experimental site***

The experiment site was Military Dairy Farm, Bisal Road, Attock, Pakistan.

***Experimental animals and feeding***

The experiment was carried out to examine the effect of HFM on the performance of growing buffalo calves. Twelve water buffalo calves were randomly clustered into three groups. Calves were 8–10 months old and their live body weight was 112 ± 1.18. Each group had four calves that were offered one of the treatment diets, *viz*. T1—basal diet (BD) 100%; T2—BD + HFM 80%:20% and T3—BD + HFM 60%:40% (Table 1). The DM content of HFM was 18.19% of the CP, neutral detergent fiber (NDF), and acid detergent fiber (ADF) content was 14.57%, 32.56%, and 18.33% on DM basis, respectively. BD had 15.80% CP and 53.88% (total digestible nutrient, TDN), according to the standard of Kearl (1982).

Each animal was fed individually and diets were offered on *ad-libitum* basis for 100 days. The first ten days served as an adaptation period, while a collection period of 10 days was observed at the end of the experiment. In addition to the BD, a standard feed mixture was individually fed at the rate of 200 g/day to cover the maintenance requirements of animals (Table 2). The BD included Green Hay (Lucerne) 80% and Wheat straw 20% (Table 1). Feed intake was recorded daily for each animal, while calves were weighed fortnightly to determine weight gain. Feed and fecal samples collected during the collection period were analyzed to check DM and CP concentration using protocols AOAC (1990) reported. Van Soest *et al*. (1991) described methods that were used to determine NDF and ADF contents.

***Hydroponic unit (low cost)***

HFM was produced by a unit measuring 8, 10, and 12 ft in length, height, and width. The unit had about 0.4% slope to remove excess water. Iron-made stands having six shelves (1 ft distance each) were used to prepare racks. Racks had a capacity of 72 hydroponic trays. Each tray was sized 3.2 × 1.5 × 0.25 ft and was made of iron laminated sheets. Each tray was irrigated with tap water (without any nutrient additive) with the help of a semi-automatic spray system. The tray had holes at the base for the drainage of water. The humidity and temperature of the production house were maintained near 68%–78% and 22°C–30°C (Table 3). The seeds

**Table 1.** Nutritional makeup of experimental diets.

| Items | T1 | T2 | T3 |
|---|---|---|---|
| Ingredients % | | | |
| Green Hay (Lucerne) | 80 | 64 | 48 |
| Wheat straw | 20 | 16 | 12 |
| HFM | 0 | 20 | 40 |
| Nutrient % | | | |
| DM | 88.2 | 74.2 | 60.2 |
| CP | 15.8 | 15.6 | 15.3 |
| NDF | 52.2 | 48.3 | 44.3 |
| ADF | 39.4 | 35.2 | 31 |

T1, T2, and T3 stand for "control (BD)," "BD 80% plus 20% hydroponically grown maize," and "BD 60% plus 40%," respectively. Dry matter, crude protein, neutral detergent fiber, and acid detergent fiber are each abbreviated as DM, CP, NDF, and ADF, respectively. HFM stand for hydroponic maize fodder.

**Table 2.** Composition of standard feed mixture.

| Ingredients | % |
|---|---|
| Corn/Maize | 30 |
| Sunflower cake | 4 |
| Canola meal | 7 |
| Rice polish | 19 |
| Rapeseed meal | 10 |
| Wheat bran | 20 |
| Salt | 1 |
| Mineral mixture | 1 |
| Cane molasses | 8 |
| Total | 100 |
| TDN | 68 |
| CP | 14 |

of maize (*Zea mays* L.) were acquired from Punjab Seed Corporation. After soaking the seed in tap water for 12 hours, the seed was transferred to gunny bags for germination. Sprouted seeds were transferred to the hydroponic tray at the 800 g/tray rate after 24–36 hours of germination. Fodder was harvested after eight days and about 12 kg HFM was produced by each kg of dry seed. Before feeding the animals, information regarding the quality and biomass of HFM was collected daily.

***Nutrient digestibility***

Nutrient digestibility was determined by the total collection method.

At the end of the trial (day 101), blood samples were gathered by puncturing the jugular vein. Blood was collected in vacutainer EDTA and heparin tubes. The hemoglobin content, differential leukocytic count, and platelets were measured in the EDTA blood samples (VetScan HM5, Abaxis, California, USA). An automated biochemical veterinary analyzer (VetScan VS2, Abaxis, California, USA) was used to assess the serum values of blood urea nitrogen, glucose, and creatinine in the heparin blood samples.

**Table 3.** The cultivation of hydroponic fodder is conducted under various conditions.

| Conditions | Values |
|---|---|
| Temperature | 25°C–30°C |
| Humidity | 68%–78% |
| Time for the sprinklers | 3 seconds/30 minutes |
| Density of grains | 2.80 kg/$m^2$ |
| Light duration | 24 hours |

***Statistical analysis***

Data were analyzed by the general linear model procedure of RCBD Steel *et al*. (1997). Using one-way ANOVA in SPSS (SPSS Inc., Chicago, IL), the Tukey test was used to differentiate between the means of different treatment groups.

***Ethical approval***

Authors adhere that procedures imposed on the animals were carried out according to the Directive 2010/63/EU of the European Parliament and of the Council of 22 September 2010 on protecting animals used for scientific purposes. Authors also adhere to the EU regulations on feed legislation, such as regulation EC No 767/2009 of the European Parliament Council of July 13, 2009. The Authors' Institution Ethics Committee approved the study at the Department of Animal Sciences, College of Agriculture, University of Sargodha, Pakistan, for animal studies, and care was taken to minimize the number of animals used.

## Results

The DM content of HFM was 18.19%. The CP, NDF, and ADF content was 14.57%, 32.56% and 18.33% on a DM basis, respectively. The DM intake was greater

**Table 4.** Nutritional intake by buffalo calves as a result of feeding them hydroponically grown corn fodder.

| Nutrient intake, g/d | T1 | T2 | T3 | SEM |
|---|---|---|---|---|
| DM | 2,998[c] | 3,153[b] | 3,277[a] | 23.9 |
| CP | 474[b] | 492[a] | 501[a] | 3.8 |
| NDF | 1,565[a] | 1,523[b] | 1,452[c] | 11.6 |
| ADF | 1,181[a] | 1,110[b] | 1,016[c] | 8.3 |

[a,b,c]Means with various superscripts in a row differ considerably ($p < 0.05$).
T1, T2, and T3 stand for "control (BD)," "BD 80% plus 20% hydroponically grown maize," and "BD 60% plus 40%," respectively. Standard error mean is referred to as SEM. Dry matter, crude protein, neutral detergent fiber, and acid detergent fiber are each abbreviated as DM, CP, NDF, and ADF, respectively.

**Table 5.** Hydroponic maize feeding effects on the growth performance of buffalo calves.

| Items | T1 | T2 | T3 | SEM |
|---|---|---|---|---|
| IW (kg) | 112.0 | 112.3 | 112.0 | 1.79 |
| FW (kg) | 156.3[a] | 165.3[b] | 165.8[b] | 1.31 |
| WG (g/d) | 490[a] | 588[b] | 595[b] | 8.54 |
| FCR | 6.33[a] | 5.40[b] | 5.38[b] | 0.10 |

[a,b]Means with various superscripts in a row differ considerably ($p < 0.05$).

T1, T2, and T3 stand for "control (BD)," "BD 80% plus 20% hydroponically grown maize," and "BD 60% plus 40%," respectively. Standard error mean is referred to as SEM. The terms initial weight, final weight, weight gain, and feed consumption ratio are abbreviated as IW, FW, WG, and FCR.

**Table 6.** Feeding effects of maize hydroponic fodder on nitrogen balance in buffalo calves.

| Items, g/d | T1 | T2 | T3 | SEM |
|---|---|---|---|---|
| Nitrogen intake, NI | 75.5[a] | 78.8[b] | 80.0[b] | 0.61 |
| Fecal nitrogen, FN | 34.7 | 34.5 | 33.7 | 0.64 |
| Nitrogen in urine, NU | 17.4 | 17.5 | 17.7 | 0.70 |
| Nitrogen balance, NB | 23.4[a] | 26.8[b] | 28.6[b] | 0.91 |

Non-significant ($p > 0.05$) and significant ($p$ 0.05) are denoted by NS and *, respectively.

[a,b]Means with various superscripts in a row differ considerably ($p < 0.05$).

T1, T2, and T3 stand for "control (BD)," "BD 80% plus 20% hydroponically grown maize," and "BD 60% plus 40%," respectively. Standard error mean is referred to as SEM.

($p < 0.05$) in group-fed hydroponic fodder-containing diets. NDF, ADF and CP intake were also higher ($p < 0.05$) in HFM fed group. CP intake was greatest in animals fed T2 and T3 diets, i.e., treatment diet containing HFM (Table 4). The nutrient digestibility of buffalo calves fed a diet containing HFM was greater ($p < 0.05$) than that of calves fed a control diet. Weight gains were 490 (T1), 588 (T2), and 595 (T3) g/d (Table 5). Feed consumption ratio (FCR) in buffalo calves fed different diets was 6.33 (T1), 5.40 (T2), and 5.38 (T3); Table 5). The best FCR values ($p < 0.05$) were recorded in calves fed the T3 diet (BD 60% + HFM 40%). The animals fed a diet containing HFM evidenced an improved nitrogen balance than the control diet (Table 6). Nutrient digestibility was highest in animals fed a BD of 60% + HFM 40% (Table 7). The average NDF digestibility observed in the present study was 53.0%, 60.3%, and 60.8% in T1, T2, and T3, respectively. ADF digestibility was better in ($p < 0.05$) calves fed HFM than observed in the control diet (Table 7). Better nitrogen balance was observed in animals fed HFM-containing diets ($p < 0.05$). In all experimental animals, no statistical differences ($p > 0.05$) were observed regarding hematology and blood metabolites ($p > 0.05$; Table 8).

## Discussion

The DM% of HFM was 18.19%, which agrees with the results reported by Naik *et al*. (2014), who found that calves fed hydroponically grown maize fodder saw a large rise in DCP values and a non-significant increase in TDN values. Additionally, Verma *et al*. (2015)

**Table 7.** The effects of feeding hydroponically grown maize on the nutrient digestibility of buffalo calves.

| Digestibility, % | T1 | T2 | T3 | SEM |
|---|---|---|---|---|
| Dry matter, DM | 55.0[a] | 67.5[b] | 68.5[b] | 0.37 |
| Crude protein, CP | 64.5[a] | 72.0[b] | 72.8[b] | 0.34 |
| Neutral detergent fiber, NDF | 53.0[a] | 60.3[b] | 60.8[b] | 0.38 |
| Acid detergent fiber, ADF | 45.0[b] | 50.3[a] | 50.5[a] | 0.34 |

[a,b]Means with various superscripts in a row differ considerably ($p < 0.05$).

T1, T2, and T3 stand for "control (BD)," "BD 80% plus 20% hydroponically grown maize," and "BD 60% plus 40%," respectively. Standard error mean is referred to as SEM.

**Table 8.** Feeding effects of maize hydroponic fodder on hematology and blood metabolites in buffalo calves .

| Items | T1 | T2 | T3 | SEM |
|---|---|---|---|---|
| Hemoglobin (g/dl) | 11.3 | 10.3 | 10.0 | 0.49 |
| Neutrophils (%) | 25.5 | 26.0 | 24.5 | 1.25 |
| Lymphocytes (%) | 63.0 | 62.5 | 65.3 | 0.93 |
| Monocytes (%) | 3.3 | 3.0 | 2.8 | 0.58 |
| Eosinophil (%) | 3.9 | 4.2 | 3.4 | 0.91 |
| Basophils (%) | 0.5 | 0.5 | 0.3 | 0.32 |
| Platelets (k/µl) | 548 | 559 | 551 | 9.28 |
| Blood urea nitrogen (mg/dl) | 33.5 | 32.5 | 33.0 | 0.37 |
| Glucose (mg/dl) | 64.0 | 66.3 | 65.5 | 0.69 |
| Creatinine (mg/dl) | 1.4 | 1.5 | 1.3 | 0.09 |

Non-significant ($p > 0.05$) and significant ($p$ 0.05) are denoted by NS and *, respectively.

T1, T2, and T3 stand for "control (BD)," "BD 80% plus 20% hydroponically grown maize," and "BD 60% plus 40%," respectively. Standard error mean is referred to as SEM.

found that Haryana calves fed hydroponically grown barley fodder experienced a significant ($p < 0.05$) increase in DCP% and a highly significant ($p < 0.01$) TDN%. Further, Dadhich *et al*. (2019) observed that hydroponic maize fodder had a significant ($p < 0.01$) impact on the percentages of DCP% and TDN% in Rathi calves. Also, Naik *et al*. (2014) found that partial replacing hydroponic maize fodder with maize grain of concentrate mixture enhanced dry matter intake per 100 kg body weight. Farghaly *et al*. (2019) indicated that hydroponic barley fed to sheep improved dry matter intake. Additionally, Dadhich *et al*. (2019) observed that hydroponic maize fodder had a significant ($p < 0.01$) impact on the percentages of DCP% and TDN% in Rathi calves. Helal (2015) noted that the TDN g $kg^{-1}$ BW and DCP% enhanced significantly ($p < 0.05$) using sprouted barley grain in goats.

On the other hand, Fazaeli *et al*. (2011) demonstrated that adding hydroponic fodder had no impact on DM intake. Results from the current study's consumption were greater than those Muhammad *et al*. (2013) reported for breastfeeding cattle given HFM (2.05). Higher DMI may be connected to higher CP T2 and T3 consumption compared to the control group. The findings of Almaz *et al*. (2012) also support the results of nutritional intake. The average digestibility of DM, CP, NDF, and ADF was significantly lower in the control group than in the other treatment groups. Better nutrient digestibility may be caused by bioactive catalysts found in HFM, which enhance nutrient digestion and absorption, according to Fayed (2011). Maximum DMD was also shown in animals fed sprouted grain-containing diets, according to Gashu *et al*. (2014). Low nutrient digestibility in the Control food may have resulted in less effective animal BD utilization (Sneath and McIntosh, 2003). Muhammad et al. (2013), who fed HFM to lactating cows, further validated these findings. Fayed (2011) stated that the results showed improved FCR in the T2 and T3 therapy groups. According to Muhammad *et al*. (2013), they contributed to the improved growth performance of ruminants given hydroponic fodder. This increased ruminal microbe activity, which eventually improved animal performance. Improvement in BWG in the trial's HFM-supplemented groups ranged from 588 to 595 g/day. Because HFM provides improved nutrition delivery and digestion, the treatment groups supplemented with a higher proportion of HFM had better FCR.

Similarly, our results also agree with those of Kide *et al*. (2015), who observed better weight gains in goats fed hydroponic fodder. Kide *et al*. (2015) indicated a significant increase in the daily weight gain of goats fed with hydroponic maize fodder at 20%, 40%, and mixed maize + barley hydroponic fodder (20%:20%). Ata (2016) showed a significant ($p < 0.05$) effect on the average daily gain of Awassi lamb fed with hydroponics maize fodder as compared to the control treatment. According to Rajkumar *et al*. (2018) reported a significant ($p < 0.01$) effect on average daily gain in a group of crossbreed calves supplemented with 7% of CP through hydroponics maize fodder. Our results do not follow those of Ayenew *et al*. (2012), who indicated that the low weight gain in the control group could be because of lower nutrient intake and poor palatability of BD (Ayenew *et al*., 2012). Not any single animal did express abnormal behavior or illness signs throughout the experiment and Blood metabolites and hematology remained unaltered ($p > 0.05$) across all treatment groups. According to Jediya *et al*. (2021), hydroponic maize fodder may substitute up to 75% of the CP in a concentrate combination, positively impacting the calves' growth performance and nutrient intake.

## Conclusion

In conclusion, animal diets containing HFM showed better FCR than those fed a control diet. Hydroponic fodder may improve animal performance in areas where conventional fodder production system are not feasible.

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***Conflict of interest***

The authors declare that there is no conflict of interest.

***Author contributions***

MA and AR, concept and design the proposal, QK, SH, NA and ME, collect the required data, MK, MT and AS analyzed the collected data. MA wrote the manuscript draft. All authors revised and approved the final manuscript.

***Availability of data***

The study's datasets are available upon reasonable request from the corresponding author.

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