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Original article

Feeding barley and corn hydroponic based rations improved digestibility and performance in Beetal goats

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ABSTRACT

The current trial aimed to determine the impacts of fed goats with hydroponic fodder-based maize or barley rations on nutrient digestibility, growth and efficiency of consumed feed, and some blood constituents. Twenty-four post-weaned growing Beetal male kids (3 months of age with an initial body weight of 12.4 ± 0.03 kg) were randomly allocated into six equal groups (n = 4, each one). Each group was offered one of the following dietary treatments: T_0, fed 100 % basal diet (BD; containing 80 % Lucerne hay and 20 % wheat straw); $T_{1,}$ fed 80 % BD + 20 % Hydroponic fodder Maize (HFM); T_2, fed 80 % BD + 20 % Hydroponic fodder Barley (HFB); T_3, fed 60 % BD + 40 % HFM; T_4, 60 % BD + 40 % HFB; T_5, 60 % BD + 20 % HFM + 20 % HFB for 90 days feeding trial period. Animals were kept under the same hygienic, rearing and environmental conditions. The dry matter and crude protein intake results revealed significant increases in all hydroponic-based rations, with T_4 and T_5 reporting higher values when compared to the control and other treated groups. Whereas, the T_1 group had the maximum fiber intake compared to the other treated and non-treated groups. At the same trend, the T_5 group recorded the highest final weight, weight gain, and total weight gain values and the lowest feed conversion ratio compared to the other experimental groups. In addition, goats fed a diet containing two types of hydroponic-based fodder (T_5) exhibited a highly significant improvement in all nutrient digestibility and total nitrogen balance compared with other experimental groups. Furthermore, feeding goats hydroponic maize and barley-based rations had no significant influence on blood biochemical and hematological parameters, except that the lymphocyte percentage increased considerably in T_2 and T_3 groups compared to other experimental groups. In conclusion, in arid and semi-arid regions where most feeds are imported and resources of both land and water are scarce, feeding animal diets incorporating hydroponic fodder might improve growth and production while filling a feed supply gap.

1. Introduction

In arid and semi-arid areas of Asia, sheep and goats are essential for development since they can convert crop wastes, forages, and household sewage into meat, wool, fiber, and milk (Arif et al., 2020). Specifically, livestock production plays a vital role in the income of the rural population in Pakistan, which owns 76.1 million head of goats. Besides, Pakistan produces 9.40 million tons of milk and 7.32 million tons of mutton from goats (Lund and

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Ahmad 2021). Furthermore, nutrition is the most important limiting factor in animal production in these regions, which are characterized by reductions in rangeland productivity owing to increased drought frequency, farmer overstocking, and climatic fluctuation and change (Seidavi et al., 2021). Therefore, animal feeding depends largely on imported concentrate feeds due to the shortage in local feed supply despite being costly and not readily available (Alqaisi et al., 2014). Besides, they are traditionally dependent on staple food crops such as maize, which creates competition in requirements between livestock and humans. Additionally, the lack of feed supply in Pakistan might be caused by urbanization and a limited land area available for fodder production (Seidavi et al., 2021).

Thus, several efforts in terms of improving land productivity, utilization of crop residue and agricultural by-products, ensilaging fodders, and introducing new fodder crops have been made to reduce the gap in feed supply (Seidavi et al., 2021). The traditional fodders production system encounters a low land holding capacity per farm, prerequisite intensive work for development (sowing, weeding, and collecting), long growing period, improper manure and fertilizer use and occasional suitable rainfall level availability (Naik et al., 2016). Conversely, a hydroponic fodder production system that does not require land, and which reduce dependency on rainfall, might be an option to reduce the gap in feed supply in arid land agriculture (Fazaeli et al., 2017). Besides, hydroponic fodder production requires a shorter growing period and less land, which makes it a suitable system especially in cities where space for growing fodder is limited (Sneath and McIntosh 2003). Furthermore, the hydroponic system enabled the production of fresh fodders from major feed grains such as barley, wheat, oat, and rye grains (Muela et al., 2005). It was recommended for goat feeding under arid and semi-arid production environments (Buston et al., 2002). Also, the hydroponic technique allows fodder production in a contaminate-free environment such as fungicides, pesticides and insecticides (Al-Karaki and Al-Hashimi 2012). For instance, Peer and Leeson (1985) found 5.7 kg increase in fodder production after seven days of sprouting. Moreover, Gebremedhin (2015) found that sprouting one kg of barley produced 7 to 10 kg of green fodder in one week. Besides, hydrolysis increases the concentration of amino acids, soluble sugars and fatty acids (Chavan et al., 1989).

Additionally, grain sprouting enhances the activity of the entire enzyme, changes the amino acids profile, and increases protein, sugars, mineral and vitamin contents; however, it reduces dry matter and starch contents (Lorenz and D'Appolonia 1980). Activation of enzymes takes place due to hydrolysis and these enzymes induce the conversion of simple components which causes an increase in the quality of amino acids and vitamins. On the other hand, hydroponic fodder production is a unique technique for efficient water use around the year (Tudor et al., 2003). Fiber content varied between 3.75 % in un-sprouted seeds and 6 % in sprouted seeds after the five-day sprouting period (Chung et al., 1989). Also, Dry matter (DM) digestibility declined when the sprouting period increased up to 7 to 8 days, while the maximum DM digestibility was recorded on the four days after the sprouting period (Peer and Leeson 1985, Peer and Leeson 1985). The variance in hydroponic fodders' nutritional characteristics was found to correlate with the grain species. For instance, Mansbridge and Gooch (1985) found that in vitro digestibility of barley sprouts varied between 72 and 74 % in 8 days sprouting period. Similarly, in vivo digestibility was found to be 73–76 % from the 6–8 days sprouting period (Cuddeford 1989). Subsequently, research has indicated that hydroponic fodder is a rich source of nutrients and improves the performance of livestock (Devendar et al., 2020). Recently, Brown et al., (2018) found that feeding maize hydroponic grains to ruminants and monogastric animals showed an improvement in performance and nutrient digestibility of weaned pigs. However, there is a scarcity of data on the usage of hydroponically barley and maize fodder in post-weaned growing Beetal male kids. Therefore, the main objective of this trial was to evaluate the diet digestibility, growth and performance, nitrogen balance and some blood constituents of goats fed on different diets containing hydroponic barley and maize fodders.

2. Materials and methods

The study was conducted at the research station located at the College of Agriculture, University of Sargodha, Pakistan.

2.1. Description of the hydroponic production unit

Green fodder maize and barley were produced at a hydroponic fodder production unit of 12 × 10 × 8.0 ft length, height and width, respectively, with 0.4 % slope for adequate removal of excess water. Iron stands with six shelves (1 ft^2 distance each) were applied to construct the racks. Each rack is made up of 72 iron laminated sheets of hydroponic trays (3.2 ft length × 1.5 ft width × 0.25 ft height) that are supported by semi-automated sprayer irrigation water. The trays have many holes in the bottom to allow excess water from irrigation to drain. Irrigation depends on tap water and is devoid of any external additions. Table 1 shows the conditions adopted during the cultivation of hydroponic fodder. Micro-sprinkler irrigation was employed to maintain a constant temperature and relative humidity inside the green house within a suitable range of 22–30 °C and 68–78 %, respectively. Barley (*Hordium vulgari.* L) and Maize (*Zea mays* L.) seed were purchased from Punjab Seed Corporation. All seeds were immersed in water for approximately at least 12 h prior to cultivation. After 24–36 hr. of germination inside a gunny bag, the sprouted seeds were dispersed on cultivation trays at a rate of 800 and 900 g/tray for maize and barley, respectively. After eight days, 12 and 13 kg of hydroponic maize and barley fodder were collected per kilogram of growing seeds, respectively. Before administering the experimental animals, the obtained biomass and quality of hydroponic fodder were assessed on a regular basis. Table 2 shows the chemical composition of the control and harvested hydroponic maize and barley fodders.

2.2. Animals and diets

At the age of 3 months, twenty-four post-weaned growing male goat kids of the Beetal breed were equally allocated into six groups of four animals each. Each group was offered one of the following diets; Basal diet (BD) 100 % (T_0); BD + Hydroponic fodder Maize (HMF) 80 %:20 % (T_1); BD + Hydroponic fodder Barley (HFB) 80 %;20 % (T_2); BD + HMF 60 %:40 % (T_3); BD + HFB 60 %:40 % (T_4); BD + HFM + HFB 60 %:20 %:20 % (T_5); for 90 days including adaptation period of 15 days. The basal diet was composed of 80 % green hay (Lucerne) and 20 % of wheat straw. In addition to treatment diets, each group was supplemented with 100 g of creep feed mixture per animal per day. The nutrient composition of the basal diet is illustrated in Table 2. The creep feed mixture is illustrated in Table 3.

Table 1
Conditions adopted during cultivation of hydroponic fodder.

Parameters/Conditions	Values
Grain density (Kg/m^2)	2.80
Sprinklers time	3 *sec* / 30 min
Humidity (%)	68–78
Light duration (h)	24
Temperature (°C)	22 – 30

Table 2
Chemical composition of control and hydroponic fodders.

Items (%)	Control	HMF	HBF
Dry Matter	88.20	18.19	13.59
Crude Protein	15.80	14.57	13.89
Neutral Detergent Fiber	52.20	32.56	33.63
Acid Detergent Fiber	39.40	18.33	14.01

HMF stands for Hydroponic Maize Fodder, HBF, Hydroponic Barley Fodder.

Feed was offered twice a day in the morning and in the afternoon, and fresh clean water was offered *ad libitum* during the experimental period. The animal body weight was recorded fortnightly. The daily consumed feed was documented and representative feed samples were pooled for the evaluation of DM and CP, according to A.O.A.C (1990) procedure. Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) were determined according to Van Soest et al., (1991) protocol. Feed intake from each feed type was recorded daily from each individual animal, and the weight gain and FCR was determined fortnightly.

2.3. Nutrient digestibility

Digestibility of nutrients was carried out during the feeding trial last week via applying a total collection procedure. Throughout the complete collection process, urine was gathered from urine collection bowls via the tiny hole at the bottom of the collection tray. These bowls contained a known volume of acidified solution with 50 % H_2SO_4 to prevent N losses during collecting (Mahr un et al., 2004). Urine and feces samples have been gathered, weighed, and kept at −20 °C for further examination. Following the collection of all required samples, feces and urine from each individual pen were thawed, composited and homogenized. Prior to grinding the samples through a 1-mm screen, they were dried at 55 °C. Fecal and feed samples were analyzed for estimating NDF and ADF values following Van Soest et al., (1991) procedure, while CP and DM were measured as ascribed by A.O.A.C (1990) protocol. At the end of the feeding trial period, blood specimens (10 mL per animal) were obtained from jugular vein punctures, then transferred into anticoagulant tubes (containing 81 µL of 15 % EDTA) and examined for all blood biochemistry measures at the local pathological laboratory. All blood biochemical values were determined using a colorimetric technique employing commercial kits (Biomerieux, Co., Egypt) spectrophotometrically as directed by the manufacturer instructions.

2.4. Statistical analysis

The collected data were statistically analyzed following Randomized Complete Block Design following the methods ascribed by Bender et al., (2020). The variance between treatments was determined employing Tukey's range test using Statistical Analysis System (SAS) V 8.1.

Table 3
Ingredient's content of creep feed mixture diet.

Ingredients	%
Maize	30
Rice polishing	19
Wheat bran	20
Canola meal	7
Rapeseed meal	10
Sunflower cake	4
Molasses	8
Mineral mixture	1
Salt	1
Total	100
Crude Protein	14
Total Digestible Nutrients	68

3. Results

Table 4 shows the results of the effect of feeding maize and barley hydroponic fodders on nutrient intake in post-weaned kids. DM intake was significantly higher ($P < 0.05$) in goats-fed diets containing hydroponic fodder. A similar trend was observed for CP, NDF and ADF intakes. The highest CP intake was observed in animals fed T_4 treatment diet containing BD 60 % + HFB 40 %. Goats fed on feed containing hydroponic fodder improved nutrient digestibility ($P < 0.05$) as compared to the control diet. Nutrient digestibility was highest in goats fed a diet containing 60 % BD + 20 % HFM, HFB 20 % (T_5). Daily live weight gain was 48.5, 64.2, 67.0, 68.2, 72.0 and 76.0 g/d in goats fed T_0, T_1, T_2, T_3, T_4 and T_5 diets, respectively (Table 4). The FCR in goats fed T_0, T_1, T_2, T_3, T_4 and T_5 diets was 7.4, 7.1, 6.8, 6.7, 6.4 and 6.1, respectively (Table 4). The lowest feed conversion ratio (FCR) values ($P < 0.05$) were detected in the goat group fed T_5 diet (BD 60 % + HFM 20 %, HFB 20 %).

Animals fed diets containing hydroponic fodder showed an improved nitrogen balance as compared to the control diet (Table 5). Average NDF digestibility coefficient values in the present study were 53.0, 59.5, 59.2, 60.0, 60.2 and 60.7 % in treatment T_0, T_1, T_2, T_3, T_4 and T_5, respectively. Similarly, ADF digestibility was significantly higher ($P < 0.05$) in goats fed hydroponic fodder compared to the control diet. Nitrogen balance was greater in animals fed T_3, T_4 and T_5 diets ($P < 0.05$) compared to animals fed only BD. In all experimental animals, non-significant variances ($P > 0.05$) were detected in blood constituents such as glucose, creatinine, and BUN (Table 6). Similar trends ($P > 0.05$) were illustrated in hematological values (Table 6).

4. Discussion

According to our findings, hydroponic barley and maize sprouts has greater nutrients than their grains form. The same findings were reported by Fazaeli et al., (2017). However, the dry matter (DM) content was lower than that of maize and barley grains, which may be attributed to the higher water intake during seed germination (Fazaeli et al., 2017). Furthermore, the reduction in DM content might explain the rise in crude protein (CP) and other nutrient levels in hydroponic maize and barley. The present findings were shown to be similar to the study results of Farghaly et al., (2019). Moreover, the chemical composition of the hydroponic barley and maize sprouts in our investigation is consistent with prior reports (Reddy et al., 1988, Kide et al., 2015). It has previously been reported that sprouting grains enhanced the activation of hydrolytic enzymes, increased the total protein and lipid levels, and remarkedly increased the concentrations of certain essential amino acids, total carbohydrate content, B vitamins, and reduced the dry matter and starch content (Chavan et al., 1989).

Several factors might influence the yield and quality of hydroponic fodder produced, including the quality of cultivated grains, soaking time, grain species, ambient temperature, irrigation water treatments, cumulative humidity, nutrient additives, mould prevalence, and the depth and density of grain in trays. Thus, pre-soaking is vital because it allows the metabolism of stored substances and the utilization of other resources for development and growth (Morgan and Hunter 1993). In the same context, Chavan et al., (1989) showed that the DM content decreased during germination owing to the higher metabolic activity of sprouting

Table 4
Effect of feeding maize and barley hydroponic fodder on nutrient intake, growth and performance in weaned goat kids.

	T0	T1	T2	T3	T4	T5	[2]SEM	Sig.
Nutrient Intake, g/d								
Dry Matter	358[b]	456[a]	457[a]	458[a]	460[a]	461[a]	2.161	*
Crude Protein	57[d]	71[bc]	72[a]	70[c]	73[a]	72[ab]	0.343	*
Neutral Detergent Fiber	187[c]	220[a]	222[a]	203[b]	206[b]	206[b]	1.049	*
Acid Detergent Fiber	141 [cd]	160[a]	157[b]	142[c]	134[e]	139[d]	0.742	*
Growth and performance								
Initial Weight (Kg)	12.1	12.3	12.4	12.5	12.5	12.6	0.032	NS
Final Weight (Kg)	16.5[e]	18.1[d]	18.4[c]	18.6[c]	18.9[b]	19.4[a]	0.076	*
Weight Gain (g/d)	48.8[e]	64.4[d]	66.7[c]	67.8[c]	72.2[b]	75.5[a]	0.838	*
Total Weight Gain (Kg)	4.4[e]	5.8[d]	6.0[c]	6.1[c]	6.5[b]	6.8[a]	0.071	*
Feed Consumed (Kg)	32.1[b]	41[a]	41.1[a]	41.2[a]	41.4[a]	41.4[a]	0.199	*
Feed Conversion Ratio	7.3 [a]	7.1 [ab]	6.8 [bc]	6.7[c]	6.4 [d]	6.1 [d]	0.1	*

[1]T0, T1, T2, T3, T4 and T5 stand for Control (Basal diet), Basal diet 80 % + maiz hydroponic fodder 20 %, Basal diet 80 % + barley hydroponic fodder 20 %, Basal diet 60 % + maiz hydroponic fodder 40 %, Basal diet 60 % + barley hydroponic fodder 40 %, Basal diet 60 % + maiz hydroponic fodder 20 %, barley hydroponic fodder 20 %, respectively. [2]SEM stand for Standard error mean. NS stand for Non-significant ($P > 0.05$) and * stand for Significant ($P < 0.05$). [a,b,c] Means in a row with different superscripts differ significantly ($p < 0.05$).

Table 5
Effect of feeding maize and barley hydroponic fodder on nitrogen balance and digestibility in weaned goat kids.

	T0	T1	T2	T3	T4	T5	[2]SEM	Sig.
Nitrogen balance g/d								
Nitrogen Intake	9.0[d]	11.3[bc]	11.5[a]	11.2[c]	11.6[a]	11.4[ab]	0.056	*
Fecal Nitrogen	2.5[d]	3.7[b]	3.6[c]	3.7[b]	3.9[a]	3.7[b]	0.026	*
Nitrogen in Urine	5.7[b]	6.1[a]	6.2[a]	5.5[b]	5.7[b]	5.7[b]	0.046	*
Nitrogen Balance	0.8[e]	1.5[d]	1.7 [cd]	2.0[bc]	2.0[ab]	2.0[a]	0.077	*
Digestibility, %								
Dry Matter	55.0[c]	66.5[b]	67.0[b]	67.5[ab]	67.5[ab]	68.5[a]	0.428	*
Crude Protein	64.5[d]	70.0[c]	71.2[b]	71.5[b]	72.0[ab]	72.7[a]	0.329	*
Neutral Detergent Fiber	53.0[c]	59.5[b]	59.2[b]	60.0[ab]	60.2[ab]	60.7[a]	0.39	*
Acid Detergent Fiber	45.0[b]	49.7[a]	49.5[a]	50.0[a]	50.2[a]	50.5[a]	0.368	*

[1]T0, T1, T2, T3, T4 and T5 stand for Control (Basal diet), Basal diet 80 % + maiz hydroponic fodder 20 %, Basal diet 80 % + barley hydroponic fodder 20 %, Basal diet 60 % + maiz hydroponic fodder 40 %, Basal diet 60 % + barley hydroponic fodder 40 %, Basal diet 60 % + maiz hydroponic fodder 20 %, barley hydroponic fodder 20 %, respectively. [2]SEM stand for Standard error mean. NS stand for Non-significant ($P > 0.05$) and * stand for Significant ($P < 0.05$). [a,b,c] Means in a row with different superscripts differ significantly ($p < 0.05$).

Table 6
Effect of feeding maize and barley hydroponic fodder on blood metabolites and blood hematology in weaned goat kids.

Items (mg/dL)	T0	T1	T2	T3	T4	T5	[2]SEM	Sig.
Blood Urea Nitrogen								
Blood Glucose	93	95.2	94.5	95.5	95.5	95	0.868	NS
Creatinine	1.5	1.6	1.5	1.5	1.5	1.6	0.397	NS
Hemoglobin (g/dL)	11.2	11.2	11	11.5	11	11	0.450	NS
Neutrophils (%)	37.5	38	36.5	36.5	38.5	38.2	1.110	NS
Lymphocytes (%)	53.0[ab]	52.5[ab]	55.2[a]	55.2[a]	52.0[b]	53.0[ab]	0.932	*
Monocytes (%)	2.7	2.5	2.2	2	3	2.5	0.534	NS
Eosinophil (%)	4.2	4.5	3.7	4	4	3.7	0.834	NS
Basophils (%)	0.5	0.5	0.25	0.25	0.5	0.5	0.298	NS
Platelets (k/µL)	545.5	556.7	549.2	546.7	559.2	539.2	8.464	NS

[1]T0, T1,T2,T3,T4 and T5 stand for Control (Basal diet), Basal diet 80 % + maize hydroponic fodder 20 %, Basal diet 80 % + barley hydroponic fodder 20 %, Basal diet 60 % + maize hydroponic fodder 40 %, Basal diet 60 % + barley hydroponic fodder 40 %, Basal diet 60 % + maize hydroponic fodder 20 %, barley hydroponic fodder 20 %, respectively. [2]SEM stand for Standard error mean. NS stand for Non-significant ($P > 0.05$) and * stand for Significant ($P < 0.05$). [a,b,c] Means in a row with different superscripts differ significantly ($p < 0.05$).

grains. While, the energy used in this metabolic process is obtained from the partial breakdown and oxidation of starch (Finney 1983).

The DM contents of hydroponic maize and barley fodder in our study were 18.2 % and 13.59 %, respectively, which agrees with some previous reports (Peer and Leeson 1985, Chung et al., 1989). According to Lorenz and D'Appolonia (1980), the elimination of starch levels was responsible for the enhanced nutritional levels in hydroponic fodders. In addition, Chavan et al., (1989) reported that increased proteolytic activity during sprouting was desirable for the nutritional richness of grains because it led to the hydrolysis of prolamins and the liberation of amino acids such as proline and glutamic acid, which are then converted to limiting amino acids such as lysine. They also observed that during sprouting and germination, increased lipolytic activity induced hydrolysis of triacylglycerols to fatty acids and glycerol. The alters that occurs to grains during seeds germination in terms of increased enzyme activity, an increase in total protein, a loss of total DM, a change in amino acid composition, increases in sugars, a decrease in starch (Lorenz and D'Appolonia 1980) may explain the increase in CP, NDF and ADF of maize and barley sprout obtained in our study, compared to their grains. Our findings were consistent with Chung et al., (1989), who discovered that the fiber content doubled from 3.75 % in unsprouted barley seed to 6 % during 5-day sprouts. Thus, the improvement in crude protein content in hydroponic fodder was related to a decrease in dry matter content, mainly carbohydrates, after germination via the respiration process (Peer and Leeson 1985). Moreover, Morgan and Hunter (1993) observed that changes in protein contents occurred rapidly from day 4th corresponding with the extension of the roots.

The higher DM intake in the goat group fed on hydroponic based-diets was due to the high palatability of these feeds, in comparison to the basal diet which had a 20 % of low digestible wheat straw and which could have reduced the diet palatability. Ibrahim et al., (2001) reported that a higher DM intake in treatment groups fed hydroponic fodder might be due to the higher palatability. Animals consumed the entire mat, green shoots as well as roots. Sprout mat was edible and palatable which minimized the leftover significantly compared with the basal diet. The greater nutrient intake reflects the DM intake variations between different hydroponic treatments, which were found to affect feed and nutrient intake.

The DM digestibility in the control group was significantly lower (55 %) than in other groups fed hydroponic feeds. The presence of low digestible wheat straw may partly explain the lower DM and nutrient digestibility in the control group. Similar results were found by Alqaisi et al., (2019) who found an improved DM and nutrient digestibility in sheep when replacing low quality Rhodes grass hay with greater feed quality such as low NDF concentrate. Fayed (2011) and Helal and Hassan (2013) ascribed the improved digestibility to the existence of bioactive catalysts, which boost nutrient absorption and digestion. Also, Melese et al., (2014) observed maximum DM digestibility by the addition of sprouted grains in the diet of ruminants. While, low CP digestibility in the control diet suggests that the CP of the control diet was less efficiently utilized by goats (Sneath and McIntosh 2003), which could be in part explained by the low wheat straw digestibility. A similar result has been reported in goats administered barley or maize hydroponic fodders (Muhammad et al., 2013, Gupta 2014) and in lambs given sprouted barley cultivated on a mixture from tamarix and rice straw (Fayed 2011). Moreover, Terrill et al., (1998) related the increase in nutritive value to the availability of grass juice and enzymes in hydroponic fodders that facilitates digestion.

Our results show 16 % improvement in FCR in both T_4 and T_5 treated groups as compared to the control group which agrees with those found by Fayed (2011). This might be explained by the sprouting' high levels of soluble protein, amino acids, and crude lipid. Better growth performance in ruminants fed hydroponic fodder was due to a better nutrient composition, enzyme and grass juice (Ibrahim et al., 2001, Muhammad et al., 2013). This could have enhanced the microbial activity in the rumen and improved feed utilization efficiency. In this experiment increase in BWG ranged between 49 g/d in the basal diet to 76 g/day in T_5 might be attributed to the higher ability of hydroponic fodder to provide essential nutrients that maximize growth and performance in animals (Muhammad et al., 2013). Low N balance in the BD and the greater N balance in goats fed varying hydroponic diets reflect the levels of N intake. Our findings are consistent with those of Shipard (2005), who demonstrated that enrichment animal diets with sprouted grains might provide diets with higher enzyme levels, resulting in all nutritional elements being highly digestible. None of the animals exhibited any type of irregular behavior or illness signs during the feeding trial period (Farghaly et al., 2019). Furthermore, blood constituents and hematology presented non-significant variance between experimental treatments compared to the basal diet.

5. Conclusion

Feeding maize and barley hydroponic fodder to goats has improved diets digestibility, performance and growth, and FCR compared to the control diet. In arid and semi-arid regions where most feed ingredients are imported, and where land and water resources are in short, hydroponic feed production can be used to reduce the gap in feed supply. Further research is needed to evaluate water and energy consumption and production cost per kg DM in comparison to typical available feeds and agricultural by-products.

Author contributions

All of the authors state that they have contributed equally to this manuscript work.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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