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Nutritional Evaluation of Hydroponic Maize (*Zea mays*) Grain Sprouts as a Newer Green Feed Resource in Lambs

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ABSTRACT

Background: Maize (*Zea mays*) grain sprouts (MGS) can be a potential source of green fodder for ruminants, especially when there is scarcity of land and water. Nutritional value of MGS grown with hydroponic technique was assessed for nutrient utilization, blood biochemical profile, immunity and growth performance in lambs.

Methods: The MGS were produced in a polyhouse and harvested on 10th day and subjected to rumen *in vitro* incubation for gas production (RIVIGP) test to predict metabolisable energy (ME) value. The feeding cum growth trial was conducted for 120 days. Eighteen healthy male lambs of 3-4 months age and comparable body weight were randomly allotted in a complete randomized design to three dietary groups of six in each. The control (T1) group lambs were fed conventional green fodder (CGF), finger millet straw (FMS) and compounded feed mixture (CFM) at 50:10:40 ratio on DM basis, In treatment group two (T2), proportion of CGF and CFM was reduced by 50% and substituted with 45% MGS on DM basis (CGF, FMS, CFM and MGS on total DM basis was in 25:10:20:45 ratio, respectively). In treatment group three (T3), CGF was completely replaced with MGS (80%) and CFM was reduced to 25% of control (CGF, FMS, CFM and MGS on total DM basis was in 0:10:10:80 ratio, respectively).

Result: Results indicated that MGS has ME (MJ/kg DM) of 9.70. The average DM intake (g/d/lamb) in T1, T2 and T3 groups was 764, 581 and 398, respectively. The average daily gain (ADG, g) in T1, T2 and T3 groups was 77.3, 48.5 and 20.9, respectively. There was a significant ($P<0.05$) decrease in DMI and ADG with reduced feed efficiency in lambs fed MGS. However, the per cent digestibility of nutrients, blood biochemical profile, immunity and serum minerals in lambs did not differ among the groups. It is concluded that replacement of compounded feed mixture or conventional green fodder with MGS will limit the dry matter intake, net nutrient availability and negatively affect the growth performance in lambs.

Key words: Blood biochemical profile, Digestibility, Growth, Lambs, Maize grain sprouts.

INTRODUCTION

Major constraint in sustainable livestock production in India is availability of quality feed and fodder throughout the year. Green fodder is a major component of livestock feeding and attempts are being made to bridge the deficit gap. Hydroponic is a technique of growing vegetation without soil (Bakshi *et al.,* 2017). It is a vertical type of farming, requires less land than conventional method of cultivation. In situations of limited arable land, water scarcity, frequent drought like situations, hydroponics is one of the options (Naik *et al*., 2015).

The nutritional content of hydroponic green fodder was increased in terms of crude protein, fibre, ether extract, vitamins and minerals when compared to original seed (Reddy *et al*., 1988; Morsy *et al.,* 2013; Chethan *et al*., 2021). Feeding of sprouted barley and maize to growing kids has shown improvement in digestibility of nutrients, body weight gain and feed conversion efficiency (Muthuramalingam *et al*., 2015; Kide *et al.,* 2015). Dung *et al.* (2010a) reported increase in voluntary dry matter intake (DMI) due to hydroponics fodder as it favours faster passage rate in the gut. In contrast to above results, decrease in DMI on feeding hydroponically grown fodder, loss of DM (7-20%) and decrease in metablizable energy (ME) compared to original seed has been reported (Reddy *et al*., 1988; Pandey and Pathak, 1991; Dung *et al*., 2010b; Fazaeli *et al*., 2011; Naik *et al*., 2014). The positive benefits of maize grain sprouts on growth performance of livestock are not always evident. However, information on utility of maize grain sprouts (MGS) grown hydroponically as a replacement for conventional green fodder or compounded feed mixture is lacking in earlier studies. Hence, this study was conducted to assess the nutritive value of MGS in terms of nutrient utilization and performance in lambs.

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MATERIALS AND METHODS

Hydroponic system and maize grain sprouts production

Fresh maize grain sprouts were produced at experimental livestock unit, ICAR-National Institute of Animal Nutrition and Physiology, Bengaluru, India during October-February 2019-2020 in a polyhouse chamber (30 × 15 × 12 feet as length × width × height, respectively) comprising of stainless steel frame (13 × 6 × 6 feet as length × width × height, respectively) in three tier system and equipped with automatic water sprinkling at three hourly interval for 10 seconds. Yellow maize (*Zea mays.*) grains were purchased from the local market and were screened to remove damaged, infested, broken grains and washed in water. Grains were soaked overnight (12 h) in a bucket containing tap water and after decanting, soaked again for 30 minutes in 4% (v/v) vinegar solution to prevent fungal contamination. Thereafter transferred to clean, porous gunny bags and wrapped tightly for germination under dark condition for 48 h period. Germinated maize grains were then uniformly spread on the plastic trays at the rate of 950 g in each tray (thickness of 1.5 cm, dimension 56 × 42 cm, length × width), the net seed rate density was equivalent to 4.0 kg/m^2. Inside the polyhouse, the germinated grains were allowed for seven days to sprout into green biomass and harvested.

Chemical analysis

The proximate composition of the feeds and fodder were determined as per AOAC (2005), fiber fractions as described by Van Soest *et al.* (1991) and ME (MJ/kg DM) was predicted by using procedures of Menke and Steingass (1988).

Animal housing and feeding trial

A feeding trial of 120 days was conducted using eighteen male lambs of comparable age (Mandya cross breed, 3-4 month) and average body weight of 12±0.2 kg. Lambs were randomly allotted based on body weight in a complete randomized design (CRD) to four dietary groups of six lambs each. All the lambs were dewormed at first day of experiment (Albendazole, 10 mg/kg body weight). All the experimental lambs were housed in well ventilated clean shed with adequate spacing for individual feeding. The experimental protocol was approved by institutional animal ethics committee, ICAR-NIANP.

The experimental diets (Table 1) were control (T1) group; lambs were fed conventional green fodder (CGF), finger millet straw (FMS) and compounded feed mixture (CFM) at 50:10:40 ratio on DM basis. In treatment group two (T2), proportion of CGF and CFM was reduced by 50% and replaced with MGS (comprising 45% of total DM) on DM basis. In treatment group three (T3), CGF was completely replaced and CFM was reduced to 25% of control with MGS (comprising 80% of total DM) on DM basis. The lambs were fed to meet nutrient requirement as per Indian standards (ICAR, 2013).

Weighed quantities of CFM, CGF consisting of green maize and sorghum (*Sorghum bicolor*) fodder at a equal proportion, MGS and finger millet straw were offered to all the experimental animals of respective groups daily and the ort on the next day morning was measured to record the actual intake of feed. All the lambs were provided with *ad libitum* clean drinking water. The harvested mats of MGS was exposed to air ventilation for one day in order to be drier, then weighed and chopped with a knife to small pieces before feeding to the animals. During this feeding trial of 120 days, individual data on daily total DMI and fortnightly body weights were recorded. The daily allowance of CFM, green fodder, MGS and finger millet straw were revised fortnightly taking into consideration the change in body weight of lambs.

Metabolic trial, sample collection and analysis

A metabolism trial of six days duration was conducted after 80 days of feeding trial on five animals of comparable body weight from each group to assess the nutrient utilization. Animals were acclimatized to metabolic cages for a period of 3 days. The feed offered and orts were weighed daily to determine the daily feed DM intake. Faeces and urine were collected quantitatively from the animals after 24 h of feeding daily and preserved. The representative samples of the diets offered, ort, faeces (1/10th) and urine (1/20th) voided were taken and analyzed. Body weight of the experimental animals was recorded before and after the metabolic trial.

For mineral balance studies approximately 2 g of dried feed and faecal sample was taken to estimate total ash as per AOAC (2005). Pooled urine sample (10 ml) was taken, oven dried and ash was determined. Mineral extract

Table 1: Dietary treatments and ingredient composition of diets (DM basis, g/kg).

Feed resource	Diet 1 (T1)	Diet 2 (T2)	Diet 3 (T3)
Cultivated green fodder (CGF)	500	250	-
Finger millet straw (FMS)	100	100	100
Compounded feed mixture (CFM)	400	200	100
Maize grain sprout (MGS)	-	450	800
Total diet DM	1000	1000	1000
CP (Calculated, g kg^{-1})	111	115	116
TDN (calculated, g kg^{-1})	588	589	585

DM was offered at 4.2% of body weight (ICAR 2013), 100 g ADG target.

Each animal was individually supplemented with 10 g mineral mixture, daily.

Cultivated green fodder: Maize green and sorghum green fodder in equal proportion.

prepared was used for estimation of minerals *viz*., calcium (Ca), magnesium (Mg), copper (Cu) and zinc (Zn), using inductively coupled plasma optical emission spectrometer (ICP-OES) (Mode: Perkin Elmer Optima 8000) with standard operating conditions. Phosphorus was estimated from the mineral extract by molybdovanadate colorimetric method as per AOAC (1975) method.

Blood biochemical, immune status and serum mineral status

During the last week of feeding trial, blood samples were collected from all lambs of three dietary groups and centrifuged at 1500 rpm for 10 minute and serum was separated and preserved at -20°C. The VETSCAN chemistry analyzer (Abaxis Inc., Union City, California, USA) was used to analyze the blood metabolites. The commercially available single use large animal profile rotors (Abaxis Inc., Union City, California, USA) were used in the analyzer to quantify the total protein (TP), albumin, globulin, blood urea nitrogen (BUN), alkaline phosphatase (ALP), alanine amino transferase (AST), gamma glutamyl transferase (GGT) and creatinine kinase (CK). Superoxide dismutase (SOD) enzyme was estimated spectrophotometrically as per method described in Stefan and Gudrun (1974) to assess the antioxidant status in serum samples. Minerals in the serum (Ca, Mg, Cu and Zn) were estimated by using ICP-OES with standard operating conditions. Serum phosphorous was estimated by the method of Fiske and Subbarow (1925).

After 100 days of experimental feeding, all the lambs from each dietary group were antigenically challenged with subcutaneous injection of commercial *pestedes petits ruminants* (PPR) vaccine. After 14 days of injection serum was collected and stored in freeze condition (-20°C) for further analysis. Antibody titer against PPR vaccine was determined using competitive enzyme linked immuno sorbent assay kit and expressed as per cent of inhibition values (Singh *et al*., 2004).

Statistical analysis

The data obtained in the *in vivo* experiment were subjected to analysis of variance (ANOVA) to compare the means of each treatment by using the procedures described by Snedecor and Cochran (1989) using Statistical Package for Social Sciences (SPSS, 2009, version 18.0 Chicago, USA).

RESULTS AND DISCUSSION

Chemical composition

The nutrient composition and ME (MJ/kg DM) content of feed and fodder offered to the lambs in the present experiment is given in Table 2. The chemical composition of the feed and fodder offered to the lambs was similar throughout the experimental period. The nutrient content was within the reported range of values (Naik *et al.,* 2015; Rajkumar *et al.,* 2018). The average DM content of MGS was found to be 16.5 per cent. The average CP content of maize grain, maize green fodder, MGS, sorghum green fodder, FMS and CFM was found to be 8.50, 7.81, 13.2, 8.10, 4.20 and 20.0%, respectively. The CP content of MGS was increased as compared to original maize grain. The DM and CP values varied due to uptake of water and sprouting process. The crude fiber (CF), NDF and ADF content of MGS was 10.0, 33.0 and 15.5 per cent, respectively and higher than the original grain. The CF, NDF, ADF and ADL contents of MGS was also similar to the values reported by Naik *et al.,* 2015. The ME (MJ/kg DM) content was 11.5, 9.18, 9.70, 8.66, 6.99, 11.5, respectively in maize grain, maize green fodder, maize grain sprout, sorghum fodder, finger millet straw and CFM. In agreement with the present findings the gross energy value of barley grain and barley sprouts as reported by Dung *et al.* (2010a) was 15.25 v/s 15.04 MJ/kg DM, respectively with 2% loss of ME. In the present study there was a loss of about 15% ME on sprouting (11.5 v/s 9.70 MJ/kg DM). Availability of ME in hydroponic barley was lower than the original barley grain

Table 2: Chemical composition* of dietary ingredients (% DM basis).

Attribute	Maize grain	CMF	MGS	SGF	FMS	CFM**
Dry matter	92.5	32.4	16.5	33.6	92.9	92.0
Organic matter	98.6	94.5	97.1	88.5	91.8	94.4
Crude protein	8.50	7.81	13.2	8.10	4.20	20.0
Ether extract	2.44	1.93	4.4	1.80	0.90	5.10
Crude fibre	2.43	27.6	10.0	33.2	36.8	4.50
Total ash	1.42	5.49	2.89	11.5	8.18	5.56
AIA	0.17	1.20	0.46	2.21	1.52	1.24
NDF	13.3	52.8	33.0	63.8	74.1	27.4
ADF	3.42	25.7	15.5	36.2	38.7	14.4
Cellulose	2.88	19.8	13.2	24.5	30.6	9.78
Hemicellulose	9.88	27.1	17.5	27.6	35.4	13.5
Acid detergent lignin	0.44	2.09	0.98	4.04	5.10	1.25
Metabolizable energy (MJ/kg)	11.50	9.18	9.70	8.60	6.99	11.5

*Each value is the average of three observations.

**Composed of (g/kg): Yellow maize 435, Wheat bran 260, groundnut cake 300 and common salt 5. CMF: Conventionally grown maize fodder; MGS: Maize grain sprouts; SGF: Sorghum green fodder; FMS: Finger millet straw; CFM: Compounded feed mixture.

(Fazaeli *et al.*, 2012). This decrease in energy density was attributed to decrease in DM and carbohydrates, which were used up in the process of sprouting. On contrary, Farghaly *et al.* (2019) reported an increase in gross energy density of sprouted barley at a rate of 19.3%.

Dry matter intake, nutrient digestibility and plane of nutrition

Dry matter intake and digestibility of nutrients in different groups are represented in Table 3. There was significant (P<0.05) decrease in DMI in lambs fed MGS as a replacement of conventional green fodder. The DMI (g/d/lamb) for MGS fed groups T2, T3 was 581 and 398 which was significantly lower than that of control T1 (764). Intake of MGS (g/d/lamb) for T2 and T3 was 241 and 276, respectively. These findings are in corroboration with the results of Reddy *et al.* (1988); Pandey and Pathak (1991); Fazaeil *et al.* (2011); Naik *et al.* (2014); Limba *et al.* (2017) and Dadhich *et al.* (2019) who reported decreased DMI by animals when hydroponically grown fodder was fed. The DMI on sole feeding of maize hydroponic fodder in lambs was 1.11 per cent of body weight and it was lower than recommended 2.6 to 2.8 per cent of body weight for maintenance (Sheik *et al.*, 2019). The decrease in DMI might be due to high moisture content of about 80-85% in MGS. As observed there was significant (P<0.05) decrease in water intake in lambs fed MGS as a replacement of conventional green fodder. The water intake during the metabolism trial (ml/d/lamb) for MGS fed groups T2 and T3 was 804.1 and 569.2 which was significantly lower than that of control T1 (1182.8). Whereas, conflicting results of increased DMI was reported in the studies of Verma *et al.* (2015) who fed hydroponic barley fodder to Haryana breed of male calves and recorded DMI of 3.35-3.38 kg/100 kg body weight. Increase in DMI was also reported by Dung *et al.* (2010c); Kide *et al.* (2015) and Rajkumar *et al.* (2018). The reasons for increase in DMI as reported by these workers are palatability of hydroponically grown fodder and faster movement in the gastro intestinal tract. Further, it was observed that, some experimental animals used to select only leafy part of the MGS leaving the root portion. In the present study, throughout the feeding trial in group fed 80% MGS (T3) faecal consistency was semi-solid to pasty in nature as compared to normal pellets in conventional green

Table 3: Nutrient digestibility, plane of nutrition and nutritive value of experimental diets.

Attribute	T1	T2	T3
Body weight of lambs (kg)	19.9±0.60[a]	16.8±0.39[b]	13.5±0.31[c]
Metabolic body weight (kg $W^{0.75}$)	9.44±0.21	8.30±0.16	7.06±0.12
Digestibility (%)			
DM	68.9±0.98[ab]	65.2±1.51[b]	72.7±1.01[a]
OM	71.7±0.88[ab]	68.4±1.43[b]	74.4±0.93[a]
CP	62.1±2.59	58.3±0.28	63.2±1.87
EE	64.9±5.47	66.2±2.65	70.1±2.02
NDF	52.3±1.71	48.1±2.47	46.1±2.09
ADF	47.9±1.77[ab]	49.0±2.16[a]	40.1±2.59[b]
Digestible OM in DM	65.4±0.80	64.1±1.35	67.8±0.99
Plane of nutrition			
DM intake (g/d/lamb)			
Compounded feed mixture	341±11.76	146±3.38	60.7±2.68
Finger millet straw	38.6±6.32	44.9±4.90	62.1±2.47
Conventional green fodder	379±29.00	149±6.52	-
Maize grain sprout	-	241±5.14	276±22.03
Total DMI	764±37.83[a]	581±11.49[b]	398±26.71[c]
DMI (% body weight)	3.8±0.09[a]	3.5±0.10[a]	2.9±0.16[b]
DMI (g/kg $W^{0.75}$)	80.9±4.01[a]	70.1±1.38[a]	56.5±3.78[b]
Water intake (ml/d/lamb)	1182.8±162[a]	804.1±153[b]	569.2±126[c]
Nutrient intake			
DCP intake (g/d/lamb)	55.8±3.56[a]	41.8±0.52[b]	34.0±1.53[b]
DCP intake (g/kg $W^{0.75}$)	5.9±0.38[a]	5.0±0.06[ab]	4.8±0.22[b]
TDN intake(g/d/lamb)	552±29.73[a]	423±6.07[b]	305±17.06[c]
TDN intake (g/kg $W^{0.75}$)	58.5±3.15[a]	51.0±0.73[ab]	43.3±2.42[b]
Nutritive value of total ration (% DM)			
CP	11.8±0.82[b]	12.3±0.91[b]	13.50±1.0[a]
DCP of diet	7.34±0.20	7.18±0.30	8.52±0.50
TDN of diet	72.6±3.51	72.9±4.01	76.4± 3.88

[abc]Mean values in a row bearing different superscripts differ significantly (P<0.05).

fodder fed groups. However, Saidi and Omar (2015); Jemimah *et al.* (2017) and Naik *et al.* (2017) observed no significant difference in feed intake. The difference in the consumption of total DMI among three groups implies that feeding of MGS may decrease the potential DMI due to physical rumen fill effect in animals leading to negative effect on performance of growing lambs. Intake of fibre fractions (NDF, ADF, cellulose, hemicellulose) was also in similar trend as DM intake.

The per cent digestibility of DM was significantly (P<0.05) higher in MGS fed group (T3) compared to control. The per cent digestibility of OM and CP in MGS fed group (T3) was comparable to control (T1) group. Also it was observed that there was no significant difference in the digestibility of EE, NDF and ADF between the control and treatment groups. Higher per cent digestibility of DM, OM and CP in T3 is probably due to low DMI accompanied with tenderness of MGS as the conventional green fodder contained higher CF and lignin. Comparable digestibility of other nutrients indicated that there was no adverse effect of MGS inclusion on the ruminal micro flora and nutrients present in the MGS were well utilized. Similar observations of increase in digestibility of nutrients from hydroponically grown fodder was reported by previous workers (Reddy *et al.*, 1988; Verma *et al.*, 2015, Naik *et al.*, 2014; Limba *et al.*, 2017; Naik *et al.*, 2017; Jemimah *et al.*, 2018; Devendar *et al.*, 2020). Contrary to the present findings, Dung *et al.* (2010c) found no significant difference in DM digestibility in sheep fed fresh hydroponic barley fodder. Similar results of no difference in DM digestibility was observed by Naik *et al.* (2013) in dairy cows and Khanna *et al.* (2016) in buffaloes fed hydroponic maize fodder and conventional green fodder.

The intake of DCP and TDN was significantly (P<0.05) lower in T3 group followed by T2 and highest intake was recorded in control group T1. The significantly (P<0.05) lower energy intake was due to the lower DMI in T3 group. Similarly, the CP intake was also decreased even though the CP content of MGS was higher than maize grain and green fodder. The DCP and TDN intake in T1 and T2 group were comparable with the requirements of ICAR (2013) feeding standards. All the lambs fed experimental rations could meet the DM requirements as per ICAR (2013) nutrient specifications except in T3 where, DMI was lowest. Present findings of DCP and TDN intakes in MGS fed group was similar to the findings of Pandey and Pathak (1991) who reported that mean daily intake of CP, DCP and TDN were higher than the maintenance requirements but lower than the total requirement for maintenance and milk production in cows fed artificially grown barley fodder. Sheik *et al.* (2019) reported that hydroponic fodder as a sole feed source did not meet maintenance requirement. On contrary, Dadhich *et al.* (2019) reported improved DCP and TDN intakes in hydroponic maize fodder fed groups as compared to control. Similar results were also reported by Verma *et al.* (2015) and Naik *et al.* (2014).

Weight gain and nitrogen balance

Average daily gain (ADG) and feed conversion ratio of different experimental groups are presented in Table 4. The average daily gain during the experimental period was significantly (P<0.05) different among the groups with lowest growth rate in 80% MGS fed group (T3) compared to control T1. Feed conversion ratio was also poor in MGS fed group (T3) as compared to control. This could be due to lower DM intake and lower energy levels of the MGS based diet. Similar results were also reported by Myers (1974) and Fazaeil *et al.* (2011) who found no effect of sprout fodder feeding on ADG or no advantage on animal performance and the feed cost was increased by 24%. The ADG and FCR were not affected by replacement of concentrate mixture at 25 and 50% with hydroponic maize fodder in goats as reported by Dhawale *et al.* (2018). Whereas, reports by Verma *et al.* (2015); Rajkumar *et al.* (2018) and Devendar *et al.* (2020) showed significantly (P<0.05) higher body weight gain and FCR on feeding hydroponic maize fodder at different levels. Similar results of improved performance in goats were also observed by Kide *et al.* (2015) and Muthuramalingam *et al.* (2015). Decreased FCR in lambs fed MGS in the present study indicated that the animals did not get required amount of nutrients due to reduced DMI.

Nitrogen balance in lambs of groups T1, T2 and T3 respectively, is summarized in Table 5. Daily intake of nitrogen was significantly (P<0.05) lower in groups T2 and T3 than control T1. Excretion of nitrogen in faeces was significantly (P<0.01) lower in T3 than T2 and T1. This is due to difference in DM intake among the groups. Nitrogen excretion in urine did not differ among the lambs fed MGS indicating optimum utilization of absorbed N. Net nitrogen balance was significantly (P<0.05) higher in control group than the MGS fed groups. Nitrogen retention as per cent of intake was also significantly (P<0.05) higher in control group than other treatment groups. All the animals in treatment groups were in positive nitrogen balance which was

Table 4: Growth performance of lambs during feeding trial.

Attributes	T1	T2	T3
Initial body weight (kg)	12.2±0.75	12.2±0.49	12.2±0.43
Final body weight (kg)	21.5±1.08[a]	18.0±0.30[b]	14.7±0.48[c]
Body weight gain (kg)	9.3±0.50[a]	5.8±0.65[b]	2.5±0.49[c]
Average daily gain (g)	77.3±4.18[a]	48.5±5.43[b]	20.9±4.11[c]
FCR (g DMI/ g wt. gain)	7.9±0.44[b]	10.6±1.43[b]	16.3±1.88[a]

[ab]Mean values in a row bearing different superscripts differ significantly (P<0.05).

Table 5: Nitrogen balance in lambs during the metabolism trial.

Parameter	T1	T2	T3
Nitrogen intake (g/d/lamb)	14.4±0.54[a]	11.5±0.16[b]	8.62±0.38[c]
Dung nitrogen (g/d/lamb)	5.41±0.35[a]	4.80±0.09[a]	3.20±0.25[b]
Urine nitrogen (g/d/lamb)	2.20±0.25	2.50±0.23	2.60±0.35
Absorbed nitrogen (g/d/lamb)	8.93±0.57[a]	6.68±0.08[b]	5.44±0.25[b]
Retained nitrogen (g/d/lamb)	6.75±0.52[a]	4.19±0.22[b]	2.82±.16[c]
N retained as % of intake	47.0±3.40[a]	36.6±2.17[ab]	33.3±3.33[b]
N retained as % of absorbed	75.4±2.62[a]	62.7±3.44[ab]	52.3±4.8[b]

[ab]Mean values in a row bearing different superscripts differ significantly (P<0.05).

suggestive of energy and N supply higher than the maintenance requirement. But in T3 group energy and protein intake was not sufficient, hence lower body weight gain was achieved as compared to control. In T3, lower amount of nitrogen was retained which might be due to less intake and faster passage rate. Though, lambs in T3 group were in positive N balance, desired growth could not be achieved due to inadequate plane of nutrition in terms of DCP and TDN intakes. Similar to the present findings, Dung *et al.* (2010c) reported that supplementing freshly sprouted barley to poor quality roughages did not affect N retention in sheep. Further, they reported that shoot portion in the hydroponic barley fodder most likely to be rapidly degraded making it to move faster in the gut and less efficient microbial protein synthesis and less nitrogen retention. Fraghaly *et al.* (2019) observed similar results of decreased N retention in rams fed sprouted barley alone as compared to those fed Egyptian clover and attributed this to lower nitrogen intake as a result of reduced DM intake of sprouted barley.

Contrary to above results, Raeisi *et al.* (2018) reported that, gradual increase in N retention as proportion of barley hydroponic fodder was increased from 7 to 21% in the diet replacing barley grain. The reason for higher N retention was due to higher DMI and improved digestibility of CP in the barley fodder fed experimental groups. Similarly, Fayed (2011) also reported increased N intake and retention in female lambs fed sprouted barley produced by utilizing dried Tamarix and rice straw as base material.

Mineral balance

All the animals in the experimental group were in positive Ca, Mg and P balance. The effect of feeding experimental diets in different treatment groups on Ca, P and Mg balance is presented in Table 6. The Ca intake for T1, T2 and T3 was 5.43, 3.79 and 2.94 (g/d/lamb), respectively. There was significantly (P<0.05) lower Ca excretion through dung in group T3. The Ca balance was significantly lower in T2 and T3 groups as compared to control group. However, Ca retained as per cent intake was significantly higher in 80% MGS fed T3 group as compared to control group due to better availability of nutrients from MGS. The lower Ca balance might be due to lower Ca content of MGS and difference in Ca intake due to reduced DM intake. Similarly, lower Mg intake and excretion through dung and urine was observed in MGS fed groups. The Mg balance was significantly lower in 80% MGS fed T3 group as compared to control group, whereas Mg retained as per cent of intake was comparable between T1 and T3 group and in T2 it was significantly lower. The P balance was similar among the treatment groups but lower than the control group. There was no significant difference in P retained as per cent of intake among the experimental groups. In contrast to the present findings Kide and Rahwa (2016) reported no difference among groups fed hydroponic maize fodder at 20 and 40% of the diet as compared to control fed FMS. However, group fed mixed hydroponic maize fodder and hydroponic barley fodder had higher intake and retention of Ca and P in goats.

The mean Cu and Zn balance for T1, T2 and T3 groups are presented in Table 7. Significantly higher Cu retention as per cent of intake in T3 group compared to control T1 was observed. There was no significant difference in Cu balance among different groups. Similarly higher Zn was retained as per cent of intake in T3 group compared to control T1. Zinc balance did not differ significantly among the experimental groups and all the animals were in positive Zn balance during the feeding trial. These results are due to higher bioavailability of trace minerals from MGS.

Blood biochemical profile, immune status and serum mineral composition

Blood biochemical parameters as influenced by different treatments are presented in Table 8. Dietary replacement of compounded feed mixture and conventional green fodder with MGS did not significantly affect the blood biochemical parameters. The values of blood biochemical parameters *viz.* ALP, AST, GGT, CK, Globulin, TP and BUN were comparable among experimental and control group. Observations on serum total protein, albumin and globulin are indicative of protein status of the animal. In the present study albumin concentration in the serum was lower in MGS fed group (T3) as compared to T2 and control. This may be due to lower protein intake resulted in less protein metabolism. However, the levels were within normal physiological range and no adverse effect on health of lambs was observed. Similar to our findings, Limba *et al.* (2018) reported no adverse effect of feeding hydroponic maize fodder on blood biochemical and hematological parameters in Rathi cows. Marsico *et al.* (2009) reported that hydroponically germinated oats partially substituted for the traditional feed

Table 6: Intake and balance of calcium, phosphorus and magnesium in lambs during the metabolism trial.

Parameter	T1	T2	T3
Calcium			
Intake (g/d/lamb)	5.43±2.43[a]	3.79±1.69[b]	2.94±1.31[c]
Dung outgo (g/d/lamb)	2.68±1.20[a]	2.48±1.11b [a]	1.07±0.48[b]
Urine outgo (mg/d/lamb)	2.70±0.0012[b]	6.60±0.0029[a]	6.40±0.0029[a]
Total voided (g/d/lamb)	2.68±1.20[a]	2.49±1.11b[a]	1.08±0.48[b]
Balance (g/d/lamb)	2.70±1.23[a]	1.30±0.58[c]	1.86±0.83[b]
Retained as % of intake	50.5±22.66[b]	34.3±15.38[c]	63.3±28.31[a]
Phosphorous			
Intake (g/d/lamb)	3.74±1.67[a]	2.22±0.73[b]	1.64±0.73[c]
Dung outgo (g/d/lamb	1.38±0.62[a]	0.90±0.40[b]	0.57±0.25b[b]
Urine outgo (g/d/lamb)	0.16±0.07	0.10±0.04	0.021±0.01
Total voided (g/d/lamb)	1.54±0.69[a]	1.01±0.45[b]	0.59±0.26[b]
Balance (g/d/lamb)	2.20±0.98[a]	1.21±0.54[b]	1.05±0.47[b]
Retained as % of intake	58.6±26.3	54.2±24.4	63.6±28.3
Magnesium			
Intake (g/d/lamb)	2.38±0.11[a]	1.63±0.03[b]	0.92±0.03[c]
Dung outgo (g/d/lamb)	0.94±0.01[a]	0.83±0.04[a]	0.36±0.02[b]
Urine outgo (g/d/lamb)	0.041±0.003[a]	0.040±0.002[a]	0.021±0.003[b]
Total voided (g/d/lamb)	0.99±0.01[a]	0.87±.04[b]	0.38±0.03[c]
Balance (g/d/lamb)	1.40±0.10[a]	0.76±0.04[b]	0.54±0.03[b]
Retained as % of intake	58.3±1.58[a]	46.7±2.19[b]	58.8±2.39[a]

[ab]Mean values in a row bearing different superscripts differ significantly ($P<0.05$).

Table 7: Intake and balance of copper and zinc in lambs during the metabolism trial.

Parameter	T1	T2	T3
Copper			
Intake (mg/d/lamb)	24.9±0.48[a]	20.2±0.11[b]	18.3±0.21[c]
Dung outgo (mg/d/lamb)	7.93±0.60[a]	5.18±0.51[b]	2.76±0.41[c]
Urine outgo (mg/d/lamb)	0.078±0.024[a]	0.016±0.003[b]	0.018±0.003[b]
Total voided (mg/d/lamb)	8.00±0.61[a]	5.19±0.51[b]	2.78±0.40[c]
Balance (mg/d/lamb)	16.9±0.87	14.9±0.32	15.6±0.32
Retained as % of intake	67.8±1.48[b]	74.2±1.34[ab]	84.9±1.07[a]
Zinc			
Intake (mg/d/lamb)	254±1.57[a]	248±0.54[b]	239±1.34[c]
Dung outgo (mg/d/lamb)	44.2±4.50[ab]	57.4±8.57[a]	26.5±4.68[b]
Urine outgo (mg/d/lamb)	1.06±0.11[a]	1.45±0.24[a]	2.22±0.69[ab]
Total voided (mg/d/lamb)	45.3±4.52[b]	58.9±8.67[a]	28.7±4.97[b]
Balance (mg/d/lamb)	209±4.78	189±8.48	210±4.06
Retained as % of intake	82.2±1.79[ab]	76.3±3.45[b]	88.0±2.02[a]

[ab]Mean values in a row bearing different superscripts differ significantly ($P<0.05$).

in the diet of goats did not significantly affect the biochemical and hematological parameters. Further, Micera *et al.* (2009) and Verma *et al.* (2015) observed that feeding of hydroponic barley did not alter the biochemical and hematological parameters. The antioxidant status in terms of SOD activity in different groups showed no significant difference. The mean concentration of serum metabolite BUN at the end of experiment in groups T1, T2 and T3 was 4.21, 5.10 and 4.21 (mmol/L), respectively. The concentration did not differ significantly among the experimental groups.

Humoral immune response to PPR antigen in the treatment groups was measured at zero and fourteen days after exposing to antigen and the per cent inhibition of PPR antigen after exposure in groups T1, T2 and T3 was 80.9, 82.6 and 81.7, respectively. Feeding of MGS did not cause any adverse effect on immune status of the lambs as humoral antibody response to PPR antigen was similar among all the treatment groups. This suggested that inspite of reduced nutrient availability in lambs fed MGS, nutrient partitioning favoured health attributes at the cost of weight gain.

Table 8: Blood biochemical, mineral profile and immune response in lambs.

Parameter	T1	T2	T3
Alkaline phosphatase (U/L)	199±17.77	176±18.90	158±22.30
Alanine amino transferase (U/L)	105±4.48	120±9.59	135±13.15
Gamma glutamyl transferase (U/L)	53.8±5.08	61.7±2.94	63.2±3.44
Creatinine kinase (U/L)	187±23.37	224±10.80	204±21.39
Albumin (g/L)	42.8±0.91[a]	40.0±1.37[a]	35.2±0.70[b]
Globulin (g/L)	24.5±1.98	23.3±2.20	26.2±1.96
Total protein (g/L)	67.3±1.93	63.8±1.96	61.2±2.12
Blood urea nitrogen (mmol/L)	4.21±0.21	5.10±0.41	4.21±0.52
Superoxide dismutase (U/L)	16.4±1.45	15.0±1.56	15.4±0.84
Serum mineral content (mg/L)			
Ca	130±3.67[a]	114±3.75[b]	114±2.48[b]
P	61.2± 3.61	60.6±3.99	62.4±3.36
Mg	26.9±2.68	26.3±1.56	25.5±1.84
Cu	1.02±0.05[b]	1.16±0.17[ab]	1.55±0.13[a]
Zn	1.12±0.12	1.00±0.05	1.10±0.08
Immune response			
% Inhibition Value at '0' day	9.77±1.22	14.2±2.01	7.17±1.27
% Inhibition Value at '14' day	80.9±6.12	82.6±7.00	81.7±8.02

[ab]Mean values in a row bearing different superscripts differ significantly (P<0.05).

Mean serum mineral (mg/L) concentration *viz*., Ca, P, Mg, Cu and Zn at the end of experiment in groups T1, T2 and T3 are presented in Table 8. Serum mineral concentrations were within the normal physiological range and did not differ significantly among the treatment groups except for Ca and Cu. Calcium concentration (mg/L) was lower in MGS fed groups (T2 and T3: 114) compared to control group (130). This could be due to significantly less Ca intake in T3 group compared to control. Copper concentration (mg/L) in serum was significantly higher in group T3 fed MGS (1.55) as compared to control group T1 (1.02). The serum Cu content in group T3 was higher compared to control, this may be due to less Cu excretion in faeces than the control and significantly higher retention. The serum mineral concentrations are key markers of general health and nutritional status of the animals. Thus, the normal physiological range of estimated serum mineral contents indicated no adverse effect to the growing lambs on inclusion of MGS to substitute conventional green fodder or compounded feed mixture.

CONCLUSION

Maize grain sprout has better crude protein, fiber and lesser energy compared to maize grain but has less fiber than the conventional green fodder. Replacement of compounded feed mixture or conventional green fodder with MGS will limit the dry matter intake, net nutrient availability and negatively affect the growth performance in lambs. Hence, complete replacement of conventional green fodder and CFM with MGS was not economical in terms of feeding cost and growth performance.

Conflict of interest: None.

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