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Original Paper

Effect of feeding frequency of curcuma longa supplemented diets on nutrients intake, growth performance and rumen fermentation characteristics of goats

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Natural feed additives are gaining increased attention due to their ability to improve animal performance. Hence, this study was carried out to determine the effect of feeding frequency of diets supplemented with or without turmeric (*Curcuma longa*) rhizome powder on goats' performance. Thus, a concentrate diet was formulated; and 300 g was fed to each of the goats per day. Meanwhile, 10 g of turmeric rhizome powder (TRP) was added to the 300 g concentrate; once a week, alternate days, daily while the control were not given TRP. Twenty goats were used for this trial, of five goats per replicate, arranged in Completely Randomized Design experiment. The feeding trial lasted 56 days. Parameters were taken on nutrients intake, utilization, weight change, microbial evaluation, rumen fermentation characteristics and data generated were subjected to apropriate statistical analysis. From the results, TRP supplemented diets did not significantly (P >0.05) influence the nutrients intake except for crude protein intake (CPI). Nitrogen retention (NR), daily weight gain (DWG) and feed conversion ratio (FCR) were significantly (P <0.05) influenced. NR (93.17%), DWG (55 g/d) and FCR (9.96) of goat-does fed TRP supplemented diets on daily basis was the best. Feeding frequency of TRP supplemented diet decreased total bacteria count (TBC) and rumen pH, while total fungi count (TFC) and total coliform count (TCC) increases as the frequency increases, with a decline in alternate days. Meanwhile, total volatile fatty acids (TVFA) progessively increased. Conclusively, daily supplementing of goats' diet with TRP at 10 g/300 g feed optimally improved goats' performance and is thus recommended.

Keywords: feeding frequency, natural feed additive, rumen ecology, ruminants, volatile fatty acids

1 Introduction

The feeding management of goats is critical to the overall success of the goat farm enterprise. Most ruminant farmers in the tropics, particularly in Nigeria, have been adopting the use of natural feed additives such as turmeric rhizome to replace the use of antibiotics, with the sole aim of improving animals' productivity. However, the question of the short- and long- term effect(s) with the rate/frequency of introduction on animal performance has been left unattended to. Though, turmeric (*Curcuma longa*), which belongs to the family Zingiberaceae has been reported to be medicinal (Jilani et al., 2012; Olatunde et al., 2014; Taoheed et al., 2017). Curcumin, being the major bioactive ingredient in turmeric is a potent anti-inflammatory, anti-platelet, hypocholesterolemic, antibacterial and antifungal effects (Peter, 2000). Curcumin is a powerful antioxidant as vitamins C, E and Beta-carotene, making turmeric usage a consumer choice for cancer prevention, liver protection and premature aging (Akram et al., 2010). Turmeric is said to stimulate appetite and feed intake thereby improving endogenous digestive secretion and activating immune responses (Nouzarian et al., 2011). Vorlaphim et al. (2011) investigated the influence of dietary curcumin on rumen fermentation, macro-nutrients digestion and nitrogen balance in beef cattle fed urea-treated rice straw and concentrates without or with 0.1% or 0.2% added curcumin. During rumen fermentation, short chain fatty

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acids and microbial cells are formed from feedstuffs, and these products serve as sources of energy and protein, respectively, to the animal. Considering the nutritional and medicinal/pharmacological properties of turmeric, it modulates/alters the rumen ecology. Summarily, it has a high nutritional status that can be exploited in ruminant production. Meanwhile, goat is an integral aspect of livestock production; and are being raised by most household in Nigeria either in small- or large- scale production. Goats have multi-faceted purposes and their meat (chevon) are widely accepted by many. The nature of their stomach enables them to handle fibrous feed materials than monogastrics. Since attention have been shifted to the use of turmeric in their nutrition, there is dire need to research into whether feeding frequency of turmeric rhizome powder will have effect(s) on goats' general wellbeing. Therefore, the concern of this study investigated the impact of feeding frequency of turmeric rhizome powder supplemented diets on nutrient intake, rumen fermentation characteristics and weight gain of goats.

2 Material and methods

2.1 Study site

The study was conducted at the Federal University of Technology, Akure (FUTA), Nigeria. The field trial was carried out at the Teaching and Research Farm of the Department of Animal Production and Health. Microbial/rumen fermentation characteristics and nutrition analyses were done at the Laboratories of the Department of Animal Production and Health and Central Research Laboratory, FUTA, respectively. FUTA is located on latitude 7.15 °N and longitude 5.12 °E and is of hot, wet equatorial climate. The mean annual rainfall is about 1500 mm while the mean annual temperature is usually around 26 °C (Nigerian Meteorological Agency, 2014).

2.2 Procurement and processing of feed materials

Fresh turmeric rhizomes were sourced from the market in Akure, Ondo State, Nigeria. The harvested rhizomes were screened, hygienically washed with potable water. Thereafter, they were then peeled, sliced into smaller pieces and air-dried to a constant weight. The dried rhizomes were then milled into fine powder (Figure 1) using electric blender before its incorporation/ thoroughly mixed with the formulated concentrate diet.

Twenty West African Dwarf breed of goat-does, age range of 18–24 months with an average live-weight of 13.84 kg, were used for this study. All the does were selected from goats Unit of Teaching and Research Farm. The goat-does were acclimatized for two weeks in their new pens,

Figure 1 Turmeric (*Curcuma longa*) rhizome powder

balanced for weight and randomly distributed into four treatments of five does per treatment. Concentrate diet was formulated (Table 1); and 300 g of concentrate was fed to each goat per day in the morning (7:00 hr) and 1200 g of the wilted *P. maximum* in the evening (15:00 hr), everyday throughout the 56 days experimental period. Meanwhile, 10 g of turmeric rhizome powder (TRP) was added to the 300 g concentrate once a week, alternate days/skip a day, daily while the control group were not given TRP. Daily records of feed intake as well as weekly weight change of each animal were determined.

Table 1 Gross composition of the formulated concentrate diet

Ingredients	Inclusion (kg)
Cassava peel meal	52.50
Wheat offal	17.50
Palm kernel cake	10.00
Brewer's dried grain	17.00
Bone meal	1.00
Salt	1.00
Vitamin-mineral premix	1.00
Total	100.00
Calculated analysis (%)	
Crude protein	9.99
Crude fibre	13.51
Calcium	0.41
Phosphorus	0.24
Metabolizable energy (kcal/kg)	1660.00

2.3 Experimental layout/design

The goat-does were randomly allotted to four treatment groups, balanced for weight comprising of five does per treatment in a Completely Randomized Design experiment. The experimental diets were fed at 7:00 hr in the morning while wilted Guinea grass (*P. maximum*)

of 1200 g in chopped form were fed at 15:00 hr. Fresh and potable water were supplied daily *ad libitum*. The feeding trial spanned for 56 days.

2.4 Performance evaluation

The changes in weight were monitored on weekly basis using hanging scale. Gross weight change is determined by deducting of initial weight from the final weight of the goat-does. The difference in total feed offered and feed left over were taken as the feed intake while the feed conversion ratio (FCR) was deduced from dividing total feed consumed (g) by weight gain (g).

2.5 Digestibility trial and nitrogen retention

Samples of faeces and urine were collected in the morning using metabolic cage. Faeces were weighed and oven dried at 105 °C for about 3 hours for dry matter (DM) determination. The faecal samples for each experimental animal were thoroughly mixed, milled to pass a 0.2 mm sieve and sealed in polythene bags. These were stored in a cupboard at room temperature until required for chemical analysis. Total urine excreted by each animal were collected in a bucket under each cage and to which few drops of 25% H_2SO_4 was added daily to prevent volatilization of ammonia from the urine. The total volume of urine output per animal were measured and aliquots (10%) of daily output per animal was saved in stopper plastics bottles, labelled and were stored in a deep freezer. Nitrogen balance is calculated as nitrogen output (nitrogen in urine and faeces) deducted from nitrogen intake. The unit is expressed in gram per day. Percentage apparent digestibility coefficient and nitrogen retention of the goats were calculated as;

$$\%\ apparent\ digestibility = \frac{\left(\begin{matrix} nutrients \\ intake \end{matrix} - \begin{matrix} nutrients \\ output \end{matrix}\right)}{nutrient\ intake} \cdot 100$$

$$\%\ nitrogen\ retention = \frac{\left(\begin{matrix} nitrogen \\ intake \end{matrix} - \begin{matrix} nitrogen \\ output \end{matrix}\right)}{nitrogen\ intake} \cdot 100$$

2.6 Determination of volatile fatty acids

At the end of the feeding trial, rumen liquor collected 3 hours post feeding from all the goats through the use of suction tube, to determine the fermentation characteristics. The liquor collected were sieved using a sterilized cheese cloth. The pH of the rumen content was measured immediately after the collection of the rumen fluid using a digitalized portable pH meter. For VFA determination, portion of rumen filtrated samples were thawed at 4 °C prior to analysis. This analysis was carried out using the high performance liquid chromatography (HPLC). Approximately 5 ml of the filtrate was acidified with 1 ml of 5% (v/v) tetra-oxo-sulphate (vi) acid (H_2SO_4) solution in a test tube and left to rest for 30 minutes. After which the test tubes were arranged in a centrifuge at 3000 rpm for 10 minutes. Then the liquid was decanted into a beaker and 2 drops of phenophalin was dropped into solution for titration with sodium hydroxide (NaOH). Acetic acid standard, propionic acid standard and butyric acid standard will be prepared; a wavelength of 210 nm will be used. The titre values were used to determine the volatile fatty acids concentration (AOAC, 2011). Another portion of rumen filtrated samples were centrifuged at 12000 x g for 20 min. 5 ml of supernatant was collected and used for determination of the ammonia content (Parsons et al., 1984).

2.7 Rumen microbial evaluation

Total bacteria count, total anaerobic bacteria count and fungi count were done by plate count method. Portion of rumen liquor from each of the goats was used to determine the bacteria, fungi and coliform present. Colony-forming units/ml (CFU/ml) of both bacterial and fungi were obtained with the pour plate technique using nutrient algae and potato dextrose agar, respectively. The majority of ruminal bacterial species were grown on relatively simple media of carbohydrates (cellulose, starch, glucose), ammonia and trypticase, b-vitamins, heme, vitamin K derivatives, mineral salts, and a reducing agent such as sodium sulfide and L-cysteine. The plates were incubated for 24 hours at 37 °C. All colonies appearing at the end of the incubation period were counted using a digital illuminating colony counter.

2.8 Determination of chemical composition

Samples of feed, faeces, urine and turmeric powder were analyzed for nutrients composition according to AOAC (2011). The neutral detergent fibre, acid detergent fibre and acid detergent lignin were analysed according to Van Soest et al. (1991). Curcumin concentration in the turmeric rhizome powder was assayed using spectrophotometry method. Dried turmeric rhizome were milled to powderic form. Extraction and purification process was done through the use of Soxhlet apparatus while the analytical process involves the use of spectrophotometer. The dietary energy was determined using bomb calorimeter. A digitalized pH meter was used to determine the rumen pH. Ammonia nitrogen were determined by titration method according to the method of (Caltado et al., 1975). Two ml of liquor was siphoned into a beaker. Then 2 ml of NaOH was poured into a distillation tube, with 2 ml of boric acid. On distillation, colour changed from blue to green. The green fluid which contained the distillation

fluid and the liquor was titrated with 0.01 M of HCl. At titration, when the green fluid turns back to blue, the titre value was determined.

2.9 Statistical analysis

Completely randomized design with the following model: $Y_{ij} = \mu + a_i + e_{ij}$ was used. Where Y_{ij} – any of the response variables; μ – the overall mean; a_i – effect of the ith treatment (i = feeding frequency/time 1, 2, 3, and 4); e_{ij} – random error due to experimentation. All data collected were subjected to analysis of variance (ANOVA) using SPSS, 2011 version 22.0. The differences between treatment means were examined by Duncan multiple range test of the same package. Level of significance were taken as (p <0.05) i.e. 95% confidence interval.

3 Results and discussion

Table 2 shows the chemical composition of concentrate diet, grass and turmeric rhizome powder. The dry matter (DM) content ranged from 27.24% (*P. maximum*) to 90.31% (turmeric rhizome powder). The dietary crude protein ranged from 5.35% (*P. maximum*) to 10.24% (turmeric rhizome powder). The dietary crude fibre ranged from 8.04% (TRP) to 19.08% (*P. maximum*). The dietary DM and fibre fractions are adequate to encourage rumination by goats. The crude protein contents of the diets (formulated concentrate – 10.05% CP and TRP – 10.24%CP) were above 8% CP required by ruminants for optimum microbial activities in the rumen (Norton, 2003) except for the grass (*P. maximum*) which is 5.35%CP. This implies that the diets were adequate to meet the protein requirement for ruminant and effective rumen function (Asaolu et al., 2012). The rumen microbes are capable of acting on the dry matter and crude fibre to release nutrients required for metabolism. The highest value of ash is recorded in grass (5.76%) and the least value was recorded in turmeric (3.62%). The ether extract and nitrogen free extract ranged from: (grass) 3.01–4.58% (turmeric) and (grass) 66.63–73.52% (turmeric), respectively. The dietary ash is an indication that the feed is capable of releasing the mineral constituents for proper development of the animals. Curcumin concentration in turmeric rhizome powder was 0.76 mg/g. Though, curcumin was not determined in the concentrate and *P. maximum* but the cumulative and residual effect of curcumin from TRP as additive in the goats' diet, is capable of altering the rumen ecosystem.

The nutrients intake by West African Dwarf goats fed diet supplemented with turmeric rhizome powder at different feeding frequency is presented in Table 3. Feeding frequency of turmeric (*Curcuma longa*) rhizome powder influenced nutrient intake numerically but only total feed intake (*P. maximum* and concentrate intake) and DMI of concentrate are statistically (p <0.05) significant while other observed parameters were not. Goats fed 10 g of TRP per 300 g feed on daily basis had the highest crude protein intake (CPI) of 90.43 g/day while those on control diets (no TRP supplementation) had the least CPI recorded (86.71 g/day). This is an indication that the turmeric rhizome powder influenced palatable and acceptable (voluntary feed intake) by the animals. Voluntary feed/nutrient intake is a function of multi-facet factors ranging from age, breed, physiological status, feed palatability, feeding conditions, livestock system among others (Rashid, 2008). Goats fed 10 g daily of TRP with 300 g concentrate had relatively best nutrient intake (Table 3). Omotoso and Fajemisin (2020) also agreed that the high dry matter intake might be attributed to protein quality, acceptability and palatable diets hence, sources of energy and nitrogen enhance rumen microbial activity.

Table 2 Chemical composition of diet fed to the experimental animals

Parameters (%)	Concentrate	*P. maximum*	TRP
Dry matter	85.39	27.24	90.31
Crude protein	10.05	5.35	10.24
Crude fibre	12.89	19.08	8.04
Ash	3.85	5.76	3.62
Ether extract	3.43	3.01	4.58
Nitrogen free extract	69.78	66.80	73.52
Acid detergent fiber	23.75	21.01	22.78
Neutral detergent fiber	73.71	64.12	68.01
Acid detergent lignin	15.09	16.99	15.83
Metabolizable energy (kcal/kg)	3126.8	2813.17	3359.82
Curcumin (mg/g)	ND	ND	0.76

TRP – turmeric rhizome powder; ND – not determined

Table 3 Nutrient intake by WAD goats fed turmeric supplemented diets at varying frequencies

Parameters (g/d)	Control	Once a week	Alternate days	Daily	*P*-value
P. maximum intake	1058.99 ±12.47^{b}	1085.80 ±9.68^{a}	1081.67 ±10.88^{a}	1051.69 ±12.01^{b}	0.02
Concentrate intake	298.77 ±2.11^{c}	298.57 ±2.09^{c}	303.88 ±3.33^{b}	308.62 ±3.14^{a}	0.01
Total feed intake	1357.76 ±8.23^{b}	1384.37 ±8.16^{a}	1385.54 ±7.88^{a}	1360.31 ±8.44^{b}	0.04
Dry matter grass	288.55 ±8.63	295.94 ±12.01	294.49 ±7.25	286.37 ±4.16	0.78
DM concentrate	255.11 ±0.26^{b}	254.66 ±1.06^{b}	261.56 ±0.26^{a}	261.56 ±1.56^{a}	0.00
Total DMI	543.66 ±8.84	550.60 ±12.40	552.87 ±4.43	547.94 ±3.29	0.87
Total CPI	86.71 ±1.28	88.57 ±2.04	90.21 ±1.29	90.43 ±1.38	0.52
Total CFI	240.52 ±3.53	246.08 ±5.95	246.69 ±4.92	242.51 ±3.05	0.74
Total EEI	43.14 ±1.52	43.12 ±1.47	43.76 ±0.60	43.86 ±1.20	0.76
Total ash intake	72.60 ±2.72	74.43 ±2.64	75.30 ±1.03	74.80 ±2.31	0.85
Total NFE intake	915.79 ±11.82	932.17 ±20.19	929.59 ±16.91	908.67 ±8.51	0.66

abc – means on the same row with different superscripts are significantly (P <0.05) different; DMI – dry matter intake; CPI – crude protein intake; CFI – crude fibre intake; EEI – ether extract intake; NFE – nitrogen free extract

Table 4 Apparent Digestibility by WAD goats fed turmeric supplemented diets at varying frequencies

Parameters (%)	Control	Once a week	Alternate days	Daily	*P*-value
Total dry matter	81.33 ±0.33^{c}	81.84 ±0.52^{bc}	82.66 ±0.15^{ab}	83.34 ±0.38^{a}	0.02
Crude protein	91.78 ±0.39^{c}	92.02 ±0.25^{bc}	92.36 ±0.22^{b}	93.17 ±0.44^{a}	0.05
Crude fibre	75.12 ±0.37^{c}	77.75 ±0.03^{b}	78.22 ±0.15^{b}	81.02 ±0.42^{a}	0.00
Ether extract	72.63 ±0.60	73.26 ±1.43	73.81 ±0.76	74.96 ±0.26	0.34
Ash	82.85 ±0.93^{c}	84.30 ±0.81^{bc}	86.14 ±0.18^{ab}	87.27 ±0.35^{a}	0.01
Nitrogen free extract	82.67 ±0.43	82.80 ±0.64	83.63 ±0.24	83.95 ±0.51	0.24
ADF	76.04 ±1.20^{c}	77.67 ±2.11^{b}	78.16 ±1.01^{ab}	78.89 ±1.07^{a}	0.02
NDF	72.67 ±3.71^{c}	74.14 ±2.00^{b}	74.90 ±1.46^{b}	75.56 ±2.01^{a}	0.02
ADL	70.17 ±5.81^{c}	70.77 ±5.69^{c}	72.43 ±3.33^{b}	76.23 ±1.71^{a}	0.04

abc – means on the same row with different superscripts are significantly (P <0.05) different; ADF – acid detergent fiber; NDF – neutral detergent fiber; ADL – acid detergent fibre

Table 4 presents the digestion coefficients of nutrients by the WAD goat-does. All the parameters observed were significantly (P <0.05) influenced except ether extract and nitrogen free extract. However, goats fed TRP supplemented diet on daily basis recorded the highest digestibility coefficient values in all the observed parameters and least in the control group (no supplementation of TRP). Digestibility of feeds refers to the percentage of the whole feed or any single nutrient in the feed, which is not excreted and thus assumed to be available to animal for absorption from the gastro intestinal tract. It is noteworthy that all of the digestibility coefficients values were greater than 70% on dry weight basis. For ruminants to express their full genetic potential for growth, the apparent digestibility should exceed 70% on dry weight basis. Ajayi et al. (2008) also reported that forage supplementation significantly improved DM and CP digestibility. Digestibility of a feed is determined largely by chemical composition of the feed.

Table 5 presented nitrogen utilization by West African Dwarf goats fed turmeric supplemented diets at different feeding frequency. Nitrogen intake ranged from 13.93 g/day (no TRP supplementation) to 14.35 g/day (daily supplementation of TRP). Conversely, the daily supplementation of TRP had the least faecal (0.80 g/day) and urinary (0.14 g/day) nitrogen outputs. Nitrogen balance (13.37 g/day) and nitrogen retention (93.17%) were highest observed values in goats fed daily supplementation of TRP diets. The nitrogen intake has a positive correlation with crude protein intake; and the fact that goats fed TRP supplemented diets on daily basis, had the highest recorded nitrogen intake and balance, this might be attributed to the ability of turmeric to stimulate appetite and increase voluntary feed intake (Nouzarian et al., 2011), and invariably contribute nitrogen to the diets. Hence, improved nitrogen availability in the rumen for microbial growth and protein synthesis. The highest nitrogen intake value

Table 5 Nitrogen utilization by WAD goats fed turmeric supplemented diets at varying frequencies

Parameters (g/day)	Control	Once a week	Alternate days	Daily	*P*-value
Total dry matter intake	543.66 ±8.84	550.60 ±12.40	552.87 ±4.43	547.94 ±3.29	0.87
Total CPI	86.71 ±1.28^{c}	88.57 ±2.04^{b}	90.21 ±1.29^{a}	90.43 ±0.38^{a}	0.27
Nitrogen intake	13.93 ±0.34^{c}	14.18 ±0.32^{b}	14.26 ±0.33^{ab}	14.35 ±0.06^{a}	0.01
Faecal nitrogen	0.93 ±0.02^{a}	0.94 ±0.01^{a}	0.93 ±0.01^{a}	0.80 ±0.03^{b}	0.01
Urinary nitrogen	0.21 ±0.00^{a}	0.18 ±0.01^{b}	0.15 ±0.00^{c}	0.14 ±0.00^{c}	0.00
Nitrogen balance	12.78 ±0.37^{c}	13.05 ±0.33^{b}	13.18 ±0.33^{ab}	13.37 ±0.12^{a}	0.00
Nitrogen retention (%)	91.78 ±0.39^{c}	92.02 ±0.25^{bc}	92.36 ±0.22^{b}	93.17 ±0.44^{a}	0.04

abc – means on the same row with different superscripts are significantly (P <0.05) different; CPI – crude protein intake

Table 6 Growth performance of WAD goats fed turmeric supplemented diets at varying frequencies

Parameters	Control	Once a week	Alternate days	Daily	*P*-value
Initial weight (kg)	13.83 ±0.15	13.83 ±0.09	13.90 ±0.32	13.79 ±0.15	0.46
Final weight (kg)	16.73 ±0.12	16.67 ±0.20	16.60 ±0.32	16.87 ±0.19	0.85
Weight gain (kg)	2.90 ±0.12^{b}	2.84 ±0.12^{b}	2.70 ±0.09^{c}	3.08 ±0.09^{a}	0.02
Daily weight gain (g/d)	51.79 ±2.06^{ab}	50.71 ±2.06^{b}	48.22 ±1.58^{bc}	55.00 ±1.58^{a}	0.02
Daily feed intake (g/d)	543.66 ±8.84	550.60 ±12.40	552.87 ±4.43	547.94 ±3.29	0.87
Feed conversion ratio	10.50 ±0.59^{b}	10.86 ±0.36^{b}	11.47 ±0.46^{a}	9.96 ±0.26^{c}	0.03

abc – means on the same row with different superscripts are significantly (P <0.05) different

was recorded for goats fed daily supplementation of TRP and could be attributed to the high protein contents of the diet. This is in agreement with the view of Ibhaze and Fajemisin (2015) that as the level of crude protein in a diet increases, nitrogen intake also increased. The lower faecal nitrogen observed in goats fed TRP supplemented diet on daily basis could be due to the high utilization of crude protein level in the diets. The urinary and faecal nitrogen values obtained agrees with the report of Okah et al. (2012) that animals which consume less DM and will have less nitrogen excrete less nitrogen in urine. The lower urinary nitrogen could also be suggesting a more conducive ruminal environment that supported better nitrogen utilization by the microbes.

From Table 6, supplementation of TRP in goats' diet influenced their weight gain. Goats fed daily supplementation of TRP had the highest weight gain of 3.08kg after the feeding trial and daily weight gain (55.00 g/day) despite no statistical variation with the initial weight of the goats. The least feed conversion ratio (9.96) was recorded for goats fed daily supplementation of TRP. Goats fed TRP supplemented diet on daily basis had highest net daily weight gain (55 g/d) and least feed conversion ratio of 9.96 (Table 6) which reiterated the potentials of turmeric to enhanced growth as earlier noted by Habeeb et al. (2012). Growth performance of small ruminant primary depends on the availability of good quality feeds and the feeding regime employed by the farmer (Shashie and Mengistu, 2019). According to Tona et al. (2014) and Alagawany et al. (2016), the higher the value of the feed conversion ratio (FCR), the less desirable is the diet, as the animal consumes more feed to produce a unit weight gain. The significant weight change and net weight change observed in the goat-does could be attributed to the antioxidant activity of the curcumin present in the turmeric powder (Al-Sultan, 2003, Semethon et al., 2020).

Total bacteria count linearly decrease with frequency of supplementation of TRP while total fungi count increase, with a slight decline in the alternate days (Figure 2). Goats fed daily supplementation of TRP had the least (3.15 colony forming units) while the control group had the highest value (3.94 cfu). The rumen fermentation characteristics of WAD goats fed turmeric supplemented diets at varying frequencies is presented in Figure 2 and Table 7. According to Mosoni et al. (2007), ruminant acquires energy through the activity of microbial fermentation and plant degradation mainly by groups of cellulolytic bacteria. The importance of cellulolytic bacteria in ruminant nutrition is due to the fact that this particular group of bacteria plays a critical role not only in utilizing feeds that are not suitable for monogastric animals, but also in facilitating animals to survive on poor quality fibrous forages (Ørskov, 1982). Hence, the turmeric rhizome powder is capable of assisting the goats in optimum utilization of the grass offered and invariably

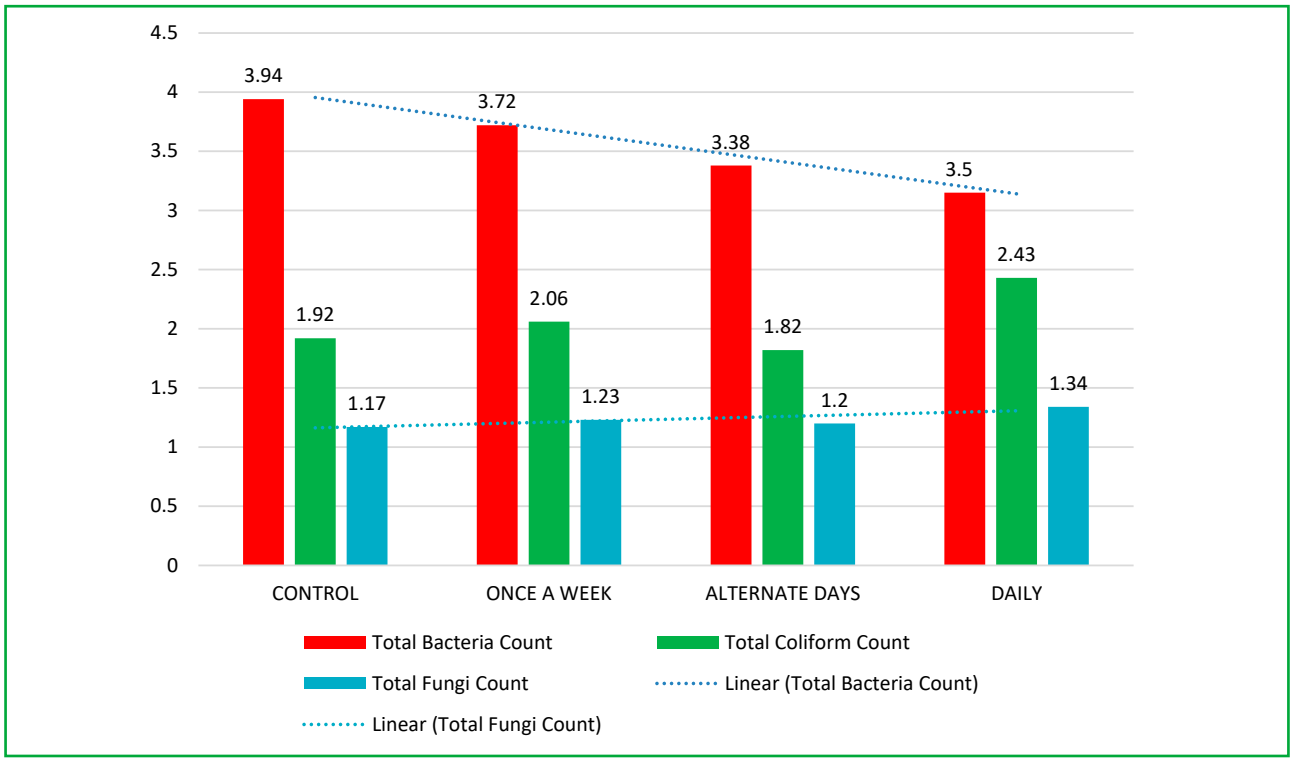

Figure 2 Microbial count of WAD goats fed turmeric supplemented diets at varying frequencies

the better performance (weight gain) recorded. Ruminal pH values were within normal range, and the reduction has minimal effects on rumen cellulolytic processes of fibre and protein digestion (6.0–7.0) (Wales et al., 2004). Total bacteria count reduced as increased feeding frequency which reiterated the efficacy of turmeric rhizome powder as anti-bacterial effects (Peter, 2000). Hence, could help improve the wellbeing of the animal. More so, the percentage ammonia nitrogen produced is an indication that the turmeric rhizome has the ability to mitigate methane production. Hence, to raise goats in an eco-friendly environment, supplementation of TRP would be encouraged, especially on daily or alternate days (Table 7).

Parameters observed were significantly (p <0.05) influenced except propionic acid, lactic acid, pH and ammonia nitrogen (NH_3N). Acetic acid and propionic acid production was highest (9.96; 9.20 mmol/100 ml) in goats fed daily supplementation of TRP and least (7.29; 7.30 mmol/100 ml) in control group, respectively. The pH ranged from 5.90 (daily supplementation of TRP) to 6.67 (control – no supplementation of TRP). The ammonia nitrogen production by WAD goats fed TRP supplemented diet at alternate days and daily supplementation are numerically similar (0.67%). *Escherichia coli* was coliform isolated in all the treatments. Meanwhile, daily supplementation of TRP suppressed the bacteria and fungi production (Table 8). In ruminants,

Table 7 Volatile Fatty Acids of WAD goats fed turmeric supplemented diets at varying frequencies

Parameters	Control	Once a week	Alternate days	Daily	*P*-value
Acetic acid (mmol/100 ml)	7.29 ±0.25^{b}	9.34 ±0.25^{a}	9.63 ±0.52^{a}	9.96 ±0.97^{a}	0.043
Propionic acid (mmol/100 ml)	7.30 ±0.48^{c}	8.88 ±1.02^{b}	9.01 ±0.31^{ab}	9.20 ±0.43^{a}	0.0197
Butyric acid (mmol/100 ml)	6.67 ±0.24^{b}	8.59 ±0.30^{a}	8.61 ±0.92^{a}	8.48 ±0.22^{a}	0.03
Valeric acid (mmol/100 ml)	6.51 ±0.22^{b}	8.37 ±0.22^{a}	8.97 ±0.89^{a}	8.38 ±0.22^{a}	0.029
Lactic acid (mmol/100 ml)	8.97 ±0.30	11.27 ±0.33	12.30 ±1.19	11.66 ±0.30	0.369
TVFA (mmol/100 ml)	51.84 ±0.79^{c}	58.19 ±0.80^{c}	61.75 ±3.81^{b}	66.16 ±0.06^{a}	0.002
Ruminal fluid pH	6.67 ±0.09	6.07 ±0.07	6.00 ±0.10	5.90 ±0.06	0.001
NH_3N (%)	0.88 ±0.01^{a}	0.81 ±0.04^{b}	0.67 ±0.03^{c}	0.67 ±0.01^{c}	0.001

abc – means on the same row with different superscripts are significantly (P <0.05) different; TVFA – total volatile fatty acids; NH_3N – ammonia nitrogen

Table 8 Rumen microbial isolate of WAD goats fed turmeric supplemented diets at varying frequencies

Parameters	Control	Once a week	Alternate days	Daily
Total bacteria isolate	*Bacteria ruminicola*, *Bacteriodes amylop*, *Pseudomonas aureginosa*	*Micrococcus acidophilus*, *Klebsiella aerogens*, *Bacteria ruminicola*, *Clostridium welchii*	*Proteus morganii*, *Micrococcus acidophilus*, *Pseudomonas aureginosa*	*Clostridium welchii*, *Enterobacter aerogens*, *Streptococcus lactis*, *Bacteria cereus*
Total coliform isolate	*Escherichia coli*	*Escherichia coli*	*Escherichia coli*	*Escherichia coli*
Total fungi isolate	*Penicilium oxysporium*, *Fusarium oxysporum*	*Aspergillus niger*, *Fusarium oxysporum*	*Penicillium oxysporium*, *Aspergillus niger*	*Penicillium oxysporium*, *Aspergillus niger*

microorganisms break down the higher carbohydrates, cellulose, pentosans and starch (protein as well) to monosaccharides and then fermented to volatile fatty acids (VFAs) and methane. Further, microorganisms synthesize essential nutrients such as B-vitamins and amino acids. It is also noteworthy that rumen fungi initiates fibre fermentation. Hence, it could be observed that feeding frequency of TRP supplemented diet aided the production of VFAs (Table 7) which provide 60–80% of the metabolizable energy used by the animals. Consequently, rumen microbes – isolate and counts (Figure 2 and Table 8) were produced most in goats fed TRP supplemented diet on daily basis and thus, could have synergistic effect, as consortia, to attack and break down feeds – grass (*P. maximum*) for nutrients absorption and invariably optimum performance.

4 Conclusions

From the foregoing, it could be concluded that:

- Frequency of feeding turmeric rhizome powder supplemented diets to goats had significant influence on their general performance.
- It could also be concluded that daily supplementation of turmeric rhizome powder at 10 g/300 g increased voluntary dry matter intake, modulated the rumen microbes for best nutrients/nitrogen utilization, and weight gain compared to other feeding frequencies examined in this study.
- It could therefore be recommended that, goats' ration be daily supplemented with turmeric rhizome powder at 10 g/300 g feed for improved and sustained goat production.

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