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Dietary Supplementation with Spring Onion on Growth, Nutrient Utilization, Economic Analyses and *In Vitro* Methane Emissions in West African Dwarf Goats

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ABSTRACT: The study was conducted to determine the effect of dietary supplementation with spring onion on growth, nutrient utilization, economic analyses and *in vitro* methane emissions in West African dwarf goats. Two hundred and forty West African dwarf male goats aged between 7 to 8 months old with initial average live body weight of 7.00 ± 0.08kg were used for the study. They were randomly allotted to four dietary treatments with sixty goats per treatment in a completely randomized design. The prepared experimental diets that were received by goats contained ED_1 (60% guinea grass with no spring onion as the control group), ED_2 (59% guinea grass with 1% spring onion), ED_3 (58% guinea grass with 2% spring onion) and ED_4 (57% guinea grass with 3% spring onion). Firstly, the evaluation comprised *in vitro* study of methane gas production and then followed by *in vivo* study of growth, nutrient utilization and economic analysis of goats. In all the diets examined, results showed that *in vitro* ammonia nitrogen concentration(12.04 mg/100ml), total volatile fatty acids(4.01 mmol), acetate (64.93 mol/100mol), butyrate (12.09 mol/100mol), methane (71.22 mL/gDM), fractional rate of gas production(0.079h^{-1}), average gas production rate(3.04Ml/h), daily feed intake (256.29g/day), feed conversion ratio (6.15), digestibility of ether extract (65.05%), ash (68.01%), faecal with urinary nitrogen output(2.98 and 1.72g/day), total nitrogen output (4.78g/day) and total cost in naira (125,400) were significantly ($p<0.05$) higher in diet ED_1 than diets ED_2, ED_3 and ED_4. Goats on diet ED_4 were significantly ($p<0.05$) improved in propionate (25.67 mol/100mol), methane/total volatile fatty acids ratio (22.23), effective dry matter degradability(60.21g/kg), true dry matter degradability(74.52g/kg), final body weight(11.96kg), total with daily weight gain 4.99kg and 71.29g), digestibility of dry matter(72.43%), crude protein (70.86%), crude fibre (71.02%), nitrogen free extract(70.17%), neutral and acid detergent fibre(69.86 and 66.21%), nitrogen intake (11.05g/day), nitrogen balance and retained (8.08 and 0.73g/day), nitrogen retention % intake (73.12%), total revenue in naria (263, 270) and net profit in naria (169,020) than those on other diets. Meanwhile, no significant differences ($p>0.05$) were found in rumen pH, acetate/propionate ratio, iso-butyrate, valerate, iso-valerate, asymptotic gas production and initial body weight among treatments. It can be concluded that inclusion levels of 3 and 4% spring onion as supplement to 58 and 57% guinea grass with 40% concentrate diet (ED_3 and ED_4) improved performance of goats and suppressed *in-vitro* methane gas with cost reduction that resulted in higher net profit.

KEYWORDS: economic-analysis, goats, in vitro methane, performance, spring onion.

INTRODUCTION

The urgent issue that the world growing population is grappling with at or presently is the need to ensure an adequate supply of animal protein to prevent protein deficiency in human's nutrition. Protein deficiencies had led to malnutrition in both children and adult in developing countries as a result of increasing problems of food scarcity. However, the demand for food has increased as the human population continues to grow as highlighted by Adegun and Aye (2013). Hence, it is crucial to find a way to harmonize the finite food supply and the nutritional needs of the expanding global population considering scarcity of natural resources. Thus, there is a growing need to create new and innovative feeds strategy for goats as one of the sources of animal protein-rich food that are nutritious, economically feasible and easily accessible to humans. Goats are known to occupy a strategic position in food supply chain in the tropics, due to their ability to produce meat, milk and skin even in hostile environments. Regardless of these attributes, the quota contributed by goats in alleviating low animal protein intake by Nigerians as noted by Yusuf *et al*. (2018) is still below the predicted values. Poor nutritional status as a result of unavailability of sustainable feed quality has been the major constraint militating against goats from attaining optimum levels of productivity (Okoruwa *et al*., 2023). Most ruminant farmers depend on pastures and conventional feeds for feeding their animals. However, lack of constant supply in terms of quantity and quality of these feeds, most especially during the dry season brings major set-back in goat productivity. In attempt to alleviate these feed scarcity and looking forward for potential feed resources, particularly those with no stiff competition with human call for the use of alternative feedstuffs. In view of this, research has shown that there is necessity to search for unconventional feed materials by animal nutritionist that can meet the nutritional requirements of goats. However, significant portion of these alternative feeds remain poorly utilized due to high fibre content and methane production during rumen fermentation

Natural feed additives can manipulate rumen function to enhance nutritional quality of high fibrous feed intake, digestibility and reduce methane emission with nitrogen excretion in goats (Kongmun *et al*., 2011). Spring onion (*Allium cepa*) is such additive that has phytogenic components that contain anti microbial, cholesterolemic, anti-stress and anti-oxidative properties which enhance digestion. This justify spring onion application as phyto-chemical additive in ruminants that can modify rumen fermentation to reduce methane emission and enhance digestibility in the intestine (Phan and Le , 2024). Therefore, the study was to assess the dietary supplementation with spring onion on growth, nutrient utilization, economic analyses and methane gas production of West African dwarf goats.

MATERIALS AND METHODS

Study Area

The study was carried out at Sheep and Goat Unit of the Teaching and Research Farm, Faculty of Agriculture, Natural Resources and Food Science, Ambrose Alli University, Ekpoma, Nigeria. The duration was between August and October, 2023. The farm is located at 6.42^0N latitude and 6.09^0E longitude with an altitude of 240 meters (778ft) above sea level. The mean annual rainfall ranges from 1552mm to 1556mm with average annual minimum and maximum temperature of 27^0 C and 31^0 C respectively. The relative humidity was between 76% and 80% as highlighted by Oyewole *et al*. (2018).

Feed ingredients and experimental diets

Fresh spring onion was purchased from the selling location in Ekpoma market and cleaned to remove foreign materials. Guinea grass was cut at the university farm at re-growth stage of between 8 and 9 weeks and allowed to wilt overnight before they were both chopped with an electric forage cutter (forage SFC1400, Central Commercial Company, Osaka, Japan) separately into small sizes of approximately 4 to 5cm lengths to ease and improve feed consumption as basal diets. The concentrate supplement diet ingredients of 15.00% maize grain, 20.00% maize offal, 10.00% wheat offal, 5.00% cotton seed cake, 45.50% cowpea husk, 2.00% bone meal, 1.50% vitamin premix and 1.00% salt were procured simultaneously from the feed store throughout the experiment. The vitamin premix supplied the following per kg of complete diet: vitamin. A, 1,500IU; vitamln .D, 550 IU; vitamin E, 10 IU; Fe (as ferrous sulfate) 20mg, Mn (as manganese sulfate) 40mg, Zn (as zinc sulfate) 30mg, I (as potassium iodide) 0,05mg Se (as sodium selenite) 0.30mg, Co (as cobait chloride) 0.20mg. However, the diet was formulated to contain 12 CP% and 2488.00 metabolizaable energy Kcal/kgDM to meet the nutrient requirements of small ruminants based on the recommendation of NRC (2007). The experimental diets that were given inform of total mixed ration to goats consisted of 60% basal diets of guinea grass and spring onion with 40% concentrate supplementary diet. Hence, experimental diets were specifically prepared to implement varying levels of spring onion supplementation in basal diets that were denoted as ED_1 (60% guinea grass as the control group), ED_2 (59% guinea grass with 1% spring onion), ED_3 (58% guinea grass with 2% spring onion) and ED_4 (57% guinea grass with 3% spring onion). All goats received 40% concentrate supplementary diet irrespective of the experimental treatments.

In-vitro trail

Rumen content was collected from four adult male goats of about 7.00 ± 0.08kg body weight for inoculum donors for the *in-vitro* incubations. They were fed with guinea grass and concentrate supplement a day before the collection of rumen content. The rumen content from each of the four goats was collected before the morning feeding and pooled into the thermal flask and immediately taken to the laboratory. The rumen fluid was strained through- four layers of cheese cloth and mixed with a buffer solution in a 1:4 ratio (vol/vol) at 39^0C under continuous flushing with carbon (iv) oxide ($C0_2$). The time required from rumen content collection to inoculation of bottles was less than 30 minutes. The basal and concentrate supplement diets were mixed inform of total mixed ration similarly to the *in-vitro* trail. However, samples of the treatment diets were ground (1mm) before analysis for chemical composition and subsequently used as substrate in the *in-vit*ro runs. One 48 hours incubation runs was carried out and four bottles per treatment diet and four bottles without added diet (blanks) were incubated in each run. Blanks were used to contest the gas production values for gas release from endogenous substrate. Samples (0.500g) of diets were carefully weighted into 120ml bottles and 60ml of the buffered rumen fluid was anaerobically added into each bottle. Bottles were sealed with butyl rubber stoppers and aluminium caps and incubated at 39ºC in a water bath. In two of the four bottles for each diet and two blanks pressure and gas volume were measured at 2, 4, 6, 8,,,,,,, and 48th of incubation using a wide range pressure meter (Sper Scientific LTD, Scottsdale, AZ, USA and a glass-calibrated syringe. (Ruthe, Normax, Marinha Grande, Portugal), respectively. In the remaining two bottles of each sample, the gas produced after 24h of incubation was measured as described above and a gas sample (about 5ml) was stored in an evacuated tube (Terumo Europe N.V., Leuven, Belgium) for the analysis of CH_4. Bottles were then uncapped, the pH was measured immediately (Crison Basic 20 pH-meter, Crisson Instruments, Barcelona, Spain), the fermentation was stopped by placing the bottles in ice water, and the following samples were taken: 2ml was added to 2ml of deproteinising solution (20g of metaphosphoric acid and 0.6g of crotonic acid per litre) for volatile fatty acid (VFA) determination and 1ml was mixed with 1ml 0.5 M HCl for NH_3-N analysis.

***In-Vivo* trail**

Experimental animals, design and management

Two hundred and fourty West African dwarf male goats aged of about 7 to 8 months old with initial average live body weight of 7.00 ± 0.08kg were used for the study. They were sourced from Ekpoma local market. Pens were thoroughly cleaned with disinfectant before the arrival of goats. They were allowed to acclimatize for 14 days before the commencement of the feeding trail. During the adaptation period, goats were treated against ecto-parasites using Ivomec long acting antibiotics injection at 2ml/10kg body weight and vaccinated against pestes-des petits ruminant (PPR) using PPR vaccine. Goats were also deworned against endo-parasites using albendazole suspension (sambezole) that was administered orally at about 1ml/10kg body weight. Thereafter, animals were randomly assigned to four treatment groups of sixty animals each with three replicates of twenty animals per replicate on the basis of average body weight in a completely randomised design. They were housed in individual semi-open sided well-ventilated pens which were bedded with wood shavings and equipped with feeders and water troughs. All goats were maintained on common feeding regime that was fed twice daily at about 8:00am and 4:00pm. The quantity of the diet given to each goat was calculated on the basis of 5% of their body weight. They also had a free access to clean water throughout the study. The management practices of all animals irrespective of group were similar. The feed supply to goats was adjusted every seven days on the basis of their body weight changes. The trial lasted for 90 days with additional 14 days of adaptation periods.

Growth, nutrient digestibility and retention:

Daily weighed feeds were offered to goats; the leftover feeds, voided faeces and urinary output from previous day feed offered were separately collected, weighed and recorded daily. Goats were weighed at the commencement of the experiment and subsequently, followed by weekly weighing in the morning before feeding for eight weeks to observe any weight change using spring balance (hanging scale).

Metabolic trail was carried out by transferring goats to metabolism crates after growth study, for total faecal and urine collection. Goats had 7 days to adjust to the condition of the metabolism crates, followed by 7 days of faecal and urine sampling. During the sampling period, feed offered and refused, faecal and urine were collected daily. Then, the daily faecal output was quantified (amount of fresh matter) before 10% of the homogenised daily faecal output was sub-sampled and kept in plastic bags in the freezer (-20%) for analysis. However, the daily urine was collected into a plastic container placed under the metabolic crates that contained 100ml of 0.1 N H_2SO_4 to prevent loss of nitrogen due to volatilization. The collected urine was strained through a layer of grass wool to remove detached hair fragments and other solid contaminants. A 10% aliquot of the total daily urine output of each of the goats was stored in the refrigerator at 4^0 C for nitrogen determination (Osuji *et al*., 1993). All aliquots per animal were pooled after the experimental period for assay. However, apparent nutrient digestibility and nitrogen retention were determined by standard procedures outlined for direct estimation of animal digestibility (Ibrahim *et al*., 2018).

Economic efficiency measures

The important economic efficiency indices investigated were; cost, revenue and net profits. The cost parameters were, total fixed cost (TFC), total variable cost (TVC), and total cost (TC). Total fixed cost includes labour, cost of purchased goats, transportation with depreciation of equipment and pens that were calculated per animal for each group. Pens were depreciated over

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12 years while the equipment over 6 years. Hence, these parameters were considered fixed costs for each of the animal used in the study. Total variable cost consists of utility costs (water, communication and electricity), veterinary service/drugs and cost of feed ingredients with cost of spring onion. The cost price was estimated in Nigerian naira over the cost of the experiment.

Chemical Analysis

The proximate analysis of feeds, experimental diets and feaces with urinary nitrogen were conducted according to standard methods of AOAC (2005). The residual dry matter of the samples was determined by oven-drying at 105 °C for 18 h. Nitrogen was determined by the micro Kjeldahl method with Tecator Product apparatus (KjeltecTM2100). The Soxhlet extraction procedure was used for the analysis of ether extract using electromantle ME. The ash was measured by combustion of the dried material in a muffle furnace at 600 °C for 8 h. Crude fibre, sequential neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined using Tecator Line (FT 122 FibertecTM) according to the method described by Van Soest *et al*. (1991). Total nitrogen in feaces and urine was determined by the micro Kjeledahl method with Tecator Product apparatus (Kjeltect TM2100).

The CH_4 concentration was determined by gas chromatography (GC) using a HP Hewlett 5890, Packard Series II gas chromatograph (Waldbronn, Germany) equipped with a flame ionization detector (FID) and with an HP-INNOWAX cross linked polyethylene glycol column (25m x 0.2mm x 0.2µm). The carrier gas was He, and peaks were identified by comparison with a standard of known composition. A sample of 0.5ml of gas was injected using a 1ml Sample-Lock syringe (Hamilton, Nevada, USA). Total and individual VFA were analyzed by gas chromatography following the methodology described by Isac *et al*. (1994). The concentration of NH_3-N was determined following the colorimetric method of. using a spectrophotometer (Thermo Scientific, Genesys 10 µV Scanning, Madison, WI53,711 USA).

Calculation and Statistical Analysis

Feed intake was calculated by deducting the leftover feeds from the feed offered while weight gain of each goat was determined by the difference between the accumulated weight and the initial weight. However, total body weight gain was obtained by the difference between the accumulated weight and initial body weight, the average daily weight gain was obtained through the relationship between the total weight gain and total days of the growth study. Feed conversion ratio was calculated by the relationship between average daily feed intake and body weight gain. Nutrient Digestibility (ND) of diets were calculated for dry matter, crude protein, crude fibre, ether extract, ash, nitrogen free extract neutral and acid detergent fibre from each treatment diet using the equation proposed by McDonald *et al.* (2002).

$$ND\ \% = \frac{\text{Total amount of nutrients in feed} - \text{total amount of nutrients in faeces}}{\text{Total amount of nutrients in feed}} \times 100$$

Nitrogen balance was determined as the differences between nitrogen intake and nitrogen excreted from faeces and urine. The nitrogen retention percentage was estimated from the nitrogen balance expressed as a percentage of nitrogen intakes.

Total cost was calculated as the sum of total fixed cost and total variable cost (Hassan *et al.,* 2016). However, total revenue were values of final body weight and litter sale, while net profit was computed by finding the difference between the total revenue and total cost.

Thus, formula for calculations were; TC = TFC + TVC

TR = Quantity x Price

NP = TR -- TC, Thus, TR – (TFC + TVC)

The gas produced in batch cultures was adjusted to the exponential model: $y = A\ (1 - e^{(-c\ (t\text{-lag})})$, where y represents the cumulative gas production (mL), t the incubation time (h), A the asymptote (total gas; mL) and c the organic matter degradation rate (h^{-1}), and lag (h) is the initial delay in the onset of gas production and values of lag were zero for all samples. Thus, parameters A, c and lag used in the study were estimated. The average gas production rate (AGPR; mL gas/h) is defined as the average gas production rate between the start of the incubation and T1/2 and was calculated as AGPR = A c/[2(1n2 + c lag)]. Finally, the effective DM degradability (EDMD) was estimated assuming a rumen particulate outflow (Kp) of 0.03 per h according to the equation: $EDMD = [(TDMD\ c)/(c + Kp)]\ e^{(-c\ lag)}$.

The amount of VFA in the batch culture bottles after 24h of incubation both for control and experimental diets was corrected for VFA in the rumen liquid used as inoculums. The amount of CH_4 produced was calculated by multiplying the gas produced with its concentration in CH_4.

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Data obtained from *in-vitro* indices, growth, nutrient digestibility and retention with economics efficiency of feeding diets to goats were subjected to analysis of variance using the general linear model (GLM) procedure of MINITAB (2000) to determine the effect dietary treatments on the various parameters studied. Where significant treatment effects were found, means were separated by Duncan's multiple range (Steel and Torrie, 1990).

RESULTS

As seen in Table 1, feed ingredients and experimental diets were examined. Guinea Grass (GG) and Spring Onion (SO) were lower in dry matter than Supplement Diet (SD), while crude protein recorded higher content in SO and SD as compared with GG. The SD values were relatively lower in crude fibre and higher in ash than what were obtained in GG and SO. However, GG marked lower value in nitrogen free extract but higher values in neutral and acid detergent fibre than values obtained in SO and SD. Furthermore, experimental diets (ED) were varied according to the type and amount of feed ingredients used. Test diets (ED_3 and ED_4) showed similar and higher values for most of the parameters with exception of neutral and acid detergent fibre that were lower with remarkable difference from diets ED_1 and ED_2

Table 1: Chemical composition (%DM) of guinea grass, spring onion, supplement diet and experimental diets

Parameters	Feed Ingredients			Experimental Diets			
	GG	SO	SD	ED_1	ED_2	ED_3	ED_4
Dry matter	89.73	87.92	91.60	89.39	90.46	90.44	91.64
Crude protein	7.49	12.53	12.10	9.33	9.59	9.43	9.56
Crude fibre	32.07	21.92	18.47	26.63	26.53	26.43	26.65
Ether extract	2.36	1.26	4.08	3.05	3.03	3.03	3.04
Ash	6.74	5.85	10.21	8.12	8.12	8.11	8.17
Nitrogen free extract	46.34	55.06	55.14	49.86	49.95	50.14	50.59
Neutral detergent fibre	57.22	24.97	36.99	49.13	48.81	48.49	48.74
Acid detergent fibre	34.71	15.06	18.44	28.21	28.01	27.81	27.96

GG = *Guinea grass*, SO = *Spring onion*, SD = *Supplement diet*

Differences were noted in some rumen fermentation parameters and methane gas production after 24h of incubation in response to the experimental diets in batch cultures inoculated with rumen microbes from goats (Table 2). No significant ($p>0.05$) effect with regards to the experimental diets on rumen pH, acetate to propionate ratio, iso-butyrate, valerate and iso-valerate were observed in this study. Diets tended to affect ammonia nitrogen concentration; total volatile fatty acids, acetate, butyrate and methane with significant ($p<0.05$) higher values observed in control diet than test diets. However, molar proportion of propionate and methane to total volatile fatty acids ratio appeared to be increased significantly ($p<0.05$) in test diets as compared with control diet.

Table 2: Rumen fermentation profile and methane gas production after 24h of incubation of the experimental diets in batch cultures inoculated with rumen microbes from goats.

Parameters	Experimental Diets				
	ED_1	**ED_2**	**ED_3**	**ED_4**	**SEM±**
Rumen pH	6.72	6.75	6.79	6.80	0.05
NH_3-N (mg/100mL)	12.04^a	10.38^b	9.94^c	9.88^c	0.07
TVFAs (mmol)	4.01^a	3.54^b	2.37^c	2.28^c	0.03
Acetate (mol/100mol)	64.93^a	61.87^b	60.83^b	60.29^b	0.69
Propionate (mol/100mol)	22.74^c	24.63^b	25.07^a	25.67^a	0.34
Butyrate (mol/100mol)	12.09^a	10.87^b	10.58^b	10.31^b	0.27

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A/P ratios (mol/100mol)	2.86	2.51	2.37	2.35	0.03
Iso-butyrate (mol/100mol)	0.76	0.58	0.32	0.14	0.05
Valerate (mol/100mol)	1.91	1.90	1.67	1.47	0.02
Iso-valerate (mol/100mol)	1.22	1.18	1.15	1.10	0.03
Methane (mL/gDM)	71.22^{a}	59.64^{b}	51.03^{c}	50.68^{c}	0.54
Methane/TVFAs ratios	17.76^{b}	16.85^{b}	21.53^{a}	22.23^{a}	0.28

^{a,b,c} Means in the same row without common superscript differ at p< 0.05, SEM = Standard error of mean, NH_3-N = Ammonia nitrogen concentration, TVFAs = Total volatile fatty acids, A/P ratios = Acetate:Propionate ratios

There was no significant (p>0.05) difference observed for asymptotic gas production (A) in Table 3, as no effect of diets were found in it. Fractional rate of gas production c(h^{-1}) and average gas production rates (AGPR) were significantly (p<0.05) increased in control diet as compared to test diets. Effective dry matter degradability (EDMD) and true dry matter degradability (TDMD) were observed to have significant (p<0.05) higher values in diets ED_3 and ED_4 than what were obtained in diets ED_1 and ED_2.

Table 3: *In–vitro* gas production kinetics and dry matter digestibility after 48h of incubation of the experimental diets in batch cultures inoculated with rumen microbes from goats

Parameters	Experimental Diets				
	ED_1	**ED_2**	**ED_3**	**ED_4**	**SEM±**
A (mL)	71.21	71.00	71.00	71.00	0.69
c (h^{-1})	0.079^{a}	0.068^{b}	0.065^{b}	0.062^{b}	0.02
AGPR (mL/h)	3.04^{a}	2.62^{b}	2.55^{b}	2.32^{b}	0.03
EDMD (g/ kg)	57.04^{b}	57.87^{b}	58.96^{ab}	60.21^{a}	0.78
TDMD (g/ kg)	69.23^{b}	69.92^{b}	70.83^{ab}	74.52^{a}	0.84

^{a,b,c} Means in the same row without common superscript differ at p< 0.05, , SEM = Standard error of mean, A = Asymptotic gas production, c = Fractional rate of gas production, AGPR = Average gas production rate, EDMD = Effective dry matter degradability for a rumen particular outflow of 0.03/h, TDMD = True dry matter degradability.

Daily feed intake and feed conversion ratio were observed to be significantly (p<0.05) lower for goats on test diets compared with control diet (Table, 4). There were no significant (p>0.05) differences in the initial body weight of goats on the four diets. Remarkable differences were more pronounced significantly (p<0.05) in final body weight with goats receiving diets ED_3 and ED_4 higher than those on diets ED_1 and ED_2. Total and daily weight gains during the trial followed the same trend as observed in final body weight.

High significant (0<0.05) digestibility of dry matter, crude protein and crude fibre were obtained in goats fed the test diets than those receiving control diet. Digestibility of ash was better in diets ED_1, ED_2 and ED_3 than diet ED_4. Apparent digestibility of nitrogen free extract, neutral and acid detergent fibre were also significantly (p<0.05) improved in the trend of test diets except for ether extract digestibility that was higher for control diet.

Nitrogen intake was significantly (p<0.05) better for goats fed diet ED_4 compared with goats receiving diets ED_1, ED_2 and ED_3. Nitrogen in faeces, urinary and total output for goats were significantly (p<0.05) affected by diets being higher for control diet as compared with test diets. Nitrogen balance and retention % intake in goats recommended higher significant values in test diets than the control diet. Nitrogen retained g/day in goats observed in this study was not significantly (p>0.05) affected by experimental diets.

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Table 4: Growth performance, nutrient digestibility and nitrogen retention in goats fed experimental diets

Parameters	Experimental Diets				
	ED_1	**ED_2**	**ED_3**	**ED_4**	**SEM±**
Growth Performance					
Daily feed intake, g/day	256.29[a]	239.86[b]	238.66[b]	236.49[b]	1.98
Initial body weight kg	7.20	7.10	7.03	6.97	0.05
Final body weight kg	10.12[b]	11.01[a]	11.74[a]	11.96[a]	0.07
Total weight gain kg	2.92[c]	3.91[b]	4.71[a]	4.99[a]	0.04
Daily weight gain g	41.71[c]	55.86[bc]	67.29[b]	71.29[a]	0.72
Feed conversion ratio #	6.15[a]	4.29[b]	3.55[c]	3.32[c]	0.03
Nutrient Digestibility %					
Dry matter	62.73[c]	65.14[bc]	69.97[b]	72.43[a]	0.72
Crude protein	60.21[c]	67.30[b]	70.52[a]	70.86[a]	0.68
Crude fibre	61.43[c]	66.09[b]	69.85[ab]	71.02[a]	0.81
Ether extract	65.05[a]	56..73[b]	53.62[c]	51.11[c]	0.72
Ash	68.01[a]	67.98[a]	67.03[a]	65.98[b]	0.59
Nitrogen free extract	60.22[c]	67.39[b]	70.16[a]	70.17[a]	0.79
Neutral detergent fibre	59.37[c]	64.00[b]	68.15[a]	69.86[a]	0.83
Acid detergent fibre	56.61[c]	61.14[b]	63.11[b]	66.21[a]	0.66
Nitrogen Retention					
Nitrogen (N) intake (g/day)	10.53[b]	10.78[b]	10.99[b]	11.05[a]	0.09
Feacal - N - output (g/day)	2.98[a]	2.63[a]	2.20[a]	1.99[b]	0.05
Urinary – N – output (g/day)	1.72[a]	1.43[b]	1.19[b]	0.98[c]	0.02
Total –N – output (g/day)	4.78[a]	4.06[a]	3.39[b]	2.97[c]	0.04
Nitrogen balance (g/day)	5.83[c]	6.72[b]	7.58[ab]	8.08[a]	0.06
Nitrogen retained (g/day)	0.55[c]	0.62[b]	0.69[b]	0.73[a]	0.03
Nitrogen retention % intake	55.37[c]	62.34[b]	68.97[b]	73.12[a]	0.25

[a,b,c] Means in the same row without common superscript differ at p< 0.05, SEM = Standard error of mean, # =Feed intake/live weight gain

Table 5 shows the economic efficiency of goats on diets containing varied levels of spring onion. Cost of goats, total fixed cost and total cost had significantly ($p<0.05$) higher values in goats placed on control diet than those on test diets. Remarkable difference in sales of goats, total revenue and net profit were more pronounced significantly ($p<0.05$) with goats on test diets than control diet. Values of feed cost, total variable costs and recreational purposes were found to be significantly ($p<0.05$) higher in goats on diets ED_2 and ED_3 as compared with goats on diets ED_1 and ED_4.

Table 5. Economic efficiency of feeding diets containing spring onion to goats.

	Experimental Diets				
Item (Naria/animal)	**ED_1**	**ED_2**	**ED_3**	**ED_4**	**SEM ±**
Fixed Cost					
Depreciation of equipment	3000	3000	3000	3000	1.07
Depreciation of pen	4000	4000	4000	4000	1.08
Labour	7000	7000	7000	7000	1.21
Cost of goats	108,000[a]	97,020[b]	92,400[b]	72,380[c]	1.56
Transportation	5,000	5,000	5,000	5,000	0.97
Total fixed costs (TFC)	105,950[a]	96,850[b]	92,950[b]	76,050[c]	1.94
Variable Cost					

Utility Cost	3,050	3,050	3,050	3,050	0.89
Veterinary drugs	4,000	4,000	4,000	4,000	1.07
Feed cost	12,400[b]	15,000[a]	14,400[ab]	11,200[c]	0.89
Total variable costs (TVC)	19,450[b]	22,050[a]	21,450[ab]	18,200[c]	1.32
Total cost (TC)	125,400[a]	15,900[c]	114,400[b]	94,250[bc]	1.49
Revenue					
Sales of goats	210,000[c]	238,000[b]	240,800[bc]	252,000[a]	1.92
Sales of litter	7,870	7,870	7,870	7,870	0.56
Recreational purposes	3,250[c]	4, 150[a]	4,100[a]	3,400[b]	0.77
Total revenue (TR)	221,120[c]	250,020[b]	252,770[b]	263,270[a]	1.96
Net profit (NP)	95,720[c]	131,120[b]	138,370[b]	169,020[a]	1.43

[a,b,c] Means in the same row with varying superscript differ significantly ($P < 0.05$)
SEM = Standard error of mean,

DISCUSSION

Feed Composition

The proximate analyses of guinea grass and spring onion in this study were comparable with the range values reported in literature by Okoruwa *et al.* (2023) and Pham Tan Nha and Le Thu Thuy (2024) respectively. Differences noticed in nutrient content for supplement and experimental diets were traced to differences in feed ingredients and quantity of nutrient supplied by the feeds. Furthermore, the experimental diet values recorded in this study were within the recommended values by NRC (2007).

In Vitro

The average rumen pH value of 6.83 recorded in this study was above the minimum threshold of 6.58 reported by Idan *et al.*(2023). This implies that the effect of phytogenic compounds in spring onion in test diets did not lower rumen pH but improved the optimal pH condition for better fermentation. It has been docummented by Sarkwa *et al.*(2023) that low rumen pH of 5.5 inhibits access of bacteria flow and enzymes to protein which subsequently reduced rumen microbial growth. The notable decrease in ammonia nitrogen concentration, in the presence of diets with spring onion could be a function of reduction in protein degradability and amino acids deamination by bacteria or protozoa in the rumen. Several studies (Idan *et al.*, 2023; Sarkwa *et al.*, 2023;) with small ruminants revealed that ammonia nitrogen concentration in the rumen ranged between 1 and 14mg/100ml, suggesting that the values obtained in this work were within the optimum microbial activity in the rumen. Total volatile fatty acids and acetate reduction also noticed in diets with spring onion corresponded with the low fractional and average gas production rate in Table 3. This could be influenced by dietary carbohydrate, test ingredient and degradability were function of protein availability and cellulose degradation (Soroor and Moeini, 2015). The increased in molar proportion of propionate with addition of spring onion indicates increase in efficiency of modify rumen microbial activity by directing the formation of propionate and reduced butyrate production. This supports the previous findings of Suharti *et al. (*2011) that *in vitro* data of lerak extract modify the composition of rumen bacteria that increase propionate but decrease butyrate. This increase in propionate production could also reduce the supply of hydrogen and competes with methanogenic bacteria to lower methane production as seen in Table 2. The improved methane/ volatile fatty acids ratio observed with the test diets could be used as an indicator of the efficiency of rumen fermentation, since the host animal derived energy from volatile fatty acids and substrates for synthesis of other compounds as noted by Lind *et al.* (2020). Moreover, acetate to propionate ratio, iso-butyrate, valerate with iso-valerate that was low and indicated no difference among diets showed that much of the energy was not derived from the protein degradation (Suharti *et al.*, 2015).

No difference was found in asymptotic gas production (A), this signifies that *in vitro* degradation of substrate samples was almost similar for the four experimental diets, confirming that inclusion of spring onion as supplement to basal diet of guinea grass did not compromise rumen fermentation. This confirms the report of Lind *et al.* (2020) who found that diets including white clover, soybean meal or *porphyra spp* did not reduce the extent of fermentation compared with the control diet. However, fractional rate of gas production (c) and average gas production rate (AGPR) were slightly lower for diets containing spring onion, this could probably be due to reduction of microbial activity and low volatile fatty acids production (Vanegas *et al.*, 2017).

However, effect dry matter degradability (EDMD) and true dry matter degradability (TDMD) that were better in substrate samples of test diets indicated that the test ingredient improved rumen outflow for better degradability than the control diet. In contrast to Lind *et al*. (2020) who noted that diets including white clover, soybean meal or *porphyra spp* did not have advantage over the control diet *in vitro* study.

In vivo

Goats on diet with no spring onion supplement consumed more than those on diets with spring onion supplement. This difference could be attributed to the organosulfur compounds, flavonoids and phenolic acids in onion that reduced the acceptability of the diets. In contrast to the report of Chouhan *et al*. (2023) who noted that garlic supplementation in goat diets did not affect their feed intake. However, goats placed on test diets (ED_2, ED_3 and ED_4) had heavier final and total weight change with daily weight gain than the control diet (ED_1). This improvement in weight might be a reflection of dense nutrient content and phytogenic compounds in the diets that aid efficiency in utilization of feeds. However, the average daily weight gain obtained in this work was higher than 54.69g/day for goats fed garlic supplement as reported by Chouhan *et al*. (2023). The animals on test diets had lower feed conversion ratio as compared with the control diet, implying that that spring onion supplementation had positive influenced on feed conversion efficiency in the study.

It was apparent that supplementation of spring onion to diets effectively increased the digestibility of dry matter and crude protein than the control diet. This difference might be attributed to the positive association effect of the bioactive components of the onion and similarity in their total dry matter intake. It has long been recognized that there is positive relationship between feed digestibility and feed intake by ruminants (Mc Donald *et al*., 2002). Digestibility of crude fibre, nitrogen free extract, neutral and acid detergent fibre was also positively influenced by the test ingredient. The presence of phenolic components in the diets might have led to the higher solubility of cell wall fraction content as well as the positive association effect of nutrient intake. Mc Donald *et al*. (2002) noted that crude fibre with its fractions in a feed has the greatest influence in its digestibility. Test diets were also seen competing favourably with the control diets in ash digestibility but ether extract digestibility was negatively related in the test diets. The reason for this adverse effect could presumably depend on phyto-chemical compounds in the diets that probably disrupted the activity of enzymes reaction in the rumen by forming an indigestible complex for fat and oil degrading components.(Brhanu and Gebremariam, 2019)

Result in Table 4 also illustrated that inclusion of spring onion in diets had positive effect, as they improved nitrogen intake and balance with reduction in faecal, urinary and total nitrogen output in goats. This result favours the absorption and retention of nitrogen that led to improvement of nitrogen utilization efficiency in goats on diets ED_3 and ED_4. This observation might be attributed to complementary/synergistic effects of the combination of the test ingredient and guinea grass used in the study. However, nitrogen retention as a percentage of intakes which is a major indicator for protein nutrition also tended to be positively affected in goats on test diets. Ibrahim *et al*. (2018), stated that high protein retention in goats is related to high biological values of protein readily digestible and absorbable. This higher positive nitrogen yield and heavier average daily weight gain obtained in goats on test diets could probably be linked with the low ammonia nitrogen concentration, average *in vitro* gas production, methane and high crude protein digestibility observed in Tables, 2, 3 and 4 respectively.

Results on Table 5 showed that there were obvious differences among goats on experimental diets in attempt to explain the relationship between total cost and net profit of goats using their performance strategies under intensive condition. Based to the data obtained using market prices, goats on diets with spring onion were quite higher in performance and generated better net profit than other goats on control group. The lower total cost per goat on diets with spring onion in this work was consistent with the work of Okoruwa *et a*l. (2021) on sheep. This shows that each kilogram of weight gain of goats at higher levels of spring onion inclusion in diets would be produced at a lower cost, thus reflecting higher efficiency in production with revenue and profit yields. Okoruwa et al. (2021); Yusuf *et al.,* (2018): Adegun and Aye, (2013) noted in their studies that natural feed additives are cost-effective nutrient sources that can be used in small ruminants feeding.

CONCLUSION

From the results, it can be deduced that spring onion supplementation in diets as measured by *in vitro* suppressed average gas production, ammonia nitrogen concentration, volatile fatty acids and methane but improved molar proportion of propionate and dry matter degradability.

However, dietary supplementation of spring onion at different levels in goat diets as seen *in vivo* study significantly improved nutrient digestibility, nitrogen retention and daily weight gain for better performance. Notwithstanding, this performance was more pronounced in goats on diets ED_3 and ED_4 than other diets.

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