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THE IMPACT OF SUPPLEMENTING PROBIOTICS AND CONCENTRATE ON INTAKE, NUTRIENT DIGESTIBILITY, AND NITROGEN BALANCE IN SAHELIAN GOATS FED A BASAL DIET OF *BRACHIARIA DECUMBENS* GRASS

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ABSTRACT

Four Sahelian bucks aged 24-26 months with a mean weight of 18.86±0.06 kg fed Brachiaria decumbens grass as a basal diet were used to investigate the supplementation effects of probiotics and concentrates relative to feed intake, nutrient digestibility, as well as nitrogen utilisation. The bucks were arranged in a 4 × 4 repeated Latin Square Design, consisting of four periods, each lasting 14 days. All bucks were adjusted to the test diets and handling conditions in metabolism cages for 2 weeks. The test diets consisted of P_0C_{500} (500 g/d concentrate without probiotics), P_0C_{1000} (1000 g/d concentrate without probiotics), $P_{100}C_{500}$ (probiotics at 100 g/100 kg of concentrate, 500 g/d concentrate), and $P_{100}C_{1000}$ (probiotics at 100 g/100 kg of concentrate, 1000 g/d concentrate). Throughout the experiment, the bucks had unfettered access to water and feed. Total amounts of urine and faeces were gathered during the final 7 days of each period for computation of nitrogen balance. Analysed results indicated that intake of basal diet was not affected ($P > 0.05$) by treatments imposed. However, increases ($P< 0.05$) in intake of water, total dry matter, and apparent digestibility of all nutrients except ash, nitrogen-free extract, and cellulose were observed. Nonetheless, nitrogen intake, digestibility, and retention in bucks on treatments P_0C_{1000} and $P_{100}C_{1000}$ were higher ($P<0.05$) compared to other treatments. Faecal nitrogen excretion was greater ($P<0.05$) than nitrogen excreted through urine. Nitrogen balance was positive across all treatments. It was concluded that supplementing probiotics and protein/energy concentrate at 1000 g/d positively influenced total intake of dry matter, nutrient digestibility, nitrogen balance, and nitrogen utilisation. Adoption of the feeding strategy of supplementing probiotics-fortified concentrates is recommended as it can offer a practical approach to improving goat productivity.

Keywords: Brachiaria decumbens, concentrate, digestibility, nitrogen balance, probiotics.

INTRODUCTION

The nutrient and energy content of livestock feed is dependent largely on digestibility, which influences intake (Norrapoke and Pongjongmit 2025). Feed intake and digestibility in turn determine the productive performance of livestock on a particular feed (Getachew *et al.* 2004; Sarkwa *et al.*,2020a; Adogla-Bessa *et al.*, 2022). Differences among livestock utilising the same diet are lower for digestibility than for feed intake, which is why digestibility is normally predicted more accurately than feed intake (Solaiman and Shoemaker 2009). Nonetheless, feed intake is seen as a more essential parameter for estimating forage quality and livestock performance (Coleman and Moore 2003; Sarkwa *et al.*, 2021).

Nitrogen is an essential requirement for microbial protein synthesis, which is a necessity for enhancing production (Ibrahim *et al.* 2016). Efficient nitrogen utilisation is necessary to prevent environmental nitrogen pollution. Excessive nitrogen release can cause acid deposition, eutrophication, respiratory issues, and climate change (Hristov *et al.* 2019), as well as air and groundwater pollution (Pfeffer *et al.* 2009). Nitrogen balance trials are used to determine how well animals maintain sufficient protein balance (Min *et al.* 2015). A positive nitrogen balance occurs when nitrogen intake exceeds nitrogen loss, indicating adequate protein synthesis and retention in the body. Goat productivity can be enhanced with concentrate supplementation (Madibela and Segwagwe 2008), as poor-quality diets with low digestible energy lead to negative nitrogen balance and reduced protein. In such situations, supplementation with fodder tree leaves (Idan *et al.* 2020; 2023) or concentrates may help boost digestibility and nitrogen retention (Abdul Aziz *et al.* 2023). Several agro-industrial by-products can be utilised in formulating home-made concentrates for ruminants, one of which is millet mash residue - an underutilised by-product from the production of 'Koko', a traditional Ghanaian porridge. With a crude protein content of 13.93% (Okai *et al.,* 2005), millet mash residue holds promise as a valuable ruminant feed supplement.

Probiotics improve gut health by promoting the growth of healthy microbiota, inhibiting harmful pathogens, enhancing colonisation of cellulolytic bacteria, boosting digestibility and mucosal immunity, and lowering the pH (Uyeno *et al.* 2015). They also enhance nutrient utilisation (Soren *et al.* 2013). Improving digestive capacity will most likely result in a better nitrogen balance. Consequently, this work sought to assess the impacts of supplementing probiotics and concentrates on dry matter intake of feed, nutrient digestibility coefficients, and nitrogen balance of Sahelian bucks fed *Brachiaria decumbens* as a basal diet.

MATERIALS AND METHODS

Location of experiment

The research was conducted at the Department of Animal Science, Kwame Nkrumah University of Science and Technology (KNUST), located at 6.6745° N, 1.5716° W in Kumasi, Ghana from April to June 2022. With an average annual rainfall of about 1194 mm and average maximum and lowest temperatures of 32.0 °C and 22.1 °C, respectively, the area exhibits a bimodal rainfall distribution (Ghana Meteorological Agency Station, KNUST 2022). All chemical analyses of feed, faeces, and urine samples were carried out at the Nutrition Laboratory of the afore-mentioned department.

Sources of feeds and probiotics

The grass basal diet consisted of *B. decumbens* regrowth, harvested after 60

days from pastures at the department. *B. decumbens* was chosen to highlight its potential, as it remains underutilised in Ghana despite its high nutritional value, ease of propagation, and high yield. Analysed chemical composition of *B. decumbens* is shown in Table 1.

Table 1: Proximate, fibre fractions and energy content (metabolisable) of air-dried *B. decumbens*

Chemical fraction	Analysed Value
Dry matter (g/kg)	875.0
Crude protein (g/kgDM)	95.0
Ether extract (g/kgDM)	58.0
Ash (g/kgDM)	67.4
Nitrogen-free extract (g/kgDM)	351.6
Neutral detergent fibre (g/kgDM)	606.5
Acid detergent fibre (g/kgDM)	335.0
Cellulose (g/kgDM)	260
Hemicellulose (g/kgDM)	271.5
Acid detergent lignin (g/kgDM)	75
*Metabolisable energy (kcal/kg)	1887.92

*** Calculated based on Pauzenga (1985), where metabolisable energy (ME) in kcal/kg is given by: ME = (35 × % crude protein) + (81.8 × % ether extract) + (35.5 × % nitrogen-free extract).**

The homemade protein-energy concentrate was compounded mainly from wheat bran and millet mash residue with small amounts of salt, oyster shell, and premix containing vitamins and minerals. The concentrate's composition and analysed chemical fractions are detailed in Table 2. These ingredients were sourced locally and thoroughly mixed manually on a pristine cemented floor, replicable by local livestock farmers.

Table 2: Feed ingredient inclusion levels and analysed composition of the concentrate supplement

Feed Ingredient	Dietary Inclusion level
Millet mash residue (g/kg)	485.0
Wheat bran (g/kg)	485.0
Vitamin Mineral Premix[1] (g/kg)	10.0
Oyster shell (g/kg)	10.0
Common salt (g/kg)	10.0
Total	1000
Analysed Composition	
Dry matter (g/kg)	860.0

Crude protein (g/kg DM)	165.0
Crude fibre (g/kg DM)	90.7
Ether extract (g/kg DM)	31.0
Ash (g/kg DM)	94.0
Nitrogen-free extracts (g/kg DM)	473.0
Neutral detergent fibre (g/kg DM)	356.0
Acid detergent fibre (g/kg DM)	120.0
Cellulose (g/kg DM)	97.0
Hemicellulose (g/kg DM)	236.0
Acid detergent lignin (g/kg DM)	23.0
*Metabolisable energy (kcal/kg)	2510.2

*** Calculated based on Pauzenga (1985), where metabolisable energy (ME) in kcal/kg is given by: ME = (35 × % crude protein) + (81.8 × % ether extract) + (35.5 × % nitrogen-free extract).**

The probiotic supplement was initially weighed and combined with 100 g of concentrate, mixed thoroughly, and then blended into the remaining portion of the compounded concentrate. This step ensured an even distribution of the probiotics throughout the concentrate. The probiotics, a multi-strain commercial product (Vicbinzy Powder, from Hebei Weierli Pharmaceutical Group Co., Ltd., China), were procured from a local supplier in Kumasi. The product contained *Lactobacillus delbrueckii* subsp. (1.8 x 109 cfu/g), *Clostridium butyricum* (≥ 5.0 x 107), and *Bacillus subtilis* (1 x 109 cfu/g).

Housing, feeding and management

The grass basal diet, *B. Decumbens* grass, was cut daily, chopped (5-10cm) with a cutlass, and fed at 50 g/kg of live weight in metabolism crates specifically crafted to separately collect faeces and urine voided. The individual metabolism cages measured 0.7 x 1.2 m. Each cage contained a wooden feed trough measuring 90 cm x 60 cm x 60 cm, divided into two sections for the grass basal diet and concentrate, along with a plastic bucket used as a water trough. The concentrate was given 2 hours before the grass to enhance consumption. Samples of the fresh grass diet were evaluated for dry matter weekly and used for adjustment of the daily offer. Orts were collected daily in the morning and weighed to determine intake of both the basal diet and supplement. Clean water was available *ad libitum.* The bucks were dewormed using Albendazole (Albazol 10% - Pyvet Holland, containing 100 mg albendazole per ml) and treated for ectoparasites with a 12% Cypermethrin pour-on solution (Hebei New Century Pharmaceutical Company Limited, China).

Experimental design and treatments

Four Sahelian bucks, averaging 18.86 ± 2.12 kg in weight and approximately 25 months in age, were assigned randomly to the four imposed dietary treatment sequences in a 4 × 4 Latin Square Design with the dietary treatments arranged as a 2x2 factorial. The Latin Square Design was chosen to ensure efficient use of resources (multiple treatments with fewer animals) and minimise variability among experimental units. The treatments imposed were designated P_0C_{500} (500 g/d of concentrate without probiotics), P_0C_{1000} (1000 g/d of concentrate without probiotics), $P_{100}C_{500}$ (probiotics at 100 g/100 kg of concentrate with 500 g/d

of concentrate supplement), and $P_{100}C_{1000}$ (probiotics at 100 g/100 kg of concentrate with 1000 g/d of concentrate supplement). All bucks were provided with *B. decumbens* as their basal diet.

Every period lasted 14 days, with 7 days for adaptation, enabling the bucks to adjust to the new treatments, followed by 7 days dedicated to data collection. The bucks were allowed to rest for 7 days after each period to clear their guts from the previous treatment diet. During this time, the bucks were housed individually in pens measuring 3 m x 1 m within the same pen that housed the metabolism cages to allow for some exercise and were fed *B. decumbens* grass, wilted for 24 hours, without any supplementation.

Measurements: Data collection and sampling

Initially, the bucks were given 14 days to adapt to their diets and handling conditions. Afterwards, they were fed the treatment diets in four successive periods.The collection of total faeces voided and urine discharged occurred from the 8th to the 14th day. Daily faecal samples were weighed and 10% were sampled for storage at -15°C in labelled plastic bags for later chemical analysis. After each period, faecal samples were defrosted and mixed by treatment to create composite samples. The composite samples were weighed, dried, milled, and bagged for chemical analysis. Urine samples were gathered in transparent plastic containers under each metabolism cage, with 100 mL of 0.2N HCl added daily to avoid loss of nitrogen through volatilisation and to stabilise urinary ammonia. Ten per cent of the daily urine volume was stored in labelled plastic bottles in a deep freezer at 5°C. After the 7-day collection period, all urine samples for each buck were combined and sub-samples were taken for the determination of nitrogen (N).

The following formulae were used to quantify N excretion and retention: N digested = N intake - Faecal N; N retained/retention = N intake - (Faecal N + Urinary N); N digestibility = (N intake - Faecal N)/N intake × 100; N retention as % of N intake = (N retained/N intake) x 100; N retention as % of N digested = (N retained/N digested) × 100.

Chemical analyses

All feed and faecal samples were chemically analysed for their proximate components and fibre fractions following the methods outlined by the Association of Official Analytical Chemists (1990) and Goering and Van Soest (1970), respectively. Urine samples were also analysed for nitrogen and used to quantify nitrogen excretion.

Animal care and welfare

The Animal Research Ethics Committee (AREC, 2018) of KNUST's Quality Assurance and Planning Unit approved the study. The approval number assigned was KNUST 0027. All of the Committee's standardised operating procedures were followed.

Statistical analysis

Data generated from calculated nutrient digestibility coefficients, nitrogen balance and utilisation were analysed using a one-way Analysis of Variance with the Glimmix procedure in SAS (2016) in a replicated 4 × 4 Latin Square Design following the statistical model outlined below:

$$Yij(k) = \mu + Pi + \tau j + A(k) + \varepsilon ij(k)$$

Where, Yijkl = measured dependent variable;

μ = overall mean;

Pi = fixed effect period i (i = 1,..,4);

$\tau(j)$ = fixed effect of diet j (j = 1,.,4);

$A(k)$ = random effect of an animal;

$\varepsilon ij(k)$ = residual variation

Tukey's pairwise comparison was used to separate the treatment means. A 5 % probability threshold was established for the declaration of significance.

RESULTS AND DISCUSSION

Chemical Composition of Diets

The CP level (95 g/kg) of *B. decumbens* basal diet fell between 66.8 to 116.8 g/kg DM (Mutimura and Everson, 2012) and 88.88 to 113.83 g/kgDM (Osafo *et al.,* 2023) for *B. decumbens* harvested at 60 and 120 days, respectively. It is noteworthy that the current CP content is higher than 7% or 70 g/kg DM critical level necessary for the sustenance of rumen microbes (Lazzarini *et al.* 2009). The current neutral detergent fibre (NDF) level (606.5 g/kg DM) was lower than the 695.6 g/kg DM and 720 g/kgDM observed by Lima *et al.* (2002) and Maia *et al.* (2014) respectively for the same grass. The present level was desirable as elevated levels of NDF increase the fibrous nature of grasses, which increases retention time in the rumen and ultimately lowers the intake of feed. Similarly, the present acid detergent fibre (ADF) content (335.0 g/kg DM) was lower than 396.6 g/kg DM (Maia *et al.*, 2014). Forages containing 40% or more ADF exhibit low digestibility, resulting in sub-standard performance (Nussio *et al.,* 1998; Costa *et al.,* 2005). Thus, the present ADF content which was less than 40% was good. The present estimated metabolisable energy (ME) content was, however lower than 2,245.15 kcal/kg reported by Aregheore (2001) and below the standard threshold of 2000.48 kcal/kg reported in 1975 by the Animal Branch of the National Council of Science and Technology. Thus, forages with ME exceeding 2000.48 kcal/kg or 8.37 MJ/kg DM are considered to be of good quality. Variations in chemical composition and ME could result from the maturity of the plant (Rambau *et al.,* 2016; Osman *et al.,* 2019), differences in species, the fertility level of the soil, as well as conditions of climate (Sarkwa *et al.,* 2020b).

The locally prepared concentrate used to supplement the grass was formulated to supply 160 g/kg CP and 2863.3 kcal/kg DM as recommended by Otaru *et al.* (2020). The current contents of CP, NDF, and ash were comparable to the 163.0 g/kg, 364.0 g/kg, and 90.0 g/kg, respectively, reported by Otaru *et al.* (2020) for concentrates fed to goats. The ADF and ME levels (250.0 g/kg and 2863.3 kcal/kg respectively) stated by the last-cited authors however, exceeded the corresponding values found in the present study. Except for ash content, the proximate fractions (890, 200, 40, 130 and 575 g/kg for DM, CP, EE, CF, and NFE respectively) of a commercial supplement for goat kids fed by Singh and Sharma (2019) were all higher than those in the present study. Similarly, a concentrate formulated for Afar goats had 258.0 g/kg, 498.0 g/kg, and 224.0 g/kg for CP, NDF, and ADF, correspondingly (Seid-Hassen *et al.,* 2020), which were all higher than the corresponding values in the current study. The variations in chemical compositions of the concentrates observed could be attributed to the different ingredients and their proportions used in the respective formulations (Osman *et al.,* 2023). However, the CP content of the concentrate exceeded the 100–120 g/kg DM recommended by Gatenby (2002) for moderate growth in small ruminants. It also surpassed the minimum CP requirement of 70 g/kg DM necessary to maintain rumen microbial activity, as stated by Lazzarini *et al.* (2009).

Effects of probiotics and concentrate supplementation on intake and live weight changes.

Effects of the treatment diets imposed on live weight changes and feed intake

of bucks are shown below in Table 3. Initial and final live weights of the bucks showed no significant (P > 0.05) difference. Supplementing higher levels of probiotics and concentrate, however, resulted in significant improvements (P < 0.05) in average daily gain and total weight gain (TWG).

A significant (P < 0.05) effect of the treatments imposed was observed for average daily gain (ADG). ADG increased progressively from 67.86 to 79.76 g with higher inclusion levels of probiotics and concentrate. According to Dutta *et al.* (2009), probiotics stimulate specific beneficial microbial populations in the rumen, which likely contributed to the observed improvement in ADG. The upward trend in ADG due to concentrate supplementation aligns with findings reported by Madibela and Segwagwe (2008) and Osman *et al.* (2023). Among the groups that received both probiotics and concentrate, those supplemented with higher levels of concentrate recorded significantly (P < 0.05) greater ADG, as shown in Table 3. A comparable pattern was reported by Singh *et al.* (2015), where goats fed both concentrate and a microbial feed additive achieved the highest ADG (76.54 g), surpassing those fed concentrate alone (69.90 g). The ADG range recorded in this study (67.86–79.76 g) exceeded the 37.5–40.3 g/day reported for Black Bengal goats by Kabir *et al.* (2002). Additionally, the highest ADG recorded (79.76 g) surpassed the 69.9 g/day obtained by Patterson *et al.* (2009) using a goat pellet containing 18% crude protein as a supplement to grass hay.

Table 3: Impacts of supplementation levels of probiotics and concentrate on feed intake and live weight changes

	Treatments					
Probiotics	**0**		**100**			
Concentrate	**500**	**1000**	**500**	**1000**	**SEM**	**P value**
	P_0C_{500}	P_0C_{1000}	$P_{100}C_{500}$	$P_{100}C_{1000}$		
Parameter						
Initial weight (kg)	18.93	18.83	18.88	18.80	0.531	0.999
Final weight (kg)	20.35	20.43	20.38	20.48	0.525	0.999
Average daily gain (g)	67.^{8}6b	76.19^{ab}	71.43^{ab}	79.^{7}6a	2.749	<0.000
Total weight gain (kg)	1.43^{c}	1.60^{ab}	1.50^{bc}	1.68^{a}	0.033	0.005
Grass intake (g DM/d)	592.99	581.56	571.89	575.03	11.6	0.943
Conc. Intake (g DM/d)	308.93^{b}	513.45^{a}	316.72^{b}	515.19^{a}	26.5	<0.000
Total intake (g DM/d)	901.91^{b}	1095.00^{a}	888.61^{b}	1090.22^{a}	28.6	0.001
Water Intake (ml/d)	435.00^{b}	656.43^{a}	477.14^{ab}	648.03^{a}	37.9	0.021
Feed conversion ratio	13.32^{ab}	14.40^{a}	12.48^{b}	13.69^{ab}	0.277	0.018

^{a,b,c,} Mean values with different superscripts within the same row are significantly different (P < 0.05).

Grass dry matter intake presented no significant effect (P > 0.05), aligning with the findings of Wambui *et al.* (2006) when Tithonia, Calliandra, and Sesbania were

used as supplements in growing goats. However, this observation contradicted the findings of Liu *et al.* (1998) as well as that of Osman *et al.* (2018), who both observed increments in basal diet intake due to supplementation. Concentrate intake rose significantly (P<0.05) in a linear manner as the level increased from 500 g/day to 1000 g/day, leading to a corresponding (P<0.05) rise in total dry matter intake for treatments P_0C_{1000} and $P_{100}C_{1000}$. Wambui *et al.* (2006) reported a similar observation of an increase in the intake of total dry matter attributable to supplementation. Goats generally do not drink a lot of water, particularly when on a diet of fresh grass (Qinisa and Boomker, 1998). Thus, the higher water intake in treatments P_0C_{1000} and $P_{100}C_{1000}$ may have been due to higher quantities of concentrate consumed (Table 3), which had a low moisture content of 14.0%.

Feed conversion ratio (FCR) showed a linear improvement with probiotic supplementation (Table 3), consistent with previous studies by Antunovic *et al.* (2006), Whitley *et al.* (2009), and Osman *et al.* (2023). The inclusion of probiotics supports gut microbial balance, thereby enhancing feed efficiency and ultimately boosting meat production, as noted by Maake *et al.* (2021) and Mani *et al.* (2021). Concentrate supplementation also had a significant (P < 0.05) positive effect on FCR, in agreement with findings by Osman *et al.* (2023). Interestingly, bucks receiving lower levels of concentrate exhibited more favourable FCR values.

Effects of probiotics and concentrate supplementation on whole tract in vivo digestibility

Effects of treatments imposed on nutrient digestibility coefficients are presented in Table 4. Except for digestibility coefficients for ash, nitrogen-free extracts, and cellulose, significant (P<0.05) differences were noted for all other nutrients due to treatment effects. Higher dry matter intakes (as seen in Table 3) appeared to be related to higher digestibility, which was in agreement with the report of Avornyo *et al.* (2020).

Table 4: Impact of supplementation levels of probiotic and concentrate on nutrient digestibility coefficients

	Treatments					
Probiotics	**0**		**100**		**SEM**	**P value**
Concentrate	**500**	**1000**	**500**	**1000**		
	P_0C_{500}	**P_0C_{1000}**	**$P_{100}C_{500}$**	**$P_{100}C_{1000}$**		
Nutrients digestibility						
DM (g/kg)	627.25^{b}	711.20^{ab}	707.83^{ab}	724.35^{a}	19.400	0.042
OM (g/kg)	668.28^{b}	682.00^{ab}	674.60^{ab}	695.75^{a}	3.710	0.019
CP (g/kg)	610.25^{c}	682.00^{ab}	654.50^{b}	712.50^{a}	10.600	<0.000
EE (g/kg)	607.50^{b}	716.25^{ab}	694.50^{ab}	744.25^{a}	27.600	0.044
Ash (g/kg)	249.50	286.75	280.50	305.50	14.500	0.563
NFE (g/kg)	548.50	570.50	568.25	582.00	7.300	0.577
NDF (g/kg)	476.75^{b}	555.25^{ab}	505.50^{ab}	586.75^{a}	13.600	0.010

ADF (g/kg)	334.00^{c}	387.75^{ab}	358.25^{bc}	410.50^{a}	8.810	0.004
Hemicellulose (g/kg)	457.75^{b}	579.75^{a}	513.25^{ab}	608.00^{a}	20.200	0.016
Cellulose (g/kg)	342.00	382.75	352.75	417.50	14.700	0.384
ADL (g/kg)	264.75^{c}	326.50^{ab}	299.00^{bc}	359.25^{a}	10.700	0.002

^{a,b,c,} Mean values with different superscripts within the same row are significantly different (P < 0.05). DM: Dry matter, OM: Organic matter, CP: Crude protein, EE: Ether extract, NFE: Nitrogen free extract, NDF: Neutral detergent fibre, ADF: Acid detergent fibre, ADL: Acid detergent lignin.

Dry matter (DM) digestibility increased with probiotics and higher concentrate level, which could be attributed to the rate at which degradable N was supplied to the rumen, harmonising with the energy supply (Colin-Schoellen *et al.* 2000). Probiotics may have helped in improving colonisation of cellulolytic bacteria, thereby increasing digestive capacity (Uyeno *et al.,* 2015). The current DM digestibility coefficients were lower than 924.9–952.8 g/kg (Njidda, 2020), but higher than the ranges of 647–698 g/kg (Bengaly *et al.,* 2007), 460.0–624.0 g/kg (Wambui *et al.,* 2006), 363.3–631.4 g/kg (Njidda, 2018) and 64.5 g/kg (Sow *et al.,* 2020). Organic matter (OM) digestibility followed a similar trend. The enhanced DM and OM digestibilities due to treatment effects agreed with the reports of Gebreslassie (2012) and Hagos (2014). Compared to OM digestibility values of 490.0–622.0 g/kg (Wambui *et al.*, 2006), 649.0 g/kg (Sow *et al.* ,(2020), and 549.0–623.1 g/kg (Njidda ,(2020), the present range of values was higher.

Digestibility of CP exhibited a significant (P<0.05) effect that ranged from 712.50 g/kg to 610.25 g/kg. CP was better utilised in $P_{100}C_{1000}$ relative to other treatments, attributed to the synergistic positive effects of probiotics and the higher concentrate level. The improved CP digestibility could also be attributed to decreased degradation by protozoa, which, as a result, may have increased the level of protein available in lower sections of the gut (Ruiz *et al.* 2001). Better protein metabolism may have been achieved by reducing ruminal fermentation of dietary protein to ammonia, which rumen microbes cannot efficiently utilise, with the help of probiotics. The enhanced CP intake due to concentrate supplementation had a positive effect on digestibility since a low level of CP (less than 80 g kg1 DM) has been proven by Norton (1994) to depress digestibility as it is not enough to meet rumen bacterial requirements. The present range of values exceeded those documented by Njidda (2018), Njidda (2020), and Sow *et al.* (2020), which were 267.0–673.3 g/kg, 225.8–682.7 g/kg, and 614.0 g/kg, respectively.

Digestibility for NDF improved from 476.75 g/kg to 586.75 g/kg, attributable to treatment effects. CP supplementation may have enhanced NDF digestibility (Teklehaymanot 2019). The present range of values exceeded the 387.6–573.0 g/kg and 278.9–362.9 g/kg documented by Njidda (2018) and Njidda (2020), respectively. The digestibility coefficients for ADF exhibited a similar pattern. The improvements attributed to probiotics are consistent with findings from earlier studies (Guedes *et al.* 2008; Marden *et al.* 2008; Boyd *et al.* 2011). Our ADF values were higher than the 113.4–211.4 g/kg and 399.0 g/kg reported by Njidda (2018) and Sow *et al.* (2020), respectively. However, they were lower than the 349.0–439.9 g/kg recorded by Njidda (2020). Variations in ADF digestibility coefficients may be due to species differences, as the cited studies

involved browse species, whereas the current study focused on *B. decumbens* grass. Hemicellulose and ADL digestibility coefficients also showed improvement with probiotics and higher concentrate levels. The improved digestibility of hemicellulose and ADL suggests greater availability and more efficient utilisation by rumen microbes, which can ultimately enhance animal performance. ADL digestibility in the current study was lower than 328.4–593.5 g/kg reported by Njidda (2020) but surpassed 223.1–307.6 g/kg reported by Njidda (2018) attributed to the aforementioned reason on species differences.

Impact of supplementing probiotics and concentrate on nitrogen intake, digestibility, and retention.

Impacts exerted by the dietary treatments imposed on nitrogen (N) intake, digestibility, and retention are provided in Table 5. Nitrogen (N) intake presented significant variation ($P < 0.05$) as a result of differences in the intake of feed dry matter and the levels of concentrate supplemented. The increase in N intake was linked to concentrate supplementation, aligning with McDonald *et al.*'s (1996) finding that dietary nitrogen intake is directly proportional to the nitrogen content of the diet.

Table 5: Impacts of supplementation levels of probiotic and concentrate on nitrogen intake, digestibility and retention

	Treatments					
Probiotics	**0**		**100**		**SEM**	**P value**
Concentrate	**500** P_0C_{500}	**1000** P_0C_{1000}	**500** $P_{100}C_{500}$	**1000** $P_{100}C_{1000}$		
N balance						
N intake (g/d)	37.52^{b}	45.55^{a}	36.97^{b}	45.35^{a}	1.190	0.001
N in faeces (g/d)	13.92^{a}	10.49^{bc}	11.81^{b}	9.97^{c}	0.498	<0.000
N in urine (g/d)	8.33	8.87	9.26	8.24	0.173	0.141
N digested (g/d)	23.60^{b}	35.07^{a}	25.16^{b}	35.38^{a}	1.530	<0.000
N digestibility (%)	62.58^{b}	76.95^{a}	68.01^{b}	78.07^{a}	1.890	<0.000
N retention (g/d)	15.27^{b}	26.20^{a}	15.89^{b}	27.14^{a}	1.560	<0.000
N retained as % of N intake	40.24^{b}	57.43^{a}	42.96^{b}	59.89^{a}	2.520	<0.000
N retained as % of N digested	63.97^{bc}	74.62^{a}	62.84^{b}	76.71^{a}	1.860	0.001

^{a,b,c,} **Mean values with different superscripts within the same row are significantly different ($P < 0.05$).**

The amount of N voided through faeces was lowest in treatment $P_{100}C_{1000}$ (9.97 g/d) due to efficiency in N utilisation. This observation was inconsistent with the report of Odoemelam *et al.* (2015), along with that of Okah *et al.* (2019), who found that N voided through faeces was not significantly affected by nitrogen intake. It is worth noting that faecal N in this study was higher than urinary N excretion. Similar findings were documented by Antwi *et al.* (2020), Jiwuba (2020), Cardoso-Gutiérrez (2020), and Idan *et al.* (2023). On the contrary, Zhao *et al.* (2007) and Decandia *et al.* (2011), found

urinary N to be higher than faecal N in their respective studies.

Urinary N was, however, unaffected (P > 0.05) by treatment differences, consistent with the results of Odoemelam *et al.* (2015) and Okah *et al.* (2019). Protein-rich diets lead to elevated levels of NH_3-N in the rumen, which are not efficiently utilised by microbes (Hadjipanayiotu *et al.* 1991), resulting in their excretion as urea via urine. The current low values for urinary N may be indicative of the efficiency of microbes, aided by probiotics, in utilising dietary protein. A similar trend was observed by Fadiyimu *et al.* (2010). Faecal and urinary N levels in this study were lower than the two-thirds of N intake lost via faeces and urine (Bruinenberg *et al.* 2003), which could be ascribed to the efficiency of N utilisation.

It can be seen from Table 5 that increased amounts of concentrate supplementation led to linear improvements (P<0.05) in N digested and apparent N digestibility. This could be due to high quantities of degradable N from higher levels of concentrate that may have energised rumen microbes, leading to enhanced digestibility. High bypass protein content that is further broken down within the small intestine, along with elevated levels of rumen-degradable N, may have also contributed to the improvements in nitrogen digestibility. The current values for apparent N digestibility were higher than the 47.10–72.70% and 58.38–72.80% obtained by Njidda (2018) and Jiwuba (2020), respectively.

Significant (P < 0.05) effects were also noted for nitrogen retention, which improved linearly with elevated supplementation levels of probiotics and concentrates. The improvements were indicative of superior N utilisation efficiency. This could be due to the synchronisation of carbohydrate and nitrogen compounds in the diet, as Howard *et al.* (2007) reported that such a relationship typically results in increased nitrogen retention. All dietary treatments imposed resulted in a positive N balance, an indication that the CP requirement for maintenance was sufficiently met. This trend also emphasised the beneficial effect of probiotics and concentrate supplementation. Nitrogen retention expressed both as a percentage of intake and as a percentage of nitrogen digested, showed significant improvements (P < 0.05), exhibiting linear increments with increased probiotic and concentrate supplementation levels

CONCLUSION

Drawing from the results presented, it can be inferred that supplementing Sahelian bucks on *Brachiaria decumbens* grass basal diet with Vicbinzy probiotics (added at the rate of 100 g per 100 kg of the concentrate) and a homemade protein-energy concentrate (composed mainly of millet mash waste/ residue and wheat bran) at 1000 g/day led to improvements in total intake of dry matter, nutrient digestibility coefficients as well as nitrogen utilisation and balance.

RECOMMENDATION

This combined feeding strategy (home-made concentrate with probiotics) is recommended as it offers a practical solution for improving goat productivity, especially in areas where conventional feed resources are limited and commercially prepared concentrates are expensive. Its adoption could contribute to enhanced animal performance, improved feed resource efficiency, and reduced environmental nitrogen load in goat production systems.

Conflict of interest

The authors declare no conflicts of interest.

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