

Growth Performance and Rumen Microbial Populations of West African Dwarf Bucks Fed Guinea Grass (*Panicum maximum*) Supplemented with Varying Levels of Concentrate

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Abstract

Concentrate supplementation influences growth performance and rumen microbial ecology in growing West African Dwarf bucks. This study evaluated the effects of Panicum maximum and varying levels of concentrate supplementation on the growth performance and rumen microbial populations of West African Dwarf (WAD) bucks. Nine healthy WAD bucks aged 6–9 months with an average initial body weight of 6.31 kg were randomly allotted to three dietary treatments in a Completely Randomized Design (CRD), with three animals per treatment. Treatment 1 (T1) received Panicum maximum only, Treatment 2 (T2) received Panicum maximum plus 800 g concentrate/head/day, while Treatment 3 (T3) received Panicum maximum plus 1000 g concentrate/head/day. The feeding trial lasted 84 days. Final body weight increased from 8.56 kg in T1 to 10.48 kg in T2 and 11.82 kg in T3, while total weight gain increased from 2.28 to 4.17 and 5.47 kg, respectively. Average daily weight gain increased from 27.14 to 49.64 and 65.12 g/day, while feed conversion ratio improved from 16.60 to 12.62 and 11.23. Bacterial populations increased, whereas fungal populations declined with concentrate supplementation. Supplementation with 1000 g concentrate/head/day improved growth performance and feed utilization while favourably modifying rumen bacterial populations, although higher concentrate levels reduced fungal abundance.

Keywords: West African Dwarf bucks; *Panicum maximum*; Concentrate supplementation; Growth performance; Rumen microbial population.

1.0 Introduction

Goat production plays a significant role in enhancing food security, improving household income and supporting the livelihoods of rural farmers, particularly in developing countries (Udo *et al.*, 2024; Ndelekwute *et al.*, 2016). Among the indigenous goat breeds in West Africa, the West African Dwarf (WAD) goat is highly valued because of its adaptability to the humid tropical environment, tolerance to endemic diseases and ability to survive on low-quality fibrous feeds (Udo *et al.*, 2025; Ogundu *et al.*, 2018; Sam *et al.*, 2017). In Nigeria, the breed contributes substantially to the supply of meat and serves as an important source of income for smallholder farmers (Anigbogu *et al.*, 2009; Okon *et al.*, 2023; Sam *et al.*, 2026). Despite these advantages, the productivity of WAD goats remains relatively low due to poor nutrition arising from seasonal fluctuations in forage quantity and quality (Alphonsus *et al.*, 2010a; Udo, 2015; Ebong *et al.*, 2023; Sam *et al.*, 2022). During the dry season, tropical grasses become highly fibrous and deficient in essential nutrients, resulting in reduced feed intake, poor nutrient digestibility and slow growth (Ekpo *et al.*, 2022; Alphonsus *et al.*, 2010b; Essien *et al.*, 2022; Efretuei *et al.*, 2024). Consequently, improving the nutritional management of WAD goats through strategic supplementation has continued to attract considerable research attention (Devendra & Burns, 1983; Van Soest, 1994; Babayemi *et al.*, 2006; Aye & Adegun, 2010).

Among the tropical grasses commonly used for feeding ruminants, *Panicum maximum* remains one of the most important because of its wide distribution, rapid growth, high biomass production and year-round availability under favourable environmental conditions (Ugundu *et al.*, 2018). However, as the grass matures, its crude protein content declines while fibre concentration increases, reducing digestibility and limiting animal performance. This has necessitated the supplementation of forage-based diets with concentrate feeds capable of supplying readily available energy, protein, minerals and vitamins required for efficient rumen fermentation and growth. Several studies have demonstrated that concentrate supplementation improves feed intake, nutrient utilization and weight gain in goats maintained on tropical forages. For instance, Eyoh *et al.* (2019) and Udo *et al.* (2015) reported improved growth performance and carcass characteristics in West African Dwarf bucks fed *Panicum maximum* supplemented with processed rubber seed meal, while Abegunde *et al.* (2017) observed enhanced nutrient utilization and live weight gain in goats receiving concentrate supplementation. These findings indicate that an appropriate combination of forage and concentrate can substantially improve the productivity of growing goats.

The productivity of ruminants is closely associated with the activities of microorganisms inhabiting the rumen. The rumen contains a complex community of bacteria, fungi, protozoa and archaea that work together to ferment feed materials that cannot be digested by the host animal. These microorganisms convert structural and non-structural carbohydrates into volatile fatty acids, synthesize microbial protein and produce essential nutrients required for growth and maintenance. Diet is one of the major factors influencing the composition and activity of rumen microorganisms. High-forage diets generally favour cellulolytic bacteria and anaerobic fungi responsible for fibre degradation, whereas increasing dietary concentrate promotes the growth of amylolytic

bacteria that utilize readily fermentable carbohydrates. Although moderate concentrate supplementation improves fermentation efficiency, excessive concentrate feeding may reduce ruminal pH, suppress fibre-degrading microorganisms and impair normal rumen function (Russell & Wilson, 1996; Russell & Rychlik, 2001; Dehority, 2003; Henderson *et al.*, 2015; Mao *et al.*, 2024).

Several studies have examined forage supplementation, concentrate feeding and growth performance in West African Dwarf goats, relatively few have simultaneously investigated their effects on growth performance and rumen microbial populations. But information on the response of rumen bacterial and fungal populations to graded levels of concentrate supplementation under *Panicum maximum*-based feeding systems remains limited, particularly under the humid tropical conditions of southern Nigeria. This study was therefore undertaken to evaluate the effects of *Panicum maximum* supplemented with varying levels of concentrate on the growth performance and rumen microbial populations of West African Dwarf bucks.

2.0 Materials and Methods

2.1 Study Site

The experiment was conducted at the Teaching and Research Farm, Akwa Ibom state University Obio Akpa, Oruk Anam, Akwa Ibom State, Nigeria. Obio Akpa is located within the humid rainforest agro-ecological zone of southern Nigeria at approximately 5°03'N latitude and 7°56'E longitude. The area experiences a tropical climate characterized by an annual rainfall of 3500–5,000 mm, mean ambient temperature of 26–30°C and relative humidity of 75–90%, which favour year-round forage production (AKSG, 2022).

2.2 Experimental Animals and Management

Nine apparently healthy West African Dwarf (WAD) bucks aged between 6 and 9 months, with an average initial body weight of approximately 6.3 kg, were purchased from reputable livestock farms within the Akwa Ibom State University Obio Akpa, Oruk Anam Campus. The animals were individually identified using numbered neck tags and subjected to a two-week quarantine and acclimatization period before the commencement of the experiment.

Three days before the arrival of the animals, the experimental pens were thoroughly cleaned and disinfected using Izal disinfectant, while fresh wood shavings were provided as bedding materials. During the quarantine period, the animals were carefully monitored for signs of disease and adaption to the management system.

Routine health management included deworming with ivermectin (0.2 mg/kg body weight) to control internal and external parasites were administered. Oxytetracycline long-acting injection was administered prophylactically against bacterial infections which was given to improve general health status. Bedding materials were replaced weekly to maintain proper hygiene and reduce microbial contamination. Throughout the

experimental period, clean drinking water and mineral salt licks were provided ad libitum.

2.3 Experimental Diets

Fresh *Panicum maximum* served as the basal forage and was offered ad libitum to all animals. Concentrate diets were formulated principally from wheat offal and supplemented with palm kernel cake, bone meal, limestone, common salt to satisfy the nutrient requirements of growing goats. The ingredient composition and calculated nutrient composition of the concentrate diets are presented in Table 2.1.

The concentrate supplements were offered once daily in the morning before the 2 kg of the basal forage at 2pm. Goats assigned to Treatment₂ received 800 g concentrate/head/day, while those in Treatment 3 received 1000 g concentrate/head/day. Refusals were collected and weighed every morning before feeding to determine daily feed intake.

2.4 Experimental Design

The experiment was arranged in a Completely Randomized Design (CRD). The nine West African Dwarf bucks were randomly allotted to three dietary treatments with three animals per treatment, and a goat was a replicate in its treatment group.

The dietary treatments consisted of:

T₁: *Panicum maximum* only (Control)

T₂: *Panicum maximum* + 800 g concentrate/head/day

T₃: *Panicum maximum* + 1000 g concentrate/head/day

The feeding trial lasted for 84 days, excluding the two-week acclimatization period.

2.5 Determination of Growth Performance

Individual body weights were recorded at the beginning of the experiment after an overnight fast using a digital livestock weighing scale. Thereafter, body weights were measured weekly before the morning feeding to monitor growth performance. At the end of the feeding trial, final body weights were recorded.

Daily feed intake was determined as the difference between the quantity of feed offered and the quantity refused on the following day.

Table 2.1. Percentage Composition and Calculated Nutrient Composition of Experimental Concentrate Diets

Ingredient (%)	T ₁	T ₂	T ₃
Panicum maximum (Basal forage)	Ad libitum	2.00	2.00
Wheat offal	—	56.00	46.00
Palm kernel cake	—	20.00	22.00
Cassava peels	—	16.00	20.00
Brewers' dried grain	—	4.00	8.00
Bone meal	—	2.00	2.00
Total	—	100.00	100.00
Calculated Nutrient Composition			
Nutrient		T ₂	T ₃
Dry matter (%)		90.6	90.3
Crude protein (%)		17.5	19.2
Crude fibre (%)		16.7	18.3
Ether extract (%)		5.5	6.4
Ash (%)		7.6	8.2
Nitrogen-free extract (%)		52.7	47.9
Metabolizable energy (MJ/kg DM)		10.7	11.0

T₁ = *Panicum maximum* only; T₂ = *Panicum maximum* + 800 g concentrate/day; T₃ = *Panicum maximum* + 1000 g concentrate/day.

2.6 Collection of Rumen Liquor Samples

At the end of the feeding trial, rumen liquor samples were collected from each experimental animal approximately three hours after the morning feeding using a sterile stomach tube connected to a suction pump. The initial portion of the sample was discarded to minimize saliva contamination. Approximately 100 mL of rumen liquor was collected from each animal into sterile thermos flasks pre-warmed to approximately 39°C and transported immediately to the Microbiology Laboratory for analysis.

2.7 Determination of Rumen pH

Immediately after sample collection, rumen pH was determined using a calibrated digital pH meter. The electrode was standardized using pH 4.0 and pH 7.0 buffer solutions before each measurement to ensure analytical accuracy.

2.8 Determination of Rumen Microbial Population

Total bacterial and fungal populations were determined using the serial dilution and standard plate count techniques. One millilitre of rumen liquor was serially diluted in sterile physiological saline solution. Appropriate dilutions were inoculated onto Nutrient Agar for bacterial enumeration and Sabouraud Dextrose Agar supplemented with antibiotics for fungal isolation. The inoculated plates were incubated under appropriate conditions, after which colony-forming units (CFU) were counted and expressed as CFU/mL of rumen liquor.

Protozoal counts were determined using a direct microscopic counting technique following fixation of rumen liquor with methyl green formal saline. Counts were expressed as cells per millilitre of rumen liquor.

2.9 Isolation and Identification of Rumen Microorganisms

Pure cultures were obtained by repeated streaking on appropriate culture media. Bacterial isolates were characterized based on colony morphology, Gram staining reaction and biochemical characteristics, including catalase, urease, oxidase, motility, indole production, citrate utilization and carbohydrate fermentation tests. Fungal isolates were identified based on colony morphology, pigmentation and microscopic examination of hyphae, spores and reproductive structures using lactophenol cotton blue staining.

2.10 Statistical Analysis

All data obtained on growth performance, rumen pH and microbial populations were subjected to one-way analysis of variance (ANOVA) appropriate for a Completely Randomized Design using Statistical Package for Social Sciences (SPSS, 2022), version 25.0.

The statistical model employed was:

$$Y_{ij} = \mu + T_i + e_{ij}$$

where:

Y_{ij} = observation on the j th animal receiving the i th dietary treatment;

μ = overall population mean;

T_i = effect of the i th dietary treatment ($i = 1, 2, 3$);

e_{ij} = random experimental error assumed to be independently and normally distributed.

Treatment means were separated using Duncan's Multiple Range Test (DMRT). Results were presented as means $\pm$ standard error of the mean (SEM), and differences were considered statistically significant at $P < 0.05$.

3.0 Results and Discussion

The results of the growth performance of West African Dwarf (WAD) bucks fed *Panicum maximum* supplemented with varying levels of concentrate are presented in Table 3.1. Initial body weight ranged from 6.28 to 6.35 kg and did not differ significantly ($P > 0.05$) among treatments groups indicating that the experimental animals were homogeneous at the commencement of the study. Consequently, the differences observed in subsequent growth performance could be attributed to the dietary treatments rather than variations in initial body weight. This observation agrees with the report of Aye and Adegun (2010), who emphasized that comparable initial body weights are essential for unbiased evaluation of dietary treatments.

Final body weight, total weight gain and average daily weight gain increased significantly ($P < 0.05$) with increasing levels of concentrate supplementation. Bucks fed 1000 g concentrate (T_3) recorded the highest final body weight (11.82 kg), total weight gain (5.47 kg) and average daily weight gain (65.12 g/day), whereas those fed forage alone (T_1) recorded the lowest values. The superior performance observed in T_3 suggests that concentrate supplementation supplied additional dietary energy and protein, thereby improving rumen fermentation, microbial protein synthesis, nutrient digestibility and tissue deposition. This finding is in line with the reports of Van Soest (1994) and Devendra and Burns (1983) and conforms with the observations of Preston and Leng (1987), who reported that concentrate supplementation enhances nutrient utilization and growth performance in ruminants. Similarly, Abegunde *et al.* (2017) and Isah *et al.* (2024) reported improved live weight and growth performance in West African Dwarf goats receiving *Panicum maximum* based diets supplemented with concentrate or multinutrient feed supplements. Comparable improvements in weight gain have also been reported by Aye and Adegun (2010), who attributed the response to improved nutrient availability and efficient rumen fermentation.

Total feed intake and daily feed intake were also significantly ($P < 0.05$) influenced by dietary treatment, with bucks receiving 1000 g concentrate consuming more feed than those on the other treatments. The increased feed intake may be attributed to improved palatability and enhanced digestibility of the supplemented diets. This observation is consistent with the reports of McDonald *et al.* (2011) and Norton (2003), who noted that concentrate supplementation improves voluntary feed intake by enhancing rumen fermentation and nutrient supply. It also conforms with the findings of Abegunde *et al.* (2017) and Arigbede, who reported increased dry matter intake in WAD goats fed *Panicum maximum* supplemented with concentrate.

Feed conversion ratio (FCR) differed significantly ($P < 0.05$), with the lowest value recorded in T_3 (11.23) and the highest in T_1 (16.60), indicating more efficient feed utilization with increasing concentrate supplementation. This finding agrees with the

observations of Church (1998) and NRC (2007), who reported that adequate dietary energy and protein improve feed conversion efficiency in growing ruminants. It also conforms with the reports of Abegunde *et al.* (2017) and Isah *et al.* (2024), who observed improved feed efficiency in West African Dwarf goats receiving concentrate supplements. The differences observed among treatments could be attributed to improved dietary nutrient supply, which enhanced rumen microbial activity, nutrient digestibility and growth performance.

3.1 Bacterial Population of West African Dwarf Bucks Fed *Panicum maximum* (Forage Only)

The bacterial population of West African Dwarf (WAD) bucks fed *Panicum maximum* as the sole diet is presented in Figure 3.1. The forage-only diet supported a normal rumen microbial ecosystem dominated by cellulolytic and fibrolytic bacteria responsible for degrading cellulose, hemicellulose and other structural carbohydrates. These microorganisms ferment fibrous feeds to produce volatile fatty acids (VFAs), particularly acetate, which is the major source of metabolizable energy for ruminants (Van Soest, 1994; Russell & Rychlik, 2001).

The predominance of fibre-degrading bacteria indicates that *Panicum maximum* supplied sufficient structural carbohydrates to sustain microbial activity. This agrees with Russell and Wilson (1996), who reported that cellulolytic bacteria thrive under forage-based diets with stable ruminal pH. Similarly, Dehority (2003) identified *Ruminococcus albus*, *Ruminococcus flavefaciens* and *Fibrobacter succinogenes* as major fibre degrading bacteria in forage fed ruminants.

The results further indicate that forage alone maintained active microbial fermentation and a stable rumen environment. This supports the findings of Hobson and Stewart (1997), Krause and Oetzel (2006), Jami *et al.* (2013) and Henderson *et al.* (2015), who reported that forage rich diets promote microbial stability, enhance fibre digestion and maintain a diverse rumen bacterial community.

Figure 3.2 shows that supplementation with 800g concentrate increased the bacterial population compared with the forage-only treatment. The additional fermentable carbohydrates and nitrogen provided favourable substrates for amylolytic bacteria, thereby enhancing microbial protein synthesis and rumen fermentation (Russell & Rychlik, 2001; Owens *et al.*, 1998).

The higher bacterial population indicates that moderate concentrate supplementation improved the rumen environment without disrupting microbial balance. This agrees with Owens *et al.* (1998) and Russell and Wilson (1996), who reported that balanced forage-to-concentrate diets promote both fibre- and starch-utilizing bacteria while maintaining normal ruminal pH.

Table 3.1. Growth Performance of West African Dwarf Bucks Fed Forage and Varying Levels of Concentrate Supplementation

Parameters	T ₁	T ₂	T ₃	SEM	P-value
Initial body weight (kg)	6.28 ± 0.18	6.31 ± 0.21	6.35 ± 0.16	0.09	0.874
Final body weight (kg)	8.56 ± 0.27 ^c	10.48 ± 0.31 ^b	11.82 ± 0.36 ^a	0.22	0.001
Total weight gain (kg)	2.28 ± 0.15 ^c	4.17 ± 0.22 ^b	5.47 ± 0.26 ^a	0.17	0.001
Average daily weight gain (g/day)	27.14 ± 1.79 ^c	49.64 ± 2.62 ^b	65.12 ± 3.08 ^a	2.06	0.001
Total feed intake (kg)	37.85 ± 0.81 ^c	52.63 ± 1.04 ^b	61.42 ± 1.18 ^a	0.73	0.001
Daily feed intake (g/day)	450.60 ± 9.64 ^c	626.55 ± 12.39 ^b	731.19 ± 14.05 ^a	8.68	0.001
Feed conversion ratio	16.60 ± 0.52 ^a	12.62 ± 0.39 ^b	11.23 ± 0.34 ^c	0.28	0.001

Means within the same row bearing different superscripts ^(a-c) differ significantly (P < 0.05). SEM = Standard Error of Mean.

3.2 Bacterial Population of West African Dwarf Bucks Fed *Panicum maximum* Supplemented with 800 g Concentrate

The results also suggest improved microbial activity and fermentation efficiency, consistent with reports by Dehority (2003), Hobson and Stewart (1997), Jami *et al.* (2013) and Henderson *et al.* (2015), who observed that moderate concentrate supplementation enhances beneficial bacterial populations while preserving microbial diversity.

3.3 Bacterial Population of West African Dwarf Bucks Fed *Panicum maximum* Supplemented with 1000 g Concentrate

As shown in Figure 3.3, supplementation with 1000 g concentrate further altered the bacterial population by favouring amylolytic bacteria due to the greater supply of readily fermentable carbohydrates (Russell & Rychlik, 2001; Owens *et al.*, 1998).

Although bacterial proliferation increased, higher concentrate levels may reduce cellulolytic bacteria if ruminal pH declines, thereby altering microbial balance. This observation agrees with Russell and Wilson (1996), Dehority (2003) and Hobson and Stewart (1997), who reported that excessive concentrate feeding suppresses fibre-degrading microorganisms and changes rumen microbial structure.

Similarly, Jami *et al.* (2013) and Henderson *et al.* (2015) demonstrated that increasing concentrate modifies rumen bacterial diversity by favouring starch-fermenting bacteria. These findings highlight the need for appropriate forage to concentrate ratio to sustain microbial diversity and efficient fibre digestion.

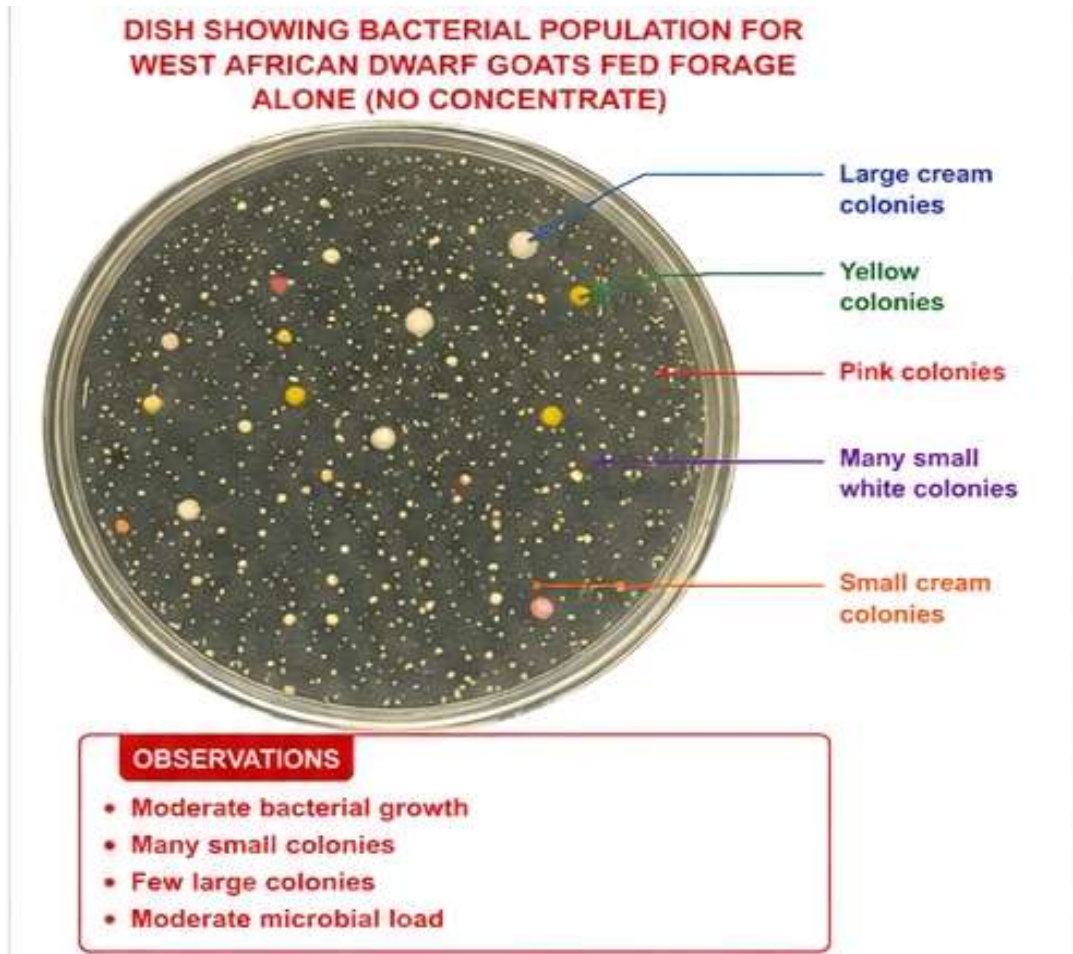


Figure 3.1 - Bacterial population (Forage only)

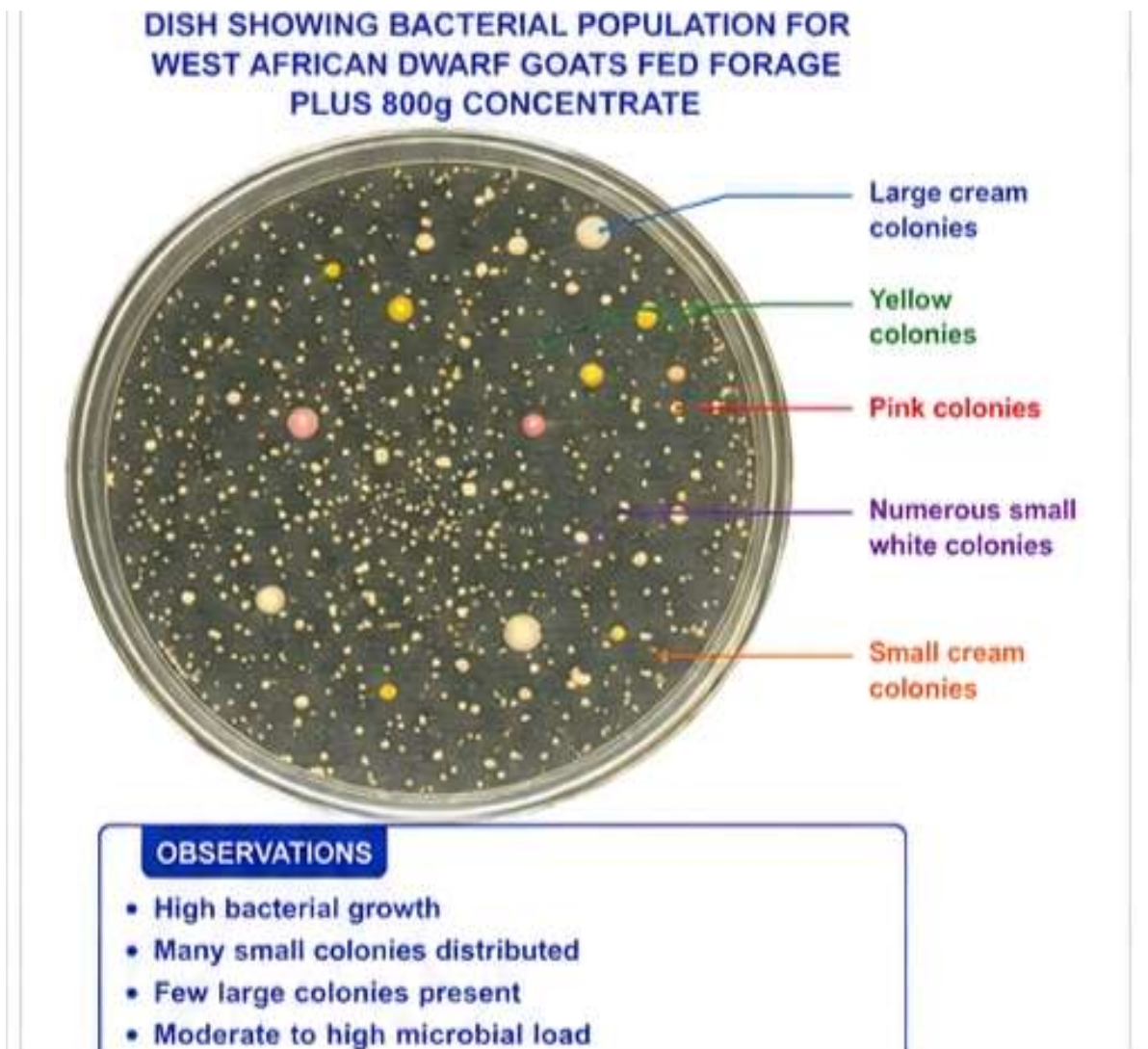


Figure 3.2 - Bacterial population (800 g concentrate)

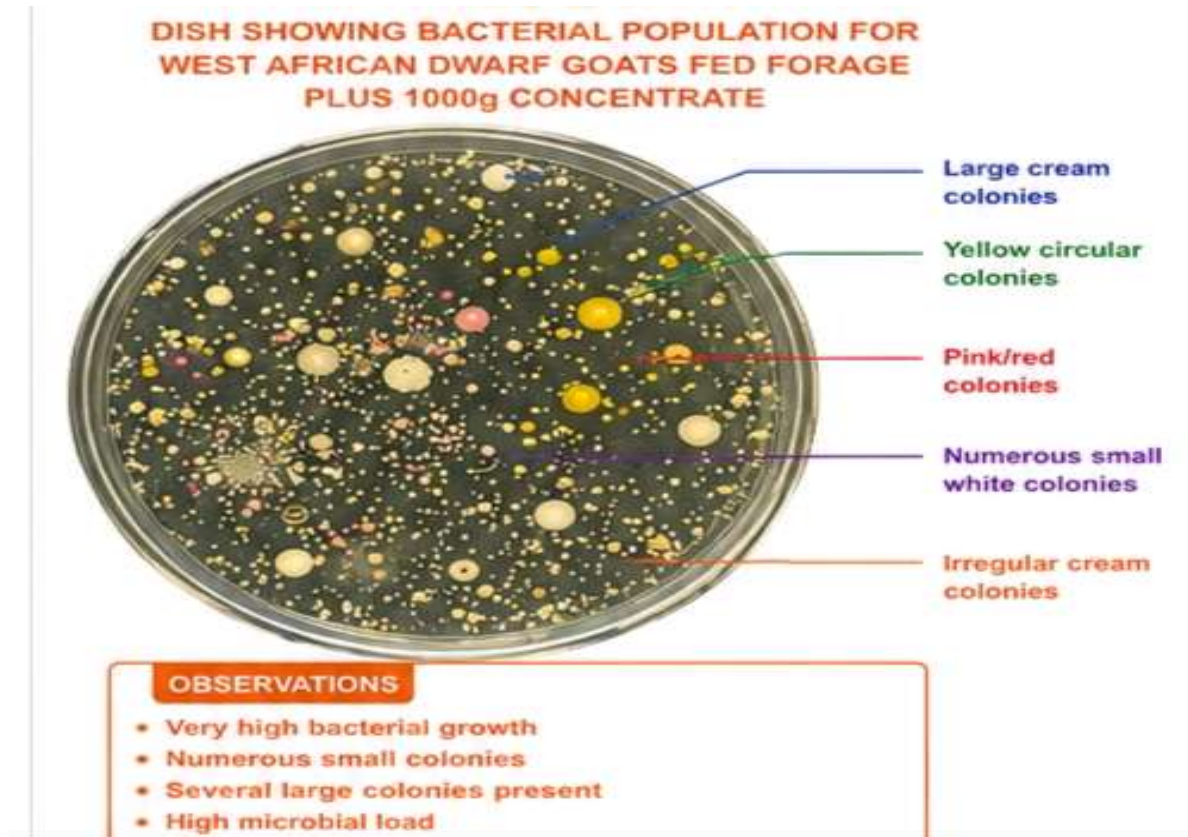


Figure 3.3 - Bacterial population (1000 g concentrate)

3.4 Fungal Population of West African Dwarf Bucks Fed *Panicum maximum* (Forage Only)

Figure 3.4 shows that the fungal population was highest in WAD bucks fed *Panicum maximum* alone. Anaerobic fungi play a major role in degrading lignified plant tissues through rhizoid penetration and fibrolytic enzyme production, thereby improving fibre digestion (Orpin, 1975; Bauchop, 1979).

The abundance of structural carbohydrates in the forage provided favourable conditions for fungal growth and colonization. This agrees with Orpin (1975) and Bauchop (1979), who reported that forage-rich diets promote anaerobic fungal activity. Dehority (2003) and Hobson and Stewart (1997) also noted that rumen fungi enhance bacterial access to plant tissues and improve fibre digestion.

These findings further support the reports of Gruninger *et al.* (2014) and Huws *et al.* (2018), who concluded that forage-based diets maintain fungal diversity and contribute to efficient rumen function.



Figure 3.4 - Fungal population (Forage only)

3.5 Fungal Population of West African Dwarf Bucks Fed *Panicum maximum* Supplemented with 800 g Concentrate

Figure 3.5 indicates that fungal population declined slightly following supplementation with 800 g concentrate, although sufficient forage remained to sustain fungal activity. The reduction may be due to increased bacterial competition following the availability of readily fermentable carbohydrates.

Despite this decline, fungal activity was maintained because adequate forage continued to provide substrates for fibre degradation. This agrees with Dehority (2003), Hobson and Stewart (1997), Orpin (1975) and Bauchop (1979), who reported that moderate concentrate supplementation causes only slight reductions in rumen fungal populations when forage intake remains adequate.

The findings also agree with Gruninger *et al.* (2014) and Huws *et al.* (2018), who observed that moderate concentrate inclusion causes only minor changes in fungal diversity while maintaining overall rumen stability.

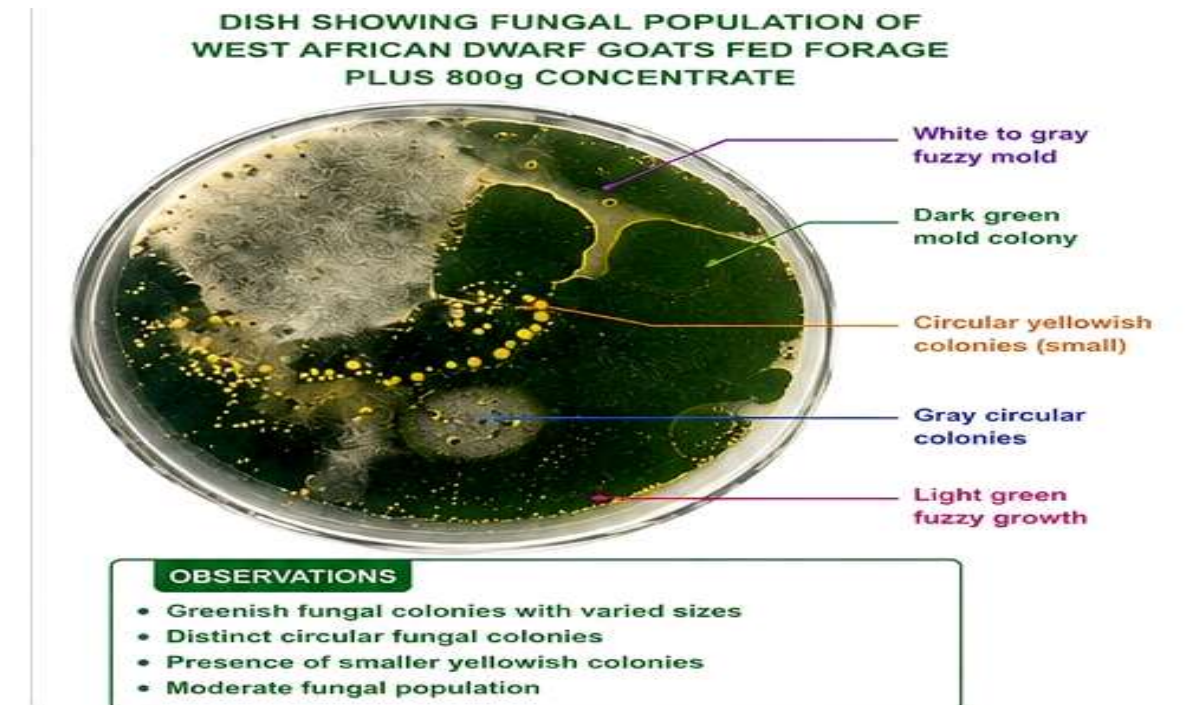


Figure 3.5 - Fungal population (800 g concentrate)

3.6 Fungal Population of West African Dwarf Bucks Fed *Panicum maximum* Supplemented with 1000 g Concentrate

Figure 3.6 shows that supplementation with 1000 g concentrate markedly reduced the fungal population compared with the forage only and 800 g concentrate treatments. The reduction was likely due to decreased fibre availability and changes in ruminal conditions associated with higher concentrate feeding (Orpin, 1975; Dehority, 2003).

The lower fungal population suggests that excessive concentrate may reduce ruminal pH and suppress fibre degrading fungi while favouring starch-utilizing microorganisms. Similar observations were reported by Orpin (1975), Dehority (2003), Hobson and Stewart (1997) and Bauchop (1979).

The present findings are also consistent with Gruninger *et al.* (2014) and Huws *et al.* (2018), who demonstrated that high-concentrate diets reduce anaerobic fungal diversity and disrupt the rumen microbial ecosystem. These results emphasize the importance of maintaining appropriate forage to concentrate ratio for efficient fibre utilization and optimum rumen function.

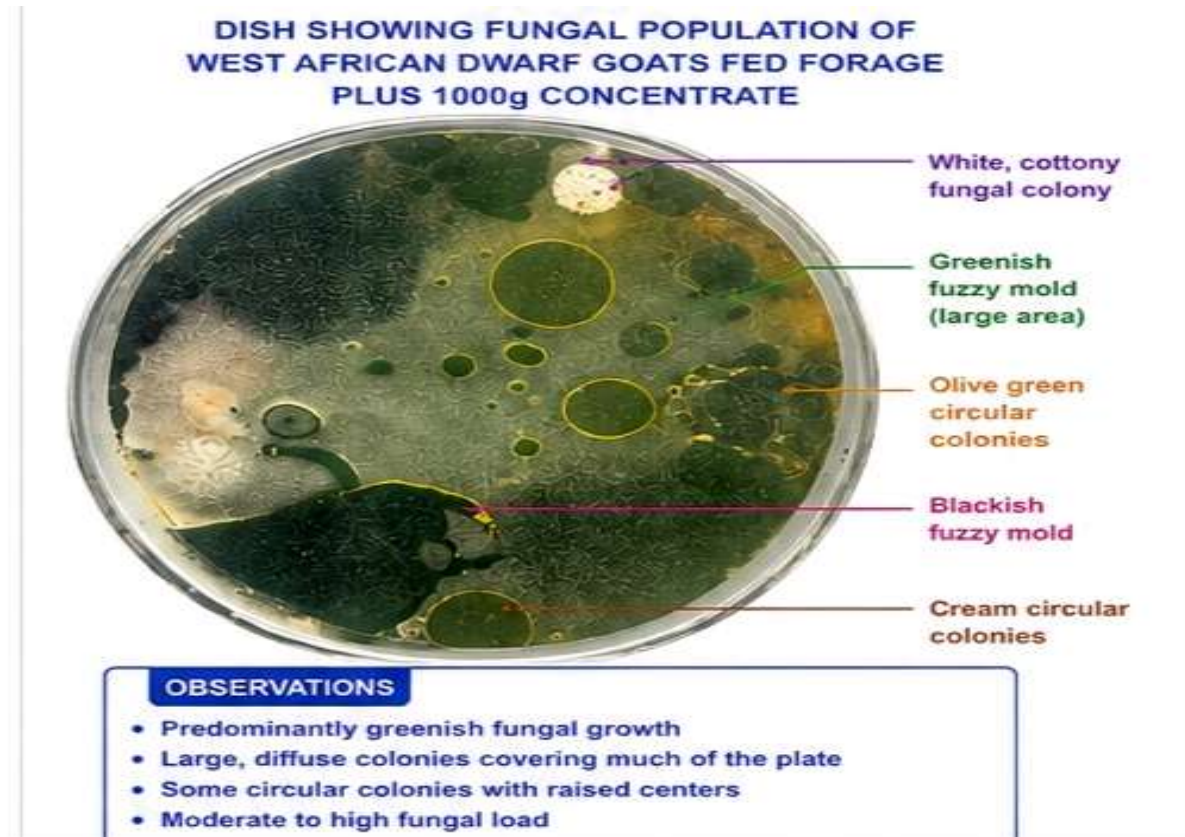


Figure 3.6 - Fungal population (1000 g concentrate)

4.0 Conclusion

The present study demonstrated that concentrate supplementation significantly improved the growth performance and modified the rumen microbial populations of West African Dwarf bucks fed *Panicum maximum*. Supplementation with 1000 g concentrate/head/day produced the highest final body weight, weight gain, average daily gain and feed intake, while achieving the best feed conversion ratio. Concentrate supplementation also increased rumen bacterial populations but reduced fungal populations as dietary concentrate level increased. These findings indicate that dietary concentrate enhanced nutrient utilization and rumen fermentation, leading to improved animal performance. Therefore, supplementing *Panicum maximum* with 1000 g concentrate/head/day is recommended for improved growth performance in growing West African Dwarf bucks, provided that adequate forage is maintained to preserve a balanced rumen microbial ecosystem and efficient fibre digestion.

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