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Evaluation of Nutrient and Anti-Nutrient Content of Ensiled Bamboo Leaves (*Bambusa vulgaris*) as Dry Season Feed for Ruminants in the Tropics

[1]Abiola-Olagunju, O.; [2]Adebayo, J. O.; [2]Adesina, M. W.; [2]Mako, A. A.

[1]Department of Biological Sciences, Faculty of Natural and Applied Science. Lead City University, Ibadan, Oyo state. Nigeria.

2Department of Animal Science, College of Agriculture and Hospitality Management, Tai Solarin University of Education, Ijagun. Ogun State, Nigeria.

Corresponding Author: abiolaolagunjuoluwanike@gmail.com
Other Authors: adebayojoseh1@gmail.com; adesinamw@tasued.edu.ng; makoaa@tasued.edu.ng

Abstract

Ensuring year-round access to affordable, high-quality ruminant feed remains a significant challenge, particularly during the dry season. This research adjudges the nutritional value of ensiled *Bambusa vulgaris* (BV) leaves as a dry-season ruminant feed. Study 1 involved ensiling BV leaves for 21 days with wheat offal (BVWHO), groundnut cake (BVGNC), or no additive (BVNAD). The Second Study assessed silage quality characteristics, while study 3 determined proximate composition (PC) and fiber fractions, study 4 evaluated the anti-nutrient content of all silages. *Silage pH ranged from 4.2 to 4.8, and temperatures from 28.5°C to 30.0°C,* in BVGNC and BVNAD, respectively. All the silage's physical characteristics presented were good. Significant differences (P < 0.05) were observed in PC, with dry matter ranging from 95.01- 95.72 % and crude fiber values ranged from 23.92- 25.89 % in BVGNC and BVNAD respectively. Crude protein is highest (18.00%) in BVGNC and lowest (17.21%) in BVNAD. Highest (1.43%) ether extract was obtained in BVNAD, while the lowest (1.36%) was recorded for BVGNC. Same trend was observed for ash content, it ranged from 11.33-11.56% in BVNAD and BVGNC respectively. Fiber fractions also differed significantly (*P*< 0.05), with neutral detergent fiber ranging from 66.30 - 68.17%, acid detergent fiber 43.05 - 44.67% and acid detergent lignin 15.17-15.76% in BVGNC and BVNAD respectively. No significant variations was observed among the means for anti-nutrients content, with tannins ranging from 0.48–0.62%, saponins 2.68–3.35%, oxalates 0.07–0.12% and phytates 0.61–0.93% in BVGNC and BVNAD respectively.. All anti-nutrients investigated fall within the normal range for optimal metabolic activities. It can be concluded ensiled *Bambusa vulgaris* leaves particularly groundnut cake silage, has potential as alternative feed resource for ruminants during the dry season.

Keywords: *Bambusa vulgaris*, Ensiling, Nutrient composition, Anti-nutrients, Ruminant feed

INTRODUCTION

Forage is the cornerstone of ruminant production, providing the most cost-effective nutrient source (Katoch, 2023). Year-round feed availability is essential to sustain animal growth and productivity, particularly in tropical regions where seasonal fluctuations challenge forage supply. In Nigeria, the rainy season (March to October) supports abundant grass growth, while the dry season (November to March) brings high temperatures, low humidity, and minimal rainfall, reducing forage quality and availability (Davies, 2024). Shrinking grazing lands due to population growth, soil degradation from over-cultivation, and erratic rainfall exacerbate feed shortages,

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limiting ruminant productivity (Mamphogoro, 2024).

Feed accounts for about 70% of the total cost of ruminant production (Thirumalaisamy *et al.* 2016). This high cost is attributed to competition among man, industry, and livestock for conventional foodstuffs (Amelie *et al.*, 2023). Therefore, there is a need to source alternative livestock feedstuffs that are cheap, readily available, and not competed by man and industry. According to Mako *et al.*, (2018), utilizing non-food parts from agricultural products as animal feed will not only enhance food security but also contribute to alleviating environmental problems associated with their disposal. The attempt to source locally available low-cost but nutritionally adequate feedstuff for ruminants has highlighted the potential of bamboo leaves as an alternative feed source.

Bambusa vulgaris, a widely distributed bamboo species in tropical regions including Nigeria, presents a viable alternative feed resource to address the high cost and competition for conventional ruminant feedstuffs. Its leaves, available year-round due to the species' rapid growth and drought tolerance, offer substantial nutritional value, including high crude protein, essential amino acids, and vitamins (Ilyas *et al.*, 2021). These attributes support rumen fermentation and animal growth, enhancing livestock productivity. Facing minimal competition from human or industrial uses, *B. vulgaris* leaves, usually discarded as agricultural waste, can be utilized to reduce reliance on costly concentrates (Mako et al., 2021). This approach lowers feed expenses, improves farm profitability, and promotes environmental sustainability by repurposing abundant local resources. In Nigeria, where dry-season feed shortage challenges ruminant production, *B. vulgaris* offers a cost-effective, nutritionally adequate feed option, contributing to sustainable livestock systems and food security (Ogunbosoye and Babayemi, 2010).

Chemical analysis, encompassing proximate composition, fiber fractions, and anti-nutrient profiling, offers a robust and cost-effective approach to evaluate livestock feed nutritional value and safety, ensuring their suitability for ruminant diets (AOAC, 2023). This methodology is particularly valuable for assessing unconventional forages, such as bamboo leaves, which are increasingly recognized for their potential to address feed scarcity in tropical regions. Quantifying key nutrients (e.g., crude protein, carbohydrates) and identifying anti-nutrients (e.g., tannins, cyanogenic glycosides), precise formulation of balanced rations is enabled through this approach. Silage-making, a technique involving preservation through anaerobic fermentation, effectively conserves excess wet-season forage for dry-season use, ensuring a consistent and high-quality feed supply during periods of scarcity (Olorunnisomo, 2014). This process not only enhances nutrient availability by breaking down complex carbohydrates but also reduces anti-nutrient levels, improving palatability and safety. Bamboo leaves, silage-making is a practical strategy to harness their evergreen biomass, supporting sustainable livestock production in tropical environments.

This study assesses the silage quality, nutrient, and anti-nutrient content of ensiled *Bambusa vulgaris* leaves to determine their suitability as a dry-season feed for ruminants in Nigeria.

MATERIALS AND METHODS

Sample Collection

Bambusa vulgaris plants within the environment of Lead City University, Ibadan, Oyo State, bearing the coordinates of (Latitude 7.327° N and Longitude 3.880° E), were randomly marked for sample collection. Approximately 3–5 kg of fresh leaves are harvested from ten marked plants during the early rainy season (April–May, 2024). Leaves were cleaned with a soft cloth to remove debris and chopped into 2–3 cm lengths with a shredding machine.

Silage Making

The chopped leaves were ensiled with different additives: (i) BVWHO (80% leaves + 20 % wheat offal), (ii) BVGNC (80% leaves + 20 % groundnut cake), (iii) BVNAD (100 % leaves with no additive). Leaves and additives were mixed at a ratio of 4:1 (4 parts leaves to 1 part additive). Each treatment was packed into 5-liter plastic buckets lined with cellophane bags to mimic a silo, compacted to eliminate air pockets, and sealed. A heavy weight was placed on each bucket to ensure anaerobic fermentation and prevent rodent attack. Silos were stored at ambient temperature (25–30°C) for 21 days. Each treatment was replicated three times.

Silage Characteristics Procedure

After 21 days, silos were opened, and silage quality was assessed. For pH, 2 g samples were mixed with 15 ml distilled water, boiled for 5 minutes, cooled, and measured using a standardized pH meter (Hanna HI98130). Temperature was recorded immediately upon opening using a digital thermometer. Aroma (pleasant/unpleasant), texture (firm/wet), and color (green/brown) were evaluated subjectively by a trained panel.

Analysis of Proximate Components and Fiber Fractions

Ensiled samples were oven-dried at 100°C until constant weight for dry matter (DM) determination. Crude protein (CP), crude fiber (CF), ether extract (EE), and ash were analyzed in triplicate using AOAC methods (2023). Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were determined per Van Soest *et al* (1995).

Analysis of Minerals

Ten minerals (Ca, Na, K, Fe, Cu, Mn, Zn, Mg, Pb, P) were analyzed. Samples were digested with a HNO3/HClO3 mixture (20:5 v/v). The digest was made up to 100 ml with deionized water. Ca, Na, K, Fe, Cu, Mn, Zn, Mg, and Pb were determined using an atomic absorption spectrophotometer (Model 420, Gallenkamp and Co. Ltd.). Phosphorus was estimated with vanadium molybdate solution, with color read at 420 nm using a spectrophotometer.

Anti-nutrients analysis

Tannins, saponins, oxalates, and phytates were quantified in triplicate. Saponins were analyzed using the spectrophotometric method of Brunner (1984) at 380 nm. Tannins were determined by methanol extraction and read at 760 nm. Oxalates were quantified by titration against 0.05N KMnO4 after precipitation. Phytates were analyzed per Makkar (2003) using spectrophotometric methods.

Statistical Analysis

Data were subjected to one-way analysis of variance (ANOVA) using SAS (2021). Significant treatment means were separated by Duncan's multiple range test at ($P < 0.05$).

RESULTS AND DISCUSSION

Quality characteristics of ensiled *Bambusa vulgaris* leaves

The temperature of ensiled *Bambusa vulgaris* leaves (Figure 1) was consistent at 27.0 ^{0}C across all *Bambusa vulgaris* leaves ensiled with additives (BVGNC and BVWHO), while the temperature recorded for BVNAD is 29 ^{0}C, aligning with values for well-preserved tropical silages (Akinwande, 2011; Mako *et al.*, 2018). This value falls within the optimal range (27–38°C) for lactobacillus activity, promoting effective fermentation without spoilage (Yamamoto *et al.*, 2011; Muck, 2012). Temperatures exceeding 30^{0}C can cause sugar caramelization, and above 55°C, reduced protein digestibility and dark discoloration may occur (Akinwande, 2011). The stable 27.0°C indicates minimal risk of mycotoxin formation, which can reduce animal intake and performance (Akinwande *et al.*, 2015). Figure 2 presents the pH values obtained in this study, ranging from 4.0 to 5.0 in BVGNC and BVNAD, respectively. These values are within the ideal range (3.5–5.5) reported for tropical silages (Obua 2018). The lower pH obtained in BVGNC suggests enhanced lactic acid production, inhibiting plant enzymes and undesirable bacteria, thus improving silage stability (Moore *et al.,* 2020). The values agree with findings of Akinwande (2011) and Akinwande *et al*., 2015), who reported a pH range of 4.45–5.40 for water hyacinth ensiled with different additives. The aroma, texture, and colour of all silages are presented in Table 1. All silages exhibited a pleasant aroma, confirming proper fermentation (Mako *et al*., 2021). The firm texture observed for BVGNC and BVWHO can be attributed to additives promoting lactic acid bacteria and reducing moisture content (Moore *et al.,* 2020). Color was brownish-green for BVGNC and BVWHO, reflecting additive influence, and greenish for BVNAD, indicating good preservation similar to the original forage (Akinwande *et al.,* 2015). These characteristics suggest that ensiled *B. vulgaris* leaves, particularly with additives, are well-suited as a stable, high-quality dry-season feed for ruminants in Nigeria.

Table 1. Quality characteristics of ensiled bamboo leaves.

Parameters	Aroma	Texture	Colour
BVGNC	Pleasant	Firm	Brownish green
BVWHO	Pleasant	Firm	Brownish green
BVNAD	Pleasant	Wet	Greenish

Bamboo leaves ensiled with groundnut cake = BVGNC; BVWHO = Bamboo leaves ensiled with Wheat offal; BVNAD = Bamboo leaves ensiled without additives

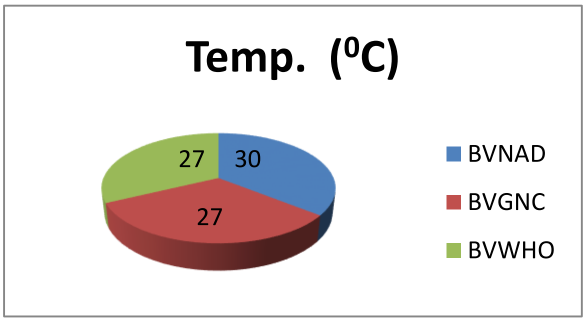

Figure 1. Temperature (^{0}C) value of *B. vulgaris* ensiled with different additives.

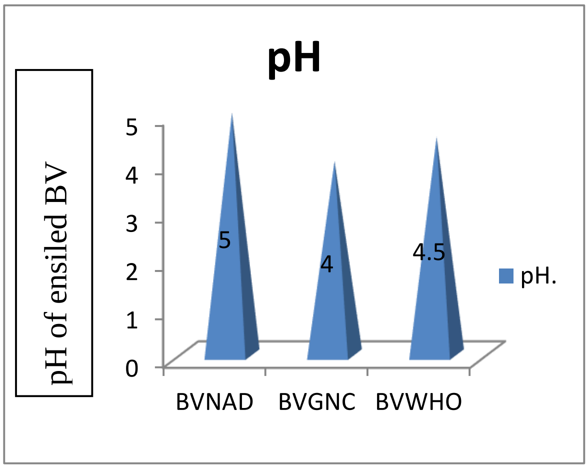

Figure 2. pH value of *B. vulgaris* ensiled with different additives.

CHEMICAL COMPOSITION OF ENSILED *BAMBUSA VULGARIS* LEAVES

Table 2 presents the chemical composition of ensiled *Bambusa vulgaris* leaves, encompassing proximate composition and fibre fractions, with all parameters exhibiting significant differences ($P < 0.05$). Dry matter (DM) ranged from 95.01% (BVGNC) to 95.72% (BVNAD), with BVWHO at 95.63%, indicating proper preservation efficiency under tropical conditions. Slight DM reductions in BVGNC and BVWHO reflect fermentation losses from additives, consistent with silage dynamics (Mako *et al.*, 2021).These values are higher than the findings of Mako *et al*. (2021), who reported a dry matter range of 50.36 – 75.52 % for ensiled *Alternanthera brasiliana*. Crude protein (CP) was highest in BVGNC (18.00%) and lowest in BVNAD (17.21%). The elevated CP in BVGNC stems from groundnut cake's high nitrogen content, which enhances microbial protein synthesis in the rumen (Mako *et al*., 2021). The CP obtained for all silages in this study exceeds the 7.7% CP requirement for small ruminants (NRC, 2024); these levels support optimal rumen function and voluntary feed intake without supplementation (Wanapat *et al*., 2013). However, these values arehigher than 15.14 % reported for cassava leaf silage (Anaetoet *al*., 2013). Crude fibre (CF) ranged from 23.92% (BVGNC) to 24.89% (BVNAD), with BVWHO at 24.73%. The lower CF in BVGNC suggests that groundnut cake's soluble nutrients reduced structural carbohydrates, improving palatability and digestion, similar to ensiled *Alternanthera brasiliana* leaves (Makoet *al.*, 2021). There was a significant reduction in the ether extract content, ranging from 1.36 – 1.43% in BVGNC and BVNAD, respectively. Similar result was obtained for the ash content. Ash content is indicative of total minerals in a feed (Getachew *et al.*, 1999); it ranged from 11.36% in BVGNC to 11.56% in BVNAD. This reduction might be due to the effluent loss (Abegunde, 2017). These values are lower than the value range of 3.90 – 4.03% reported for cassava leaves silage fermented with rice bran and palm kernel cake (Priabudiman and Sukaryana, 2022. Nitrogen-free extract (NFE), representing digestible carbohydrates available to an animal in a feed and supporting energy supply to rumen microbes, was highest in BVGNC (45.39%)and lowest in BVWHO (44.73%), agreeing with the values (48.20–50.10%) reported for water hyacinth silage (Akinwande *et al.*, 2015). Fibre fractions are pivotal for assessing feed digestibility. Neutral detergent fibre (NDF) ranged from 66.30% (BVGNC) to 68.17% (BVNAD), acid detergent fibre (ADF) varied from 43.05% (BVGNC) to 44.67% (BVNAD), aligning with the value range of 47.18–50.31% reported for shed leaves (Alemawor*et al.*, 2009), indicating enhanced digestibility compared to other browse plants. Acid detergent lignin (ADL) ranged from 15.17% (BVGNC) to 15.76% (BVNAD). The lower

NDF, ADF, and ADL in BVGNC could be attributed to the provision of fermentable substrates, which reduce lignocellulosic components during ensiling, a mechanism observed in *Alternanthera brasiliana* silage (Mako*et al.*, 2021). Fiber is essential for ruminant diets, providing roughage that stimulates rumination (Ani and Adiegwu, 2005). NDF regulates voluntary feed intake, while ADF correlates negatively with digestibility (Ismartoyo *et al.*, 2022). Higher NDF and ADF in BVNAD may limit intake and digestion, whereas BVGNC's lower values enhance feed quality and animal performance (Ismartoyo*et al.*, 2022). The indigestible lignin fraction (ADL) further underscores BVGNC's digestibility advantage, as lower lignin improves rumen fermentation efficiency. These fibre profiles indicate that ensiled *B. vulgaris* leaves are ideally suited for ruminants, as high fibre levels restrict digestion in monogastrics (Ani and Adiegwu, 2005). The inverse relationship between NDF and ADF and intake highlights the nutritional superiority of BVGNC and BVWHO over BVNAD for tropical ruminant systems (Ismartoyo*et al*, 2022). The high CP, substantial mineral content, and digestible fibre fractions of ensiled *B. vulgaris* leaves align with the goal of silage's preserving forage quality for dry-season feed in Nigeria (Mako*et al.*, 2021). Groundnut cake's enhancement of CP and reduction of fibre components make BVGNC particularly valuable, supporting rumen health, intake, and growth. These characteristics address feed scarcity in tropical regions, positioning ensiled *B. vulgaris* leaves as a sustainable, nutrient-rich feed option for ruminants, capable of improving productivity in resource-constrained environments.

Table 2. Chemical composition (%) of ensiled bamboo leaves.

Parameters	BVNAD	BVGNC	BVWHO	SEM
Dry matter	95.72^a	95.01^c	95.63^b	0.15
Crude protein	17.21^c	18.00^a	17.64^b	0.05
Crude fibre	24.89^a	23.92^c	24.73^b	0.01
Ether extract	1.43^a	1. 36^c	1. 40^b	0.001
Ash	11.56^a	11.33^c	11.50^b	0.02
NFE	44.91^b	45.39^a	44.73^c	0.05
NDF	68.17^a	66.30^c	67.44^b	0.50
ADF	44.67^a	43.05^c	44.00^b	0.05
ADL	15.76^a	15. 17^c	15.23^b	0.02

a,b, c= means on the same column with different superscript differed significantly ($p<0.05$). Bamboo leaf ensiled with groundnut cake= BVGNC; BVWHO= bamboo leaf ensiled with wheat offal; BVNAD= bamboo leaf ensiled without additive; NFE =Nitrogen-free extract; NDF= Neutral detergent fibre; ADF= Acid detergent fibre and ADL= Acid detergent lignin. SEM= standard error of mean

The anti-nutrient content of ensiled Bamboo (*Bambusa vulgaris*)

No significant variation occurred among the treatment means. Tannin, saponin, oxalate, and phosphate levels obtained in this study ranged from 0.48 -0.62 %, 2.68 -3.35%, 0.07-0.12%, and 0.61- 0.93%, respectively. Tannins are plant polyphenols, which can form complexes with metal ions and macromolecules such as proteins and polysaccharides, thereby protecting from ruminal degradation (Abu *et al*, 2022). Saponin suppresses methanogens, a major energy loss to animals (Mako *et al.*, 2020). Oxalate forms complexes with most essential trace elements, making them unavailable (Eneobong, 2001). Phytic acid inhibits the absorption and utilization of some mineral elements (Eneobong 2001). All phyto-chemicals in Bamboo (*Bambusa vulgaris*) leaf are below the toxic level, which means the presence of anti-nutritional factors ensiled Bamboo (*Bambusa vulgaris*) leaf benefits animals.

Table 3. Anti-nutrient composition (mg/100g) of ensiled bamboo (*Bambusa vulgaris*) leaves.

Parameters	Tannin	Saponin	Oxalate	Phytate
BLNAD	0.62	3.35	0.12	0.93
BLGNC	0.48	2.68	0.07	0.61
BLWHO	0.54	2.90	0.09	0.70
SEM	1.15	1.50	1.10	1.10

Bamboo leaf ensiled with groundnut cake= BVGNC;
BVWHO= bamboo leaf ensiled with wheat offal;
BVNAD= bamboo leaf ensiled without additives
SEM=standard error of mean

CONCLUSION

Based on the findings, ensiled *Bambusa vulgaris* leaves exhibit high nutritive value, making them an effective feed resource for ruminant production in Nigeria. The silage quality, with optimal pH, temperature, and firm texture, ensures good keeping quality. High crude protein and low digestible fiber fractions, particularly with groundnut cake, support the nutrients of ruminants. Anti-nutrients (tannins, saponins, oxalates, and phytates) are below toxic levels, enhancing safety. Ensiled *B. vulgaris* leaves, especially with groundnut cake or wheat offal, are recommended as a dry-season feed supplement, suitable for direct feeding or diet incorporation. Awareness campaigns should promote their cost-effective benefits to rural farmers, improving livestock nutrition in the tropics. This innovation offers a sustainable, low-cost feed alternative that could enhance smallholder ruminant productivity in tropical regions.

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