

Response of West African Dwarf Bucks to Diets containing *Morinda lucida* Benth (Brimstone) Leaf Powder as Phytogetic Feed Additive

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Abstract

Rumen manipulation to reduce nutrients excretion is desirable to increase productivity in ruminants. A study was conducted to assess the dietary effects of *Morinda lucida* leaf powder (MLLP) on the growth performance and rumen fermentation parameters of growing West African Dwarf goats. Twenty-four West African Dwarf bucks were divided into four treatment groups of six animals in a completely randomized design. The animals were fed basal diet of *Panicum maximum* and concentrate supplement containing MLLP at 0, 5, 10, and 15mg/kg DM. Mineral composition of MLLP was determined. Feed intake, weight gain, nutrient digestibility and feed conversion ratio of the experimental goats were calculated and rumen fermentation parameters were determined. Results showed that MLLP contains calcium, phosphorus, magnesium, iron and zinc. Dietary inclusion of MLLP increased ($p < 0.05$) daily weight gain, feed conversion ratio, crude protein, neutral detergent fibre (NDF), and acid detergent fibre (ADF) digestibility at 10 and 15mg/kg DM. Nitrogen intake and faecal nitrogen were not significantly ($p > 0.05$) affected by the inclusion of MLLP. Higher nitrogen retention (62.96% and 65.36%) were also recorded at 10 and 15mg/kg DM. The inclusion of MLLP in the diet of the goats improved total volatile fatty acid production. It was therefore concluded that 10mg/kg DM MLLP can be utilized as phytogetic additive in the diet of growing WAD goats to improve feed intake, weight gain, nitrogen retention and volatile fatty acids production.

Keywords: Phytogetic additive, digestibility, nitrogen retention, volatile fatty acids, weight gain

Réponse des boucs nains d'Afrique de l'Ouest aux régimes alimentaires contenant de la poudre de feuilles de *Morinda lucida* Benth (soufre) comme additif alimentaire phytogénique



Resume

La manipulation du rumen pour réduire l'excrétion de nutriments est souhaitable pour augmenter la productivité des ruminants. Une étude a été menée pour évaluer les effets alimentaires de la poudre de feuilles de *Morinda lucida* (MLLP) sur les performances de croissance et les paramètres de fermentation ruminale de chèvres naines d'Afrique de l'Ouest en croissance. Vingt-quatre boucs nains d'Afrique de l'Ouest ont été répartis en quatre groupes de traitement de six animaux selon un plan entièrement randomisé. Les animaux ont reçu une ration de base composée de *Panicum maximum* et un complément concentré contenant de la MLLP à 0, 5, 10 et 15 mg/kg de matière sèche. La composition minérale de la MLLP a été déterminée. La consommation alimentaire, le gain de poids, la digestibilité des nutriments et l'indice de consommation des chèvres expérimentales ont été calculés et les paramètres de fermentation ruminale ont été déterminés. Les résultats ont montré que la MLLP contient du calcium, du phosphore, du magnésium, du fer et du zinc. Français L'inclusion alimentaire de MLLP a augmenté ($p < 0,05$) le gain de poids quotidien, l'indice de conversion alimentaire, les protéines brutes, les fibres au détergent neutre (NDF) et la digestibilité des fibres au détergent acide (ADF) à 10 et 15 mg/kg de matière sèche. L'apport en azote et l'azote fécal n'ont pas été significativement ($p > 0,05$) affectés par l'inclusion de MLLP. Une rétention d'azote plus élevée (62,96 % et 65,36 %) a également été enregistrée à 10 et 15 mg/kg de matière sèche. L'inclusion de MLLP dans l'alimentation des chèvres a amélioré la production totale d'acides gras volatils. Il a donc été conclu que 10 mg/kg de matière sèche de MLLP peuvent être utilisés comme additif phytogénique dans l'alimentation des

chèvres WAD en croissance pour améliorer l'ingestion d'aliments, le gain de poids, la rétention d'azote et la production d'acides gras volatils.

Mots clés: Additif phytogénique, digestibilité, rétention d'azote, acides gras volatils, prise de poids

Introduction

Efficient rumen fermentation is a prerequisite to improved productivity of ruminant livestock. Rumen fermentation results in the production of volatile fatty acids, ammonia-N, carbon dioxide and methane. Volatile fatty acids are the major energy source for ruminants. Excessive production of ammonia-N and methane lead to loss of nitrogen and energy respectively, which could otherwise be utilized for meat and milk production. Rumen manipulation to reduce nutrients excretion is therefore desirable to increase productivity in ruminants. Animal nutritionists have identified the potential of phytobiotics inherent in phytogetic/medicinal plants and their extracts as natural rumen modulators. Bamipidis *et al.* (2006) and Stefanska *et al.* (2021) reported that phytobiotics in medicinal plants have a particular broad spectrum of action. According to Varga-Visi *et al.* (2023) and Rochfort *et al.* (2008) phytobiotics have promising effect on nutrient utilization and health of animals. Phytogetic plants have emerged as alternatives to antibiotics and synthetic chemicals due to their ban, and increased public and scientific concern regarding residual effects, drug resistance and environmental issues (Jouany and Morgavi 2007; Katsoulos *et al.*, 2017).

Phytogetic plants contains a wide variety of phytochemicals, which are also regarded as plant secondary metabolites or phytobiotics. Phytobiotics are natural bioactive compounds that are derived from plants and incorporated into animal feed to enhance productivity (Gadde *et al.*, 2017). The beneficial effects of phytobiotics are attributed to their digestion-stimulating effect (Abdel-wareth and Lohakare 2020) anti-inflammatory effect (Lu *et al.*, 2020), antimicrobial and antioxidant effects among others. Phytobiotics are relatively high and accumulated in some parts of the plants like the leaves, rhizomes, roots, flowers, bark, fruits or seeds (Foksowicz-Flaczyk *et al.*, 2022).

Phytobiotics include polyphenols especially essential oils, saponins and terpenoids (Windisch *et al.*, 2008). The efficiency of phytogetic feed additives is affected by several factors such as plant species, extract composition, application methods and levels (Sevim and Gufadar 2017; Abdel-wareth and Lohakare 2020). Phytogetic plants have been used in various studies for manipulation of rumen fermentation to reduce methane production (Flachowsky and Lebzien 2012, Oni *et al.*, 2021; Adebayo *et al.*, 2023), reduction of oxidative stress and increase in antioxidant activity in various tissues (Settle *et al.*, 2014), reduction in faecal egg count in goats (Adebayo *et al.* 2019; Adebayo *et al.*, 2022) improved nutrient digestibility (Adebayo *et al.*, 2022), improved milk yield (Rahman *et al.*, 2024), improved meat quality (Redoy *et al.*, 2020) and for improved immune response (Lee *et al.*, 2010; Nworu *et al.*, 2012, Redoy *et al.*, 2020; Rahman *et al.*, 2024).

Morinda lucida is a natural, well-known medicinal plant in West Africa (Lawal *et al.*, 2008). The plant is an excellent source of phytobiotics and nutritive components. The leaves contain high level of vitamin K which helps in building of strong bone. It is reported to possess strong trypanocidal and aortic vasorelaxant activities. The leaf and stem bark is reported to possess anticancer, hepatoprotective, cytotoxic, and genotoxic, anti-spermatogenic, hypoglycemic and anti-diabetic activities (Adeleye *et al.*, 2018a). Phytochemicals associated with *Morinda lucida* include 10 anthraquinones, alkaloids, tannins, flavonoids, saponins, glucosides, and triterpenoids (Adeleye *et al.*, 2018b). Evans *et al.* (2002) reported the presence of Oruwacin in the roots and, ursolic and oleanolic acids which are also classified as triterpenes in the leaves of *Morinda lucida*. In Ghana, a tetracyclic iridoid named molucidin and its derivatives have been isolated and characterized from the leaves of M.

lucida through a bioassay guided fractionation process in the quest for drug development against parasitic infections such as trypanosomiasis, malaria and leishmaniasis (Suzuki *et al.*, 2015; Kwofie *et al.*, 2016). Gadde *et al.* (2017) reported that the immune-activating properties of *Morinda lucida* have been used to stabilize the microbial community of the rumen, and Adebayo *et al.*, (2023) reported the potential of *Morinda lucida* in methane mitigation. Many studies (Ola-Fadunsin and Ademola, 2014; Olayemi, *et al.*, 2016; Lala, *et al.*, 2018) have been done to assess the effects of *Morinda lucida* on poultry performance. However, there is dearth of information on its effect on ruminants' performance. Hence, this study aim at assessing the effect of *Morinda lucida* leaf powder as phytogetic feed additive on growth performance, nutrient digestibility and rumen fermentation parameters in West African dwarf goats.

Material and Methods

Experimental site

The experiment was carried out at the Small Ruminant unit of the Directorate of University Farms (DUFARMS), Federal University of Agriculture (FUNAAB), Abeokuta, Ogun State, Nigeria. The University is located in the derived savannah vegetation zone of South - Western Nigeria (Latitude 7^o, 13' 35.48"N, longitude 3^o 2'E) with elevation of 415 feet and eye altitude of 75m-77m above sea level (Google Earth, 2023). The area lies in the tropical climate with mean average rainfall of 1.037mm and a main ambient temperature of about 34.7 °C and yearly average humidity of 83% (Metrological Station, Water Resources Management and Agrometrology Department, FUNAAB).

Harvesting and Processing of Morinda lucida leaves

Morinda lucida leaves were plucked fresh from its trees within the premises of the University.

The harvested leaves were identified at the Department of Pure and Applied Botany, FUNAAB. They were air-dried to a constant moisture content level and were later milled to pass through 2mm sieve and kept for later use.

Experimental Animals and their Management

Twenty-four (24) growing West African Dwarf (WAD) bucks with average weight of 7.65±0.35 were purchased for the study from villages around the University. The animals upon arrival were kept in the quarantine pen for two weeks and anti-stress, antibiotics and dewormer were administered to them. During the course of quarantine, the goats were fed with wilted *Panicum maximum* and cassava peels while water was provided unrestricted. At the end of the quarantine period the animals were weighed and divided into four treatment groups of six animals each on weight equalization basis. The goats were housed in well disinfected individual pens and fed twice daily (8:00am and 12:00pm). They were weighed weekly to monitor weight changes.

Experimental Diets

The diets consist of basal diet of *Panicum maximum* and supplemental concentrate. The *P. maximum* was cut after 6 weeks of regrowth at 15cm above ground level from an established pasture. Concentrate supplement was formulated to contain *Morinda lucida* leaf powder as additive at 0, 5, 10 and 15mg/g inclusion levels (Table 1). Panicum and concentrate supplement were offered to the animals at a ratio of 60:40 respectively based on 5% body weight while fresh and clean water was offered *ad libitum*. The concentrate supplement was offered first at 8.00 am and Panicum at 12.00pm in separate feeding troughs. Left over of the feed offered was weighed and recorded every morning for each goat to determine feed intake. The experiment lasted for 112 days; 14 days for adaptation, 84 days for feeding trial and 14 days for digestibility study.

Table 1: Gross composition (%) of concentrate Supplement

Ingredients	Levels of inclusion of MLLP (mg/g)			
	0	5	10	15
Wheat offal	30	30	30	30
Maize bran	30	30	30	30
Palm kernel cake	20	20	20	20
Rice bran	17	17	17	17
Bone meal	2	2	2	2
Salt	1	1	1	1
<i>Morinda lucida</i> leaf powder	-	+	++	+++
Total	100	100	100	100

MLLP – *Morinda lucida* leaf powder

Apparent Nutrient Digestibility and Nitrogen Balance Measurements

The digestibility experiment was carried out for a 14 day period. Four animals per treatment were transferred into individual metabolic cages where known quantity of feed was provided, and water was provided *ad-libitum*. The first 7 days was for adaptation and adjustment of the animals to the metabolic cage and the last seven (7) days served for collection of samples. Daily output of faeces for each animal was collected and weighed fresh. Ten percent of each day's collection for each animal were taken, dried at 60°C in the oven to a constant weight and bulked for each goat for the 7 days. Urine was collected in plastic bottles containing 2ml of 10% H₂SO₄ solution to prevent ammonia-N loss and maintained pH below 3.0 (Chen and Gomez, 1992). Total volume of urine voided was measured and 10% aliquot was retained daily, bulked for each goat within the collection period and stored in the refrigerator for subsequent analysis. Apparent nutrient digestibility was calculated as the difference between the nutrients in the feed intake and that of faeces expressed as a percentage of intake;

$$\text{Digestibility (\%)} = \frac{\text{Nutrient intake (g/d)} - \text{Faecal nutrient (g/d)}}{\text{Nutrient intake (g/d)}} \times 100$$

intake (g/d)

Nitrogen content of feed, faeces and urine was determined and the following calculations were made:

Nitrogen intake (g/d) = feed intake DM x nitrogen in the feed

Total nitrogen output (g/d) = faecal nitrogen + urinary nitrogen

Nitrogen balance (g/d) = nitrogen intake - total nitrogen output

Nitrogen absorption (g/d) = nitrogen intake - faecal nitrogen

Nitrogen retention = $\frac{\text{Nitrogen balance}}{\text{Nitrogen intake}} \times 100$

Determination of rumen fermentation parameters

On the last day of the digestibility trial, rumen fluid was collected from four (4) goats per treatment at 4 hours post feeding period. The fluid was freed from coarse particles by filtration through four-layered cheese cloth and pH was measured using portable pH meter (HANNA instruments HI 98153). One half of the fluid was acidified with few drops of concentrated H₂SO₄ and stored frozen at -20°C for the determination of ammonia-N concentration using steam distillation procedures (Ogubai and Sereke, 1997). The second half was stored frozen at -20°C for the determination of total volatile fatty acid (TVFA) concentration using Markham apparatus as described by Barnett and Reid (1956). This was carried out by adding 2 ml of rumen fluid together with 1 ml 10 % Potassium oxalate buffer and 1 ml oxalic acid injected into the Markham apparatus, where a distillate of 100ml was collected. This was then titrated against a standard 0.01N NaOH with 2 drops of

phenolphthalein as indicator. Concentration of TVFA was then calculated using the following equation:

$$\text{TVFA (Mm)} = (\text{NaoH volume} \times \text{NaOH normality} \times 1000) / \text{rumen inoculum volume}$$

Chemical analyses of the samples

Proximate analyses of the diets, faeces and urine were determined by the methods of the Association of Official and Analytical Chemists (A.O.A.C, 2005). The fibre fractions; neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to Van Soest *et al.*

Results and Discussion

Results

Table 2: Chemical composition (%) of experimental diets and *Morinda lucida* leaf powder

Parameters	*Concentrate	* <i>Panicum maximum</i>	<i>Morinda lucida</i> leaf powder
Dry matter	93.77	44.51	91.40
Crude Protein	14.18	8.05	8.85
Crude fibre	12.67	20.00	9.00
Ether extract	4.50	3.00	2.50
Ash	9.83	9.25	10.83
Nitrogen Free Extract	58.82	59.70	68.82
Neutral Detergent fibre	59.00	64.33	38.33
Acid Detergent Fibre	21.00	29.00	24.33
Acid Detergent Lignin	19.33	27.33	23.67
Metabolizable Energy (MJ/Kg)	12.24	11.91	12.03

*Adebayo *et al.* (2023)

Table 3: Phytochemical and mineral composition of *Morinda lucida* leaf powder

*Phytochemicals (mg/100g)	Content
Tannin	511.41
Phenolic acid	328.15
Oxalate	110.58
Glycoside	4.34
Flavonoids	595.63
Trypsin inhibitor	229.01
Saponin (%)	8.62
Alkaloids (%)	3.48
Minerals (mg/100g)	
Calcium	2513.59
Phosphorus	389.82
Magnesium	850.80
Iron	117.75
Zinc	4.11
Selenium	0.001

(1991). Nitrogen free extract was calculated as 100-(CP+CF+EE+Ash).

Statistical Analysis

Data obtained were subjected to one-way analysis of variance in a completely randomized design using version 9.1 of SAS software (SAS 2003) with the following model: $Y_{ij} = \mu + T_i + e_{ij}$, where Y_{ij} = observed variation, μ = population mean, T_i = effect of varying levels of *Morinda lucida* leaf powder and e_{ij} = error term. Means were separated using Duncan's procedure of the same software.

* Adebayo *et al.* (2023)**Table 4: Growth Performance of West African Dwarf goats fed diets containing *Morinda lucida* leaf powder (MLLP)**

Parameters	Inclusion levels of MLLP (mg/g)				SEM	P value
	0	5	10	15		
Weight measurements (kg)						
Initial weight	7.32	7.08	7.30	7.28	0.19	0.97
Final weight	10.11 ^b	9.94 ^b	10.35 ^a	10.75 ^a	0.24	0.04
Total weight gain	2.79 ^b	2.86 ^b	3.05 ^b	3.47 ^a	0.11	0.03
Daily weight gain (g)	33.21 ^b	34.05 ^b	36.3 ^{ab}	41.31 ^a	1.25	0.04
Dry matter intake (kg)						
Grass intake	20.37	20.24	20.68	20.37	0.15	0.76
Concentrate intake	12.12	11.56	12.14	12.18	0.20	0.67
Total dry matter intake	32.49	31.80	32.82	32.55	0.28	0.64
Daily dry matter intake (g)	386.79	378.57	390.71	387.50	3.20	0.64
Feed conversion ratio	11.65 ^a	11.12 ^b	10.76 ^{bc}	9.38 ^c	0.50	0.01

^{abc} Means in the same row having different superscripts are significantly different ($P < 0.05$).**Table 5: Nutrient Digestibility and Nitrogen Utilization in West African Dwarf goats fed diets containing *Morinda lucida* leaf powder (MLLP)**

Parameters	Inclusion levels of MLLP (mg/g)				SEM	P value
	0	5	10	15		
Digestibility (%)						
Dry matter	71.18	72.49	73.71	73.55	0.47	0.21
Crude Protein	73.75 ^b	73.98 ^b	76.83 ^a	77.50 ^a	1.30	0.01
Crude fibre	68.46	64.77	71.07	68.27	1.86	0.78
Ether Extract	71.94	72.24	71.03	71.11	0.25	0.08
Ash	58.63	61.49	61.39	62.81	1.35	0.67
Neutral Detergent fibre	61.61 ^b	60.41 ^b	65.75 ^a	64.98 ^a	1.02	0.04
Acid Detergent Fibre	59.53 ^b	63.18 ^{ab}	66.60 ^a	64.57 ^{ab}	1.08	0.04
Acid Detergent Lignin	48.09	48.09	50.86	49.96	0.52	0.12
Nitrogen utilization (g/day)						
Nitrogen intake	4.40	4.39	4.40	4.39	0.01	0.87
Faecal Nitrogen	1.48	1.39	1.33	1.32	0.10	0.95
Urinary Nitrogen	0.60 ^a	0.35 ^b	0.30 ^b	0.20 ^b	0.06	0.02
Total nitrogen output	2.08	1.74	1.63	1.52	0.10	0.92
Nitrogen Absorption	2.92	3.00	3.07	3.07	0.10	0.03
Nitrogen retained	2.32 ^b	2.65 ^a	2.77 ^a	2.87 ^a	0.10	0.96
Nitrogen Retention (%)	52.72 ^c	60.36 ^b	62.96 ^{ab}	65.36 ^a	2.32	0.00

^{abc} Means in the same row having different superscripts are significantly different ($P < 0.05$).**Table 6: Ruminal pH, ammonia Nitrogen (NH₃-N) and total volatile fatty acids (TVFA) production in West African dwarf goats fed diets containing *Morinda lucida* leaf powder (MLLP)**

Parameters	Levels of inclusion of MLLP (mg/g)				SEM	p-value
	0	5	10	15		
Pre-feeding (0 hours)						

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pH	6.50	6.62	6.63	6.60	0.1165	0.81
NH ₃ -N (mg/dl)	21.55	24.15	21.84	23.89	2.1139	0.05
TVFA (mM)	32.67	38.13	35.60	32.40	1.5205	0.74
Post-feeding (6 hours)						
pH	6.36	6.39	6.30	6.36	0.1437	0.21
NH ₃ -N (mg/dl)	36.16 ^a	30.05 ^b	31.04 ^b	32.19 ^b	3.2284	0.17
TVFA (mM)	36.20 ^b	50.27 ^a	52.67 ^a	48.13 ^a	3.2877	0.02

Means on the same row with different superscript are significantly different (p<0.05)

Dietary inclusion of *Morinda lucida* leaf powder (MLLP) significantly (p<0.05) influenced final weight, total weight gain, daily weight gain and feed conversion ratio of the experimental goats (Table 4). Total weight gain (3.47kg) was highest in goats fed 15mg/g DM MLLP. Final weight gain and daily weight gain were highest in goats fed diets containing 10 and 15mg/g DM MLLP. Feed conversion ratio was best in goats fed diets containing 10 and 15mg/g DM MLLP. Total and daily dry matter intake were not significantly (p>0.05) affected by the inclusion of MLLP in diet of the animals. Presented in table 5 is the nutrient digestibility and nitrogen utilization in goats fed diets containing MLLP. Dry matter, crude fibre, ether extract, ash and acid detergent lignin digestibility were not affected (p>0.05) by the experimental diets. Crude protein and neutral detergent fibre (NDF) digestibility was significantly (p<0.05) higher in goats fed 10 and 15g/kg DM MLLP. Acid detergent fibre digestibility was highest in goats fed diets containing MLLP and lowest in goats on the control diet. In all the parameters measured for nitrogen utilization in the experimental goats only urinary nitrogen, nitrogen retained (g/day) and nitrogen retention (%) were influenced (p<0.05) by inclusion of MLLP in the diets. Urinary nitrogen was highest in goats fed diets containing no MLLP (control) and lowest in goats fed varying levels of MLLP. This trend was reversed for nitrogen retained as the highest values was observed in goats fed diets containing MLLP and lowest in goats fed the control diet. Highest nitrogen retention values (65.36%) and (62.96) were recorded in goats fed diet containing 15 and 10mg/g DM MLLP

and the lowest value (52.72%) was recorded in goats fed the control diet

Table 6 shows the rumen fermentation parameters of goats fed diet containing varying levels of MLLP. Total volatile fatty acids and ammonia-nitrogen were affected (p<0.05) by inclusion of MLLP in the diet. Total volatile fatty acids production increased in goats fed diets containing MLLP. However, rumen ammonia nitrogen decreased in goats fed diets containing MLLP. The pH was not significantly (p>0.05) affected by inclusion of MLLP in the diet.

Discussion

Morinda lucida leaf powder (MLLP) used in this study was found to be high in calcium, phosphorus, magnesium and iron relative to zinc and selenium. Enabulele *et al.* (2017) also reported a high level of calcium and potassium but low level of zinc in *M. lucida* leaf extract. This result shows that MLLP can be a good source of calcium, phosphorus, magnesium and iron supplement for ruminants. Calcium and phosphorus are of great significant for growing ruminants (Okunade *et al.*, 2014). They are required for bone formation and development, muscle contractions, enzyme activation and among others (Harty, 2014). Gaal *et al.* (2004) reported that Mg remarkably improved the digestibility of feed. Mg plays a key role in enzymes, muscle and nerve function (Appel 1999). Trace elements possess a positive effect on the oxidative and immune status, with a moderate effect on glucose and fatty acid metabolism (Mohanta and Garg 2023). These trace elements include iron, zinc and selenium. According to Van den Top (2005) Fe is

necessary for normal enzyme function of the electron transport chain, cytochrome oxidase, ferredoxin, myeloperoxidase, catalase, succinate dehydrogenase and the cytochrome P-450 enzymes. All energy metabolism stages in all tissues required iron. Selenium plays an important role in fertility and immune response of animals. Its deficiency result in reduced fertility and placental retention (Eulogio *et al.*, 2012; Sordillo 2013). It also plays an active role in the defense against the accumulation of hydroperoxides from cellular metabolism (Sordillo 2016).

Positive weight gain was recorded for all the experimental animals. According to Anele *et al.* (2010) positive body weight gain suggested that the diets supplied more than the nutrients required for maintenance resulting in improved weight gain. The inclusion of *Morinda lucida* leaf powder (MLLP) at 10 and 15mg/g DM in the diets of the animals resulted in improved weight gain and feed conversion ratio (FCR). This suggests that the phytochemicals in MLLP did not hindered nutrients digestion and absorption hence the animals fed diets containing 10 and 15mg/g DM MLLP utilized the diets better for increased weight gain. This also points out that more protein is available for digestion and absorption in the small intestine for the growth of the animals. According to Adebayo *et al.* (2022) better feed conversion ratio is an indication of efficient conversion of feed to flesh. The additive minimized protein digestibility in the rumen (Alves Junior *et al.*, 2017) and increased its availability in the abomasum and small intestine. McDonald *et al.* (2011) opined that improved weight can be attributed to better microbial protein synthesis and increased microbial and total protein supplies to the body tissues. Redoy *et al.* (2020) attributed improved weight gain and FCR of sheep fed herbal-supplemented diets to decrease nutrient losses, increase nutrient turnover and reduce parasite count. Coelho *et al.* (2020) opined that secondary compounds in phytogetic additives allow for increased feed efficiency and invariably animal performance. Contrary to the results obtained in the study,

Adebayo *et al.*, (2019) and Olagoke (2021) observed no significant difference in the feed intake, weight gain and feed conversion ratio of West African dwarf goats fed diets containing *Ocimum gratissimum* (bitter leaf) and *Petiveria alliacea* (Guinea hen weed) leaf powder respectively as phytogetic feed additives. This might be as a result of variations in the type and quantity of phytochemicals in the plants, as well as the varying levels of inclusion used.

Choubey *et al.* (2015) reported that phytogetic feed additive improved digestibility of all nutrients in goats. However in this study MLLP improved digestibility of crude protein (CP), neutral detergent fibre (NDF) and acid detergent fibre (ADF). Increased crude protein digestibility in goats fed diets containing 10 and 15 mg/g DM MLLP could be responsible for the improvement observed in daily weight gain and feed conversion ratio of goats on those inclusion levels. Protein is responsible for growth and repair of worn-out tissues. Increased CP digestibility may indicate an increase in microbial protein synthesis and increased availability of amino acid for growth and other production functions in the lower tract. Coelho *et al.* (2020) also reported an increase in crude protein digestibility in sheep with phytogetic additive administration. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) digestibility were also higher in goats fed diets containing 10 and 15mg/g DM MLLP, which implied that the phytochemicals in MLLP at these levels did not interfere with the activities of microbes responsible for fibre digestion. Improved digestibility of fibre is advantageous as it increases the production of volatile fatty acids. Volatile fatty acids are the major source of energy for ruminants. However, Contrary to the results obtained in this study, Aderao *et al.* (2018) and Joch *et al.* (2019) reported a decrease in feed digestibility as a result of addition of phytogetic feed additives. The contradiction may be attributed to the differences in types of test ingredients (with varying composition of phytochemicals),

processing methods, level of inclusion, and mode of administration used.

The nitrogen intake did not differ in the experimental goats, which is not unconnected to the similarity observed in the feed intake. However, nitrogen output decreased with similar significant values in goats fed varying levels of MLLP. This might be attributed to the activities of phytochemicals in MLLP which probably reduced protein degradation in the rumen hence reduction in ammonia-nitrogen absorbed through the ruminal wall into the portal vein and converted to urea in the liver. Ammonia nitrogen in excess of microbial requirement is lost as urea in the urine. Tannins have the ability to bind to protein, inhibiting their degradation in the rumen and making them available post-ruminally (Nigrant *et al.*, 2017). Goats fed diets containing the varying levels of MLLP had higher nitrogen retention. This may be related to decrease observed in urinary nitrogen at those levels of inclusion. The highest percentage retention observed at 10 and 15mg/g DM inclusion level indicated better utilization of protein which translated to better weight gain and feed conversion ratio observed at the inclusion level. According to Saka *et al.* (2020) nitrogen retention is the fraction of nitrogen intake that is utilized by the animals for body processes. Jiwuba *et al.* (2021) also observed a higher nitrogen retention in goats fed *Nauclea latifolia* as phytogetic feed additive.

Ammonia-N is important for microbes for the synthesis of microbial proteins needed to meet the maintenance requirement of ruminants (Akinbode *et al.*, 2021). Reduction in rumen ammonia-nitrogen in goats fed diets containing varying levels of MLLP indicated reduction in protein digestibility in the rumen as a result of phytochemicals in MLLP. Tannin and saponin have been implicated in reducing protein degradation in the rumen (Patra and Saxena 2010; Bodas 2012) hence rumen ammonia-N. Kholif *et al.* (2017) reported a reduction in rumen ammonia-N when lemongrass was included in the diet of goats. A slight reduction in ammonia nitrogen is desirable to prevent

nitrogen excretion in the urine because excessive production above the microorganisms' requirement for microbial protein production is lost as urea in the urine. Reduction in protein digestion and ammonia-N production in the rumen will make feed protein available for enzymatic digestion in the lower tract to amino acids which is utilized by the host animal for growth and other production functions. Adebayo *et al.* (2023) also reported a decreased in *in vitro* ammonia-nitrogen concentration with the addition of MLLP at 8 and 10mg/g DM. Diets containing varying levels of MLLP recorded higher total volatile fatty acids production which implied that the phytochemicals at the varying levels of inclusion did not interfere with fibre degradation in the rumen. Akinbode *et al.* (2021) opined that higher volatile fatty acids production can be attributed to higher nutrient content and digestibility of feed. Van Soest *et al.* (1994) reported that factors such as production rate, absorption across the rumen wall and utilization by microbes affect the concentration of volatile fatty acids in the rumen. Hence, MLLP can be used to manipulate rumen fermentation to reduce protein excretion and increase production of volatile fatty acids in goats, thereby increasing productivity and profit margin of the resource poor farmers in developing countries. *Morinda lucida* is a medium-sized tree well known for its medicinal properties in Nigeria thus it is within the reach of farmers who might have been consuming it to get rid of some ailments.

Conclusion

Morinda lucida leaf powder improved fibre digestibility, nitrogen retention, volatile fatty acids production and weight gain in West African dwarf goats at 10 and 15 mg/g DM.

It can therefore be concluded that 10mg/g DM *M. lucida* could be utilized as phytogetic feed additive to manipulate rumen fermentation for improved fibre digestibility, nitrogen retention, volatile fatty acids production and weight gain in growing West African dwarf goats.

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