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Replacement value of white mulberry forage for pennisetum purpureum on nutrients digestibility, weight gain and blood profile of sheep

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Aditional keywords

Blood markers.
Feed conversion.
Grass.
Nitrogen content.
Mulberry.
WAD sheep.

SUMMARY

A sixty-three day study that involved twenty (20) West African Dwarf (WAD) sheep aged 8 - 9 months with average live-weight of 7.44 ± 0.18 kgW0.75 was carried out to evaluate nutrients intake, nitrogen metabolism, weight gain and blood profile of sheep fed Pennisetum purpureum was substituted with white mulberry leaves. The sheep were divided into 5 groups of four sheep per group and allotted to individual pens in a Completely Randomized Design. Five diets fed to the sheep were formulated thus: diets A (100 % P. purpureum), B (75 % P. purpureum + 25 % mulberry leaves), C (50 % P. purpureum + 50 % mulberry leaves), D (25 % P. purpureum + 75 % mulberry) and E (100 % mulberry leaves). Dry matter ranged 89.03 - 90.16 % and the highest (21.05 %) crude protein was obtained in diet E. Nutrients intake, daily weight gain and feed to gain ratio were significantly ($p<0.05$) influenced by the treatments. The highest DM (250.38 gW0.75/day) and CP (52.70 gW0.75/day) intake were observed in sheep fed diet E. The diets were adequately digested, highest nitrogen balance (5.75 gW0.75) was obtained in sheep fed diet E. Consequently, the best daily weight gain (16.10 gW0.75g/day) and least feed conversion ratio (15.55). Haematological and serum biochemical indices were within normal range for WAD sheep. Thus, sole feeding of white mulberry leave could offer a reliable source of protein for improved nutrients digestibility and nitrogen utilization by WAD sheep without detrimental effects on their wellbeing.

Valor de reposición del forraje de morera blanca para pennisetum purpureum sobre la digestibilidad de los nutrientes, el aumento de peso y el perfil sanguíneo de las ovejas

Palabras Clave

Marcadores sanguíneos.
Conversión alimenticia.
Hierba.
Contenido de nitrógeno.
Mora.
Ovejas enanas de África Occidental (WAD).

RESUMEN

Se llevó a cabo un estudio de sesenta y tres días en el que participaron veinte ovejas enanas de África Occidental (WAD) de 8 a 9 meses con un peso vivo promedio de 7,44 ± 0,18 kgW0,75 para evaluar la ingesta de nutrientes, el metabolismo del nitrógeno, el aumento de peso y el perfil sanguíneo de las ovejas alimentadas con Pennisetum purpureum se sustituyó con hojas de morera blanca. Las ovejas se dividieron en 5 grupos de cuatro ovejas por grupo y se asignaron a corrales individuales en un diseño completamente aleatorio. Se formularon cinco dietas: dietas A (100 % P. purpureum), B (75 % P. purpureum + 25 % hojas de morera), C (50 % P. purpureum + 50 % hojas de morera), D (25 % P. purpureum + 75 % morera) y E (100 % hojas de morera). La materia seca varió 89,03 - 90,16 % y la proteína bruta más alta (21,05 %) se obtuvo en la dieta E. La ingesta de nutrientes, el aumento de peso diario y la relación alimentación-ganancia fueron significativamente influenciados ($p<0,05$) por los tratamientos. La mayor ingesta de DM (250,38 gW0,75/día) y PC (52,70 gW0,75/día) se observó en ovejas alimentadas con dieta E. Las dietas fueron digeridas adecuadamente, se obtuvo el mayor balance de nitrógeno (5.75 gW0.75) en ovejas alimentadas con dieta E. En consecuencia, la mejor ganancia de peso diaria (16.10 gW0.75g / día) y la menor relación de conversión alimenticia (15.55). Los índices hematológicos y bioquímicos séricos estaban dentro del rango normal para las ovejas (WAD). Por lo tanto, la alimentación exclusiva de hojas de morera blanca podría ofrecer una fuente confiable de proteínas para mejorar la digestibilidad de los nutrientes y la utilización de nitrógeno por parte de las ovejas (WAD) sin efectos perjudiciales para su bienestar.

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INTRODUCTION

The extensive grasslands in the savanna zones of Nigeria constitute a most valuable feed resource for development of ruminant production systems. Yet, the scarcity or seasonal fluctuation of these forages among others is one of the major constraint to sheep production in developing countries like Nigeria. The natural pastures and crop residues available for animals after crop harvest are usually fibrous and devoid of most essential nutrients which are required for improved microbial fermentation and improved performance of host animal (Ahamefule *et al*., 2006). This manifest in loss of weight, reduced reproduction capacity and increased mortality rate. Pennisetum purpureum is a robust perennial grass that has been widely used as tropical forage, producing greater dry matter (DM) yield than other tropical grasses (Hanna *et al*., 2004).

Although, it has low protein concentration, it can provide a satisfactory forage source for dairy cows, if supplemented with legumes and protein concentrates (Nyambati *et al*., 2003). More so, the feeding of grass solely is being discouraged because it may not meet the nutrient requirement for optimum performance. These problems propelled the animal nutritionists to focus attention on nutritious drought-resistant forages (such as White Mulberry) which are available throughout the seasons in order to sustain the livestock industry (Fajemisin, 2017). Mulberry is a shrub or tree traditionally used in sericulture in various countries. The White Mulberry belongs to the order Urticales, the family Moraceae and the genus Morus. The most common species are: Morus alba, the White Mulberry, Morus nigra, the Black Mulberry, Morus rubra the Red berry and Morus indica (Prasad and Reddy, 1991). After evaluating the nutritive value of this plant, Prasad and Reddy (1991) concluded that leaf and cell wall contents, together with structural carbohydrates and ash indicate that mulberry is an excellent feed for high yielding animals and can be offered fresh or dried in compound feeds. Fajemisin (2017) also proffered that mulberry foliage can be used as a supplement to poor quality forage based diets or as the main component of a ration in livestock production systems.

However, White Mulberry has been used to supplement basal diets such as the grasses, the preferred feedstock for silkworms, and is also cut as food for livestock (cattle, goats, rams, etc.) in areas where dry seasons restrict the availability of quality vegetation. The following nutrient composition had been reported for White Mulberry leaf: (g/kg on dry matter basis): 262.2 dry matter, 101.8 ash, 231.9 crude protein, 384.2 crude fibre, 31.8 ether extracts, 250.3 nitrogen-free extracts (Prasad and Reddy, 1991; Bamikole *et al*., 2005). Thus, it is probable that the increasing proportion of mulberry leaves replacing the P. purpureum would result in reduced rumen methane production following reports from Maselema and Chigwa (2017) and Preston *et al*. (2019) that in vitro rumen methane was higher in animals fed grasses than those fed leaves from trees and shrubs. Furthermore, analysis of haematological parameters of animals is very important for the diagnosis of various pathological, metabolic disorders, impact of environmental, nutritional and pathological stresses (Elagib and Ahmed, 2011). Also, in feeding trials, blood could be the means of assessing clinical and health status of animals (Aletor *et al*., 1998). This study was therefore designed to evaluate the nutritive effect of white mulberry leave replaced with P. purpureum on nutrients intake, digestibility, nitrogen utilization, weight gain and blood profiles of West African Dwarf sheep.

MATERIALS AND METHODS

Description of the Study Area

The experiment was carried out at the Small Ruminants Unit of Teaching and Research Farm, laboratory analysis was done at Nutrition Laboratory Unit, Department of Animal Production and Health, Federal University of Technology, Akure (FUTA), Ondo State, Nigeria.

Collection and Processing of the Forages

P. purpureum leaves were harvested from the pasture of the Teaching and Research Farm, FUTA, while White Mulberry was harvested from the pasture of Ondo State Sunshine Agro-based Empowerment Centre, Wealth Creation Agency, Ondo Road, Akure in the evenings on daily basis and air dried before use the following day.

Sheep Management, Experimental Design and Diet Formulation

Twenty (20) West African Dwarf (WAD) sheep aged 8 – 9 months and live weight of 7.44 ± 0.18 kgW0.75 were selected from sheep of the Teaching and Research Farm. The experiment was laid on a Completely Randomized Design of five treatments replication four time, with each WAD sheep representing a replicate. Five diets were formulated such that P. purpureum was substituted with White mulberry leaves such as: diet A (100 % P. purpureum), diet B (75 % P. purpureum + 25 % mulberry leaves), diet C (50 % P. purpureum + 50 % mulberry leaves), diet D (25 % P. purpureum + 75 % mulberry) and Diet E (100 % mulberry leaves). The diets were thoroughly mixed together, fed to the sheep and fresh clean water was offered ad libitum at 8.00 am every morning for a period of 63 days.

Digestibility Trial and Nitrogen Balance

Samples of faeces and urine were collected in the morning before feeding and watering during the period of the experiment. Faeces were weighed and oven dried at 105 °C for three hours for dry matter (DM) determination. The faecal samples for each experimental animal were thoroughly mixed, milled to pass a 0.2 mm sieve and sealed in polythene bags. These were stored in a cupboard at room temperature until required for chemical analysis. Total urine excreted by each animal was collected in a plaque bucket under each cage and to which five drops of 25 % H2SO4 was added daily to prevent volatilization of ammonia from the urine. The total volume of urine output per animal was measured and aliquots (10 %) of daily output per animal was saved in stopper plastics bottles, labeled and stored in a deep freezer. Nutrient digestibility coefficient and nitrogen balance of the sheep were recorded and calculated at the end of the experiment according to the method of Ahamefule *et al*. (2006).

$$\text{Apparent digestibility} = \frac{\text{Nutrients intake} - \text{nutrients in faeces}}{\text{Nutrient intake}} \times 100$$

Nitrogen balance/retention = Nitrogen intake – (faecal nitrogen + Urinary nitrogen).

Blood Collection and Analysis

At the end of the experiment, blood was collected through the jugular vein of the experimental animals into a labeled bijour bottle containing ethyl-diamine tetra-acetic acid (EDTA) as anticoagulant and to another without EDTA. The blood in the bottle with EDTA was used in the determination of haematological parameters such as red blood cell (RBC) count, white blood cell (WBC) count, packed cell volume (PCV) and haemoglobin (Hb) using the method by Dacie and Lewis (1991), while that without EDTA was be used in determining blood serum biochemical indices such as serum total protein, serum albumin, globulin, alkaline phosphatase (ALP), alanine aminotransferase (ALT) and aspartate aminotransferase (AST) using the method of Reitman and Frankel (1957).

Data Collection and Feed Analysis

Daily voluntary feed intake of sheep was estimated as the difference between daily feed offered and orts. Sheep were weighed weekly to determine changes in live weight, Samples of feed, faeces and urine were analyzed for chemical composition using the methods of AOAC (2002) and Van Soest *et al*. (1991) as appropriate.

Data Analysis

All data generated were subjected to analysis of variance (ANOVA), and the treatment means were compared by the methods of Duncan's Multiple Range Test using SAS (2010) version 9.3. Significant difference was set at p<0.05.

RESULTS AND DISCUSSION

The result of chemical composition of P. purpureum substituted with mulberry leaves is shown in **Table I**. The concentrations of nutrients determined were significantly influenced (p<0.05) by the treatment except for dry matter. The reported high DM (89.03 – 96.01 %) might be attributed to the age (maturity) of the forages, curing process and season of harvest which might have contributed to its high lignifications. The observed DM values compared favourably to dry matter values (68 – 92 %) observed by Bamikole *et al*. (2001) while evaluating nutritive properties of some forage leaves. The recorded CP contents (11.40 – 21.05 %) in the diets were above the critical 8 % crude protein required by ruminants for optimum microbial activities in the rumen (Norton, 2003). It was observed that protein (13.72 - 21.05 % CP) contribution of Mulberry improved the protein quality of diets B, C, D and E. Hence, Mulberry could be an alternative source of protein feed ingredient during dry season. The fibre fractions' contents obtained in diet A was higher than other tested diets and this could be attributed to the crude fibre (36.91 – 45.58 %) contents in the P. purpureum (Widiyastuti *et al*., 2014).

The nutrients intake by the sheep was positively influenced by the substitution of mulberry in the diets (**Table II**). The dry matter intake by the sheep fed P. purpureum substituted with mulberry was highest (250.38 gW0.75) in sheep fed diet E. The high DM intake might be attributed to increased inclusion levels of mulberry leaves and protein quality, acceptability and palatable diets hence, sources of energy and nitrogen that might enhance rumen microbial activity (McDonald *et al*., 1995). The crude protein intake was adequate for all the sheep, those fed diet E had the highest crude protein (52.70 gW0.75) intake. This observation could be attributed to the protein quality of the diets which was enhanced by the mulberry substitution. The crude fibre intake decreased with increasing inclusion levels of mulberry in the diets. This observation might be attributed to the improved protein quality of the diets. It was also observed that crude fibre intake decreased as crude protein intake increases, this observation corroborates the report of Fajemisin *et al*. (2013) when varying levels of fresh *Tithonia diversifora* and *P. maximum* were fed to Yankasa sheep. The fibre fractions intake in sheep fed diet A was high except hemicelluloses and cellulose compared to intake of other sheep indicating more lignin contents in *P. purpureum*.

The results of nutrients digestibility (%) of the sheep revealed that *P. purpureum* substituted with mulberry leaves enhanced the degradation activities of the rumen microbes significantly except dry matter (**Table III).**

Table I. Chemical composition (%) of *Pennisetum purpureum* substituted with mulberry leaves (*Composición química (%) de Pennisetum purpureum sustituido por hojas de morera*).

Parameters	Chemical composition (%)				
	Diets				
	A	B	C	D	E
Dry matter	89.03±0.52	90.16±0.61	89.68±0.68	89.14±0.67	89.18±0.44
Crude protein	11.40±0.90^{c}	13.72±0.09^{bc}	16.39±1.09^{ab}	18.28±1.31^{ab}	21.05±1.19^{a}
Crude fibre	31.38±1.24^{a}	23.03±1.89^{b}	20.35±2.01^{b}	15.66±1.69^{c}	14.25±1.70^{c}
Ash	12.16±0.56^{a}	11.06±0.55^{ab}	10.63±0.48^{ab}	9.81±0.57^{ab}	7.94±0.48^{b}
Ether extract	1.61±0.09^{b}	2.14±0.10^{a}	1.66±0.08^{b}	1.15±0.14^{c}	1.71±0.07^{ab}
Nitrogen free extract	43.45±1.09^{c}	50.05±1.20^{b}	50.97±1.19^{b}	55.10±1.09^{a}	55.05±1.60^{a}
Neutral detergent fibre	70.17±5.31^{a}	66.41±4.91^{b}	51.20±5.11^{c}	45.80±5.28^{d}	38.88±4.63^{e}
Acid detergent fibre	58.11±2.91^{a}	45.71±3.00^{b}	37.23±2.75^{c}	34.86±2.78^{c}	27.95±2.61^{d}
Acid detergent lignin	44.46±2.56^{a}	30.59±2.45^{b}	25.42±2.20^{c}	25.09±1.09^{c}	20.16±3.09^{d}
Hemicellulose	12.06±0.90^{b}	20.70±1.35^{a}	13.93±1.08^{b}	10.94±1.00^{b}	10.93±1.07^{b}
Cellulose	13.65±0.79^{ab}	15.12±0.46^{a}	11.81±0.92^{abc}	9.77±1.02^{bc}	7.79±1.00^{c}

abcde = Means on the same row with different superscripts are significantly (P<0.05) different. (Las medias de la misma fila con diferentes superíndices son significativamente (P<0.05) diferentes).

Table II. Nutrient Intake (gW$^{0.75}$/day) by WAD sheep fed *P. purpureum* substituted with white mulberry leaves (Ingesta de nutrientes (gW0.75/día) por ovejas WAD alimentadas con *P. purpureum* sustituido con hojas de morera blanca).

Parameters	Nutrient Intake (gW$^{0.75}$/day) Diets				
	A	B	C	D	E
Dry matter	206.09±3.39^{e}	228.34±5.03^{d}	237.24±3.12^{c}	243.15±4.09^{b}	250.38±5.14^{a}
Crude protein	23.49±2.23^{e}	31.33±3.46^{d}	38.88±3.08^{c}	44.45±2.09^{b}	52.70±3.04^{a}
Crude fibre	64.67±3.06^{a}	52.59±2.99^{b}	48.28±2.64^{b}	38.08±3.37^{c}	35.68±2.17^{c}
Ether extract	25.06±0.63^{a}	25.25±0.63^{a}	25.22±0.78^{a}	23.85±0.87^{a}	19.88±0.57^{b}
Ash	3.32±0.25^{bc}	4.89±0.27^{a}	3.94±0.34^{ab}	2.80±0.11^{c}	4.28±0.26^{ab}
Nitrogen free extract	89.55±5.01^{d}	114.28±4.67^{c}	120.92±2.36^{b}	133.98±4.69^{a}	137.83±6.04^{a}
NDF	144.61±6.00^{b}	151.64±5.03^{a}	121.47±4.48^{c}	111.36±6.10^{d}	97.35±5.56^{e}
Acid detergent fibre	119.76±5.68^{a}	104.37±4.49^{b}	88.32±4.78^{c}	84.76±3.49^{c}	69.98±4.67^{d}
Acid detergent lignin	91.63±3.76^{a}	69.85±4.90^{b}	60.31±3.67^{c}	61.01±2.80^{c}	50.48±3.56^{d}
Hemicellulose	24.85±2.29^{c}	47.27±3.01^{a}	33.05±2.46^{b}	26.60±2.01^{c}	27.37±1.47^{c}
Cellulose	28.13±1.08^{ab}	34.53±2.01^{a}	28.02±1.00^{ab}	23.76±1.57^{bc}	19.50±2.36^{c}

abcde = Means on the same row with different superscripts are significantly ($P<0.05$) different. NDF - Neutral detergent fibre (Las medias de la misma fila con diferentes superíndices son significativamente ($P<0.05$) diferentes. NDF - Fibra detergente neutra).

Table III. Apparent Nutrient digestibility coefficients (%) by WAD sheep fed *P. purpureum* substituted with white mulberry leaves (*Coeficientes de digestibilidad aparente de nutrientes (%) por ovejas WAD alimentadas con P. purpureum sustituidas con hojas de morera blanca*).

Parameter	Nutrient digestibility (%) Diets				
	A	B	C	D	E
Dry matter	68.80±0.89	70.40±0.79	68.50±0.60	68.10±0.69	70.40±0.88
Crude protein	68.40±0.71^{c}	68.90±0.90^{c}	72.50±0.28^{b}	73.30±0.78^{ab}	74.50±0.65^{a}
Crude fibre	67.19±1.58^{b}	75.07±1.39^{ab}	75.25±1.31^{ab}	79.43±1.79^{a}	79.54±1.73^{a}
Ether extract	55.90±2.09^{b}	59.30±3.03^{b}	61.10±2.31^{b}	69.40±2.07^{a}	77.20±1.00^{a}
NDF	66.40±1.03^{b}	74.30±1.19^{a}	76.60±1.13^{a}	76.70±1.11^{a}	76.60±1.56^{a}
ADF	66.60±1.93^{b}	73.90±1.89^{ab}	75.80±1.88^{a}	76.60±1.00^{a}	79.60±1.00^{a}
ADL	57.12±3.31^{c}	65.53±2.33^{b}	76.36±2.12^{ab}	76.96±2.09^{ab}	79.49±2.03^{a}
Hemi cellulose	59.18±1.13^{c}	64.65±1.85^{bc}	66.58±1.23^{b}	70.02±1.30^{ab}	75.07±2.36^{a}
Cellulose	60.76±1.23^{c}	70.74±1.93^{b}	73.15±1.14^{b}	78.13±3.00^{a}	80.41±2.31^{a}

abcd = Means on the same row with different superscripts are statistically ($P<0.05$) different (Las medias de la misma fila con diferentes superíndices son estadísticamente diferentes ($P<0,05$).

This observation agreed with the report of McDonald *et al.* (1995) that protein quality and intake enhance digestibility of feed. Crude protein digestibility coefficient was higher than the range of 56.2 – 63.10 % reported by Olorunnisomo (2010) for lambs fed with sweet potatoes with mixture of the forage and root. Digestible crude fibre values were higher compared to the values (27 – 68 %) reported by Ahamefule *et al*. (2006).

The nitrogen metabolism, feed conversion ratio and weight gain of the sheep were significantly ($p<0.05$) influenced by the treatments (**Table IV**). The highest weight gain (16.10 gW0.75) and nitrogen balance (5.75 gW0.75) obtained in sheep fed diet E might be attributed to the palatability, high dry matter, crude protein intake and better digestibility of the diet as weight gain is dependent of these factors (McDonald *et al*., 1995).

From **Figure 1** and **2**, the linear increase in growth rate and nitrogen balance due to increasing level of mulberry leaves in the diet is not thought to be because of increased crude protein levels per se but rather to the nature of the protein: as being mostly in the form of "true" protein; and through its association with phenolic compounds (eg: condensed tannin) that protect it from microbial attack in the rumen (Barry and McNabb 1999), thus facilitating the rumen escape/bypass of the protein for more efficient enzymic digestion in the intestine.

Table V presents the haematological and serum biochemical indices of WAD sheep fed *P. purpureum* substituted with white Mulberry leaves. All the parameters observed were significantly ($p<0.05$) influenced by mulberry leave except the mean cell haemoglobin concentration (MCHC), ALP and AST. Meanwhile, all results obtained were within the range for healthy

Table IV. Nitrogen balance, feed conversion ratio and Weight gain of WAD sheep fed *P. purpureum* substituted with white mulberry leaves (Balance de nitrógeno, relación de conversión alimenticia y aumento de peso de ovejas WAD alimentadas con *P. purpureum* sustituidas con hojas de morera blanca).

Parameters g/dW$^{0.75}$	Response Criteria Diets				
	A	B	C	D	E
Nitrogen intake	3.75±0.52^{c}	5.01±0.58^{bc}	6.22±0.42^{bc}	7.11±0.57^{ab}	8.43±0.48^{a}
Faecal nitrogen	0.24±0.12^{c}	1.05±0.15^{b}	1.36±0.20^{b}	1.32±0.13^{b}	2.08±0.19^{a}
Urinary nitrogen	0.15±0.05^{c}	0.32±0.07^{b}	0.58±0.06^{a}	0.58±0.07^{a}	0.57±0.02^{a}
Nitrogen balance	3.36±0.32^{c}	3.64±0.39^{c}	4.28±0.26^{bc}	5.21±0.28^{ab}	5.75±0.29^{a}
Initial weight	7.37±0.17	7.48±0.18	7.49±0.19	7.40±0.17	7.47±0.18
Final weight	7.76±0.38	8.12±0.32	8.28±0.29	8.37±0.28	7.89±0.28
DM intake	206.09±3.39^{e}	228.34±5.03^{d}	237.24±3.12^{c}	243.15±4.09^{b}	250.38±5.09^{a}
Daily weight gain	6.19±0.82^{d}	10.16±0.87^{c}	12.54±1.01^{b}	15.40±0.90^{a}	16.10±0.96^{cd}
FCR	33.29±1.72^{a}	22.47±2.11^{c}	18.92±1.86^{d}	15.79±2.09^{e}	15.55±1.49^{b}

abcde = Means on the same row with different superscripts are significantly ($P < 0.05$) different (Las medias en la misma fila con diferentes superíndices son significativamente diferentes ($P < 0.05$) diferentes).

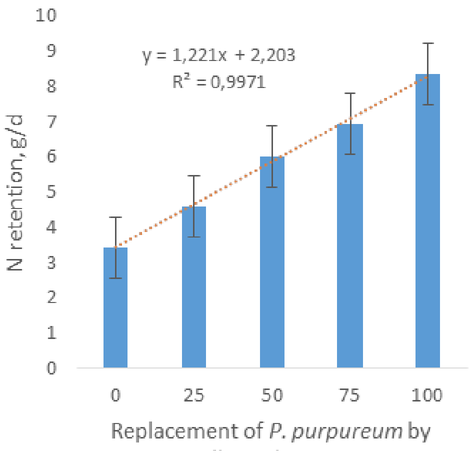

Figure 1. Nitrogen balance by WAD sheep fed *P. purpureum* substituted with mulberry leaves (Balance de nitrógeno por ovejas WAD alimentadas con *P. purpureum* sustituido con hojas de morera).

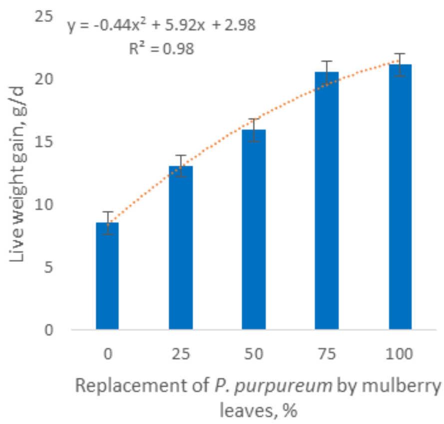

Figure 2. Live weight gain by WAD sheep fed P. purpureum substituted with mulberry leaves (Aumento de peso vivo por ovejas WAD alimentadas con *P. purpureum* sustituido con hojas de morera).

sheep. Analysis of haematological parameters of animals is very important for the diagnosis of various pathological, metabolic disorders, impact of environmental, nutritional and pathological stresses (Elagib and Ahmed, 2011). Also, in feeding trials, blood could be the means of assessing clinical and health status of animals (Aletor *et al*., 1998). Packed Cell Volume (PCV) is involved in the transport of oxygen and absorbed nutrients (Isaac *et al*., 2013), when the value of PCV falls below normal range, it is an indication of poor quality of protein in diets and consequently anaemia (Awoniyi *et al*., 2004). Hence, with the value obtained in this study for sheep fed P. purpureum substituted with white mulberry leaves, it could be inferred that the protein content in the mulberry leaves was adequate since the PCV values were within normal range for WAD goats (Daramola *et al*., 2005). Haemoglobin (Hb) is blood pigment that carries oxygen. Its high concentration is an indication of good carriage capacity of oxygen to various parts of the body which results in healthy living of animals. In this study as the values for RBC and Hb indicated that substitution of mulberry leave had no detrimental effect on oxygen carriage capacity of the sheep since the concentrations of Hb and RBC were within normal range for healthy small ruminant. The major functions of the WBC and its differentials are to fight infections, defend the body by phagocytocis against invasion by foreign organisms and to produce or at least transport and distribute antibodies in immune response. White blood cells of the sheep were influenced by dietary treatments; values were higher in sheep fed *P. purpureum* substituted with white Mulberry leaves. However, the observed WBC values were within normal range for healthy goats and sheep (Daramola *et al*., 2005; Plumb, 2018), hence the immune system of the sheep were not compromised by mulberry leave supplementation. The total protein (TP) and albumin observed in this trial, ranged: 6.83 – 7.92 g/dl and fell within the normal range of 6.3 – 8.5 g/dl reported by Daramola *et al*. (2005) for WAD goats. The information obtained with respect to TP and albumin, indicated that there were adequate protein in the diets (Aletor *et al*., 1998) and the blood of the goats had excellent clotting ability thereby could prevent haemorrhage

Table 5: Haematological and Serum Biochemical indices of WAD sheep fed *P. purpureum* substituted with white mulberry leaves (Índices hematológicos y bioquímicos séricos de ovejas WAD alimentadas con *P. purpureum* sustituidas con hojas de morera blanca).

Parameters	Haematological and Serum Biochemical indices				
	Diets				
	A	B	C	D	E
Whole blood count					
White blood cell (x 10^3µl)	7.26±0.22^c	8.59±0.30^b	8.87±0.45^b	10.50±0.25^a	11.69±0.58^a
Red blood cell (x 10^6µl)	9.29±0.14^e	10.54±0.21^d	11.26±0.10^c	12.60±0.04^b	14.02±0.21^a
Haemoglobin (g/dl)	8.12±0.06^e	8.35±0.03^d	8.88±0.07^c	9.35±0.08^b	9.77±0.09^a
Packed cell volume (%)	26.46±0.66^b	27.14±1.09^b	28.69±0.43^b	32.42±1.16^a	34.20±1.57^a
Mean cell volume (µ^3)	28.47±0.37^a	25.82±1.57^{ab}	25.47±0.22^{ab}	25.73±1.01^{ab}	24.44±1.49^b
Mean Cell Haemoglobin (pg)	8.74±0.07^a	7.93±0.16^b	7.88±0.10^b	7.42±0.06^c	6.97±0.15^d
MCHC (g/dl)	30.70±0.55	30.86±1.19	30.92±0.67	28.91±1.04	28.65±1.11
Serum parameters					
Total protein (g/dl)	6.83±0.77	7.26±0.22	7.36±0.25	7.54±0.27	7.92±0.04
Albumin (g/dl)	3.60±0.04^a	2.29±0.14^c	3.34±0.32^b	3.26±0.10^b	3.54±0.16^a
Globulin (g/dl)	3.23±0.77^c	4.97±0.22^a	4.02±0.21^b	4.28±0.30^{ab}	4.39±0.33^{ab}
Alkaline phosphatase (IU/l)	50.46±9.87	56.20±11.94	58.81±2.10	60.02±10.47	65.42±9.68
Aspartateaminotransferase (IU/l)	60.83±2.65	62.50±3.77	66.83±1.17	68.83±2.17	72.67±6.09
Alanine aminotransferase (IU/l)	9.80±1.10^b	12.84±0.54^{ab}	13.28±1.47^{ab}	13.33±1.27^{ab}	14.33±1.20^a

a,b,c, means on the same row with different superscripts are significantly ($P < 0.05$) different (a,b,c, las medias en la misma fila con diferentes superíndices son significativamente ($P < 0.05$) diferentes).
MCHC – Mean Cell Haemoglobin Concentration (Concentración media de hemoglobina en células).

(Daramola *et al*., 2005). Globulins values ranged between 3.23 g/dL (diet A) and 4.97 g/dL (diet B), this was higher than 0.16 - 1.6 g/dL reported by Daramola *et al*. (2005) for WAD goats. The highest values of globulin concentration was observed in sheep fed diets B, C, D, and E. This implied that Mulberry leave supplementation has the potential of improving immunity in the sheep since higher value of globulin has been observed to enhance better defense against infection because globulin is well-known for its immunological functions.

The serum ALP concentration in all the sheep fell within normal ALP values for WAD goats reported by Daramola *et al*. (2005). This enzyme (ALP) is believed either to increase the local concentration of inorganic phosphate or to activate the collagen fibres in such a way that they cause deposition of calcium salts (Guyton and Hall, 1998). Thus, the higher values of ALP observed in the sheep fed diets B, C, D and E is an indication that mulberry leave supplementation with grasses has the potentials to facilitate bone formation especially in growing animals. The level of AST were found to be statistically non-significant ($p>0.05$) among the groups and fell within the normal range for WAD sheep and goat (Daramola *et al*., 2005). This indicates that the sheep were maintained in normal health condition without any cellular dysfunction, since AST and ALT values higher than the normal range would affect cellular synthesis of proteins and growth performance.

CONCLUSION

This study revealed that there were increases in feed intake, nitrogen balance and growth rate, with related improvement in feed conversion, as mulberry leaves replaced *P. purpureum* forage in the diet. The net result from mulberry leaves replacing *P. purpureum* would this be a linear increase in growth rate and improved health status of the WAD sheep fed as the AST levels were not elevated beyond normal to cause liver infarction. The study further established that mulberry leaves could furnish the required protein – energy for enhanced sheep production in the tropics without any deleterious effect(s) and is thereby recommended either as sole or supplementation in ruminant feeding.

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