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Protein supplementation value of sun-dried ensiled sunflower (*Tithonia diversifolia*) in grower pigs: Growth performance and nitrogen utilization

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24 male pigs of similar crosses and initial weight of 13.2±0.1 kg were used to determine the effect of sun-dried ensiled *Tithonia diversifolia* leaf meal (DETD) on their growth performance and nitrogen utilization at dietary inclusion of 10, 20 and 30%. All diets were isocaloric and contained about 19% crude protein. The animals were randomly assigned into four dietary treatments and individually housed. There was a significant reduction (P<0.05) in the average daily weight gain (AWG) for pigs across the experimental diets. Daily feed intake (ADF) and feed conversion ratio (FCR) had similar trend varying significantly (P>0.05) from 96.03 g/day for pigs on the control diet to 102.67 g/day for pigs on diet with 30% DETD inclusion for feed intake, while FCR ranged from 0.67 for pigs on 10% DETD inclusion level to 1.0 for pigs on 30% DETD inclusion level. Nitrogen retention (NR) had the highest significant value (P>0.05) of 21.01 g/N/pig/day for pigs on 10 and 20% DETD. Protein efficiency ratio varied significantly (P>0.05) from 4.65 on 20% DETD inclusion to 6.45 on 10% DETD level. The potential value of DETD as novel feed resource was revealed and levels not exceeding 10% of DETD are supported for optimum growth performance and nitrogen utilization.

Key words: Sun-dried ensiled *Tithonia diversifolia* leaf meal, growth performance, nitrogen studies.

INTRODUCTION

In the last two decades, the major preoccupation of animal nutritionists in developing countries (Nigeria inclusive) has been to find alternative ingredient sources in compounding feeds for livestock animals such that the use of conventional ingredients that are also consumed by man can be minimized. The conventional ingredients particularly those of protein origin are becoming very expensive to incorporate into animal feed resulting in expensive finished feed with concomitant rise in the unit cost of meat and meat products (Fasuyi, 2005). The extremely high cost of conventional feed ingredient in Nigeria has increased the feeding cost to about 60 to 80% of total cost of intensive livestock production especially for poultry and pigs (Tewe, 1997). The leaves of some leguminous plants and other plant species have been sparingly used as a source of crude protein in pig diets (Ugwu and Chukwuka, 2001). This is in spite of their appreciable high crude protein content and luxuriant growth in various parts of the tropics. One of such potential plant species is *Tithonia diversifolia* (Fasuyi et al., 2010). Wild sunflower (*T. diversifolia*) is a green plant that originated from Mexico, and it is now widely distributed throughout the humid and sub-humid tropics in Central and South America, Asia and Africa (Sonka, 1997). *T. diversifolia* was probably introduced into Africa as an ornamental plant and can be found on roadsides

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and as invader of field crops in the forest savanna transition zones in Nigeria (Ayeni et al., 1997; Fasuyi et al., 2010). Reported to have a crude protein content of 18.9 to 20.6%, 11 to 18.9% crude fibre, 4.0 to 5.5% ether extract, 42.5% carbohydrates and 13.2 to 14.0% ash (Olayeni et al., 2006).

However, the major limitation to the use of *T. diversifolia* leaves in livestock feeds is the ample presence of some antinutrients notably phytins and tannins with some traces of alkaloids, saponins, oxalates and flavonoids (Fasuyi et al., 2010). Fasuyi et al. (2010) surmised in their study with ensiled *T. diversifolia* that all samples except samples at 0% molasses level turned yellow-brown on the 7th day and the colour deepened with increased molasses addition. All silages had attractive smell.

pH dropped from an average of 6 at the start of ensiling and continued to decrease with increasing length of duration and increasing levels of molasses. The NH_3-N and water soluble N increased with increasing length of ensiling. Major anti-nutrients in *T. diversifolia* leaves (phytin, tannin, oxalate, alkaloid and flavonoid) gradually decreased with lengthening duration of ensiling.

Ensiling is the preservation of forage (or crop residue or by-product) of high moisture content based on a lactic (ideally) fermentation under anaerobic conditions (McDonald et al., 2002; Moran, 2005). Ensiling is a feed processing technique reported to have helped in enhancing the feeding quality of agro-industrial by-products and other potential plant feedstuffs by reducing the level of toxicants where present, improving the nutrient value, acceptability of feed and utilization by animals (Ranjit and Kung, 2000; Fasuyi et al., 2010).

This study is therefore aimed at investigating the potentials of sun-dried ensiled Mexican sunflower (*T. diversifolia*) leaf as a protein supplement in feeds of growing pigs.

MATERIALS AND METHODS

Location and preparation of the test ingredients (sun-dried ensiled *T. diversifolia* leaf meal, DETD)

The experiment was carried out in the Teaching and Research Farm of Ekiti State University. Leaves of *T. diversifolia* (wild sunflower) were harvested fresh from maturing *T. diversifolia* plants with sharp knives from the top to the middle of the plant when the first inflorescence had opened in 60 to 80% of *Tithonia* plants. Harvesting of the leaves was done in Ekiti State University, within Ado-Ekiti, a town in the Southwest Nigeria in the rain forest zone on latitude 7° 40' North of the equator and longitude 5° 15' East of the Greenwich Meridian with ambient temperature of 25 to 37°C; relative humidity of 70%; wind, SSW at 11 mph (18 km/h); barometric pressure of 29.68' Hg(F). They were chopped with a sharp kitchen knife into small pieces of about 2 to 3 cm before ensiling. The chopped leaves were ensiled with 4% molasses of the total weight of *T. diversifolia* leaves. The ensiled material was kept in an airtight plastic for a period of 21 days for proper fermentation (Fasuyi et al., 2010). At the end of 21 days, moisture content and pH of the silage were recorded and the silage formed was sundried. Sun-drying was carried out to facilitate a further elimination of inherent anti-nutrients and to ensure a proper mix of DETD with other feed components.

Sun-drying was done for four days to achieve an even drying of 12 to 13% moisture content. The silage formed was taken to the mill and converted to a meal. Samples of DETD were taken to the laboratory for proximate and chemical analyses before the inclusion of the dried samples into the diets.

Experimental animals, management and feeding trial

A total of twenty four (24) male growing pigs (about 2½ months old) of commercially available crosses with a mean body weight of 13.3 ± 0.5 kg were used for this study. The experimental pigs were given adequate medication to prevent piglet anaemia and worms at the first week of their arrival. The feeding trial was carried out for a period of 63 days.

Feeding trial

The 24 male growing pigs were all randomized into separate pens for initial pre-feeding acclimatization period. They were initially served a standard growing diet for pigs compounded with conventional feedstuffs. The pre-feeding trial was conducted for 10 days. Water was given to the pigs *ad libitum* throughout the period of the trial. The feeding trial proper was carried out at the Piggery Unit of the Teaching and Research Farm of Ekiti State University, Ado-Ekiti for a period of 63 days. Four diets (D1, D2, D3 and D4) were formulated to contain about 19.0% crude protein and a digestible energy value of about 12.55 MJ kg^{-1}. The control diet was a standard growing diet for pigs, compounded with conventional feed stuffs for example, maize, soybeans, palm kernel cake (PKC), oyster shell, bone meal, brewer's dried grains (BDG), wheat offals, fish meal, salt and grower premixes. The other three diets were compounded such that sun-dried ensiled *T. diversifolia* leaf meal (DETD) progressively replaced soybeans at 10, 20 and 30% inclusion levels in diets 2, 3 and 4, respectively. Daily feeding rate was 3.30% of the pigs' live weight (Chhay and Preston, 2005). Water was given to the pigs *ad libitum* throughout the period of the experiment.

The daily feed consumption in g/day was calculated and was divided by the average daily weight gain (g/day) to get the feed conversion ratio means for all the pigs on the four experimental diets. Nitrogen studies were carried out and relevant parameters were calculated namely:

$$\text{Nitrogen retention (NR)} = \text{NI} - (\text{FN} + \text{UN})$$

$$\text{Nitrogen digestibility (ND)} = \frac{\text{NI} - (\text{FN} + \text{UN})}{\text{NI}} \%$$

$$\text{Protein efficiency ratio (PER)} = \frac{\text{Gain in body weight (g)}}{\text{Protein intake (g)}}$$

Where, NI, Nitrogen intake; FN, feacal nitrogen; UN, urinary nitrogen.

Nitrogen balance trial

For nitrogen retention trial, two pigs with similar weights and sex were selected from each treatment after 63 days of the experiments,

Table 1. Proximate/chemical composition of the experimental diets.

Ingredient	Diets (% inclusion levels of DETD)			
	Diet 1 (control)	Diet 2	Diet 3	Diet 4
	0% DETD	10% DETD	20% DETD	30% DETD
Maize	35.00	30.00	25.00	20.00
SBM	15.00	10.00	10.00	5.00
PKC	10.00	20.00	15.00	15.00
BDG	12.50	12.50	12.00	12.00
Wheat offals	20.00	10.00	10.00	10.00
Fish meal	2.00	2.00	2.00	2.00
*DETD	0.00	10.00	20.00	30.00
Bone meal	4.00	4.00	4.00	4.00
Oyster shell	1.00	1.00	1.00	1.00
** Premix	0.25	0.25	0.25	0.25
Salt (NaCl)	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00
Analysed composition				
CP (%)	18.62	18.89	18.91	18.88
CF (%)	6.97	7.84	9.31	12.45
EE (%)	4.77	5.27	4.98	5.26
Ash	7.06	13.95	12.72	12.74
MC (%)	8.33	9.74	12.55	9.92
CHO (%)	54.27	45.30	42.55	43.47

SBM, Soybean meal; PKC, palm kernel cake; BDG, brewery dried grains; CF, crude fibre; CP, crude protein; EE, ether extract; MC, moisture content; CHO, carbohydrate; *DETD, sun-dried ensiled tithonia diversifolia leaf meal; **Premix contained: vitamins A (10,000,000 iu); D (2,000,000 iu); E (35,000 iu); K (1900 mg); B12 (19 mg); riboflavin (7,000 mg); pyridoxine (3800 mg); thiamine (2,200 mg); D pantothenic acid (11,000 mg); nicotinic acid (45,000 mg); folic acid (1400 mg); biotin (113 mg) and trace elements as Cu (8000 mg); Mn (64,000 mg); Zn (40,000 mg); Fe (32,000 mg); Se (160 mg); I2 (800 mg) and other items as Co (400 mg); choline (475,000 mg); methionine (50,000 mg); BHT (5,000 mg) and spiramycine (5,000 mg) per 2.5 kg.

and were transferred into metabolism cages. Total faeces voided during the last five days were collected, weighed, dried in the sun and preserved while the corresponding feed consumed was also recorded for nitrogen studies.

The nitrogen contents of the samples were determined by appropriate method of AOAC (1995). Nitrogen retained was calculated as the algebraic difference between feed nitrogen and faecal nitrogen (on dry matter basis) for the period. Nitrogen digestibility was computed by expressing the nitrogen retained as a fraction of the nitrogen intake multiplied by 100.

Statistical analysis

The data collected in the completely randomized experimental design were subjected to statistical analysis using the Minitab Computer Software package (2005 version).

Experimental diets

Four diets (D1, D2, D3 and D4) were formulated to contain about 19.0% crude protein and a digestible energy value of about 12.55 MJ kg^{-1} (Table 1).

RESULTS

Proximate/chemical compositions of sun-dried ensiled *T. diversifolia* leaf, DETD

The dry matter component of DETD was slightly higher than the un-ensiled *T. diversifolia* leaf (Table 2). Descriptive statistical comparison indicated that the values obtained from the proximate analyses for crude protein, ether extract, carbohydrate and ash of DETD were consistently higher than for *T. diversifolia* leaf meal. The antinutrients compositions of DETD were also notably reduced. The pH which was 6.35 at the beginning of the ensiling process decreased to 3.76 on the 14th day.

Performance characteristics

Since feed intake (FI) was 3.30% of the experimental pigs' live weights, all FI values were similar. However, average daily weight gain (AWG) was similar for experi-

Table 2. Proximate/chemical characteristics of the *T. diversifolia* leaf meal (TDLM) and ensiled TDLM.

Proximate/chemical characteristic	TDLM*	DETD
Dry matter (%)	11.0	13.0
Percentage (%) of DM		
Crude protein	20.6	21.3
Crude fibre	18.9	15.3
Ether extracts	4.0	5.2
Carbohydrate	42.5	57.1
Ash	14.0	14.7
pH	6.35	3.76
Antinutrients (mg/100 g)		
Phytin	79.1	51.1
Tannin	0.39	0.21
Oxalate	1.76	0.33
Saponin	2.36	NA
Alkaloid	1.23	0.75
Flavonoid	0.87	0.74

Means are for duplicate determination n = 2; NA, Not available; *Source: Fasuyi et al. (2010) and Fasuyi and Ibitayo (2011).

Table 3. Performance characteristics of growing pigs fed with sun-dried ensiled *T. diversifolia* leaf meal, DETD.

Parameter	Diet					
	1	2	3	4		
	% inclusion levels of DETD					
	0	10	20	30	SEM	P
Feed intake (g/day)	351.2±6.42	344.9±3.94	345.5±9.59	347.9±12.73	0.25	0.060
Daily weight gain (g/day)	110.0±6.32[a]	106.7±8.10[a]	107.3±11.95[a]	86.6±5.07[b]	0.19	0.001
Feed conversion ratio	3.19±0.29[a]	3.23±0.13[a]	3.22±0.06[a]	4.02±0.20[b]	0.54	0.021
Protein efficiency ratio	1.68±0.21[a]	1.63±0.07[a]	1.64±0.01[a]	1.32±0.07[b]	0.7	0.002

Means of the same superscript in the same horizontal row are not significantly different (P>0.05).

mental animals on the control diet without DETD, 10 and 20% DETD inclusions. Only pigs on diet 4 (30% DETD) had significantly lower AWG (Table 3). The feed conversion ratio (FCR) expectedly had similar values for pigs on the control diet without DETD, 10 and 20% DETD diets. The FCR value for pigs on 30% DETD had the highest value (Table 3). The protein efficiency ratio (PER) were also similar for pigs on the control diet without DETD, 10 and 20% DETD diets. Only pigs on 30% DETD diet had the lowest (P<0.05) PER value.

Nitrogen balance study

Nitrogen intake was also similar for all experimental pigs since diets were isocaloric and feed intake was based on the 3.30% of the body weights of the pigs. The highest faecal nitrogen (FN) value was obtained for pigs on 30% DETD diet (Table 4). The FN values were similar for pigs on 10 and 20% DETD diets. Even though, the lowest FN value was obtained for the pigs on the control diet without DETD, it was however similar to FN value obtained for pigs on 10% DETD diet. Urinary nitrogen (UN) values were similar for pigs on the control diet without DETD, 10 and 20% DETD diets. The highest UN value was obtained for pigs on 30% DETD diet. The highest nitrogen retention (NR) value was obtained for pigs on the control diet without DETD. This value was however similar to the NR value obtained for pigs on 10% DETD diet. The lowest NR value was obtained for pigs on 30% DETD diet. Nitrogen digestibility (ND) had the same trend with NR with the lowest ND obtained for the experimental pigs on 30% DETD diet. The similarity in the nitrogen balance in the study particularly amongst pigs fed the

Table 4. Nitrogen utilization of growing pigs fed with sun-dried ensiled *T. diversifolia* leaf meal (DETD).

Nitrogen parameter (g/N/pig/day)	Diet					
	1	2	3	4		
	% inclusion levels of DETD					
	0	10	20	30	SEM	P
Nitrogen intake (NI)	10.45±0.24	10.43±0.27	10.45±0.21	10.52±0.17	0.03	0.014
Faecal nitrogen (FN)	2.24±0.27[a]	2.49±0.07[ab]	2.78±0.14[b]	4.67±0.12[c]	0.002	0.001
Urinary nitrogen (UN)	1.09±0.26[a]	1.02±0.31[a]	1.03±0.27[a]	1.94±0.07[b]	0.001	0.09
Nitrogen retention (NR)	7.12±0.05[a]	6.92±0.04[ab]	6.64±0.14[b]	3.91±0.71[c]	0.31	0.10
Nitrogen digestibility (%)	68.13±0.14[a]	66.35±0.07[ab]	63.54±0.24[b]	37.17±0.21[c]	0.002	0.01

[a, b, c, d]Means of different superscripts in the same horizontal row are significantly different ($P<0.05$).

control diet without DETD, 10 and 20% DETD diets could only be indicative of the proper nitrogen digestibility when TDLM was further processed by ensiling.

The fact that FN, UN and NR had similar values for the pigs fed with the standard diet (control diet without DETD) and other diets at 10 and 20% DETD meant that the ensiling process must have improved the protein quality of the TDLM such that the bioavailability of protein had been enhanced.

DISCUSSION

Proximate/chemical compositions of sun-dried ensiled *T. diversifolia* leaf, DETD

The ensiling process of *T. diversifolia* leaf possibly facilitated the breakdown of complex non starch polysaccharides (NSPs) and subsequently increased the soluble carbohydrates. It is also conceivable that the fermentation process during ensiling of *T. diversifolia* leaf must have contributed to the significant reduction of antinutrient composition of *T. diversifolia* leaf. This reduction of the antinutritional factors such as phytin, tannin, oxalate, alkaloids and flavonoids in *T. diversifolia* leaf when ensiled agreed with previous study (Fasuyi et al., 2010). Ensiling has also been suggested to be more effective than sun-drying in reducing calcium oxalate in Taro (*Colocasia esculenta*) (Tiep et al., 2006). Further studies on the treatment of palm kernel cake (PKC) using fibrolytic microbes revealed that the PKC was used as a growth substrate for the microbes that degraded the fibrous materials and that the growth of fibrolytic microbes also increased the protein content of PKC and improved the overall nutritive value of PKC (Iluyemi et al., 2006).

Performance characteristics

The similarity and adequate consumption of experimental feeds by pigs placed on different inclusion levels of DETD indicated that the factor/s responsible for reduced intake must have been sufficiently eliminated as previous study on *T. diversifolia* leaf meal (TDLM) revealed that pigs did not consume TDLM adequately (Fasuyi and Ibitayo, 2011). The poor feed intake associated with un-ensiled TDLM by pigs was attributed to the low palatability as a result of tannin (Farinu et al., 1999; Togun et al., 2006; Fasuyi and Ibitayo, 2011). The similarity among AWG and FCR values of pigs on the control diet without DETD, 10 and 20% DETD was a strong indication that the process of ensiling must have broken down some antinutrients such as phytin, tannin, alkaloids and flavonoids which were hitherto responsible for the poor growth indices recorded for studies in which un-ensiled TDLMs were used in pig feeding trials (Farinu et al., 1999; Togun et al., 2006; Fasuyi and Ibitayo, 2011).

It has been suggested that a high phytin value of 79.10 mg/100 g in TDLM (Fasuyi et al., 2010) could lower bioavailability of minerals and inhibition of several proteolytic enzymes and amylases (Erdman, 1979). This is further buttressed by the submission that antinutritional nature of phytin lies in its ability to chelate certain mineral elements especially Ca, Mg, Fe and Zn, thereby rendering them metabolically unavailable and leading to the subsequent development of osteomalacia when certain legumes and cereals are fed to growing animals (Forbes and Erdman, 1983).

Nitrogen balance study

This result is an improvement over previous result in which 20 and 30% inclusion levels of un-ensiled TDLM in growing pig rations had negative net nitrogen retention (Fasuyi and Ibitayo, 2011). It can therefore be surmised that amino acid profile may not be the major limiting factor in TDLM (Fasuyi and Ibitayo, 2011). The process of ensiling the *T. diversifolia* leaves could have facilitated its bioavailability and thus, a better utilization of the DETD.

Conclusion

There seemed to be a remarkable improvement in the consumption and utilization of ensiled TDLM when fed to growing pigs and this could have been occasioned by the activities of anaerobic, facultative and aerobic microorganisms responsible for the degradation of the complex fibrous and other antinutritional compounds naturally present in TDLM. The inclusion level of TDLM can be further enhanced when ensiled and this could replace other conventional protein ingredients appreciably at levels of about 20% in growing pig rations. There is no doubt that ensiling *T*. *diversifolia* leaves before sun drying into *T*. *diversifolia* leaf meal (DETD) had beneficial nutritional quality as manifested in the investigated performance characteristics in this present study.

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