Acta Scientiarum
http://periodicos.uem.br/ojs
ISSN on-line: 1807-8672
https://doi.org/10.4025/actascianimsci.v48i1.75231

RUMINANT NUTRITION

Nutrient digestibility, performance and serum metabolite assay of sheep fed silage supplemented with shrimp waste

Patrick Chinedu Emerue[1], Elizabeth Toluwani Amusan[2*] and Deborah Dara Oladeji[3]

[1]Institute of Agricultural Research and Training, Moor Plantation, Ibadan, Nigeria. [2]Department of Animal Science, Faculty of Agricultural Production and Management, Osun State University, Osogbo, Nigeria. [3]Department of Animal Production Technology, Federal College of Agriculture, Moor Plantation, Ibadan, Nigeria. *Author for correspondence: elizabethakinbola90@gmail.com

ABSTRACT. This study aims to estimate the nutrient digestibility, performance and serum metabolites of sheep fed guinea grass silage supplemented with shrimp waste meal (SWM). A total of sixteen West African Dwarf male sheep of 18 months old, with average weight of 20.25±0.08 kg were randomly assigned according to weight into four treatments, with four sheep per treatment in a completely randomized design, (T1 – 100% silage + 0% SWM, T2 – 95% silage + 5% SWM, T3 – 90% silage + 10% SWM and T4 – 85% silage + 15% SWM). Data on growth performance, nutrient digestibility and serum metabolites were taken. Analysis of variance at $p<0.05$ was used for data analysis and Duncan Multiple Range Test for mean separation. There was a significant decrease ($p<0.05$) in the crude protein digestibility (90.02%) at 15% inclusion of shrimp waste. Total weight gain and total feed intake were higher in sheep fed 10% of SWM compared to others. Higher total protein, albumin and urea were observed in sheep fed diet with 0% SWM and 10% SWM. It was concluded from this study that growth performance, digestibility and serum metabolites were best and without any adverse effect, when silage was supplemented with shrimp waste at 10% inclusion.

Keywords: shrimp processing; silage making; guinea grass; sheep; performance; blood chemistry.

Received on January 13, 2025.
Accepted on January 14, 2026.

Introduction

Inadequate availability of protein for those classes of animals that are ruminants especially during hot and dry climatic condition is a recurrent problem in Nigeria as well as shortage of forages contributing a major difficulty to successful and profitable animal farming (Cooke et al., 2025). The most common trend in many parts of the country is the sufficient availability of pasture and forage during rainy season and the subsequent decline in forage quantity and quality during the dry season (Kubkomawa & Lawal, 2021). In environments where grasses abound, they are usually of low nutritive value with protein content as low as 4 g 100 g^{-1}. This manifests in nutritional deficiency among the flock, during the dry season, leading to a drastic reduction in animal productivity (Jayasinghe et al., 2022). Grass, which is the cheapest feed for ruminant, is unreliable because the nutritional quality declines during the dry season. Supplementary feeding strategy in ruminant and non-ruminant production could help to reduce the problem posed by inadequate nutrient content, aid absorption of nutrient in forage, improve blood profile and general performance characteristic of animals (Anaeto et al., 2013, Akinbola et al., 2019, Emerue et al., 2022a, Emerue et al., 2022b, Oladeji et al., 2022). Hence, this irregularity in forage quantity and quality can therefore be solved through preservation of forages as hay or silage for especially ruminant animals such as sheep (Kubkomawa & Lawal, 2021). One of the grasses grown and consumed by animals such as cattle in the tropical areas of the world especially in is Guinea grass. This crop is useful in making silage and hay for animal consumption since it has high yield and readily available (Dondu Bilgin, 2021). However in the tropics, silage making has earned more crucial since it depends less on environmental situation (Mulubrhan et al., 2021). Silage has an advantage of durability even for years which makes it suitable and easy to use. Moreover, guinea grass silage quality may be improved absolutely when protein supplements are added, most especially the cheap and locally available ones. There are some protein supplements which can be termed as conventional but many of them are expensive, difficult to get especially by subsistence livestock farmers. There are some products and by-products from agricultural practices, such as shrimp waste that are useful to substitute conventional feed ingredients in terms of nutrients like protein (Abuzar et al., 2023).

Shrimps are found in fresh and salt water virtually all the world over and many larger species are consumed by man. Shrimp waste meal is of high nutritive value, having good taste and special smell. The parts of the shrimp include the head, gut area and exoskeleton. The nutrient content consists of lysine, which contributes to its richness when combined with cereal. It also supplies calcium and phosphorus in available forms as well as choline, niacin, riboflavin, B1 and B12 vitamins, pantothenic and nicotinic acid. It is an alternative protein source with good potential as a supplement (Abuzar et al., 2023). The proximate composition of shrimp shows that ash content ranged from 3.21 to 4.93%, moisture content ranged from 70.42 to 71.40%, fat and oil content ranged from 0.79 to 1.89%, Crude fiber ranged from 0.15 to 1.27%, protein content ranged from 13.87 to 20.87%, and carbohydrate ranged from 1.36 to 8.57%. It also contains a well-balanced profile of amino acid (Ogbu et al., 2024). Some experiments have been previously carried out using shrimp waste to supplement partially or totally for protein in the diets of birds (Abuzar et al., 2023; Ogbu et al., 2024). Fanimo et al. (1996) also revealed that shrimp waste meal in broiler ration and weaned pig diets can be used to substitute 66% of the protein contributed by fish meal without significantly affecting performance.

Presently, there is limited research on inclusion of shrimp waste meal in ruminant feed such as sheep; therefore, the objective of this study is to assess the nutrient digestibility, growth performance and serum metabolites of sheep fed guinea grass silage supplemented with shrimp as source of protein

Materials and methods

Location of study

The site of the experiment was the Teaching and Research Farm, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria, Latitude 7°12'N and Longitude 3°20'E, with average monthly temperature range between 24.9 and 31.5°C and mean annual rainfall of 1156 mm. This manuscript adheres to ARRIVE guidelines and checklists in reporting. The authors declare that all applicable institutional and national guidelines for the welfare and use of the animals were followed in accordance with the NIH guide for the care and use of laboratory animals.

Experimental animals and management

A total of 16 West African Dwarf (WAD) male sheep of 18 months old with an average initial weight of 20.25±0.08 kg were used for this experiment. The animals were offered for the purpose of this research, by the Teaching and Research Farm, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria. The sheep were randomly assigned according to weight into four (4) treatments, with four sheep per treatment in a completely randomized design, with each sheep as a replicate. (T1 – 100% silage + 0% SWM, T2 – 95% silage + 5% SWM, T3 – 90% silage + 10% SWM and T4 – 85% silage + 15% SWM). They were housed individually in previously washed, disinfected pens with concrete floors. The litter material used was wood shavings and litters were packed and replaced weekly. Prior to the onset of the experiment, the animals, were given sufficient time to rest and adapt to their new pens and diets for a period of 2 weeks. The weight of individual animals were determined and recorded and all the animals were treated against infections and parasites (ecto-parasites and endo-parasites). Salt-licks were provided throughout the experimental time frame. The animals were divided randomly into 4 treatments based on diet with 4 sheep per treatment. The animals were fed two times in a day at 08:00 and 15:00 hour. Fresh water was provided ad libitum and the entire study duration period was 21 days. Hygienic protocol was duly followed all through and the experimental design was completely randomized design.

Silage preparation

Guinea grass (*Panicum maximum)* was carefully identified by the research team members, selected and obtained at booting stage from The Federal University of Agriculture Teaching and Research rangeland site, and ensiled inside plastic drums lined with appropriate polythene sheets, ensuring their extension above the plastic drums. The loading of the grasses was done by thorough compression, in order to dislodge trapped air. Therefore, the protruded polythene sheets were folded inward and sand bags were placed on top of the drums (Babayemi, 2009). The grasses were left to ferment for 42 days before opening, giving it an acceptable aroma with no mold growth. The shrimp waste meal was later added to the different containers at 0, 5, 10 and 15% and the animals were fed for 3 weeks. The weights were taken on weekly basis.

Experimental design

The experimental design was a completely randomized design.

T1:100% silage + 0% shrimp waste (Control group)

T2: 95% silage + 5% shrimp waste

T3: 90% silage + 10% shrimp waste

T4: 85% silage + 15% shrimp waste

Data Collected and evaluated include growth performance, blood analysis and digestibility:

Growth Performance: daily feed intake was calculated by subtracting the leftover feed from feed served. Feed conversion ratio was obtained by dividing the total feed intake by the total weight gain. Total weight gain of the sheep was determined by subtracting the initial weight from the final weight.

Blood collection and analysis: On day 21, 5 mL of blood sample was taken from each animal by collecting from their jugular veins, according to standard procedures for serum biochemical analysis. This was done early around 7:00 am in the morning before feeding. Blood samples were collected into glass tubes without EDTA (ethylene- diamine- tetra- acetic acid) that have been sterilized. Centrifugation at 3500 revolutions per minute (rpm) was done for 15 minute, in order to allow for proper separation of the serum from the blood cells. Biuret procedure was used to analyse for serum total protein (Kohn & Allen, 1995) while Bromocresol green method (BCG) was used to measure the albumin content of the blood. Creatinine was determined after serum deproteinisation and alkaline picrate reagent producing an orange colour (Yoshio, 2017).

Digestibility trial: on day 21, four animals, one from each treatment were transferred to metabolic cages where urine and faeces were collected daily from day 22 to day 28. The faeces and the urine were subjected to proximate analysis; the urine was analyzed for nitrogen (AOAC International, 2016) and the faeces for dry matter, crude protein, crude fibre, ash, moisture and ether extract. The digestibility was later calculated using the following Formula:

Apparent digestibility = (*Nutrient consumed - Nutrient excreted in faeces*)/(*Nutrient consumed*) ×100

N retention = *N in feed consumed* - (*N excreted in faeces* + *N excreted in urine*)

where N = Nitrogen.

Statistical analysis

Data were analysed using descriptive statistics (Mean + Standard Error of Mean) ANOVA, Statistical Analysis System (2016), and mean separation was done using Duncan's multiple range test at $p<0.05$.

Results and discussion

The chemical constituents of silage and shrimp waste meal (SWM) are presented in Tables 1 and 2. The crude protein content, crude fibre content and ether extract observed in the silage were 5.98, 29.12, 3.94% while the total percentage dry matter was 96.32% and metabolizable energy of 3100 Kcal kg^{-1}. The crude protein content of shrimp waste meal was 46.30 g $100g^{-1}$ Dm (Dry matter) while crude fibre was 4.30 g $100g^{-1}$ Dm. The ash content, calcium content and phosphorus content of SWM were 17.04 g $100g^{-1}$ Dm, 7.0 g $100g^{-1}$ Dm and 3.03 g $100g^{-1}$ Dm respectively. The ether extract was 9.04 g $100g^{-1}$ Dm while the metabolizable energy obtained was 2500 Kcal kg^{-1}. The crude protein content of the shrimp waste meal used in this study (46.303 g $100g^{-1}$ Dm) was similar to the value (42.53 g $100g^{-1}$ Dm) obtained in the study of Eggink et al. (2024). However, the ash content of SWM (17.04 g $100g^{-1}$ Dm) in this study was lower compared to 25.9 g $100g^{-1}$ Dm obtained according to the findings of Eggink et al. (2024). The crude fiber 4.3 g $100g^{-1}$ Dm value observed in this research was also greater than what was obtained in the study of Fanimo et al. (1996). It may be because in this study, the fibre component and chitin were used together without separation when compared to other available literatures. The value of calcium content (7.0 g $100g^{-1}$ Dm) in the shrimp waste meal used in this experiment was in close range to the values of Eggink et al. (2024), although the phosphorus content was higher in this study (3.03 g $100g^{-1}$ Dm) as compared to the findings of Eggink et al. (2024).

However, the crude protein content in the silage that was a bit higher than that of 5.2% in the study of Ajayi et al., 2007 may be due to age of forage which has always been reported to contribute a significant role in the nutrient composition. Some major indisputable characteristics of forages grown in the tropics are their low level of available protein as well as the rapid development of lignin particularly when they grow older

(Nurdianti et al., 2024, Riaz et al., 2025). The crude protein value obtained was minimal when compared with 7.7% or 70 g kg^{-1} (critical value) postulated for consumption in small ruminants animals (Mahgoub et al., 2025). Therefore the protein content of grass used in this study showed that it has limited protein level and hence requires a supplementation with richer protein sources. The crude fibre content reported in the chemical composition of silage was the same as reported by Babayemi (2009). The reduced value of ether extract observed could be due to the age at which the grass was uprooted. The total percentage of dry matter was closely related to the value reported by Tesfaye et al. (2016).

Table 1. Chemical Constituent of Silage Used for the Experiment.

Parameters	Silage (%)
Crude protein	5.98
Crude fibre	29.12
Ether extract	3.94
Ash	13.69
Moisture	3.68
Dry matter	96.32
Calcium	2.50
Phosphorus	0.10
Metabolizable Energy (kcal kg^{-1})	3100

Table 2. Chemical Constituent of Shrimp Waste Used for the Experiment.

Parameters	Shrimp waste (g $100g^{-1}$ Dm)
Crude protein	46.30
Crude fibre	4.30
Ether extract	9.04
Ash	17.04
Chitin	9.82
Calcium	7.00
Phosphorus	3.03
Metabolizable Energy (Kcal kg^{-1})	2500

Dm = Dry matter

The result of the digestibility trial is as shown Table 3. There were no significant differences ($p>0.05$) in the ether extract, ash and crude fibre digestibility, but the dry matter and crude protein digestibility were significantly different ($p<0.05$). Crude protein and dry matter digestibility decreased with increased level of inclusion of silage and SWM. The value for dry matter digestibility of the diets ranged 63.48 at 15% inclusion level to 84.55 in 0% inclusion level. It was also observed that animals fed with silage without inclusion of SWM and with 5% inclusion obtained the highest crude protein digestibility. Reduced crude protein and dry matter digestibility observed in sheep fed 15% inclusion of shrimp waste could have also been responsible for the reduction in the total weight gain of the birds in comparison to birds from other groups. Abun et al. (2022) also observed poor degradation and digestibility of unprocessed shrimp waste in poultry due to limitations in digesting food substances containing chitin and high crude fiber. Hence, the least dry matter digestibility of 63.48 in 15% inclusion may be due to increased fibre content of diet.

Table 3. Nutrient digestibility of sheep fed silage supplemented with shrimp waste.

Parameters	(0%)	(5%)	(10%)	(15%)	SEM
CP (%)	99.59^{a}	99.35^{a}	98.9^{a}	90.02^{b}	0.14
EE (%)	99.83	99.83	99.30	99.81	0.03
CF (%)	99.89	99.01	99.54	99.06	0.21
ASH (%)	99.04	98.78	97.87	97.86	0.27
DM (%)	84.55^{a}	80.48^{a}	64.94^{b}	63.48^{b}	5.92

a, b Means in the same row with different superscripts are significantly different ($p< 0.05$); SEM = standard error of mean, CP = crude protein, EE = ether extract, CF = crude fibre; DM = dry matter.

The performance characteristics of WAD sheep fed ensiled Guinea grass silage supplemented with shrimp waste is presented in Table 4. There were significant differences in the weekly weight gain, total weight gain and total feed intake amidst treatments. The result showed that animals fed 10, 5 and 15% inclusion of silage and shrimp waste meal inclusion had total weight gain of 9.2, 3.77 and 3.82 kg respectively. Significantly ($p<0.05$) reduced total feed intake was observed at 15% cray fish waste meal inclusion levels (44.80 kg) compared to those fed 10% cray fish waste meal inclusion (56.20 kg). The feed conversion ratio was lower and better at 10% SWM than in other treatments. Animals fed 10% silage and shrimp waste meal inclusion also had higher total weight gain and favourable response in most of the other parameters as well.

Table 4. Performance characteristics of sheep fed silage supplemented with shrimp waste.

Parameters	(0%)	(5%)	(10%)	(15%)	SEM
Avg. initial weight (kg)	20.00	20.00	20.80	20.20	1.67
Avg. final weight (kg wk^{-1})	23.90^{b}	22.90^{b}	30.00^{a}	22.90^{b}	1.39
Weekly weight gain (kg wk^{-1})	1.92^{ab}	1.26^{b}	3.06^{a}	1.27^{b}	0.73
Total weight gain (kg)	5.75^{ab}	3.77^{b}	9.2^{a}	3.82^{b}	0.78
Total feed intake (kg)	56.70^{a}	46.00^{b}	56.20^{a}	44.80^{b}	0.81
Avg. daily feed intake (kg day^{-1})	2.70^{a}	2.19^{b}	2.68^{a}	2.13^{b}	0.42
Feed conversion ratio	9.85^{b}	12.20^{a}	6.11^{c}	11.72^{a}	1.60

a, b Means in the same row with different superscripts are significantly different ($p< 0.05$). SEM = standard error of mean, Avg = Average, wk = week.

Inclusion level of 10% silage and shrimp waste in the diet of the animals that consequently led to an increase in the average daily feed intake supports the study of Oduguwa and Adu (2021) who stated that incorporation of shrimp waste meal increased the average daily feed intake and acceptability of the diet (palatability) compared with the diet containing only soybean stover in West African Dwarf Sheep. Meyers (1986) also affirmed that shrimp meal can contain amino acid content close to that of fish meal when it is properly treated and processed. This can make it to contribute immensely to the rapid growth and survival of animals. Therefore, increase in growth rate of sheep fed these diets could be attributed to the encouragement of rapid growth by some steroids since there was increase in feed intake. Fanimo et al. (1996) also reported that when fish meal was substituted with shrimp waste up to 33%, there was positive change in the weight of the animals. In comparison with the other groups, animals fed 10% silage and shrimp waste meal inclusion, having the least feed conversion ratio implied that they were able to easily turn feed to build up flesh better when compared to sheep in other groups.

However, significantly reduced total feed intake that was observed at 15% cray fish waste meal inclusion levels could have resulted to the consequent significant decrease in total weight gain and weekly weight gain. This experience of lower feed intake, as obtained in some other researches, might be due to the undesirable and sharp taste, odour or anorectic properties of shrimp meal or waste, marine waste and some other protein substitute fed to broiler birds, leading to reduced appetite of birds and decrease in feed consumption. Also, shrimp waste may contain high ash and chitin content. Hence, adding to the diets of the sheep at higher quantity of 15% might have negatively affected palatability and digestibility in the sheep (Cobos et al., 2002).

The serum metabolites of sheep fed silage supplemented with shrimp waste is shown in Table 5. Except for creatinine with no significant difference ($p>0.05$), other serum metabolites were influenced by dietary treatments. The total protein values ranged from 37.00 to 56.50 mg dL^{-1}. The highest total protein values were from animals fed with silage without SWM and 10% inclusion of SWM (56.00, 56.50 mg dL^{-1}) while the least was in 5% inclusion (37.00 mg dL^{-1}). The albumin values ranged from 22.00 to 35.00 mg dL^{-1}. The values of urea was altered significantly ($p<0.05$) and was increased at 0 and 10% SWM inclusions (28.00, 29.00 mg dL^{-1}). This followed the same trend as the total protein. The overall serum urea level range observed was 19.0 - 29.0 mg dL^{-1} while the overall creatinine range was 0.9 - 1.4 mg dL^{-1}. The result of total protein obtained was in proximity to the normal range (61.6 – 63.7 mg dL^{-1}) according to Kareem-Ibrahim et al., (2023), for West African Dwarf Sheep. The highest total protein values were from animals fed 10% inclusion of SWM proving that 10% inclusion did not have adverse effect but rather increased the blood protein and contains sufficient protein, calcium and chitin usable in animal diet. In this study, albumin value obtained fell close to 28.3 - 34.1 mg dL^{-1} reported by Kareem-Ibrahim et al. (2023). The albumin content obtained in the diets used was sufficient in all the groups since there was no negative influence on serum indices.

The serum urea and creatinine level (19.00 - 29.00 mg dL^{-1} and 0.90 - 1.40 mg dL^{-1}) observed was within the normal value of 14.25 and 1.03 mg dL^{-1} respectively, according to the study of Kareem-Ibrahim et al. (2023) and Nafisat et al. (2021) for physiologically healthy sheep. Higher serum urea in the blood occurs when there is high rate of ammonia absorption from rumen leading to high rate of ammonia release in to the blood and excessive catabolism of tissue protein. Reduced level of blood urea Nitrogen may be due to lower consumption of protein or liver damage and protein absorption difficulty. This is an indication that shrimp waste inclusion probed no difficulty on the mass of lean tissue contained in the sheep. Kidney and liver function could be assessed using the urea and creatinine concentrations in the bloodstream as the blood urea nitrogen to serum creatinine ratio can be a valuable tool in the determination of renal functional and structural integrity. Serum creatinine is a more accurate assessment of renal function compared to urea (Gounden et al., 2024).

Table 5. Serum metabolites of sheep fed silage supplemented with shrimp waste.

PARAMETERS	T1 (0%)	(5%)	(10%)	(15%)	SEM
Total protein (mg dL^{-1})	56.0[a]	37.0[c]	56.5[a]	53.0[b]	0.90
Albumin (mg dL^{-1})	34.0[a]	22.0[c]	35.0[a]	32.0[b]	1.00
Urea (mg dL^{-1})	28.0[a]	19.0[c]	29.0[a]	26.0[b]	1.00
Creatinine (mg dL^{-1})	1.3	0.9	1.4	1.2	0.10
Uric acid (mg dL^{-1})	4.2[a]	2.8[c]	4.3[a]	4.0[b]	0.10

a, b Means in the same row with different superscripts are significantly different ($p < 0.05$). SEM = standard error of mean.

Conclusion

The experiment suggests that dietary inclusion of shrimp waste meal at 10% produced a better result in the animals' total weight gain, feed conversion ratio and in most of the other growth performance and digestibility parameters, without also eliciting deleterious effects on serum metabolites of sheep. Therefore, it can be recommended from this study that feeding sheep and other ruminant animals with silage supplemented with shrimp waste meal up to 10% inclusion level may be beneficial without any adverse effect, as higher levels of shrimp waste inclusion may elicit reduction in feed intake and growth performance.

Data availability

Data will be made available by the corresponding author upon reasonable request

References

Abun, A., Tuti, W., & Kiki, H. (2022). The effect of treatment of shrimp waste with three microbial on nutrient content and digestibility of feed in native chicken. *World Journal of Advanced Research and Reviews, 15*(1), 619-625. https://doi.org/10.30574/wjarr.2022.15.1.0756

Abuzar, H. R. S, Sharif, M. K., Arshad, R., Rehman, A., Ashraf, W., & AL-Sameen, M. A. (2023). Potential industrial and nutritional applications of shrimp by-products: a review. *International Journal of Food Properties, 26*(2), 3407-3432. https://doi.org/10.1080/10942912.2023.2283378

Ajayi, A. F., Farinu, G. O. Ojebiyi, O. O., & Olayeni, T. B. (2007). Performance evaluation of male weaner rabbits fed diets containing graded levels of blood-wild sunflower leaf meal mixture. *World Journal of Agricultural Science, 3*(2), 250-255.

Akinbola, E. T., Aromoye, R. A., Oladimeji, S. O., & Tewe, O. O. (2019). Growth performance, haematology and serum biochemistry of rabbits fed varying levels and forms of cassava peel. *Tropical Animal Production Investigations, 22*(2), 35 - 45.

AOAC International. (2016). *Official Methods of Analysis*.

Anaeto, M., Sawyerr, A. F., Alli, T. R., Tayo, G. O., Adeyeye, J. A. & Olarinmoye, A. O. (2013). Cassava leaf silage and cassava peel as dry season feed for West African dwarf sheep. *Global Journal of Science Frontier Research Agriculture and Veterinary Sciences,* 13(1), 1 – 5.

Babayemi, O. J. (2009). Silage quality, dry matter intake and digestibility by West African dwarf sheep of Guinea grass (*Panicum maximum* cv Ntchisi) harvested at 4 and 12 week regrowth. *African journal of Biotechnology, 8*(16), 3983-3988.

Cobos, M. A., Garcia, L. E., González, S. S., Barcena, J. R., Hernández, D. S., & Pérez-Sato, M. (2002).The effect of shrimp shell waste on ruminal bacteria and performance of lambs. *Animal Feed Science and Technology, 95*(3-4), 179 – 187. https://doi.org/10.1016/S0377-8401(01)00319-4.

Cooke, A. S., Machekano, H., Gwiriri, L. C., Tinsley, J. H. I., Silva, G. M., Nyamukondiwa, C., Safalaoh, A., Morgan, E. R., & Lee, M. R. F. (2025). The nutritional feed gap: seasonal variations in ruminant nutrition and knowledge gaps in relation to food security in Southern Africa. *Food Security, 17*(1), 73-100. https://doi.org/10.1007/s12571-024-01509-1

Dondu Bilgin (2021). Guinea grass (Panicum maximum) forage: a review. *MAS Journal of Applied Sciences, 6*(1), 77-82. https://doi.org/10.52520/masjaps.25

Emerue, P. C., Akinbola, E. T., & Omole, A. J. (2022a). Effects of dietary replacement of fish meal with crayfish waste meal on the blood profile of rabbits. *Nigerian Journal of Animal Production, 49*(1), 304- 312. https://doi.org/10.51791/njap.v49i1.3429

Emerue, P. C., Akinbola, E. T., Faniyi, T. O., & Salem, A. Z. M. (2022b). Dietary inclusion of kenaf (Hibiscus cannabinus L.) seed meal on the haematological and serum biochemical response of rams in southwestern Nigeria. *Tropical Animal Health and Production, 54*(6), 1-7. https://doi.org/10.1007/s11250-022-03400-7

Fanimo, A. O., Mudama, E., Umukoro, T. O., & Oduguwa, O. O. (1996). Substitution of shrimp waste meal for fish meal in broiler chicken rations. *Tropical Agriculture, 73*(3), 201-205.

Gounden, V., Bhatt, H., & Jialal, I. (2024). Renal function tests. In *StatPearls [Internet]*. StatPearls Publishing. Available from: https://www.ncbi.nlm.nih.gov/books/NBK507821/

Jayasinghe, P., Ramilan, T., Donaghy, D. J., Pembleton, K. G., & Barber, D. G. (2022). Comparison of nutritive values of tropical pasture species grown in different environments, and implications for livestock methane production: a meta-analysis. *Animals, 12*(4), 1-17. https://doi.org/10.3390/ani12141806

Kareem-Ibrahim, K. O., Abanikannda. O. T. F., Adeagbo, A. J., & Nzekwe, C.C. (2023). Haematological and Serum biochemical profiles of four Sheep breeds in Nigeria. *Nigerian Journal of Animal Production*, 50(4), 10-19. https://doi.org/10.51791/njap.v50i4.8012

Kohn, R. A., & Allen, M. S. (1995). *Enrichment* of proteolytic activity relative to nitrogen in preparation from the rumen for in vitro studies. *Animal Feed Science and Technology, 52*(1-2), 1-14. https://doi.org/10.1016/0377-8401(94)00711-H

Kubkomawa, H. I. & Lawal, A. U. (2021). Management practices of pasture, range and grazing reserves for livestock production in the tropics: a review. *American Journal of Entomology, 5*(2), 18-26. https://doi.org/10.11648/j.aje.20210502.11.

Eggink, K., E., Gonçalves, R., & Scov, P. V. (2024). Shrimp processing waste in aquaculture feed: nutritional value, applications, challenges, and prospects. *Reviews in Aquaculture, 17*(1), e12975. https://doi.org/10.1111/raq.12975

Mahgoub, O., Osman, N. E. H. I. E., & Lu, C. D. (2025). Nutrient utilization and requirements in sheep and goats raised under different systems and fed low nutritional novel feeds for meat production. *Animals*, *15*(18), 2658. https://doi.org/10.3390/ani15182658

Meyers, S. P. (1986). Utilization of shrimp processing wastes. *Infofish Marketing Digest, 4*(86), 18-19.

Mulubrhan, B., Ayantunde, A., Amole, T., Njarui, D., Bhutikini, D., Nkosi, F.L., Müller, R. M., Tlou, J., Tjelele, I. M., Malebana, O. R., Madibela, W. S., Boitumelo, B. L., Lukuyu, A. W., Elias, M. & Adegbola, T. A. (2021). Forage conservation in sub-Saharan Africa: review of experiences, challenges, and opportunities. *Agronomy Journal, 114*(1), 75-99. https://doi.org/10.1002/agj2.20954

Nafisat, A., Boyi1, B., Mbap, S. T., Elizabeth, T., Ibrahim, Y., Ja'afar, A. M., & Shuaibu, A. (2021). Effect of breed, sex, age and season on the haematological parameters of sheep in Bauchi State, Nigeria. *Nigerian Journal of Animal Science, 23*(2), 28-37.

Nurdianti, R. R., Dickhoefer, U., & Castro-Montoya, J. M. (2024). Relationship between nutritional composition and fibre digestibility in tropical forages compared to temperate forages. *Italian Journal of Animal Science, 23*(1), 1839-1853. https://doi.org/10.1080/1828051x.2024.2434697

Oduguwa, B., & Adu, I. (2021). Feeding value of shrimp waste meal for West African Dwarf sheep fed soybean stover basal diet. *Nigerian Journal of Animal Production, 37*(1), 71-84. https://doi.org/10.51791/njap.v37i1.662

Ogbu, E. C., Ogugbue, C. J., & Fajoyomi, B. U. (2024). Proximate assessment of shrimp (Macrobrachium Felicinum) sourced from crude oil polluted sites in rivers state, Nigeria. *Asian Journal of Food Research and Nutrition, 3*(4), 821-831.

Oladeji, D. D., Akinbola, E. T., Faniyi, T. O., Tirado-Estrada, G., & Molina, O. M. (2022). Converting the waste of orange fleshed sweet potato biomass to improve performance characteristics and vitamin profile of broiler chickens. *Waste and Biomass Valorisation, 13*(3), 1-9. https://doi.org/10.1007/s12649-022-01839-1

Riaz, R., Bilal, R. M., Hassan, M. U., Todaro, M., Gannuscio, R., Inal, F., Haque, M. N. U., & Tahir, M. N. (2025). Crude protein degradation kinetics of selected tropical forages in buffalo using nor for in situ standards. *Animals*, *15*(4), 585. https://doi.org/10.3390/ani15040585

Statistical Analysis System. (2016). *SAS User's guide Version 9.4*. SAS Institute Incorporations.

Yoshio, T., Yoshikawa, T., Sato, H., Mori, Y., Hosain, Z., Kishimura, A., Mori, T., & Katayama, Y. (2017). Encapsulation of a nitricoxide-donor into a liposome to boost the enhanced permeation and retention (EPR) effect. *Medical Chemical Communications*, *8*(2), 415–421.

Tesfaye, M., Mengistu, U., & Getachew, A. (2016). Effect of different proportions of *Peninsetum purpureum* silage and natural grass hay on feed utilization, milk yield and composition of crossbred dairy cows supplemented with concentrate diet. *Journal of Biology, Agriculture and Health Care, 6*(11), 2224-3208.

Associate Editor in charge:
Leandro Dalcin Castilha
ORCID: https://orcid.org/0000-0003-4799-2839