



International Journal of Veterinary Medicine and Animal Science (IJVMAS)

ISSN: 3064-8041 (ONLINE)

VOLUME 2 ISSUE 1 (2025)



PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

Growth Performance and Digestibility of Red Sokoto Goat Fed *Jatropha curcas* Kernel Cake Treated with *Pseudomonas aeruginosa*

Akeem Owolabi Ganiyu^{1*}, Moshood Adewale Belew², Nathaiel Funminiyi Ogunkunle³, Ridwan Olarewaju Imam¹

Article Information

Received: December 05, 2024

Accepted: January 12, 2025

Published: February 08, 2025

Keywords

Digestibility, Jatropha, Performance, Pseudomonas Aeruginosa, Red Sokoto

ABSTRACT

Good quality feed has been a major challenge in livestock production in the tropics, especially during the dry season, which is characterized by low-quality forages. Good nutrition is important because it is associated with improving the performance, health, reproduction and productivity of animals. This study aimed to evaluate the growth performance and digestibility of Red Sokoto goats fed *Jatropha curcas* kernel cake treated with *Pseudomonas aeruginosa*. Twenty Red Sokoto goats with average weight of 8.20 ± 1.1 kg were completely randomized into diets A (control: 0% *Jatropha curcas* kernel cake), B (10% *Pseudomonas* treated *Jatropha curcas* kernel cake), C (15% *Pseudomonas* treated *Jatropha curcas* kernel cake), and D (20% *Pseudomonas* a treated *Jatropha curcas* kernel cake). *Jatropha curcas* kernel cake was used as a replacement for groundnut cake over a 70-day experimental period. Data was analyzed as one-way ANOVA in SAS and means were separated with Duncan multiple range test at alpha of 5%. There was significant variation in the crude protein, ether extract and crude fiber of the experimental diets. A significant ($p < 0.05$) difference was observed in the dry matter intake of the animals with values of 433.48g, 426.46g, 339.29g and 328.78g for diets A, B, C and D respectively. Dry matter intake was significantly lower ($p < 0.05$) for animals fed diets C and D. The crude protein (12.02-15.85%), crude fiber (5.88-8.76%) and gross energy (376.97-388.43Kcal/100g) contents were adequate for animals of such age. The nutrient digestibility was significantly ($p < 0.05$) higher in diets supplemented with treated *Jatropha* kernel cake. There was no significant difference in the weight gain of the animals on diets A, B and C, however, animals fed diet D had significantly ($p < 0.05$) lower weight gain and average daily gain. It was concluded that treatment of *Jatropha curcas* cake with *Pseudomonas aeruginosa* was effective in detoxifying *Jatropha curcas* kernel cake as it has no deleterious effect on growth performance and improved nutrient digestibility of the experimental animals.

INTRODUCTION

Nutrition is an important aspect of livestock production because it is linked to animal performance, health, welfare, productivity and reproduction (Belew, 2006). Feed determines the growth rate of young animals; feeding a nutritionally deficient diet to animals often leads to disease susceptibility with the animals failing to reach their genetic potential (Belew *et al.*, 2013). Sheep and goats make up about 36% of Nigeria's overall meat supply with enormous development potential (Oni, 2002). Goat also features prominently in the economic and social lives of Nigerians. Due to the fast geometric growth of the current human population and the desire for animal protein especially in Nigeria, this livestock production system needs to be enhanced (Yahya, 2020). Tropical livestock production is severely hampered by low quality and insufficient animal feed supplies, especially during the dry season. Feed efficiency and utilization of feedstuff is a limiting factor in improving animal performance and productivity. The availability of quality and highly digestible feedstuff including their physical form is important in animal nutrition (Belew *et al.*, 2013). Feedstuff, particularly energy and protein sources primarily cereal-grains and leguminous seeds which

often constitute a larger component of the animal feed is limiting due to the competition for available resources between man and livestock. This led to the continuous increase in the cost as well as scarcity of conventional feedstuff like maize, wheat, sorghum, soybean, fish meal and groundnut especially in developing countries (Lee *et al.*, 2016).

There is need to explore more livestock feed resources to solve the problem of feed shortage. Researchers are studying the potential of different non-conventional feed resources especially crop residues and industrial byproducts (Ogunkunle *et al.*, 2024) needed to sustain livestock industry in Nigeria as well as to reduce the pressure on conventional feed resources that are being competed for by both humans and livestock. Attaining feed security for livestock is crucial as it can also help in reducing environmental hazards that may arise from wastes generated by industrial processing (Adejoro & Hassen, 2017; Panda *et al.*, 2018; Salami *et al.*, 2019). It is necessary to explore other alternative plant protein sources and underutilized agro-industrial byproducts that are less competitive between humans and livestock. Exploring these alternative sources can encourage the use of locally grown crops as well as creating a steady

¹ Department of Dairy Science, Faculty of Agriculture, University of Abuja, Abuja, Nigeria

² Department of Animal Production, University of Ilorin, Ilorin, Kwara State, Nigeria

³ Department of Food and Animal Sciences, Alabama A&M University, Normal, AL, USA

* Corresponding author's e-mail: akeem.ganiyu@uniabuja.edu.ng

feed supply for livestock production at a cheap cost. Among these alternative sources is jatropha kernel cake (JKC) which is a waste byproduct of biodiesel production industry (Gallegos-Tintore *et al.*, 2011). This industry processes extracted oil from Jatropha kernel into biodiesel that can be used in place of fossil fuel and turn out large quantities of Jatropha kernel cake as waste. The detoxification and reuse of JKC could make it a valuable feedstuff to livestock industry and reduce the potential environmental damage that may arise from improper disposal of this byproduct (Kasuya *et al.*, 2013).

Jatropha seed has high nutrient contents in terms of protein, energy and minerals (Boguhn *et al.*, 2010). Unfortunately, incorporating it in animal diet remains a challenge because of its phytochemical composition such as cyanide, saponin, tannin, phytate, and phorbol ester which limit its usage as livestock feed. Several processing methods including physical, biological, mechanical, and chemical methods have been explored for the reduction of these phytochemicals and detoxification of JKC with different degree of success (Ahluwalia *et al.*, 2017; Belewu *et al.*, 2010; De Barros *et al.*, 2011). Solid State Fermentation (SSF) seems to be the most promising and inexpensive way to improve the nutritive value of JKC. Solid state fermentation can alleviate the antinutritional compounds, regulate loss of protein, decrease environmental degradation and proffer an economically feasible method compared to other strategies (Aljuobori *et al.*, 2014; Çabuk *et al.*, 2018; Shi *et al.*, 2015). Solid state fermentation is a bioprocessing technique that has been reported to improve nutrient composition of several agro-industrial byproducts and underutilized crops by catalyzing antinutrients through the synthesis of exogenous enzymes as well as utilization of these antinutrients as substrate for microbial growth (Ahmed *et al.*, 2014).

Pseudomonas aeruginosa is a gram-negative, rod-shaped, asporogenous, and monoflagellated bacterium that has an incredible nutritional versatility (Wu *et al.*, 2015). It can biodegrade countless toxic compounds that are recalcitrant to other bacterial species, subsequently delivering auxiliary metabolites and biopolymers, making these strains helpful in medical and pharmaceutical industries (O'Brien *et al.*, 2014). *Pseudomonas aeruginosa* has valuable purposes in different modern applications and industrial sectors as these bacteria incorporates the ability to biodegrade waste, petroleum processing derived from plants, agribusiness, mash and paper, mining etc. (Lakshmanan *et al.*, 2020). Because of its ability to live in both inanimate and human environments, it has been characterized as “ubiquitous” microorganism (Wu *et al.*, 2015). This versatility is made possible by a large number of enzymatic secretions such as proteases and lipases that allow it to use a diversity of substances as nutrients.

However, *P. aeruginosa* can be use as biodegrading agent in removing or reducing the toxicity of chemical compound like phobol ester present in *jatropha curcas* cake obtained after oil extraction from jatropha seed. Joshi *et al.* (2011) reported an untraceable quantity of phobol-ester in JKC after nine days of microbial fermentation while Ganiyu and Belewu, (2023) reported improved feeding value of JKC after nine days of microbial fermentation.

We hypothesized that treating jatropha kernel cake with *Pseudomonas aeruginosa* will improve the growth performance and nutrient digestibility when fed to Red Sokoto goats. Therefore, this study evaluated the growth performance and digestibility of Red Sokoto goat fed graded levels of *jatropha curcas* Kernel cake treated *Pseudomonas aeruginosa*.

MATERIALS AND METHODS

Experimental Location

The experiment was carried out for 70 days at the Teaching and Research Farm, Federal College of Education (Technical) Bichi, Bichi Local Government, Kano state, Nigeria.

Collection and Preparation of the Substrate

The substrate (dehulled *J. curcas* kernel) was purchased from reputable source in Nigeria, milled, dried and then soaked in petroleum ether for 24 hours after which it was squeezed in a sieve cloth and air dried for three days to remove its oil after which the defatted cake was autoclaved at 121°C for 15 minutes.

Chemical Treatment

After autoclaving, the defatted cake was treated with Ferric chloride solution (FeCl₃·8H₂O) at 180mg/kg kernel cake to achieve homogenous paste texture.

Inoculation and Incubation of the Jatropha Kernel Cake

The treated Jatropha kernel cake was inoculated with the spores of *Pseudomonas aeruginosa* obtained from Department of Microbiology, University of Ilorin Laboratory. The inoculated substrate was covered with black polythene bags and incubated at room temperature to allow the organism to grow over the substrate for nine days. After which the growth was terminated by oven drying at 70°C for 24 hours. The spent substrate was then used in the formulation of the experimental diets.

Experimental Diets

The composition of the experimental diets is presented in Table 1. The experimental diets include a control with 0% jatropha kernel cake while the remaining diets contained 10, 15 and 20% inclusion level of jatropha kernel cake as replacement for groundnut cake.

Table 1: Composition of experimental diets

Ingredients (%)	Diet			
	A	B	C	D

Cassava peel	40.00	40.00	40.00	40.00
Cowpea husk	38.00	38.00	38.00	38.00
Groundnut cake	20.00	10.00	5.00	0.00
Jatrophakernel cake	0.00	10.00	15.00	20.00
Salt	1.00	1.00	1.00	1.00
Premix	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00

A: control, 0% jatropha kernel cake; B:10% jatropha kernel cake; C:15% jatropha kernel cake; D: 20% jatropha kernel cake

Experimental Animal and Management

Twenty weaners Red Sokoto goats (8.20±1.1kg BW) used for this experiment were purchased from local markets in Bichi local government area, Kano State, Nigeria. The animals were treated against parasites (ecto and endo) with Ivermectin. The animals were randomly assigned to experimental diets with five animals per treatment in a completely randomized design model. Each animal was placed in an individual pen with access to water and feed. Feeding was based on 5% body weight of individual animal and water was given ad libitum. Individual animal feed intake was recorded daily while body weight was recorded on weekly basis; feed conversion ratio and average daily gain were calculated using the weight gain of individual animal. Fecal samples were collected daily, refrigerated and bulked at the end of the experiment to determine the apparent nutrient digestibility coefficient.

Analysis

The chemical analysis of the experimental feed and fecal samples was conducted in the laboratory for proximate compositions using the method of AOAC (2000) and data obtained from various parameters was subjected to one-way analysis of variance in a completely randomized design model using the software package of SAS 9.1, means were separated using Duncan's Multiple Range test at 5% alpha level.

RESULTS AND DISCUSSION

Proximate Composition of Experimental Diets

There was significant difference ($p < 0.05$) among the mean composition of the experimental diets as presented in Table 2. Diet B had the highest dry matter content (92.85%), followed by diet A (92.40%), diet C (92.25%) and the least was diet D (91.90%). All were within the range (92-93%) reported by (Belewu *et al.*, 2013) but lower than (94.43-96.55%) observed by (Sanusi *et al.*, 2013). The crude protein content of diet A (15.85%) was higher than the diets containing treated JKC (15.54%, 13.04% and 12.02%) for diets B, C and D respectively.

The lower crude protein observed in the JKC supplemented groups could be attributed to the lower crude protein content of JKC compared to groundnut cake, the result in this study was lower than 22.78-27.33% reported by Belewu *et al.* (2013), the variation could be as a result of the different treatment method for JKC and the inclusion levels. Meanwhile, the crude fiber and ether extract content of diets containing treated JKC diets were higher than diet A (5.88% and 4.05% respectively) due to the high fiber content in JKC. The crude fiber in this study was lower than 21.83-34.23% reported by Belewu *et al.* (2010a). The gross energy of the diets containing JKC was higher than control diet (376.97Kcal/100g).

Table 2: Proximate Composition of Experimental Diets

Parameters (%)	Diet				SEM	P-Value
	A	B	C	D		
Dry Matter	92.40 ^b	92.85 ^a	92.25 ^c	91.90 ^d	0.13	<0.0001
Crude protein	15.85 ^a	15.54 ^b	13.04 ^c	12.02 ^d	0.61	<0.0001
Crude fiber	5.88 ^d	7.71 ^c	8.37 ^b	8.76 ^a	0.42	<0.0001
Ether extract	4.05 ^d	6.09 ^c	6.41 ^b	7.17 ^a	0.44	<0.0001
Ash	12.00 ^b	13.00 ^a	11.00 ^d	11.25 ^c	0.29	<0.0001
NFE	54.63 ^a	50.52 ^d	53.44 ^b	52.52 ^c	0.56	<0.0001
G.E (Kcal/100g)	376.97 ^c	385.03 ^b	388.43 ^a	387.99 ^a	1.74	<0.0002

^{abc} Means with different superscripts in a row are significantly ($P < 0.05$) different

NFE- Nitrogen Free Extract, G.E- Gross Energy; A: control, 0% jatropha kernel cake; B:10% jatropha kernel cake; C:15% jatropha kernel cake; D: 20% jatropha kernel cake

Growth Performance

Table 3 shows the growth performance parameters of Red Sokoto goats fed JKC treated with *Pseudomonas aeruginosa*. There was significant ($p < 0.05$) difference in

dry matter intake of the animals, diet A (433.48 g/day) had higher dry matter intake than the JKC supplemented groups. The dry matter intake decreased with increasing JKC inclusion. The decrease in dry matter intake could be

attributed to the phytochemical contents present in the JKC and the processing method adopted in this study. This corroborates the report of Belewu *et al.* (2010b) who reported a decrease in dry matter intake as fungal treated JKC inclusion increased, however, Félix-Bernal *et al.* (2014) did not observe a significant difference in dry matter intake when non-toxic JKC was fed to lambs. The variation in results could be attributed to the different varieties of jatropha used in the research.

There was no significant difference in final weight of the animals with animals in diets A, B, C and D having final weights of 9.39, 9.10, 8.85 and 8.35kg respectively. A significant ($p < 0.05$) difference was observed in the weight gain and average daily gain of the animals, diet A had 1.14kg and 20.31g/day, 1.0kg and 17.86g/day in diet B, 0.70kg and 12.50g/day in diet C and 0.05kg and 4g/day in diet D for weight gain and average daily gain respectively. There was no significant difference between

diets A and B indicating they had similar effects on the growth performance of the animals. The average daily gain in this study was similar to the 4.11-21.96g/day reported by Belewu *et al.* (2010a) and higher than -0.14-0.08g/day reported by Sanusi *et al.* (2013) for WAD goats fed JKC. Previous study by Ganiyu and Belewu (2022) reported that replacing soybean meal with JKC upto to 20% of the diet did not have any detrimental effects on hematological parameters and serum biochemistry of Sokoto Red goats, however, animals in the 15% and 20% JKC diets had lower weight gain and average daily gain, they look weak and emaciated compared to animals in the 0% and 10% group. This was in agreement with Chivandi *et al.* (2006) who noticed a similar trend in pigs supplemented with JKC. There was no significant effect on the feed conversion ratio of the animals. Feed conversion for diet A was 22.81, diet B with 28.54, diet C had 36.43 and diet D with 46.06.

Table 3: Growth Performance of Red Sokoto goats fed *Jatropha curcas* Kernel Cake Treated with *Pseudomonas aeruginosa*

Parameters	Diet				SEM	P-value
	A	B	C	D		
DM Intake (g/day)	433.48 ^a	426.46 ^a	339.29 ^b	328.78 ^b	16.60	0.017
Initial Weight (kg)	8.30	8.25	8.15	8.10	0.13	0.953
Final Weight (kg)	9.39	9.10	8.85	8.35	0.19	0.511
Weight gain (kg)	1.14 ^a	1.00 ^a	0.70 ^{ab}	0.05 ^b	0.15	0.061
ADG (g)	20.31 ^a	17.86 ^a	12.50 ^{ab}	4.00 ^b	2.28	0.061
FCR	22.81	28.54	36.43	46.06	5.90	0.579

^{abc}Means with different superscripts in a row are significantly ($P < 0.05$) different

DM: dry matter; ADG: average daily gain; FCR: feed conversion ratio; Diet A: control, 0% jatropha kernel cake; B:10% jatropha kernel cake; C:15% jatropha kernel cake; D: 20% jatropha kernel cake

Nutrient Digestibility

Table 4 shows the nutrient digestibility coefficient of Red Sokoto goats fed *Jatropha curcas* Kernel Cake Treated with *Pseudomonas aeruginosa*. There was significant ($p < 0.05$) difference in dry matter, digestible energy, crude protein, crude fiber and nitrogen free extract digestibility. Animals on diet D had significantly ($p < 0.05$) highest digestibility of nutrients while animals on diet A had the least digestibility coefficient meanwhile, the digestible energy in diet D (78.50%) was significantly lower ($p < 0.05$) than diet B (81.83%) and diet C (80.05%) but significantly higher ($p < 0.05$) than diet A (77.76%). The crude protein digestibility was higher than previous study 48.66-74.40% by Belewu *et al.* (2010b). More so, the crude fiber digestibility value in this study was lower than 87.50-93.10% reported by Belewu and Akande (2010) and 88.85-94.34% reported by Belewu *et al.* (2010b),

this could be as a result of variation in detoxification and treatment methods used. Higher percentage values obtained in digestible energy, crude protein and crude fiber in diets containing JKC is an evidence of feed quality which increased activities of degrading bacteria in the rumen. The digestibility of feedstuff is the major determinant of the quality of the feed therefore, higher digestibility coefficient of nutrients obtained in this study indicates that the diets were highly digestible as the inclusion level increased, this could be attributed to the bacteria treatment of the JKC. The high nutrient digestibility in the JKC supplemented groups recorded in this study contradicts the report of Belewu *et al.* (2010b) who observed a reduction in nutrient digestibility when goats were fed fungal treated JKC. This indicates the efficacy of bacteria in detoxifying the phytochemicals and antinutrients in JKC as well as enhancing its digestibility.

Table 4: Apparent Digestibility Coefficient of Red Sokoto goats fed *Jatropha curcas* Kernel Cake Treated with *Pseudomonas aeruginosa*

Parameters	Diet				SEM	P-value
	A	B	C	D		
DMD	85.96 ^d	89.12 ^b	87.69 ^c	92.00 ^a	0.83	<0.0001

CPD	88.69 ^d	92.49 ^b	89.48 ^c	93.35 ^a	0.74	<0.0001
CFD	50.81 ^d	74.76 ^c	76.85 ^b	89.57 ^a	5.29	<0.0001
EED	76.38 ^d	91.84 ^b	90.36 ^c	95.02 ^a	2.69	<0.0001
NFED	91.27 ^c	93.67 ^b	93.65 ^b	94.99 ^a	0.51	<0.0001
DE	77.76 ^d	81.83 ^a	80.05 ^b	78.50 ^c	0.59	<0.0001

^{abc}Means with different superscripts in a row are significantly ($P < 0.05$) different

DMD: Dry matter content digestibility, CPD: Crude protein content digestibility, CFD: Crude fibre content digestibility, EED: Ether extract content digestibility, NFED: Nitrogen free extract digestibility, DE: Digestible Energy; Diet A: control, 0% jatropha kernel cake; B: 10% jatropha kernel cake; C: 15% jatropha kernel cake; D: 20% jatropha kernel cake

CONCLUSION

From the results of this study, feeding goats with diet containing *Jatropha curcas* kernel cake treated with *Pseudomonas aeruginosa* improved nutrient digestibility in the goats, incorporating 10% jatropha kernel cake showed similar weight gain and average daily gain to the control group that was fed groundnut cake with lower feed intake. This indicates that inoculating jatropha kernel cake with bacteria improved its potential to be used as protein feed ingredient in livestock ration without deleterious effects on animal growth performance. It can be concluded that supplementing bacteria-treated jatropha kernel cake in goat diet up to 10% optimized their performance and nutrient digestibility; therefore, it can be a potential protein feedstuff for ruminant animals. Further studies need to be carried out to detect the metabolites and different pathways that are upregulated in ruminant animals fed jatropha kernel cake. This will shed more light on the mechanism by which jatropha kernel cake contributes to animal performance and feed efficiency.

REFERENCE

- Adejoro, F., Hassen, A. (2017). Effect of supplementing or treating *Eragrostis curvula* hay with urea or nitrate on its digestibility and in vitro fermentation. *South African Journal of Animal Science*, 47(2), 168–177. <https://doi.org/10.4314/sajas.v47i2.8>
- Ahluwalia, S., Sharma, J. G., & Singh, P. (2017). Degradation of phorbol esters in *Jatropha* seed cake by *Pseudomonas aeruginosa* DS1. *International Journal of Pharma and Bio Sciences*, 8(2), 542–546. <https://doi.org/10.22376/ijpbs.2017.8.2.b542-546>
- Ahmed, A., Zulkifli, I., Farjam, A. S., Abdullah, N., Liang, J. B., & Awad, E. A. (2014). Effect of solid-state fermentation on nutrient content and ileal amino acid digestibility of canola meal in broiler chickens. *Italian Journal of Animal Science*, 13(2). <https://doi.org/10.4081/ijas.2014.3293>
- Aljuobori, A., Zulkifli, I., Soleimani, A. F., Abdullah, N., Liang, J. B., & Mujahid, A. (2016). Higher inclusion rate of canola meal under high ambient temperature for broiler chickens. *Poultry Science*, 95(6), 1326–1331. <https://doi.org/10.3382/ps/pew023>
- Annongu, A. A., Joseph, J. K., Apata, D. F., Adeyina, A. O., Yousuf, M. B., & Ogunjimi, K. B. (2010). Detoxification of *Jatropha curcas* seeds for use in nutrition of monogastric livestock as alternative feedstuff. *Pakistan Journal of Nutrition*, 9, 902–904. <https://doi.org/10.1016/j.psj.2023.103072>
- AOAC. (2000). *Official methods of analysis* (14th ed.). Association of Official Analytical Chemists.
- Banson, K. E., Muthusamy, G., & Kondo, E. (2015). The import-substituted poultry industry: Evidence from Ghana. *International Journal of Agriculture and Forestry*, 5(2), 166–175.
- Belewu, M. A. (2006). *A functional approach to dairy science and technology*. Adlek Press.
- Belewu, M. A., & Akande, B. A. (2010). Biological upgrading of the nutritional quality of *Jatropha curcas* kernel cake: Effect on performance characteristics of goats. *International Research Journal of Biotechnology*, 1(2), 19–22.
- Belewu, M. A., Belewu, K. Y., & Ogunsola, F. O. (2010a). Nutritive value of dietary fungi-treated *Jatropha curcas* kernel cake: Voluntary intake, growth, and digestibility coefficient of goats. *Agriculture and Biology Journal of North America*, 1(2), 135–138.
- Belewu, M. A., Eniolorunda, O. O., & Ilori, G. I. (2010b). Response of goats to fungi (*Rhizopus oligosporus* and *Rhizopus nigricans*)-treated *Jatropha curcas* kernel cake. *Archives of Applied Science Research*, 2(4), 255–261.
- Belewu, M. A., Tijani, A. A., & Inamette, F. J. (2013). Synergistic effect of *Aspergillus niger* and *Penicillium chrysogenum* on *Jatropha curcas* kernel cake: Influence on performance of sheep. *International Journal of Science and Nature*, 4(4), 624–626.
- Boguhn, J., Makkar, H. P. S., Becker, K., & Rodehutscord, M. (2010). Amino acid digestibility of detoxified *Jatropha* kernel meal in turkeys. *World Poultry Science Journal Supplement*, 66, 476. 13th European Poultry Conference, France, August 23-27, 2010.
- Çabuk, B., Nosworthy, M. G., Stone, A. K., Korber, D. R., Tanaka, T., House, J. D., & Nickerson, M. T. (2018). Effect of fermentation on the protein digestibility and levels of non-nutritive compounds of pea protein concentrate. *Journal of Food Technology and Biotechnology*, 56(2), 257–264. <https://doi.org/10.17113/ftb.56.02.18.5450>
- Chivandi, E., Erlwanger, K. H., Makuza, S. M., Read, J. S., & Mtimuni, J. P. (2006). Effects of dietary *Jatropha curcas* meal on percent packed cell volume, serum glucose, cholesterol, triglyceride concentration, and alpha-amylase activity of weaned fattening pigs. *Research Journal of Animal and Veterinary Science*, 1(1), 18–24.

- De Barros, C. R. M., Ferreira, M. M. L., Nunes, F. M., Bezerra, R. M. F., Dias, A. A., Guedes, C. V., Cone, J. W., Marques, G. S. M., & Rodrigues, M. A. M. (2011). The potential of white-rot fungi to degrade phorbol esters of *Jatropha curcas* L. seed cake. *Engineering in Life Sciences*, 11(1), 107–110.
- Elbehri, A., Segerstedt, A., & Liu, P. (2013). A global assessment of sustainability biofuels and sustainability challenge: Issues, trends, and policies for biofuels and related feedstocks. FAO.
- Félix-Bernal, J. A., Angulo-Escalante, M. A., Estrada-Angulo, A., Heredia, J. B., Muy-Rangel, D., López-Soto, M. A., Barreras, A., & Plascencia, A. (2014). Feeding value of nontoxic *Jatropha curcas* seed cake for partially replacing dry-rolled corn and soybean meal in lambs fed finishing diets. *Animal Feed Science and Technology*, 198, 107–116. <https://doi.org/10.1016/j.anifeedsci.2014.10>
- Gallegos-Tintoré, S., Torres-Fuentes, C., Martínez-Ayala, A. L., Solorza-Feria, J., Alaiz, M., Girón-Calle, J., & Vioque, J. (2011). Antioxidant and chelating activity of *Jatropha curcas* L. protein hydrolysates. *Journal of the Science of Food and Agriculture*, 91(9), 1618–1624. <https://doi.org/10.1002/jsfa.4357>
- Ganiyu, A. O., & Belewu, M. A. (2022). Effect of biochemically treated *Jatropha curcas* kernel cake on hematological and serum biochemical parameters of Red Sokoto goats. *International Journal of Phytofuels and Allied Sciences*, 11(1), 11–18.
- Ganiyu, A. O., & Belewu, M. A. (2023). Comparative evaluation of proximate composition of bacterial (*Pseudomonas aeruginosa*) treated and untreated *Jatropha curcas* L. kernel cake. *Nigerian Journal of Animal Production*, 49(5), 156–161. <https://doi.org/10.51791/njap.v49i5.3586>
- Joshi, C., Mathur, P., & Khare, S. K. (2011). Degradation of phorbol esters by *Pseudomonas aeruginosa* PseA during solid-state fermentation of deoiled *Jatropha curcas* seed cake. *Bioresource Technology*, 102(7), 4815–4819.
- Kasuya, M. C. M., da Luz, J. M. R., Pereira, L. P. D., Montavani, H. C., & Rodrigues, M. T. (2013). Bio-detoxification of *Jatropha* seed cake and its use in animal feed. In *Biodiesel feedstocks, production, and application*.
- Lakshmanan, R., Kalaimurugan, D., Sivasankar, P., Arokiyaraj, S., & Venkatesan, S. (2020). Identification and characterization of *Pseudomonas aeruginosa*-derived bacteriocin for industrial applications. *International Journal of Biological Macromolecules*, 165, 2412–2418. <https://doi.org/10.1016/j.ijbiomac.2020.10.126>
- Makkar, H. P. S., & Becker, K. (1997). Potential of *Jatropha curcas* seed meal as a protein supplement to livestock feed, constraints to its utilization, and possible strategies to overcome constraints. *Proceedings Jatropha 97*, Managua, Nicaragua.
- O'Brien, S., Hodgson, D. J., & Buckling, A. (2014). Social evolution of toxic metal bioremediation in *Pseudomonas aeruginosa*. *Proceedings of the Royal Society B: Biological Sciences*, 281(1787), 20140858. <https://doi.org/10.1098/rspb.2014.0858>
- Ogunkunle, N. F., Adeniyi, N. O., & Simpson, M. D. (2024). The use of pomace as animal feed: A review of grape and tomato pomace. *Journal of Agricultural Science*, 16(10). <https://doi.org/10.5539/jas.v16n10p1>
- Oni, J. A. (2002). Marketing of small ruminants in Nigeria. In C. A. M. Lakpini, A. M. Adamu, O. W. Ehoche, & J. O. Gefu (Eds.), *Manual for small ruminant production in Nigeria* (pp. 77–85). Workshop at National Animal Production Research Institute, Ahmadu Bello University, Shika, Nigeria, January 13th-18th.
- Panda, R., Das, B. C., Swain, P., & Chandrakar, K. (2018). Knowledge level of goat farmers of Mayurbhanj district of Odisha, India on health care and general management. *Exploratory Animal and Medical Research*, 8(2), 173–177.
- Raheman, H. (2012). *Jatropha* (Chapter 14). In C. K. Chittaranjan, C. P. Joshi, & D. R. Shonnard (Eds.), *Handbook of bioenergy crop plants* (pp. [page range]). CRC Press, Taylor & Francis Group.
- Salami, S. A., Luciano, G., O'Grady, M. N., Biondi, L., Newbold, C. J., Kerry, J. P., & Priolo, A. (2019). Sustainability of feeding plant by-products: A review of the implications for ruminant meat production. *Animal Feed Science and Technology*, 251, 37–55. <https://doi.org/10.1016/j.anifeedsci.2019.02.006>
- Sanusi, G. O., Belewu, M. A., & Oduguwa, B. O. (2013). Changes in chemical composition of *Jatropha curcas* kernel cake after solid-state fermentation using some selected fungi. *Journal of Biology, Agriculture and Health Science*, 2(2), 62–66.
- Shi, C., He, J., Yu, J., Yu, B., Huang, Z., Mao, X., Zheng, P., & Chen, D. (2015). Solid-state fermentation of rapeseed cake with *Aspergillus niger* for degrading glucosinolates and upgrading nutritional value. *Journal of Animal Science and Biotechnology*, 6, 13. <https://doi.org/10.1186/s40104-015-0015-2>
- Yahya, M. M., Umar, F., & Yakubu, A. K. (2020). Effect of feeding graded levels of probiotic-supplemented sugarcane bagasse on performance and haematological parameters of Red Sokoto goats. *Journal of Agriculture and Environment*, 16(1), 41–48.
- Wu, W., Jin, Y., Bai, F., & Jin, S. (2015). *Pseudomonas aeruginosa*. In *Molecular medical microbiology* (pp. 753–767). Academic Press.