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Feed intake and digestibility co-efficient of West African Dwarf goats fed Bio-chemically treated *Jatropha curcas* kernel cake

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Abstract

Jatropha curcas is high in protein with about 58.1 percent crude protein content and a rich source of essential amino acids, it would be an excellent feed resource for livestock if the antinutrients and toxicity level is drastically reduced. The toxicity is primarily due to the presence of phorbolesters which limits its use as an animal feed material. This study was aimed at evaluating the feed intake of West African Dwarf goats fed bio-chemically treated Jatropha curcas kernel cake included in a cassava-based diet. The bio-chemical method involves the use of Hydrogen peroxide with Iron (iii) oxide as catalyst as pre-treatment before the use of solid-state fermentation on the milled kernel cake. The inclusion level of the Jatropha curcas kerne cake in the diet are 6 perecent each of B (60mg H_20_2/kg cake treated with Penicillum expansum) ,C 120mgH_20_2/kg cake treated with Penicillum expansum), D (180mgH_20_2/kg cake treated with Penicillum expansum) respectively with the control having 12% soybean. There was a significant difference in the dry matter intake ($P<0.05$) and other nutrient intake of animals in the treatment groups compared to those on the control diet. There was also a significant difference ($P<0.05$) in the nutrient digestibility and digestible nutrient intake of animals on the treatment compared to those on the control diet. The value of Dry Mater Intake ranged from 2050 to 2750g/d, the apparent dry matterdigestibility ranged from 97.07 to 97.81%, the Dry Matter Digestible Nutrient Intake ranged from 1989.90 to2690g/d, while the the average weight gain ranged from 1.60 to 3.64g/animal/day. There was no sign of toxicity observed during this study. The results of this study show that the bio-chemically treated Jatropha curcas kernel cake can be included in the diet of WAD goats without any toxic effect on the animals.

Keywords: West African Dwarf Goats, *Jatropha curcas*, Solid state fermentation, Digestible nutrient intake, Nutritional quality.

Running title: Bio-chemical treatment impact on performance of West African dwarf Goats

Prise alimentaire et coefficient de digestibilité des chèvres West African Dwarf nourries avec un tourteau de graines de *Jatropha curcas* traité biochimiquement

Résumé

Jatropha curcas est riche en protéines, avec environ 58,1 % de teneur en protéines brutes, et constitue une source importante d'acides aminés essentiels. Il pourrait donc être une excellente ressource alimentaire pour le bétail si les antinutriments et le niveau de toxicité étaient considérablement réduits. La toxicité est principalement due à la présence de phorbol esters, qui limite son utilisation comme matière première pour l'alimentation animale. Cette étude visait à évaluer la prise alimentaire des chèvres West African Dwarf nourries avec un tourteau de graines de Jatropha curcas traité biochimiquement et incorporé dans un régime à base de manioc. La méthode biochimique implique l'utilisation de peroxyde d'hydrogène avec de l'oxyde de fer (III) comme catalyseur en prétraitement, suivie d'une fermentation en milieu solide sur le tourteau de graines moulu. Les niveaux d'inclusion du tourteau de Jatropha curcas dans le régime étaient de 6 % pour chaque traitement : B (60 mg H2O2/kg de tourteau traité avec Penicillium expansum), C (120 mg H2O2/kg de tourteau traité avec Penicillium expansum), D (180 mg H2O2/kg de tourteau traité avec Penicillium expansum), tandis que le régime témoin contenait 12 % de tourteau de soja. Une différence significative a été observée dans la prise de matière sèche ($P < 0,05$) et dans l'ingestion d'autres nutriments chez les animaux des groupes traités par rapport à ceux du régime témoin. Il y avait également une *différence significative (P < 0,05) dans la digestibilité des nutriments et l'ingestion de nutriments digestibles entre les animaux des régimes traités et ceux du régime témoin. Les valeurs de la prise de matière sèche variaient entre 2050 et 2750 g/j, la digestibilité apparente de la matière sèche entre 97,07 et 97,81 %, l'ingestion de nutriments digestibles secs entre 1989,90 et 2690 g/j, et le gain de poids moyen entre 1,60 et 3,64 g/animal/jour. Aucun signe de toxicité n'a été observé au cours de cette étude. Les résultats montrent que le tourteau de graines de Jatropha curcas traité biochimiquement peut être inclus dans l'alimentation des chèvres West African Dwarf sans effet toxique sur les animaux.*

Mots-Clés: Chèvres West African Dwarf, *Jatropha curcas*, Fermentation en milieu solide, Ingestion de nutriments digestibles, Qualité nutritionnelle.

Introduction

Jatropha curcas seed meal has a higher potential as a protein replacement in animal feed (Yinuo *et al., et al* 2018). Shrestha *et al.* (2013) reported that the seeds contain up to 60% oil with a fatty acid pattern similar to those of other oilseeds and with a crude protein content of between 58 and 64% (Makkar and Becker,1997; Trabi *et al.,* 1997). Due to the presence of lectin, phorbol esters, saponin, protease inhibitor and phytate neither the seed nor the cake can be used for human and animal nutrition without processing. Wink (1993) reported that cooking ground seeds for five minutes deactivates only the lectin content. It was also noted that heat treatment could not destroy phorbol ester, as it is heat labile and can withstand high temperature of 160°C for 130 minutes. The seed cake is reported to be high in nutrient content and contain various anti-nutrients which hinders its utilization (Yinuo *et al.,* 2018). Various chemical treatments were reported with no encouraging results. Consequently, the biological treatment reported by Belewu (2008), Belewu and Ogunsola (2010) and de Barros *et al. (*2024) showed substantial reduction in the various anti-nutrients especially when *Jatropha curcas* kernel cake was incubated with *Rhizopus oligosporus* and *Aspergillus niger* by the process of solid-state fermentation. The results obtained from these studies prompted the need to investigate the efficacy of combining the biological and chemical treatment approach on the reduction of anti-nutritional factors which have made impossible the use of *Jatropha curcas* kernel cake in animal feed. Good nutrition is important in the proper functioning of the tissue and which in advent will keep the animal productive and healthy. This study focused on the efficacy of treated *Jatropha curcas* kernel cake (JKC) as a feedstuff for WAD goats

The objectives of this study are:

- To evaluate the nutritional feed intake and weight gain of WAD goats fed the bio-chemically treated *Jatropha curcas* kernel cake.
- To determine the digestibility co-efficient and digestible nutrient intake of West African Dwarf goats fed the bio-chemically treated *Jatropha curcas* kernel cake.

Materials and Methods

Seed Collection/ Chemical Treatment

Matured and sundried seeds of *Jatropha curcas* was collected and also purchased around Ilorin metropolis. The seed coat was removed to obtain the kernel. The kernel was milled using the mechanical grinder, and the oil extracted using the mechanical hydraulic oil press. The cake was packed in polyethylene bags for autoclaving at 121°C so as to get rid of any microbes that could be present in the cake. The autoclaved cake was used as substrate for fungal growth. The milled cake was subjected to treatment with hydrogen peroxide at 60, 120 and 180mg each with iron (iii) oxide serving as catalyst. The treated cake is further placed in a waterbath according to the methods described by Devappa *et al.* (2012).

Fungi

The fungus *Penicillum expansum* was collected from the Department of Microbiology, Obafemi Awolowo University, Ile Ife, Nigeria and maintained on Potato Dextrose Agar contain in petri dishes. Twenty millilitres from the suspension ($5x10^4$spore/mL) was used to inoculate 1kg of the autoclaved kernel cake in layers in a container. The whole content was incubated in an incubator at room temperature for 7 days.

Inoculation and Incubation of Substrate

Suspension of actively growing mid-log phased culture of the *Penicillum expansum* was individually adjusted to $5x10^4$spores/mL with sterile distilled water. 20mL from the suspension ($5x10^4$spores/mL) was used to inoculate 1kg of the autoclaved and hydrogen peroxide treated kernel cake arranged in layers in a container as described by Belewu and Ogunsola (2010). The whole content was incubated in an incubator at room temperature for 7 days.

The autoclaved kernel cake was incubated separately with the fungus at room temperature (21°C) for 7days. The growth was terminated by oven drying at 80°C for 24 hours when the inoculum enveloped the substrate.

Experimental Site

Suspension of actively growing mid-log phased culture of the *Penicillum expansum* was individually adjusted to $5x10^4$spores/mL with sterile distilled water. 20mL from the suspension ($5x10^4$spores/mL) was used to inoculate 1kg of the autoclaved and hydrogen peroxide treated kernel cake arranged in layers in a container as described by Belewu and Ogunsola (2010). The whole content was incubated in an incubator at room temperature for 7 days. The autoclaved kernel cake was incubated separately with the fungus 21°C for 7days. The growth was terminated by oven drying at 80°C for 24 hours when the inoculum enveloped the substrate.

This feeding trial was carried out at the Ruminant Unit of The Teaching and Research Farm, University of Ilorin, Nigeria.

Animal and Management

Twenty Eight weaned West African Dwarf goats weighing between 7-9kg were used for the experiment which lasted for 70days. The animals were treated against ecto and endo parasites using ivomec injection and later weighed at the start and fortnightly till the end of the experiment to calculate the average weight gain. They were randomly allocated to four treatments each with seven replicates. Experimental diet (Table 4.1) and water were fed to animals *ad libitum*. Daily feed intake was obtained by deducting the left over from the daily feed supplied. Daily feed intake = feed supplied - feed leftover

The digestibility trial was determined for a 21day period; the animals were placed in metabolic cages for proper collection of faecal samples. The total faecal output for each animal was collected into a collection bag, weighed, mixed well and oven dried (60°C) to prevent microbial growth. Feed conversion ratio was calculated as: Feed Intake/Weight gain.

Chemical Analysis

The proximate composition of the diets and faeces were determined using the methods of AOAC (1990).

Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) of a completely randomized design model using the SAS (2002); the treatment means were separated using the same package. The metabolizable energy (ME) was calculated as follows: Pauzenga (1985)

ME (kcal/kg DM) = (37 x % CP) + (81.8 x % Fat) + (35.5 x % NFE)

Results and Discussion

Table 1: Composition of Experimental Diets fed to goats

Parameters	DIET A (Control)	DIET B	DIET C	DIET D
Cassava wastes	53.00	53.00	53.00	53.00
Rice husk	33.00	33.00	33.00	33.00
Soyabean cake	12.00	6.00	6.00	6.00
Bio-chemically treated jkc	-	6.00[a]	6.00[b]	6.00[c]
Common salt	1.00	1.00	1.00	1.00
vitamin-mineral premix	1.00	1.00	1.00	1.00
Total	**100**	**100**	**100**	**100**

B = 60mg H_20_2/kg cake treated with *Penicillum expansum*

C = 120mgH_20_2/kg cake treated with *Penicillum expansum*

D = 180mgH_20_2/kg cake treated with *Penicillum expansum*
JKC=Jatropha Kernel Cake ,Cassava waste consists of peels, stumps and the whitish skin of tuber parts

Table 2: Nutrient Intake (DM BASIS) and Weight Gain of West African Dwarf Goat fed Bio-Chemically Treated *Jatropha curcas* Kernel Cake

Parameters	Diet A	Diet B	Diet C	Diet D	±SEM
Dry Matter Intake (g/d)	2050^{a}	2191^{c}	2090^{b}	2750^{d}	11.40
Crude Protein Intake (g/d)	225.64^{a}	244.33^{b}	238.91^{b}	316.02^{c}	3.74
Crude Fibre Intake (g/d)	500.00^{b}	504.87^{b}	482.50^{a}	636.56^{c}	2.83
Ether Extract Intake (g/d)	195.51^{a}	276.25^{b}	275.28^{b}	353.55^{c}	1.88
Ash Intake (g/d)	299.10^{b}	300.43^{b}	293.65^{a}	384.33^{c}	1.33
NDF Intake (g/d)	334.14^{b}	329.11^{a}	392.91^{c}	568.98^{d}	1.28
ADF Intake (g/d)	778.99^{a}	881.34^{b}	961.39^{c}	1292.60^{d}	5.51
ADL Intake (g/d)	543.23^{a}	626.89^{c}	610.27^{b}	822.27^{d}	3.27
Cellulose Intake (g/d)	237.74^{a}	293.71^{b}	328.12^{c}	462.01^{d}	1.60
Hemicellulose Intake (g/d)	444.84^{a}	569.89^{b}	566.38^{b}	717.75^{c}	2.95
Initial body weight (Kg)	7.57^{a}	7.86^{ab}	9.00^{b}	7.86^{ab}	0.42
Final body weight (Kg)	8.35^{a}	8.68^{ab}	10.00^{b}	9.64^{ab}	0.50
Average Weight Gain (g/animal/day)	1.60^{a}	1.89^{a}	2.04^{a}	3.64^{b}	0.54
Feed Conversion Ratio	2.66	2.36	2.09	1.54	0.53

^{abc} means on the same row with different superscripts are significantly different ($p<0.05$)
NDF-Neutral Detergent Fibre
ADF- Acid Detergent Fibre
ADL- Acid Detergent Lignin

Table 3: Apparent Digestibility Co-Efficient of West African Dwarf Goat fed Bio-Chemically treated *Jatropha curcas* Kernel Cake

Digestibility (%)	Diet A	Diet B	Diet C	Diet D	±SEM
Dry matter	97.07^{a}	97.25^{b}	97.11^{a}	97.81^{c}	0.02
Crude Protein	82.64^{a}	82.81^{a}	82.13^{a}	86.91^{b}	0.23
Crude fibre	94.65^{b}	94.23^{a}	94.98^{c}	95.25^{d}	0.03
Ether Extract	91.10^{a}	92.89^{b}	93.57^{c}	94.07^{d}	0.06
Neutral detergent fibre	87.40^{a}	87.54^{a}	89.11^{b}	92.40^{c}	0.06
Acid detergent fibre	86.62^{a}	90.15^{b}	90.61^{b}	92.61^{c}	0.17
Acid detergent lignin	84.60^{a}	86.96^{c}	86.03^{b}	89.51^{d}	0.10
Hemicellulose	89.53^{a}	91.96^{b}	91.74^{b}	93.27^{c}	0.11
Cellulose	82.19^{a}	86.09^{b}	87.00^{c}	90.64^{d}	0.11

^{abc} means on the same row with different superscripts are significantly different ($p<0.05$

Table 4. Digestible Nutrient Intake of West African Dwarf Goat fed Bio-Chemically Treated *Jatropha curcas* Kernel cake

Parameters (g/d)	Diet A (Control)	Diet B	Diet C	Diet D	±SEM
DDMI	1989.90^{a}	2131.80^{c}	2029.80^{b}	2690^{d}	11.45
DCPI	186.58^{a}	202.39^{b}	196.96^{ab}	274.62^{c}	3.75
DCFI	473.27^{b}	475.84^{b}	458.29^{a}	606.36^{c}	2.82

DEEI	178.13^{a}	256.62^{b}	257.39^{b}	332.58^{c}	1.82
DNDFI	292.04^{a}	288.11^{a}	349.11^{b}	525.88^{c}	1.46
DADFI	690.36^{a}	794.60^{b}	871.13^{c}	1201.00^{d}	5.62
DADLI	459.60^{a}	545.20^{b}	525.03^{c}	736.00^{d}	3.22
DHMI	389.30^{a}	523.91^{b}	519.65^{b}	669.50^{c}	2.94
DCLLI	193.73^{a}	252.86^{b}	285.48^{c}	418.78^{d}	1.56

^{abc} means on the same row with different superscripts are significantly different (p<0.05)
DDMI=DIGESTIBLE DRY MATTER NUTRIENT INTAKE
DCPI=DIGESTIBLE CRUDE PROTEIN INTAKE
DCFI=DIGESTIBLE CRUDE FIBRE INTAKE
DEEI=DIGESTIBLE ETHER EXTRACT INTAKE
DNDFI- DIGESTIBLE NEUTRAL DETERGENT FIBRE INTAKE
DADFI- DIGESTIBLE ACID DETERGENT FIBRE INTAKE
DADLI- DIGESTIBLE ACID DETERGENT LIGNIN INTAKE
DHMI- DIGESTIBLE HEMICELLULOSE INTAKE
DCLLI- DIGESTIBLE CELLULOSE INTAKE

Discussion

The nutrient intakes observed in this study could be a reflection of the relative acceptability and palatability of the diets (Asaolu *et al.,* 2012: Okoruwa, 2019: Saka *et al.,*2020) as a result of the inclusion of fermented *Jatropha curcas* cake in the diet of WAD goats. The intake could also be due to the adequacy of the crude protein level in the diet which was above the critical protein level (7%) below which the intake of ruminants may be lowered (Gurung, 2020; Rongfeng *et al.*, 2023). The dry matter intake noted in this study is in agreement with the values reported by Castillo-caamal *et al.* (2003); Ahamefule (2005); Ukpabi (2007); Belewu and Ogunsola (2010); Odoemelam (2015) who fed leguminous seed cakes to WAD goats. The DMI was also within the range reported by Asaolu *et al.* (2012) and Ukanwoko *et al.* (2009) who fed cassava-based diets to WAD goats. The treated cake in this study had a chocolate flavour that could have added to the high acceptability of the diet that contained the cake by the WAD goats; this was in line with the report of Shakumtal and Shadaksha (2012; Ikyume *et al.,* 2018) that fermentation produces flavour and textural changes making fermented food more nutritious. The crude protein level of the diets was higher than the critical protein level requirements (7%) of goats, hence it supported the microbial fermentation in the rumen thereby enhancing intake (Rongfeng *et al.,* 2023). *Idan et al*., (2020) describes feed intake as a measure of diet appreciation, selection and consumption by animals. The increased DMI (p<0.05) observed could also be due to the increased CPI, as *Saro et al.,* (2020) reported a positive correlation between crude protein intake and dry matter intake.

The crude protein intake was a reflection of the crude protein content of the cake; this agreed with the reports of Asaolu *et al* (2012; Lee *et al.,*2020). It also agreed with the works of Belewu and Popoola (2007), Miszkikiewics *et al*. (2004) and Regassa *et al.* (2022) who all reported a higher crude protein intake for animals fed fungus-treated feedstuffs.

The value obtained for ether extract intake could be due to the addition of fermented *Jatropha curcas* kernel cake in the diet of WAD goats as ether extract was observed to increase in the bio-chemically treated *Jatropha curcas* kernel cake. This is in line with the report of Ogunjemite and Ibhaze (2020 ; Ari *et al.* (2012), and Belewu and Fagbemi (2007) who reported improved ether extract intake for WAD goat fed fungus treated feedstuff.

The higher Crude fibre intake in the treatment groups was in line with the works of Omotoso et al., 2023*;* Belewu *et al.* (2007). This also showed that that there was effective chewing and a healthy ruminal function as a result of the high fibre content of the diet.

The NDF, ADF and ADL intake noted in this study could be as a result of the dry materials used in the formulation of the diets. Roger *et al.* (1996), Oni *et al.* (2006) and Akinyemi *et al.*, *(*2020) all reported that the use of dried materials affects the chemical composition leading to a higher intake of these fibre fractions. ADF and NDF intake are reported to be enhanced by including fermented feedstuff in a diet (Ettu and Onwuka, 2014; Sadeghi *et al.*, 2024). Cellulose and Hemicellulose intake depends on the level of intake of NDF, ADF and ADL, hence the factors that influence them also have a resonating effect on hemicelluloses and cellulose (Arigbede *et al.*, 2006; Oni *et al.,* 2006 and Demirgül and Öztürk (2021)).

The observed weight gain may be due to the ability of the WAD goats to efficiently utilize the diet for body weight gain. This was in line with the report of Shalu *et al* (2004) and Teixera *et al.*, (2024) that an efficient utilization of nutrients that provides energy and protein is required for growth in goats. The observed higher weight gain of the animals on bio-chemically treated *Jatropha curcas* kernel cake could be ascribed to the more efficient feed utilization by the animals as indicated by their low feed conversion ratios compared to the control, and this is in line with the reports of Belewu *et al.* (2003), Belewu and Fagbemi (2007) and Li *et al.*, 2015 for fungal treated shea butter cake, cassava and *Jatropha curcas* kernel meals respectively. It could also be due to the voluntary dry matter intake and the by-pass of the nutrients from the rumen resulting in digestion and absorption in the abomasum and duodenum (Otukoya and Babayemi, 2007; Thakur *et al.*, 2024). The animals did not show any signs of Jatropha toxicity during the duration of the experiment, this may be due to the reduction to tolerable levels of phorbol ester as a result of the bio-chemical treatment. Devappa *et al* (2012) reported a reduction in phorbol ester as a result of the oxidative properties of hydrogen peroxide, as phorbol ester is highly susceptible to oxidative degeneration. Furthermore, *Penicillium expansum* secretes the enzyme esterase (Donaghy and Mckay, 1996) which may have helped in reducing the phorbol ester to a tolerable level, hence the acceptability of the feed. The Solid-state fermentation can also act as an oxidative sink for hydroxyl radicals generated during oxidative degradation, potentially reducing the extent of oxidation in the cake. This corroborates the assertion of Zhao *et al.,* 2021 that fermentation affects antioxidants activities in plant based food materials. The high digestibilities observed in this study is in line with the findings of Bhat *et al.* (1996), Jaquelin *et al.* (1996) Xu *et al. (*2022), this could be due to the reduction to below tolerable level of the anti-nutrients in the Jatropha kernel cake. This confirms the assertions of Belewu *et al.* (2010) and Xu *et al. (*2022) that, reduction in levels of anti-nutrients improves digestibility. The improvement in the dry matter digestibility across the treatment agreed with the observations of Belewu and Adeniyi (2001); Belewu and Ogunsola (2010). The reduced level of tannin in the treated samples could be the reason why the intake and nutrient digestibility of goats on the treated samples were higher than that obtainable for the control. Also, the Saponin reduction in the diet with treated cake samples could have helped in the uptake of nutrients by the animals, as saponin (Ali, 2011) was reported to reduce the uptake of some essential nutrients.

The crude protein digestibility observed in the Treatments could be due to the ability of the *Pennicillum expansum*/hydrogen peroxide treatment to detoxify the *Jatropha curcas* kernel cake. Arigbede *et al. (*2006), Belewu and Ogunsola (2010) Ajomiwe *et al.,* (2024) and Shokri and Jarpa-parra (2025) reported that protein supplementation enhanced digestibility. The crude protein digestibility recorded by animals in this study could also be due to the reduction in the phytate content, as phytate is known to form complexes with protein making it unavailable (Kumar and Singha, 2018). This report agreed with the reports of FAO (1990) that phytate forms a complex with protein thereby inhibiting its digestion. The increase in the digestibility and intake obtained in this study were directly proportional, and this agreed with the submissions of Anil *et al.* (1993); Provenza (1995); Cho *et al.* (2007) and Kim *et al*. (2007) that improvement in the nutrient digestibility of animals could be due to the feeding of fermented feedstuff in their diets. The fermentation process could have conferred a by-pass status on the cake hence making it escape ruminal degradation and available only in the abomasum and small intestine for digestion and absorption (Calvo-lerma *et al.*, 2022). Makkar *et al.* (1997), Alatise *et al.,* (2014) and Yinuo *et al.*, (2018) all reported that *Jatropha curcas* cake has a significant amount of by-pass protein which will be available to the animals post-rumen.

The high crude fibre digestibility values also suggest that the diets were highly degraded in the rumen. This was similar to the results of Eniolorunda *et al*. (2008) who suggest that high digestibility of crude fibre fractions clearly show the ability of ruminants to utilize structural carbohydrates, for nutritional benefits. It also supports the findings of Akinfemi *et al.* (2009) and Takizawa *et al., (*2023) suggests an increase in the activities of fibrolytic microbes as a result of the available nutrients (protein, energy and minerals) proportions that enhance their growth and multiplication. The results of the digestible nutrient intake observed in this study could be due to a drastic reduction to tolerable levels of the anti-nutrients and toxins in the cake, and it could also be due to the addition of fermented cake in the diets of the animals. This was in line with the works of Oboh and Akindahunsi (2003) and Emmanuel *et al.*, (2024) that the fermentation of cassava peels enhanced protein digestibility and crude protein content. The higher digestible nutrient intake observed in the treatment groups could also be attributed to the high crude protein intake, when compared to the control and this was in line with the assertion of Bello and Tsado, (2013).

The similar trend between weight gain and the feed conversion ratio can be attributed to the influence of better nutrient density and quality of nutrients available for utilization. This is similar to the reports of Asaolu *et al.* (2012), Gaillard *et al.*, (2020)

Conclusion

The inclusion of bio-chemically treated *Jatropha curcas* kernel cake in the diet of WAD goats showed encouraging results in the intake and digestibility of the animals. It can be concluded that the treatment was effective in reducing the phorbol ester level to tolerable levels making *Jatropha curcas* kernel cake an alternative protein source in the diet of WAD goats. It also helped the utilization of the experimental diet weight gain.

References

Ahamefule, F. O. 2005. Evaluation of Pigeon Pea-cassava Peel Based Diets for Goat Production in South Eastern Nigeria. Ph.D dissertation. Michael Okpara University of Agriculture Umudike, Nigeria.

Ajomiwe, N, Boland, M, Phongthai, S, Bagiyal, M, Singh, J, Kau,r L. 2024. Protein Nutrition: Understanding Structure, Digestibility, and Bioavailability for Optimal Health. Foods. 2024 Jun 5;13(11):1771.

Akinfemi, A, Adu, O. A. and Doherty, F. 2009. Assesment of the Nutritive Value of Fungi Treated Maize Cob using *In vitro* Production Technique. *Livestock Research for Rural Development,* 21(11).

Akinyemi, B. T. Babatunde, M. O. Alli, J. A. Ogunsanya, O. A. Jolaosho, A. O. Arigbede, O. M. and Adelusi, O. O. 2020. The effect of drying methods on the chemical composition and in-vitro digestibility of some browse plants. *Nigerian Journal of Aniimal Production*., 47(2):271 – 279.

Alatise, S. P. Adedokun, M. A. Adelodun, O. B. and Ajiboye, G. E. 2014. Effects of Boiled Jatropha Kernel Meal as a Substitue for Soyabeans Meal in Diet of African Mud Catfish (*Clarias gariepinus*) Fingerlings. *Journal of Fisheries and Aquatic Science, 9: 446-454.*

Alemede, I. C. Adama, J. Y. Ogunbajo, S. A. and Abdullahi J. 2010. Haematological Parameters of Savanna Brown Does Fed Varying Dietary Levels of Flamboyant Tree Seed Meal. *Pakistan J Nut*, 9 (2): 167-170.

Ali, A. 2011. Major Anti-nutrients and Phytochemical Investigation Found in an Iranian Edible Plant Source. *J. Nat. Prod. Plant Resource*, 1 (2): 56-61.

Anil, M. H. Mbanya, J. N. Symonds, H. W. and Forbes, J. M. 1993. Responses in the Voluntary Intake of Hay or Silage by Lactating Cows to Intraruminal Infusions of Sodium Acetate or Sodium

Propionate, the Tonicity of Rumen Distensions. *Brit J. Nutr*, 69:699-712.

AOAC. 1990. Official Methods of Analysis Association of Official Analytical Chemists. 15th Edition. Washington D.C pp1094.

Ari, M. M. Ayanwale, B. A, Adama, T. Z. and Olatunji, E. A. 2012. Effects of Different Fermentation Methods on the Proximate Composition, Amino acid profile and some Antinutritional Factors (ANFs) in Soyabean (*Glycine max*). *Fermentation Technology and Bioengineering*, 2:6-13.

Arigbede, O. M. Anele, U. Y., Olanite, J. A. Adekunle, I. O, Jolaoso, O. A. and Onifade, O. S. 2006. Seasonal Degradability of Dry Matter, Organic Matter and Crude Protein in Some Multipurpose Tree Species by WAD Goats. Proc. 27th Ann. Conf.Nig.Soc for Anim. Prod, pp191-194.

Asaolu, V. Binuomote, R. Akinlade, J. Aderinola, O. Oyelami, O. 2012. Intake and Growth Performance of West African Dwarf Goats Fed *Moringa oleifera*, *Gliricidia sepium* and *Leucaena leucocephala* Dried Leaves as Supplements to Cassava Peels. *Journal of Biology, Agriculture and Healthcare* www.iiste.org ISSN 2224-3208 (Paper) ISSN 2225-093X (Online) Vol 2, No.10.

Belewu, M. A. 2008. Replacement of Fungus Treated *Jatropha curcas* Kernel Meal for Soyabean Meal in the Diet of Rats. *Green farming*, 2(3): 154-157.

Belewu, M. A. and Fagbemi, O. O. 2007. Performance Characteristics of West African Dwarf Goat fed Aspergillus Treated Cassava (*Manihot esculentus*) Waste Based Diets. *American-Eurasian J.Agric & Environ*. Sci, 2(3):268-270.

Belewu, M. A. and Adeniyi, A. O. 2001. Apparent Digestibility of Solid State Fermentation of Cotton Waste with Fungus (*Pleurotus sajor caju*) Using West African Dwarf Goats. *NISEB*, 1(2):123-128.

Belewu. M. A. and Ogunsola, F. O. 2010. Haematological and Serum Indices of Goat fed Fungi Treated *Jatropha curcas* Kernel Cake in a Mixed Ration. *Journal of Agricultural Biotechnology and Sustainable Development*, 2(3):035–038.

Belewu, M. A. and Popoola, M. A. 2007. Performance Characteristics of West African Dwarf Goats fed Rhizopus Treated Sawdust. *Scientific Research and Essay*, 2(9): 496-498.

Belewu, M. A. Yousuf, M. B. Afolabi, E. O. 2003. Nutritional Evaluation of Graded Levels of Aspergillus Treated Rice Husk on the Performance Characteristics of Pregnant WAD goats. *Int. J. Agric. S Rural Dev.* 4:87-91.

Belewu, M. A. Fagbemi, T, Olatunde, B. J. and Otonekwo, I.P. 2007. Replacement Value of *Etanda africana* Seed Meal for Soyabean Meal in the Diet of Growing West African Dwarf Goats. *African. J. Agricultural Research*, 2(10):555-557.

Belewu, M. A. Belewu, K. Y. and Ogunsola, F. O. 2010. Nutritive Value of Dietary Fungi Treated *Jatropha curcas* Kernel Cake: Voluntary intake, growth and digestibility co-efficient of goat. *Agric.Biology Journal of North America*, 1(2):135-138.

Bello, A. A. and Tsado, D. N. 2013. Feed Intake and Nutrient Digestibility of Growing Yankasa Rams fed Sorghum Stover Supplemented with Graded Levels of Dried Poultry Droppings Based Diets. *Asian Journal of Animal Science*, 7(2):56-63.

Bhat, T. K Makkar H. P. S. and Singh. B. 1996. Isolation of Tannin Protein Complex Degrading Fungus from Faeces of Hill Cattle. Lett. *Appl.Microb*. 22: 257-258.

Calvo-Lerma, J. Asensio-Grau, A. García-Hernández, J. Heredia, A. Andrés, A. 2022. Exploring the Impact of Solid-State Fermentation on Macronutrient Profile and Digestibility in Chia (*Salvia hispanica*) and Sesame (*Sesamum Indicum*) Seeds. *Foods 11*(3), 410;2022,

Castillo-caamal, J. B, Jimenez-Osomio, J J. Lopez-perez, A, Aguilar-cordero, W. and Castillo-caamal, A .M. 2003. Feeding *Mucuna* beans to small ruminants of Mayan farmers in the

Yucaten peninsula, Mexico. Tropical and sub tropical Agroecosystem. 1:113-117.

Cho, J. H. Min, B. J.. Chen, Y. J.. Yoo, J. S. Wang, Q. Kim, J. D. and Kim, I. H. 2007. Evaluation of FSP (fermented soy protein) to Replace Soyabean Meal in Wean(ed Pigs: Growth Performance, Blood Urea Nitrogen and Total Protein Concentrations in Serum and Nutrient Digestibility. *Asian-Aust. J. Anim. Sci*, 20:1874-187.

De Barros, C. R. Luis Miguel, M. F. Fraga, I. Mourao, J.. and Rodrigues, M. A. 2024. Detoxification Methods of *Jatropha curcas* Seed Cake and its Potential Utilization as Animal Feed.Fermentation. 10(510050256).

Demirgül, K. and Öztürk, E. 2021. Changes in Nutrients, Energy, Antioxidant and Carotenoid Levels of Dried Tomato (Lycopersicon esculentum) Pomage Treated with Aspergillus niger Solid-State FermentationTurkish Journal of Agriculture - Food Science and Technology, 9(4): 701-708, 2021

Devappa, R, Nitayavardhana, S. and Khanal, S. K. 2012. Detoxification of Jatropha Seed Meal for Animal Feed Applications. *Journal of Agriculture and Food Chemistry. Manuscript.*

Donaghy, J. and Mckay, A. M. 1996. Purification and Characterization of a Feruloyl Esterase from the Fungus *Penicillum expansum. Journal of Applied Microbiology*, 83:713-726.

Emmanuel, S. S. Odunlade, T. A. and Zubair, I. J. 2024. Nutritive value of fermented cassava peel meal on growth performance and nutrient digestibility of broiler chickens. International Journal of Multidisciplinary Research and Growth Evaluation. 5(3) 839-843

Eniolorunda, O. O. Jinadu, O. A. Ogungbesan, M. S. A. and Bawala, T. O. 2008. Effects of Combined Levels of *P.maximum* and *Gliricidia sepium* on Nutrient Digestibilities and Utilization of WAD Goats fed Cassava Offals Based Concentrate. *Research Journal of Animal Science*, 2(5):149-153.

Ettu, R. O. and Onwuka, C. F. I. 2014. Mineral and Fibre Intake West African Dwarf Sheep Fed Boiled Cocoa Seed Testa and Sorghum Malt Dustin Cassava Root Meal Based Diet. *Nigerian Journal of Animal Production. Pp147-154.*

FAO. 1990. "Roots, Tubers, Plantains, and Bananas in Human Nutrition". FAO Corporate Document Repository: Rome, Italy. FAO FOOD AND NUTRITION No 24.

Gaillard, C. Brossard, L, and Dourmad, J. 2020. Review articleImprovement of feed and nutrient efficiency in pig production through precision feeding. Animal Feed Science and Technology.Volume 268. , 11461

Gurung, N. 2020. Nutritional Requirements of different Types of Meat Goats.. Professional Agricultural workers Journal . Vol 63(10).

Idan, F.Adogla-Bessa, T. and Amarning-Kwarteng, K. 2020. Prefernce, Voluntary Feed Intake and Digestibility of Sheep fed Untreated Rice Straw and Supplemented with Sole or Combined Fodder Tree Leaves. European Journal of Agriculture and Food Sciences 2(4) 89.

Ikyume,T. T.. Eigege, N. K. B asi, D.T.Oche, N. P. Abdulraheem, A. I. Ojabo, M and Akalika, I.P. 2018. Growth Performance, Blood Profile and Economics of Production of West African Dwarf Goats fed Fermented Baobab (*Andasonia digitata*) seed meal..Journal of animal Husbandry and Dairy Science. Volume 2 Issue 1 pp 30-36.

Jacqueline, E.W. Broerse and Visser, B. 1996. Assessing the Potential: In Biotechnology Building on Farmer's Knowledge. Edited by Joske Bunders Bertus Haverkort, WIM Hiermstra Published by Macmillian Education Ltd.. London and Basingstoke.

Kim, Y. G. Lohakare, J. D. Yun, J. H. Heo, S. and Chae, B. J. 2007. Effect of Feeding Levels of Microbial Fermented Soy Protein on the Growth Performance, Nutrient Digestibility and Intestinal Morphology in Weaned Piglets. *Asian-*

Aust. J. Anim. Sci, 20:399-404.

Kumar, V. and Sinha, V. 2008. Enzymes in Human and Animal Nutrition.Chapter three Pages 53-72.

Lee, Y. H. Ahmadi, F. Lee, M. Oh, Y. Kwak, W. S. 2020. Effect of Crude Protein Content and Undegraded intake Protein level on Productivity, Blood Metabolites, Carcass Characteristics and Production economics of Hanwoo Steers.Asian-Australas Journal of Animal Science25;33 (30): **1599-1609.**

Li, Y. Chen, L. Lin, Y. Fang, Z. F. Che, L.Q. Xu, X. Y. Wu, D. 2015. Effects of replacing soybean meal with detoxified *Jatropha curcas* kernel meal in the diet on growth performance and histopathological parameters of growing pigs. Animal Feed Science and Technology Volume 204, June 2015, Pages 18-27

Makkar, H. P. S and Becker, K. 1997a. *Jatropha curcas* Toxicity: Identification of Toxic Principle. In the 9th Int'l Symposium on Poisonous Plants. May 9th -23rd: San Angelo, Texas USA.

Makkar, H. P. S. Becker, K. Sporer, F. and Wink, M. 1997. Studies on Nutritive Potentials and Toxic Constituents of Different Provenances of *Jatropha curcas*. *J.Agric. Food. Chem*, 45:3152-3157.

Masafu, M. M. 2006. The Evaluation of *Leucaena leucocephala* (Lam) DE WIT: A Renewable Protein Supplement for Low Quality Forages. Ph.D. Thesis, University of South Africa.

Miszkiewics, H. Bizukoje, M. Rozwandewicz, A. and Bielecki, S. 2004. Physiological properties and enzymatic activities of Rhizopus oligosporus in solid state fermentations. Elect. *J. Polish Agric. Uni. (Biotechnology series).* 7: 1-6.

Mtega, L. and Shoo, R . 1990. Growth Rate, Feed Intake and Feed Utilization of Small East African Goats Supplemented with *Leucaena leucocephala*. *Small Ruminant Research,* 3:9–18.

Oboh, G. and Akindahunsi, A. A. 2003. Chemical Changes in Cassava peels Fermented with Mixed Culture of *Aspergillus niger* and Two Species of *Lactobacillus Integrated* Bio System. *Appl. Trop. Agric*, 8: 63-68.

Odoemelam, V. U. Ahiwe, E. U. Ekwe, C. C Obikaonu, H. O. and Obi, J. I. 2015. Dry Matter Intake, Nutrient Digestibility and Nitrogen Balance of West AFRICAN Dwarf (WAD) Bucks fed *Panicum maximum* Supplemented Concentrate containing Bambara Nut (*Vigna subterranea*) Meal. *Nigerian Journal of Agriculture, Food and Environment.* 11(2):59-65.

Ogunjemite, G. E. and Ibhaze, G. A. 2020. Performance of West African Dwarf Goats fed Microbial treated maize Cob and Husk Diets. *Animal Research International*. 17(3)3799-3808.

Okoruwa, M. I. 2019. Feed Intake, Relative Preference Index, Rumen Digestion Kinetics, Nutrient Digestibility and Liveweight Change of Goats fed Selected Browses. *Livestock Research for Rural Development* 31(4) 2019.

Omotoso, O. B. Rafiu, M. O. and Oso, T. S. 2023. Crude Protein Intake and Growth Performance of West African Dwarf Goats fed Cassava Peels substituted with Cowpea Haulms. *Livestock Research for Rural Development.* 35(8)

Oni, A. O. Onwuka, C. F. I. Oduguwa, O. O. Onifade, O. S. Arigbede, O. M. Oni, O. O. and Anele ,U. Y. 2006. Nutrient Intake and Digestibility by WAD Goats Fed *Enterobolium cyclocarpum* (Jacq.) Griseb Basal Diet and Citrus Pulp-Based Diets. *Journal of Animal and Veterinary Advances 5(10):828-831.*

Otukoya, F. A. and Babayemi, O. J. 2007. Intake, Growth and Digestibility of *Albizia saman* Pod by the West African Dwarf Goats. *Trop. J. Anim. Science*, 10(1-2):469-473.

Pauzenga, U. 1985 Feeding Parent Stock. Zoo Technical International, pp 22-24.

Provenza, F. D. 1995. Postingestive Feedback as an Elementary Determinant of Food Preference Intake in Ruminants. *J.Range Manage*, 48:2-17.

Regassa, B. R. Mengistu, U. L. Tegene, N. A. Getachew, A. M. 2022. Intake, Digestibility, Growth Performance and Blood profile of Rams fed Sugarcane bagasse or Rice Husk Treated with *Trichiderma viride* and effective microorganisms.Heliyon Volume 8 Issue 12.

Roger, C. M. Pond, K. R. Burns, J. C. and Fisher, D. S. 1996. Condensed Tannin in *Calliandra calothyius* and their Effects on Feeding Value. In Proceedings of a Workshop held in Bogor, Indonesia Forest, Farm and Community Tree Research Reports (Special Issue). *Winrock International, Morrilton, ArkansasUSA.* Pp 222-233.

Rongfeng, D. Xaoming, M. Renqing, D.. Chun, H. Yongfu, L. Xinyi, L. Xianoyong, Ma. Xianyun, W. Min, C, Xian, G. Jie, P. Ping, Y. and Chunian, L. 2023. Effects of Dietary Crude Protein levels in the concentrate supplement after grazing on rumen microbiota and metabolites by using metagenomics and metabolomics in Jersey-yak. Front Microbiol 14:1124917.

Sadeghi, K., Parnian-Khajehdizaj, F., Ganjkhanlou, M. 2024. Feeding biotreated rumen digesta affects nutrient digestion, ruminal fermentation, and blood parameters in calves. *Sci Rep* **14**, 31114 SAS® 2002. SAS User's Guide Statisyics. SAS Inc. Cary, North Carolina, 2002 Edition.

Shakumtal, M. N. and Shadaksharaswamy, M. 2012. Food, Facts and Principle. 3rd revised edn. pp441. New Age Intl Ltd Publisher.

Saro, C. Mateo, J. Caro, I. Carballo, D.E. Fernandez, M. Valdes, C. Bodas, R. Giraldez, F. J. 2020. Effect of Dietary Crude Protein on Animal Performance, Blood Biochemistry profile, Ruminal Fermentation parameters and Carcass and Meat quality of Heavy Fattening Assaf Lambs. Animals 10. 2117.

Shalu, T. Goetsch, A. L Luo, J. Nsahlai, I. V. Moore, J. E. Galyean, M. I, Owens, F. N. Ferrel, C. I .and Johnson, Z. B. 2004. Nutrient Requirements of Goats: Developed Equations, Other Considerations and Future Research to Improve Them. *Small Rumin Res*, 53:191 – 219.

Shokri, S. and Jarpa-Parra, M. 2025 Editorial: Advancements in protein modification for enhanced digestibility. *Front. Nutr*. 12:1603394. doi: 10.3389/fnut.2025.1603394

S**hrestha, K. Ghimire, J. R. and Gewali, M. B. 2013**. Biodesiel Production from *Jatropha curcas* (L) of Nepal by Transesterification Process. IJPCBS (2013 3(3; 603-609).

Takizawa1, S. Asano, R. Abe, K. Fukuda, Y. Baba, Y. Sakurai, R. Tada1, C. and Nakai, Y. 2023. Relationship Between Rumen Microbial Composition and Fibrolytic Isozyme Activity During the Biodegradation of Rice Straw Powder Using Rumen Fluid. Microbes Environment. 38(3), 2023

Teixeira, I. A. Härter, C. J. Vargas[c], J. A. Souza, A. P. Fernandes, M. H. 2024. Review: Update of Nutritional Requirments of Goats for Growth and Pregnancy in Hot Environments. Animal The *International Journal of Biosciences* 18

T**hakur, S. Dey, A and Kumar, S. 2024.** Rumen bypass protein: An effective technology for enhancing performance of ruminants. *Indian J Anim Health (2024),* 63(2)-Special Issue: 43-52

Trabi, M, Gubitz, G. M. Steiner, W. and Foidi, N. 1997. Toxicity of *Jatropha curcas* seed. Proceedings Jatropha 97. Managua, Nicaragua. Feb 23-27.

Ukanwoko, A. I. Ahamefule, F. O. and Ukachukwu, S. N. 2009. Nutrient Intake and Digestibility of West African Dwarf Bucks Fed Cassava Peel-Cassava Leaf Meal Based Diets in South Eastern Nigeria. *Pakistan Journal of Nutrition, 8: 983-987.*

Ukpabi, U. H. 2007. Evaluation of *Mucuna* seed meal based diets for goat production in south eastern Nigeria. PhD dissertation. Michael Okpara University of Agriculture Umudike, Nigeria.

Wink, M. 1993. Production and Application of Phytochemicals from an Agricultural Perspective. In: "Phytochemistry and

Agriculture" (T.A. van Beek, H. Breteler, eds.), *Proc. Phytochem. Soc. Europe*, 34:171-213, Oxford University Press, 1993.

Xu1, R. Kiariel, E. G. Yiannikouris, A. Sun, L. and Karrow, N. A. 2022. Nutritional impact of mycotoxins in food animal production and strategies for mitigation. Xu et al. *Journal of Animal Science and Biotechnology* 13:69

Yinuo, Z. Yuboo, W. Haifeng.W. Yuerning,W., Harinder, P. W. and Jianxin, L. 2018. Nutritional value of detoxified *Jatropha curcas* cake protein isolates using rats as an animal model. *Animal Nutrition*. 4(2018) 429-434

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