

PHOSPHORUS UTILIZATION EFFICIENCY IN WEST AFRICAN DWARF (WAD) GOATS: EVALUATING GROUNDNUT CAKE, DRIED ACTIVATED SEWAGE SLUDGE, AND POULTRY WASTE BASED DIETS

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Abstract

This study was carried out to evaluate phosphorus utilization efficiency in diets containing Groundnut Cake (GNC), Dried Activated Sewage Sludge (DASS), and Poultry Waste (PW) using eighteen West African Dwarf (WAD) goats. Phosphorus digestibility was assessed and it showed significant differences in utilization among diets. Digestibility coefficients for phosphorus were 56.46% (GNC), 51.06% (DASS), and 60.20% (PW). Statistical analysis showed significant differences ($P < 0.05$) in phosphorus intake and retention across the three diets, with PW demonstrating the highest phosphorus balance. These findings highlight the potential of alternative feed sources to enhance phosphorus nutrition in WAD goats while also supporting sustainable and cost-effective livestock management practices.

Keywords: Phosphorus Utilization, West African Dwarf Goats, Groundnut Cake, Dried Activated Sewage Sludge, Poultry Waste.

INTRODUCTION

West African Dwarf (WAD) goats are an essential part of food security and economic stability in West Africa. These goats are commonly raised by smallholder farmers for their meat, milk, and manure, making them a vital component of the region's agricultural landscape. However, one of the biggest challenges in raising WAD goats is ensuring they receive adequate nutrition, especially during the dry season when natural forage is scarce and of poor quality. Traditionally, groundnut cake has been a popular protein source for ruminants due to its high crude protein content, supporting strong growth and development. However, groundnut cake is expensive and competes with human food production, making it an unsustainable option for small-scale farmers. Given the high cost of conventional protein sources, there is a pressing need to explore alternative feed ingredients that are both cost-effective and beneficial to livestock health.

A key concern for WAD goat farmers is phosphorus deficiency, which can hinder growth, reproduction, and overall animal health. Phosphorus plays a critical role in metabolism, bone development, and cellular function. Without enough phosphorus, goats can suffer from poor skeletal development, reduced fertility, and general ill health. Addressing this nutritional gap requires finding affordable, phosphorus-rich feed sources that align with sustainable farming practices. Several alternative feed sources have been suggested as substitutes for groundnut cake, including poultry waste and dried activated sewage sludge (DASS).

Poultry waste, when properly processed, is rich in essential minerals and can significantly improve growth performance in ruminants. Similarly, DASS, a recycled agro-industrial by-product, provides a sustainable source of phosphorus. However, the bioavailability of nutrients in these alternative sources varies, requiring careful evaluation to determine their effectiveness in supporting animal health and productivity.

Despite the potential benefits of using poultry waste and DASS in WAD goat diets, there is limited research comparing their phosphorus efficiency to that of groundnut cake. There is a lack of comprehensive studies examining the long-term effects of these alternative phosphorus sources on goat growth, reproductive health, and overall productivity. Bridging this research gap is crucial for developing optimized feeding strategies that enhance both animal well-being and farm sustainability.

Recognizing the importance of phosphorus in WAD goat nutrition, this study aims to compare the efficiency of dried activated sewage sludge and poultry waste as replacements for groundnut cake. The research will focus on phosphorus digestibility, balance, and the practical implications of these alternative feed sources for livestock management. By identifying sustainable and cost-effective feeding strategies, this study will contribute to improving the productivity and profitability of WAD goat farming, benefiting smallholder farmers and the broader agricultural sector.

MATERIALS AND METHODS

Experimental Site

The field study was carried out at the Teaching and Research Farm of the University of Ibadan, Ibadan.

Sourcing and Preparation of Test Ingredients

Dry Activated Sewage Sludge was sourced from the sewage treatment plant at University College Hospital (U.C.H.), Ibadan. Additionally, poultry waste (only droppings) for the experiment were collected from the layer unit at the Teaching and Research Farm of the University of Ibadan.

The poultry droppings were air-dried to reduce moisture content and prevent spoilage. Drying also helped in reducing pathogens, making the droppings safe for feeding. After drying, the droppings were grounded and incorporated into the goat's ration.

Diet Formulation

Three isonitrogenous diets (14%) were prepared: Diet I consisted of a basal diet supplemented with a concentrate ration made up of groundnut cake (GNC); Diet II consisted of a basal diet supplemented with a concentrate ration made up of dried activated sewage sludge (DASS); and Diet III consisted of a basal diet supplemented with a concentrate ration incorporating poultry droppings (PD). The compositions of the experimental diets are provided in Table 1, ensuring uniformity in macronutrient ratios except for the phosphorus source.

Experimental Design

A 21-day feeding trial was conducted, consisting of a 14-day preliminary feeding period followed by a 7-day collection phase, to assess phosphorus utilization efficiency in diets containing Groundnut Cake, Dried Activated Sewage Sludge, and Poultry Droppings. The preliminary period was to allow the animal to adjust to the experimental diet.

The Feeding trial was carried out using 18 West African Dwarf (WAD) goats (6 males and 12 females) certified free from helminths and intestinal parasites were randomly assigned to the three different experimental diets in six replicates of one goat per replicate in a completely randomized design. The goats were housed in separate metabolism cages specifically designed for accurate measurement of food and water intake, separate collection of feces and urine, and a controlled environment to minimize feed contamination.

Each animal was fed daily with 1kg of the basal diet made up of giant Star grass (*Cynodon nlemfuensis*) plus 1kg of concentrate. They had free access to fresh and clean water daily. Feeds leftover from the previous day's ration were collected and weighed daily to estimate the feed intake by each animal. Each animal was weighed at the beginning and the end of the collection period.

DATA COLLECTION AND ANALYSIS

Faecal Collection

The feces of each animal were collected each morning during the 7-day collection period before feeding the animal its ration for the day. The feces collected daily from each animal during the collection period were weighed and dried in a forced-draught oven at 70°C to constant weight. The dried samples were bulked, and stored at room temperature. Dried feces were analyzed for phosphorus content using the Technicon AutoAnalyzer II following digestion with nitric and perchloric acids

Statistical Analysis

Data were analyzed using one-way ANOVA, with significant differences ($P < 0.05$) identified via post hoc comparisons (Steel & Torrie, 1960).

RESULTS

Table 1: Composition of Experimental Supplement Ration

Ingredients	Diet one	Diet Two	Diet Three
Cassava flour	49.5	37.0	32.5
Groundnut cake	25	-	-
Poultry Dropping	-	-	42
Dried Activated Sewage Sludge	-	37.5	-
Dried brewers' grain	25.0	25.0	25
Mineral Mixture	0.25	0.25	0.25
Salt	0.25	0.25	0.25

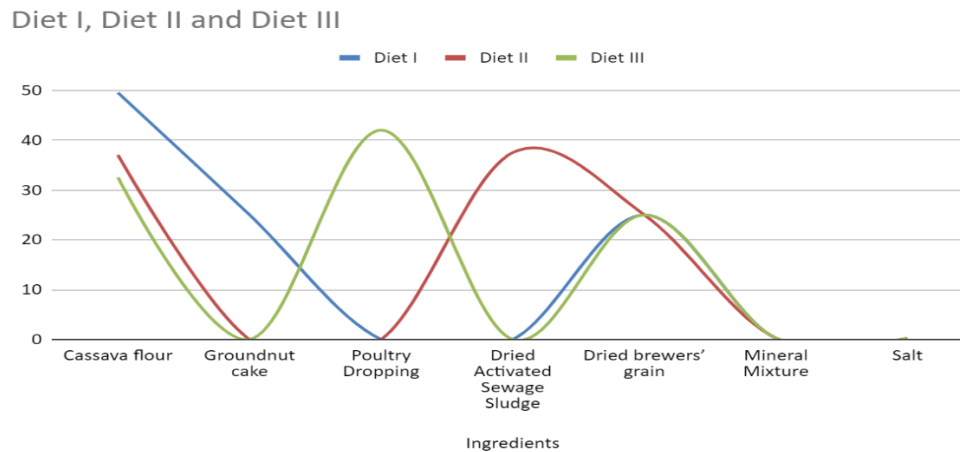


Fig 1: Composition of Experimental Supplement Ration

Table 1 and Figure 1 depicts the composition of the experimental supplement rations for the different diets. Diet I, which contains a high proportion of cassava flour (49.5%) and groundnut cake (25%), contrasts with Diet II, where groundnut cake is excluded and replaced by dried activated sewage sludge (37.5%), and Diet III, which includes poultry droppings (42%) as the primary ingredient for phosphorus. The consistency of dried brewers' grain (25%) across all diets, alongside the constant amounts of mineral mixture and salt, suggests that these ingredients may serve a stabilizing role across the diets.

Table 2: Nutrient Composition of The Diet

	Grass (<i>Cynodon nlemfuensis</i>)	Supplemental Ration			Dried Activated Sewage Sludge	Poultry Dropping
		I	II	III		
Dry Matter	62.1	94	97	98.3	94	90.5
Crude Protein	6.8	14.4	14.8	14.2	27.7	25.4
Crude Fibre	51.9	9.5	25.7	18.8	6.9	1.8
Ether Extract	1.5	2	2.5	3.5	4	20.8
Ash	5.0	6	33.5	8.5	40.0	20.3
Nitrogen Free Extract	34.9	63.3	23.5	50.6	15.2	22.2

Table 2 highlights significant variations in the nutrient profiles of the experimental diets. Diet III (PD) had the highest crude protein (14.2%) and ether extract (20.8%), while Diet I (GNC) exhibited a balanced composition with moderate protein (14.4%) and fiber (9.5%). DASS (Diet II) contained the highest ash content (33.5%), reflecting its mineral-rich nature and exhibited higher crude protein (14.8%).

Table 3: Apparent Digestibility of the Experimental Diet

Parameters	Diet I	Diet II	Diet III
Dry Matter Intake (g/goat)	664.91 ^a	388.78 ^a	606.39 ^a
Faecal Output	101.92 ^b	51.44 ^c	121.73 ^a
Digestibility Coefficient (%)	84.35 ^a	82.2 ^a	78.59 ^b

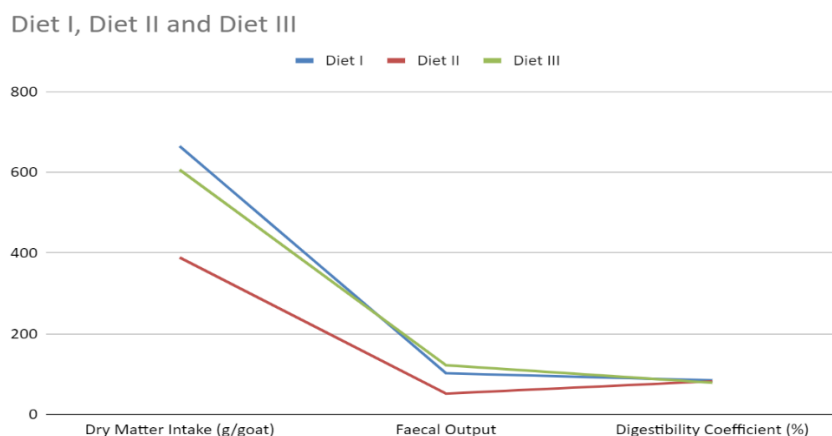


Fig 2: Apparent Digestibility of The Experimental Diet

Table 3 and Fig 2 show that Diet I and Diet III have significantly ($P>0.05$) higher DMI than Diet II while the Fecal Output for the goats fed the three different were significantly ($P<0.05$) different from each other. Diet III has the highest fecal output followed by Diet I and then Diet II. Digestibility coefficients for Diet I and Diet II were not significantly ($P>0.05$) different but were significantly ($P<0.05$) higher than that of the digestibility coefficient of Diet III.

Table 4: Phosphorus Utilization by WAD fed Groundnut Cake, Dried Activated Sewage Sludge, and Poultry Waste based diets

Parameters	Diet I	Diet II	Diet III
Phosphorus Intake (g)	1.768 ^a	1.320 ^a	2.361 ^b
Phosphorus in Feces (g)	0.812 ^a	0.403 ^a	1.065 ^b
Digestibility Coefficient (%)	56.46 ^a	51.06 ^a	60.20 ^b
Phosphorus Balance (g/day)	1.090 ^a	0.657 ^a	1.451 ^b
Phosphorus Balance (g/day/kgw ^{0.75})	0.275 ^a	0.158 ^a	0.395 ^b

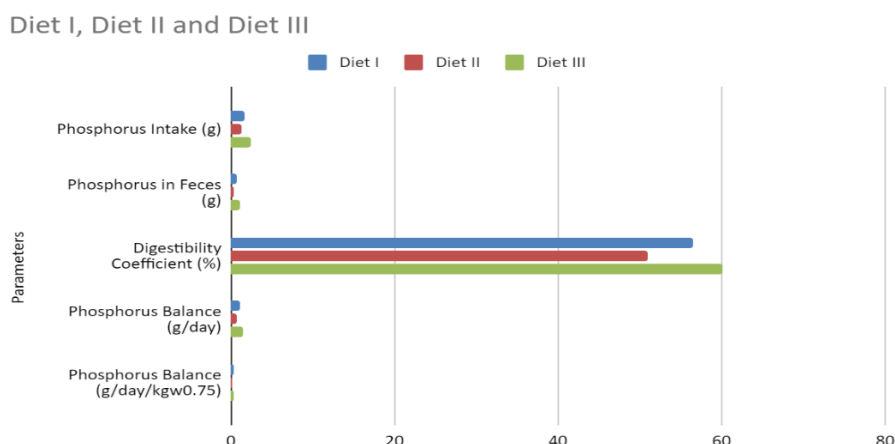


Fig 3: Phosphorus Utilization

Phosphorus Digestibility and Utilization

Table 4 and Fig. 3 summarizes phosphorus utilization metrics. Diet III exhibited the highest phosphorus intake (2.361 g/day) and digestibility coefficient (60.20%), translating into superior retention (1.451 g/day). Despite lower intake, Diet II showed efficient phosphorus absorption, evidenced by minimal fecal phosphorus output (0.403 g/day). Diet I balanced phosphorus intake and retention but underperformed compared to Diet III.

DISCUSSION

Nutrient Composition

The study revealed that diet composition significantly influenced phosphorus utilization in WAD goats. Diet III, rich in protein and phosphorus, demonstrated superior intake and retention, aligning with previous findings on the efficacy of processed poultry waste in livestock nutrition (Sarmiento-Franco et al., 2021). However, its high fecal phosphorus output suggests inefficiencies in digestibility, potentially due to indigestible phosphorus fractions.

The nutrient composition of the diets, particularly crude fiber and ether extract content, plays a significant role in phosphorus utilization efficiency. High crude fiber content, as seen in Diet I, can hinder nutrient absorption by increasing the rate of passage through the digestive tract, thereby reducing the time available for phosphorus absorption. On the other hand, diets with higher ether extract content, such as Diet III, may aid the absorption of fat-soluble nutrients, including certain forms of phosphorus.

However, excessive ether extract can also interfere with fiber digestion and overall nutrient balance. Therefore, balancing these components would enhance phosphorus utilization and overall diet efficiency.

Dry Matter Intake, Phosphorus Intake, and Absorption

Diet I recorded the highest dry matter intake (664.91 g/goat), followed closely by Diet III (606.39 g/goat), while Diet II had the lowest DMI (388.78 g/goat). Higher DMI leads to increased phosphorus intake, which can enhance absorption up to the point of the animal's physiological capacity. However, if the phosphorus in the diet is in a less bioavailable form, as in the case of groundnut cake, increased intake may not correspond to increased absorption, leading to higher fecal phosphorus excretion. Therefore, both the quantity of intake and the bioavailability of phosphorus sources are crucial determinants of phosphorus retention and utilization in goats.

Also the high DMI observed in Diet I could be attributed to the palatability and nutrient balance of the diet, which likely encouraged higher feed consumption. Similar results were reported by Njidda (2020), who found that diets with balanced nutrient content, especially protein and energy, significantly improve feed intake in ruminants. Diet III, while also having a relatively high DMI, could indicate a good acceptance of the poultry droppings included in the feed, which aligns with the findings of Fajemisin (2019), who observed that poultry waste can be palatable when adequately processed.

The low DMI in Diet II (Dried Activated Sewage Sludge) suggests a lower palatability or nutrient density, which might have led to reduced feed intake, as Obi et al. (2019) indicated that sewage sludge can have lower palatability and nutrient quality when compared to other protein-rich feeds.

Fecal Phosphorus Output

The presence of indigestible fractions in diet components significantly affects fecal phosphorus output and digestibility coefficients. In Diet III, while poultry waste provides highly bioavailable phosphorus, it may also contain indigestible components that contribute to higher fecal output. This is reflected in the higher fecal phosphorus observed in goats fed Diet III which corroborates the report by Adeoye et al. (2022), who found that poultry waste diets tend to increase fecal output due to their fiber composition and partially indigestible matter. The low fecal output observed for Diet II might reflect better nutrient absorption from the sewage sludge conforming with the report of Ajagbe and Aribido (2021) and Bravo et al. (2019) who reported that properly processed sewage sludge could enhance nutrient uptake and reduce waste. Diet I, while nutritionally balanced, was outperformed by Diet III, emphasizing the benefits of animal-based phosphorus sources over plant-based alternatives in promoting retention and absorption.

Digestibility Coefficient (%)

Diet III (PW) shows the highest phosphorus digestibility coefficient (60.20%), indicating better overall phosphorus utilization compared to the other diets. Diet I and Diet II have lower but relatively comparable digestibility coefficients of 56.46% and 51.06%, respectively. These values suggest that although Diet II (DASS) and Diet I (GNC) provide less phosphorus, their digestibility rates are still reasonable and aligned with the absorption capabilities of WAD goats. Poultry manure contains phosphorus that may be bound to organic compounds, explaining the slightly higher digestibility in Diet III, though it can vary based on waste composition (Bravo et al. 2019). Adegbaaju et al. (2020) reported similar trends, noting that phosphorus digestibility increased when microbial treatments enhanced the bioavailability of phosphorus in diets with waste components

Phosphorus Balance (g/day and g/day/kgw^{0.75})

Phosphorus balance represents the net phosphorus retained by the animal after accounting for intake and fecal output. Diet III demonstrates the highest phosphorus balance (1.451 g/day), suggesting that more phosphorus was absorbed and retained. Similarly, when adjusted for metabolic body weight (g/day/kgw^{0.75}), Diet III again has the highest balance (0.395 g), indicating more efficient phosphorus retention per unit of body weight. This higher retention can be linked to the larger intake of phosphorus in poultry waste, despite some inefficiencies in digestibility. This aligns with the findings of Okagbare & Akinsoyinu (2021), who observed higher nutrient retention in poultry waste-based diets compared to sewage sludge-based ones in WAD goats. Diet I and Diet II show lower phosphorus balances, reflecting their lower intake and digestibility rates. These trends align with previous findings, which suggest that phosphorus bioavailability varies with feed source and that plant-based phosphorus (in groundnut cake) may not be as readily available as animal-based phosphorus.

Implications and Conclusion

Efficient phosphorus utilization is important for the health and productivity of WAD goats. Adequate phosphorus intake supports skeletal development, energy metabolism, and reproductive performance. Diets that enhance phosphorus digestibility and balance, such as those incorporating bioavailable sources like poultry waste, can improve growth rates and milk production. DASS presents a sustainable alternative, though its lower intake may limit practical applications without enhanced processing methods. However, it is essential to balance phosphorus intake to prevent deficiencies, which can lead to poor growth and reproductive issues, or excesses, which can cause metabolic disorders and environmental concerns due to phosphorus excretion. Therefore, careful diet formulation and monitoring are necessary to ensure optimal health and productivity in WAD goats.

This study underscores the importance of considering both the bioavailability of phosphorus sources and the potential risks associated with alternative feed components. While poultry waste offers a highly bioavailable phosphorus source, attention must be given to processing and inclusion rates to mitigate health and environmental risks. Dried activated sewage sludge presents a sustainable option but requires thorough safety evaluations and palatability enhancements. Groundnut cake, though less bioavailable in phosphorus, remains a valuable protein source. Future research should focus on optimizing the use of these alternative feeds to enhance phosphorus utilization while ensuring the health and productivity of WAD goats.

In conclusion, Diet III (PW) demonstrated the highest phosphorus utilization efficiency, making it a promising option for improving WAD goat productivity. Further research should explore strategies to enhance the bioavailability of phosphorus in alternative feed ingredients to optimize their use in sustainable livestock systems.

Declaration Of Conflict of Interest: None

Declaration of Generative AI in Scientific Writing

During the preparation of this work, the author used ChatGPT to write up the research findings correctly avoiding grammatical errors. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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