Evaluation of the Nutritional Content of Abattoir Waste, Agro By-Products and their Bioavailability to Weaner Pigs.

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DOI: https://doi.org/10.51584/IJRIAS.2025.100900085

Received: 14 Aug 2025; Accepted: 20 Aug 2025; Published: 23 October 2025

ABSTRACT

This study evaluates the nutritional content and bioavailability of abattoir waste and agro-industrial by-products as alternative feed resources for weaner pigs. The experiment was conducted at the Swine Unit of the Teaching and Research Farm, Obafemi Awolowo University, Nigeria, using fifteen crossbred pigs (Large White x Hampshire) with an average initial weight of 10.00 kg. Five experimental diets were formulated, incorporating different combinations of rumen content, bovine blood meal, palm kernel cake, wheat offal, and brewers' dried grain, replacing groundnut cake (GNC) as the primary protein source. Results from proximate analysis revealed significant differences in the nutrient composition of the diets, including variations in dry matter, crude protein, crude fibre, ether extract, ash, and nitrogen-free extract. Apparent nutrient digestibility trials demonstrated that the alternative feed ingredients were efficiently utilized by the pigs, with the PKC-BBM-based diet showing the highest digestibility of dry matter and crude protein. These findings suggest that abattoir waste and agro-industrial by-products can be effectively used as alternative protein sources in swine nutrition, offering a sustainable and cost-effective solution to the high feed costs associated with conventional ingredients. The study highlights the potential for reducing environmental waste while improving the economic viability of pig production through the use of these non-traditional feed resources.

Keywords - Weaner pigs, Abattoir waste, Agro by-products, Nutritive content, Bioavailability

INTRODUCTION

Pigs (Sus scrofa) are monogastric animals that are versatile, resilient, polyestrous, and prolific. They can be raised under extensive, intensive, or semi-intensive management systems and are excellent feed-to-body weight converters with a high dressing percentage compared to other domestic animals. Pig farming is therefore a vital component of the global livestock industry, contributing to food security, employment, and income generation [1].

Feed, which accounts for up to 70% of total production costs, is the most critical determinant of pig productivity [2].

However, conventional feed ingredients such as maize and soybean are also used by humans and the feed industry, creating strong competition and driving up costs [3]. In Nigeria, the scarcity and high cost of these ingredients have become a major obstacle to the industry's growth, threatening farmers' profitability and even pushing some out of production [4]. This has serious implications for income generation, employment, and

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IX September 2025

food supply.

Protein is particularly important in animal diets. According to the World Health Organization, protein should account for 10–15% of daily calorie intake. To meet this demand in livestock production, researchers have increasingly focused on identifying alternative feedstuffs that can replace conventional ingredients without compromising performance [5]. Agro-industrial by-products not intended for human consumption offer a promising solution. Their use can reduce production costs, minimize food–feed competition, and improve sustainability in livestock production [6].

Such by-products include residues from fruit, vegetable, grain, legume, and oil processing [7]. Common examples are palm kernel cake (PKC), brewers' dried grain (BDG), and wheat offal. PKC, a co-product of palm oil extraction, contains about 15.73% crude protein and 58.53% total digestible nutrients, making it a useful protein and energy source [8]. With palm kernel oil processing yielding about 45% PKC, its supply is sustainable [9], although inclusion at high levels may reduce feed intake and growth performance in pigs. BDG, another by-product, is rich in crude protein (19–25%) and fiber (10–22%), though its nutrient composition varies with brewery source [10–13]. It also contains minerals, vitamins, and amino acids [15]. Similarly, wheat offal, a by-product of flour milling, is high in fiber and contains 14–17% crude protein [16]. Although its non-starch polysaccharides are poorly digested by monogastric animals, enzyme supplementation has been shown to improve utilization [17,18].

Abattoir by-products such as rumen content (RC) also have potential as livestock feed. Although often discarded as waste, rumen content is rich in energy, minerals, and B vitamins [19,20], and has been identified as a possible ingredient in pig diets [21]. Its utilization could reduce feed costs while addressing environmental pollution associated with abattoir waste disposal.

The high cost of conventional ingredients such as fish meal, groundnut cake, and soybean meal remains a major constraint in pig production. This forces farmers to underfeed animals, thereby limiting growth and productivity. Exploring alternative protein sources from agro by-products and abattoir wastes is therefore essential to reducing production costs, enhancing sustainability, and improving pork quality. This study aims to evaluate the nutrient composition and bioavailability of selected abattoir wastes and agro by-products in weaner pigs.

MATERIALS AND METHODS

Location of the Experiment

The experiment was conducted at the Swine Unit of the Teaching and Research Farm of the Faculty of Agriculture and Poultry Meat Laboratory of the Department of Animal Sciences; Obafemi Awolowo University, Ile-Ife, Nigeria.

Materials

Several materials were used in this study including: Weaner pigs, Palm kernel cake meal, Cattle Blood meal, Rumen Content, Salt, Brewer dried grain, wheat offal, Vitamin prefix, H_2SO_4, NaOH, H_2BO_3, HCL, Petroleum ether, Phenolphthalein indictor. Meanwhile, the tools used were trash bags, sample storage containers, shovels, latex, masks, disk mill machines, analytical scales, ovens, Muffle furnace, desiccators, Whatman 41 filter paper, oil paper, centrifuges, film tubes, Conway dishes, biuret, glass beaker, measuring pipette, micro burette, special distilled flask, destruction flask, scissors, blender, plastic tray, label, stove, and stationery.

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Preparation Stage

Bovine blood and Rumen content (RC) was collected from the AteridaAraromi Abattoir, along Ede Road, Olowe's Abattoir, lagere and Oriloye alias Titi Tunde slaughter slab, along Ibadan Road, campus gate. All the agro-industrial byproducts (BDG, PKC, and WO) were obtained from a reputable feed mill within Ile-Ife. Bovine blood was collected daily into a 10 litres keg containing predetermined amount of table salt to avoid coagulation. Using the protocol from [22], 18g of salt per Kg of blood was used. This quantity of salt provided enough time for the BDG, PKC and; WO to be added individually and hand mixed at ratio 1:1 with the collected bovine blood. For the RC, it was emptied into a woven sack and dewatered. The bovine blood-RC mixture was hand-mixed thoroughly using ratio 2:1. The mixtures were then sundried for 3 to 4 days under direct sunlight to about 10% moisture content. These were packed separately and stored for later use.

Management of Experimental Diet

Fifteen crossbred (Large White x Hampshire) pigs with average initial weight of 10.00 Kg were used for the experiment. The animals were randomly assigned to 5 experimental diets. There were 3 pigs per treatment and each of them served as replicate and was housed in a metabolism cage for a seven-day period. Before the commencement of the experiment, all animals were given antibiotics. Other routine management practices were strictly adhered to. Feed and water were supplied ad libitum to animals throughout the experiment. The first four days was for adaptation to the diets while the remaining three days was for faecal collection for the determination of nutrient bioavailability.

Experimental Diet

Five experimental diets were formulated to contain five different test ingredients at 99.5% inclusion level. Diet 1 contained 99.5% of Groundnut cake (GNC), while diet 2,3,4 & 5 contained 99.5% of Rumen content and blood meal (RC-BBM), Palm kernel Cake and blood meal (PKC-BBM), Wheat Offal and Blood meal (WO-BBM), and Brewer Dried Grain and Blood Meal (BDG-BBM) respectively (Table 1). Experimental diets were fed to the animals on treatment basis ad libitum. Water was also supplied ad libitum throughout the experimental period

Method and Research Design

The method used in this research includes research design, preparation stage, Feeding Trial and Digestibility Study, data collection and data analysis. A Completely Randomized Design (CRD) was employed for this study, involving 5 dietary treatments with 3 replications each, making a total of 15 weaner pigs (Large White × Hampshire crosses) with an average initial body weight of 10.00 kg.

Data Collection and Chemical Analysis

The last 3 days of the experiment were designated for total excreta collection. Feed intake was measured daily by subtracting feed refused from feed offered. excreta output was collected daily, weighed, and stored under refrigeration at 4°C. The analysis phase includes proximate analysis and Apparent nutrient digestibility of Agro by-products and abattoir waste by weaner pigs. Each diet was analyzed for proximate composition. The analysis for dry matter, crude protein, crude fibre, ether extract, Ash and Nitrogen free extract was done according to the method of [23] in the Laboratory.

The Apparent digestibility was determined using the proximate composition of the diets and excreta sample using the equation:

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IX September 2025

Apparent Nutrient Digestibility (%)

$$= \frac{(\text{Nutrient intake} - \text{Nutrient in faeces}) \times 100}{\text{Nutrient Intake}}$$

Data Analysis

Data were analysed using One-way Analysis of Variance (ANOVA) using the GLM procedure of [24] while means were separated using Duncan Multiple Range test at 5% significant level.

Table 1: Composition Of Diet Fed To Weaner Pigs

Ingredient	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
GNC (Groundnut Cake)	99.50	–	–	–	–
RC-BBM	–	99.50	–	–	–
PKC-BBM	–	–	99.50	–	–
WO-BBM	–	–	–	99.50	–
BDG-BBM	–	–	–	–	99.50
Vitamin Premix	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100

Each diet contained a primary protein source: Diet 1: GNC: Groundnut cake; Diet 2: RC-BB: Rumen content and Bovine blood; Diet 3: PKC-BB: Palm kernel cake and Bovine blood; Diet 4: WO-BB: Wheat offal and Bovine blood; Diet 5: BDG-BB: Brewers' dried grain and Bovine blood. All diets included 0.25% vitamin premix and 0.25% salt.

RESULTS

Proximate Composition of the experimental diet

The proximate composition of diets fed to animals is shown in Table 2 below, the result showed varied composition of dry matter content, crude fibre, crude protein, ether extract, ash, nitrogen free extract content. The dry matter content of the experimental diets varied between 94.23% to 90.12%. The lowest and highest values were found in diets 1 (90.12%) and 4 (94.23%) respectively. The crude fibre content ranged from 6.01% to 9.45%. Diet 1 had the least (6.01%) while diets 3 had the highest crude fibre content (9.45%). The crude protein content varied between 38.51% to 45.87%. The lowest and highest values were found in diets 1 (38.51%) and 5 (45.87%) respectively. The ether extract content ranged from 3.43% to 8.53%. Diet 5 had the lowest ether extract (3.43%) while diet 1 has the highest (8.53%). The ash content varied between 6.01% to

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IX September 2025

20.02%. Diet 1 the lowest ash content (6.01%) while diet 2 has the highest (20.02%). The nitrogen free extract content of the diets varied between 22.97% to 29.47%. The lowest and highest values were found in diets 3 (22.97%) and 1 (29.47%) respectively.

Apparent Nutrient digestibility of Agro by-products and abattoir waste by weaner pigs.

The apparent nutrient digestibility coefficient is shown in Table 3 below. The dry matter content was highest in diet 3 (95.32%) and least in diet 5 (90.65%). Pigs on diet 1 had the better crude fibre digestibility (25.35%) while those fed diet 3 had the least (14.01%). Also, pigs fed diet 3 had the best crude protein digestibility (28.29%) while those fed diet 2 had the poorest (20.18%). The ether extract content was highest in diet 1 (4.68%) and least in diet 2 (0.12%). Pigs fed diet 9 had the best ash digestibility (15.35%) while those fed diet 3 had the poorest (8.68%). Also, pigs on diet 3 had the better nitrogen free extract digestibility (43.60%) while those fed diet 5 had the least (29.03%).

Table 2: Proximate Composition Of The Experimental Diet

Parameter (%)	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	SEM	P-Value
Dry matter	90.12	93.68	92.00	94.23	91.43	4.83	<0.0001
Crude fibre	6.01	8.27	9.45	7.11	6.89	5.19	<0.0001
Crude protein	38.51	44.51	43.12	42.87	45.87	0.73	<0.0001
Ether extract	8.53	5.79	4.32	4.01	3.43	0.86	<0.0001
Ash	6.01	20.02	16.32	18.58	15.01	0.87	<0.0001
NFE	29.47	23.47	22.97	26.11	23.11	0.81	<0.0001

Each diet was formulated with a distinct primary protein source: diet 1 = groundnut cake (GNC); diet 2 = rumen content and bovine blood (RC-BB); diet 3 = palm kernel cake and bovine blood (PKC-BB); diet 4= wheat offal and bovine blood (WO-BB); diet 5= brewer dried grain and bovine blood (BDG-BB). Significant differences observed across all parameters ($P < 0.0001$). SEM = Standard Error of Mean.

Table 3: Apparent Nutrient Digestibility Of Agro By-Products And Abattoir Waste By Weaner Pigs

Parameter (%)	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	SEM	P-value
Dry matter	93.32 ^{ab}	93.32 ^{ab}	95.32^{a}	91.32 ^{b}	90.65 ^{b}	0.53	0.0332
Crude fibre	25.34 ^{a}	24.01 ^{a}	14.01^{c}	16.68 ^{b}	18.02 ^{b}	0.72	<0.0001
Crude protein	20.18 ^{c}	20.42 ^{d}	28.29^{a}	25.49 ^{b}	26.84 ^{b}	0.49	<0.0001
Ether extract	4.68^{a}	0.12^{c}	0.74^{bc}	0.74^{bc}	1.14^{b}	0.29	<0.0001

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Ash	10.68 b	14.67 a	8.68[b]	14.68 a	15.35 a	0.58	<0.0001
NFE	30.44 bc	34.10 b	43.60[a]	33.73 b	29.03 c	0.50	<0.0001

Values are means of triplicate determinations. Superscripts (a, b, c, d) within the same row indicate significant differences ($P < 0.05$) according to Duncan's Multiple Range Test. SEM = Standard Error of Mean. NFE = Nitrogen-Free Extract.

DISCUSSION

The present study investigated the potential of abattoir waste and agro-industrial by-products as alternative feed sources for weaner pigs. Specifically, the study focused on assessing the nutrient composition and bioavailability of these unconventional feed ingredients when incorporated into the diets of weaner pigs, as well as their comparative efficiency against conventional feedstuffs like groundnut cake (GNC).

The results of this experiment provide valuable insights into the role of such feed resources in enhancing the sustainability and cost-effectiveness of pig production in Nigeria and other regions where the high cost of conventional feed ingredients is a major concern.

This discussion contextualizes the findings of the study in relation to the nutritional profiles, digestibility, and potential application of these feed resources in swine nutrition.

Proximate Composition of Experimental Diets

The proximate analysis revealed significant variations in the nutrient content across the experimental diets, which were formulated using five different feed ingredients: Groundnut Cake (GNC), Rumen Content and Bovine Blood Meal (RC-BBM), Palm Kernel Cake and Bovine Blood Meal (PKC-BBM), Wheat Offal and Bovine Blood Meal (WO-BBM), and Brewers Dried Grain and Bovine Blood Meal (BDG-BBM).

These results suggest that the feed ingredients sourced from agro-industrial by-products and abattoir waste have the potential to provide a diverse range of essential nutrients, although their profiles may vary significantly depending on the source.

The dry matter (DM) content, a key parameter in determining the overall nutrient density of feed, ranged from

90.12% in the GNC-based diet (Diet 1) to 94.23% in the WO-BBM-based diet (Diet 4). This finding is consistent with previous reports showing that agro-industrial by-products such as wheat offal and brewers' dried grains generally exhibit high DM content [25]. The high DM content in Diet 4 could be attributed to the relatively low moisture content of wheat offal compared to other by-products like BDG and PKC. A higher DM content typically implies a more concentrated nutrient source, making the feed more efficient in terms of energy and nutrient delivery per unit of intake.

The crude protein (CP) content of the diets ranged from 38.51% in the GNC-based diet (Diet 1) to 45.87% in the BDG-BBM-based diet (Diet 5). The high protein content in Diet 5 can be explained by the use of brewers' dried grain, which is known for its relatively high protein content [26]. The elevated protein levels in Diet 5 suggest its potential for supporting growth and muscle development in pigs.

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Additionally, the protein quality of these agro-industrial by-products could be enhanced by their combination with bovine blood meal, which is rich in essential amino acids. However, it should be noted that protein digestibility can vary depending on the specific feed ingredient and its level of inclusion, as discussed below. Moreso, the crude fibre content was found to be highest in the PKC-BBM-based diet (Diet 3), with a value of 9.45%. This is consistent with the known composition of palm kernel cake, which considered as a high fiber co-product [27]. While crude fibre is essential for promoting gut health and aiding in the prevention of constipation, excessive fibre levels in swine diets may lead to reduced feed intake and growth performance [25]. Therefore, a careful balance of fibre content is necessary to optimize the growth performance of weaner pigs, especially when incorporating high-fibre agro-industrial by-products.

The ether extract (EE) content, which is indicative of the fat content of the feed, was highest in the GNC-based diet (Diet 1, 8.53%). This high fat content may be beneficial for providing the necessary energy required for growth and development in young pigs. However, diets that are too high in fat can negatively affect feed intake and nutrient absorption [28]. The lower fat content in the other diets, such as the BDG-BBM-based diet (Diet 5), may suggest that these feed ingredients are more energy-dense due to their relatively higher carbohydrate content, which is also reflected in the nitrogen-free extract (NFE) values.

Additionally, ash content, which provides an estimate of the mineral content in the feed, was highest in the RC-BBM-based diet (Diet 2, 20.02%). This is likely due to the mineral-rich nature of rumen content, which contains significant levels of calcium, phosphorus, and trace minerals essential for bone development and overall health in pigs. The relatively high ash content in Diet 2 highlights the potential of rumen content as a valuable source of minerals, although the impact of such high mineral levels on nutrient balance and pig health requires further investigation.

Apparent Nutrient Digestibility

The apparent digestibility of the nutrients was assessed by measuring the difference between nutrient intake and nutrient content in the faeces. The digestibility of dry matter (DM) varied significantly across the diets, with the highest digestibility observed in the PKC-BBM-based diet (Diet 3, 95.32%) and the lowest in the BDG-BBM-based diet (Diet 5, 90.65%). This finding aligns with previous studies indicating that palm kernel cake, when properly processed, is highly digestible and well-utilized by monogastric animals like pigs [25]. The high DM digestibility in Diet 3 suggests that palm kernel cake may be a superior ingredient for optimizing feed efficiency in weaner pigs compared to other agro-industrial by-products.

The digestibility of crude fibre was highest in the GNC-based diet (Diet 1, 25.35%), suggesting that the relatively low fibre content of groundnut cake contributes to its higher digestibility. This result supports the idea that low-fibre ingredients are more readily utilized by pigs, particularly during the early growth phase when energy and protein requirements are critical. In contrast, the PKC-BBM-based diet (Diet 3) showed the lowest crude fibre digestibility (14.01%), likely due to the high fibre content of palm kernel cake, which can reduce nutrient utilization in pigs [27].

The crude protein digestibility was highest in the PKC-BBM-based diet (Diet 3, 28.29%) and lowest in the RC-BBM-based diet (Diet 2, 20.18%). This indicates that pigs fed the PKC-BBM diet could better utilize the protein derived from palm kernel cake and bovine blood meal, likely due to the superior protein quality and amino acid composition of these ingredients. Studies have shown that the inclusion of palm kernel cake in pig diets does not significantly impair nutrient digestibility and can maintain or even improve protein utilization efficiency [29]. Furthermore, graded levels of bovine blood meal have been demonstrated to support good growth performance, corroborating the high protein digestibility observed with PKC-BBM-based diets [30]. Conversely, the relatively low crude protein digestibility in the RC-BBM diet may be attributed to the inferior

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IX September 2025

protein quality of rumen contents compared to other protein sources such as groundnut cake and brewers' dried grain. Literature indicates that rumen content proteins are less digestible, which adversely affects the overall protein utilization in pigs fed such diets [31]. These differences in ingredient quality likely underpin the observed variation in protein digestibility across diets.

The digestibility of ether extract was highest in the groundnut cake (GNC)-based diet (Diet 1, 4.68%) due to the high fat content of groundnut cake, which provides an easily digestible energy source for pigs. In contrast, diets with more fiber-rich ingredients such as the PKC-BBM and WO-BBM diets showed significantly lower ether extract digestibility. This reduction is primarily because dietary fiber interferes with fat absorption, limiting the energy pigs can derive from these diets. Recent research confirms that higher fiber content negatively affects fat digestibility and overall nutrient utilization in pigs, as fiber hinders the digestion and absorption processes of fats. Moreover, variations in ether extract digestibility related to ingredient composition have been documented across different feed sources, highlighting the importance of diet formulation to optimize fat utilization [32, 33].

The digestibility of ash, which is a proxy for mineral absorption, was highest in the BDG-BBM-based diet (Diet 5, 15.35%), suggesting that brewers' dried grain, in combination with bovine blood meal, may enhance the availability of essential minerals like calcium and phosphorus for weaner pigs. This finding is particularly important, as mineral deficiencies can impair growth and bone development in young pigs [26]. Finally, the nitrogen-free extract (NFE) digestibility was highest in the PKC-BBM-based diet (Diet 3, 43.60%), which is consistent with the higher carbohydrate content of palm kernel cake. Carbohydrates are an important energy source for pigs, and the efficient digestion of NFE in this diet suggests that palm kernel cake may be an effective energy-dense ingredient for weaner pigs [25].

Implications for Sustainable Pig Production

The findings of this study highlight the promising potential of incorporating abattoir waste and agro-industrial by-products as cost-effective alternatives to conventional feed ingredients like groundnut cake in pig diets. Utilizing these alternative feed resources can substantially reduce feed costs, which represent a major portion of total production expenses in intensive pig farming systems. Research shows that abattoir and agro-food wastes, rich in nutrients, can be repurposed as sustainable feed ingredients that help minimize waste disposal costs and support circular economy approaches in animal production. However, the efficacy and safety of these alternative feeds depend on factors such as inclusion rates and proper processing to maintain animal health and performance. Overall, their use presents a viable strategy for lowering feed expenses while promoting environmental sustainability in pig production [34].

Additionally, these alternative feed ingredients are more readily available and cost-effective, making them an attractive option for farmers in regions where conventional feed ingredients are scarce and expensive [25].

Furthermore, the use of abattoir waste, such as rumen content, as a protein source in pig diets offers an opportunity to reduce environmental pollution associated with the disposal of such waste products [35]. Properly processed and formulated, rumen content and bovine blood meal can provide essential amino acids and minerals necessary for optimal pig growth, thereby contributing to a more sustainable and circular approach to animal feed production.

In conclusion, the study demonstrates that abattoir waste and agro-industrial by-products are nutritionally viable alternatives to conventional feed ingredients in the diets of weaner pigs. The findings indicate that these alternative feed resources, when properly processed and formulated, can improve nutrient digestibility, support growth performance, and enhance the sustainability of pig production systems. By utilizing these readily

available, cost-effective ingredients, pig farmers can reduce feed costs while improving the quality and quantity of pork production, thereby contributing to the economic and environmental sustainability of the industry.

CONCLUSION

This study demonstrates that abattoir waste and agro-industrial by-products, including rumen content, palm kernel cake, wheat offal, brewers' dried grain, and bovine blood meal, can serve as valuable, cost-effective alternatives to traditional feed ingredients like groundnut cake in the diets of weaner pigs. The proximate composition analysis revealed significant nutrient variability among the diets, with certain by-products offering high levels of crude protein, energy, and essential minerals. Importantly, the apparent nutrient digestibility trials showed that these alternative ingredients were efficiently utilized by the pigs, with the palm kernel cake and bovine blood meal combination (PKC-BBM) offering the highest digestibility of dry matter and crude protein. The findings suggest that these agro-industrial by-products and abattoir wastes can support pig growth and health when incorporated into diets, reducing the reliance on expensive conventional feedstuffs and enhancing feed sustainability.

This approach not only offers a solution to the escalating feed costs in pig production but also promotes the recycling of waste products, thereby contributing to environmental sustainability. The results of this study highlight the potential for integrating these non-traditional feed resources into commercial pig farming, providing a pathway to more affordable and sustainable animal protein production, with implications for both economic and environmental gains in the agricultural sector.

ACKNOWLEDGMENT

I want to appreciate the support of Dr. Adeniji Adegboyega for his support towards the writing of this paper.

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ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IX September 2025

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