


Nutrient Utilisation of Weaner Pigs Fed Fibre Feedstuffs Treated with Complex Probiotics


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Abstract

The nutritional inferiority and variations in nutrient composition of agro-industrial by-products necessitated the need to improve the nutrient composition of these feedstuffs through the use of probiotics. The effect of complex probiotics on fibre feedstuffs was determined on growth response, apparent utilisation of nutrients, protein, and metabolizable energy of weaner pigs. 18 weaner pigs of average weight 6.17 ± 0.44 kg of Large White \times Hampshire breed were assigned randomly to six diets. Three pigs were allocated per diet. Each animal served as a replicate. 25% of brewer's dry grain (BDG-P), Wheat offal (WO-P), and palm kernel cake (PKC-P) without probiotics were denoted as diets 1, 3, and 5. In contrast, diets 2, 4, and 6 had similar feedstuffs supplemented with commercial probiotics (Re3) at 2.5 ml kg⁻¹ of feed. The commercial probiotics comprised: Lactobacilli (1×10^8 cfug⁻¹), Bacillus (1×10^{12} cfug⁻¹), Saccharomyces cerevisiae, yeast (1×10^5 cfug⁻¹) and yeast as a fermentation agent. Animals were given feed and water without restriction for 10 weeks. Results showed that average final weight and feed conversion ratio (FCR) significantly differed, while no significant difference ($P > 0.05$) existed among diets for average daily feed intake and weight gain. WO-P diet gave the best (2.14) FCR. The apparent nutrient digestibility, utilisation of protein and metabolisable energy showed significant differences ($P < 0.05$) across the diet. Metabolizable energy intake/kg gain ($P < 0.05$) of PKC+P and BDG+P fed pigs decreased by 7% and 8.90% respectively. Conclusively, probiotics inclusion improved the crude protein of diets, as well as the growth and utilisation of PKC and BDG diets, with a depressing effect on wheat offal diets.

Keywords: Probiotics, Growth response, Digestibility, Crude protein, Metabolisable energy, *Ad libitum*

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1. Introduction

Pig production is an important contributor to sustainable food security, economic growth, and animal protein source. Despite the importance of pig production to the world's economy such as high prolificacy, source of employment, animal protein source, income e.t.c. It is faced with high cost of feeding resulting from competition with humans, incessant rise in price of traditional feedstuffs such as maize, groundnut cake e.t.c and unavailability of quality feed resources, which exacts a significant influence on health of animals, growth performance and production efficiency (Jalal et al., 2023). Hence, there is a need to search for alternative feed ingredients which are nutritionally viable, economical, accessible, advancing sustainability, and capable of reducing the cost of production amongst livestock farmers (Paul et al., 2019).

Agro-industrial by-products (AIBPS) used in most pig farming system is presently gaining attention by farmers and researchers due to their ability to rescue the scarcity and high cost of conventional feedstuffs (Olaniyan et al., 2020), resulting from competition with human consumption, reliance on imported feed ingredients and rain-fed crops and climate change effects (Nwachukwu et al., 2022). The less competition with humans, low cost and availability of these by-products make them a better alternative to conventional feedstuffs and promote sustainability (Esonu et al., 2021).

Adequate processing of agricultural resources and produce resulted in the production of agro-industrial by-products, which are often underutilised, unassessed or rejected as waste. This includes palm kernel cake (PKC), corn bran, wheat offal, cassava peels, rice bran, brewers' dried grains (BDG), and blood meal, e.t.c. (Hossain et al., 2025). thereby commiserating with consumers' demand for low price feedstuffs, improved animal growth and health status.

Weaner pigs are faced with a deprived ability to digest nutrients from plant-based fibrous-rich diets due to their undeveloped gut system and absence of digestive enzymes during the transition phase of gut development (Marton et al., 2023). This may result in weaning phase mishaps such as reduced growth rate, decreased feed efficiency, intestinal dysfunction and diarrhoea related to post-weaning due to stress (Guevarra et al., 2019; Nguyen et al., 2019). Several antibiotics has therefore been used at therapeutic levels to control post-weaning-related challenges.

Antibiotics in diets of livestock are widely used for promoting growth, prophylaxis purposes and improving health status (Frimpong et al., 2021). However, its excess use has been reported to result in deposition of residues resistant to the same antibiotic base in animal meat and food products (Wang et al., 2023). Therefore, probiotics could be a possible substitute for antibiotics in diets (Hou et al., 2015).

Probiotics can therefore be described as a directly fed live microbes administered to animals to confer a beneficial physiological effect, improve growth, stimulate immune function, prevent infections (Ali et al., 2023) and pathogenic microorganisms (Frimpong et al., 2021), maintain intestinal microbe barrier integrity and balance (Tang et al., 2020), produce digestive enzymes and increase nutrient digestibility.

Most farmers use both bacteria, such as *Lactobacillus spp*, *Enterococcus faecium*, *Streptococcus thermophilus*, *Bifidobacterium spp.*, *Escherichia coli*, *Enterococcus faecalis*, fungi etc. classified as probiotics of economic importance, such as *Saccharomyces cerevisiae* and *Saccharomyces spp*. (Sarmad et al., 2020) As probiotics.

Findings of several researchers (Amoah, 2010; Liao and Nyachoti, 2017; Anyalogbu et al., 2021; Ali et al., 2023; Galli et al., 2024) unveiled importance of supplementing probiotics in the diets of animals as a means of reducing diarrhoea infection severity, improving growth and digestibility. Lan et al. (2016) reported that inclusion of *Bacillus spp* and *Clostridium spp* probiotics in a weaner pig diet improved dry matter, protein, and energy digestibility.

Kahraman et al. (2024) findings showed that *Bacillus spp*. isolate lacks haemolytic and lecithinase activities, thereby are not capable of transferring plasmid gene, which could initiate pathogenicity and enterotoxin formation by not showing any form of antibiotic resistance, which is a characteristic upon which it can be used as a bio-control promoter of growth in animals diets (Güler et al., 2025).

Reports from research findings regarding use of complex probiotics such as Rumen enhancer (RE-3) probiotics comprising combinations of two or more microbes in weaning pig diet as additive capable of improving feed

efficiency, nutrient digestibility, gut integrity, immunity, reduce diarrhea and bacterial infections (Ali et al., 2023) are not consistent and have little or no information on their utilization. Henceforth, there is a need to provide more details on its effects and utilisation by weaning pigs. The study, however, evaluates whether treating fibrous feedstuffs with or without complex probiotics would significantly impact growth response, apparent nutrient digestibility, energy, and protein utilization of weaner pigs.

2. Materials and Methods

2.1 Experimental location

Trial took place at Swine Unit, Faculty of Agriculture Teaching and Research Farm, and Poultry Meat Laboratory, Department of Animal Science, all located within Obafemi Awolowo University, Ile-Ife, Osun state, Nigeria.

2.2 Collection of fibre ingredients

All the fibrous feed ingredients viz: palm kernel cake, brewer's dried grain, wheat offal, and other feedstuffs, were procured from a commercial feed outlet located at Ikire township of Osun State, Nigeria. The RE-3 probiotics were produced in Canada by Basic Environmental Systems and Technology and obtained from Lagos, Nigeria. Being a complex probiotic, it comprises *Lactobacilli* (1×10^8 cfug⁻¹), *Bacillus* (1×10^{12} cfug⁻¹), *Saccharomyces cerevisiae*, yeast (1×10^5 cfug⁻¹). Presence of yeast serves as the fermentation agent. The probiotics were stored in a calm, hygienic and dry place at 26 °C room temperature before and after use.

2.3 Experimental diets

The experimental diet gross composition and proximate composition is revealed in *Table 1 and 2*. Six (6) different diets were composed. Diet (1) contained 25 % Brewer's Dried Grain (BDG) without probiotics (BDG – P) while diets 5 and 3 contained 25 % palm kernel cake (PKC) and wheat offal (WO) without probiotics (PKC – P and WO – P) replacing BDG – P. Diets 2, 4 and 6 contained BDG, WO and PKC with probiotics (BDG+P, WO+P and PKC+P) respectively replacing BDG – P in diet while the remaining feed ingredients were fixed across the diets to maintain iso caloric and iso nitrogenous. The probiotics were included at 2.5 ml per Kilogram of feed. The feedstuffs were mixed and packed into sacs for storage and future use for not more than a week.

Table 1. Experimental Diets Gross Composition

Parameters (%)	DIETS					
	BDG–P	BDG+P	WO – P	WO+P	PKC–P	PKC+P
Maize	45.00	45.00	45.00	45.00	45.00	45.00
Soybean Meal	10.00	10.00	10.00	10.00	10.00	10.00
Groundnut Cake	15.00	15.00	15.00	15.00	15.00	15.00
Brewer's Dried Grain (BDG)	25.00	-	-	-	-	-
BDG + 2.5 ml/kg probiotics	-	25.00	-	-	-	-
Wheat offal	-	-	25.00	-	-	-
Wheat offal + 2.5 ml kg ⁻¹ probiotics	-	-	-	25.00	-	-
Palm Kernel cake (PKC)	-	-	-	-	25.00	-
Palm Kernel cake + 2.5 ml kg ⁻¹ probiotics	-	-	-	-	-	25.00
fish meal	2.00	2.00	2.00	2.00	2.00	2.00
Bone meal	2.50	2.50	2.50	2.50	2.50	2.50
Salt	0.25	0.25	0.25	0.25	0.25	0.25
Premix	0.25	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00	100.00
Nutrient Breakdown						
Metabolizable Energy (kcal/kg)	2763.50	2763.50	2736.00	2736.00	2812.25	2812.25
crude protein (%)	21.26	21.26	21.01	21.01	21.26	21.26
crude fibre (%)	6.68	6.68	3.80	3.80	4.68	4.68

The premix in each kilogram of feed contained: Vitamins: 4,000,000 IU Vitamin A, 800,000 IU Vitamin D₃, 12,000 IU Vitamin E, 0.80g Vitamin K, 0.60 g of Vitamin B₁, 2.0 g vitamin B₂, 1.40g pantothenic acid, 20.00 mg of biotin, 0.40 g of folic acid, and 120.0 g of choline chloride. Minerals: 8.0 g of zinc, 40.0g of manganese, 20.0 g of iron, 18.0 g of zinc (note: zinc is listed twice with different amounts), 0.80 g of copper, 0.60g of iodine, 0.09 g of cobalt, and 0.04 g of selenium. Others is 36.0 g of lasalocid (Avatec).

Dietary treatments included Diet 4: Palm kernel cake without probiotics (PKC–P), Diet 1: Brewer's Dried Grain without probiotics (BDG–P), Diet 2: Wheat offal without probiotics (WO–P), Palm Kernel Cake with probiotics (PK+P), Diet 1: Brewer's dried grain with probiotics (BDG+P), Diet 2: Wheat offal without probiotics (WO+P),

Table 2. Nutrient Composition of Experimental Diet

Parameters (%)	Diets						SEM (\pm)
	BDG-P	BDG+P	WO - P	WO+P	PKC- P	PKC+P	
Dry matter (DM)	87.75	83.39	80.2	83.73	83.80	84.70	1.55
Ash	17.97	17.41	6.67	8.45	6.68	7.51	1.05
Ether extract (EE)	1.97	2.45	2.25	1.68	1.60	1.55	0.11
Crude fibre (CF)	3.23	3.08	3.31	4.08	3.57	5.81	0.24
Crude protein	22.75	23.19	18.16	18.38	19.47	19.91	0.51
NFE	41.83	37.26	49.88	51.14	52.48	49.92	1.91

Dietary treatments included Diet 4: Palm kernel cake without probiotics (PKC-P), Diet 1: Brewer's Dried Grain without probiotics (BDG-P), Diet 2: Wheat offal without probiotics (WO-P), Palm Kernel Cake with probiotics (PK+P), Diet 1: Brewer's dried grain with probiotics (BDG+P), Diet 2: Wheat offal without probiotics (WO+P), Nitrogen-Free Extract, or NFE.

2.4 Management of experimental animals

Eighteen (18) cross-bred both sexes (Hampshire x large white) weaner pigs of average weight 6.17 ± 0.44 kg were randomly allotted into six (6) diets in groups of three (3) animals on each diet, with individual animal as replicate. The animals remained housed individually in a pen and supplied *ad libitum* with feed and water. On daily basis, measured feed were given to the experimental animals twice daily in the morning and evening. Cleaning of pens, drinkers and feeders was carried out daily. Animals were dewormed and treated against mange using ivermectin and vitamins before commencement of the study to prevent mange and worms. The animal body weights were taken weekly. The experiment lasted for ten weeks (70 days).

2.5 Apparent nutrient digestibility study

Eighteen (18) cross-bred both sexes of Hampshire x large white breed of average weight 13.00 ± 0.40 kg were purchased separately for this study. The animals were allotted randomly to six (6) diets of three (3) animals on each diet. An individual animal serves as a replicate. The animals were discreetly placed in a locally constructed metallic metabolic crate with dimensions of 107 cm \times 60 cm \times 55 cm for 10 days. Before the study commenced, animals were fasted for 12 hours to clear their stomachs of food. There were watering and feeding troughs in the cages. After weighing, animals were given 4% body weight dry matter quantity of feed and an unlimited supply of drinking water. On the last seven days of the metabolic trial, total faeces were collected every day, oven dried at 60°C, weighed, put in nylon and plastic bags with labels, and kept in a deep freezer for examination. Following the trial's conclusion, the stored faeces, previously dried, were mixed with a spatula before milling. After milling, samples were analysed chemically for proximate composition at the laboratory.

2.6 Data collection

Data collected on growth response, protein, and metabolisable energy utilisation parameters were determined throughout the experiment. On a daily basis, measured feed were given to the animals. At the end of the week, the feed remnant was weighed back, and quantitative feed intake was determined. The feed conversion ratio evaluates the quantity of feed converted to 1 kg body mass and was determined as the ratio of feed intake to weight gain. The protein efficiency ratio (PER) was evaluated as the ratio of body weight gain to protein intake.

2.7 Chemical analysis

Proximate analysis of the diets and faecal samples was determined in the laboratory using the AOAC (2019) protocol. The samples were carefully separated from dirt and ground into fine particles before being analysed for proximate as described by AOAC (2019).

The dry matter was determined by hot weighing an empty crucible, followed by transferring 0.5 grams of the feed and fecal sample into it, and placing it in the oven overnight. The final weight was deducted from initial weight. To determine ash, the feed and fecal samples left from dry matter analysis were placed in a muffle furnace with an initial weight taken overnight at a temperature of 500°C for ashing. The crucible was then hot weighed with ash, and the quantity of ash was calculated.

The ether extract was determined by continuous evaporation and condensation of ether through an ether extractor apparatus, Manon SO X500, using diethyl ether for extraction of the oils from the samples. The extracted material (crude fat) was dried and weighed as an ether extract. The crude protein was determined by evaluating total Nitrogen using Kjeldah method. It involves digestion using concentrated sulphuric acid, distillation, and titration. The distillate was titrated against a standard acid (0.1 normal Hydrochloric acid), and from this Nitrogen was determined. The crude protein was therefore determined by multiplying %Nitrogen by 6.25. The metabolizable energy composition of the diet was analysed using a bomb Calorimeter Model -IKA C2000 in the laboratory.

2.8 Statistical analysis

Data was collected and analysed using a 2x2 factorial design of General linear model executed with the use of SAS (2015) software package.

3. Results and Discussion

3.1 Experimental diet proximate composition

Research investigation on proximate composition is an important tool capable of providing basic data concerning the nutritive composition of feedstuffs (AOAC, 2019). The proximate nutrient composition of the experimental diet (*Table 2*) showed dry matter ranging from 80.27% to 87.75 %, with BDG–P having the highest (87.75 %). The BDG–P had the highest (17.97 %) ash. The ether extract (EE) ranged from 1.60 to 2.45 % with the PKC+P-based diet having the lowest EE (1.60 %) and highest crude fibre (5.81 %). The highest crude protein (23.19 %) was observed in BDG +P and lowest (18.16 %) in WO–P diet. The nitrogen-free extract (NFE) is highest (52.48 %) in PKC–P based diets and lowest (37.26 %) in BDG+P based diets.

The increased ash composition ($P < 0.05$) observed in BDG-based diets may be due to increased degradation process by bacteria and other microorganisms contained in the probiotics on the fibre diets and decreased organic matter resulting from microbial activity (Onyeike et al., 2015). This agreed with discoveries of Wang et al. (2020) concerning ability of different probiotic microbes capable in producing different enzymes, which could improve livestock nutrition in different ways. The improvement observed in the ether extract agreed with discoveries of Gheorghe et al. (2020), who reported the effect of adding *Lactobacillus* and *Streptomyces* species on enhancement of crude fat contents of fibre diets. The reduced crude protein observed in WO and PKC-based diets may improve energy and feed efficiency (Pedersen et al., 2018). The increased crude protein of probiotics-treated diets may be ascribed to fermentation activities of the probiotic microbes (Anyalogbu et al., 2021). The rise in crude protein and decrease in crude fibre observed from this study may be due to increased activities of the probiotic enzymes (protease and cellulase) ensuing from the fermentation process (Zhang et al., 2024). The diet NFE disparity could be due to variations in other proximate components analysed, while the low NFE indicates a lower amount of carbohydrate fractions.

3.2 Growth response of weaner pigs fed experimental diet

Growth is an indispensable characteristic of animal life. Evaluation of growth response parameters is an indicator capable of providing major information and understanding about the animal general health standing (Kozaklı et al., 2022; Öztop et al., 2024). *Table 3* revealed growth response of weaner pigs fed diets treated with probiotics. Final weight and feed conversion ratio varied significantly ($P < 0.05$) among the different diets. The final weight ranged ($P < 0.05$) from 17.67 to 24.17 kg, with WO–P having the highest (24.17 kg). Pigs fed WO–P WO–P-based diet had the least feed conversion ratio (2.14).

There are no significant differences in average daily weight gain and feed intake across the diets ($P > 0.05$). But numerical variation in values exists. The average daily weight gain of animals fed PKC+P and BDG+P improves ($p > 0.05$) by 10.11% and 9.25%, respectively, while the inclusion of probiotics depresses average daily weight gain in the WO-based diet by 8.40 %.

The non-significant reduction of BDG+P and WO+P fed pigs average daily feed intake might be ascribed to differences in the diet metabolizable energy (Fang et al., 2019), improved nutrient retention and utilisation arising from an improved gastrointestinal tract environment arising from the presence of beneficial microorganisms in the probiotics fed (Zhang et al., 2024).

The reports of Amoah (2010); Sarfo et al. (2018); Frimpong et al. (2021) aligned with the results recorded from this study for average daily feed intake when the RE3-supplemented diet was fed to pigs. In contrast, Shengfa and Martins (2017) observed significant differences in growth response parameters of growing pigs fed diets supplemented with probiotics.

The appreciable rise in weight gain observed in pigs fed BDG +P and PKC+P diets may be due to the hind gut-promoting effect described in previous research of Ogunjobi et al. (2021) and the presence of microbes in the probiotics capable of secreting enzymes and enhancing endogenous enzymes' catalytic activities. These aligned with report of Su et al. (2017) that combining *Enterococcus faecalis* and *Lactobacillus casei* may increase average daily weight gain significantly (Su et al., 2017) while the findings of Liu et al. (2018) do not agree with this report.

The increased quantity of energy liberated from the diet may be responsible for the improved FCR (Sarfo et al., 2018). The decrease in FCR observed in BDG+P and PKC+P may be attributed to variations in ADF and cellulose of the fibre sources, prebiotic activity exhibited by the fibre sources (Ogunjobi et al., 2021), and nutrient-releasing capacity of the probiotics (Akinfala et al., 2023). Sarfo et al. (2018) gave a similar report when probiotics were fed to guinea fowl and broilers.

The improvement ($P < 0.05$) in final weight may be ascribed to an appreciable increase in the weight gain, which may be affected by feeding, environment, health status and increased resistance against gastrointestinal infections (Wen et al., 2018) and the fermentation role of *lactobacillus spp.* contained in the probiotics as growth promoters existing in nature (Celik et al., 2024). The growth response discrepancy of pigs fed diet supplemented with probiotics may be ascribed to sanitation level, stress, ventilation of the housing, spacing amongst animals (Payling et al., 2021), microbial strains, dosage level, interval of treatment and husbandry practices (Shengfa and Martins, 2017).

Table 3. Growth Response of Weaner pigs fed Experimental Diet

Parameter	DIETS						SEM (\pm)	P(diet)	P(level)	P(diet*level)
	BDG-P	BDG+P	WO-P	WO+P	PKC-P	PKC+P				
initial weight (kg)	6.17	7.17	7.00	6.50	6.33	6.17	0.44	0.216	0.68	0.152
final weight (kg)	17.67	20.00	24.17	22.17	21.17	22.50	1.44	0.05	0.84	0.033
ADWG ($\text{kg}^{-1} \text{d}$)	0.160	0.178	0.238	0.218	0.206	0.227	0.02	0.027	0.91	0.016
ADFI ($\text{kg}^{-1} \text{d}$)	0.456	0.453	0.518	0.500	0.488	0.503	0.08	0.214	0.83	0.146
FCR	2.93	2.53	2.14	2.30	2.39	2.23	0.03	0.032	0.76	0.019

Dietary treatments included Diet 4: Palm Kernel Cake without probiotics (PKC-P), Diet 1: Brewer's Dried Grain without probiotics (BDG-P), Diet 2: Wheat Offal without probiotics (WO-P), Palm Kernel Cake with probiotics (PK+P), Diet 1: Brewer's Dried Grain with probiotics (BDG+P), Diet 2: Wheat Offal without probiotics (WO+P), Nitrogen-Free Extract, or NFE. P stands for the probability of significance at $P < 0.05$. ADFI means Average Daily Feed Intake. ADWG refers to Average Daily Weight Gain. FCR is the Feed Conversion Ratio.

3.3 Protein and metabolisable energy utilisation of weaning pigs fed experimental diet

The major active nutrients in animal production are energy and dietary crude protein. The protein and metabolizable energy utilisation of weaning pigs fed fibre feedstuff-based diets supplemented with probiotics (Table 4). The ME intake/day, diet ME, diet CP, ME intake kg^{-1} gain and protein efficiency ratio revealed significant differences. Metabolisable energy intake /day was ($P < 0.05$) highest (1417.20 Kcal $\text{kg}^{-1} \text{d}^{-1}$) in WO-P diet and lowest (1252.80 Kcal $\text{kg}^{-1} \text{d}^{-1}$) BDG+P-based diets.

The ME intake/kg gain ($P < 0.05$) was highest (9211.70 Kcal kg^{-1}) in the BDG-P-based diet. The protein efficiency ratio was ($P < 0.05$) highest (2.58) in WO-P WO-P-based diet. There were no significant differences in protein intake per day and digestible crude protein among the diets. BDG-P pigs had the lowest digestible crude protein (92.20%). The digestible crude protein of WO+P and PKC+P-based diets was close and similar, likewise for PKC-P and BDG-P-based diets.

The low crude protein and high-ME combinations observed in PKC and WO-based diets may hinder their growth response because high ME in diet may result in reduced intake of protein necessary for the synthesis of ingested protein and reduced feed intake (Catanese et al., 2015), while diets containing high crude protein and low

ME in the diet could supply inadequate ME necessary for growth and reduced amino acid acceleration needed for catabolism into ammonia (Strifler et al., 2023; Kuritzta et al., 2022).

Pigs fed high CP diet (BDG based diet) have been reported for varying population of gut microbiota through reduced diversity of bacteria and pro-inflammatory enrichment species such as *Fusobacterium* (Gao et al., 2020) while animals fed with low CP diet may promote energy efficiency (Zhang et al. 2024), beneficial microbial populations, support gut health, reduced inflammation due to increased anti-inflammatory bacteria abundance (Pieper et al., 2016), presence of increased number of bacteria capable of degrading fibres and *Lactobacillus spp* necessary for promoting a stable and beneficial microbiome (Marchetti et al., 2023).

Differences observed for metabolisable energy may arise from variations in protein amino acid composition and fatty acid composition of lipids (Noblet et al., 2023). The decline observed in crude protein of the diet may improve energy efficiency, lessen heat production (Zhang et al., 2024) and decrease post-weaning diarrhea risk resulting from utilization of undigested proteins by pathogenic bacteria (Fang et al., 2019) while extreme intake of dietary crude protein (CP) would lessen energy utilisation, feed efficiency and improved loss of energy through urine (Pedersen et al., 2018).

The values reported for protein efficiency ratio are an indication of adequate crude protein; hence, there would be a decrease in protein excretion, reduced environmental pollution, and greenhouse gas emission (Ewaoluwabemiga et al., 2023).

The long-term supplementation of dietary probiotics has been reported by Wang et al. (2020) to increase bacterial population responsible for energy metabolism, energy recycling, and intestinal development of weaner pigs. Higher Metabolisable energy was reported by Ribeiro et al. (2016).

Table 4. Protein and Metabolisable Energy Utilisation of Weaning Pigs Fed Experimental Diet

Parameters	DIETS						SEM (±)	P(diet)	P(level)	P(level*diet)
	BDG-P	BDG+P	WO - P	WO+P	PKC-P	PKC+P				
Diet ME (Kcal/Kg)	2764.00	2764.00	2736.00	2736.00	2812.00	2812.00	7.65	0.067	0.978	0.042
Diet Crude Protein (%)	22.75	23.19	18.16	18.38	19.47	19.91	0.64	0.001	0.546	0.001
ME intake day ⁻¹ (Kcalkg ⁻¹ d ⁻¹)	1261.10	1252.80	1417.20	1372.60	1373.30	1415.50	91.86	0.024	0.91	0.014
ME intake kg ⁻¹ gain	9211.70	8391.80	7277.80	7487.50	8033.70	7471.20	219.04	<0.001	0.002	<0.001
Protein intake day ⁻¹ (kg ⁻¹ d ⁻¹)	0.10	0.08	0.10	0.11	0.10	0.10	0.01	0.944	0.847	0.89
Protein Efficiency Ratio	1.53	2.18	2.58	1.92	2.10	2.29	0.09	0.067	0.74	0.042
Digestible CP (%)	92.20	95.90	94.10	93.49	92.60	93.66	0.72	0.495	0.003	0.57

Dietary treatments included Diet 4: Palm Kernel Cake without probiotics (PKC-P), Diet 1: Brewer's Dried Grain without probiotics (BDG-P), Diet 2: Wheat Offal without probiotics (WO-P), Palm Kernel Cake with probiotics (PK+P), Diet 1: Brewer's Dried Grain with probiotics (BDG+P), Diet 2: Wheat Offal without probiotics (WO+P), Nitrogen-Free Extract, or NFE. P- probability of significance at P < 0.05.

3.4 Apparent nutrient utilisation of weaning pigs fed experimental diet

Digestibility of nutrients plays a significant part in the efficient utilisation of feed resources in swine production (Sampath et al., 2021). The apparent nutrient digestibility result of weaning pigs fed fibre feedstuffs treated with a complex probiotics-based diet (Table 5). There were significant differences in the apparent digestibility of several key components, including dry matter (DM), crude fiber (CF), fats (ether extract, EE), ash, and digestible carbohydrates (nitrogen-free extract, NFE). Ash digestibility (95.34 %), and ether extract digestibility (95.40 %) were highest (P < 0.05) in BDG +P. Crude protein digestibility is not significant (P > 0.05) and highest (95.90 %) in BDG +P. Addition of probiotics significantly lowered crude fibre digestibility by 1.6% and non-significantly lowered crude protein digestibility of WO-based diets by 2.27% respectively. The Nitrogen-free extract (P < 0.05) was most digested (93.97 %) in WO+P.

The increment observed in dry matter, crude protein and nitrogen-free extract digestibility of pigs fed probiotic-treated diet may be due to the suppression of potentially pathogenic coliforms and *Salmonella*, reduced nutrient and pathogenic competition, which aligned with the findings of Zhao and Kim (2015) and Lan et al. (2016). The reduced (P < 0.05) EE digestibility of PKC-P based diet pigs may be due to an upsurge in non-starch polysaccharides present in the feed, which may lead to reduced fat absorption.

The improvement observed in apparent nutrient digestibility of all the nutrients by growing pigs fed probiotics-supplemented diets reported by researchers (Shengfa and Nyachoti, 2017; Liu *et al.*, 2018; and Jorgensen *et al.*, 2016) agreed with the result obtained from this study. This improvement may be due production of digestive enzymes like protease and phytase by *Lactobacillus spp* present in the probiotics (Dowarah, 2018), increased surface area for nutrient absorption resulting from increased height of villi: crypt ratio resulting in surface area increment for absorption of nutrients (Galli *et al.*, 2024), regulation of gut microbiota, enhanced gut morphology, and increased gut metabolic products capable of enhancing absorption of nutrients nutritionally (Zhao *et al.*, 2024). Also, through regulation of gut microbiota, enhanced gut morphology, and increased gut metabolic products capable of enhancing nutrient absorption necessary for improved nutrient utilisation and animal performance (Zhao *et al.*, 2024).

Table 5. Apparent Nutrient Utilisation of Weaning Pigs fed Experimental Diet

Parameter (%)	Diets						SEM (±)	P(diet)	P(level)	P(level*diet)
	BDG-P	BDG+P	WO-P	WO+P	PKC-P	PKC+P				
Dry Matter (DM)	90.12	94.70	91.30	91.40	90.75	92.35	0.91	0.007	0.003	0.04
Ash	85.90	95.34	81.65	87.25	81.30	83.70	2.16	0.003	0.005	0.001
Ether Extract (EE)	83.27	95.40	89.46	85.08	77.99	82.80	2.58	<0.001	<0.001	<0.001
Crude Fibre (CF)	75.82	87.05	77.00	76.87	65.19	81.58	3.71	<0.001	<0.001	0.001
Crude Protein	92.20	95.90	94.10	93.49	92.60	93.66	0.72	0.495	0.234	0.57
NFE	88.54	90.01	87.71	93.97	90.92	89.43	0.72	0.041	0.004	0.004

Dietary treatments included Diet 4: Palm Kernel Cake without probiotics (PKC-P), Diet 1: Brewer's Dried Grain without probiotics (BDG-P), Diet 2: Wheat Offal without probiotics (WO-P), Palm Kernel Cake with probiotics (PK+P), Diet 1: Brewer's Dried Grain with probiotics (BDG+P), Diet 2: Wheat Offal without probiotics (WO+P), Nitrogen-Free Extract, or NFE. P- probability of significance at $P < 0.05$.

4. Conclusions

The study concluded that probiotics improved crude protein of the diet, growth response, and apparent nutrient digestibility of PKC and BDG-based diets. Treatment of fibrous feedstuffs with probiotics would improve feed efficiency, support early life gut development, optimize feed formulation strategies by enhancing the use of fibrous feedstuffs through unlocking of their values, and promote less reliance on imported ingredients. Future studies should consider long - term feeding trial, carcass analysis, micro biome profiling through the use of molecular tools to confirm duration of the probiotics effectiveness.

Ethical Statement

The research was approved on the permission number ANS/ETH/04/24, dated 16/04/2024, from the Ethics Committee of the Animal Science Department, Obafemi Awolowo University, Ile-Ife, Nigeria.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Akinfala, E. O.; Design: Akinfala, E. O.; Data Collection or Processing: Ogundeji, S. T.; Statistical Analyses: Ogundeji, S. T.; Literature Search: Ogundeji, S. T.; writing, Review and Editing: Ogundeji, S. T. and Akinfala, E. O.

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