

## **Carcass Characteristics, Haemato-Biochemical Indices and Antioxidant Status of Weaned Pigs Fed Diets Supplemented with Varying Levels of Fresh Waterleaf (*Talinum triangulare*)**

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**Target Audience:** Animal nutritionists, Pig farmers and students

### **Abstract**

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*A 56-day feeding study was carried out using eighteen (18) weaned pigs randomly allotted to three dietary treatments containing 0, 5, and 10g/kg of fresh waterleaf, with six replicates per treatment, in a completely randomized design (CRD) to evaluate the effects of dietary supplementation with fresh waterleaf on carcass characteristics, haemato-biochemical indices, and antioxidant status of weaned pigs. Carcass characteristics revealed significant ( $P < 0.05$ ) differences only in lung and kidney weights. Pigs fed diet T3 had the heaviest lung weight (0.10kg), while pigs fed diet T1 recorded the highest value for kidney weight (0.20kg). Eviscerated weight, slaughtered weight, live weight, head, neck, carcass length, forelimb, hindlimb, liver, and intestine did not differ significantly ( $P > 0.05$ ) among treatments. Haematological indices indicated that pigs fed diet T1 had the highest packed cell volume (PCV; 43.00%), and white blood cell count (WBC;  $18.65 \times 10^9/L$ ) while pigs fed diet T3 had the highest red blood cell count (RBC;  $3.90 \times 10^6/L$ ). Serum biochemistry showed that pigs fed diet T1 had the highest aspartate aminotransferase (AST; 48.33IU/L) and alanine aminotransferase (ALT; 23.19IU/L). The antioxidant status observed for pigs fed diet T1 had the highest superoxide dismutase (SOD; 17.67U/mL) while glutathione (GSH) was highest in pigs fed diets T2 (8.01U/mL) and diet T3 (8.39U/mL). Supplementation with diet T2 produced optimum values across most parameters analysed. The study indicates that fresh waterleaf can be included in weaned pig diets as a functional and cost-efficient feed ingredient in resource-limited areas to enhance pig production.*

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**Keywords:** Haematological; Serum biochemical; Antioxidant; Waterleaf; Carcass and organ characteristics

### **Description of problem**

Animal feeds are not readily available and where they are, they are not easily accessible for an average farmer. As a result of the cost of feed, farmers find it difficult to meet the demands of the animals in terms of feeding to meet the growth and development requirements, which leads to poor growth and development and low production. As a result of this, various alternatives and research have been carried out for

alternative feed ingredients to ameliorate the effect of high feed cost. Agriculture is an important sector providing employment for most Nigerians and it is responsible for more than one-third of the total gross domestic product (GDP) and labour force (1). The livestock sub-sector is also crucial to the national economy as it is the main supplier of the highly essential animal protein (2,3). The lack, or insufficient supply of animal protein resulting in protein malnutrition is a

major problem coupled with the challenge of feeding (4).

Pigs are the most important domestic animals in Nigeria, not only by the number of farmers rearing it, but also by its economic value (5). Pig production is advancing in the society where farmers are shifting from ruminant production to monogastric production due to increasing demand for the meat and the by-products. Studies show that pigs have a shorter life-cycle and produce with higher return rates with high feed efficiency (1)(6).

Waterleaf (*Talinum triangulare*) is a rich source of vitamin C, vitamin E, Omega-3 fatty acids, calcium, magnesium, soluble fibres (pectin), potassium,  $\beta$ -carotene, proteins and dietary fibre (7). Diets with vitamins C, vitamin E, zinc and selenium can help protect animals from the damage of internal organs caused by free radicals. Waterleaf is rich in minerals, amino acids, and indigestible fiber which aids in digestion (8). (9) carried out a study to determine the responses of broiler chickens fed varying levels of dietary Waterleaf (*Talinum triangulare*) and it was concluded that Waterleaf (*Talinum triangulare*) improves feed utilization, stimulates appetite and is a good source of electrolytes. It was therefore recommended to supplement monogastric diets with Waterleaf (*Talinum triangulare*). These benefits recorded from previous research has propelled the interest to examine the nutritional and therapeutic activity of waterleaf on pig via examining the live and carcass weight, amount of fat, lean, bone, protein, lipid, white blood cell count to determine the health and diseases, antioxidant level which indicates the risk of oxidative stress and nutritional status to identify deficiencies. Blood acts as a pathological reflector of the status of the exposed animal, to toxicants and other conditions. The

examination of blood provides the opportunity to clinically investigate the presence of metabolites and other constituents in the blood of animals and it plays a major role in the physiological, nutritional and pathological status of an animal. These changes are important in assessing the response of farm animals to various physiological situations. These changes are often caused by several factors such as sex, breed and management systems. These are among the factors that influence blood-based parameters of farm animals (10). Antioxidant status refers to the ability of the animal body to neutralize harmful reactive oxygen species and free radicals, which are byproducts of cellular metabolism. These reactive molecules can cause oxidative stress, leading to cellular damage, aging and various diseases (11).

## **MATERIALS AND METHODS**

### **Experimental site**

The experiment was conducted at the piggery section of the Teaching and Research Farm, Federal University of Technology Akure, Ondo State Nigeria. The farm is sited within the latitude 7.49178<sup>0</sup>N. Longitudes 4.944055<sup>0</sup>E and 5.82864<sup>0</sup>W with annual temperature range of 27 to 38<sup>0</sup>C. it receives between 1,300 mm and 1,650 mm of precipitation annually (12).

### **Source dietary ingredients and experimental diets**

The feed ingredients for basal diet were procured within Akure metropolis and formulated in a reputable feed mill. A basal diet was formulated to meet the National Research Council requirement for weaned pigs. Fresh waterleaf was harvested within the vicinity of Federal University of Technology Akure, Ondo State Nigeria. The leaves were collected, cleaned and allowed to wilt for one day to

reduce the moisture content. The basal diet was divided into three portions with addition of waterleaf at 0, 5 and 10g/kg of

feed and designated as diets T1, T2 and T3 respectively. The gross composition of the basal diet is shown in Table 1.

**Table 1: The gross composition of basal diet fed to weaned pigs**

| <b>Ingredients</b>             | <b>Quantity (Kg)</b> |
|--------------------------------|----------------------|
| Maize                          | 25.00                |
| Groundnut cake                 | 5.00                 |
| Soya bean meal (42)            | 6.00                 |
| Wheat offal                    | 5.80                 |
| Palm kernel cake               | 55.00                |
| Bone meal                      | 1.50                 |
| Limestone                      | 1.00                 |
| Premix                         | 0.25                 |
| Methionine                     | 0.10                 |
| Lysine                         | 0.10                 |
| Salt                           | 0.25                 |
| <b>Total</b>                   | <b>100.00</b>        |
| <b>Calculated composition</b>  |                      |
| Crude protein (%)              | 17.50                |
| Metabolizable energy (kcal/kg) | 2500.00              |
| Calcium (%)                    | 1.10                 |
| Phosphorus (%)                 | 0.45                 |

### **Experimental Animals and Experimental design**

A total number of eighteen (18) weaned pigs were used for the experiment. The pigs were allotted to three dietary treatments (T1, T2 and T3). Each treatment consists of six pigs in a completely randomized design and the experiment lasted for 56 days. The pigs were acclimatized for two weeks before the commencement of the experiment. Experimental diet was given to the pigs at 7.0% of their body weight.

### **Data collection**

**Haematological and serum biochemistry studies** - Blood samples (approximately 5 ml) were collected from each of the randomly selected experimental weaned pigs through the venipuncture from the external jugular

vein at the end of 56 days feeding trial. 5ml of the blood sample were collected into Ethylene Diamine Tetra Acetic acid (EDTA) bottles to prevent blood clotting the blood samples was used for haematological assay according to the methods of (13). The parameters assayed were PVC, Hb count, red blood cell (RBC) and white blood cell (WBC) counts, mean haemoglobin (MCH), mean corpuscular volume (MCV), mean corpuscular haemoglobin concentration (MCHC), lymphocyte and monocyte as described by (13). The serum indices measured were total protein, creatinine, aspartate aminotransferase (AST), alanine aminotransferase (ALT), cholesterol, albumin, globulin and glucose out according to the methods of (14).

**Carcass characteristics** - At the end of the 56 days, randomly selected pigs were

slaughtered for carcass characteristics. Pigs were fasted for 12 hours then weighed before slaughtering and after slaughtering to get the slaughtered weight. The weights of the following parts were measured: head, neck, lungs, back, intestine, spleen, hindlimbs, forelimbs, heart, liver, kidney, and carcass length.

**Antioxidant status** - 5ml of the blood sample was collected in bottles of lithium heparin for antioxidant properties. Glutathione was analysed using Ellman reagent (15), superoxide dismutase (SOD), catalase was analysed according to (16). Spectrometer were used in quantifying the assay.

**Statistical analysis** - All data obtained were subjected to a one-way analysis of variance (ANOVA). Duncan's multiple tests was used to compare the mean at ( $P < 0.05$ ) using the SPSS package version 26. The standard error was determined for each mean using the statistical SPSS package version 26.

**Results and discussion**

The proximate analysis of waterleaf as presented in Table 2 showed that moisture content was 74.38%, while the ash content was 1.81%. However, the fat, crude fibre, crude protein and carbohydrate contents were 1.96%, 5.77%, 7.81% and 8.28%, respectively on dry matter basis. The results for functional properties of waterleaf as presented in Table 3 showed that waterleaf had 121.56% water absorption capacity and 28.17% oil absorption capacity. However, foaming capacity, foaming stability, emulsifying capacity and bulk density of the waterleaf were 36.64%, 18.95%, 7.35% and 0.69%, respectively.

The results for mineral composition of waterleaf as presented in Table 4 revealed that waterleaf had 87.35ppm sodium,

210.5 ppm calcium and 418.7ppm potassium. It was also noted that zinc was 3.08ppm, magnesium recorded 28.16ppm, selenium 0.34ppm, while copper, manganese and phosphorus were 0.28ppm, 0.59ppm and 96.18ppm, respectively. The result of phytochemicals (Table 5) revealed that the alkaloid was 65.89mg/100g, while flavonoid recorded 14.71mg/100g. However, phenol, tannin, saponin and terpernoid were 5.61mg/100g, 19.28mg/100g and 2.19 mg/100g, respectively.

**Table 2: Proximate analysis of waterleaf**

| Parameters       | Diet  |
|------------------|-------|
| Moisture (%)     | 74.38 |
| Ash (%)          | 1.81  |
| Fat (%)          | 1.96  |
| Fiber (%)        | 5.77  |
| Protein (%)      | 7.81  |
| Carbohydrate (%) | 8.28  |

**Table 3: Functional properties of waterleaf**

| Parameters | Diet   |
|------------|--------|
| WAC (%)    | 121.56 |
| OAC (%)    | 28.17  |
| FC (%)     | 36.64  |
| FS (%)     | 18.95  |
| EC (%)     | 7.35   |
| B/D(g/ml)  | 0.69   |

WAC: Water absorption capacity, OAC: Oil absorption capacity, FC: Foaming capacity, B/D: Bulk density

**Table 4: Mineral composition of waterleaf**

| Parameters | Diet   |
|------------|--------|
| Na (ppm)   | 87.35  |
| Ca (ppm)   | 210.50 |
| K (ppm)    | 418.70 |
| Zn (ppm)   | 3.08   |
| Mg (ppm)   | 28.16  |
| Se (ppm)   | 0.34   |
| Fe (ppm)   | 1.82   |
| Cu (ppm)   | 0.28   |
| Mn (ppm)   | 0.59   |
| P (ppm)    | 96.18  |

Na: Sodium, Ca: Calcium, K: Potassium, Zn: Zinc, Mg: Magnesium, Se: Selenium, Fe: Iron, Cu: Copper, Mn: Manganese, P: Phosphorus

**Table 5: Phytochemicals of waterleaf**

| Parameters           | Diet  |
|----------------------|-------|
| Alkaloid (mg/100g)   | 65.89 |
| Flavonoid (mg/100g)  | 14.71 |
| Phenol (mg/100g)     | 48.78 |
| Tannins (mg/100g)    | 5.61  |
| Saponin (mg/100g)    | 19.28 |
| Terpernoid (mg/100g) | 2.19  |

The results for proximate analysis of basal feed with varying levels of waterleaf is presented in Table 6 The results showed significant difference ( $P < 0.05$ ) across all the parameters analyzed. It was recorded that basal diet with the supplementation of 5g/kg waterleaf (T2) had highest moisture

content (13.19%), ash (3.76%), fibre (4.26%) and protein (19.17%) while diet with the supplementation of 10g/kg of waterleaf recorded the lowest fat (5.93%), fibre(3.20%) and protein. It was also recorded that the highest fat was recorded in the basal diets with no supplementation of waterleaf, while carbohydrate recorded the least in treatment containing 5g/kg of waterleaf. However basal diet with 10g/kg had the highest carbohydrate.

The results for functional properties of basal diet supplemented with varying level of waterleaf are shown in Table 7. The functional properties showed that there were significant ( $P < 0.05$ ) differences in all the parameters measured except water absorption capacity. The basal diet with 10g/kg of waterleaf had the highest oil absorption capacity (53.74%) and emulsifying capacity (31.26%), while control diet had the least oil absorption capacity (44.77%), foaming capacity (24.36%), emulsifying capacity (24.81%) and bulk density (0.69g/ml). However, the basal diet with 5g/kg of waterleaf had highest foaming capacity (30.73%), foaming stability (96.14%) and bulk density and the least value for foaming stability was recorded in basal diet with 10g/kg of waterleaf.

The results for mineral composition of basal diet supplemented with varying level of waterleaf are in Table 8 the study showed that there were significant ( $P < 0.05$ ) differences in all the parameters analyzed. Basal diet with 5g/kg of waterleaf consistently had the highest sodium (75.40ppm), calcium (162.15ppm), potassium (407.85ppm), zinc (3.52ppm), magnesium (18.62ppm), iron(2.18ppm) and potassium (131.61ppm) while basal diet with no waterleaf showed the least sodium (68.80%), potassium (364.55ppm), zinc (2.69ppm), manganese (15.85ppm), selenium(0.47ppm), iron (1.51ppm) and

manganese (0.25ppm). However basal diet with 10g/kg had the highest selenium (0.72ppm) and manganese while basal

diet with 5g/kg waterleaf had least copper (0.16ppm)

**Table 6: Proximate analysis of basal diet supplemented with varying levels of waterleaf**

| Parameters        | T1                 | T2                 | T3                 | S.E.M | P. Value |
|-------------------|--------------------|--------------------|--------------------|-------|----------|
| Moisture (%)      | 12.41 <sup>c</sup> | 13.19 <sup>a</sup> | 12.94 <sup>b</sup> | 0.11  | 0.01     |
| Ash (%)           | 4.53 <sup>b</sup>  | 3.76 <sup>c</sup>  | 4.63 <sup>a</sup>  | 1.39  | 0.01     |
| Ether extract (%) | 6.27 <sup>a</sup>  | 6.06 <sup>b</sup>  | 5.93 <sup>c</sup>  | 0.05  | 0.03     |
| Crude fibre (%)   | 3.46 <sup>b</sup>  | 4.26 <sup>a</sup>  | 3.20 <sup>c</sup>  | 0.16  | 0.04     |
| Protein (%)       | 18.53 <sup>b</sup> | 19.17 <sup>a</sup> | 16.95 <sup>c</sup> | 0.32  | 0.01     |
| Carbohydrate (%)  | 54.80 <sup>b</sup> | 53.57 <sup>c</sup> | 56.35 <sup>a</sup> | 0.40  | 0.01     |

<sup>abcd</sup>: Mean with different superscript along the same column and for the same parameters are significantly different ( $P < 0.05$ ) different, T1: Basal diet without waterleaf, T2: Basal diet with 5g/kg of waterleaf, T3: Basal diet with 10g/kg of waterleaf, S.E.M: Standard error of mean.

**Table 7. Functional properties of basal diet supplemented with varying levels of waterleaf**

| Parameters | T1                 | T2                 | T3                 | S.E.M | P. Value |
|------------|--------------------|--------------------|--------------------|-------|----------|
| WAC (%)    | 81.63              | 87.36              | 50.58              | 9.27  | 0.24     |
| OAC (%)    | 44.77 <sup>c</sup> | 49.66 <sup>b</sup> | 53.74 <sup>a</sup> | 1.29  | 0.01     |
| FC (%)     | 24.36 <sup>c</sup> | 30.73 <sup>a</sup> | 28.86 <sup>b</sup> | 0.95  | 0.03     |
| FS (%)     | 94.23 <sup>b</sup> | 96.14 <sup>a</sup> | 91.36 <sup>c</sup> | 0.69  | 0.01     |
| EC (%)     | 24.81 <sup>c</sup> | 26.58 <sup>b</sup> | 31.26 <sup>a</sup> | 0.96  | 0.02     |
| B/D (g/ml) | 0.69 <sup>c</sup>  | 0.75 <sup>a</sup>  | 0.72 <sup>b</sup>  | 0.01  | 0.01     |

WAC: Water absorption capacity, OAC: Oil absorption capacity, FC: Foaming capacity, B/D: Bulk density  
<sup>abcd</sup>: Mean with different superscript along the same column and for the same parameters are significantly different ( $P < 0.05$ ) different, T1: Basal diet without waterleaf, T2: Basal diet with 5g/kg of waterleaf, T3: Basal diet with 10g/kg of waterleaf, S.E.M: Standard error of mean.

**Table 8: Mineral composition of basal diet supplemented with varying levels of waterleaf**

| Parameters | T1                  | T2                  | T3                  | S.E.M | P. Value |
|------------|---------------------|---------------------|---------------------|-------|----------|
| Na (ppm)   | 68.80 <sup>c</sup>  | 75.40 <sup>a</sup>  | 70.75 <sup>b</sup>  | 0.97  | 0.02     |
| Ca (ppm)   | 158.40 <sup>b</sup> | 162.15 <sup>a</sup> | 150.70 <sup>c</sup> | 1.69  | 0.01     |
| K (ppm)    | 364.55 <sup>c</sup> | 407.85 <sup>a</sup> | 397.50 <sup>b</sup> | 6.53  | 0.02     |
| Zn (ppm)   | 2.69 <sup>c</sup>   | 3.52 <sup>a</sup>   | 2.81 <sup>b</sup>   | 0.13  | 0.01     |
| Mg (ppm)   | 15.85 <sup>c</sup>  | 18.62 <sup>a</sup>  | 17.98 <sup>b</sup>  | 0.42  | 0.01     |
| Se (ppm)   | 0.47 <sup>c</sup>   | 0.53 <sup>b</sup>   | 0.72 <sup>a</sup>   | 0.04  | 0.01     |
| Fe (ppm)   | 1.51 <sup>c</sup>   | 2.18 <sup>a</sup>   | 2.09 <sup>b</sup>   | 0.10  | 0.03     |
| Cu (ppm)   | 0.19 <sup>a</sup>   | 0.16 <sup>c</sup>   | 0.18 <sup>b</sup>   | 0.00  | 0.04     |
| Mn (ppm)   | 0.25 <sup>c</sup>   | 0.31 <sup>b</sup>   | 0.37 <sup>a</sup>   | 0.02  | 0.01     |
| P (ppm)    | 120.58 <sup>b</sup> | 131.61 <sup>a</sup> | 115.81 <sup>c</sup> | 2.34  | 0.01     |

Na: Sodium, Ca: Calcium, K: Potassium, Zn: Zinc, Mg: Magnesium, Se: Selenium, Fe: Iron, Cu: Copper, Mn: Manganese, P: Phosphorus, <sup>abcd</sup>: Mean with different superscript along the same column and for the same parameters are significantly different ( $P < 0.05$ ) different, T1: Basal diet without waterleaf, T2: Basal diet with 5g/kg of waterleaf, T3: Basal diet with 10g/kg of waterleaf, S.E.M: Standard error of mean.

The results for carcass characteristics of basal diet supplemented with varying levels of waterleaf are in Table 9 among all the parameters measured, lungs and kidneys showed significant difference ( $P < 0.05$ ). The highest lung weights were recorded in pigs fed diet T3 (0.18kg) and the least was observed in pigs fed diet T1 (0.15kg). The highest kidney weight was

obtained from pigs fed with diet T2 (0.20kg) and the least was recorded for pigs fed diet T1 (0.07kg) and diet T3 (0.07kg). No significant ( $P > 0.05$ ) difference was observed in the live weight, slaughtered weight, eviscerated weight, head, carcass length, forelimb, hind limb, liver, heart and intestine weight measured.

**Table 9: Carcass characteristics of weaned pigs fed basal diet supplemented with varying levels of waterleaf**

| Parameters       | T1                | T2                | T3                | S.E.M | P. Value |
|------------------|-------------------|-------------------|-------------------|-------|----------|
| Live weight (Kg) | 17.67             | 18.00             | 16.73             | 0.49  | 0.61     |
| S/W (Kg)         | 16.33             | 16.19             | 15.50             | 0.47  | 0.79     |
| E/W (Kg)         | 12.41             | 12.38             | 11.59             | 0.38  | 0.67     |
| Head (Kg)        | 1.86              | 1.92              | 1.72              | 0.05  | 0.36     |
| Neck (Kg)        | 0.60              | 0.54              | 0.55              | 0.05  | 0.89     |
| C/L (CM)         | 24.57             | 26.00             | 25.75             | 0.35  | 0.22     |
| F/L (Kg)         | 2.56              | 2.43              | 2.34              | 0.08  | 0.66     |
| H/L (Kg)         | 3.50              | 3.15              | 3.09              | 0.13  | 0.42     |
| Liver (Kg)       | 0.36              | 0.48              | 0.44              | 0.03  | 0.11     |
| Lung (Kg)        | 0.15 <sup>b</sup> | 0.16 <sup>b</sup> | 0.18 <sup>a</sup> | 0.01  | 0.01     |
| Heart (Kg)       | 0.22              | 0.07              | 0.07              | 0.04  | 0.21     |
| Kidney (Kg)      | 0.07 <sup>b</sup> | 0.20 <sup>a</sup> | 0.07 <sup>b</sup> | 0.02  | 0.01     |
| Intestine (Kg)   | 2.79              | 2.80              | 2.37              | 0.09  | 0.08     |

S/W: Slaughtered weight, E/W: Eviscerated weight, CL: Carcass length, FL: Front limb, H/L: Hind limb, <sup>abcd</sup>: Means with different superscript along the same column and for the same parameters are significantly different ( $P < 0.05$ ) different, S.E.M: Standard error of mean, T1: Basal diet without waterleaf, T2: Basal diet with 5g/kg of waterleaf, T3: Basal diet with 10g/kg of waterleaf

The results for haematological indices of weaned pigs fed basal diets supplemented with varying level of waterleaf are presented in Table 10. The parameters analyzed showed significant differences ( $P < 0.05$ ) across all parameters except MCHC. Pigs fed with diet T1 had the highest PCV (43.00%), MCV (130.42fL), MCH (43.48pg/cell), haemoglobin (14.34Hbg/dl), WBC ( $18.65 \times 10^9/L$ ), granulocyte ( $7.80 \times 10^9/L$ ) and lymphocyte ( $10.55 \times 10^9/L$ ) though similar to PCV (42.50%), MCV (124.62fL), MCH (41.54pg/cell) and haemoglobin (14.17Hbg/dl) recorded in pigs fed basal diet T2 (5g/kg). However, the pig fed basal diet supplemented with 5g/kg of waterleaf had the least WBC

( $11.70 \times 10^9/L$ ), lymphocyte ( $6.97 \times 10^9/L$ ), and monocyte ( $0.0 \times 10^9/L$ ). Furthermore, pigs fed basal diet supplemented with 10g/kg of waterleaf had least PCV (40.00%), MCV (102.71 fL), MCH (34.24 fL), haemoglobin (13.34 Hbg/dl) and granulocyte ( $2.85 \times 10^9/L$ ).

The results for serum biochemistry of weaned pigs fed diets supplemented with varying level of waterleaf (Table 11) showed significant differences ( $P < 0.05$ ) in aspartate aminotransferase (AST), alanine aminotransferase (ALT) and glucose, while other parameters were not affected. Pigs fed basal diet with no waterleaf showed highest AST (48.33IU/L) and ALT (23.19IU/L).

However, Pigs fed basal diet supplemented with 5g/kg of waterleaf had the least AST (36.40IU/L) and ALT (20.58IU/L). Furthermore, pigs fed basal diet supplemented with 10g/kg of waterleaf had the highest glucose (16.15 mmol/L) though similar to pigs fed basal

diet supplemented with 5g/kg of waterleaf, while pigs fed basal diet without waterleaf had least glucose (13.75mmol/L). No significance ( $P>0.05$ ) difference was observed in creatinine, cholesterol, total protein, albumin and globulin.

**Table 10: Haematological indices of weaned pigs fed basal diet supplemented with varying levels of waterleaf**

| Parameters                        | T1                  | T2                  | T3                  | S.E.M | P. value |
|-----------------------------------|---------------------|---------------------|---------------------|-------|----------|
| PCV (%)                           | 43.00 <sup>a</sup>  | 42.50 <sup>ab</sup> | 40.00 <sup>b</sup>  | 0.60  | 0.01     |
| RBC (x10 <sup>6</sup> /L)         | 3.30 <sup>b</sup>   | 3.47 <sup>ab</sup>  | 3.90 <sup>a</sup>   | 0.12  | 0.02     |
| MCHC (g/dl)                       | 33.25               | 33.29               | 33.25               | 0.02  | 0.73     |
| MCV (fL)                          | 130.42 <sup>a</sup> | 124.62 <sup>a</sup> | 102.71 <sup>b</sup> | 4.86  | 0.02     |
| MCH (pg/cell)                     | 43.48 <sup>a</sup>  | 41.54 <sup>a</sup>  | 34.24 <sup>b</sup>  | 1.62  | 0.02     |
| Haemoglobin (Hgb/dl)              | 14.34 <sup>a</sup>  | 14.17 <sup>ab</sup> | 13.34 <sup>b</sup>  | 0.20  | 0.01     |
| WBC (x 10 <sup>9</sup> /L)        | 18.65 <sup>a</sup>  | 11.70 <sup>b</sup>  | 13.80 <sup>b</sup>  | 1.18  | 0.01     |
| Granulocyte (x10 <sup>9</sup> /L) | 7.80 <sup>a</sup>   | 4.77 <sup>b</sup>   | 2.85 <sup>c</sup>   | 0.76  | 0.00     |
| Lymphocyte (x10 <sup>9</sup> /L)  | 10.55 <sup>a</sup>  | 6.97 <sup>b</sup>   | 10.80 <sup>a</sup>  | 0.74  | 0.03     |
| Monocyte (x10 <sup>9</sup> /L)    | 0.30 <sup>a</sup>   | 0.00 <sup>b</sup>   | 0.15 <sup>ab</sup>  | 0.05  | 0.03     |

PCV: Packed Cell Volume, RBC: Red Blood Cells, MCHC: Mean Cell Haemoglobin Concentration, MCV: Mean Cell Volume, MCH: Mean Cell Haemoglobin, <sup>abcd</sup>: Means with different superscript along the same column and for the same parameters are significantly different ( $P < 0.05$ ) different, S.E.M: Standard error of mean, T1: Basal diet without waterleaf, T2: Basal diet with 5g/kg of waterleaf, T3: Basal diet with 10g/kg of waterleaf.

**Table 11: Serum biochemistry of weaned pigs fed basal diet supplemented with varying levels of waterleaf**

| Parameters          | T1                 | T2                 | T3                  | S.E.M | P. Value |
|---------------------|--------------------|--------------------|---------------------|-------|----------|
| Creatinine (µmol/L) | 220.50             | 202.00             | 208.00              | 5.49  | 0.43     |
| Cholesterol (g/L)   | 5.25               | 5.20               | 5.30                | 0.03  | 0.42     |
| AST (IU/L)          | 48.33 <sup>a</sup> | 36.40 <sup>b</sup> | 39.20 <sup>ab</sup> | 2.32  | 0.05     |
| ALT (IU/L)          | 23.19 <sup>a</sup> | 20.58 <sup>b</sup> | 20.50 <sup>b</sup>  | 0.56  | 0.04     |
| Total protein (g/L) | 51.20              | 51.30              | 49.90               | 0.35  | 0.19     |
| Albumin (g/L)       | 19.50              | 18.55              | 22.65               | 1.34  | 0.49     |
| Globulin (g/L)      | 31.70              | 32.75              | 27.25               | 1.34  | 0.22     |
| Glucose (mmol/L)    | 13.75 <sup>b</sup> | 15.50 <sup>a</sup> | 16.15 <sup>a</sup>  | 0.41  | 0.01     |

ALT: Alanine Aminotransferase, AST: Aspartate Aminotransferase, <sup>abcd</sup>: Means with different superscript along the same column and for the same parameters are significantly different ( $P < 0.05$ ) different, S.E.M: Standard error of mean, T1: Basal diet without waterleaf, T2: Basal diet with 5g/kg of waterleaf, T3: Basal diet with 10g/kg of waterleaf.

The results for antioxidant status of weaned pigs fed basal diet supplemented with varying level of waterleaf as presented in Table 12 revealed that SOD and GSH were significantly ( $P<0.05$ ) affected by the supplementation of waterleaf in the diet. Pigs fed basal diet

with no waterleaf had the highest SOD (17.67U/mL), while GSH recorded higher values in pigs fed basal diet supplemented with 5g/kg of waterleaf (8.01U/mL) and pigs fed basal diet supplemented with 10g/kg of waterleaf (8.39U/mL). The least GSH was observed

in pigs fed basal diet without waterleaf (7.23 U/mL), while the least SOD was obtained in pigs fed basal diet supplemented with 5g/kg of waterleaf (16.99U/mL) and in pigs fed basal diet

supplemented with 10g/kg of waterleaf (16.93U/mL). No significant ( $P>0.05$ ) difference was observed in the CAT for pigs.

**Table 12: Antioxidant status of weaned pigs fed basal diet supplemented with varying levels of waterleaf**

| Parameters | T1                 | T2                 | T3                 | S.E.M | P. Value |
|------------|--------------------|--------------------|--------------------|-------|----------|
| SOD (U/mL) | 17.67 <sup>a</sup> | 16.99 <sup>b</sup> | 16.93 <sup>b</sup> | 0.12  | 0.05     |
| CAT (U/mL) | 12.37              | 12.13              | 12.22              | 0.13  | 0.81     |
| GSH(U/mL)  | 7.23 <sup>b</sup>  | 8.01 <sup>a</sup>  | 8.39 <sup>a</sup>  | 0.20  | 0.02     |

SOD: Superoxide dismutase, CAT: Catalase, GSH: Glutathione, <sup>abcd</sup>Mean with different superscript along the same column and for the same parameters are significantly different ( $P < 0.05$ ) different, S.E.M: Standard error of mean, T1: Basal diet without waterleaf, T2: Basal diet with 5g/kg of waterleaf, T3: Basal diet with 10g/kg of waterleaf.

## Discussion

Proximate composition of waterleaf showed that moisture content of waterleaf was 74.38%. Waterleaf contains high moisture content due to its succulent leaf nature which enables them to withstand drought conditions (17). The crude protein content (7.81%) of waterleaf observed in this study was higher than the values reported by (18) who reported the crude protein of fresh waterleaf to be 3.52%. The fat content of waterleaf obtained from this study was 1.96%. Waterleaf contains fat which has essential oils, alpha tocopherols and beta-tocopherols. The crude fibre reported was 1.77%, low fibre could be as a result of growing season and plant age at harvest. The ash content reported from this study was 1.81%. The results reported contradicted the range 2.0 – 3.0% reported by (19). Waterleaf is a good source of minerals, which are essential for body function of a pig. Generally, waterleaf contains low carbohydrate compared to other vegetables.

Water absorption capacity indicates the ability of a material to retain water. The functional properties of waterleaf revealed that the water absorption capacity reported from this study was 121.56% which was lower than the report

of (20) who reported the value of water absorption capacity to be 137.5%. Water absorption capacity of a waterleaf is attributed to its significant content of dietary fibre, mucilage and polysaccharides. The oil absorption capacity reported was 28.17%, oil absorption capacity is the ability of a substance to retain oil or the amount of oil that can be held under specific condition (21). Waterleaf demonstrated good foaming capacity which refers to the ability of waterleaf to trap air when mixed vigorously with water. The value reported from this study was 18.95%, which was higher than the value reported by (22), who reported 10.10% for a defatted sesame flour. (20) reported 4.30% which was lower than the value reported in the study. Waterleaf has low foaming stability because of weak interfacial film strength, high water content and low surface-active protein level (23). The emulsifying capacity reported was 7.35% which was lower than the report of (20) who reported 27.7%. the variation maybe attributed to environmental factor. According to (21), emulsifying capacity is how well a substance can create a stable oil-water interface. The value reported for this study was 0.69g/mol. The bulk density can be improved when the particle is smaller, properly compactible (24).

In this study, sodium content reported was 87.35ppm, which is slightly higher than (81.67ppm) (25). Increase in sodium content of a diet causes electrolyte imbalance in the body of the pig, and it can be concluded that increase in quantity of waterleaf leads to a corresponding increase in the quantity of sodium. Moreover, the value of calcium and phosphorus reported from this study were 210.5ppm and 96.18ppm respectively, which aligned with the standard proportion of 2:1. Furthermore, the iron is the key component of haemoglobin in red blood cells that carries oxygen from the lungs to the rest of the body. The iron reported in the study was 1.82ppm which is slightly lower than the report of (26) who reported the iron content of spinach was 1.6mg/100g. The potassium (418.7ppm), zinc (3.08ppm), magnesium (28.16ppm), selenium (0.34ppm), copper (0.28ppm) and manganese (0.59ppm) were within normal range as reported by (19). The variation may be attributed to the environmental and soil condition where the waterleaf was harvested.

Phytochemicals analysis is very useful in the evaluation of some active biological components of some vegetables and plants. Presence of alkaloids (65.89mg/100g) and saponin (19.28mg/100g) contributed to the medicinal value of waterleaf. Saponin inhibits sodium efflux by the blockage of the entrance of the sodium out of the cell. The flavonoids reported from this study was (14.71 mg/100g), lower than the results reported by (18). However, the level of tannin recorded from this study was 5.61mg/100g. According to (27) who reported that the lethal value of tannin in animal nutrition is 5%, addition of waterleaf in the diet of animal may not elicit any harmful effect. The phenol reported from the study was 48.78mg per 100g compared to the values by (28) who reported 11.42mg per 100g. The high

value obtained for phenol could be attributed to climatic factors in different localities. It also contains terpenoids which has anti-hepatic properties, thus help to prevent liver damage and equally has antimicrobial or antiseptic properties.

Proximate composition of basal diet supplemented with varying levels of waterleaf revealed that basal diets with 5g/kg of waterleaf had highest moisture content of 13.19% which can be attributed to inclusion of waterleaf because waterleaf contains high moisture compared to the basal diet without waterleaf which had the least moisture content (4.41%). In addition, the ash content which represents the inorganic minerals was highest in diet with 10g/kg of waterleaf and least in basal diet with 5g/kg of waterleaf suggesting diet with 10g/kg of waterleaf enhance mineral availability. The fat content reduced significantly from basal diet with 0g/kg of waterleaf (6.27%) which had the highest in basal diet with 10g/kg of waterleaf (5.93%) which had the least. The crude fibre indicated that basal diet with 5g/kg of waterleaf (4.26%) had highest fibre which may be attributed to the addition of waterleaf in the basal diet, Crude protein was the highest in basal diet with 5g/kg of waterleaf (19.17%). Carbohydrate contents showed the highest value in basal diet 10g/kg of waterleaf (56.35%) while basal diet with 5g/kg waterleaf had the least carbohydrate content (53.57%).

The functional properties of basal diet supplemented with varying levels of waterleaf analyzed in this study showed that the oil absorption capacity showed that basal diet with 10g/kg of waterleaf had the highest oil absorption capacity while basal diet with 0g/kg of waterleaf had the least oil absorption capacity. Oil absorption capacity is the ability of a protein to absorb fat (29). The foaming capacity had the highest in basal diet with 5g/kg of waterleaf. Foaming stability is

an indicator of feed's ability to sustain physical quality, resist spoilage and preserve nutritional value. Basal diet with 5g/kg of waterleaf (96.14%) had highest level of foaming stability. This indicated that slight addition of waterleaf increased the foaming stability of the feed. Basal diet with 10g/kg of waterleaf (91.36%) recorded the lowest value which could be attributed to moisture content, fibre content and dietary interaction of the diet and waterleaf. This may affect the quality of the feed, reduce palatability and impact animal performance. An increasing trend in emulsifying capacity was observed in which basal diet with 10g/kg of waterleaf (31.26%) had the highest value and basal diet with no waterleaf (24.81%) had the least. An increase in emulsifying capacity improves the diet shelf life by ensuring droplets are evenly distributed. The bulk density had the highest level in basal diet with 5g/kg of waterleaf (0.75%). This indicated that waterleaf had positive effect on the feed.

The analysis of mineral content of basal diet supplemented with varying levels of waterleaf showed that the sodium content was significantly high in basal diet with 5g/kg of waterleaf (75.40%) while the basal diet with no waterleaf had the least value. Basal diet with 0g/kg of waterleaf had the least. Calcium, potassium, zinc and magnesium level were significantly high in the basal diet with 5g/kg of waterleaf. Calcium is essential in blood clotting, nerve impulse transmission and muscle contraction. Potassium is involved in nerve muscle function, electrolyte balance and ammonium ion excretion by kidney (30). Selenium was highest in basal diet with 10g/kg of waterleaf. Iron showed a significant increase in 5g/kg of waterleaf compared to control. Iron is a trace element needed in the body for haemoglobin formation, normal functioning of the central nervous system (31). Copper level showed the

highest level in basal diet with 0g/kg of waterleaf and the least was obtained in basal diet with 5g/kg of waterleaf. There was a significant increase in the level of manganese, in which the highest level was observed in basal diet with 10g/kg of waterleaf compared to the basal diet with 0g/kg of waterleaf which had the least. Phosphorus obtained the highest in diet with 5g/kg of waterleaf.

The analysis of carcass characteristics showed that the lung's weight was significantly heavier in weaned pigs fed basal diet with 10g/kg of waterleaf (0.18kg) than in basal diet with no waterleaf (0.15kg) and basal diet supplemented with 5g/kg of waterleaf (0.16kg). The increasing order in lung's weight observed from basal diet with no waterleaf and basal diet with 5g/kg of waterleaf differs from the report by (32) when weaned pigs were fed wild sunflower/ bloodmeal mixture. Moderate lung weight suggests that the lungs are free from pathological conditions such as pneumonia, parasitic infections which typically increase lung mass (33) and also indicator of good farm management (34). Moreover, the weight of kidney was significantly high in weaned pig fed basal diet supplemented with 5g/kg of waterleaf, while similarities was observed in weaned pigs fed basal diet with 10g/kg of waterleaf and basal diet with no waterleaf. The increase in values obtained is an indication that waterleaf affected the function of these organs. The eviscerated weight, slaughtered weight, live weight, head, neck, carcass length, forelimb, hindlimb, liver and intestine did not show any significant ( $P>0.05$ ) differences. Although, all the diet supported carcass yield relative to the amount of feed consumed.

The analysed haematological indices showed that weaned pig fed basal diet with 10g/kg of waterleaf had the least values for PCV, MCV, MCH, WBC,

haemoglobin, and granulocyte. This could indicate the physiological and nutritional status of the pigs, as high level of packed cell volume in the body indicates increase in oxygen delivery to tissues and organs, supporting growth, reproduction and overall health while low levels could signify anaemia (35). Moreover, there was significant increase in the concentration of RBC in weaned pig fed basal diet with 5g/kg of waterleaf compared to pig fed basal diet with 0g/kg of waterleaf. This observation is favourably compared to the report of (36) which stated that animals are likely to perform well when animals are fed with balance diets. MCV, MCH and haemoglobin recorded were within normal range values in pig haematological parameter. Immune defense system is the role of WBC, granulocyte, monocyte and lymphocyte. Addition of waterleaf in the diet showed lower values for the WBC, granulocyte, and monocyte as compared to the blood profile of pigs fed diet T1, this could be as a result of microbes and parasites.

The analysis of serum biochemistry revealed that ALT showed higher concentration in pig fed basal diet 0g/kg without waterleaf (23.19 U/mL). There were no significant ( $P>0.05$ ) differences in pigs fed basal diet 5g/kg (20.58 U/mL) of waterleaf and pig fed 10g/kg of waterleaf (20.50 U/mL) pig fed basal diet with 5g/kg of waterleaf but had the least value. It was observed in this study that pig fed basal diet 0g/kg without waterleaf (48.33 U/mL) had highest AST and pig fed basal diet with 5g/kg of waterleaf (36.40 U/mL) had the least value. The alanine aminotransferase and aspartate aminotransferase are usually analysed concurrently as part of liver function test to determine any inflammation, damage or disease to the liver. There was a decrease with addition of waterleaf which connoted that waterleaf didn't have

harmful effect on the liver. Furthermore, glucose level was significantly increased in pig fed basal diet 10g/kg of waterleaf (16.15 mmol/L) and the least was obtained in pig fed basal diet without waterleaf (13.75 mmol/L). The decrease may be attributed to waterleaf as it contains moderate content of energy. The glucose reported falls within the normal range of 9.31-12.13 mmol/L reported by (37).

The analysis of antioxidant status showed that waterleaf had significant effect on SOD and GSH concentrations. Moreover, there was decrease in level of SOD. The highest SOD concentration was observed in pigs fed basal diet without waterleaf while there was no significant difference in pig fed basal diet with 5g/kg of waterleaf (16.99 U/mL) and pig fed basal diet with 10g/kg of waterleaf (16.93 U/mL). Low SOD could indicate oxidative stress which can lead to cellular damage, dysregulation of the antioxidant system leading to impaired antioxidant function and contribute to various disease (38). The waterleaf had significant ( $P<0.05$ ) difference on GSH analyzed, pig fed basal diet with 10g/kg of waterleaf (8.39 U/mL) had the highest concentration of GSH which was lower when compared with previous research of (38) who reported GSH value of 10-30 U/mL. GSH functions in detoxification of harmful substances by conjugating with various electrophiles, facilitating their elimination from the body through the urine and bile (39). No significant effect of waterleaf was observed in catalase, but the values reported were within the normal range (38).

## Conclusion and Application

This study revealed that

1. Supplementation of waterleaf (*Talinum triangulare*) in the formulated diet of weaned pig

- revealed its impact on the chemical feed composition, carcass characteristics, haemato-biochemical indices and antioxidant status in weaned pigs.
- The findings suggest that waterleaf can be included in weaned pig diet as a functional and cost-efficient feed ingredient in resources limited area for optimal pig production. Moderate supplementation of waterleaf at about 5g/kg is recommended for an optimal nutrition in pig production in this study.

## REFERENCES

- Adetunji M. O., and Adeyemo K. E. (2012). Economic efficiency of pig production in Oyo State, Nigeria: a stochastic production frontier approach. *American Journal of Experimental Agriculture* 2(3): 382–394.
- Okuneye B. A. (2002). Livestock sub-sector in Nigeria: Challenges and prospects. In: *Bullion-bulletin of the Central Bank of Nigeria*. July/September 2002. pp. 16–22.
- Ogbu C. C. (2010). Genetic Change in the Nigerian Heavy Local Chicken Ecotype through Selection for Body Weight and Egg Production Traits. Unpublished Ph.D. Thesis submitted to the Department of Animal Science, Faculty of Agricultural Science, University of Nigeria, Nsukka.
- Adeleke M. A., Peters S. O., Bamgbose A. M., and Adebambo F.A. (2005). Effect of Strains on Egg Production Traits of Crossbred Chickens in South-West of Nigeria. *Nigerian Journal of Genetics* 19: 92–101.
- Osondu C. K., Ijioma J. C., Anyiro C. O., and Obike K. (2014). Economic Analysis of Pig Production in Abia State, Nigeria. *International Journal of Applied Research and Technology* 3(3): 3–10.
- Ogunniyi, L. T., and Omoteso, O. A. (2011). Economic analysis of swine production in Nigeria: A case study of Ibadan Zone of Oyo State. *Journal of Human Ecology*, 35(2), 137–142.
- Ezekwe, Besong, S. A., and Igbokwe, P. E., (2001). "Beneficial influence of purslane and water leaf supplement to human." *FASEB Journal*, vol. 16, p. A639.
- Swarna, JTS. Lokeswari, M. Smita and R. Ravindhran. (2013). "Characterisation and determination of In vitro antioxidant potential of Betalains from *Talinum triangulare* (Jacq) wild" *Food chemistry* 141 (4): 4382-90
- Ekine, O. A., Orindu, A. N. and Ukanwoko A. I. (2020). Responses of broiler chickens fed varying levels of dietary waterleaf (*Talinum triangulare*). *Journal of Bioscience and Agriculture Research*, 24(01), 1999-2005.
- Etim, N.N., Williams, M.E., Akpabio, U. and Offiong, E.E.A. (2014). Haematological Parameters and Factors Affecting Their Values. *Agricultural Science*, 2, 37-47
- Halliwell, B., and Gutteridge, J. M. C. (2015). Free radicals in biology and medicine (5th ed.). *Oxford University Press*. p.312
- Daniel, O. A. (2015). *Urban extreme weather: a challenge for a healthy Living environment in Akure, Ondo State, Nigeria*. *Climate*, 3(4): 775 – 791
- Kohn, R. A. and Allen, M. S. (1995). Enrichment of proteolytic activity relative to Nitrogen in preparation from the rumen for in vitro studies. *Animal Feed Science and Technology*, 52(1/2): 1-14
- Cork, S. C., and Halliwell, R. W. (2002). The veterinary laboratory

- and field manual: A guide for veterinary laboratory technicians and animal health advisors. Nottingham University Press. Pg 145.
15. Ellman G.L (1959). "Tissue sulfhydryl groups". *Arch. Biochemistry and Biophysics*. 82 (1): 70-7.
  16. Aebi, H. (1984). Catalase in Vitro. *Methods Enzymology*, 105, 121-126.
  17. Fonten, J. M., and Schippers, R. R. (2004). Water spinach and fresh cassava leaves.
  18. Aja, P.M., Okaka, A. N. C., Onu, P.N., Ibiam, U., and Urako, A.J. (2010). Phytochemical composition of *Talinum triangulare* (water leaf) leaves. *Pakistan Journal of Nutrition*, 9(6), 527–530.
  19. Food and Agriculture Organization of the United Nations. (2017). Food composition table for use in Africa. FAO, Rome
  20. Ogunbenle, H. N., Akinsola, A. F., Olatunde, O. C., and Lijoka, A. O. (2018). Chemical, functional properties and amino acid composition of waterleaf (*Talinum triangulare*). *Journal of Chemical Health Risks*, 8(1), 1–8.
  21. Adebowale, K. O., Afolabi, T. A., and Oshodi, A. A. (2005). Functional properties of some newly developed varieties of cassava (*Manihot esculenta* Crantz) starches. *Food Research International*, 38(4), 417–423.
  22. Ogunbenle, H. N., and Otemuyiwa, F. F. (2015). Functional properties and amino acid composition of waterleaf (*Talinum triangulare*). *Chemistry Research Journal*, 3(3), 7–16.
  23. Oloyede, O. O., James, S., Ocheme, O. B., Chinma, C. E., and Akpa, V. E. (2016). Effects of fermentation time on the functional and pasting properties of defatted *Moringa oleifera* seed flour. *Food Science and Nutrition*, 4(1), 89-95.
  24. Iwe, M. O., and Olorunfemi, O. O. (2016). Proximate analysis and anti-nutritional factors of *Talinum triangulare* (waterleaf) leaves. *International Journal of Nutrition and Food Sciences*, 5(1), 1–6.
  25. Echesirim, B. E., Oladeji, J. B., Edun, A., Ojeilua, C. H., Grace, A. I., & Ezeigbokwe, A. C. (2025). Proximate and mineral composition of *Talinum triangulare* (Waterleaf) from quarry and non-quarry sites in Port Harcourt: Implications for nutrition and food safety. *Asian Journal of Basic Science & Research*, 7(3)
  26. Turan, M., and Yildirim, E. (2003). Effect of organic and organomineral fertilizers on the growth and yield of *Amaranthus* in Turkey. *Acta Agriculturae Scandinavica, Section B – Soil and Plant Science*, 53(3), 157–160.
  27. Adebayo, O. O., and Akinmoladun, F. O. (2000). Proximate composition and mineral content of some Nigerian vegetables. *Food Chemistry*, 70(3), 289–292.
  - Eleazu, C.O., and K.C Eleazu. (2013). "Bioactive constituents and in vitro antioxidant capacity of waterleaf (*Talinum triangulare*) as affected by domestic cooking". *European Journal of Medicinal plants*, 3 (4): 540-551
  28. Kinsella, J. E., and Whitehead, D. M. (1976). Functional properties of proteins in foods: A survey. *Critical Reviews in Food Science and Nutrition*, 8(3), 219–280.
  29. National Research Council. (1988). Nutrient Requirements of Dairy Cattle: Sixth Revised Edition. *The National Academies Press*. 42
  30. Adeyeye, E. I., and Otokiti, M. K. O. (1999). Proximate composition and some nutritionally valuable minerals

- of two varieties of *Capsicum annum* (bell and cherry peppers). *Discovery and Innovation*, 11(1), 75–81.
31. Olayeni, T. B., Ojedapo, L. O., and Ademola, I. A. (2009). Performance and carcass characteristics of weaner pigs fed wild sunflower (*Tithonia diversifolia*) leaf meal. *Nigerian Journal of Animal Production*, 36(1), 1–8.
  32. Radostits, O. M., Gay, C. C., Hinchcliff, K. W., and Constable, P. D. (2007). *Veterinary medicine: A textbook of the diseases of cattle, horses, sheep, pigs and goats* (10th ed.). *Saunders Elsevier*.
  33. Gallo, A., and Kipper, M. (2013). Growth performance, carcass traits and meat quality of pigs fed diets containing different levels of crude glycerin. *Journal of Animal Science*, 91(5), 2345–2353.
  34. National Research Council. (2012). *Nutrient Requirements of Swine: Eleventh Revised Edition*. *The National Academies Press*. 420
  35. Oke, O. L., Akinmoladun, F. O., and Olayemi, F. F. (2007). Evaluation of the effects of dietary supplementation of mucuna leaf meal on growth performance and haematological characteristics of weaner pigs. *African Journal of Agricultural Research*, 2(4), 145–150.
  36. Oloruntola, O. D., Ogunsipe, M. H., Ibadapo, I., and Agbede, J. O. (2019). Performance of weaner pigs fed increasing levels of cocoa bean shell meal replacing maize. *African Journal of Agricultural Technology and Environment*, 8(2), 1–8.
  37. Makinde, O. I., Akinmoladun, F. O., and Olorunfemi, O. O. (2020). Evaluation of heavy metal concentrations and proximate compositions of *Amaranthus spinosus* and *Talinum triangulare*. *Environmental and Earth Sciences Research Journal*, 7(1), 1–9.
  38. Sies, H., and Jones, D. P. (2007). Oxidative stress. In G. Fink (Ed.), *Encyclopedia of Stress* (2nd ed., pp. 45–48).