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# EFFECT OF VITAMIN C (ASCORBIC ACID) SUPPLEMENTATION ON GROWTH PERFORMANCE, ECONOMIC INDICES, HAEMATOLOGY, SERUM BIOCHEMISTRY AND CARCASS CHARACTERISTIC OF WEANER PIGS

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## ABSTRACT

Seven weeks old weaned pigs (Yorkshire x Landrace, n = 32, mean weight = 12.32 ± 0.59 kg) were allotted to 4 treatments (diets) consisting of 8 replicates each: diet A−basal diet; diet B−basal + ascorbic acid at 1 g.kg$^{-1}$ diet; diet C−basal + ascorbic acid at 2 g.kg$^{-1}$ diet; and diet D−basal + ascorbic acid at 3 g.kg$^{-1}$ diet. Growth performance, economic indices, haematological parameters, serum biochemistry and carcass characteristics were measured. After 49 days, the pigs on diet with ascorbic acid at 2 g.kg$^{-1}$ had significantly higher daily feed intake (1.54 kg per pig) ($p < 0.05$). The feed cost per kg increased significantly ($p < 0.05$) across the diets from the control (Nigerian naira, ₦ 97.60) to basal + ascorbic acid at 3 g.kg$^{-1}$diet (₦ 103.50). Significantly higher ($p < 0.05$) red blood cell, haemoglobin, haematocrit and mean corpuscular volume values were recorded in pigs fed ascorbic acid at 2 g.kg$^{-1}$ diet, while pigs fed ascorbic acid at 3 g.kg$^{-1}$ diet had the highest cholesterol, triglyceride, glucose, creatinine, urea, total protein and globulin ($p < 0.05$) levels. Pigs offered ascorbic acid had significantly higher bleed weight, carcass weight, belly, abdominal fat, back fat thickness and whole and empty stomach weight than those fed the control diet. It can be concluded that vitamin C supplementation (up to 3 g.kg$^{-1}$) had no negative impact on the growth performance and economic indices (except the feed cost) of the pigs, while it improved the haematological parameters and carcass weight and also enhanced fat deposition.

**Key words:** ascorbic acid; blood; cost-benefit; performance; primal cuts, weaned-grower pig

## INTRODUCTION

Feed additives play important roles in the well-being and performance of livestock (Ferronato and Prandini, 2020). Their impact ranges from health and digestion to meeting deficiencies. For health, it could be to strengthen the immune system, enhance enzyme activities, subdue gram-negative microbes in the gut or change the pH and modulate physiological processes. For digestion, it could be to increase feed intake, reduce feed conversion ratio, increase digestibility or supply deficient nutrients, alter metabolism and gut morphology. Some of the additives can affect the taste of the feed. Feed additives not only enhance performance in fatteners but also lower nitrogen and phosphorus released into the ecosystem (Suiryanrayna and Ramana, 2015).

Ascorbic acid, a feed additive, also known as a vitamin C, is highly soluble in water. It is available naturally in fruits and vegetables but also available in the concentrated synthetic form. Bioavailability


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in the natural form is not easily quantified. Although, Carr and Vissers (2013) established that both are chemically identical, however, other nutrients and phytochemicals in natural form in fruits and vegetables could be impaired because of chemical interactions. The antioxidant properties of vitamin C and the potential against oxidative stress and infection have been established in livestock. It is also important under other stressful conditions like heat, weaning, parturition and lactation (Lechowski *et al*., 2015; Ahmadu *et al*., 2016). It was previously thought for many years that pigs are able to synthesize enough vitamin C, however, their deficiency has been proved to be unsafe (Ching *et al*., 2001; Kolb and Seehawer, 2001; Lauridsen and Jensen, 2005; Chung, 2006).

Kim *et al*. (2005) explained that vitamin C acts like an acidifier that lowers the gastro pH, favours proteolytic enzymes and inhibits GIT pathogenic flora, thus, enhancing digestion, nutrient retention and performance (Partanen and Mróz, 1999). Rebouche (1991) and Ramanau *et al*. (2004) determined that vitamin C supplementation increases physical efficiencies attributable to activities of carnitine hydroxylases. Vitamin C catalyses the syntheses of immunoglobulins (Lauridsen and Jensen, 2005) evidently at high concentrations in leukocytes (Pinelli-Saavedra *et al*., 2008). Levine *et al*. (1996) reported that vitamin C elevates the protein content in plasma by altering serum total protein components and ratio. Lechowski *et al*. (2015) proved this by an increased level of protein in colostrum, milk and also increased fat components. This improves the survivability of piglets by facilitating rapid growth and development. The acid class of additives also acts as a substrate for epithelial mucosa influencing villi morphology and precursor for amino acid formation (Mroz, 2005).

In accordance with the context, the objective of this investigation was to evaluate the effect of vitamin C on performance, economic indices, haematological parameters, serum biochemistry and carcass characteristic of weaned-to-grower pigs.

**Table 1. Gross composition of experimental diets**

| Ingredients (%) | A | B | C | D |
|---|---|---|---|---|
| Cashew kernel meal | 15.00 | 15.00 | 15.00 | 15.00 |
| Palm kernel meal | 57.00 | 57.00 | 57.00 | 57.00 |
| Corn bran | 18.30 | 18.30 | 18.30 | 18.30 |
| Soybean meal | 8.00 | 8.00 | 8.00 | 8.00 |
| Limestone | 1.00 | 1.00 | 1.00 | 1.00 |
| Lysine | 0.20 | 0.20 | 0.20 | 0.20 |
| Premix | 0.25 | 0.25 | 0.25 | 0.25 |
| Salt | 0.25 | 0.25 | 0.25 | 0.25 |
| Ascorbic acid | - | + | ++ | +++ |
| Total (kg) | 100.00 | 100.00 | 100.00 | 100.00 |
| Calculated nutrient composition | | | | |
| Crude protein | 19.93 | 19.93 | 19.93 | 19.93 |
| Ether extract | 6.35 | 6.35 | 6.35 | 6.35 |
| Crude fiber | 8.70 | 8.70 | 8.70 | 8.70 |
| Calcium | 0.97 | 0.97 | 0.97 | 0.97 |
| Phosphorus | 0.38 | 0.38 | 0.38 | 0.38 |
| Lysine | 0.87 | 0.87 | 0.87 | 0.87 |
| Methionine | 0.40 | 0.40 | 0.40 | 0.40 |
| Metabolizable energy (MJ) | 11.36 | 11.36 | 11.36 | 11.36 |

A: basal diet (control); B: basal + ascorbic acid at 1 g.kg$^{-1}$diet (+); C: basal + ascorbic acid at 2 g.kg$^{-1}$ diet (++); D: basal + ascorbic acid at 3 g.kg$^{-1}$ diet (+++).

## MATERIAL AND METHODS

### Animals and Experimental design

The dietary test was performed at the Piggery Unit of the University Research Farm, Ogbomoso. Ogbomoso is longitudinally on 4° 16' E and latitudinal on 8° 10' N. It is about 300 meters above sea level, with a mean temperature of about 26.9 °C and 1248 mm precipitation in the derived savannah zone. The feeding trial complied with the Ladoke Akintola University of Technology Animal Research Ethics.

The Ascorbic acid was purchased from Animal Health, Member Bv, 17A, ZA Venter-Holland (colour – white, physical consistency – coated powder).

Thirty-two weaned pigs aged 7 weeks (Yorkshire x Landrace) with a mean weight of 12.32 ± 0.59 kg were obtained from the experimental unit. They were weighed, ear-tagged and randomly allotted to 4 treatment groups of 8 replicates each. The pigs were housed in open-sided pens with concrete floors, individually. They had *ad-libitum* access to feed and water. The pigs were monitored for a week before they were placed on the experimental diets. The trial period lasted for 49 days.

The basal diet, formulated as isocaloric and isonitrogenous, contained mainly palm kernel cake, corn bran and cashew kernel meal. The vitamin C was added to the diet as following:

Diet A: basal diet (control)
Diet B: basal diet + ascorbic acid at 1 $g.kg^{-1}$ diet
Diet C: basal diet + ascorbic acid at 2 $g.kg^{-1}$ diet
Diet D: basal diet + ascorbic acid at 3 $g.kg^{-1}$ diet

The pigs were allotted to the dietary groups in a completely randomized manner.

### Experimental controls

### Growth performance

A known amount of feed was offered every day and leftover feed weight was deducted to record the feed intake, while the weight of each pig was taken weekly. Feed conversion was estimated as the ratio of feed consumed to weight gain.

### Economic indices

Economic indices were calculated as following:

The quantity of each ingredient, multiplied by the unit cost of each ingredient, divided by 100 and then all summed together was used to obtain the feed cost per kg ($FC.kg^{-1}$) for each dietary group. To obtain the $FC.kg^{-1}$ weight gain, the $FC.kg^{-1}$ value was multiplied by the feed conversion ratio. Furthermore, income per kg weight gain was estimated by multiplying the selling price per kg and final weight per pig and dividing the outcome by the weight gain. The difference between the income and $FC.kg^{-1}$weight gain was used to obtain the profit per kg weight gain, while the economic efficiency of the gain was determined by multiplying the profit and $FC.kg^{-1}$ weight gain and dividing the product by 100.

### Blood (haematology and serum biochemistry) parameters

Three pigs per dietary group were randomly picked up for blood examination after the seven-week feeding trial when the animals were aged fourteen weeks. They were bleed after being fasted overnight. About 5 ml of blood was each siphoned into pre-labelled tubes for haematological and serum examination through the jugular vein puncture method using sterilized needles and syringes. Blood specimens were taken into pre-labeled heparinized vacutainer bottles for haematology and plain vacutainer tubes for serum biochemical parameters. A full automatic haematological analyzer (BC-3000 mindray brand) was used to determine the haematological parameters. Blood serum metabolites – alanine aminotransferase, aspartate transaminases and alanine phosphatases, were evaluated manually by a spectrophotometric method (Schmidt, 1963). Urea and creatinine were evaluated by urease and Folin methods, respectively. Total protein (TP) and albumin were measured as described by Peters *et al*. (1982), while globulin value was estimated as the differential between the TP and albumin. Cholesterol, triglyceride, and glucose were also determined.

### Carcass characteristics

Three pigs were selected per treatment. The pigs were rendered unconscious mechanically and a sharp knife was then used to slit their throats and the pigs were allowed to bleed completely. Afterward, the pigs were weighed (using a digital crane™ 300 scale) to calculate the bled weight. The eviscerates were separated and weighed and the remaining portion was considered as the eviscerated weight. The carcass weight was determined after the removal of the head and trotters. Moreover, various internal organs were weighed using a digital sensitive scale (Kerro BL 30001E). The carcass was separated into primal cuts.

**Statistical Analysis**

Recorded data were analyzed using a one-way ANOVA with SPSS 16v software at 5 % of significance. The significant mean values were separated by Duncan's multiple test (Duncan, 1955).

## RESULTS AND DISCUSSION

**Effect of ascorbic acid supplementation on growth performance of pigs**

The growth patterns of weaned pigs offered ration supplemented with ascorbic acid are shown in Table 2. The results indicate that the total and daily feed intake (DFI) are significantly influenced ($p < 0.05$) by the diet. Pigs fed ascorbic acid at 2 g per kg diet (1.54 kg) had a higher DFI, while those on ascorbic acid at 1 g per kg diet (1.33 kg) had the lowest value. Observed feed intake was contrary to the findings of Zhao *et al*. (2002) on the effect of vitamin C supplement on the performance of weaned piglets, but corroborated the finding of Njoku *et al*. (2015), who restricted the feed intake of pigs and supplemented the diet with ascorbic acid. The authors reported an increase in feed intake as the level of ascorbic acid increased. This indicates that the inclusion of ascorbic acid stimulates palatability. The increased feed intake among the pigs offered ascorbic acid induced the stress ameliorating effect of vitamin C, because reduced stress will prompt feed consumption (Abidin and Khatoon, 2013).

**Effect of ascorbic acid supplementation on economic benefits of pigs**

Economic indices of weaned pigs fed ascorbic acid supplemented diet are shown in Table 3. Feed cost per kilogram (FC.kg$^{-1}$) in pigs kept on ascorbic acid at 3 g per kg (₦ 103.50) increased significantly ($p < 0.05$) compared to pigs kept on control diet (₦ 97.60). The observed result is similar to the observation of Ojediran *et al*. (2020), when an enzyme was added to the palm kernel based diet for weaned pigs. There was a linear increase in feed cost with increasing ascorbic acid dose across the diets. It was as a result of using the same feed formulation but added different levels of ascorbic acid. This indicates that addition of ascorbic acid to the feed increased the feed cost. Our results are in contradiction with the finding of Ojediran *et al*. (2021), when the dietary protein was reduced and supplemented with lysine. However, the addition of ascorbic acid up to 3 g per kg did not influence FC.kg$^{-1}$ weight gain, income, profit and economics of gain.

**Effect of ascorbic acid supplementation on haematological parameters of pigs**

Table 4 shows several haematological parameters of weaned pigs, such as red blood cell (RBC), haemoglobin (Hb), haematocrit (HCT), mean corpuscular volume (MCV) and lymphocytes were influenced by ascorbic acid supplementation ($p < 0.05$). In particular, pigs given ascorbic acid at 2 g per kg diet (8.18 x $10^6$ per µl) or 3 g per kg diet

**Table 2. Growth pattern of weaned pigs offered ration supplemented with ascorbic acid**

| Parameters | A | B | C | D | SEM | *P*-value |
|---|---|---|---|---|---|---|
| Initial weight (kg) | 12.43 | 12.28 | 12.33 | 12.23 | 0.59 | 1.00 |
| Final weight (kg) | 36.73 | 32.35 | 37.58 | 36.80 | 1.50 | 0.64 |
| Total weight gain (kg) | 24.30 | 20.08 | 25.25 | 24.58 | 1.10 | 0.36 |
| Daily weight gain (kg) | 0.50 | 0.41 | 0.52 | 0.50 | 0.28 | 0.36 |
| Daily feed intake (kg) | 1.43$^c$ | 1.33$^d$ | 1.54$^a$ | 1.48$^b$ | 0.02 | 0.01 |
| Feed conversion ratio | 2.90 | 3.47 | 3.03 | 3.02 | 0.15 | 0.58 |

$^{a, b, c, d}$ Means with different superscripts on the same row are significantly different ($p < 0.05$). A: basal diet (control); B: basal + ascorbic acid at 1 g.kg$^{-1}$ diet; C: basal + ascorbic acid at 2 g.kg$^{-1}$ diet; D: basal + ascorbic acid at 3 g.kg$^{-1}$ diet.
SEM: standard error of mean.

**Table 3. Economic indices of weaned pigs fed diet supplemented with ascorbic acid**

| Parameters | A | B | C | D | SEM | *P*-value |
|---|---|---|---|---|---|---|
| Feed cost.kg$^{-1}$ (₦) | 97.60$^{bc}$ | 99.80$^{bc}$ | 102.70$^{ab}$ | 103.50$^{a}$ | 0.75 | 0.01 |
| Feed cost.kg$^{-1}$ weight gain (₦) | 283.45 | 344.33 | 309.35 | 314.65 | 14.33 | 0.56 |
| Income.kg$^{-1}$ weight gain(₦) | 906.80 | 980.38 | 891.85 | 902.95 | 17.94 | 0.30 |
| Profit.kg$^{-1}$ weight gain (₦) | 623.40 | 636.02 | 582.53 | 588.30 | 15.70 | 0.60 |
| Economic efficiency of gain | 223.43 | 197.70 | 192.45 | 192.23 | 12.30 | 0.82 |

$^{a, b, c}$ Means with different superscripts on the same row are significantly different ($p < 0.05$). A: basal diet (control); B: basal + ascorbic acid at 1 g.kg$^{-1}$ diet; C: basal + ascorbic acid at 2 g.kg$^{-1}$ diet; D: basal + ascorbic acid at 3 g.kg$^{-1}$ diet. SEM: standard error of mean. (₦ = Naira; $1 = ₦ 420 and € 1 = 463.33 during period of feeding trial).

(6.73 x $10^6$ per µl) differed significantly in RBC counts. Moreover, the pigs offered diet with ascorbic acid at 2 g per kg (12.35 g per dl) had the highest Hb value, while those fed diet with ascorbic acid at 1 g per kg (11.25 g per dl) showed the lowest value ($p < 0.05$). HCT values for pigs given control diet (45.85 %) and ascorbic acid at 1 g per kg diet (46.05 %) were similar ($p > 0.05$), as was also observed for pigs on diets with ascorbic acid at 2 g per kg (50.65 %) and 3 g per kg (49.65 %). However, the pairs differ significantly ($p < 0.05$). MCV value for pigs offered diet with ascorbic acid at 2 g per kg (61.90 fl) significantly differed from those fed control (58.25 fl) and ascorbic acid at 1 g per kg (58.95 fl) diets. There was an increase in the lymphocyte value (60.90 – 70.30 x $10^3$ per µl$^{-1}$) as the ascorbic acid increased ($p < 0.05$). Haematological parameters can reveal the health status of pigs (Eze *et al.*, 2000); pigs with normal values showed good performance (Buzzard *et al.*, 2013) because they are within normal range for healthy pigs (Thorn, 2000). Observed haemoglobin, haematocrit and mean corpuscular volume values increased with increasing ascorbic acid, indicating that the pigs were not anaemic, as stated by Dlamini *et al*. (2017). Higher white blood cell (WBC) count indicates pneumonia and presence of parasites. Lymphocyte count indicates that antibody function or immunity of the animal was improved by ascorbic acid supplementation (Dlamini *et al.*, 2017; El-Senousey *et al.*, 2018) because ascorbic acid had been shown to stimulate immunoglobulin production (Zhao *et al.*, 2002).

**Table 4. Haematological parameters of weaned pigs offered ration supplemented with ascorbic acid**

| Parameters | A | B | C | D | SEM | *P*-value |
|---|---|---|---|---|---|---|
| White blood cell (x $10^3$.µl$^{-1}$) | 17.45 | 18.50 | 18.05 | 13.90 | 0.80 | 0.15 |
| Red blood cell (x $10^6$.µl$^{-1}$) | 7.89$^{ab}$ | 7.82$^{ab}$ | 8.18$^{a}$ | 6.73$^{b}$ | 0.22 | 0.04 |
| Haemoglobin (g.dl$^{-1}$) | 11.50$^{bc}$ | 11.25$^{c}$ | 12.35$^{a}$ | 12.00$^{ab}$ | 0.14 | 0.01 |
| Haematocrit (%) | 45.85$^{b}$ | 46.05$^{b}$ | 50.65$^{a}$ | 49.65$^{a}$ | 0.75 | 0.03 |
| Mean corpuscular volume (fl) | 58.25$^{b}$ | 58.95$^{b}$ | 61.90$^{a}$ | 60.30$^{ab}$ | 0.52 | 0.04 |
| Mean corpuscular haemoglobin (pg) | 14.65 | 14.40 | 15.10 | 14.60 | 0.13 | 0.29 |
| MCHC (g.dl$^{-1}$) | 25.05 | 24.45 | 24.40 | 24.25 | 0.15 | 0.25 |
| Platelets (x $10^3$.µl$^{-1}$) | 345.00 | 420.00 | 391.00 | 402.50 | 16.92 | 0.49 |
| Lymphocytes (x $10^3$.µl$^{-1}$) | 60.90$^{bc}$ | 58.20$^{c}$ | 64.50$^{b}$ | 70.30$^{a}$ | 1.32 | 0.00 |

$^{a, b, c}$ Means with different superscripts on the same row are significantly different ($p < 0.05$). A: basal diet (control); B: basal + ascorbic acid at 1 g.kg$^{-1}$ diet; C: basal + ascorbic acid at 2 g.kg$^{-1}$ diet; D: basal + ascorbic acid at 3 g.kg$^{-1}$ diet. MCHC = mean corpuscular haemoglobin concentration. SEM = Standard error of mean.

**Effect of ascorbic acid supplementation on serum biochemistry of pigs**

Table 5 shows the serum biochemistry of weaned pigs offered ration supplemented with ascorbic acid. Cholesterol, triglyceride, high-density lipoprotein (HDL), low-density lipoprotein (LDL), alanine transaminase (ALT), glucose, creatinine, urea, total protein, albumin, and globulin differ significantly ($p < 0.05$), unlike aspartate aminotransferase and alkaline phosphatase ($p > 0.05$). The cholesterol content increased ($p < 0.05$) from 90.65 $mg.dl^{-1}$ in pigs fed the control diet to 151.58 $mg.dl^{-1}$ in ascorbic acid supplemented group at 3 $g.kg^{-1}$ diet. Pigs fed control diet (103.07 mg per dl) and those given ascorbic acid at 2 $g.kg^{-1}$ (124.80 $mg.dl^{-1}$) diet were not different ($p > 0.05$). However, they differed in triglyceride content from pigs offered ascorbic acid at 3 $g.kg^{-1}$ diet (169.14 $mg.dl^{-1}$). This trend was similar also for LDL. HDL values in diets with ascorbic acid at 1 $g.kg^{-1}$ diet (41.08 $mg.dl^{-1}$) and 2 $g.kg^{-1}$ diet (42.13 $mg.dl^{-1}$) ($p > 0.05$) were higher, while those on other diets were lower. The ALT increased significantly ($p < 0.05$) in pigs fed ascorbic acid at 1 $g.kg^{-1}$ diet (59.70 $U.l^{-1}$) while those given other diets recorded lower values. Glucose level in pigs offered ascorbic acid at 2 $g.kg^{-1}$ (50.07 $mg.dl^{-1}$) was significantly lower compared to higher value recorded in pigs given other diets (69.42-76.08 $mg.dl^{-1}$). This trend was similar for creatinine. The urea, total protein and globulin increased as the ascorbic acid increased ($p < 0.05$) across the dietary groups. This study shows that vitamin C support the synthesis of fat, triglyceride and LDL in weaned pigs. This can also be observed in the abdominal fat and back fat thickness (Table 6). Cholesterol level is a subject to feed type consumed, while triglyceride are energy fatty acid chains providing fuel for cell activities (Yue *et al*., 2015). He *et al*. (2004) found a relationship between heart disease and elevated cholesterol and triglyceride levels. This study observed a positive relationship between triglyceride and LDL levels, unlike HDL, as stated by Rauw *et al*. (2004) in pigs. Navab *et al*. (2011) stated that HDL can promote reverse cholesterol path through anti-atherogenic effect influencing foam cell formation. ALT, being liver serum marker, was elevated in feeds with ascorbic acid, thus, suggesting liver impairment, as observed by Unigwe *et al*. (2018). Glucose value peaked at the highest level of ascorbic acid supplementation. This corroborated with the findings of Hancock and Viola (2002) and Vandamme and Revuelta (2016), that ascorbic acid can be produced from glucose industrially. The urea and creatinine levels in this study showed that ascorbic acid did not affect the kidney functions, as reported by Adesehinwa (2007), which implied

**Table 5. Serum biochemistry of weaned pigs offered ration supplemented with ascorbic acid**

| Parameters | A | B | C | D | SEM | *P*-value |
|---|---|---|---|---|---|---|
| Cholesterol ($mg.dl^{-1}$) | $90.65^{c}$ | $100.84^{bc}$ | $110.18^{b}$ | $151.58^{a}$ | 6.39 | 0.00 |
| Triglyceride ($mg.dl^{-1}$) | $103.07^{b}$ | $111.13^{b}$ | $124.80^{b}$ | $169.14^{a}$ | 8.25 | 0.01 |
| High-density lipoprotein ($mg.dl^{-1}$) | $23.23^{b}$ | $41.08^{a}$ | $42.13^{a}$ | $30.95^{b}$ | 2.35 | 0.01 |
| Low-density lipoprotein ($mg.dl^{-1}$) | $46.80^{b}$ | $37.54^{b}$ | $43.10^{b}$ | $86.81^{a}$ | 5.29 | 0.00 |
| Aspartate aminotransferase ($U.l^{-1}$) | 121.05 | 94.74 | 96.71 | 108.16 | 11.12 | 0.86 |
| Alanine aminotransaminase ($U.l^{-1}$) | $40.08^{b}$ | $59.70^{a}$ | $43.00^{b}$ | $45.36^{b}$ | 2.30 | 0.01 |
| Alkaline phosphatase ($U.l^{-1}$) | 43.18 | 41.94 | 43.78 | 42.84 | 0.38 | 0.42 |
| Glucose ($mg.dl^{-1}$) | $69.42^{a}$ | $70.57^{a}$ | $50.07^{b}$ | $76.08^{a}$ | 3.70 | 0.04 |
| Creatinine ($mg.dl^{-1}$) | $0.69^{b}$ | $1.47^{a}$ | $0.63^{b}$ | $1.47^{a}$ | 0.14 | 0.02 |
| Urea ($mmol.dl^{-1}$) | $1.65^{b}$ | $1.94^{ab}$ | $1.76^{ab}$ | $2.22^{a}$ | 0.08 | 0.04 |
| Total Protein ($g.dl^{-1}$) | $4.14^{c}$ | $4.85^{b}$ | $4.83^{b}$ | $5.99^{a}$ | 0.19 | 0.00 |
| Albumin ($g.dl^{-1}$) | $3.14^{b}$ | $3.18^{a}$ | $3.14^{ab}$ | $3.11^{b}$ | 0.01 | 0.05 |
| Globulin ($g.dl^{-1}$) | $1.01^{c}$ | $1.67^{b}$ | $1.70^{b}$ | $2.88^{a}$ | 0.19 | 0.00 |

$^{a, b, c}$ Means with different superscripts on the same row are significantly different ($p < 0.05$). A: basal diet (control); B: basal + ascorbic acid at 1 $g.kg^{-1}$ diet; C: basal + ascorbic acid at 2 $g.kg^{-1}$ diet; D: basal + ascorbic acid at 3 $g.kg^{-1}$ diet.
SEM = Standard error of mean.

that there were no muscular wastage as the feeds were well utilized. Total protein and globulin level ratio reflects protein quality. Caprarulo *et al*. (2020) revealed that albumin level is a predictor of growth response in pigs.

**Effect of ascorbic acid supplementation on carcass characteristics of pigs**

Carcass characteristics of weaned pigs offered diet supplemented with ascorbic acid are presented in Table 6. The result showed that all parameters differ significantly ($p < 0.05$) except buston butt and loin. The bled weight increased in pigs offered diets supplemented with ascorbic acid (94.62 – 95.17 %) compared to those fed control diet (92.50 %; $p < 0.05$). This was similar to the observation on carcass weight, abdominal and back fat, whole and empty stomach. The eviscerated weight was not significantly different in pigs fed control (68.78 %) and ascorbic acid at 2 $g.kg^{-1}$ (68.34 ) diets ($p > 0.05$), but were different from pigs fed other diets (70.19 – 71.93 %; $p < 0.05$). Values obtained for gastro-intestinal tract, trotters, head, jowl, picnic shoulder and ham ($p < 0.05$) showed no definite pattern across the diets. The weight of the belly ranged from 6.16 % in the pigs fed control diet to 9.66 % in pigs offered ascorbic acid at 2 $g.kg^{-1}$. This study shows that ascorbic acid supplementation improved the bleed weight, eviscerated weight, carcass weight, belly, abdominal fat, back fat and stomach weight in contrast to the result of O'Shea *et al*. (2014) and Choe *et al*. (2017) on enzyme supplementation. Our results suggest that ascorbic acid may influence protein accretion in weaned pigs. Observed increase in belly weight in pigs fed diet supplemented with ascorbic acid could be attributed to the elastic nature of stomach and belly but the result on feed intake in this study cannot be said to be responsible. This also could be the reason why the stomach both full or empty showed significant increase as the ascorbic acid supplementation increased across the dietary groups. The observed cholesterol and triglycerides in blood serum in this study confirmed an increase in the abdominal and back fat in diets with ascorbic acid.

**Table 6. Carcass characteristics of weaned pigs offered diet supplemented with ascorbic acid (as % of live weight)**

| Parameters | A | B | C | D | SEM | *P*-value |
|---|---|---|---|---|---|---|
| Live weight (kg) | $33.30^{a}$ | $29.40^{b}$ | $33.15^{a}$ | $35.05^{a}$ | 0.66 | 0.04 |
| Bled weight | $92.50^{b}$ | $94.90^{a}$ | $95.17^{a}$ | $94.62^{a}$ | 0.29 | 0.00 |
| Eviscerated weight | $68.78^{c}$ | $71.93^{a}$ | $68.34^{c}$ | $70.19^{b}$ | 0.43 | 0.01 |
| Carcass weight | $52.70^{b}$ | $54.21^{ab}$ | $53.12^{ab}$ | $55.57^{a}$ | 0.46 | 0.00 |
| Gastro-intestinal tract | $22.67^{ab}$ | $21.26^{b}$ | $24.26^{a}$ | $21.73^{b}$ | 0.38 | 0.01 |
| Trotters | $1.65^{b}$ | $1.87^{a}$ | $1.66^{b}$ | $1.32^{c}$ | 0.06 | 0.00 |
| Head | $8.25^{b}$ | $9.37^{a}$ | $6.54^{b}$ | $8.78^{a}$ | 0.38 | 0.03 |
| Jowl | $3.16^{b}$ | $2.55^{bc}$ | $3.61^{a}$ | $2.35^{c}$ | 0.16 | 0.01 |
| Picnic shoulder | $9.76^{b}$ | $11.04^{a}$ | $9.67^{b}$ | $10.35^{ab}$ | 0.20 | 0.04 |
| Buston butt | 4.66 | 4.93 | 4.96 | 5.01 | 0.09 | 0.56 |
| Loin | 6.92 | 6.78 | 7.39 | 7.09 | 0.15 | 0.54 |
| Sirloin | $7.07^{b}$ | $7.82^{a}$ | $6.85^{b}$ | $6.60^{b}$ | 0.16 | 0.01 |
| Belly | $6.16^{c}$ | $7.48^{b}$ | $7.95^{b}$ | $9.66^{a}$ | 0.38 | 0.01 |
| Ham | $15.92^{b}$ | $18.16^{a}$ | $15.42^{b}$ | $16.55^{ab}$ | 0.39 | 0.04 |
| Abdominal fat | $0.26^{b}$ | $0.47^{ab}$ | $0.67^{a}$ | $0.54^{ab}$ | 0.06 | 0.04 |
| Back fat (cm) | $0.55^{b}$ | $0.60^{a}$ | $0.60^{a}$ | $0.60^{a}$ | 0.01 | 0.05 |
| Whole stomach | $1.70^{b}$ | $2.27^{ab}$ | $2.94^{a}$ | $2.76^{a}$ | 0.16 | 0.01 |
| Empty stomach | $0.68^{b}$ | $0.84^{ab}$ | $0.99^{a}$ | $0.98^{a}$ | 0.04 | 0.01 |

[a, b, c] Means with different superscripts on the same row are significantly different ($p < 0.05$). A: basal diet (control); B: basal + ascorbic acid at 1 $g.kg^{-1}$ diet; C: basal + ascorbic acid at 2 $g.kg^{-1}$ diet; D: basal + ascorbic acid at 3 $g.kg^{-1}$ diet.
SEM = Standard error of mean.

## CONCLUSION

Our study shows that ascorbic acid supplementation in the diet of pigs from 1 g.kg$^{-1}$ to 3 g.kg$^{-1}$ had no deleterious impact on growth performance; although it increased the feed cost, however did not have negative impact on other economic indices. The haematological parameters indicated improved health status of the pigs. This feeding trial showed that including up to 3 g.kg$^{-1}$ of dietary vitamin C into the diet for pigs is a potent tool to improve the carcass weight. Moreover, ascorbic acid supplementation stimulates the synthesis of cholesterol and fat, which is needed in the lard production.

### *AUTHOR CONTRIBUTIONS*

Conceptualization: Ojediran, T. K., Emiola, I. A.

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Investigation: Ojediran, T. K., Ajewole, T. M., Taiwo, O., Emiola, I. A.

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All authors have read and agreed to the published version of the manuscript.

### *INFORMED CONSENT STATEMENT*

Not applicable.

### *DATA AVAILABILITY STATEMENT*

The data presented in this study are available on request from the corresponding author.

### *CONFLICTS OF INTEREST*

The authors declare no conflict of interest.

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