Evidence of the Impact of Activated Charcoal on the Availability of Hydrogen Cyanide in Cassava Root Meal Diets of Growing Pigs

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Abstract— The impact of activated charcoal on the availability of hydrogen cyanide in cassava root meal diets of growing pigs was examined using Large White x Landrace crosses (n=32, age = 16 weeks, $\bar{x} = 27.32\pm0.24$ kg) assigned to eight groups with four pigs per group, and each pig was a replicate. Two sets of four diets were formulated. Maize was replaced with cassava root meal (CRM) at 0, 25, 50 and 75% in both sets but the first set had no activated charcoal while the next set of four diets had activated charcoal (AC) at 40g/kg as a supplement per diet. The experiment was a 2 x 4 factorial arrangement in a completely randomized design. The result indicated that the interaction effect differs significantly (p< 0.05) for Daily Feed Intake (DFI), and Hydrogen Cyanide (HCN) intake. Diets with Activated Charcoal Supplementation (ACS) were significant (p<0.05) with higher feed intake (1.50 vs 1.61 kg/d) and hydrogen cyanide (15.29 vs 16.60 mg/kg) intake. Crude protein, ether extract, crude fibre, ash, nitrogen-free extract and hydrogen cyanide digestibility showed significant (p<0.05) effects of the interactions. Charcoal supplementation significantly (p<0.05) improved hydrogen cyanide digestibility (57.98 vs 68.17 %) while those of crude protein (62.83 vs 60.88 %) and ether extract (91.52 vs 89.73 %) were significantly (p<0.05) depressed. Grower pigs fed 0, 25, 50 and 75% CRM without activated charcoal supplementation had significant (p<0.05) dissimilarity in cyanide degradability in the stomach, caecum and the small intestine. In the stomach and caecum the values were higher at 75% CRM level whereas in the large intestine, it was at 50% CRM level. Significant (p<0.05) differences existed in the cyanide degradability in all segments with activated charcoal supplementation. It can be concluded that grower pigs could tolerate up to 75% cassava root-based diets as a replacement for maize with or without activated charcoal supplementation. The hydrogen cyanide content of cassava root meal that imposed limitations on the use of the meal in diets of pigs could be overcome by supplementing with activated charcoal for increased degradability in the stomach and caecum.

Keywords— Activated charcoal, Cyanide, Hydrogen cyanide, Cassava tuber, Swine.
I. INTRODUCTION

Activated charcoal is a fire-black form of carbon, odourless and tasteless granules or powder with increased surface area (Olayeni et al., 2023, 2024) for absorption of many toxins, gases, and drugs (Kutlu et al. 2002). It has been reported to enhance the intake of poisonous plants (Poage et al., 2000). It is an insoluble, non-specific molecule absorbent (Olayeni et al., 2023) preventing their absorption in the gastrointestinal tract. Choi et al. (2009) observed that wood vinegar enhanced growth indices, nutrient absorption and inhibition of coliforms when added to weaned pigs’ diet. Olayeni et al., (2024) also established the potential of activated charcoal to lower bioavailability of hydrogen cyanide in pig diet.

Cassava is rich in calories and in excellent energy source (Ojediran et al., 2022, 2023). Cassava use as feedstuff has been inhibited by the existence of inherent cyanogenic glycosides, hydrogen cyanide (Esonu, 2006, Udedibie et al., 2008). Various methods have been used singly or in combination to reduce the cyanide level. These include peeling, chopping, grating, soaking, drying, boiling, or fermenting (Chandrasekara and Kumar, 2016). These cultural methods lower the degree of the cyanide depending on the method applied, duration or the combination, increase nutritive value, and transform the perishable tubers into a stable material (Ojediran et al., 2024).

Olayeni et al., (2023) demonstrated that the addition of activated charcoal, a non-nutritive adsorptive material to diets decreased the absorption of HCN from the GIT. This would add to a variety of physical and chemical techniques that had been employed to detoxify cassava. About 86% free HCN can be lost to sun drying because it can vaporize at about 280°C, however, bound cyanide is more stable and contributes more to cyanide toxicity (Gomez et al., 1984).

Therefore, this study was aimed at assessing the impact of activated charcoal on the availability of hydrogen cyanide in cassava tuber meal in the diets of weaner-growing pigs and the effects on growth performance, nutrient digestibility, and cyanide degradability in various segments of the GIT).

II. MATERIALS AND METHODS

Location

The Ladoke Akintola University of Technology Teaching and Research Farm Piggery unit is situated in the derived savannah zone, between 8° 069’N and 8° 118’N and 4° 039’E and 4° 147’E with an average annual rainfall, temperature, humidity and altitude of 1248mm and 26.3 ° C, 85% and 501m respectively (Ojediran et al. 2020).

Cassava root meal and Activated charcoal (test materials)

Fresh cassava sweet variant (TMS 3052) and activated charcoal were procured locally. The cassava roots were washed, chopped, and sun-dried until constant weight was attained. The chips were hammer-milled to derive cassava root meal (CRM) (Olayeni et al., 2023).

Preparation of experimental diets

Two sets of four diets were formulated. Maize was replaced with cassava root meal (CRM) at 0, 25, 50 and 75% in both sets but the first set had no activated charcoal while the next set of four diets had activated charcoal (AC) at 40g/kg diet as a supplement. The experiment was a 2 x 4 factorial arrangement in a completely-randomised-design (Table1)

<table>
<thead>
<tr>
<th>Ingredients (%)</th>
<th>1(0%)</th>
<th>2(25%)</th>
<th>3(50%)</th>
<th>4(75%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>55.00</td>
<td>41.25</td>
<td>27.50</td>
<td>13.75</td>
</tr>
<tr>
<td>Cassava RM</td>
<td>0.00</td>
<td>13.75</td>
<td>27.50</td>
<td>41.25</td>
</tr>
<tr>
<td>Soybean meal</td>
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<td>24.00</td>
<td>24.00</td>
<td>24.00</td>
</tr>
<tr>
<td>Fish meal</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Blood meal</td>
<td>3.25</td>
<td>4.25</td>
<td>5.25</td>
<td>6.25</td>
</tr>
<tr>
<td>Wheat offal</td>
<td>10.00</td>
<td>9.00</td>
<td>8.00</td>
<td>7.00</td>
</tr>
<tr>
<td>Bone meal</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Oyster shell</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
</tr>
<tr>
<td>Salt</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>5%Premix</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
</tbody>
</table>

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**RM – Root Meal, A. - Activated**

* Each kg feed contained: Vit. A, 1500IU; A, 1500IU; Vit. 2, 500IU; Vit B3 40mg; Vit B6, 20mg; Chlorine chloride, 400mg; Mn 120mg; Fe 70mg; Cu 100mg; I 2.2m Se 0.2mg; Zn 45mg; Co 0.02mg.

**Experimental animals and management**

Thirty-two weaned pigs (Large White-Landrace crossbred, age = 8 weeks) were assigned to eight groups with four pigs per group, and each pig was a replicate. A set of four diets formulated, contained cassava root meal (CRM) at 0, 25, 50 and 75% replacing maize such that they were without activated charcoal while the next set of four diets had activated charcoal (AC) at 40g/kg diet as a supplement. Each pig was housed in a pen measuring 0.46m x 0.9m with a concrete floor. They were acclimatised for a week. Feed and water were supplied ad libitum.

**Experimental design**

The experiment was a 2 x 4 factorial arrangement in a completely randomised design.

**Data Collection**

**Feed intake:** From the weighed quantity of feed supplied, left-over were collected on a daily basis to determine the feed intake.

**Weight gain:** The weekly weight gains were estimated by deducting the previous week’s weight from the present week’s weight.

**Daily weight gain:** This was determined by dividing the total weight gain by the number of days the animals were placed on the experiment.

**Feed to gain Ratio:** This is a measure of the efficiency of feed utilization by the pigs obtained by dividing the total feed intake by the total weight gained.

**Cyanide Intake:** This was determined using the analysed cyanide in the feed to multiply the total feed consumed.

**Sample collection and handling**

**Nutrient Digestibility**

At the end of the 8th week of the experiment, the four animals per group were housed individually in metabolic cages. Each pig also had access to an individual feeder and drinker. The animals were fed *ad libitum* for three days for acclimatization. Faecal samples were collected from the animals for 5 days. The fresh samples for each day were weighed and oven-dried at 105°C for 24 hours. Faecal samples collected from animals on each treatment were bulked and milled, and sub-samples for each group were stored for proximate analysis.

**Hydrogen cyanide degradability in various segments of GIT/digesta collection**

The whole lengths of the digestive tracts of slaughtered animals were removed for GIT sampling. Samples of digesta were collected from the stomach, caecum, and the middle part of the large intestine for analysis.

**Proximate analysis**

Sample of the cassava root meal (CRM), experimental diets, faecal samples as well as digesta from different segments of the gastro-intestinal tract (GIT) were analysed to determine the proximate composition by the
standard methods of AOAC (1990). The cyanide levels of the experimental diets, CRM and the digesta were determined using the procedure described by Bradbury et al. (1999) and Egan et al. (1998).

**Statistical analysis**

All data generated were subjected to statistical analysis of variance (ANOVA) using 2 x 4 factorial in a completely randomized design of SAS (2000) and where significant differences were observed in the means they were compared using Duncan’s Multiple Range Test of the same statistical software (Duncan, 1955).

### III. RESULTS

**Growth performance**

Table 2 shows the treatment effect of dietary cassava root meal on the growth performance of grower pigs. Cassava root meal level had no significant (p>0.05) effect on final live weight, weight gain/ day and feed gain ratio. Feed and hydrogen cyanide intake were significantly (p<0.05) affected by the CRM level. Hydrogen cyanide intake significantly (P<0.05) increased from the control to 75% CRM level.

The effect of activated charcoal supplementation on the growth performance of grower pigs fed CRM is shown in Table 3. Only the feed intake and hydrogen cyanide intake were significantly (p<0.05) affected. Activated charcoal supplementation significantly (p<0.05) increased the feed intake and hydrogen cyanide intake from 1.50 to 1.61kg and 15.29g to 16.60mg/kg respectively.

Table 4 shows the interaction effect of CRM and activated charcoal supplementation on the growth performance of grower pigs. Final live weight, weight gain per day and feed- to- gain ratio for grower pigs fed 0, 25,50 and 75% CRM without activated charcoal supplementation were not significantly (P>0.05) different when compared with activated charcoal supplementation. However, feed and hydrogen cyanide intake showed significant (P<0.05) interaction effect. At the supplementation level, feed intake was significantly (p<0.05) encouraged although not linearly at various inclusion levels of CRM. Activated charcoal supplementation increased both the feed intake and hydrogen cyanide intake at 25 and 75% CRM levels.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>0% CRM</th>
<th>25% CRM</th>
<th>50% CRM</th>
<th>75% CRM</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial weight (kg)</td>
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<td>27.16</td>
<td>27.16</td>
<td>27.50</td>
<td>2.50</td>
</tr>
<tr>
<td>Final weight (kg)</td>
<td>50.55</td>
<td>51.16</td>
<td>50.50</td>
<td>51.94</td>
<td>1.27</td>
</tr>
<tr>
<td>Daily weight gain (kg/day)</td>
<td>0.42</td>
<td>0.44</td>
<td>0.40</td>
<td>0.44</td>
<td>0.02</td>
</tr>
<tr>
<td>Feed intake (kg/day)</td>
<td>1.55ab</td>
<td>1.63a</td>
<td>1.47b</td>
<td>1.56ab</td>
<td>0.04</td>
</tr>
<tr>
<td>Feed/ gain ratio</td>
<td>3.73</td>
<td>3.78</td>
<td>3.68</td>
<td>3.65</td>
<td>0.19</td>
</tr>
<tr>
<td>HCN intake (mg/kg)</td>
<td>0.00d</td>
<td>11.20c</td>
<td>20.28b</td>
<td>32.30a</td>
<td>0.23</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameters</th>
<th>-</th>
<th>+</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial weight (kg)</td>
<td>27.18</td>
<td>27.42</td>
<td>0.18</td>
</tr>
<tr>
<td>Final weight (kg)</td>
<td>51.19</td>
<td>50.89</td>
<td>0.78</td>
</tr>
<tr>
<td>Daily weight gain (kg/day)</td>
<td>0.43</td>
<td>0.42</td>
<td>0.02</td>
</tr>
<tr>
<td>Feed intake (kg/day)</td>
<td>1.50b</td>
<td>1.61a</td>
<td>0.03</td>
</tr>
<tr>
<td>Feed/ gain ratio</td>
<td>3.55</td>
<td>3.87</td>
<td>0.13</td>
</tr>
<tr>
<td>HCN intake (mg/kg)</td>
<td>15.29b</td>
<td>16.60c</td>
<td>3.07</td>
</tr>
</tbody>
</table>

ab: Means in the same row with different superscripts differ significantly (p<0.05)
Table 4: Interaction effects of cassava root meal and activated charcoal on the growth performance of grower pigs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Charcoal supplementation</th>
<th>% CRM</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>Initial weight (kg)</td>
<td>-</td>
<td>27.25</td>
<td>27.00</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>27.50</td>
<td>27.31</td>
</tr>
<tr>
<td></td>
<td>SEM</td>
<td>0.25</td>
<td>0.24</td>
</tr>
<tr>
<td>Final liveweight (kg)</td>
<td>-</td>
<td>51.00</td>
<td>50.50</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>50.10</td>
<td>50.82</td>
</tr>
<tr>
<td></td>
<td>SEM</td>
<td>0.85</td>
<td>2.06</td>
</tr>
<tr>
<td>Daily weight gain (kg/day)</td>
<td>-</td>
<td>0.43</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>0.41</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>SEM</td>
<td>0.02</td>
<td>0.04</td>
</tr>
<tr>
<td>Feed intake (kg/day)</td>
<td>-</td>
<td>1.51</td>
<td>1.53</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>1.59</td>
<td>1.73</td>
</tr>
<tr>
<td></td>
<td>SEM</td>
<td>0.08</td>
<td>0.03</td>
</tr>
<tr>
<td>Feed /gain ratio</td>
<td>-</td>
<td>3.53</td>
<td>3.40</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>3.94</td>
<td>4.17</td>
</tr>
<tr>
<td></td>
<td>SEM</td>
<td>0.19</td>
<td>0.31</td>
</tr>
<tr>
<td>HCN intake (mg/kg)</td>
<td>-</td>
<td>0.00</td>
<td>10.51</td>
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<tr>
<td></td>
<td>+</td>
<td>0.04</td>
<td>11.89</td>
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<tr>
<td></td>
<td>SEM</td>
<td>0.00</td>
<td>0.19</td>
</tr>
</tbody>
</table>

abcd Means in the same row with different superscripts differ significantly (P<0.05)
xy: Means along the same column with different superscripts differ significantly (P<0.05)

- : Non – charcoal supplementation
+ : Charcoal supplementation

Nutrient Digestibility

The effects of cassava root meal level on the nutrient digestibility of grower pigs is presented in Table 5. Crude protein, crude fibre, ash, nitrogen-free extract and hydrogen cyanide digestibility were significantly (p<0.05) influenced by the cassava root meal level, while ether extract was similar (p>0.05) at all levels of CRM. Crude fibre digestibility for the control did not differ (p>0.05) from that of 75% CRM level, while that of 25 and 50% CRM were similar. Nitrogen free extract digestibility significantly (p<0.05) decreased in pigs fed 25% CRM but significantly increased in 50% which is similar to that of 75% CRM. Hydrogen cyanide digestibility significantly (p<0.05) increased as the level of CRM increased.

Table 6 shows the supplementation effect of activated charcoal on the nutrient digestibility of grower pigs. Crude protein, ether extract and hydrogen cyanide digestibility were significantly (p<0.05) affected by activated charcoal supplementation.

Charcoal supplementation significantly (p<0.05) improved hydrogen cyanide digestibility while those of crude protein and ether extract were significantly (p<0.05) depressed. Crude fibre, ash and nitrogen-free extract digestibility were similar.

The interaction effect of CRM and activated charcoal supplementation on the nutrient digestibility of grower pigs is presented in Table 7. Crude protein, ether extract, crude fibre, ash, nitrogen-free extract and hydrogen cyanide digestibility showed significant (p<0.05) effects of the interactions. Crude protein digestibility for the grower pigs fed 25, 50 and 75% CRM without charcoal supplementation did not differ but were significantly (p<0.05) reduced when compared with the control diet. However, those that were supplemented had similar values at 25 and 50% CRM levels which were significantly (p<0.05) lower to those of the control and 75% CRM that are similar. Charcoal supplementation significantly (p<0.05) reduced the crude protein digestibility at
0 and 25% CRM. Ether extract digestibility for charcoal and non-charcoal supplementations was not significantly (p>0.05) different at various levels of CRM. Crude fibre digestibility was highest (p<0.05) at 50% CRM level with and without charcoal supplementation. The digestibility of ash was not affected by supplementation of various CRM levels. Digestibility of nitrogen-free extract followed a similar trend to that of ash except that for charcoal supplementation, digestibility significantly (p<0.05) improved at 75% CRM level.

Hydrogen cyanide digestibility significantly (p<0.05) increased as CRM level increased both with and without charcoal supplementation.

| Table 5: Treatment effect of dietary CRM on the nutrient digestibility of grower pigs. |
|----------------------------------|---------|---------|---------|---------|---------|
| Nutrient (%)                     | 0       | 25      | 50      | 75      | SEM     |
| Crude protein                    | 71.54<sup>a</sup> | 52.18<sup>b</sup> | 52.85<sup>b</sup> | 70.85<sup>a</sup> | 0.40    |
| Ether extract                    | 90.78   | 89.94   | 90.93   | 90.85   | 0.48    |
| Crude fibre                      | 70.39<sup>b</sup> | 42.44<sup>c</sup> | 82.63<sup>a</sup> | 26.11<sup>d</sup> | 0.62    |
| Ash                              | 18.72   | 31.38<sup>ab</sup> | 26.51<sup>b</sup> | 35.98<sup>b</sup> | 2.10    |
| Nitrogen free extract            | 62.19<sup>b</sup> | 54.75<sup>c</sup> | 71.22<sup>a</sup> | 72.72<sup>a</sup> | 1.01    |
| HCN                              | 0.00<sup>d</sup> | 75.68<sup>c</sup> | 82.95<sup>b</sup> | 96.67<sup>a</sup> | 0.76    |

<sup>abc</sup>: Means in the same row with different superscripts differ significantly (P<0.05)

| Table 6: Supplementation effects of activated charcoal on the nutrient digestibility of grower pigs. |
|----------------------------------|---------|---------|---------|---------|---------|
| Nutrient (%)                     | -       | +       | SEM     |
| Crude protein                    | 62.83<sup>a</sup> | 60.88<sup>b</sup> | 2.43    |
| Ether extract                    | 91.52<sup>a</sup> | 89.73<sup>b</sup> | 0.33    |
| Crude fibre                      | 55.92   | 54.86   | 5.63    |
| Ash                              | 28.79   | 27.51   | 2.12    |
| Nitrogen free extract            | 64.43   | 66.02   | 1.99    |
| HCN                              | 57.98<sup>b</sup> | 68.17<sup>a</sup> | 9.60    |

<sup>ab</sup>: Means in the same row with different superscripts differ significantly (P<0.05)

+ : Charcoal supplementation
- : Non – charcoal supplementation

| Table 7: Interaction effects of CRM and activated charcoal supplementation on the nutrient digestibility of grower pigs. |
|----------------------------------|---------|---------|---------|---------|---------|
| Nutrient (%)                     | Charcoal Supplementation | 0       | 25      | 50      | 75      | SEM     |
| Crude protein                    | -       | 72.60<sup>x</sup> | 53.36<sup>x</sup> | 53.66<sup>x</sup> | 71.70<sup>x</sup> | 0.64    |
|                                | +       | 70.48<sup>y</sup> | 51.00<sup>y</sup> | 52.03<sup>y</sup> | 70.00<sup>y</sup> | 0.55    |
|                                | SEM     | 0.47<sup>x</sup> | 0.55<sup>x</sup> | 0.66<sup,x</sup> | 0.55<sup,x</sup> |
| Ether extract                    | -       | 91.97<sup>x</sup> | 90.91<sup>x</sup> | 91.70<sup>x</sup> | 91.52<sup>x</sup> | 0.52    |
|                                | +       | 89.60<sup>x</sup> | 88.97<sup>x</sup> | 90.16<sup,x</sup> | 90.18<sup,x</sup> | 0.64    |
|                                | SEM     | 0.63<sup>x</sup> | 0.26<sup,x</sup> | 0.30<sup,x</sup> | 0.78<sup,x</sup> |
| Crude fibre                      | -       | 71.44<sup>ab</sup> | 43.24<sup>c</sup> | 83.51<sup>a</sup> | 25.47<sup>d</sup> | 0.88    |
|                                | +       | 69.33<sup>bc</sup> | 41.63<sup>c</sup> | 81.74<sup>a</sup> | 26.74<sup>d</sup> | 0.75    |
|                                | SEM     | 0.41<sup>x</sup> | 0.66<sup,x</sup> | 0.97<sup,x</sup> | 1.23<sup,x</sup> |
| Ash                              | -       | 18.96<sup>x</sup> | 32.35<sup>ab</sup> | 26.91<sup>bc</sup> | 36.92<sup>a</sup> | 2.36    |
|                                | +       | 18.49<sup>y</sup> | 30.41<sup>a</sup> | 26.11<sup>ab</sup> | 35.03<sup>y</sup> | 2.18    |
|                                | SEM     | 1.78<sup>x</sup> | 1.12<sup,x</sup> | 5.51<sup,x</sup> | 0.67<sup,x</sup> |
| Nitrogen free extract            | -       | 61.57<sup>x</sup> | 53.72<sup>c</sup> | 70.80<sup>y</sup> | 71.63<sup>xy</sup> | 0.94    |
|                                | +       | 62.82<sup>y</sup> | 55.97<sup>c</sup> | 71.64<sup>y</sup> | 73.82<sup>xy</sup> | 1.29    |

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Cyanide digestibility in various segments of the GIT of grower pigs

The effect of dietary cassava root meal on the cyanide degradability at the various segments of GIT is presented in Table 8. Cyanide degradability in the stomach, caecum and large intestine were significantly (p<0.05) affected by the CRM levels. Cyanide degradability significantly (p< 0.05) increased as CRM level increased in the GIT segments, with highest values obtained at 75% CRM level in both the stomach and caecum but at 50% CRM level in the large intestine.

Table 9 shows the supplementation effects of activated charcoal on the cyanide degradability at various segments of the GIT of grower pigs. Cyanide degradability was not significantly (p>0.05) affected by charcoal supplementation in the stomach, caecum and large intestine.

Table 10 shows the interaction effect of CRM and activated charcoal supplementation on the cyanide degradability at various segments of GIT of grower pigs. Grower pigs fed 0, 25, 50 and 75% CRM without activated charcoal supplementation had significant (p<0.05) dissimilarity in cyanide degradability in all segments under consideration.

In the stomach and caecum the values were higher at 75% CRM level whereas in the large intestine, it was at 50% CRM level. Significant (p<0.05) differences existed in the cyanide degradability in all segments with activated charcoal supplementation. The presentation is similar to what happened without activated charcoal supplementation. Activated charcoal supplementation significantly (p<0.05) affected cyanide degradability only in the caecum and large intestine at 50% and 75% CRM levels.

Table 8: Treatment effect of CRM diets on the cyanide digestibility at various segments of GIT of grower pigs.

<table>
<thead>
<tr>
<th>Parameters (%)</th>
<th>0</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stomach</td>
<td>0.00&lt;sup&gt;d&lt;/sup&gt;</td>
<td>28.58&lt;sup&gt;c&lt;/sup&gt;</td>
<td>31.64&lt;sup&gt;b&lt;/sup&gt;</td>
<td>61.27&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.13</td>
</tr>
<tr>
<td>Caecum</td>
<td>0.00&lt;sup&gt;d&lt;/sup&gt;</td>
<td>16.67&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14.96&lt;sup&gt;c&lt;/sup&gt;</td>
<td>22.88&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.09</td>
</tr>
<tr>
<td>Large intestine</td>
<td>0.00&lt;sup&gt;d&lt;/sup&gt;</td>
<td>41.69&lt;sup&gt;b&lt;/sup&gt;</td>
<td>76.61&lt;sup&gt;a&lt;/sup&gt;</td>
<td>21.83&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.14</td>
</tr>
</tbody>
</table>

<sup>abcd</sup>: Means in the same row with different superscripts differ significantly (P<0.05)

Table 9: Supplementation effect of activated charcoal on the cyanide digestibility at various segments of GIT of grower pigs.

<table>
<thead>
<tr>
<th>Parameters (%)</th>
<th>Activated charcoal</th>
<th>+</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stomach</td>
<td>30.23</td>
<td>30.52</td>
<td>3.17</td>
</tr>
<tr>
<td>Caecum</td>
<td>13.39</td>
<td>13.87</td>
<td>1.23</td>
</tr>
<tr>
<td>Large intestine</td>
<td>34.87</td>
<td>35.19</td>
<td>4.12</td>
</tr>
</tbody>
</table>

<sup>+: Charcoal supplementation</sup>
<sup>-: Non – charcoal supplementation</sup>

Table 10: Interaction effect of CRM and activated charcoal on the cyanide digestibility at various segments of GIT of grower pigs.

<table>
<thead>
<tr>
<th>Parameters (%)</th>
<th>Charcoal Supplementation</th>
<th>0</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stomach</td>
<td>-</td>
<td>0.00&lt;sup&gt;d&lt;/sup&gt;</td>
<td>28.21&lt;sup&gt;c&lt;/sup&gt;</td>
<td>31.52&lt;sup&gt;b&lt;/sup&gt;</td>
<td>61.19&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>0.00&lt;sup&gt;d&lt;/sup&gt;</td>
<td>28.95&lt;sup&gt;c&lt;/sup&gt;</td>
<td>31.76&lt;sup&gt;b&lt;/sup&gt;</td>
<td>61.35&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.18</td>
</tr>
</tbody>
</table>
Growth Performance

The significant variations noticed in feed intake and hydrogen cyanide intake with activated charcoal supplementation suggest improved palatability. The biological mechanisms in the body of these animals for cyanide detoxification presumably cope with the amounts of cyanide supplied by the cassava root meal. The use of activated charcoal supplementation on the grower pigs fed cassava root-based diets affected the feed intake and hydrogen cyanide intake (Olayeni et al., 2024). Prolonged ingestion of activated charcoal substantially increased feed intake. This is similar to the report of Jiya et al., (2013) who fed activated coconut shell charcoal-supplemented meal to broiler chickens. Banner et al., (2000) observed that lambs on a basal diet of alfalfa pellets supplemented with a charcoal–barley mix ate more sagebrush than lambs supplemented only with barley. Hesham et al., (2004) also observed that the addition of kaolin or activated charcoal to aflatoxin-contaminated diets tended to improve feed utilization.

The interaction effect of cassava root meal and activated charcoal supplementation was also significant for the feed intake and hydrogen cyanide intake. Jiya et al., (2013) observed no significant difference in body weight gain at the starter phase however, at the finisher phase, there was a significant difference. The source of activated charcoal had been reported to affect the efficacy (Wang et al., 2006). Ayanwale et al., (2006) also reported that the effectiveness of activated charcoal is dose dependent. This has not been evaluated in this study. In this study, it was observed that at charcoal supplementation favoured feed and cyanide intake unlike at the weaner phase where live weight, weight gain and feed-to-gain ratio were also influenced.

Nutrient Digestibility

Crude protein digestibility of grower pigs fed cassava root meal-based diet compared favourably with that of the control (maize-based diets) especially animals fed diet 4. This could be a result of similarity in feed intake. These high values indicated efficient utilization of the diets. De Blas et al., (1981) also made a similar observation and Cheeke et al., (1987). Serious depression in crude fibre digestibility as levels of CRM increased especially in the 75% CRM diet could not be explained. Gidenne and Perez, (2000) reported that the appropriate proportion of low-digestible fibre and high-digestible fibre in diets affects fibre digestibility. Other nutrients (ash, nitrogen-free extract and Hydrogen cyanide) digestibility favoured CRM diets at higher inclusion levels.

It has been reported that optimum utilization of nutrients occurred when pigs were in the growing-finishing stage. Balagopalan et al., (1988), also affirmed that the digestibility of cassava-based diets by swine are high and similar to cereal-based diets.

The observation that activated charcoal supplementation lowered the digestibility of crude protein and ether extract but did not affect crude fibre, ash and the nitrogen-free extract is an indication that activated charcoal played a significant role in nutrient utilization. The significant Hydrogen cyanide digestibility in the charcoal supplementation could be a result of the quantity of cyanide intake. Jiya et al., (2013) observed better ash utilization when birds were fed with coconut shell charcoal. Also, better digestibility of hydrogen cyanide could be linked to the ability of activated charcoal to bind with HCN (Poage et al., 2000). The same observation was made by Villalba et al., (2002).

Hydrogen Cyanide Digestibility at Various Segments of GIT

The significant increase in cyanide degradation in the stomach (treatment effect) as cassava root meal increased could be related to intake and to some extent gastric secretions. Just et al., (1983) observed rapid hydrolysis of the starch to glucose by gastric secretions. In addition, Cunningham et al., (1963) have detected volatile fatty acids and lactic acid in the stomach. Therefore, rapid hydrolysis of starch in cassava could have
increased the cyanide digestibility in the stomach. Cassava intake has been identified to cause a longer retention time in the stomach of growing pigs causing a slower rate of passage and thereby exposing the nutrients to gastric secretions and bacterial digestion (Keys and DeBarthe, 1974). Cyanide degradability in the large intestine did not demonstrate the influence of cyanide intake because at the highest level of inclusion (75% CRM) cyanide degradability is low. Basilisia (1997) observed that in the middle of the large intestine, the flow of DM, OM and energy tended to be less for cassava than for sorghum and barley. The ability of activated charcoal to bind with chemicals might have favoured the higher degradability in the stomach, caecum and large intestine (Olayeni et al., 2024). In an in-vitro gastrointestinal model, activated charcoal reduced the availability of ZEA and/or DON and nivalenol (Avantaggiato et al., 2003, 2004).

V. CONCLUSIONS

The results obtained revealed that grower pigs fed varying levels of CRM with or without activated charcoal supplementation had comparable final live weight, weight gain and feed/gain ratio. Prolonged ingestion of CRM-based diets significantly improved crude protein, ash, nitrogen-free extract and hydrogen cyanide digestibility. Ash, nitrogen-free extract and hydrogen cyanide digestibility significantly increased by increasing CRM levels with or without activated charcoal. However, it was only nitrogen free extract and HCN digestibility at 75% CRM that were favoured by activated charcoal supplementation. Hydrogen cyanide degradability increased in the stomach and caecum as CRM level increased. Grower pigs that were fed CRM at 75% level showed comparable value for HCN digestibility in the stomach and caecum for both the supplementation and non-supplementation in the caecum while charcoal supplementation caused depression.

Grower pigs could tolerate up to 75% cassava root-based diets as a replacement for maize. The hydrogen cyanide content of cassava root meal that imposed limitations on the use of cassava root meal in diets of pigs could be overcome by supplementing with activated charcoal.

REFERENCES


