The effect of using solid-state fermented peeled and unpeeled cassava root tubers and limiting amino acid supplementation on metabolisable energy for meat-type cockerels

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The effect of using solid-state fermented peeled and unpeeled cassava root tubers and limiting amino acid supplementation on metabolisable energy for meat-type cockerels

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A preliminary *in-vitro* solid-state fermentation of peeled (PCRM) and unpeeled cassava root meal (UCRM) using *Aspergillus niger* was conducted followed by a force-feeding experiment to investigate the effect of processing, solid-state fermentation and limiting amino acid supplementation on metabolisable energy (ME) of peeled (PCRM) and unpeeled (UCRM) cassava root meal for meat-type cockerels. Forty eight, 84 d-old meat-type cockerels (Ross 308) were assigned to 8 treatments consisting of 6 birds per treatment laid out in a $2 \times 2 \times 2$ factorial arrangement of treatment consisting of PCRM and UCRM subjected or not to solid-state fermentation and supplemented with and without limiting amino acids. Additional 6 cockerels were also used for endogenous study. Peeling of cassava root increased ($P < 0.05$) gross energy content of the resultant cassava meal when compared with UCRM. Solid-state fermentation using *Aspergillus niger* increased ($P < 0.05$) the crude ash, ether extract and arginine concentration of PCRM and UCRM. Solid-state fermented PCRM recorded the highest ($P < 0.05$) amylopectin, least ($P < 0.05$) resistant starch and hydrocyanide concentration. Highest ($P < 0.05$) apparent metabolisable energy (AME) and nitrogen corrected AME (AMEn) values were obtained for cockerels fed with solid-state fermented PCRM supplemented with or without amino acid. However, supplementation of solid-state fermented PCRM with amino acid resulted in highest ($P < 0.05$) true metabolisable energy (TME) and nitrogen corrected TME (TMEn) for meat-type cockerels. Reduced ($P < 0.05$) AME and AMEn values were recorded for UCRM, regardless of solid-state fermentation and amino acid supplementation. In conclusion, solid-state fermentation and amino acid supplementation of PCRM resulted in improved AME, AMEn, TME and TMEn values for meat-type cockerels. Amino acid supplementation had no improvement on AME, AMEn and TME values of UCRM for meat-type cockerels.
Keywords: Amino acid supplementation, Cassava root meal, Cockerels, Metabolisable energy, Solid-state fermentation

1. INTRODUCTION

Cassava (*Manihot esculenta*) root is a cheap and sustainable energy feedstuff with potential to replace most conventional cereal grains in the tropics (Oso et al., 2014). Cassava root is rich in digestible starch, gross energy content (El-sharkawy, 2012) and has been used to a limited extent in poultry nutrition (Eruvbetine et al., 2003; Oso et al., 2014). However, the presence of hydrocyanide (HCN) residues, reduced protein levels, poor protein quality and reduced concentration of sulphur containing amino acids in cassava root constituted the major constraints to its maximal utilization as energy feedstuffs in poultry nutrition (Banea-Mayambu et al., 1997).

During cassava processing which convert cyanide to a less toxic thiocyanate, the enzyme ‘rhodnase’ contained in cassava root utilizes the constituent methionine and other sulphur containing amino acids as sulfur donor (Cardoso et al., 2005). Thus, sulphur amino acids become grossly deficient in cassava-based diets fed to poultry birds. Hence, to maximally harness the rich energy potential of cassava root in poultry nutrition, it is essential to supplement cassava root based diets with limiting amino acids.

Cassava peeling process is the removal of the topmost layer of cassava root prior utilization as food or feed. This processing methods helps to reduce the resultant hydrocyanide (HCN) content in cassava root product since the largest concentration of HCN in cassava root is located on the uppermost layer (Bruijn, 1973). Preliminary study showed improved growth performance
of broilers fed diet containing graded levels of peeled cassava root meal when compared with

group fed diet containing unpeeled cassava root meal (Akapo et al., 2014).

Solid-state fermentation with fungal culture has been recognized as a means of nutritionally
enriching and detoxifying few cassava products (Oboh and Akindahinsi, 2003). Filamentous
fungi such as \textit{Aspergillus niger} been widely used in food industries for commercial solid-state
fermentation due to its ease of culturing and absence of pathogenic ability (Berka et al., 1992).
\textit{Aspergillus niger} has the capacity to produce extracellular enzymes (such as hemicellulases,
hydrolases, pectinases, protease, amylase and lipases), degrade fibre and enrich its substrate
(Mathivanan et al., 2006; Villena and Gutierrez-Cornea, 2007). The present study seeks to
evaluate the effect of processing, solid-state fermentation and limiting amino acid
supplementation on metabolisable energy of peeled and unpeeled cassava root meal for meat-
type cockerels.

2. MATERIALS AND METHODS

2.1. Processing of cassava root

Freshly harvested cassava root tubers (TMS 30572) were washed with water and divided into
two equal batches. One batch was manually chipped without prior peeling to obtain the whole
cassava chips (WCC) while the other batch was peeled (removal of 0.5 cm uppermost thick
layer) before chipping to yield the peeled cassava chips (PCC). Both WCC and PCC were dried
(10–11 % moisture content) and milled (2.5 mm sieve) separately to yield the unpeeled (UCRM)
and peeled cassava root meal (PCRM), respectively.
2.2. Solid-state fermentation of cassava root meal

Pure laboratory strain of *Aspergillus niger* (Chinese International Centre for Type Culture Collection; CICC, No. 41126) was used as inoculum. A total of 8 kg cassava meal (consisting of 4 kg UCRM and 4 kg PCRM) were measured and used for this study. Twenty (20) sub-samples of UCRM and PCRM, each weighing 200 g were measured and placed into separate conical flasks. Thus, forty (40) conical flasks were used in all for the study (20 flasks for UCRM and 20 flasks for PCRM group). All UCRM and PCRM samples contained in flasks were randomly assigned, each into 2 treatments consisting of solid-state fermented and unfermented group. Thus there were four treatments in all laid out in a 2 × 2 factorial arrangement of peeled (PCRM) and unpeeled (UCRM) cassava root meal, each subjected or not to solid-state fermentation. Samples (contained in flasks) subjected to solid-state fermentation were moistened (250 g/kg Moisture content) each with nutrient solution (containing analytical grade of 80 g urea, 7 g MgSO\(_4\).2H\(_2\)O, 13 g KH\(_2\)PO\(_4\) and 20 g citric acid) and inoculated with \(2 \times 10^7\) fungal spore of *A. niger* per gram of sample. Each conical flask was air-sealed and the substrate incubated (30°C) for 6 days in a bed-packed incubator. At the end of incubation period, fermented samples (contained in each flask) were sterilized (120°C for 20 min) and used for subsequent chemical analysis.

2.3 Chemical analysis of samples

Fermented samples of UCRM (\(n = 10\)) and PCRM (\(n = 10\)) and respective unfermented samples were analyzed for dry matter (DM) by drying at 80°C for 24 h (AOAC; 925.10). Ash was measured in a muffle furnace (510°C for 18 h), crude protein (6.25 × N) was determined by LECO FP-200 Analyser (St Joseph, MI, USA), oil was extracted with petroleum spirit using the soxhlet method (AOAC, 1990). Gross energy (Adiabatic bomb calorimeter, Model 1261; Parr
Instrument Co., Moline, IL, USA), fibre fraction (Van Soest et al., 1991), tannin (Makkar et al.,
1993) and hydrocyanide content (De Bruijn, 1971) of samples were determined following
standard procedures. The amylopectin (Amylose/Amylopectin kit, Megazyme International Co.
Ireland) and resistant starch content (KRSTAR 08/11 Test kit, Megazyme International Co.
Ireland) of samples were determined using appropriate commercial kits. Mineral analysis (ICP–
MS, Agilent 7500 cx, Agilent Technologies) and amino acid analysis (RP-HPLC; Agilent 1100,
Palo Alto, CA, USA) of the samples were also determined. All laboratory analysis was done at
the Key Laboratory of Agro-ecological Processes in Subtropical Region, Institute of Subtropical
Agriculture, Chinese Academy of Sciences, Hunan Province, China.

2.4 Metabolisable energy determination using gavage method

The experimental protocol used in this study was approved by the Institutional Animal Care and
Welfare Committee of the Institute of Subtropical Agriculture (ISA), Chinese Academy of
Sciences, P.P.R China (Approval No. ISA AEC 2013-014). A total of fifty four (54) meat-type
cockerels (Ross 308, 12-weeks-old) of average weight 2250g ± 115 were used in all for this
experiment. Forty eight (48) cockerels were assigned to 8 treatments in a 2 × 2 × 2 factorial
arrangement of treatment consisted of peeled (PCRM) and unpeeled (UCRM) cassava root
meals, fermented or not with *A. niger* and supplemented with and without limiting amino acids.
There were 6 replicates per treatment of 1 bird per replicate. The remaining 6 cockerels were
used for endogenous study. Birds were kept in individual iron-type battery cages (each of
dimension 35 × 35 × 50; LBH) and fed commercial diets prior the commencement of the
experiment. The amino acids supplemented were as follows: L-lysine (0.75 g/100 g cassava
meal), DL-methionine (1.5 0 g/100 g cassava meal), L-arginine (0.75 g/100 g cassava meal) and
L-cysteine (0.75 g/100g cassava meal). Birds were orally gavaged 30 g of respective processed
cassava meal after 48 hr of starvation following the standard procedure outlined by McNab and Blair (1988). All birds had free access to drinking water while birds assigned to endogenous group were dosed each with warm glucose solution (30 g of glucose/50 ml of warm water). Excreta voided from each bird following the feeding procedure were collected quantitatively. All the birds survived the experiment as no mortality was recorded throughout the study. Gross energy of samples of excreta was measured while the following equations were used to calculate apparent metabolisable energy (AME), nitrogen corrected apparent metabolisable energy (AMEn), true metabolisable energy (TME), and nitrogen corrected true metabolisable energy (TMEn) of test ingredient (Sibbald, 1989):

\[
\text{AME} / \text{g of feed} = \frac{[(\text{Fi} \times \text{GEf}) - (E \times \text{GEe})]}{\text{Fi}}
\]

Where \( \text{Fi} \) is the feed intake (g on dry matter basis), \( E \) is quantity of excreta output (g on dry matter basis), \( \text{GEf} \) is the gross energy (MJ/kg) of feed, and \( \text{GEe} \) the gross energy (MJ/kg) of excreta.

\[
\text{AMEn} / \text{g of feed} = \frac{[(\text{Fi} \times \text{GEf}) - (E \times \text{GEe})] - (\text{NR} \times 36.5)}}{\text{Fi}}
\]

where nitrogen retention (NR) = (Fi \times Nf) – (E \times Ne), \( Nf \) is the nitrogen content (g/kg) of feed, \( Ne \) is the nitrogen content (g/kg) of excreta.

\[
\text{TME} / \text{g of feed} = \frac{[(\text{Fi} \times \text{GEf}) - (E \times \text{GEe})] + (\text{FEm} + \text{UEe})]}{\text{Fi}}
\]
where FEm is metabolic faecal energy (kJ) (calculated from gross energy of excreta from endogenous loss), and UEe is endogenous urinary energy (kJ) (This is assumed zero since urine and faeces are passed together).

\[
TMEn /g \text{ of feed} = \frac{[(Fi \times GEf) - (E \times GEe)] - (NR \times K)}{Fi} + \{(FEm + UEe) + (NRo \times 36.5)\}
\]

Where NR and NRo are estimates of nitrogen retention for fed (experimental) and starved (control) birds, respectively.

2.5 Statistical Analysis

As regards data obtained from compositional chemical analysis of unfermented and solid-state fermented UCRM and PCRM, replicate units in conical flasks (\(n = 10\) per treatment) served as experimental units for statistical analysis. These data was analysed as a two factor model (cassava peeling \(\times\) solid-state fermentation) consisting of peeled and unpeeled cassava root, subjected or not to solid-state fermentation. For the analysis of data obtained from estimation of metabolisable energy using gavage method, individual bird was used as the experimental unit (\(n = 6\) per treatment). Data obtained from gavage studies were analysed as a three factor model (cassava peeling \(\times\) solid-state fermentation \(\times\) amino acid supplementation) consisting of peeled and unpeeled cassava root, subjected or not to solid-state fermentation and supplemented with or without amino acids. All data generated in this study were subjected to analysis of variance using the general linear models procedure of the SAS (SAS Institute, 2002) to determine the main effects and their respective interactions. Significant differences were considered at \(P < 0.05\).

2.6 Statistical Model
For two factor model (cassava peeling × solid-state fermentation) analysis of chemical composition of peeled and unpeeled cassava root, the model used is as follows:

\[ Y_{ij} = \mu + A_i + B_j + AB_{ij} + \varepsilon_{ijk} \]

Where \( Y_{ij} \) = Observed value of the dependent variable

\( \mu \) = Population mean

\( A_i \) = Main effect of cassava peeling (peeled, unpeeled)

\( B_j \) = Main effect of solid state fermentation (fermented, unfermented)

\( AB_{ij} \) = Interaction effect of cassava peeling and solid state fermentation

\( \varepsilon_{ijk} \) = Random residual error.

For three factor model (cassava peeling × solid-state fermentation × amino acid supplementation) analysis of metabolisable energy determination of peeled and unpeeled cassava root, the model used is as follows:

\[ Y_{ij} = \mu + A_i + B_j + C_k + AB_{ij} + BC_{jk} + AC_{ik} + ABC_{ijk} + \varepsilon_{ijkl} \]

Where \( Y_{ij} \) = Observed value of the dependent variable

\( \mu \) = Population mean

\( A_i \) = Main effect of cassava peeling

\( B_j \) = Main effect of solid state fermentation

\( C_k \) = Main effect of amino acid supplementation

\( AB_{ij} \) = Interaction effect of cassava peeling and solid state fermentation

\( BC_{jk} \) = Interaction effect of solid state fermentation and amino acid supplementation

\( AC_{ik} \) = Interaction effect of cassava peeling and amino acid supplementation

\( ABC_{ijk} \) = Interaction effect of cassava peeling, solid state fermentation and amino acid supplementation

\( \varepsilon_{ijkl} \) = Random residual error
3. RESULTS AND DISCUSSION

3.1. Solid-state fermentation of peeled (PCRM) and unpeeled (UCRM) cassava root meal

Solid-state fermentation of PCRM and UCRM with *A. niger* resulted in increased (*P < 0.05*) ether extract, crude ash and reduced (*P < 0.05*) dry matter content (Table 1). Increased ether extract content of resultant meal (UCRM and PCRM) following solid-state fermentation could be attributed to the ability of *A. niger* to synthesize long chain fatty acids from acetyl co-enzymes A and other complex unsaturated lipids during fermentation (Iyayi and Aderolu, 2004). Increased ash content recorded for fermented UCRM and PCRM when compared with unfermented meal could be due to increased available mineral caused by metabolic activities of the fermenting organism. The highest (*P < 0.05*) ash content obtained for fermented UCRM could be attributed to the rich mineral content of the outer cassava peel contained in UCRM coupled with the fermentation. The outer layer of cassava root (peel) has been reported to contain richer macro-minerals than the pulp (Akapo et al., 2014).

Peeling of cassava root subjected or not to solid-state fermentation using *A. niger* resulted in improved (Cassava processing × Solid-state fermentation, *P < 0.05*) gross energy content and reduced (*P < 0.05*) hydrocyanide content (HCN) of the resultant meal when compared with the unpeeled cassava meal. UCRM contain fibrous outer peels which could lead to a dilution effect of the constituent energy hence reduced energy content. Cassava root peeling led to reduced HCN because the highest concentration of HCN in cassava root is located on the outer peel when compared with the inside pulp (Bruijn 1973). Hence, peeling of cassava root to yield UCRM will yield a product with reduced HCN content.

Solid-state fermentation of PCRM using *A. niger* resulted in a fermented product with reduced NDF (*P < 0.01*) and ADF (*P < 0.05*) content. Fermentation with *A. niger* thus resulted
in efficient breakdown of the constituent fibre. *A. niger* has been earlier reported to produce ligno-cellulolytic enzymes during fermentation which break down constituent fibre in cassava root (Mathivanan et al., 2006; Villena and Gutierrez-Cornea, 2007). Solid-state fermentation of PCRM in the current study also showed reduced \( P < 0.05 \) resistant starch content and improved \( P < 0.05 \) amylopectin content suitable for products that required adhesion (Bergmann et al., 1988). *A. niger* has been reported to degrade starch granules for substrate enrichment (Soccol et al., 1994).

Solid-state fermentation of both PCRM and UCRM showed reduced \( P < 0.05 \) Cu levels of the resultant fermented products. In fact, solid-state fermentation of PCRM resulted in reduced \( \text{(Cassava processing} \times \text{Solid-state fermentation, } P < 0.05 \) K and Zn content of the fermented cassava products (Table 1). The effect of solid-state fermentation on mineral profile of cassava products has not been extensively investigated in literatures. The reduced concentration of Cu noticed for solid-state fermented PCRM and UCRM could be due to the adsorption ability of the fungi. *A. niger* is known to produce large quantities of organic acids such as citrate and gluconate, both of which are capable of leaching or precipitating metals out of a number of substrate by either adsorption to fungal cell wall components, or complexation of the metals (Bosshard et al., 1996).

Amino acid profile of PCRM and UCRM subjected or not to solid-state fermentation is as shown in Table 2. Solid-state fermentation of PCRM and UCRM increased \( P < 0.05 \) the arginine concentration of the resultant fermented products. The improved arginine concentration obtained in fermented PCRM and UCRM when compared with the unfermented meals corroborated the earlier findings that fungal fermentation of cassava products improved the
resultant amino acid profile (Oboh and Akindahinski, 2003). Arginine is noted for its role in protein synthesis and its consequence influence on growth of animals (Kidd et al., 2001).

3.2. Metabolisable energy determination of PCRM and UCRM using gavage method

Metabolisable energy values of PCRM and UCRM subjected or not to solid-state fermentation and supplemented with and without amino acids is as shown in Table 3. Solid-state fermentation of PCRM supplemented or not with amino acid recorded the highest (Cassava processing × Solid-state fermentation × amino acid supplementation, $P < 0.05$) AME and AMEn for meat-type cockerels. Highest AME and AMEn values of fermented PCRM recorded in this study regardless of amino acid supplementation could be due to improved gross energy content and reduced HCN content of PCRM following cassava root peeling and solid state-fermentation. This improved AME and AMEn of fermented PCRM could also be linked with the increased oil content produced by $A. niger$ during solid-state fermentation (Iyayi and Aderolu, 2004). Mathivanan et al. (2006) reported that solid-state fermentation produce digestive enzymes which pre-digest substrates and thus foster increased nutrient availability, digestibility and energy metabolisability.

Reduced (Cassava processing × Solid-state fermentation × amino acid supplementation, $P < 0.05$) AME and AMEn values of UCRM (regardless of solid-state fermentation and amino acid supplementation) obtained in the present study for meat-type cockerels could be linked with high fibrous constituent of UCRM. Fibrous feedstuffs have been reported to reduce energy metabolisabilty of poultry birds (Janssen and Carré, 1985). Meanwhile, peeling of the outer layer of cassava root helps in reducing the constituent fibre and thus leads to increased available
energy of the resultant product (PCRM). Amino acid supplementation showed no positive
contribution to AME and AMEn values of UCRM from this study.

Highest (Cassava processing × Solid-state fermentation × amino acid supplementation, \( P < 0.05 \)) TME and TMEn values obtained for fermented and amino acid-supplemented PCRM
obtained for meat-type cockerels in the present study underscores the importance of cassava
peeling process, solid-state fermentation and amino acid supplementation in improving the TME
and TMEn values of PCRM. However, amino acid supplementation showed no improvement on
TME and TMEn values of unfermented UCRM. Although, slight improvement on TMEn values
of UCRM was noticed following solid-state fermentation, however these TMEn values were
lower than corresponding values obtained for cockerels fed with fermented and amino acid-
supplemented PCRM.

4. CONCLUSION

The present study provides background information on the possible utilization of peeled
and unpeeled cassava root as energy feedstuffs in the nutrition of meat-type cockerels. It was
concluded that solid-state fermentation and amino acid supplementation of peeled cassava root
meal had the best metabolisable energy values (AME, AMEn, TME and TMEn) for meat-type
cockerels. Although solid-state fermentation of unpeeled cassava root meal had little prospect for
improved TMEn, amino acid supplementation of unpeeled cassava root meal had no
improvement on AME and AMEn values for meat-type cockerels.

ACKNOWLEDGEMENTS
The authors express their gratitude to the Chinese Academy of Sciences Visiting Fellowship for Researchers from Developing Countries (Grant No. 2014FFZA0012) and key program of Changsha Scientific and Technology Planning Project (k1403031-21) who funded the projects.

5. REFERENCES


Table 1. Effect of solid-state fermentation on the chemical composition and energy content of unpeeled and peeled cassava root meal

<table>
<thead>
<tr>
<th>Cassava root processing (CRP)</th>
<th>Unpeeled</th>
<th>Peeled</th>
<th>Pooled</th>
<th>Level of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid-state fermentation (SSF)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Dry matter (g/kg)</td>
<td>907.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>719.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>910.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>722.50&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Crude ash (g/kg)</td>
<td>11.4&lt;sup&gt;c&lt;/sup&gt;</td>
<td>15.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>13.2&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ether extract (g/kg)</td>
<td>12.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>17.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>18.3&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Crude protein (g/kg)</td>
<td>14.5</td>
<td>15.0</td>
<td>14.1</td>
<td>15.5</td>
</tr>
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<td>Gross energy (MJ/kg)</td>
<td>14.10&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14.21&lt;sup&gt;b&lt;/sup&gt;</td>
<td>16.98&lt;sup&gt;a&lt;/sup&gt;</td>
<td>17.25&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>NDF (g/kg)</td>
<td>360.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>330.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>320.7&lt;sup&gt;c&lt;/sup&gt;</td>
<td>305.2&lt;sup&gt;d&lt;/sup&gt;</td>
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<tr>
<td>ADF (g/kg)</td>
<td>250.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>227.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>225.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>200.7&lt;sup&gt;c&lt;/sup&gt;</td>
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<td>Amylopectin (g/kg)</td>
<td>809&lt;sup&gt;c&lt;/sup&gt;</td>
<td>834.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>830.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>874.5&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>Resistant starch (g/kg)</td>
<td>98.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>48.0&lt;sup&gt;c&lt;/sup&gt;</td>
<td>70.50&lt;sup&gt;b&lt;/sup&gt;</td>
<td>35.0&lt;sup&gt;d&lt;/sup&gt;</td>
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<tr>
<td>Hydrocyanide (mg/kg)</td>
<td>30.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>30.20&lt;sup&gt;a&lt;/sup&gt;</td>
<td>23.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>22.50&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>Tannin (%)</td>
<td>0.32</td>
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<td>0.30</td>
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<td>Ca (mg/kg)</td>
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<td>Mg (mg/kg)</td>
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<td>Mn (mg/kg)</td>
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<td>0.008</td>
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<td>Cu (mg/kg)</td>
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<td>0.003&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.009&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.002&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>Fe (mg/kg)</td>
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<td>0.10</td>
<td>0.11</td>
<td>0.10</td>
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<tr>
<td>K (mg/kg)</td>
<td>6.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.70&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Zn (mg/kg)</td>
<td>0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.01&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a,b</sup> Mean with different superscripts in each row are significantly different (P<0.05)
### Table 2. Effect of solid-state fermentation on amino acid profile of unpeeled and peeled cassava root meal

<table>
<thead>
<tr>
<th>Measurements (g/100g protein)</th>
<th>Cassava root processing (CRP)</th>
<th>Solid-state fermentation (SSF)</th>
<th>Unpeeled</th>
<th>Peeled</th>
<th>Pooled</th>
<th>SEM</th>
<th>Level of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td></td>
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<tr>
<td>Asparagine</td>
<td>0.14</td>
<td>0.15</td>
<td>0.15</td>
<td>0.14</td>
<td>0.002</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Threonine</td>
<td>0.04</td>
<td>0.05</td>
<td>0.05</td>
<td>0.04</td>
<td>0.002</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Serine</td>
<td>0.07</td>
<td>0.07</td>
<td>0.08</td>
<td>0.07</td>
<td>0.003</td>
<td>NS</td>
<td>NS</td>
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<tr>
<td>Glutamine</td>
<td>0.40</td>
<td>0.42</td>
<td>0.41</td>
<td>0.40</td>
<td>0.001</td>
<td>NS</td>
<td>NS</td>
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<tr>
<td>Glycine</td>
<td>0.10</td>
<td>0.10</td>
<td>0.11</td>
<td>0.10</td>
<td>0.003</td>
<td>NS</td>
<td>NS</td>
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<tr>
<td>Alanine</td>
<td>0.14</td>
<td>0.14</td>
<td>0.12</td>
<td>0.14</td>
<td>0.005</td>
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<tr>
<td>Cysteine</td>
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<td>0.05</td>
<td>0.05</td>
<td>0.04</td>
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<td>Valine</td>
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<td>0.10</td>
<td>0.09</td>
<td>0.10</td>
<td>0.02</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Methionine</td>
<td>0.01</td>
<td>0.02</td>
<td>0.10</td>
<td>0.10</td>
<td>0.002</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Isoleucine</td>
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<td>0.06</td>
<td>0.05</td>
<td>0.06</td>
<td>0.001</td>
<td>NS</td>
<td>NS</td>
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<td>Leucine</td>
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<td>0.16</td>
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<td>NS</td>
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<tr>
<td>Tyrosine</td>
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<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.002</td>
<td>NS</td>
<td>NS</td>
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<tr>
<td>Phenylalanine</td>
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<td>0.06</td>
<td>0.06</td>
<td>0.07</td>
<td>0.001</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Lysine</td>
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<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.002</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Histidine</td>
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<td>0.02</td>
<td>0.02</td>
<td>0.001</td>
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<td>NS</td>
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<tr>
<td>Arginine</td>
<td>0.08^a</td>
<td>0.15^a</td>
<td>0.09^b</td>
<td>0.17^a</td>
<td>0.012</td>
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<td>&lt;0.05</td>
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<tr>
<td>Proline</td>
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<td>0.16</td>
<td>0.15</td>
<td>0.16</td>
<td>0.004</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

*^a, b* Mean with different superscripts in each row are significantly different (P<0.05)

NS= Not significant
Table 3. Metabolisable energy values of peeled and unpeeled cassava root meal subjected to solid-state fermentation and supplemented with or without amino acids for meat-type cockerels

<table>
<thead>
<tr>
<th>Attributes</th>
<th>AME</th>
<th>AMEn</th>
<th>TME</th>
<th>TMEn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassava root processing</td>
<td>Solid-state fermentation</td>
<td>Amino acid supplementation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unpeeled No No</td>
<td>11.62&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.85&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.01&lt;sup&gt;c&lt;/sup&gt;</td>
<td>12.33&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Unpeeled No Yes</td>
<td>11.70&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.90&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.15&lt;sup&gt;c&lt;/sup&gt;</td>
<td>12.44&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Unpeeled Yes No</td>
<td>11.92&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.20&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.42&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>12.64&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Unpeeled Yes Yes</td>
<td>11.99&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.35&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.50&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>12.80&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Peeled No No</td>
<td>12.22&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.32&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.51&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>12.59&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Peeled No Yes</td>
<td>12.10&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.15&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.49&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>12.60&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Peeled Yes No</td>
<td>12.85&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.90&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.29&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13.34&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Peeled Yes Yes</td>
<td>12.75&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.84&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.67&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.76&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>Pooled SEM</td>
<td>2.22</td>
<td>2.07</td>
<td>2.10</td>
<td>2.05</td>
</tr>
</tbody>
</table>

**Significance**

- Cassava root peeling: NS <0.05 <0.05 NS
- Solid state fermentation: NS <0.05 <0.05 NS
- Amino acid supplementation: NS NS NS NS
- Cassava root peeling × Solid state fermentation: <0.05 <0.05 <0.05 <0.01
- Cassava root peeling × Amino acid supplementation: NS <0.05 <0.05 <0.05
- Solid state fermentation × Amino acid supplementation: NS <0.05 <0.01 <0.05
- Cassava root peeling × Solid state fermentation × Amino acid supplementation: <0.05 <0.05 <0.05 <0.05
Values in the same column not sharing a common superscript are significantly different at $P < 0.05$.

NS = Not significant