

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

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22 **ABSTRACT**

23 A preliminary *in-vitro* solid-state fermentation of peeled (PCRM) and unpeeled cassava root
24 meal (UCRM) using *Aspergillus niger* was conducted followed by a force-feeding experiment to
25 investigate the effect of processing, solid-state fermentation and limiting amino acid
26 supplementation on metabolisable energy (ME) of peeled (PCRM) and unpeeled (UCRM)
27 cassava root meal for meat-type cockerels. Forty eight, 84 d-old meat-type cockerels (Ross 308)
28 were assigned to 8 treatments consisting of 6 birds per treatment laid out in a $2 \times 2 \times 2$ factorial
29 arrangement of treatment consisting of PCRM and UCRM subjected or not to solid-state
30 fermentation and supplemented with and without limiting amino acids. Additional 6 cockerels
31 were also used for endogenous study. Peeling of cassava root increased ($P < 0.05$) gross energy
32 content of the resultant cassava meal when compared with UCRM. Solid-state fermentation
33 using *Aspergillus niger* increased ($P < 0.05$) the crude ash, ether extract and arginine
34 concentration of PCRM and UCRM. Solid-state fermented PCRM recorded the highest ($P <$
35 0.05) amylopectin, least ($P < 0.05$) resistant starch and hydrocyanide concentration. Highest (P
36 < 0.05) apparent metabolisable energy (AME) and nitrogen corrected AME (AMEn) values were
37 obtained for cockerels fed with solid-state fermented PCRM supplemented with or without
38 amino acid. However, supplementation of solid-state fermented PCRM with amino acid resulted
39 in highest ($P < 0.05$) true metabolisable energy (TME) and nitrogen corrected TME (TMEn) for
40 meat-type cockerels. Reduced ($P < 0.05$) AME and AMEn values were recorded for UCRM,
41 regardless of solid-state fermentation and amino acid supplementation. In conclusion, solid-state
42 fermentation and amino acid supplementation of PCRM resulted in improved AME, AMEn,
43 TME and TMEn values for meat-type cockerels. Amino acid supplementation had no
44 improvement on AME, AMEn and TME values of UCRM for meat-type cockerels.

45 *Keywords:* Amino acid supplementation, Cassava root meal, Cockerels, Metabolisable energy,
46 Solid-state fermentation

47

48 **1. INTRODUCTION**

49 Cassava (*Manihot esculenta*) root is a cheap and sustainable energy feedstuff with potential
50 to replace most conventional cereal grains in the tropics (Oso et al., 2014). Cassava root is rich in
51 digestible starch, gross energy content (El-sharkawy, 2012) and has been used to a limited extent
52 in poultry nutrition (Eruvbetine et al., 2003; Oso et al., 2014). However, the presence of
53 hydrocyanide (HCN) residues, reduced protein levels, poor protein quality and reduced
54 concentration of sulphur containing amino acids in cassava root constituted the major constraints
55 to its maximal utilization as energy feedstuffs in poultry nutrition (Banea-Mayambu et al., 1997).
56 During cassava processing which convert cyanide to a less toxic thiocyanate, the enzyme
57 ‘rhodnase’ contained in cassava root utilizes the constituent methionine and other sulphur
58 containing amino acids as sulfur donor (Cardoso et al., 2005). Thus, sulphur amino acids become
59 grossly deficient in cassava-based diets fed to poultry birds. Hence, to maximally harness the
60 rich energy potential of cassava root in poultry nutrition, it is essential to supplement cassava
61 root based diets with limiting amino acids.

62 Cassava peeling process is the removal of the topmost layer of cassava root prior utilization
63 as food or feed. This processing methods helps to reduce the resultant hydrocyanide (HCN)
64 content in cassava root product since the largest concentration of HCN in cassava root is located
65 on the uppermost layer (Bruijn, 1973). Preliminary study showed improved growth performance

66 of broilers fed diet containing graded levels of peeled cassava root meal when compared with
67 group fed diet containing unpeeled cassava root meal (Akapo et al., 2014).

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

78

79 **2. MATERIALS AND METHODS**

80 *2.1. Processing of cassava root*

81 Freshly harvested cassava root tubers (TMS 30572) were washed with water and divided into
82 two equal batches. One batch was manually chipped without prior peeling to obtain the whole
83 cassava chips (WCC) while the other batch was peeled (removal of 0.5 cm uppermost thick
84 layer) before chipping to yield the peeled cassava chips (PCC). Both WCC and PCC were dried
85 (10–11 % moisture content) and milled (2.5 mm sieve) separately to yield the unpeeled (UCRM)
86 and peeled cassava root meal (PCRM), respectively.

87 *2.2. Solid-state fermentation of cassava root meal*

88 Pure laboratory strain of *Aspergillus niger* (Chinese International Centre for Type Culture
89 Collection; CICC, No. 41126) was used as inoculum. A total of 8 kg cassava meal (consisting of
90 4 kg UCRM and 4 kg PCRM) were measured and used for this study. Twenty (20) sub-samples
91 of UCRM and PCRM, each weighing 200 g were measured and placed into separate conical
92 flasks. Thus, forty (40) conical flasks were used in all for the study (20 flasks for UCRM and 20
93 flasks for PCRM group). All UCRM and PCRM samples contained in flasks were randomly
94 assigned, each into 2 treatments consisting of solid-state fermented and unfermented group. Thus
95 there were four treatments in all laid out in a 2×2 factorial arrangement of peeled (PCRM) and
96 unpeeled (UCRM) cassava root meal, each subjected or not to solid-state fermentation. Samples
97 (contained in flasks) subjected to solid-state fermentation were moistened (250 g/kg Moisture
98 content) each with nutrient solution (containing analytical grade of 80 g urea, 7 g $\text{MgSO}_4 \cdot 2\text{H}_2\text{O}$,
99 13 g KH_2PO_4 and 20 g citric acid) and inoculated with 2×10^7 fungal spore of *A. niger* per gram
100 of sample. Each conical flask was air-sealed and the substrate incubated (30° C) for 6 days in a
101 bed-packed incubator. At the end of incubation period, fermented samples (contained in each
102 flask) were sterilized (120° C for 20 min) and used for subsequent chemical analysis.

103 *2.3 Chemical analysis of samples*

104 Fermented samples of UCRM ($n = 10$) and PCRM ($n = 10$) and respective unfermented samples
105 were analyzed for dry matter (DM) by drying at 80°C for 24 h (AOAC; 925.10). Ash was
106 measured in a muffle furnace (510° C for 18 h), crude protein ($6.25 \times \text{N}$) was determined by
107 LECO FP-200 Analyser (St Joseph, MI, USA), oil was extracted with petroleum spirit using the
108 soxhlet method (AOAC, 1990). Gross energy (Adiabatic bomb calorimeter, Model 1261; Parr

109 Instrument Co., Moline, IL, USA), fibre fraction (Van Soest et al., 1991), tannin (Makkar et al.,
110 1993) and hydrocyanide content (De Bruijn, 1971) of samples were determined following
111 standard procedures. The amylopectin (Amylose/Amylopectin kit, Megazyme International Co.
112 Ireland) and resistant starch content (KRSTAR 08/11 Test kit, Megazyme International Co.
113 Ireland) of samples were determined using appropriate commercial kits. Mineral analysis (ICP–
114 MS, Agilent 7500 cx, Agilent Technologies) and amino acid analysis (RP-HPLC; Agilent 1100,
115 Palo Alto, CA, USA) of the samples were also determined. All laboratory analysis was done at
116 the Key Laboratory of Agro-ecological Processes in Subtropical Region, Institute of Subtropical
117 Agriculture, Chinese Academy of Sciences, Hunan Province, China.

118 *2.4 Metabolisable energy determination using gavage method*

119 The experimental protocol used in this study was approved by the Institutional Animal Care and
120 Welfare Committee of the Institute of Subtropical Agriculture (ISA), Chinese Academy of
121 Sciences, P.P.R China (Approval No. ISA AEC 2013-014). A total of fifty four (54) meat-type
122 cockerels (Ross 308, 12-weeks-old) of average weight $2250\text{g} \pm 115$ were used in all for this
123 experiment. Forty eight (48) cockerels were assigned to 8 treatments in a $2 \times 2 \times 2$ factorial
124 arrangement of treatment consisted of peeled (PCRM) and unpeeled (UCRM) cassava root
125 meals, fermented or not with *A. niger* and supplemented with and without limiting amino acids.
126 There were 6 replicates per treatment of 1 bird per replicate. The remaining 6 cockerels were
127 used for endogenous study. Birds were kept in individual iron-type battery cages (each of
128 dimension $35 \times 35 \times 50$; LBH) and fed commercial diets prior the commencement of the
129 experiment. The amino acids supplemented were as follows: L-lysine (0.75 g/100 g cassava
130 meal), DL-methionine (1.5 0 g/100 g cassava meal), L-arginine (0.75 g/100 g cassava meal) and
131 L-cysteine (0.75 g/100g cassava meal). Birds were orally gavaged 30 g of respective processed

132 cassava meal after 48 hr of starvation following the standard procedure outlined by Mc Nab and
 133 Blair (1988). All birds had free access to drinking water while birds assigned to endogenous
 134 group were dosed each with warm glucose solution (30 g of glucose/50 ml of warm water).
 135 Excreta voided from each bird following the feeding procedure were collected quantitatively. All
 136 the birds survived the experiment as no mortality was recorded throughout the study. Gross
 137 energy of samples of excreta was measured while the following equations were used to calculate
 138 apparent metabolisable energy (AME), nitrogen corrected apparent metabolisable energy
 139 (AMEn), true metabolisable energy (TME), and nitrogen corrected true metabolisable energy
 140 (TMEn) of test ingredient (Sibbald, 1989):

$$141 \quad \text{AME /g of feed} = [(F_i \times \text{GE}_f) - (E \times \text{GE}_e)]/F_i$$

142 Where F_i is the feed intake (g on dry matter basis), E is quantity of excreta output (g on dry
 143 matter basis), GE_f is the gross energy (MJ/ kg) of feed, and is GE_e the gross energy (MJ/ kg) of
 144 excreta.

$$145 \quad \text{AMEn /g of feed} = \frac{\{[(F_i \times \text{GE}_f) - (E \times \text{GE}_e)] - (\text{NR} \times 36.5)\}}{F_i}$$

147 where nitrogen retention (NR) = $(F_i \times N_f) - (E \times N_e)$, N_f is the nitrogen content (g/kg) of
 148 feed, N_e is the nitrogen content (g/kg) of excreta.

$$149 \quad \text{TME /g of feed} = \frac{\{[(F_i \times \text{GE}_f) - (E \times \text{GE}_e)] + (\text{FEm} + \text{UE}_e)\}}{F_i}$$

151 where FEm is metabolic faecal energy (kJ) (calculated from gross energy of excreta from
152 endogenous loss), and UEe is endogenous urinary energy (kJ) (This is assumed zero since urine
153 and faeces are passed together).

$$154 \quad \text{TME}_n / \text{g of feed} = \frac{\{[(F_i \times \text{GE}_f) - (E \times \text{GE}_e)] - (\text{NR} \times K)\} + \{(F_{\text{Em}} + \text{UE}_e) + (\text{NR}_o \times 36.5)\}}{F_i}$$

155
$$F_i$$

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

158 *2.5 Statistical Analysis*

159 As regards data obtained from compositional chemical analysis of unfermented and solid-state
160 fermented UCRM and PCRM, replicate units in conical flasks ($n = 10$ per treatment) served as
161 experimental units for statistical analysis. These data was analysed as a two factor model
162 (cassava peeling \times solid-state fermentation) consisting of peeled and unpeeled cassava root,
163 subjected or not to solid-state fermentation. For the analysis of data obtained from estimation of
164 metabolisable energy using gavage method, individual bird was used as the experimental unit (n
165 $= 6$ per treatment). Data obtained from gavage studies were analysed as a three factor model
166 (cassava peeling \times solid-state fermentation \times amino acid supplementation) consisting of peeled
167 and unpeeled cassava root, subjected or not to solid-state fermentation and supplemented with or
168 without amino acids. All data generated in this study were subjected to analysis of variance using
169 the general linear models procedure of the SAS (SAS Institute, 2002) to determine the main
170 effects and their respective interactions. Significant differences were considered at $P < 0.05$.

171

172 *2.6 Statistical Model*

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

$$175 Y_{ij} = \mu + A_i + B_j + AB_{ij} + \epsilon_{ijk}$$

176 Where Y_{ij} = Observed value of the dependent variable

177 μ = Population mean

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

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

180 AB_{ij} = Interraction effect of cassava peeling and solid state fermentation

181 ϵ_{ijk} = Random residual error.

182

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

$$186 Y_{ijk} = \mu + A_i + B_j + C_k + AB_{ij} + BC_{jk} + AC_{ik} + ABC_{ijk} + \epsilon_{ijkl}$$

187 Where Y_{ijk} = Observed value of the dependent variable

188 μ = Population mean

189 A_i = Main effect of cassava peeling

190 B_j = Main effect of solid state fermentation

191 C_k = Main effect of amino acid supplementation

192 AB_{ij} = Interraction effect of cassava peeling and solid state fermentation

193 BC_{jk} = Interraction effect of solid state fermentation and amino acid supplementation

194 AC_{ik} = Interraction effect of cassava peeling and amino acid supplementation

195 ABC_{ijk} = Interraction effect of cassava peeling, solid state fermentation and amino acid
196 supplementation

197 ϵ_{ijkl} = Random residual error

198 **3. RESULTS AND DISCUSSION**

199 *3.1. Solid-state fermentation of peeled (PCRM) and unpeeled (UCRM) cassava root meal*

200 Solid-state fermentation of PCRM and UCRM with *A. niger* resulted in increased ($P <$
201 0.05) ether extract, crude ash and reduced ($P < 0.05$) dry matter content (Table 1). Increased
202 ether extract content of resultant meal (UCRM and PCRM) following solid-state fermentation
203 could be attributed to the ability of *A. niger* to synthesize long chain fatty acids from acetyl co-
204 enzymes A and other complex unsaturated lipids during fermentation (Iyayi and Aderolu, 2004).
205 Increased ash content recorded for fermented UCRM and PCRM when compared with
206 unfermented meal could be due to increased available mineral caused by metabolic activities of
207 the fermenting organism. The highest ($P < 0.05$) ash content obtained for fermented UCRM
208 could be attributed to the rich mineral content of the outer cassava peel contained in UCRM
209 coupled with the fermentation. The outer layer of cassava root (peel) has been reported to contain
210 richer macro-minerals than the pulp (Akapo et al., 2014).

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

219 Solid-state fermentation of PCRM using *A. niger* resulted in a fermented product with
220 reduced NDF ($P < 0.01$) and ADF ($P < 0.05$) content. Fermentation with *A. niger* thus resulted

221 in efficient breakdown of the constituent fibre. *A. niger* has been earlier reported to produce
222 ligno-cellulolytic enzymes during fermentation which break down constituent fibre in cassava
223 root (Mathivanan et al., 2006; Villena and Gutierrez-Cornea, 2007). Solid-state fermentation of
224 PCRМ in the current study also showed reduced ($P < 0.05$) resistant starch content and improved
225 ($P < 0.05$) amylopectin content suitable for products that required adhesion (Bergmann et al.,
226 1988). *A. niger* has been reported to degrade starch granules for substrate enrichment (Soccol et
227 al., 1994).

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

238 Amino acid profile of PCRМ and UCRM subjected or not to solid-state fermentation is as
239 shown in Table 2. Solid-state fermentation of PCRМ and UCRM increased ($P < 0.05$) the
240 arginine concentration of the resultant fermented products. The improved arginine concentration
241 obtained in fermented PCRМ and UCRM when compared with the unfermented meals
242 corroborated the earlier findings that fungal fermentation of cassava products improved the

243 resultant amino acid profile (Oboh and Akindahinsi, 2003). Arginine is noted for its role in
244 protein synthesis and its consequence influence on growth of animals (Kidd et al., 2001).

245

246 3.2. Metabolisable energy determination of PCRМ and UCRM using gavage method

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

259 Reduced (Cassava processing × Solid-state fermentation × amino acid supplementation,
260 $P < 0.05$) AME and AMEn values of UCRM (regardless of solid-state fermentation and amino
261 acid supplementation) obtained in the present study for meat-type cockerels could be linked with
262 high fibrous constituent of UCRM. Fibrous feedstuffs have been reported to reduce energy
263 metabolisability of poultry birds (Janssen and Carré, 1985). Meanwhile, peeling of the outer
264 layer of cassava root helps in reducing the constituent fibre and thus leads to increased available

265 energy of the resultant product (PCRM). Amino acid supplementation showed no positive
266 contribution to AME and AMEn values of UCRM from this study.

267 Highest (Cassava processing × Solid-state fermentation × amino acid supplementation, *P*
268 < 0.05) TME and TMEn values obtained for fermented and amino acid-supplemented PCRM
269 obtained for meat-type cockerels in the present study underscores the importance of cassava
270 peeling process, solid-state fermentation and amino acid supplementation in improving the TME
271 and TMEn values of PCRM. However, amino acid supplementation showed no improvement on
272 TME and TMEn values of unfermented UCRM. Although, slight improvement on TMEn values
273 of UCRM was noticed following solid-state fermentation, however these TMEn values were
274 lower than corresponding values obtained for cockerels fed with fermented and amino acid-
275 supplemented PCRM.

276

277 **4. CONCLUSION**

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

285

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

Cassava root processing (CRP)	Unpeeled		Peeled		Pooled SEM	<i>Level of significance</i>		
	Solid-state fermentation (SSF) No	Yes	No	Yes		CRP	SSF	CRP × SSF
Measurements								
Dry matter (g/kg)	907.1 ^a	719.2 ^b	910.25 ^a	722.50 ^b	40.22	NS	<0.05	<0.05
Crude ash (g/kg)	11.4 ^c	15.1 ^a	10.9 ^c	13.2 ^b	4.00	<0.05	<0.01	<0.05
Ether extract (g/kg)	12.5 ^b	17.5 ^a	12.2 ^b	18.3 ^a	3.99	NS	<0.05	<0.05
Crude protein (g/kg)	14.5	15.0	14.1	15.5	0.12	NS	NS	NS
Gross energy (MJ/kg)	14.10 ^b	14.21 ^b	16.98 ^a	17.25 ^a	4.02	<0.05	NS	<0.05
NDF (g/kg)	360.5 ^a	330.0 ^b	320.7 ^c	305.2 ^d	36.44	<0.01	<0.01	<0.01
ADF (g/kg)	250.2 ^a	227.5 ^b	225.7 ^b	200.7 ^c	32.55	<0.05	<0.05	<0.05
Amylopectin (g/kg)	809 ^c	834.9 ^b	830.9 ^b	874.5 ^a	72.10	<0.05	<0.05	<0.05
Resistant starch (g/kg)	98.50 ^a	48.0 ^c	70.50 ^b	35.0 ^d	12.75	<0.05	<0.05	<0.05
hydrocyanide (mg/kg)	30.4 ^a	30.20 ^a	23.6 ^b	22.50 ^b	4.74	<0.05	NS	<0.05
Tannin (%)	0.32	0.30	0.30	0.29	0.02	NS	NS	NS
Ca (mg/kg)	0.31	0.29	0.30	0.30	0.001	NS	NS	NS
P (mg/kg)	0.52	0.50	0.51	0.54	0.055	NS	NS	NS
Mg (mg/kg)	0.62	0.59	0.60	0.60	0.082	NS	NS	NS
Mn (mg/kg)	0.009	0.008	0.009	0.009	0.0001	NS	NS	NS
Cu (mg/kg)	0.009 ^a	0.003 ^b	0.009 ^a	0.002 ^b	0.0007	NS	<0.05	<0.05
Fe (mg/kg)	0.11	0.10	0.11	0.10	0.004	NS	NS	NS
K (mg/kg)	6.2 ^a	5.70 ^a	6.4 ^a	5.0 ^b	0.92	NS	<0.05	<0.05
Zn (mg/kg)	0.03 ^a	0.02 ^a	0.03 ^a	0.01 ^b	0.007	NS	<0.05	<0.05

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

371 **Table 2.** Effect of solid-state fermentation on amino acid profile of unpeeled and peeled cassava
 372 root meal

Cassava processing (CRP)	root	Unpeeled		Peeled		Pooled SEM	<i>Level of significance</i>		
		No	Yes	No	Yes		CRP	SSF	CRP × SSF
<i>Measurements (g/100g protein)</i>									
	Asparagine	0.14	0.15	0.15	0.14	0.002	NS	NS	NS
	Threonine	0.04	0.05	0.05	0.04	0.002	NS	NS	NS
	Serine	0.07	0.07	0.08	0.07	0.003	NS	NS	NS
	Glutamine	0.40	0.42	0.41	0.40	0.001	NS	NS	NS
	Glycine	0.10	0.10	0.11	0.10	0.003	NS	NS	NS
	Alanine	0.14	0.14	0.12	0.14	0.005	NS	NS	NS
	Cysteine	0.04	0.05	0.05	0.04	0.010	NS	NS	NS
	Valine	0.09	0.10	0.09	0.10	0.02	NS	NS	NS
	Methionine	0.01	0.02	0.10	0.10	0.002	NS	NS	NS
	Isoleucine	0.05	0.06	0.05	0.06	0.001	NS	NS	NS
	Leucine	0.15	0.15	0.15	0.16	0.001	NS	NS	NS
	Tyrosine	0.04	0.05	0.05	0.05	0.002	NS	NS	NS
	Phenylalanine	0.07	0.06	0.06	0.07	0.001	NS	NS	NS
	Lysine	0.02	0.01	0.01	0.01	0.002	NS	NS	NS
	Histidine	0.03	0.03	0.02	0.02	0.001	NS	NS	NS
	Arginine	0.08 ^b	0.15 ^a	0.09 ^b	0.17 ^a	0.012	NS	<0.05	<0.05
	Proline	0.15	0.16	0.15	0.16	0.004	NS	NS	NS

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

374 NS= Not significant

375 **Table 3.** Metabolisable energy values of peeled and unpeeled cassava root meal subjected to
 376 solid-state fermentation and supplemented with or without amino acids for meat-type cockerels

Attributes			AME	AMEn	TME	TMEn
Cassava root processing	Solid-state fermentation	Amino acid supplementation				
Unpeeled	No	No	11.62 ^b	11.85 ^b	12.01 ^c	12.33 ^c
Unpeeled	No	Yes	11.70 ^b	11.90 ^b	12.15 ^c	12.44 ^c
Unpeeled	Yes	No	11.92 ^b	12.20 ^b	12.42 ^{bc}	12.64 ^b
Unpeeled	Yes	Yes	11.99 ^b	12.35 ^b	12.50 ^{bc}	12.80 ^b
Peeled	No	No	12.22 ^b	12.32 ^b	12.51 ^{bc}	12.59 ^b
Peeled	No	Yes	12.10 ^b	12.15 ^b	12.49 ^{bc}	12.60 ^b
Peeled	Yes	No	12.85 ^a	12.90 ^a	13.29 ^b	13.34 ^b
Peeled	Yes	Yes	12.75 ^a	12.84 ^a	13.67 ^a	13.76 ^a
Pooled SEM			2.22	2.07	2.10	2.05
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

377 ^{a,b,c,d} Values in the same column not sharing a common superscript are significantly different at P

378 <0.05 .

379 NS= Not significant