Nig. J. Anim. Prod. 2019, 46(3):205 - 218
Nigerian Journal of Animal Production

High quality cassava peel® production and its utilization in pig production: A review

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Abstract

The cassava peel has been investigated as a good source of energy for various categories of livestock and it has been reported as a good substitute for maize for all classes of pigs. International Livestock Research Institute (ILRI) has transformed fresh cassava peels into high quality, safe and hygienic livestock feed, known as High Quality Cassava Peel®. High Quality Cassava Peel® was produced by sorting, grating, pressing, sieving and drying of fresh cassava peels. Sorting of the fresh (harvested the same day) cassava peels was done by removal of the stumps, large sized woody tubers and other foreign materials before grating, to gradually reduce the particle size, ensure rapid dewatering, drying and easy handling of the sorted peels. Next is the pressing of the grated peels in woven bags using a hydraulic jack and wooden planks. The resultant cassava peel cake after pressing around 30- 35% moisture had shelf life of 5- 7 days. The pressed cassava peel cake was re-grated to loosen it into a free flowing material that can be subjected to sieving to separate the fine mash (lower fiber, high energy content) from the coarse mash (higher fiber, lower energy content). The resultant fine or coarse mash was further dried by toasting or sun-drying to a moisture level of 10-12%. The final product with 10–12% moisture content was bagged and stored safely for 4- 6 months without any spoilage. Proximate analysis of the HQCP® further clarified its quality over that of other processed cassava peels. Series of trials conducted have proved High Quality Cassava Peel as a good substitute for significant portion of maize in the diet of growing and weaned pigs without any adverse effect on the performance and blood parameters determined in each of the studies. The results of the studies conducted on the utilization of the high quality cassava peel as a substitute for maize in the diet of weaned and growing pigs have shown the efficacy of HQCP® to replace significant quantities of maize in their diet. High Quality Cassava Peel demonstrated potential for replacement of up to 15% of the 40% maize inclusion in the diet of weaned pigs and 30% in the diet of growing pigs with or without direct fed microbial (DFM) supplementation. No significant effect of DFM was noticed in the utilization of HQCP® by both weaned and growing pigs. All the hematological and serum biochemical parameters determined were within the normal range for healthy pigs. Based on the outcome of the feeding trials, HQCP® has been proved to replace a substantial portion of maize in the diet of weaned and growing pigs, thereby bringing about a decrease in the cost of production.

Keywords: High quality cassava peel®, weaned and growing pig feeding, growth performance, direct fed microbial, hematology, serum biochemical parameters

Introduction

Cassava is an important food crop in many African countries. Cassava processing generates cassava peels, stumps and other undersized/damaged tubers, which together, accounts for up to a third of processed whole-tuber weight. About 14 million tonnes of byproducts, comprising peels, stumps, woody and undersized tubers currently disposed off as waste, are generated from the processing of cassava (*Manihot esculenta*) (Okike *et al.*, 2015). Cassava peel is the main byproduct from the processing of cassava into various products such as gari for human consumption and others, such as cassava starch. FAO (2001) estimated that about 250-300kg of cassava peel is produced per tonne of fresh cassava root. The cassava peel has been investigated as a good source of energy for various categories of livestock and it has been reported as a good substitute for maize for all classes of pigs (Onyimonyi and Okeke, 2005; Adesehinwa *et al.,* 2008; Nnadi *et al*., 2013). Constraints that limit the inclusion of cassava peel in the diet of pigs and other animals include large amount of cyanogenic glycosides, high phytate content, low crude protein content, poor amino acid pro?le, comparatively high ?bre content and quick spoilage, if left unprocessed, particularly during the rainy season. Most of the methods that have been used to combat these constraints include soaking, sun-drying and ensiling (Salami and Odunsi, 2003), fermentation and sun drying (Onyimonyi and Okeke, 2005) and amino acid supplementation (Olufemi *et al.,* 2013). Drying is the most practical, and the main method of processing cassava peels into useful animal feed. Drying considerably reduces the HCN levels, and sun-drying had been demonstrated to be more effective than oven-drying (Tewe *et al.* 1980). Apart from the fact that sun drying of cassava peels takes a longer period (approximately 3-5 days) for it to be properly dried, it is also only feasible during the dry season of the year. Moreover, the drying of cassava peels, particularly during the rainy season, can pose serious problems of microbial contamination and this could be more serious than the hydrocyanic acid in dried cassava peels. Because of this constraint of drying, most of cassava peels produced during the rainy season are mostly disposed off by burning or allowing them to rot in heaps, causing pollution. The new innovative processing method of fresh cassava peels by the International Livestock Research Institute (ILRI) has transformed fresh cassava peels into high quality, safe and hygienic livestock feed, and has been demonstrated as technically feasible and economically competitive against existing equivalents. It has also dramatically improved the nutritive value of cassava peel and resulted in an end product known as High Quality Cassava Peel (HQCP®) which can either be fine or coarse. Fine mash is appropriate for poultry, fish, and pigs while coarse mash was targeted at feeding cattle, goat, sheep and pigs.

Processing of cassava peels into High quality cassava peel (HQCP®) as livestock feed ingredient

Cassava peels are perishable and are mostly disposed off by burning or allowing them to rot in heaps, causing pollution. In collaboration with its CGIAR research partners, ILRI developed an innovative processing technology for converting fresh peels into high quality cassava peel (HQCP) mash for use as livestock feed. The various steps followed in processing the peels into HQCP mash are briefly described in this paper.

Sorting

The quality of the finished product is as good as the quality of the raw material used, so cassava peels that entered the process was fresh (harvested the same day) and free from contaminants. It was noted that when processing was delayed beyond a day, the peels start to ferment and become soggy/slippery and difficult to grate. Stumps, large sized wood tubers, and other foreign materials were sorted out and discarded before grating the peels to avoid damage to the rasper.

Grating

Grating was done three times because of the tough nature of the peels. With each grating, the particle size reduced gradually. The reduced particle size facilitated rapid dewatering, drying, and easier handling.

Grating

Pressing

Pulverizing

1st grating

2nd grating

3rd grating

Pressing

The grated peel was pressed using hydraulic jack, wooden planks, woven bags and a metal frame, which held the loaded bags of freshly grated peels. Grated peels were packed in small quantities of 8- 10 kg and the bags were stacked in the metal frame. Using planks and jacks, the grated peels were squeezed to rapidly get rid of as much water as possible. Approximately 50% of the weight of grated material was lost as the water was removed during this process. The resulting cassava peel cake after dewatering had around 38- 42% moisture and had a shelf life of 5- 7 days.

Pulverizing and sieving cassava peel cake

To process the cassava peel cake further into dry mash, it was re-grated to loosen it into a free flowing material that can be subjected to sieving, to separate the fine mash (lower fiber, high energy content) from coarse mash (higher fiber, lower energy content). Sieving was done manually or by using a mechanical device.

Drying or toasting

After separation, the resulting fine and coarse mash with a moisture content of 38- 42% was further dried properly for better storage. Drying was feasible on sunny days, with the fine and coarse mash dried by spreading thinly over commonly available surfaces (e.g. plastic and metal sheets, cement slabs) with frequent stirring of the materials at hourly intervals.

Sun drying on plastic sheet

Toasting in a metal pan

Proper drying of the mash until it reaches 10–12% moisture level required a period of 6–8 hours. On rainy days, when sun drying was not feasible, the sieved mash was toasted over a metal pan using firewood, coal or other materials, e.g. palm kernel shells. The dried material had 10–12% moisture before being packed into bags and stored safely for 4- 6 months before being used for feeding without any spoilage (Okike *et al.*, 2015).

Proximate Compositions of Cassava Peel and High Quality Cassava Peel

Apart from all the benefits of HQCP® over other processed cassava peels such as reduction in the drying duration, lower amount of cyanogenic glycosides and extended storage period, Fatufe *et al*. (2017) compared the proximate composition of the HQCP® with that of ordinary sundried or fresh cassava peel. HQCP® had a higher dry matter content (90.94%). Same goes for the crude protein content (6.63%), except for the crude protein of cassava peels determined by Onyimonyi and Okeke (2005). Nutrient profiles of HQCP® and ordinary sundried cassava peels are shown in Table 1.

Table 1: Comparison between proximate compositions of cassava peel and high quality cassava peel

	CASSAVA PEEL					HQCP®
Parameters	Devandra (1977)	Ogbonna and Adebowale (1993)	Onyimonyi and Okeke (2005)	Aro *et al.* (2010)	Adesehinwa *et al*. (2011)	Adesehinwa *et al*. (2016)
% Dry matter	ND	86.2	ND	17.9	89.24	90.94
% Crude Protein	4.8	5.1	7.50	4.2	3.15	6.63
% Crude Fibre	21.1	16.7	17.73	29.6	33.96	8.7
% Crude fat	1.2	1.2	7.81	3.26	0.34	2.47
% Ash	4.2	9.5	12.82	7.47	1.44	3.28
% NFE	68.6	67.5	54.14	55.5	50.35	70
Metabolizable energy (kcal/kg)	ND	3210	ND	ND	ND	2985

Studies on the Use of High Quality Cassava Peel for feeding of weaned pigs

The results of all the studies conducted on the utilization of the high quality cassava peel as a substitute for maize in the diet of weaned and growing pigs have shown the efficacy of HQCP® to replace a significant quantity of maize in their diet. Adesehinwa *et al*. (2017) conducted a feeding trial with weaned crossbred (Large white × Landrace) pigs to determine the replacement value of high quality cassava peel fine mash for maize and its optimal dietary inclusion levels in weaned pigs' diet. One hundred and five weaned pigs with an average initial weight of 7.45 ± 0.17 kg were allotted to five dietary treatment groups in the study. Dietary treatments consisted of control diet with 40% maize without HQCP®, while HQCP® replaced maize at 7.5, 15, 22.5 and 30% in the other diets, respectively. The result of the work is presented in Table 2.

Table 2: Performance of weaned pigs fed diets containing graded levels of HQCP®

Parameters	T1	T2	T3	T4	T5	P (ANOVA)	±SEM
Initial weight (kg)	7.59	7.81	7.36	7.36	7.12	0.7368	0.17
Final weight (kg)	24.62^{a}	22.00^{ab}	19.49^{bc}	17.84^{cd}	15.57^{d}	<.0001	0.60
Body weight gain (kg)	17.05^{a}	14.19^{b}	12.12^{bc}	10.52^{c}	8.45^{d}	<.0001	0.47
Average daily weight gain (g)	243.50^{a}	202.72^{b}	173.13^{bc}	150.26^{cd}	120.75^{d}	<.0001	6.77
Average daily feed intake (g)	661.65^{a}	579.25^{ab}	502.14^{b}	511.52^{b}	398.53^{c}	<.0001	17.03
Feed conversion ratio	2.7261^{b}	2.8502^{b}	2.9572^{b}	3.4820^{a}	3.3290^{a}	<.0001	0.01

SEM - Standard error of mean
Source- Adesehinwa *et al*. (2017)

Pigs on the control diet had significantly (P<0.05) higher daily gains and feed intake compared to the pigs on the other treatment groups. Average daily weight gain and average daily feed intake tended to decrease linearly with increasing levels of HQCP®. However, feed conversion ratio was comparable at the 0 (control), 7.5 and 15% HQCP® groups. Pigs on 22.5 and 30% HQCP® levels had significantly (P<0.05) higher feed conversion ratio compared to pigs on replacement levels up to 15%. Although they concluded that HQCP® was inferior to maize grains for optimum performance of the weaned pigs because of their significant performance in average daily weight gain and average daily feed intake, and suggested the possible need for energy and protein fortification to match the nutrient profile of the maize grains. In terms of feed conversion ratio, HQCP® demonstrated the potential for replacement of up to 15% of the 40% maize inclusion in the diet.

Based on the results of the first study, Adesehinwa *et al*. (2018) conducted another study where the authors checked if supplementation of direct fed microbial (DFM) will improve the utilization of HQCP® by weaned pigs or not. The basis for the study was the result of an experiment conducted by Fatufe *et al.* (2016) which compared the utilization of two dietary fibre sources supplemented with direct-fed microbial in growing pigs. The result showed significant improvement in the performance of growing pigs fed palm kernel cake-based diet supplemented with multi-strain direct-fed microbial. The experimental animals were assigned to five dietary treatments in a 2 × 2 +1 factorial design of eighteen weaned pigs per treatment. Control pigs (T1) in the study were given 40% maize-based diet without HQCP® while 7.5kg (18.75%) and 15kg (37.5%) of the total maize were replaced with HQCP® in the treatment diets. The pigs on T4 were given diet containing the same quantity of HQCP® (7.5kg) as in T2 with the addition of the multi-strain DFM while pigs on T5 were given diet containing the same quantity of HQCP® (15kg) with those on T3 with addition of the multi-strain DFM.

The result of the study is presented in Table 3. There were no significant ($p>0.05$) differences in the final weights across the treatments. The lowest numerical final weight (24.42kg) was recorded in pigs on 15kg HQCP® diet without the addition of DFM (T3) while the highest (26.97kg) was recorded in pigs on 7.5kg HQCP® diet without the addition of DFM (T2). Likewise, no significant difference was observed in the average daily weight gain, average daily feed intake and feed conversion ratio. Pigs on treatment 4 recorded the lowest average daily weight gain (236.57g) while the highest average daily weight gain (769.50g) was recorded with pigs fed treatment 2 diet.

Table 3: Performance of weaned pigs fed experimental diets

Parameters	T1	T2	T3	T4	T5	P (ANOVA)	±SEM
Initial weight (kg)	10.97	10.96	10.88	11.46	11.53	0.99	0.50
Final weight (kg)	25.95	26.97	24.42	24.71	26.42	0.87	0.85
Daily weight gain (g)	267.49	285.87	241.78	236.57	265.87	0.33	8.22
Average daily feed intake (g)	716.51	769.50	691.80	672.24	753.29	0.77	26.35
feed conversion ratio	2.80	2.60	2.91	3.10	2.98	0.65	0.10

SEM - Standard error of mean
Source- Adesehinwa *et al*. (2018)

The addition of DFM did not improve performance of the pigs fed diets T4 and T5 over the pigs on treatments T2 and T3 without the DFM addition. This showed that the DFM may not have any effect on the levels of HQCP® used in the study, taking into consideration the crude fibre content and fibre fractions of the test diets. The least average daily feed intake (672g) was recorded in pigs on T4, while those on T2 recorded the highest average daily feed intake (770g). Although there were no significant differences in the feed intake and body weight gain, the treatment with the highest feed intake (T2) also recorded the highest weight gain vis-à-vis the one with lowest feed intake, which also recorded the lowest weight gain. The feed conversion ratios ranged from 2.60 to 3.10.

Studies on the use of High Quality Cassava Peel for growing pigs feeding

In the study with growing pigs on their utilization of the HQCP®, Adesehinwa *et al.* (2016) carried out a feeding trial of 56 days to determine the effect of partial replacement of maize with graded levels of high quality cassava peel mash on growth performance, cost of production, haematological and serum biochemical responses of growing pigs. Control diet T1 had 40% of maize while the dietary treatments T2, T3, T4 and T5 had 7.5, 15, 22.5 and 30kg of HQCP® corresponding to replacement of maize with 0, 19, 38, 56 and 75% respectively. The results of the study are summarized in Table 4.

Table 4: Performance of growing pigs fed experimental diets

Parameters	T1	T2	T3	T4	T5	P(ANOVA)	±SEM
Initial weight (Kg)	31.67	31.22	31.11	32.00	31.67	0.998	0.83
Final weight (Kg)	54.56	53.33	53.44	52.22	51.44	0.949	1.23
Daily weight gain (g)	408.73	394.84	398.81	361.11	353.17	0.340	0.01
Average Daily feed intake (g)	2030.65^{b}	1935.04^{d}	1850.16^{e}	2042.73^{a}	1995.35^{c}	<0.001	10.82
FCR	5.05	5.00	4.90	5.97	5.70	0.118	0.16

FCR- Feed Conversion Ratio
Source- Adesehinwa *et al.* (2016)

Apart from average daily feed intake which was significantly different, the other growth parameters were comparable. However, the highest numerical final body weight value (54.56 kg) was recorded in pigs on T1 which was the maize-based control diet and the least value (51.44kg) was recorded in pigs fed CP-T5. Growing pigs on T1 (maize based diet) consumed ($P<0.05$) a higher quantity of feed than those fed HQCP® based diets except for pigs on treatment 4 that consumed the highest quantity of feed. Within the HQCP® diets, pigs on treatment 3 consumed the least amount of feed while those on treatment 4 had the highest feed intake. The best feed conversion ratio numerically was recorded in T3, implying that the least amount of feed was required to gain 1kg of weight, even though this may not be totally attributable to the HQCP® inclusion level of 15% of diet. They therefore concluded that feeding growing pigs with HQCP® as a replacement for maize had beneficial effect on the overall performance and can replace up to 75% of the maize in the diet (representing 30kg of HQCP® as a replacement of the 40kg maize in the control diet, weight for weight) of growing pigs, without any adverse effect on the weight gain and feed conversion ratio.

To further elucidate the effect of feeding high quality cassava peel mash on the performance of growing pigs, Adesehinwa *et al.* (2018) conducted a trial by supplementing HQCP® with or without multi-strain direct fed microbial (DFM) as replacement for the maize portion of the diet of growing pigs. A total of 90 growing pigs with average initial weight of 25.36±0.87 kg were randomly assigned to five dietary treatment groups in a 2×2+1 factorial arrangement in a completely randomised design. The factors were 2 levels of HQCP® (7.5% and 15%), two DFM inclusion rates and a control diet with neither HQCP® nor DFM. Pigs on T1 were given a corn based diet (40%) without HQCP® nor DFM, T2 had 7.5% of maize replaced by HQCP® and T3 had 15% of total maize replaced by HQCP®. The pigs on T4 were given same diet as those on T2 with addition of multi-strain DFM while, animals on T5 were given the same diet as those on T3, with addition of multi-strain DFM. The result of the study is presented in Table 5.

Table 5: Growth response of growing pigs fed high quality cassava peel supplemented with direct fed microbial

Parameters	T1	T2	T3	T4	T5	P(ANOVA)	±SEM
Initial weight (kg)	25.95	26.97	23.81	23.77	26.28	0.70	0.87
Final weight (kg)	38.92	40.25	37.36	36.77	37.25	0.93	1.31
Body weight gain (kg)	12.97	13.28	13.56	13.00	10.97	0.49	0.49
Daily weight gain (g)	308.90	316.22	322.75	309.52	261.24	0.49	11.76
Total feed intake (g)	53128	55468	49493	51628	50058	0.71	1430.24
Average daily feed intake (g)	1265.00	1320.70	1178.40	1229.20	1191.80	0.71	34.05
Feed conversion ratio	4.50	4.40	3.98	4.35	4.77	0.51	0.14

SEM - Standard error of mean,
Source- Adesehinwa *et al.* (2018)

The highest final weight of 40.25 kg numerically, was recorded in pigs on T2 which were fed 15% HQCP® as replacement for the maize portion of the diet. This was however not significantly (P>0.05) different from what was recorded in other treatments. The lowest final weight (36.77 kg) was recorded for pigs on T4. The supplementation of the diets with the DFM (1×10^{8} CFU/g *Lactobacillus* sp, 4×10^{12} CFU/g *Bacillus sp* and 11×10^{5} CFU/g *Saccharomyces cerevisiae*) did not have any significant (P>0.05) influence on the body weight gain and FCR of the growing pigs in this study. The feed intake of the pigs on the different treatments was also not significantly influenced by the inclusion of HQCP® nor DFM in the diets of the pigs. However, the least numerical value for the FCR (3.98) was observed in T3 and the highest (4.77), in T5.

In order to verify the nutrient utilization of the HQCP®, Fatufe *et al.* (2017) conducted a total tract digestibility trial to determine the effect of partial replacement of maize with graded levels of HQCP® mash on the nutrient digestibility and fibre fraction digestibility of growing pigs. Twenty growing pigs with an average initial weight of 53±0.5 kg were randomly assigned to five dietary treatments in a completely randomized design with four replicates per treatment and one animal in each replicate. The control diet T1 had 40% of maize, while the other dietary treatment groups T2, T3, T4 and T5 had 7.5, 15, 22.5 and 30kg of HQCP® corresponding to replacement of maize by 0, 19, 38, 56 and 75% respectively. The result of the trial is presented in Table 6.

Table 6 : Apparent nutrient and fibre fraction digestibility coefficient (%) of growing pigs fed HQCP® experimental diets (%)

Parameters	T1	T2	T3	T4	T5	P-Value	±SEM
Dry matter	64.3	64.9	67.5	64.7	63.9	0.46	0.60
Crude protein	81.9^{a}	79.0^{bc}	80.6^{ab}	77.8^{c}	77.1^{c}	0.004	0.53
Organic matter	86.8	88.6	87.8	88.9	86.5	0.60	0.54
Crude fibre	15.9	24.6	29.6	23.8	22.9	0.07	1.52
Ether extract	80.7^{a}	69.0^{b}	63.3^{b}	69.5^{b}	70.4^{ab}	0.04	1.87
Nitrogen free extract	88.2	90.8	89.4	91.5	91.7	0.49	0.70
Energy	88.9	89.0	89.7	88.8	88.4	0.47	0.20
NDF	71.1^{b}	74.3^{ab}	76.4^{a}	74.0^{ab}	73.3^{ab}	0.03	0.55
ADF	69.6^{b}	76.5^{a}	78.3^{a}	76.3^{b}	75.6^{a}	0.0001	0.78
ADL	69.3^{b}	82.4^{a}	82.4^{a}	80.3^{a}	79.9^{a}	<.0001	1.17
Hemicellulose	72.2	72.0	74.4	71.6	70.8	0.31	0.51
Cellulose	69.8	72.9	75.1	73.4	72.2	0.06	0.59

SEM - Standard error of mean
Source- Fatufe *et al.* (2017)

There were no significant differences (P>0.05) in the apparent nutrient digestibility coefficient of dry matter, nitrogen free extract, crude fibre, organic matter and energy, but there were significant (P<0.05) variations in the apparent digestibility of crude protein and ether extract. The crude protein digestibility decreased as the level of HQCP® increased from 7.5 to 30%. There was also a significant (P<0.05) increase in the acid detergent fibre and the acid detergent lignin digestibility, with the inclusion of HQCP® compared to the control, whereas there was no significant (P>0.05) influence of HQCP® inclusion on hemicellulose and cellulose digestibility among the treatments. They thus concluded that the nutritional potential of high quality cassava peel can still be realized when fed up to 30% in the diet of growing pigs.

Effect of high quality cassava peel supplementation on the economics of production

Feed constitute 60-80% of the variable cost of production in a livestock enterprise. Achieving a comparable good performance by feeding at reduced cost will be beneficial in production. Results of studies on the economic analysis of high quality cassava peel (HQCP) fine mash as a replacement for maize in diets of weaned and growing pigs supplemented with or without multi-strain direct fed microbial are shown in Tables 7 to 10. Economics of production of growing pig fed on high quality cassava peel fine mash as a replacement for maize as presented in Table 7 revealed that the control diet gave significantly (P<0.05) higher total feed cost and average cost of feeding per day than the HQCP diets due to the higher cost per kg of maize against HQCP (<60 versus <25), even though there was no significant reduction in the cost of production (feed cost/kg weight gain) with increased inclusion level of HQCP (Adesehinwa *et al.*, 2016). This was contrary to the findings of Adesehinwa *et al.* (2011), who reported decrease in cost per kg weight gain as a result of feeding growing pigs with enzyme supplemented cassava peels based diet.

Table 7: Cost analysis of growing pigs fed high quality cassava peel fine mash as a replacement for maize

Parameters	T1	T2	T3	T4	T5	P(ANOVA)	±SEM
Cost of feed (</Kg)	71.0[a]	68.4[b]	65.8[c]	63.1[d]	60.1[e]	<0.001	0.56
Total cost of feeding (<)	8090[a]	7409[b]	6812[d]	7222[c]	6760[e]	<0.001	72.71
Average cost of feed per day (<)	145[a]	132[b]	121[d]	129[c]	121[e]	<0.001	1.30
Feed Cost/kg Weight Gain (</Kg)	359	342	322	377	345	0.515	9.87

SEM - Standard error of mean. Source: Adesehinwa *et al.* (2016)

In Table 8, there were significant (P<0.05) difference in all the economic parameters assessed. The cost per kg feed decreased as the level of HQCP increased from T1 to T5. Based on the economy of producing a kilogram of body weight, 30% HQCP diets was the cheapest feed while 0% HQCP diet was most expensive (Table 8). With respect to the weaned pig trial (Adesehinwa *et al.*, 2017), the cost of feeding per unit weight gain was comparable among the groups mainly due to the savings on account of the lower cost of HQCP® compared to maize grains, with the exception of T4 (22.5% HQCP®).

Table 8: Economic analysis of high quality cassava peel mash as an alternate source of energy supplement in weaned pig diet

Parameters	T1	T2	T3	T4	T5	P(ANOVA)	±SEM
Cost of feed (</Kg)	199.0[a]	112.2[b]	105.5[c]	97.7[d]	92.0[e]	<.0001	0.942
Total cost of feeding (<)	5511.4[a]	3945.5[b]	4277.6[b]	3535.7[b]	2566.4[c]	<.0001	147.806
Average cost of feed per day (<)	78.73[a]	56.36[b]	61.11[b]	50.51[b]	53.66[c]	<.0001	2.112
Feed Cost/kg Weight Gain (</Kg)	324.39[ab]	319.92[b]	311.97[b]	343.8[a]	306.26[b]	0.0150	3.694

SEM - Standard error of mean. Source: Adesehinwa *et al.* (2017)

With the addition of DFM in another weaned pig study by Adesehinwa *et al.* (2018), the highest cost of feed was recorded in treatment 4 (15% HQCP®) due to the additional cost of DFM. The cost of feed per unit weight gain (N/kg) was comparable across the groups and there were no significant differences in the total cost of feed (N), and average cost of feed consumed by the animal per day (N).

Table 9: Economic Analysis of weaned pigs fed HQCP diets supplemented with multi-strain direct fed microbial

Parameters	T1	T2	T3	T4	T5	P(ANOVA))	±SEM
Cost of feed (</Kg)	137.37^b	134.56^d	131.75^e	137.76^a	134.95^c	<.0001	0.23
Total cost of feeding (<)	5511.90	5798.30	5104.00	5186.00	5692.70	0.7745	199.35
Average cost of feed per day (<)	98.43	103.54	91.14	92.61	101.65	0.7745	3.60
Feed Cost/kg Weight Gain (</Kg)	385.20	349.79	383.98	427.25	402.40	0.5702	14.26

SEM - Standard error of mean. Source: Adesehinwa *et al.* (2018)

The feed cost among the treatments differ significantly (P<0.05) from one another (Table 10). The significantly (P<0.05) lowest feed cost of <131.75/kg of feed was recorded in diet T3 fed the highest level of HQCP without DFM while the significantly highest feed cost of <137.76/kg was recorded in T4. The addition of DFM to diet as in T4 and T5 increased the cost of the feed when compared with T2 and T3 respectively that has the same level of HQCP but without DFM. The feed cost per weight gain showed no significant difference among the treatments and ranged between <524.31 and <643.79 in treatment T3 and T5 respectively (Adesehinwa *et al.*, 2018).

Table 10: Economic Analysis of growing pigs fed HQCP diets supplemented with multi-strain direct fed microbial

Parameters	T1	T2	T3	T4	T5	P(ANOVA)	±SEM
Cost of feed (</Kg)	137.37^b	134.56^d	131.75^e	137.76^a	134.95^c	<.0001	0.23
Total cost of feeding (<)	7298.1	7463.6	6520.6	7112.1	6755.2	0.5403	194.49
Average cost of feed per day (<)	173.77	177.70	155.25	169.34	160.84	0.5403	4.63
Feed Cost/kg Weight Gain (</Kg)	618.53	592.48	524.31	598.85	643.79	0.3647	19.35

SEM - Standard error of mean. Source: Adesehinwa *et al.* (2018)

Generally, it could be said that there was a reduction in the cost of feed per kilogramme diet as the level of HQCP® was increased in the study with or without DFM supplementation for both weaned and growing pig studies. 30% HQCP® diet was the cheapest feed while 0% HQCP® control diet was the most expensive.

Effect of high quality cassava peel supplementation on blood parameters

The results of haematological and serum biochemical parameters of growing pigs fed graded levels of high quality cassava peel fine mash as a replacement for maize supplemented with or without direct fed microbials is shown in Tables 11 to 14. There were significant difference (P<0.05) in White blood cell, neutrophils, eosinophils, monocytes, lymphocytes across all the dietary treatments (Table 11). Total WBC and neutrophil were significantly higher in CP-1 than other treatments, while eosinophil counts were significantly higher in CP-5 and animals on CP-4 recorded the highest monocyte count. All the values for all the haematological parameters were within the physiological normal range for healthy growing pig (Merck Manual 2012a) implying that inclusion of HQCP in the diets did not show any adverse effect during the experimental period (Adesehinwa *et al.*, 2016).

Table 11: Haematological parameters of growing pigs fed graded levels of high quality cassava peel fine mash as a replacement for maize

Parameters	CP-1	CP-2	CP-3	CP-4	CP-5	P(ANOVA)	±SEM
White Blood Cell (10^3)	9.33[a]	6.50[b]	8.88[ab]	8.98[ab]	7.51[ab]	0.044	0.39
Neutrophils (%)	49.67[a]	46.00[a]	47.17[ab]	47.17[ab]	41.50[b]	0.028	1.05
Eosinophils (%)	2.17[a]	1.83[a]	2.17[a]	2.00[a]	2.50[a]	0.884	0.20
Monocytes (%)	1.67[b]	1.67[b]	2.00[b]	3.33[a]	1.67[b]	<0.001	0.17
Lymphocytes (%)	46.50[b]	46.00[b]	48.67[ab]	47.50[b]	54.33[a]	0.031	1.05

Source: Adesehinwa *et al.* (2016)

All the Serum parameters measured were significantly ($p< 0.05$) different (Table 12) and most of which were within the normal range for healthy growing pigs (Merck Manual 2012b). Alanine transaminase (ALP) values for maize based diets were higher than that of the HQCP incorporated diets. The blood urea concentration significantly ($P<0.05$) differed among the treatments with lowest numerical value in CP-4 (21.17mg/dL) and the highest in CP-1 ((32.57mg/dL control). This trend suggested that there was no kidney damage due to HCN from HQCP or other anti-nutrients in the diets, since the values were lower in the HQCP incorporated diets. Urea is the main nitrogenous end product arising from the catabolism of amino acids that are not used for biosynthesis in mammals (Adesehinwa 2004). The values for the creatinine and thiocyanate are within the normal range reported in the Merck manual for the pigs (Adesehinwa *et al.*, 2016).

Table 12: Serum biochemical parameters of growing pigs fed graded levels of high quality cassava peel fine mash as a replacement for maize

PARAMETERS	T1	T2	T3	T4	T5	P(ANOVA)	±SEM
ALT (IU/L)	13.9[b]	13.9[b]	17.4[a]	15.2[ab]	16.6[ab]	0.034	0.52
ALP (IU/L)	33.70[a]	24.24[ab]	20.83[b]	25.32[ab]	25.90[ab]	0.033	1.63
Creatinine (mg/dL)	2.00[b]	3.00[a]	2.83[ab]	2.17[ab]	2.67[ab]	<0.001	0.14
Urea (mg/dL)	32.57[a]	30.02[ab]	28.35[ab]	21.17[b]	27.37[ab]	0.042	1.44
Cholesterol (mg/dL)	133.02[ab]	119.54[b]	114.36[b]	148.27[a]	132.76[ab]	0.028	4.19
HDL – Cholesterol (mg/dL)	103.80[a]	107.80[a]	103.65[a]	106.43[a]	97.44[a]	0.358	2.95
LDL – Cholesterol (mg/Ll)	11.65[ab]	11.47[ab]	12.90[a]	5.34[c]	8.69[b]	0.001	0.69
Thioc. (mg/mL)	1.72[bc]	0.74[d]	1.41[cd]	2.45[ab]	2.90[a]	<0.001	0.18
SOD ($\times10^{-2}$ unit/mL)	5.73[a]	5.83[a]	7.00[a]	5.80[a]	5.95[a]	0.211	0.004

ALT- alanine aminotransferase, ALP- alkaline phosphatise, SOD-Superoxide dismutase, HDL- high-density lipoproteins cholesterol, LDL- low-density lipoproteins cholesterol.
Source: Adesehinwa *et al.* (2016)

The effect of feeding HQCP supplemented with DFM in the diets of growing pigs on the haematological parameters is as shown in Table 13. No significant ($P>0.05$) difference was observed in all the parameters examined. The highest concentration of lymphocyte (54.00 %) was recorded on T1 where the diet contained no inclusion of HQCP and DFM while the lowest concentration of the lymphocyte was observed in T3. The values obtained for haematological parameters in this study falls within the physiological normal range of a healthy pig (Merck Manual, 2012a). The level of RBC and WBC recorded from this study indicated that no pathological effect was induced and thus, the health of the animals was not compromised (Adesehinwa *et al.*, 2018). This supported the report of Chen *et al.* (2005) and Ojebiyi *et al.* (2015) that the addition of direct fed microbials (DFM) to diet of livestock does not illicit pathogenic effect on the host.

Table 13: Effect of direct fed microbials and high quality cassava peel on the haematology of growing pigs

Parameters	T1	T2	T3	T4	T5	P(ANOVA)	SEM
PCV (%)	34.500	34.500	31.000	32.750	35.250	0.7500	1.047
H.b (g/dL)	11.500	11.498	10.335	10.913	11.750	0.7504	0.35
RBC ($X10^6$)	6.120	6.700	6.453	6.053	7.060	0.8442	0.29579
WBC ($X10^3$)	8638	8950	7175	7613	9838	0.7463	645.450
Lymp (%)	54.00	51.75	47.25	49.75	48.50	0.1825	0.965
Neut (%)	39.25	41.50	45.50	44.25	44.75	0.2030	0.958
Mono (%)	3.50	2.75	2.75	2.25	3.00	0.4910	0.225
Eos (%)	3.25	4.00	4.75	5.00	3.75	0.4550	0.327
Platelets	148250	199750	147750	125000	171500	0.5307	13711.21

Note: SEM = Standard error of mean, DFM = Direct fed microbial, PCV = Packed cell volume, Hb = Haemoglobin, RBC = Red blood cells, WBC = White blood cells, Lymp = Lymphocyte, Neut – Neutrophils, Mono = Monocytes, Eos = Eosinophils.
Source: Adesehinwa *et al.* (2018)

The serum biochemical analysis helps in providing information about state of tissues, organs and metabolic state of the body. The serum biochemistry of growing pigs fed HQCP and DFM in the diet is as presented in Table 14. The serum biochemical indices observed in this study did not differ significantly (P>0.05) among the treatments. This result was similar to the report of Chen *et al.* (2005) who stated that determined haematology and serum chemistry parameters including Albumin, total protein, RBC, WBC and lymphocyte were not affected by the addition of *Lactobacillus acidophilus* 1.0×10^7 CFU/g, *Saccharomyces cerevisae* 4.3×10^6 CFU/g and *Bacillus subtilis* 2.0×10^6 CFU/g to diet of growing pigs. The lower cholesterol level observed in diet T5 with probiotics supplementation could be attributed to probiotics effect and its ability to bind cholesterol in the small intestines (Ojebiyi *et al.,* 2018). The serum biochemical value reported in this study fell within the normal physiological range of a healthy animal (Merck Manual, 2012b). In another study reported by Adesehinwa *et al.* (2016), replacing maize with HQCP up to 30% in the diet of growing pigs did not influence the haematological and serum biochemical properties of the pigs negatively (Adesehinwa *et al.*, 2018). Lactic acid bacteria (LAB) can inhibit pathogenic bacteria by competing for nutrients in the gut or at binding sites in the intestinal epithelium (Malago and Koninkx, 2011) and thus prevent them from eliciting pathogenic effect on the host (Havenaar *et al.,* 1992).

Table 14: Serum biochemistry of growing pigs fed high quality cassava peel and direct fed microbials

Parameters	T1	T2	T3	T4	T5	P(ANOVA)	SEM
Chol (mg/dl)	142.50	129.17	176.25	170.42	119.58	0.0805	8.03
UR (mg/dl)	22.23	18.99	19.29	22.01	21.66	0.1949	0.57
CRT (mg)	1.50	1.58	1.50	1.70	1.25	0.4252	0.07
HDL (mg/dl)	59.45	49.72	63.89	59.45	52.78	0.5182	2.73
LDL (mg/dl)	19.945	21.910	17.020	17.705	18.62	0.0672	0.61
Thio (mg/ml)	17.04	16.73	18.68	17.83	16.78	0.5413	0.40
AST (I.U/l)	25.92	16.55	23.22	30.98	24.41	0.3980	2.25
ALP (I.U/l)	46.25	50.72	48.22	48.39	51.52	0.9251	1.85

Note: SEM - Standard error of mean, Chol – Cholesterol, UR – Urea, CRT – Creatinine, Thio – Thiocyanate, AST – Aspertate amino transferase, ALP – Alkaline phosphatase, HDL – High density lipoprotein LDL - Low density lipoprotein. Source: Adesehinwa *et al.* (2018).

Conclusion

Based on the outcome of the various feeding trials above, high quality cassava peel has been proved to replace a substantial portion of maize in the diet of pigs thereby bringing about a decrease in the cost of production. High quality cassava peel can be used up to 30% as replacement for maize in the diet of growing pigs and 15% in the diet of weaner pigs. Addition of multi-strain direct fed microbial to high quality cassava peel in the diet of growing pigs did not enhance the performance of the animals.

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Received: 12th August, 2018
Accepted: 9th February, 2019