African Journal of Rural Development, Vol. 8 (2): April-June 2023: pp.107-118 ISSN 2415-2838

Effects of Partial replacement of Maize with Sundried and Fermented Cassava Peels in Broiler Diets

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ABSTRACT

The unprecedented increase in demand of conventional energy sources for livestock like maize, sorghum and wheat coupled with competition as human food in developing countries calls for a search for alternative non-competitive sources especially for poultry. The objective of this study was to determine the effects of the partial replacement of maize with sun-dried (SC) and fermented (FC) cassava peels in broiler chicken diets on broiler performance. The SC and FC peels were incorporated in the diets at different levels to make seven treatments at 0, 5, 10 and 15%: C, SC5, SC10 SC15 for sundried and FC5, FC10 and FC15 for the fermented peels, respectively. Two hundred and ten (210) day-old cobb-500 broiler chicks were randomly allocated the seven diets replicated three times with ten birds in each replicate. The birds were fed on both starter and finisher rations formulated to be iso-caloric and iso-nitrogenous. The feed intake and weight gain were recorded and the feed conversion ratio calculated. On day 43 of the feeding trial, one bird per replicate cage was sacrificed for the determination of the carcass characteristics. The digestibility of the diets was determined using the total fecal collection method. The mean daily feed intake varied from 114.8g/d for FC15 to 125.7 g/d for SC15 with SC15 being significantly ($p<0.05$) higher. The average body weight gain (BWG) ranged from 59.47 g/d for treatment SC15 to 64.72g/d for treatment FC15. The feed conversion ratio (FCR) varied from 1.77 in FC15 to 2.12 in SC15 and was affected by treatment. The CF apparent digestibility ranged from 33.02 for SC15 and 39.98% for FC15 treatment and differed significantly ($p<0.05$) between treatments. The study demonstrated that sun-dried and fermented with cassava peels can be included in broiler diets to partially replace conventional energy sources without affecting their performance.

Keywords: *Aspergillus oryzae*, broilers, carcass, Cassava peels, chicken feeds, sun drying

RÉSUMÉ

L'augmentation sans précédent de la demande de sources d'énergie conventionnelles pour le bétail, comme le maïs, le sorgho et le blé, conjuguée à la concurrence pour l'alimentation humaine dans les pays en développement, appelle à la recherche de sources alternatives non compétitives, notamment pour la volaille. L'objectif de cette étude était de déterminer les effets du remplacement partiel du maïs par des épluchures de manioc séchées au soleil (SC) et fermentées (FC) dans les régimes alimentaires des poulets de chair sur leurs

Cite as: Mwangi, E., Gachuiri, K.C., Wakesho Mwang'ombe, A. and Atela, A.J. 2023. Effects of partial replacement of maize with sundried fermented cassava peels in broiler diets. African Journal of Rural Development 8 (2):107-118.

performances. Les épluchures SC et FC ont été incorporées dans les régimes alimentaires à différents niveaux pour créer sept traitements à 0, 5, 10 et 15% : C, SC5, SC10 SC15 pour les épluchures séchées et FC5, FC10 et FC15 pour les épluchures fermentées, respectivement. Deux cent dix (210) poussins de chair Cobb-500 âgés d'un jour ont été répartis aléatoirement sur les sept régimes, répliqués trois fois avec dix oiseaux par réplique. Les oiseaux ont été nourris avec des rations de démarrage et de finition formulées pour être iso-caloriques et iso-azotées. La consommation d'aliments et le gain de poids ont été enregistrés et le ratio de conversion alimentaire calculé. Au jour 43 de l'essai d'alimentation, un oiseau par cage de réplique a été sacrifié pour la détermination des caractéristiques de la carcasse. La digestibilité des régimes a été déterminée en utilisant la méthode de collecte totale des fèces. La consommation alimentaire quotidienne moyenne variait de 114,8 g/j pour FC15 à 125,7 g/j pour SC15, SC15 étant significativement (p<0,05) plus élevée. Le gain de poids corporel moyen (BWG) variait de 59,47 g/j pour le traitement SC15 à 64,72 g/j pour le traitement FC15. Le ratio de conversion alimentaire (FCR) variait de 1,77 pour FC15 à 2,12 pour SC15 et était affecté par le traitement. La digestibilité apparente de la CF variait de 33,02 pour SC15 à 39,98% pour le traitement FC15 et différait significativement (p<0,05) entre les traitements. L'étude a démontré que les épluchures de manioc séchées au soleil et fermentées peuvent être incluses dans les régimes alimentaires des poulets de chair pour remplacer partiellement les sources d'énergie conventionnelles sans affecter leurs performances.

Mots-clés : Aspergillus oryzae, poulets de chair, carcasse, épluchures de manioc, aliments pour poulets, séchage au soleil

Introduction

Inadequate and expensive feed resources have been ranked highly among the constraints to poultry production due to the increased demand and competition with human food (Bakshi *et al*., 2016). Maize, the main energy source for poultry feed is primarily produced for human food resulting in high cost of feed and inadvertently poultry products (FAO, 2013). This scenario calls for alternative feed resources that can be used to reduce reliance on maize.

Cassava is grown in most of the drier parts of Kenya including coastal, eastern and western regions with the resultant peels from tuber processing posing environmental problems due to dumping and decomposition (Githunguri and Gatheru, 2017). Cassava peels use in animal feeding has been hampered by high levels of antinutritive factors such as hydrogen cyanide and high fibre and low protein content (Kortei *et al*., 2014). Hydrogen cyanide (HCN) is one of the major reasons for the low adoption of cassava products in livestock feeding as it lowers the oxygen-carrying capacity of blood through the formation of complexes with cytochrome oxidase eventually leading to hypoxia, respiratory distress and death (Ufaysa, 2019).

As such there is need to process the cassava peels to reduce the HCN and fibre contents and improve the protein quantities of cassava-based products. Sun drying is the most commonly utilized method owing to its low-cost input (Ngiki *et al*. 2014).

Cassava peels fermentation has proved to be effective in reducing the hydrogen cyanide content (by up to 95%) and improving the protein content (increase by 79.8%) and hence their potential for utilization as animal feeds (Sudharmono *et al*., 2016). The HCN reduction and protein increase is dependent on the fermentation time and microorganisms involved in this process (Uguru *et al*., 2022). Previous studies on broilers with sun-dried cassava peels reported varied performance attributable to the cassava variety, maturity, peeling method and the source of the peels. Babatunde *et al*. (2013) reported no adverse effect on broiler growth and carcass characteristics which were fed on sun-dried cassava peel meal at 10% and recorded a reduced feed cost. Though inclusion of cassava pulp fermented with *Aspergillus oryzae* has been reported by Khempaka *et al*. (2014) to improve the performance of broiler chicken, the effects of inclusion of the cassava peels meal fermented with this microorganism in broiler chicken diets has not been well documented. The current study investigated the effects of the inclusion of sundried cassava(SC) and fermented cassava (FC) peel meals in diets of broiler chicken in terms of weight gain, feed intake, digestibility, carcass characteristics, and yeild.

Materials and Methods

The study was carried out at the poultry unit in the Department of Animal Production, Faculty of Veterinary Medicine at the University of Nairobi, Kenya. Whole cassava tubers (Kibanda meno cultivar) were acquired from Kilifi County and transported to the food processing plant at Nairobi University where the tubers were processed for human consumption and the resultant peels either sundried or fermented. The fermented cassava peels were prepared through a slightly modified procedure of Okrathok *et al*., (2018). The *Aspergillus oryzae* culture was obtained from the Department of Veterinary Pathology and Microbiology, University of Nairobi and maintained on a Potato-Dextrose-Agar (PDA) medium. The microbial slants were grown at 30℃ for three days and stored at 4℃. Prior to the inoculation of microorganisms into the substrate, the spores of *A. oryzae* were dislodged from the PDA slant culture using 0.85% NaCl under sterile conditions for further use in preparation of the bulk *A. oryzae* starter. One kilogram of rice was soaked in water for an hour and autoclaved at 121℃ for 15 minutes then allowed to cool on a tray. Subsequently 100ml of the stock solution of *A. oryzae* was mixed thoroughly with the steamed rice in a blender and the mixture then spread on the tray and covered with aluminum foil, incubated for four days and then dried for two days. Colony counting method was used to count the number of spores in a gram of the starter used to ferment the peels.

A batch of 50 kg of fresh cassava peels was placed into a plastic bag and autoclaved at 121°C for 15 minutes, allowed to cool in the bags then thoroughly mixed with 500g of the *A.oryzae* starter (1.56×106CFU/g). The mixture was then incubated in a horizontal 50kg capacity feed mixer for three days at room temperature being turned daily. The peels were removed from the mixer at the end of the fermentation period and then sun dried until the moisture level was below 14% and subsequently ground to pass through a 3mm mesh sieve. Prior to diet formulation, different batches of the fermented material were sampled for proximate and cyanide analysis. Seven diets were formulated such that they were iso-nitrogenous and iso-caloric. The control diet had 0% inclusion of cassava peels, other six diets had inclusion levels of 5%, 10%, and 15% of respective treated cassava peel to make diets SC5, SC10 and SC15 for sundried peels and FC5, FC10 and FC15 for fermented peels. The diets (both starter and finisher) were formulated so as to be iso-calorific and iso-nitrogenous. The feeding trial diets were formulated to contain a minimum 3000 Kcal/kg, 220g CP/kg for broiler starter and 3000 Kcal, 180g CP/kg for broiler finisher diets (KeBS, 2019). Table 1 shows the ingredients and the nutrient composition of the formulated diets.

Feeding experiment data collection and analysis. Two hundred and ten,(210) day old Cobb 500 broilers acquired from a reputable hatchery were used for the experiment.

Table 1. Ingredient composition (% as fed) of the experimental diets

								Broiler finisher Mash						
Diet	C	SC5	CS10	SC15	FC5	FC10	FC15	C	SC5	CS10	SC15	FC5	FC10	FC15
Ingredient (%)														
Maize	59.7	53.7	48.1	42.9	53.8	48.1	42.9	59.0	57.0	54.0	50.0	59.1	54.0	50.0
Wheat Pollard	7.0	7.0	7.0	6.6	7.0	7.0	6.6	17.6	13.0	9.9	8.8	12.5	9.9	8.0
Omena (silver cyprinid)	10.1	10.0	10.0	10.0	10.0	10.0	10.0	9.1	12.0	10.0	10.1	11.0	10.0	10.1
Soya Bean Meal	21.2	20.4	21.0	21.0	20.4	21.0	21.0	11.0	9.5	12.0	12.0	9.1	12.0	12.0
Cassava Peels	0	5	10	15	5	10	15	0	5	10	15	5	10	15
Oil (vegetable)	0.0	1.5	2.0	2.5	1.5	2.0	2.5	1.0	1.0	2.0	2.0	1.0	2.0	2.0
Limestone Powder Coral	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Toxin B/Mold Inhib	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Vitamin-Premix*	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Coccidiostat	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Monocalcium phosphate	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
DL-Methionine	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
L-lysine HCl	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Enzyme**	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Calculated nutrient content														
ME (Kcal/kg) ***	3027	3058	3032	3011	3021	3042	3037	3056	3046	3067	3038	3015	3068	3027
CP***	21.5	21.1	21.0	20.8	21.2	20.8	21.1	18.2	18.0	18.0	17.9	18.0	18.3	18.2

C= Control Diet (0% cassava peels), SC5= 5% Sun-Dried Cassava Peel Meal, SC10= 10% Sun-Dried Cassava Peel Meal, SC15= 15% Sun-Dried Cassava Peel Meal, FC5= 5% Fermented Cassava Peal Meal, FC10= 10% Fermented Cassava Peel Meal, FC15= 15% Fermented Cassava Peel Meal

**Vitamin mineral premix- The composition of the premix was: vitamin A, 10,000,000 IU; vitamin D3 2,000,000 IU; vitamin E, 24,000 *IU; vitamin K3, 3,200 mg; choline chloride, 350,000 mg; folic acid, 960 mg; thiamine, 1,600 mg; riboflavin, 5,600 mg; Nicotinic acid, 32,000mg; pantothenic acid, 8,000 mg; pyridoxine, 4,000 mg; Biotin, 96 mg; vitamin B12, 24 mg; Copper, 5,000 mg; Iron, 40,000 mg; Manganese, 150,000 mg; Zinc, 45,000 mg; Cobalt, 200 mg; Iodine, 1,400 mg; and Selenium, 120 mg;*
** Phytase enzyme; ***Calculated from ingredient composition*

Temperatures were maintained at 32°C during the first week, and reduced by 2 °C every week by adjusting the height of the infrared bulbs, to 26°C by the end of the third week. During the first five days, all the chicks were fed on a composite of the seven formulated diets. On the fourth day, the birds were feather sexed and randomly allocated into 21 cages (1m width x1m length x 0.9m height and floor covered with wood shaving to a depth of 10 cm), with each cage holding ten birds.

Each experimental diet was allocated three cages to make three replicates. A plastic feeder and a plastic drinker were provided in each cage. The cages were placed in a clean, well-lit and well-ventilated poultry house. They chicks were vaccinated against Gumboro on the 7th day and New Castle Disease on the 14th day. Any mortality that occurred in the course of the experimental period was recorded. The birds were fed for three weeks on starter and three weeks on finisher diets. Feed and water were provided ad *libitum* throughout the experiment period. The total feed intake and weight gain of the birds were assessed weekly. On every first day of the experimental week, the birds in each cage were weighed by placing them into a tared plastic bucket and weighed using a digital weighing scale. The difference in the bird's current week weight and their previous week's weight was treated as the bodyweight gain.

The feed intake was determined by the weight difference between the initial feed availed at the start of the experimental week and the amount of feed remaining at the conclusion of the experimental-week. At the beginning of the experimental week, known quantity of the experimental diets was weighed for each respective replicate into a plastic bucket, from which feed was transferred into the respective plastic feeders throughout the experimental week. At the end of the week, the feed remaining in the plastic feeders was scooped and put back into the respective buckets and weighed. The ratio of the weekly feed intake and weekly weight gain was used to determine the feed conversion ratio.

On 43rd day of the feeding experiment, one bird from each replicate was transferred into a metabolic cage for a digestibility trial. The birds were allowed three days to acclimatize to the new environment, and each bird continued on its previous experimental diet. Individual feed intake was determined by the difference between the amount of feed provided at the start of the experimental period and the amount of feed remaining after four days of digestibility data collection. Total fecal material was collected every day for four days from aluminum trays lined with polythene placed at the base of the cage. The fecal material from each bird was collected daily and weighed then thoroughly mixed, sundried followed by oven drying at 60°C, composited and sampled for chemical analysis.

The nutrient digestibility was calculated using the formula; Nutrient digestibility %= (NF-NE) *100)/NF

Where NF = nutrient in feed and NE = Nutrient in Excreta (Mujahid *et al*., 2003)

The cassava peels, fecal material, and the formulated test diets were sampled for laboratory analysis. The Dry Matter (DM), Crude Fiber (CF), Crude Protein (CP), crude ash and Ether Extracts (EE) were done in accordance to standard methods (AOAC, 2005). Gross energy determination was done at the Kenya Industrial Research and Development Institute (KIRDI) using an Adiabatic Bomb Calorimeter (McGill *et al*., 2004). All data obtained on feed intake, body weight gain, FCR, and digestibility trial were subjected to a one-way Analysis of Variance (ANOVA) using Genstat Discovery 14th edition (Payne *et al* 2011). Significant treatment means were separated using Tukey Multiple Comparison Procedure and the level of significance set at $P \leq 0.05$.

Table 2: Chemical composition of the experimental diet

	Broiler Starter Mash							Broiler Finisher Mash						
	C	SC5	SC10	SC15	FC5	FC10	FC15	C	SC5	SC10	SC15	FC5	FC10	FC15
Dry Matter (DM)	89.44	88.88	89.02	89.00	88.91	89.20	89.40	89.98	90.13	89.77	89.17	89.91	90.44	90.00
Crude Protein (CP)	22.93	21.47	22.49	22.53	22.81	21.71	22.61	18.11	18.93	18.24	18.48	18.45	18.65	18.86
Ether Extract (EE)	6.2	6.5	6.8	6.2	6.5	7.9	7.2	6.5	6.1	6.9	6.9	6.1	7.9	6.9
Crude Fibre (CF)	6.2	6.1	6.3	6.4	5.9	5.8	6.1	5.6	6.1	6.2	6.1	5.6	5.8	5.7
Ash	6.9	7.1	7.3	7.5	7.2	8.5	11.0	7.7	7.4	7.9	7.7	8.3	8.7	9.5

Means in a row with no/similar superscript letter are not significantly different ($p>0.05$; C= Control Diet (0% cassava peels), SC5= 5% Sun-Dried Cassava Peel Meal, SC10= 10% Sun-Dried Cassava Peel Meal, SC15= 15% Sun-Dried Cassava Peel Meal, FC5= 5% Fermented Cassava Peal Meal, FC10= 10% Fermented

Results

The chemical composition of the starter and finisher experimental diets is shown in Table 2. The DM content of both starter and finisher rations ranged from 88.88 to 90.44%.

The DM content of both starter and finisher rations ranged from 88.88 to 90.44%. The CP content ranged from 21.47% to 22.93% and from 18.11% to 18.93% for the starter and finisher rations, respectively. The target for the crude protein (CP) in the diet was at least 21% and 18% during the starter and finisher period, respectively. The EE (6.2-7.9 and 6.1-7.9), CF (5.9-6.4 and 5.6 -6.2) and Ash (7.1-11 and 7.4-9.5) were the values for the starter and finisher ration, respectively.

The cyanide content of the processed and unprocessed peels is shown in Figure 1 below.

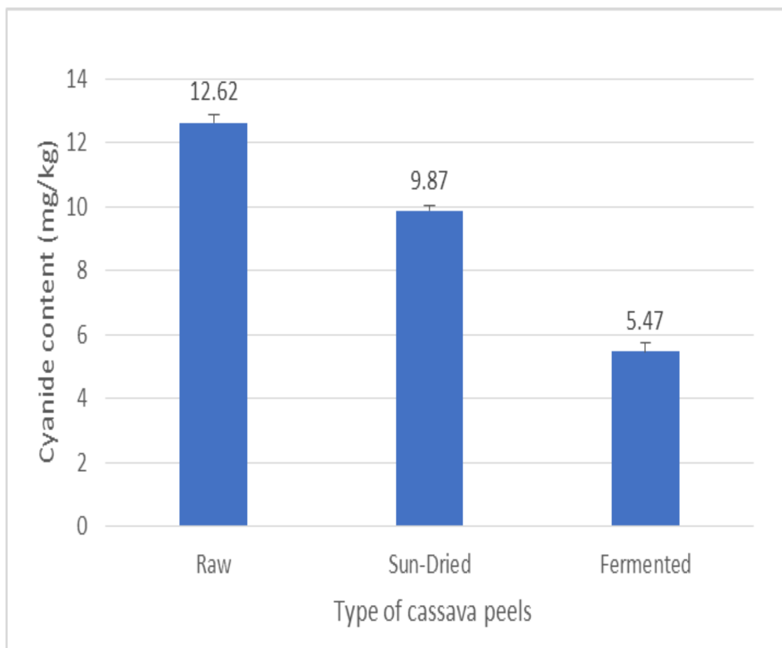

Figure 1. Cyanide composition (mg/kg) of the cassava peels

The raw cassava peels had the highest amount of cyanide (12.62mg/kg) followed by sun-dried cassava peels (9.87 mg/kg) while the fermented cassava peels recorded the lowest amount of cyanide at 5.47 mg/kg. The treatment of the cassava peels by sun-drying and fermentation resulted in a 21.79% and 56.65% decrease in cyanide content, respectively, in comparison to the raw cassava peels.

The effect of inclusion of cassava peels meal in broiler diets on performance is shown in Table 3. During the starter phase, the mean ADFI for all treatments ranged from 79.73 for FC10 to 90.52 for SC15 with only SC15 being significantly different (P<0.05) from the others. The body weight gain (41.57-47.62g/d) and the FCR (1.74 to 2.16) were not affected (P>0.05) by the treatment. During the finisher phase, the mean ADFI varied with treatment. Compared with the control (170.61g/d), birds on sun-dried CPM diets had a slightly, but not significantly, lower (157.27 to 162.79 g/d) ADFI while for the birds on fermented CPM the FC5 (168.9) and FC10 (160.54) were similar to control but FC 15 (147.59) was significantly lower compared to all other treatments. The mean BWG during the finisher phase varied from 76.72 to 84.07 g/d and was similar (p>0.05) for birds in all the treatments. The FCR ranged from 2.03 to 2.21 and 1.76 to 2.08 for birds on sundried and fermented CPM, respectively. Birds on FC15 had a significantly lower (P<0.05) FCR compared to all other treatments. During the entire growth phase, the ADFI varied from 114.8 to 125.8g/d for birds on all treatments. The birds fed on all levels sundried CPM and those on FC5 and FC10 had ADFI similar to control while those fed on FC15 had a significantly lower (114.8g/d) compared to all other treatments. Within the SC fed birds, the ADFI tended to increase (though non-significantly) with increased SC inclusion in the diet. The BWT gain varied from 59.47 g/d for treatment SC15 to 64.72g/d in treatment FC15. Compared with the control, all sundried CPM and FC5 and FC10 diets had similar body weight gains while treatment FC15 had the highest gain of 64.72g/d which significantly differed with SC15. The FCR ranged from 1.77 in FC15 to 2.12 in SC15 and was significantly affected by treatment. Birds on fermented peels (FC15) had a significantly (p<0.05) lower FCR in comparison with those on all other treatments.

Table 3. Effect of inclusion of sundried and fermented cassava peels meal in broiler diets on feed intake,weight gain and feed conversion ratio

	Treatments								
	C	**SC5**	**SC10**	**SC15**	**FC5**	**FC10**	**FC15**	SEM	*P-value*
Starter phase (d1-d21)									
Initial weight (g) d1	87.23	89.39	90.43	88.73	89.33	89.91	87.74	2.67	0.383
Final weight (g) d21	1036	962	1013	967	1095	1048	1040	19.3	0.409
ADFI (g/day)	79.75^{a}	84.74^{ab}	86.40^{ab}	90.52^{b}	82.74^{a}	79.73^{a}	81.99^{a}	1.39	0.002
BWG (g/day)	45.20	41.57	43.91	41.84	47.62	45.61	45.32	1.93	0.425
FCR	1.76	2.04	1.97	2.16	1.74	1.75	1.83	0.10	0.138
Finisher phase (d22-d42)									
Initial weight (g) d22	1036	962	1,013	967	1095	1048	1040	23.14	0.409
Final weight (g) d42	2732^{ab}	2587^{a}	2624^{ab}	2584^{a}	2766^{ab}	2773^{ab}	2806^{b}	68.53	0.013
ADFI (g/day)	170.61^{b}	157.27^{ab}	162.79^{ab}	160.82^{ab}	168.9^{b}	160.54^{ab}	147.59^{a}	3.16	0.004
BWG (g/day)	80.74	77.37	76.72	76.98	79.57	82.17	84.07	2.22	0.213
FCR	2.11^{b}	2.03^{ab}	2.13^{b}	2.21^{b}	2.08^{b}	1.96^{ab}	1.76^{a}	0.08	0.005
Entire Feeding period									
Initial weight d1 (g)	87.23	89.39	90.43	88.73	89.33	89.91	87.74	9.88	0.94
Final weight d42 (g)	2732^{ab}	2587^{a}	2624^{ab}	2584^{a}	2766^{ab}	2773^{ab}	2806^{b}	71.60	0.013
ADFI (g/day)	125.2^{b}	121.0^{ab}	124.6^{b}	125.7^{b}	125.8^{b}	120.1^{ab}	114.8^{a}	2.07	0.014
BWG g/day	62.97^{ab}	59.47^{ab}	60.32^{ab}	59.41^{a}	63.6^{ab}	63.88^{ab}	64.72^{b}	1.08	0.011
FCR	1.97^{ab}	2.02^{b}	2.01^{b}	2.12^{b}	1.99^{ab}	1.93^{ab}	1.77^{a}	0.047	0.005

C= Control Diet (0% cassava peels), SC5= 5% Sun-Dried Cassava Peel Meal, SC10= 10% Sun-Dried Cassava Peel Meal, SC15= 15% Sun-Dried Cassava Peel Meal, FC5= 5% Fermented Cassava Peal Meal, FC10= 10% Fermented Cassava Peel Meal

The apparent dry matter, crude protein and crude fibre digestibility are shown in Table 4. The apparent digestibility of DM% ranged from 69.39% for SC15 treatment to 75.3% for FC15 and was similar (p>0.05) for all treatments. The apparent digestibility of CP% ranged from 64.13% for SC15 to 70.4% for FC15 treatment and was similar (P>0.05) for all treatments. The CF apparent digestibility ranged from 33.02 for SC15 and 39.98% for FC15 treatment. Compared to the control (36.74), SC15 (33.02) had significantly lower value while FC15 (39.98) had value. The CF digestibility decreased with increased inclusion of SC and increased with increased levels of FC peels meals in the boiler rations.

The mean total feed intake (TFI) for the whole feeding period ranged from 5.04 to 5.25 and was similar for all treatments. The feeding cost during whole rearing period ranged from 279.2 (SC5) to 313.4 ksh/bird for the control diet. The feeding cost for birds in the control treatment was significantly higher compared to all other treatments. The mean live weight at the end of feeding period ganged from 2.59 to 2.18 and was similar for all treatments. The cost of gain per kg/live weight was highest for control (114ksh) and lowest for FC10 (102.2) with the cost for fermented CPM tending to be lower. The income from sale of birds ranged from 568.5 for SC15 to 617.3 Ksh/bird for FC15 with the latter being significantly higher compared to other treatments. The gross margin varied from 277.3 in SC15 to 326.6 Ksh/bird, and was significantly higher (P<0.05) for the birds fed on fermented cassava. The CBR varied from 2.2 for SC to 2.4 for FC15 while the ROI varied from 95.2 for SC15 to 115.2Ksh/bird for FC10 with both FC10 and FC15 being significantly (P<0.05) higher compared to the others.

Table 4. Effects of the level of inclusion sundried and fermented cassava peels on apparent digestibility (%) of dry matter, crude protein and crude fiber in broiler chicken

	Treatments								
	C	SC5	SC10	SC15	FC5	FC10	FC15	SEM	P-Value
DM %	73.95	73.96	72.71	69.39	74.22	74.90	75.36	1.355	0.088
ApCP %	68.08	65.89	65.59	64.13	68.58	69.67	70.40	1.786	0.174
ApCF %	36.74^{b}	36.27^{b}	35.44^{ab}	33.02^{a}	36.83^{b}	37.69^{bc}	39.98^{c}	0.549	<0.001

Means in a row with no/similar superscript letter are not significantly different (p>0.05; DM- Dry Matter; Ap CP- Crude Protein Apparent digestibility; ApCF- Crude Fibre Apparently digested; C= Control Diet (0% cassava peels), SC5= 5% Sun-Dried Cassava Peel Meal, SC10= 10% Sun-Dried Cassava Peel Meal, SC15= 15% Sun-Dried Cassava Peel Meal, FC5= 5% Fermented Cassava Peal Meal, FC10= 10% Fermented Cassava Peel Meal, FC15= 15% Fermented Cassava Peel Meal

Discussion

The analyzed nutrient composition of the diets met the requirements for both starter and finisher phases for CP, CF and ME (KEBS, 2009). The slight deviations in the crude protein (CP) contents of the experimental diets (approximately 1%) could be attributed to the mixing and sampling errors. The reduction in the hydrogen cyanide content is attributable to the fact that the HCN is highly heat labile for the sun-dried peels (Uzochukwu *et al* 2013). The HCN reduction during fermentation could also be attributed to the *Aspergillus oryzae* sun-dried peels (Uzochukwu *et al*, 2013).

Table 5. Economic analyses of the test diets fed to the broiler chicken

	Treatments								
	C	SC5	SC10	SC15	FC5	FC10	FC15	SEM	P-Value
Cumulative feed intake (kg)	5.26	5.09	5.23	5.27	5.30	5.04	5.19	0.08	0.272
Total feed cost (C)	313.4^{b}	279.2^{a}	290.6^{a}	291.5^{a}	291.4^{a}	282.8^{a}	290.7^{a}	4.38	0.002
Liveweight at end of feeding period (g/ bird)	2.73	2.59	2.62	2.58	2.77	2.77	2.81	0.05	0.013
Cost per kg liveweight	114.1^{c}	108.0^{ab}	111.0^{bc}	112.7^{c}	105.1^{ab}	102.2^{a}	103.6^{ab}	1.66	<0.001
Sale of birds[1] (S)	601.0^{ab}	569.0^{ab}	577.2^{ab}	568.5^{a}	610.1^{ab}	608.5^{ab}	617.3^{b}	10.10	0.012
Gross profit margin[2] (P)	287.6^{ab}	289.8^{ab}	286.6^{ab}	277.3^{a}	318.7^{b}	325.7^{b}	326.6^{b}	8.40	0.002
Cost benefit ratio[3] (CBR)	1.91^{a}	2.04^{bc}	1.99^{ab}	1.95^{ab}	2.09^{bc}	2.15^{d}	2.13^{c}	0.03	<0.001
Return on Investment[4] (RoI)*	91.8^{a}	103.8^{bc}	98.6^{bc}	95.2^{ab}	109.4^{bc}	115.2^{c}	112.6^{c}	3.10	<0.001

Means in a row with no/similar superscript letter are not significantly different (p>0.05); BW-Body Weight; FI- Feed Intake;

C= Control Diet (0% cassava peels), SC5= 5% Sun-Dried Cassava Peel Meal, SC10= 10% Sun-Dried Cassava Peel Meal,

*SC15= 15% Sun-Dried Cassava Peel Meal, FC5= 5% Fermented Cassava Peal Meal, FC10= 10% Fermented Cassava Peel Meal, FC15= 15% Fermented Cassava Peel Meal; [1]220 Ksh/Kg live weight; [2]P=S-C; [3]CBR=S/C; [4]RoI={S-C}/C*100;*

Currency exchange rate at the time of study (1USD=112Ksh)

The HCN reduction during fermentation could be attributed to the *Aspergillus Oryzae* producing linamarase enzyme that degrades the glycosides in the cassava peels (Okrathok *et al*., 2018). The HCN content in the fermented peels was similar with the findings by Oboh (2006) of 6.2mg/kg in cassava peels after seven-day fermentation period. The slightly, but non-significant, higher BWG of birds on FC peels meal during the finisher phase could be attributed to the fermentation process improving the digestibility of the peels through decreasing the fibre, antinutritive factors (tannin and phytin) and HCN content (Figure 1) as earlier observed by Oresegun *et al*. (2016). The lower BWG of the birds on SC15 in comparison to the control during the entire feeding period is attributable to the significantly lower apparent digestibility of the Crude Fibre (CF) in this diet in comparison to the control as seen on Table 4. Adekeye *et al*. (2021) observed a significant difference in BWG across the treatments (150, 200, 250 kg/t) in broiler chicken fed on sun-dried cassava peels in comparison to the control. The experimental diets of the previous study had lower CF content (range 5.11 to 5.43) in comparison the current results (Table 2).

The disparity in BWG with the current study might have resulted from the nature of the peel due to processing differences and different agroecological conditions under which the cassava for individual study were grown. As the cassava matures, the level of CF in the root and peels increases while the cyanide levels decrease. Different cassava cultivars also have varied cyanide levels in the roots and the peels (Gourilekshmi *et al*., 2020).

The lower ADFI for birds fed on FC15 diets in comparison to control treatment during the entire feeding period could be attributed to the improved nutrient digestibility of fermented diet resulting in the birds consuming less to cover their energy needs. Dairo (2011) reported lower ADFI (range 92.17 to 95.03g/d) compared with the values in the current study when they fed a mixture of fermented cassava peels and caged layers manure to broiler chicken for 56-day period. Adekeye *et al*. (2020) observed that broiler chicken fed on sun-dried cassava peels at different inclusion levels (150, 200, 250 kg/t) had no effect on feed intake compared with the control. The lower feed intake recorded for the birds fed FC15 compared to the control and other treatments may have resulted in lower feed conversion ratio (FCR) observed in these birds.

The significantly higher FCR during the entire feeding period for SC fed birds in the current study could be attributed to higher feed intake accompanied by lower body weight gain due to higher HCN, non-starch polysaccharides and tannins common in unprocessed and sun-dried cassava peels. Oyebimpe *et al*., (2006) and Dairo, (2011) and reported higher FCR (2.66 to 2.69 and 3.64 to 3.87 respectively) than that observed in the current study. In the previous studies, broiler chicken were fed on fermented and sun-dried CPM respectively. The high FCR observed in the previous studies could be due to high feed intake and low body weight gain, indicating the low conversion efficiency of the feed, which could be due to low digestibility, high levels of antinutritive factors or a nutrients imbalance (Aggrey *et al*., 2010).

The higher content of indigestible fiber in SC15 (Table 4) decreased feed digestibility resulting in low weight gain compared to the other treatments and the control. This diet had the lowest apparent digestibility of CF (33.02%) in comparison with other treatments (range 35.44-39.94). The fibre in the cassava peels exists mainly in the form of insoluble fibre, and Oladunjoye *et al*. (2016) reported 36.7% neutral detergent fibre, 9.8% acid detergent fibre and 3.9% acid detergent lignin that is largely indigestible by chicken. In contrast, layer birds could tolerate higher inclusion cassava peels in their diet owing to their lower energy requirement in comparison to broiler chickens (Avinesh *et al*., 2018). Oladunjoye *et al*. (2010) replaced maize with 50% sun-dried cassava peels meal in laying hen diets and observed no effect on egg parameters and blood characteristics.

The range of DM digestibility in this study were slightly higher than 60.20 to 69.09% and 67.3 to 69.8% reported by Foluke and Olufemi (2013) and Khempaka *et al*. (2014) when broiler chicken were fed sundried and fermented cassava peels respectively. Similary the previous studies by Foluke *et al*. (2013) and Khempaka *et al*. (2014) showed an increase in DM% digestibility on increased inclusion of FC similar to the current study. A significant increase in apparent DM digestibility of (63 and 60.2%) was reported at 75 and 100% replacement of wheat with cassava peels compared with 70% digestibility for control diet (Foluke and Olufemi, 2013). The differences in the values observed in the current study could be attributed to the higher inclusion levels of cassava peels (replacing maize at 25 to 100%) in the previous studies. These could also be explained by the differences in cassava cultivar, maturity and different ecological growth locations of the cassava used in the two studies (Gourilekshmi *et al*., 2020). As the cassava matures, the level of CF in the root and peels increase while the cyanide levels decrease. Different cassava cultivars also have varied cyanide levels in the roots and the peels.

The apparent digestibility of dietary CP ranged from 64.13% for SC10 treatment to 70.4% for SC15 but was not affected by the treatment. The CP apparent digestibility appeared to decrease with increased inclusion of SC peel meal in the diets. This could probably be due to the presence of antinutritive factors including tannins, phytin and HCN (Figure 1) in the SC cassava peels that limits utilization of nutrients. It has also been shown that high levels of indigestible fibre in the diets affects effective utilization of nutrients (Tejeda *et al*., 2021). The present results agrees with the finding by Adebowale and Ogbonna (1993) where the protein retention was lowest on highest inclusion of sun-dried cassava peel meal. The apparent digestibility of CP for the birds on FC peel meal increased with the increase of the FC peels in the diet but not significantly.

The study showed that the diets with SC had the highest crude fibre content (SC15 at 6.4% and SC10 at 6.2%) in comparison to the starter FC can be attributed to the ability of A. oryzae to secrete hydrolyzing enzymes including and SC10 at 6.2%) in both the starter and finisher formulations unlike the sun-dried cassava peels having higher fibre content. The CF digestibility increase with increased inclusion of FC and this can be attributed to the ability of *A. oryzae* to secrete hydrolyzing enzymes including cellulases, amylases and glucoamylases that reduce the CF in the cassava peels (Begum *et al*., 2009). A study conducted by Abel (2014) on broilers fed on diets with fermented cassava peels included by upto 40% had CF apparent digestibility of 46.51 to 53.64% that decreased on increased level of the peels in the diets. The difference in CF digestibility in the current study and the previous one could be attributed to the source of the cassava peels and probable difference in maturity of the tubers that determines the acid detergent fibre content in the cassava peels used in both studies (Gourilekshmi *et al*., 2020). The improved fibre digestibility in FC diets led to better nutrient retention hence the appreciable weight gain, favorable DFI and FCR (Table 2)

The significantly high return on investment from birds on FC10 diets in comparison to the control is attributable to their low cost of production per kilogram liveweight (Table 5). The lower return on investment for the birds on SC15 could be attributed to the fact that they recorded the highest feed intake but lowest weight gain translating to lower returns. This could also be explained by the lower efficiency of utilization (FCR) of the SC15 diet as seen in Table 4. Oyebimpe *et al*. (2006) fed broiler chicken a diet containing sundried cassava peels (100 to 300 g/kg) and observed a significant reduction in the cost of production on high cassava peels inclusion. This was attributed to the high cost of maize in comparison to the cassava peels. This is also true in the current study where the control treatment had the lowest return on investment due to the high cost per kilogram of weight gain.

Conclusion

Incorporation of up to 15% *A. oryzae* fermented cassava peels in broiler diets improved feed intake, weight gain and feed conversion ratio (FCR) compared to the control. The inclusion of 10 and 15% fermented cassava peel meal (FCPM) in the broiler diets resulted in the highest gross margins and offered the highest return on investment. As such, sundried and fermented cassava peels can be utilized in broiler feed formulations reducing reliance on conventional energy sources and lowering cost of production.

Acknowledgement

The authors thank RUFORUM and Mastercard Foundation for financing this study. The RUFORUM project supported the field survey, sourcing of cassava materials, processing, feeding trials and other aspects to which the authors of this study are indebted.

Statement of Conflict of Interests

The authors declare no conflict of interest in the paper.

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