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Rabbits fed fermented cassava starch residue I: Effect on performance and health status

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SUMMARY

The feeding and growth models vis-à-vis the health status of rabbits fed diets in which maize was replaced with microbially fermented cassava starch residue (MFCSR) was evaluated in an eight weeks trial. One hundred and fifty, 5- week old weaner rabbits were randomly allotted to 5 dietary treatments in a completely randomized design. Each treatment was replicated 10 times with 3 rabbits per replicate. The average daily feed intake of the rabbits increased (59.83-68.02g per rabbit per day) with increased MFCSR inclusion (y3= 5.2202x3+3355.9; R2=0.36); while the total weight gain only increased with increased MFCSR inclusion (1106.89-1264.89 g per rabbit) up to 50% (y2=1234.8-3.7045x2; R2=0.31) and thereafter decreased. This was supported by 2o polynomial mathematical models. Only the slaughtered weight (1346.71 – 1818.88g), dressed weight (704.83-832.02g) and relative weight of the kidney (0.53-0.74%) were significant (P<0.05). While the blood indices measured varied, the serum metabolites except LDL were stable among the treatment groups. It is suggested that the maize component of growing rabbit's diet could be replaced up to 50% with MFCSR and the developed growth/feeding models could be adopted using MFCSR to enhance rabbit production.

Additional keywords

Cassava sievate.
Health implication.
Agro industrial waste.
Growth promoter.
Monogastric herbivores.

Les lapins nourris avec de l'amidon de manioc fermentée je résidus: Effet sur le rendement et l'état de santé

RÉSUMÉ

L'alimentation des modèles de croissance et vis-à-vis de l'état de santé des lapins nourris au maïs qui a été remplacé par des résidus d'amidon de manioc fermentée par voie microbienne (MFCSR) a été évaluée dans un essai de huit semaines. Cent cinquante, 5 semaine sevré les lapins ont été aléatoirement affectés à 5 traitements alimentaires dans un complètement aléatoire. Chaque traitement a été répliqué 10 fois avec 3 lapins par répétition. La moyenne quotidienne de la prise de l'alimentation le lapin a (59.83-68.02g par lapin par jour) avec l'augmentation de l'inclusion (MFCSR y3 = 5.2202x3 3355.9 ; R2 = 0,36) ; alors que le gain de poids total n'a augmenté avec l'augmentation de l'inclusion (MFCSR 1106.89-1264.89 g par lapin) jusqu'à 50 % (y2 =1234.8-3.7045x2 ; R2 = 0,31) et a diminué par la suite. Cela a été appuyé par des modèles mathématiques polynôme 2o. Seul le poids abattu (1346.71 - 1818.88g), habillé (poids 704.83-832.02g) et poids relatif des reins (0.53-0.74 %) étaient significatives (P < 0,05). Alors que le sang, les indices mesurés varient à l'exception des métabolites sériques ont été LDL stable entre les groupes de traitement. Il est suggéré que la composante de maïs du régime alimentaire du lapin en croissance pourrait être remplacé jusqu'à 50 % avec MFCSR et la croissance et d'alimentation développés modèles pourraient être adoptées à l'aide d'MFCSR d'améliorer la production de lapins.

Mots clés supplémentaires

Sievate le manioc.
Implication de la santé, de l'
Agro les déchets industriels.
Promoteur de croissance.
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INTRODUCTION

The gap in animal protein production and consumption between the citizens of the Western countries and those living in Africa, Asia and the Pacifics is enormous. This can be narrowed down by encouraging the production of rabbits; a short generation polytocous animal for meat (Oloruntola et al., 2015) using locally available and cheap feed resources. Rabbit has some important potentials among which are: ability to convert highly fibrous feed to meat, high average daily weight gain, high prolificacy and short gestation period among others (Biobaku and Dosumu, 2003). However, these attributes are attainable, if nutritious but cheap finished feeds meant for rabbits are fed. These feeds can be formulated from agro-industrial wastes such as cassava processing wastes (Akaeze et al., 2015; Ogunsipe et al., 2015; Oloruntola et al., 2016) and essentially cassava starch residue.

Cassava is a major food reserve in Africa, Asia and Latin America and cassava starch residue (CSR) is one of the main wastes arising from its processing which is under-utilized in animal feeding. Cassava starch residue is the residual pulp separated in the processing of cassava starch which represents about 10 percent by weight of the cassava roots (Aro et al., 2010). Cassava starch residue offers a potential as a cheap substitute for maize and other cereal grains. It contains cyanogenic glycosides, although in a lesser quantity than cassava peels (Heuze et al., 2012), has low crude protein and high fibre of 3.56 g/100g DM and 12.52 g/100g DM respectively (Oloruntola, 2015). However, its nitrogen free extract value shows that CSR contains appreciable level of soluble carbohydrates sufficient enough for successful microbial fermentation (Aro et al., 2010).

Improvement in nutritive value of cassava peel has been achieved through rumen liquor fermentation (Oloruntola et al., 2015). According to Aro (2008), fermentation through microbial inoculation could be a possible way to transform agro-waste into a better-utilizable feed ingredient for livestock, particularly monogastrics and monogastric herbivores like rabbits. Diets of monogastric herbivores (rabbit inclusive) are usually expensive because they are based on relevant amounts of cereal grains and protein concentrates which are the main components of human food (Silva et al., 2000). Therefore, partial or complete replacement of maize with microbially fermented cassava starch residue (MFCSR) could reduce the cost of rabbit production with a concomitant increase in rabbit meat production and affordability by resource limited populace, especially if adaptable feeding model is developed for use by farmers. The present study was therefore carried out not only to evaluate the performance and health status of weaner rabbits fed graded levels of MFCSR in place of maize but also to develop growth/feeding models for feeding MFCSR.

MATERIALS AND METHODS

Table I. Microorganisms isolated from bovine rumen liquor (Micro-organismes isolés de l'alcool du rumen).

Microorganism	% isolates
Bacteria	
Lactobacillus sp.	37.50
Pseusomonas sp.	6.25
Streptocoocus sp.	43.75
Micrococcus sp.	12.50
Fungi	
Penicillium sp.	57.14
Fusarium sp.	35.71
Aspergilus sp.	7.14

This study was approved by the Research Committee of the Department of Animal Production and Health, The Federal University of Technology, Akure, Nigeria.

Test ingredients and experimental diets

Cassava starch residue was obtained from MATNA FOODS, located at Oke Odo along Owo-Benin high way, Ondo State, Nigeria, sundried and milled. Layer's droppings were obtained from the laying unit of the Teaching and Research Farm of the Agricultural Technology Department of the Federal Polytechnic, Ado Ekiti, Nigeria, sundried, autoclaved to destroy any microbial growth, re-sundried and milled. Rumen liquor was collected from freshly slaughtered cattle at government abattoir in Ado Ekiti, isolated and characterized **(Table I)** as earlier described by Cheesbrough (2005) and Oyeleke and Okunsanmi (2008). The liquor was immediately squeezed out of the rumen content using a muslin cloth. The ground cassava starch residue was fermented as earlier described by Oloruntola et al. (2015). The ground cassava starch residue was mixed with the autoclaved ground dried layer droppings at the rate of 100 g /kg of CSR in black polythene bag, sprayed with rumen liquor at rate of 250ml and fermented anerobically for duration of 7 days. The fermented CSR was sundried for 3 to 4 days depending on the intensity of sun. Thereafter, one basal grower rabbit diet was formulated in which maize was the main energy source. The maize content of the basal diet was replaced with MFCSR at 0, 25, 50, 75 and 100% and designated as diets 1, 2, 3, 4 and 5 respectively **(Table II)**. The diets were thereafter pelletized (4mm diameter and 8 mm long).

Experimental Animal And Management

The rabbits were managed according to the Recommendations and Guidelines for Applied Nutrition Experiments in Rabbits (Fernández-Carmona et al., 2005). One hundred and fifty (150), 5 weeks old weaner rabbits of cross-breeds and mixed sexes were randomly allotted to five dietary treatments after balancing for weight in a completely randomized design. Each treatment was replicated ten times with three weaner rabbits per replicate. The rabbits were housed in cages and managed as previously described by Oloruntola et al. (2016). The experiment was conducted at the Rabbit unit of the Teaching and Research Farm of the Agricultural Technology Department, The Federal Polytechnic, Ado Ekiti, Nigeria. The Study area have the mean annual rainfall of 1247mm, mean annual temperature of 26.2°C, relative humidity of 70 to 85% relative humidity and is located between latitude 7°37'N and 7°12'N and longitudes 5°11'E and 5°31'E. The rabbits were housed individually in wooden framed and wire meshed cage, housed in well ventilated (natural ventilation) pen. A week to the commencement of the experiment, the growing rabbits were administered prophylactic coccidiostat, tetracycline and ivomectin against coccidiosis, bacteria infection and ectoparasites. The experimental diets and water were offered *ad libitum* for a period of 8 weeks.

Response criteria

Performance And Growth/Feeding Models

The initial weight of the rabbit was subtracted from the final weight at end of each week to obtain the wee-

Table II. Gross and analyzed composition of experimental diets and MFCSR (Gross et analysé la composition des régimes expérimentaux et MFCSR).

	Level of MFCSR Inclusion (%)					MFCSR
	0 Diet 1	25 Diet 2	50 Diet 3	75 Diet 4	100 Diet 5	
Ingredients (g/kg)						
Maize	430.0	322.5	215.0	107.5	0.00	
MFCSR	0.00	107.5	215.0	322.5	430.0	
Maize husk	224.0	224.0	224.0	224.0	224.0	
Wheat offal	80.0	80.0	80.0	80.0	80.0	
BDG	100.0	100.0	100.0	100.0	100.0	
Soya bean meal	148.5	148.5	148.5	148.5	148.5	
Bone meal	10.0	10.0	10.0	10.0	10.0	
Methionine	1.5	1.5	1.5	1.5	1.5	
Lysine	1.0	1.0	1.0	1.0	1.0	
Premix	2.5	2.5	2.5	2.5	2.5	
Salt	2.5	2.5	2.5	2.5	2.5	
Total	1000.0	1000.0	1000.0	1000.0	1000.0	
Calculated analysis (g kg^{-1})						
Lysine	7.6	7.3	7.0	6.8	6.5	
Methionine	3.9	3.7	3.5	3.3	3.1	
Calcium	4.3	4.3	4.3	4.2	4.2	
Available Phosphorus	3.8	3.7	3.6	3.6	3.5	
ME (kcal kg^{-1})	2965.04	2963.75	2962.46	2961.17	2959.88	
Analyzed composition						
Dry matter	927.8	937.6	940.7	941.3	945.5	939.8
Crude protein	154.4	164.1	162.6	163.0	162.2	94.5
Crude fibre	114.2	127.5	132.6	138.4	144.1	79.0
Ether extract	21.6	22.6	22.0	21.7	21.2	31.7
Ash	68.8	72.1	69.3	67.0	64.8	74.0
Nitrogen free extract	641.0	614.7	613.5	609.9	607.7	720.8
Hydrogen cyanide	0.00	0.002	0.004	0.006	0.009	0.02

BDG: Brewer dried grain; MFCSR: Rumen liquor fermented cassava starch residue. *ME: metabolizable energy= (37x%CP) + (81.8x%FAT) + (35.5x%NFE) (Pauzenga, 1985).

kly weight gain. The feed consumption was calculated as the difference between the feed left over and feed given daily, and the feed conversion ratio was calculated as the ratio of feed consumed to the total weight gain.

In order to establish a relationship between input (MFCSR) and observed output (Final Weight Gain or Total Feed Intake) a mathematical model was proposed. The polynomial equation of the form:

$$y = \sum_{i}^{n} a_i x^i + c \qquad (1)$$

where $i = 1,2,3,\cdots n$, n is the order of the polynomial, a_i are the polynomial constants to be determined. A system of linear equations of order n is then formulated

$$\begin{aligned} y_1 &= a_1 x_1^2 + a_2 x_1 + c_1 \\ y_2 &= a_1 x_2^2 + a_2 x_2 + c_1 \\ y_m &= a_m x_m^m + a_m x_m + c_1 \\ y_n &= a_n x_n^n + a_n x_n + c_1 \end{aligned} \qquad (2)$$

The set of linear equation (equation 1) was solved using Gaussian Elimination Method to obtain the coefficients a_1, a_2, c_1 .

Evaluating model performance: The root mean square error (RMSE), sum of squared error (SSE) and coefficient of determination (r^2) were used. The sum of square error is defined as: ,

$$SSE = \sum_{I=1}^{N} w_i (y_i - \hat{y}_i)^2$$

where $y_i \hat{y}_i$ are the observed and fitted values respectively.

The root mean square error (RMSE) is defined as:

$$RMSE = \sqrt{\frac{SSE}{v}}$$

Where v is the number of independent pieces of information involving n data points that are required to calculate the sum of squares.

The coefficient of determination indicates the proportionate amount of variation in the response variable y explained by the independent variables x in the linear regression model. It is computed from the expression:

$$r^2 = 1 - \frac{SSE}{SST}$$

Where SST is the sum of squared total (MATLAB© 2013 user manual).

The data (Final Weight Gain and Total Feed Intake) for each concentration of MFCSR (0%, 25%, 50%, 75%, 100%) were averaged.

Carcass evaluation and organ weights

At the end of the trial, fifteen rabbits from each treatment were fasted overnight, slaughtered according to the guidelines of the World Rabbit Science Association (Blasco And Ouhayoun, 1996), skinned and dressed (Blasco And Ouhayoun, 1996). Thereafter, the dressed weights were measured and used to determine the dressed percentage for the rabbits. The weight of the internal organs (lungs, liver, kidney, heart, pancreas and bile) were also obtained and expressed as a percentage of slaughtered weight.

Haematological variables and serum metabolites determination

Blood samples were collected as described by Burnett et al. (2006). Blood samples were collected into two different tubes. Thus, blood samples were collected in a blue top tube containing potassium ethylene diamine tetra acetic acid (K-EDTA) and the second sample into plain purple top tubes. The blood in EDTA containing bottles were analysed for white blood cells, lymphocytes, monocytes, granulocytes, red blood cells, haemoglobin concentration, haematocrit, platelets, mean corpuscular volume, mean corpuscular haemoglobin and mean corpuscular haemoglobin concentration using Shenzhen Mind ray Auto Haematology Analyzer, Model Bc-3200 (Shenzhen Mind ray Biomedical Electronics Co. Hamburg 20537, Germany). The sera which were separated from plain purpled top bottle blood samples were analysed for cholesterol, urea, creatinine, high density lipoprotein (HDL), low density lipoprotein (LDL), bilirubin, Aspertate amino transaminase (AST) EC 2.6.1.1.1, Alanine amino transaminase (ALT) EC 2.6.1.1.2, Alkaline phosphatase (ALP) EC 3.1.3.1, amylase, total protein, albumin, globulin and glucose with a Reflectron ® Plus 8C79 (Roche Diagnostic, GmbH Mahnheim, Germany), using commercial kits.

Chemical analysis

Proximate composition of MFCSR, maize, maize husk, wheat offals, BDG and soyabean meal (this was done to prevent large variation in nutrient composition after mixing) and experimental diets were determined as described by AOAC (1995) methods, while cyanide content was determined by the silver nitrate method (Oboh et al., 2002).

Statistical analysis

Data obtained were subjected to analysis of variance (ANOVA) using SPSS version 20, while the difference between treatments mean were determined by Duncan multiple range test of the same package. Relationship between MFCSR replacement levels and performance characteristics, carcass characteristics and some serum metabolites were determined using linear regression analysis. The rabbit growth and feeding models were developed using MATLAB © 2013.

RESULTS

Table II shows that while 94.5 g/kg crude protein (CP) and 79.0 g/kg crude fibre (CF) were observed for MFCSR, the CP of the test diets ranged between 154.4 and 163.1g/kg and the crude fibre (CF) ranged between 114.2 g/kg and 144.1 g/kg.

Table III shows that the final live weight (FLW) 1893.01g and the total weight gain (TWG) 1264.89g of rabbit fed 50% MFCSR-based diet were significantly (P<0.001) higher than those fed 75% and 100% MFCSR-based diets but similar to those fed on the control and 25% MFCSR-based diets. The total feed intake (TFI) of the rabbits increased as the level of maize replacement with MFCSR increased. The feed conversion ratios of

Table III. Performance characteristics of weaner rabbits fed microbially fermented cassava starch residue (Caractéristiques de performance sevré lapins recevant les résidus d'amidon de manioc fermenté d'origine microbienne).

Parameters	Level of MFCSR Inclusion (%)					SEM	P Value
	0 Diet 1	25 Diet 2	50 Diet 3	75 Diet 4	100 Diet 5		
Initial live weight (g per rabbit)	632.49	629.99	628.12	630.25	631.25	11.54	0.357
Final live weight (g per rabbit)	1739.38^{ab}	1843.13^{ab}	1893.01^{a}	1607.13^{b}	1401.88^{c}	38.91	0.001
Total weight gain (g per rabbit)	1106.89^{ab}	1213.13^{a}	1264.89^{a}	976.88^{b}	770.63^{c}	37.52	0.001
Average daily weight gain (g per rabbit per day)	19.65^{ab}	21.55^{a}	22.48^{a}	17.33^{b}	13.65^{c}	0.66	0.001
Total feed intake (g)	3350.7^{c}	3406.75^{bc}	3666.81^{ab}	3795.07^{a}	3809.06^{a}	49.26	0.001
Average daily feed intake (g per rabbit per day)	59.83^{c}	60.83^{bc}	65.48^{ab}	67.77^{a}	68.02^{a}	0.88	0.001
Feed conversion ratio	3.03^{a}	2.81^{a}	2.89^{a}	3.88^{b}	4.94^{c}	0.18	0.001

Means with different superscripts in the same row are significant (P<0.001).

the rabbits fed the control, 25 and 50% MFCSR-based diets (3.03, 2.81 and 2.89, respectively) were similar but significantly (P<0.001) better than those fed 75 and 100% MFCSR-based diets (3.88 and 4.94, respectively). The levels of MFCSR (x_i) in the diets negatively correlated with FLW (y_1= 1866.8 -3.432x_1, R^2: 0.25), TWG (y_2=1234.8-3.7045x_2, R^2: 0.31) but positively correlated with TFI (y_3=5.2202x_3+3355.9) (Table IV). The results of second order polynomial models for growth and feed intake ($y = a_i x^2 + a_2 x + c_i$, depicted in **Figures 1** and **2**, respectively) with model parameters and goodness of fit **(Table V)** showed that while weight gain of rabbits increased up to 50% MFCSR inclusion level, the feed intake increased with increased inclusion of MFCSR with control diet having the least feed intake.

Table VI shows that the slaughter weight (SW) of rabbits fed the control diet (1717.71g) was similar to those fed 25, 50 and 75% MFCSR-based diets (1730.04g, 1818.88g and 1628.37g, respectively) but all were significantly (P<0.05) higher than those fed 100% MFCSR-based diet. The dressed weight (DW) was similar and higher (P<0.001) for rabbits fed 0, 25 and 50% MFCSR-based diets than those fed 75% and 100%. Also, the relative weight of kidney of rabbits fed the control, 25, 75 and 100% MFCSR-based diets inclusions were similar (P<0.05) but higher than those

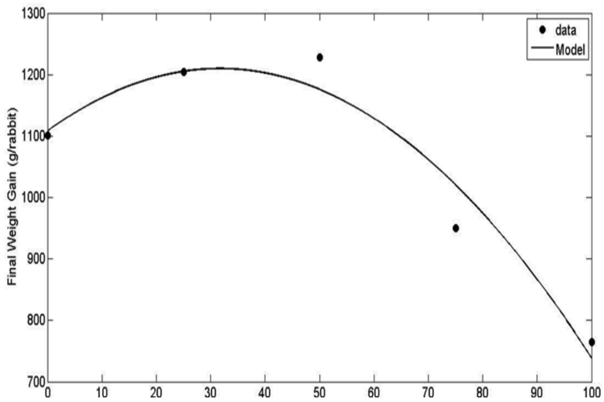

Figure 1. Weight gain of growing rabbit fed microbially fermented cassava residue used for modeling (Gain de poids de plus en plus lapins recevant les résidus d'amidon de manioc fermenté d'origine microbienne utilisés pour la modélisation).

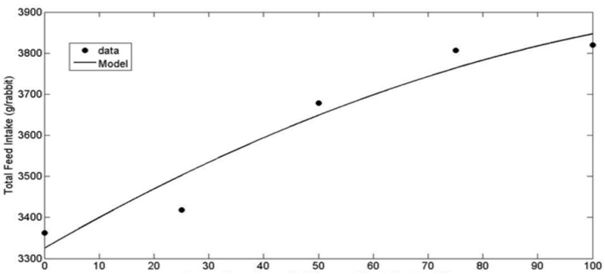

Figure 2. Total feed intake of growing rabbit fed microbially fermented cassava starch resdue for modeling (Prise de l'alimentation totale de plus en plus nourris de lapin recevant les résidus d'amidon de manioc fermenté d'origine microbienne pour la modélisation).

Table IV. Regression equations derived from parameters of rabbits fed graded levels of microbially fermented cassava starch residue (MFCSR) (Les équations de régression des paramètres dérivés de lapins recevant des niveaux gradués de résidus d'amidon de manioc fermenté d'origine microbienne (MFCSR))

Parameters	Regression equation	R^2	*P*
Performance characteristics			
Level of MFCSR replacement vs FLW	y_1= 1866.8 -3.432x_1	0.25	0.001
Level of MFCSR replacement vs TWG	y_2= 1234.8 -3.7045x_2	0.31	0.001
Level of MFCSR replacement vs TFI	y_3= 5.2202x_3+3355.9	0.36	0.001
Carcass characteristics			
Level of MFCSR replacement vs SW	y_4= 1773.8 -3.098x_4	0.18	0.006
Level of MFCSR replacement vs DW	y_5= 847.39 -1.0189x_5	0.53	0.001
Haematological and serum indices			
Level of MFCSR replacement vs PCV	y_6= 35.701- 0.0088x_6	0.005	0.775
Level of MFCSR replacement vs WBC	y_7= 0.0458x_7+7.139	0.46	0.001
Level of MFCSR replacement vs MCHC	y_8= 0.0132x_8+33.805	0.36	0.006
Level of MFCSR replacement vs LDL	Y_9= 0.4711x_9+42.95	0.366	0.924

FLW: Final live weight; TWG: Total weight gain; TFI: Total feed intake; SW: Slaughter weight; DW: Dressed weight; PCV: Packed cell volume; WBC: White blood cell; MCHC: Mean cell haemoglobin; LDL: Low density lipoprotein.

fed on 50% MFCSR-based diet. The levels of MFCSR in the diet also negatively correlated with SW (y_4) and DW (y_5) with equations y_4= 1773.8 -3.098x_4, R^2=0.18 and y_5= 847.39 -1.0189x_5, R^2=0.53 respectively **(Table IV)**.

Table VII shows that all the haematological parameters considered were significantly (P<0.01, 0.001) affected by the dietary treatments. Generally, the packed cell volume (PCV), red blood cells (RBC), haemoglobin concentration (Hbc), and MCV were highest in rabbit fed on 25% MFCSR-based diet and lowest in those fed the control diet.The highest white blood cell (WBC) value was recorded in rabbits fed 100% MFCSR (11.78 x10^9/l) but this was similar to those fed 50 and 75% MFCSR inclusion levels (10.54 and 10.00 x10^9/l, respectively) respectively. Also, the values of mean cell haemoglobin (MCH), mean cell haemoglobin concentration (MCHC); and platelets did not follow a particular trend with highest values of 22.24 pg, 35.33%; and 405.75 (10^3/l) observed in rabbits fed on 75% MFCSR-based diet and the control diet respectively. The level of MFCSR (x) in the diet negatively correlated with PCV values (y_6= 35.701-0.0088x_6, R^2=0.005) and positively

Table V. Model parameters and goodness of fit for rabbit fed microbially fermented cassava starch residue (MFCSR) (Les paramètres du modèle et la qualité de l'ajustement pour lapins les résidus d'amidon de manioc fermenté d'origine microbienne MFCSR)

	a_1	a_2	a_3	SSE	r^2	RMSE
Final weight gain	-0.10095	6.396636	1108.42	10064.74	0.93	70.93919
Total feed intake	-0.02522	7.744245	3324.623	14271.14	0.93	84.47229

a_1, a_2 and a_3 = coefficient of linear equation.

correlated with WBC (y_7= 0.0458x_7+7.139, R^2=0.46) and MCHC (y_8= 0.0132x_8+33.805, R^2=0.36) (Table V).

Table VIII shows that of the entire serum metabolites measured, only the low density lipoprotein (LDL) was significantly (P<0.05) influenced by the dietary treatment. The LDL of rabbits fed the control (51.96mg per dl) and those fed on 25 to 75% MFCSR-based diets (58.61, 51.98 and 59.57mg per dl respectively) were similar among them (P>0.05) but significantly (P<0.05) lower than 110.38 mg per dl observed for rabbits fed on 100% MFCSR-based diet. The level of MFCSR (x) in the diet positively correlated with LDL (y_9= 0.4711x_9+42.95, R^2=0.366) **(Table IV)**.

DISCUSSION

Feed cost is perhaps the major concern in intensive livestock production in developing and developed countries. The price of maize, which is the main source of energy provider in feed is now out of the reach of most non-ruminant livestock farmers especially in developing countries owing partly to the recent low occurrence of precipitation and increase plant diseases plaguing maize in sub-Saharan Africa, Asia and Pacifics and also due to the high demand for maize for human consumptions and industrial uses (Oloruntola et al., 2016; Ogunsipe et al., 2017). Thus, the need to source for alternative feed resources that can partially or wholly replace maize has now become more compelling. Also, the need to develop growth-feeding models for such alternative resource in animal balance studies cannot be underscored.

In this study, the crude protein (94.5 g/kg) of MFCSR was found to be higher than 64.5 gk/g reported by Nwafor and Ejukonemu (2004) for fermented cassava starch residue when fermented with *Saccharomyces cerevisae*, lower than 185 g/kg reported by Nur (1995) after fermentation with *Aspergillus niger*, but comparable to the value reported for maize (NRC, 1994).

Also, the present study showed that unlike the FLW and average daily weight gain (ADWG) which increased up to 50% MFCSR inclusion, the average daily feed intake (ADFI) of the rabbits increased with increased MFCSR inclusion level with a concomitant reduction in the feed utilization suggesting that the optimal level of MFCSR substitution for maize in the diet of growing rabbit could be 50%, beyond which the FLW, ADWG and FCR decreased. This is further corroborated by the regression of TWG$_{(y_2)}$ against MFCSR$_{(x_2)}$, which had prediction equation y_2=1234.8-3.7045x_2 (R^2=0.31, P<0.001). Arising from this is that the MFCSR inclusion level accounted for about 31% of the variation in TWG of the rabbits and for every gram increase in MFCSR level, there was corresponding decrease of TWG of the rabbits by 3.70g. This is further explained by the 2º polynomial growth model derived from **Figure 1** which showed declination in the growth pattern as the inclusion level of MFCSR exceeded 50% in the diet. Also from the model, the inclusion level in excess of 50% (75% and 100%) for maize would lead to 11.75% and 30.38% TWG reduction with resultant decline in feed utilization as evident in the value of the feed conversion ratio (FCR), respectively. By implication it will no

Table VI. Carcass and relative organ weight (% slaughter weight) of weaner rabbits fed microbially fermented cassava starch residue (MFCSR) (Le poids relatif des organes et de la carcasse (% poids d'abattage) de sevré lapins recevant des résidus d'amidon de manioc fermenté d'origine microbienne)

Parameter (%)	Level of MFCSR Inclusion (%)					SEM	P Value
	0 Diet 1	25 Diet 2	50 Diet 3	75 Diet 4	100 Diet 5		
Slaughter weight (g)	1717.71[a]	1730.04[a]	1818.88[a]	1628.37[a]	1346.71[b]	44.90	0.004
Dressed weight (g)	823.23[a b]	829.85[a]	832.02[a]	808.96[b]	704.83[c]	9.27	0.001
Dressed %	47.92602	47.9671	45.74353	49.67913	52.33718	1.36	0.489
Lung **(%)**	0.83	0.67	0.62	0.70	0.72	0.03	0.102
Liver **(%)**	2.22	2.43	2.07	2.46	2.25	0.38	0.365
Kidney **(%)**	0.59[ab]	0.64[ab]	0.53[b]	0.66[ab]	0.74[a]	0.12	0.029
Heart **(%)**	0.20	0.24	0.20	0.24	0.20	0.05	0.346
Pancrease **(%)**	0.05	0.05	0.04	0.04	0.05	0.00	0.593
Bile **(%)**	0.05	0.04	0.04	0.05	0.06	0.00	0.114

Means with different superscripts in the same row are significantly different (P<0.05; 0.001)

Table VII. Haematology of weaner rabbits fed microbially fermented cassava starch residue (MFCSR) (L'hématologie de sevré lapins recevant l'amidon de manioc fermenté d'origine microbienne)

Parameter	Level of MFCSR Inclusion (%)					SEM	P Value
	0 Diet 1	25 Diet 2	50 Diet 3	75 Diet 4	100 Diet 5		
PCV (%)	30.38[d]	41.98 [a]	37.87 [b]	31.62[c]	34.46[c]	1.04	0.001
Haemoglobin conc. (g/dl)	10.35[d]	14.88[a]	12.99[ab]	10.89[cd]	12.67[bc]	0.45	0.001
Red blood cells (x10^{12}/l)	5.47[c]	6.73[a]	6.39[ab]	5.77[bc]	6.41[ab]	0.14	0.012
White blood cells (x10^{9}/l)	7.29[b]	7.53[b]	10.54[a]	10.00[ab]	11.78 [a]	0.55	0.017
Lymphocytes (x10^{9}/l)	3.24[c]	3.53[c]	6.06[a]	3.53[c]	4.80[b]	0.28	0.001
Monocytes (x10^{9}/l)	0.90[b]	1.07[b]	1.78 [a]	1.70 [a]	2.13 [a]	0.13	0.001
Granulocytes (x10^{9}/l)	3.15[b]	2.48[b]	3.43[b]	5.67 [a]	6.04 [a]	0.39	0.001
MCV (fl)	55.25[c]	63.75 [a]	61.75[ab]	60.25[b]	59.50[b]	0.74	0.001
MCH (pg)	19.03[c]	21.15[ab]	20.75[b]	22.24 [a]	21.81[ab]	0.29	0.001
MCHC (%)	34.15[b]	33.88[b]	33.90[b]	35.33 [a]	35.08 [a]	0.18	0.005
Platelets (10^{9}/l)	405.75[a]	213.25[c]	218.50 [c]	266.50[c]	242.00[bc]	16.62	0.001

Means with different superscripts in the same row are significantly different (P<0.01, 0.001)
PCV: Packed cell volume; MCV: Mean cell volume; MCH: Mean cell haemoglobin; MCHV: Mean cell haemoglobin concentration

longer be cost effective using MFCSR to replace maize beyond 50%. This finding is suggestive of the fact that the observed decline in the ADWG could be as a result of the cumulative negative effect of cyanide content which will normally increase progressively as the level of MFCSR increased in the diets. There are scanty reports of toxicity in rabbit due to cassava cyanide. However, report by Aro et al. (2015) showed that HCN led to nutrient digestibility reduction with a resultant decline in the performance of pigs due to a significant increase in grain replacement without proper protein supplementation. From this current study, the 50:50

Table VIII. Serum Metabolites of weaner rabbits fed varying levels of microbially fermented cassava starch residue (MFCSR) (Métabolites sériques de sevré lapins recevant divers niveaux de résidus d'amidon de manioc fermenté d'origine microbienne)

Parameter	Level of MFCSR Inclusion					SEM	P Value
	0 Diet 1	25 Diet 2	50 Diet 3	75 Diet 4	100 Diet 5		
Total protein (g/l)	66.61	71.61	69.28	69.27	73.29	0.87	0.117
Albumin (g/l)	50.88	53.88	52.55	51.55	55.21	0.77	0.430
Globulin (g/l)	12.82	14.82	13.82	14.82	15.15	4.35	0.468
Cholesterol (mmol/L)	1.39	1.46	1.39	1.65	1.7	0.06	0.308
Urea (mg/dl)	31.49	38.44	31.49	44.19	40.34	2.06	0.201
Creatinine (mg/dl)	1.094	1.054	1.094	1.394	1.234	0.06	0.415
HDL (mg/dl)	36.32	32.45	36.32	38.82	33.52	1.08	0.400
LDL (mg/dl)	51.96[b]	58.61[b]	51.98[b]	59.57[b]	110.38[a]	7.36	0.023
Bilirubin (μ/l)	0.46	0.34	0.46	0.48	0.55	0.03	0.137
AST (μ/l)	84.92	102.72	84.92	65.87	71.12	7.67	0.654
ALT (μ/l)	92.68	151.88	92.68	135.88	109.28	8.88	0.101
ALP (μ/l)	169.99	122.59	169.99	142.69	80.84	12.48	0.100
Amylase (μ/l)	531.61	784.41	531.61	599.91	545.41	34.10	0.057
Glucose (mg/dl)	91.94	78.24	91.94	102.89	85.34	4.20	0.487

Mean within rows having different superscripts are significant (P<0.05); HDL: Higher density lipo-protein; LDL: Low density lipo-protein; AST: Aspertate amino transaminase; ALP: Alkaline phosphate; ALT: Alanine aminotransferase.

maize:MFCSR might contain the needed crude protein to crude fibre (1:1.23) that could improve intestinal physiological activities with a resultant increase in the FLW and TWG, suggesting that 50% RLFSCR replacement for maize could be the optimum replacement level in growing rabbit diets. This is in consonance with the previous report of Oloruntola et al. (2016). Of interest is that ADWG observed in this study, 13.65 to 22.48g/day, is in most cases higher than 12.38 to 17.75 g/rabbit/day reported by Oloruntola et al., (2016) and Ayodele et al., (2016) and 6.55 to 12.70g/rabbit/day reported by Ibrahim et al., (2014) but lower than 44.1to 45.1 g/rabbit/day reported by Mora et al. (2014).

Conversely, a progressive increase in feed intake of rabbits on MFCSR-based diets was observed in the current study. This was corroborated by the regression of TFI (y) against MFCSR (x), which had the prediction equation y_3= 5.2202x+3355.9 (R^2=0.36, P<0.001) which implies that, the MFCSR level accounted for about 36% of the variation in TFI of the growing rabbits. Thus for every gram increase in MFCSR level, there was a corresponding increase of 5.2202g in TFI of the rabbit, while for every gram increase in other factors aside MFCSR level there was a corresponding increase of 3355.9g in TFI. This is further supported by the second order polynomial feeding model which showed a progressive increase in the TFI with increase in inclusion level of MFCSR as depicted in **Figure 2**. The plausible reason for this could be that there was a decrease in the energy contents of the diets **(Table II)** which stimulated feed intake as animals eat to meet their caloric needs' (McDonald et al., 1995). Also, the increased dietary fibre in the diets could also be implicated as rabbits appetite is stimulated by increase in fibre contents (de Blas and Wiseman, 2003).

However, the increased TFI was not properly utilized for muscle development by the experimental rabbits as evident in the FCR values. Nevertheless, the FCR observed in this study were similar to 3.03-4.98 reported by Oloruntola et al. (2016) for rabbits fed fermented cassava peels but better than 5.39-6.30 reported by Ogunsipe et al. (2011) for rabbits fed graded levels of gliricidia leaf protein concentrates and 4.42-5.85 reported by Ekwe et al. (2011) for those fed cassava sievate.

The importance of 'carcass cut' as growth indices in rabbit study can not be over emphasized. The variation in the slaughter weight (SW) and dressed weight (DW) in this study could be attributed to the variation in the live weights of the experimental rabbits, which increased as the level of maize replacement with MFCSR increased to 50% and thereafter decreased, implying that the values of DW and SW are function of the FLW. This is further supported by the regression of SW against MFCSR level (y_4= 1773.8-3.098x_4, R^2 = 0.18, P<0.05), and DW against MFCSR level (y_5= 847.39-1.0189x_5, R^2=0.53, P<0.05). Thus, MFCSR level in the diets accounted for 18% and 53% of the variations observed for the SW and DW in the rabbits respectively. This is of economic benefit, because MFCSR level after initialization contributed more to the flesh portion of the experimental rabbits. In general, the observed SW range in this study was lower than 1677.44-2218.01 g reported by Ogunsipe et al. (2014) while the DW was higher than 48.70-49.45% documented by Oteku and Igene (2006).

This study also showed that of the relative organ weights measured; only the relative weight of the kidney was statistically affected by the dietary treatments suggesting that the test diets promoted similar organ's development as the control diet.

Blood and serum indices are important when the health status of animal fed certain feed is to be assessed. Madubuike and Ekenyewu (2000) reported that blood variables are indicators of the physiological disposition of animal to the plane of nutrition. Thus, the blood parameters of importance include WBC, PCV and blood absolute values such as MCV, MCH and MCHC (Aro and Akinmoegun, 2012). In this study, the PCV, Hb, RBC, lymphocyte, MCV and MCH of rabbits fed the test diets were consistently higher than those fed the control diet and in most cases, rabbits fed 25% MFCSR-based diet had the highest values in the experimental rabbits.

This is further confirmed by the positive correlations that existed between the levels of MFCSR and WBC (y_7= 0.0458$_{x7}$+7.138, R^2=0.46, P<0.001) and (y_8= 0.0132$_{x7}$+33.805, R^2=0.36, P<0.006). Also, the observed stability values of serum metabolites (except LDL) which were not statistically affected by the dietary treatments coupled with better haematological indices of rabbits on the test diets compared with those on the control diet implied that the test diets when consumed by the rabbit did not precipitate adverse health challenge to the rabbits.

CONCLUSIONS

Within the limit of the present study, replacing maize with MFCSR beyond 50% led to reduction in the total weight gain of the rabbits and this was supported by the growth model developed using second order polynomial. Also, up to 50% MFCSR replacement for maize did not lead to adverse effect on the health status of the rabbits.

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