ISSN 0189-0514
J. Anim. Prod. Res. (2016) 28(2):102-117

National Animal Production Research Institute
Ahmadu Bello University
P.M.B 1096, Shika-Zaria,
Kaduna State, Nigeria.
Email: japr@napri-ng.org Website: www.naprijapr.org

CARCASS CHARACTERISTICS, PROXIMATE COMPOSITION AND RESIDUAL RETINOL IN MEAT OF BROILER CHICKENS FED B-CAROTENE CASSAVA (*MANIHOT ESCULENTA* CRANTZ) GRITS BASED DIETS

Ogunwole, O. A., Lawal, H. O., Idowu, A. I., Oladimeji, S. O., Abayomi, F. D., and Tewe, O. O.

Agricultural Biochemistry and Nutrition Unit, Department of Animal Science, University of Ibadan, Ibadan, Nigeria

Correspondence Author's E-mail: droaogunwole@gmail.com

ABSTRACT

Effect of replacing maize with β-carotene biofortified cassava grits on physico-chemical attributes of carcass and meat of broilers was investigated in an experiment which lasted 42 days. In a completely randomized design, 210 one-day old Arbor Acre broiler chicks were allotted to seven dietary treatments in triplicates of ten birds per replicate. At both the starter and finisher phases, yellow maize based diet was the control (1). Other six diets were made by replacing 25, 50 and 75% of yellow maize with grits from two different cassava varieties; TMS 01/1371, a β-carotene bio-fortified yellow cassava (2, 3, 4) and TME 419, a conventional white cassava (5, 6, 7), respectively. There was no significant difference (P>0.05) in weight of primal cuts excepting back where birds fed T5 had higher (P<0.05) yield (15.19%) compared with those fed other diets (14.66, 13.65, 14.72, 14.13, 14.38 and 15.01% for birds fed 1, 2, 3, 4, 6 and 7, respectively). Meat pH, water holding capacity and cooking loss were not significantly (P>0.05) affected by the treatment. Meat of birds on 7 had significantly lower (P<0.05) shear force (3.65 kg/cm^3) compared to those on other treatments. Dietary β-carotene cassava grits significantly increased (P<0.05) meat retinol and reduced meat lipid oxidation. However, there was no significant effect (P>0.05) of the replacement on meat proximate composition. Meat colour, tenderness and juiciness differed significantly (P<0.05) among treatments while aroma, flavour and overall acceptability were similar (P>0.05). In conclusion, maize could be replaced with cassava grits from TME 419 and TMS 01/1371 up to 75% without adversely affecting broiler chicken meat yield and quality. Dietary β-carotene bio-fortified cassava up to 75%, improved shelf life and oxidative stability of broilers meat.

Keywords: β-carotene bio-fortified cassava, Cassava grits, Meat shelf stability, Meat residual retinol,

INTRODUCTION

Maize, the main ingredient in poultry feed which is usually included at the rate of 40 to 60% of the formulated diet for broiler chicken is expensive or at times scarce. Cassava is not only high in energy but also available in large quantity in Nigeria and has been investigated to serve as alternative main energy source in broiler rations (Adebayo *et al*., 2010). Various cassava products have also been used in feeding livestock (Ngoka *et al*., 1984; Balagopan *et al*., 2002; Eruvbetine *et al*., 2003). Cassava root meals have been substituted for maize at 0-50-70-100% in the diets for layers, broilers and breeder stock. A substitution level of up to 75% was recommended when appropriately detoxified (Ngoka *et al*., 1984).

However, conventional cassava roots and products are known to be deficient in β-carotene and other carotenoids (Omole, 1977) which could consequently lead to nutritional deficiencies and also cause *in vivo* oxidative stress with the attendant effects on animal products (Ngiki *et al*., 2014). The new biofortified cassava varieties from IITA (2011) aside from its high yielding are also innately rich in β-carotene. These varieties could aside from serving as alternative energy source to broilers, also supply the much desired provitamin A, thereby providing cost effective way of combating vitamin A nutritional deficiency (Ngiki *et al*., 2014).

Earlier documentations on cassava use as ingredient focussed on broiler chickens performance (Omole, 1977; Ngoka *et al*., 1984; Balagopan *et al*., 2002; Eruvbetine *et al*., 2003; Ngiki *et al*., 2014). The inherent provitamin A composition of the biofortified cassava varieties and its bioavailability to chicks have been determined (Ogunwole *et al*., 2015). There is however, dearth of information on the effects of dietary biofortified cassava on carcass primal cuts, proximate composition and residual retinol content in meat of the fed broiler chickens which this study was aimed at investigating.

MATERIALS AND METHOD

The experiment was carried out at the Poultry Unit, Teaching and Research Farm, University of Ibadan, Ibadan, Nigeria. Ibadan is located on latitude 7^0 20^1N, longitude 3^0 50^1E, and 200m above the sea level, in tropical rain forest vegetation zone. Laboratory analyses were undertaken at the Department of Animal Science, University of Ibadan, Ibadan, Nigeria.

Experimental Animals and Management

A total of 210 Arbor Acre, one-day old broiler chicks was obtained from Amo Byng Farm and Sieberer Hatcheries, Awe, Oyo State, Nigeria. The chicks were randomly allotted to the seven dietary treatments; each treatment was in triplicate of ten birds per replicate. Birds were raised in a deep litter system with separate feeder and water trough. The experimental diets and clean drinking water were offered to birds' *ad-libitum* throughout the course of the experiment. Standard management practice and routine health specifications were undertaken as outlined (Oluyemi and Roberts, 2000).

Experimental Diets

Seven isocaloric and isonitrogenous diets were compounded to contain cassava grits made from two cassava varieties: TMS 01/1371 a β-carotene bio-fortified variety with yellow root and TME 419 a conventional cassava variety (Tewe, 2005) by replacing yellow maize in the control diet at 25, 50 and 75% levels. The starter and finisher diets contained 3100 kcal/kg and 21.0%; 3200 kcal/kg and 19.0% gross energy and crude protein, respectively. Details of the dietary composition for starter chicks have been reported (Ogunwole *et al*., 2015,) while gross dietary basal composition for both starter and finisher broiler chicken have been documented (Ogunwole *et al*., 2016) and are shown also shown in Tables 1a and b.

At day 42 of the experiment, two birds with body weight closest to the group mean weight in each replicate were selected, properly tagged, starved of feed over night and their live weight recorded. The birds were thereafter sacrificed, bled, defeathered and properly dissected into primal cuts. The primal cuts (breast, back, thigh and drumstick) were weighed. The weights of

different cut parts were related to percentage of the live weight of birds. The pH values were determined by the use of a digital pH meter (Digimed® DM-22) equipped with an electrode (Digimed® DME-R12). The carcass pH was obtained by a direct probe thrusting into the breast muscle and the reading was taken and recorded while the meat pH was obtained after brief homogenization of 10 g of muscle sample with 90 mL of distilled water (Conte-Junior *et al*., 2008). Cooking loss was determined (Omojola and Adesehinwa, 2007). Shear force was performed using the modified Warner Braztler shear force procedure (Bouton and Harris, 1978). Meat water holding capacity (Hamm, 1986) and proximate composition were determined (AOAC, 2000). Meat retinol content was determined by spectrophotometric analysis (AOAC, 1990) and meat sensory evaluation undertaken (AMSA, 1995). The degree of meat lipid oxidation was analyzed as thiobarbituric acid reactive substances (TBARS) (Pensel, 1990).

Statistical Analysis

Data were subjected to analysis of variance and regression at $\alpha_{0.05}$ (SAS, 2002) and means separated using Duncan's multiple range test of the same software.

RESULTS AND DISCUSSION

Primal carcass cuts of the experimental birds are presented in Table 2. Drumstick yield of birds fed diets 1 to 7 were 11.14, 11.22, 10.99, 11.33, 11.15, 11.33 and 10.92, respectively. The thigh yield ranged from 10.50 to 11.28% while the wings yield was between 7.58 and 7.94%. Decreased breast meat yield with increased inclusion level was observed in birds fed TME 419 based grit. There were no significant differences ($P>0.05$) in the obtained values of drumstick, thigh, wing and breast among treatments. However, dietary treatments had significant effect ($P<0.05$) on broilers back yield. Birds fed diet 7 had the highest value (15.01%) while those fed diet 2 (13.65%) was lowest. Findings here agree with the earlier report (Awojobi and Adekunmi, 2002) of the insignificant effects of dietary maize replacement with cassava tuber meal which did not affect the meat characteristics of broilers. Other workers (Tavarez *et al*., 2011) noted that antioxidant supplementation of cassava based meal had no significant effect on broiler chickens meat yield. This implied that feeding broilers with β-carotene biofortified cassava may not alter the meat yield of broiler chickens as indeed corroborated in this study.

Table 1a. Gross composition (g/100g) of the experimental starter diets fed to broiler chickens

Ingredients	0 1	25 2	50 3	75 4	25 5	50 6	75% 7
Yellow Maize	50.00	37.50	25.00	12.50	37.50	25.00	12.50
TME 419	0.00	0.00	0.00	0.00	12.50	25.00	37.50
TMS 01/1371	0.00	12.50	25.00	37.5	0.00	0.00	0.00
Soybean meal (42% CP)	35.9	39.00	41.50	43.14	39.5	42.00	44.00
Wheat offal	8.24	5.14	2.64	1.0	4.64	2.14	0.14
DL-Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20
L-lysine	0.10	0.10	0.10	0.1	0.10	0.10	0.10
Oyster shell	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Palm oil	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Dicalcium phosphate	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Vitamin/mineral Premix*	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Avatec	0.06	0.06	0.06	0.06	0.06	0.06	0.06
TOTAL	100	100	100	100	100	100	100
Calculated values							
M.E (Kcal/kg)	3080.39	3091.87	3098.37	3097.73	3093.52	3097.52	3097.37
Crude Protein (%)	20.97	20.88	20.64	20.19	20.93	20.61	20.17
Methionine (%)	0.52	0.51	0.50	0.49	0.52	0.51	0.49
Lysine (%)	1.30	1.33	1.36	1.37	1.34	1.37	1.38
Available Phosphorus (%)	0.52	0.52	0.52	0.51	0.52	0.52	0.51
Calcium (%)	0.97	1.00	1.03	1.05	1.00	1.03	1.05

Note. Diet 1: A maize based diet. Diet 2: TMS 01/1371 replacing yellow maize at 25%. Diet 3: TMS 01/1371 replacing yellow maize at 50%. Diet 4: TMS 01/1371 replacing yellow maize 75%. Diet 5: TME 419 replacing yellow maize at 25%. Diet 6: TME 419 replacing yellow maize at 50%. Diet 7: TME 419 replacing yellow maize at 75%. Diet 8: A white maize based diet, beta-carotene deficient diet (inhibited with the addition of 5gliquid paraffin in 100g of diet). M.E: Metabolizable Energy.

*Each 1.25 kg vitamin/mineral premix contain: vitamin A-10,0000,0000 I.U, vitamin D_3-22000000 I.U., vitamin E-10,000 mg, vitamin K_3-2,000, Folic Acid-500 mg, Niacin-15,000 mg, Calpan-5000 mg, vitamin B_2-5,000 mg, vitamin B12-10 mg, vitamin B1-1500 mg, vitamin B6-1500 mg, Biotin-20 mg, antioxidant-125,000mg, selenium-200 mg, iodine-1000 mg, iron-40,000 mg, cobalt 200 mg, manganese-70,000 mg, copper-4000 mg, Zinc-50,000 mg, choline chloride 150,000 mg and yolk colorant.

Table 1b: Gross compostion (g/100gDM) of experimental finisher diets fed to broiler chickens

INGREDIENTS	0	25	50	75	25	50	75%
	1	2	3	4	5	6	7
Yellow Maize	52.00	39.00	26.00	13.00	39.00	26.00	13.00
TME 419 cassava	0.00	0.00	0.00	0.00	13.00	26.00	39.00
TMS 01/1371	0.00	13.00	26.00	39.00	13.00	26.00	39.00
Soya bean meal	35.90	39.00	41.50	43.14	34.00	36.50	39.90
Wheat offal	8.24	5.14	2.64	1.00	8.24	5.74	2.34
DL-Methionine	0.20	0.20	0.20	0.20	0.20	0.20	0.20
L-lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Oyster shell	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Palm oil	2.50	2.50	2.50	2.50	2.40	2.40	2.40
Dicalcium Phosphate	1.50	1.50	1.50	1.50	1.50	1.50	1.50
*Premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Table Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Avatec	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Nutrients Composition							
ME (Kcal/kg)	3080.3	3091.8	3098.4	3097.7	3082.5	3097.4	3119.9
CP (%)	20.97	20.88	20.64	20.19	19.42	19.11	19.03
DL Methionine (%)	0.52	0.51	0.50	0.49	0.50	0.48	0.48
Lysine (%)	1.30	1.33	1.36	1.37	1.23	1.25	1.29
Av. P (%)	0.52	0.52	0.52	0.51	0.50	0.50	0.50
Calcium (%)	0.98	1.00	1.03	1.05	0.85	0.87	0.90

DCP- Dicalcium phosphate; ME- Metabolisable energy; CP- Crude protein; Av P- Available phosphorus

*Each 1.25 kg vitamin/mineral premix contain: vitamin A-10,0000,0000 I.U, vitamin D3 22000000 I.U., vitamin E-10,000 mg, vitamin K3-2,000, Folic Acid-500 mg, Niacin-15,000 mg, Calpan-5000 mg, vitamin B2-5,000 mg, vitamin B12-10 mg, vitamin B1-1500 mg, vitamin B6-1500 mg, Biotin-20 mg, antioxidant-125,000mg, selenium-200 mg, iodine-1000 mg, iron-40,000 mg, cobalt 200 mg, manganese-70,000 mg, copper-4000 mg, Zinc-50,000 mg, choline chloride 150,000 mg and yolk colorant.

Table 2: Relative primal carcass cuts of broiler chickens fed β-carotene bio-fortified cassava based diets

Parameters (%)	0 1	25 2	50 3	75 4	25 5	50 6	75 7	SEM
Drumstick	11.14	11.22	10.99	11.33	11.15	11.33	10.92	0.131
Thigh	11.03	10.60	10.50	11.28	10.61	11.13	10.58	0.104
Wing	7.71	7.94	7.89	7.66	7.61	7.79	7.58	0.064
Breast	24.54	23.04	24.73	23.62	25.23	24.73	23.53	0.246
Back	14.66^{ab}	13.65^{b}	14.72^{ab}	14.13^{ab}	15.19^{a}	14.38^{ab}	15.01^{ab}	0.159

a, b: means within rows with the same superscript are not significantly (P>0.05) different
1, 2, 3….7: Treatments, SEM: standard error of the mean

The pH of meat of broilers fed β-carotene biofortified cassava based diets is presented in Table 3. There were no significant differences in the intramuscular pH of breast muscle till 12 hours but the pH values were higher than 5.3. Report (Sante *et al.,* 1991) indicated that as the muscle reaches a pH of 5.3, water binding potential is expected to be significantly reduced because at this pH the isoelectric point of myosin is attained. In this study, pH values below 5.3 were not observed. Thus, the result suggests that breast muscles did not exhibit extremely rapid *post-mortem* metabolism that could be indicative of pale, soft and exudative (PSE) like problems in all the treatments (Warris and Brown, 1987). However at 12 hours, significant differences were observed in the obtained pH values. This could be as a result of varying rate of declining metabolic glycolysis in the meat of the experimental animals as oxidative respiration ceases with passing time post-mortem (Ogunwole *et al*., 2013).

The attributes of meat from broiler chickens fed β-carotene biofortified cassava based diets are shown in Table 4. The percentage cooking loss ranged between 30.81 and 33.60% while percentage water holding capacity ranged from 53.36 to 56.66%. There was no significant (P>0.05) effect of replacement of maize with the two varieties of cassava on cooking loss and water holding capacity of meat from the experimental birds. However, 75% replacement of maize with TME 419 (diet 7) had significant effect (P<0.05) on shear force of meat of the experimental birds. There were no significant difference (P>0.05) in the values at 75% replacement with both varieties of cassava.

Water holding capacity is defined as the ability of meat to retain its water upon the application of an external force (Hedrick *et al*., 1994). It is an important meat quality attribute because color, juiciness, and tenderness are all partially dependent on the ability of the meat to retain moisture under normal storage conditions and during thermal processing (Jeffery, 1983; Honikel, 2004; Mehaffey *et al.,* 2006). The lack of significant differences in water holding capacity measures of meat in this experiment was expected since there was no significant difference in the muscle pH values among treatments.

The pH has direct effect on water holding capacity (Offer and Knight, 1988; Qiao *et al*., 2001; Fletcher, 2002; Huff-Lonergan and Lonergan, 2005). As the pH falls, the actomyosin linkage intensifies promoting the passage of the meat from a gel to a more compact crystalline structure resulting in a reduced water holding capacity (Alais and Linden, 1999). Cooking yield of meat is dependent on cooking loss while cooking loss is a function of the water holding capacity because

cooking loss has an inverse relationship with water holding capacity (Geesink *et al*., 2001) as also observed in this study. Report (Rogers *et al*., 1967) indicated that changes in the myofibrillar protein as a result of increased temperature causes shrinkage of the meat tissue leading to the release of juices.

Table 3: pH of meat from broilers fed β-carotene bio-fortified cassava based diets

		REPLACEMENT LEVELS OF MAIZE WITH CASSAVA (%)						
		TMS 01/1371			TME 419			
TIME(hrs)	Control	25	50	75	25	50	75	SEM
	1	2	3	4	5	6	7	
0	6.10	6.14	6.25	6.09	6.42	6.09	6.19	0.053
6	5.54	5.48	5.76	5.57	5.58	5.60	5.73	0.032
12	5.64^{ab}	5.54^{ab}	5.73^{ab}	5.77^{a}	5.43^{b}	5.85^{a}	5.64^{ab}	0.039
18	5.55	5.60	5.71	5.68	5.49	5.70	5.58	0.026
24	5.64	5.64	5.68	5.56	5.54	5.58	5.61	0.045

TMS 01/1371- β-carotene biofortified cassava grit TME 419- Conventional cassava grit
a, b: means within rows with the same superscript are not significantly (P>0.05) different
SEM: standard error of the mean

Effect of β-carotene bio-fortified cassava based diets on organoleptic attributes of meat from broilers is presented in Table 5. Diet did not have significant effect (P>0.05) on aroma, flavour and overall acceptability while significant differences (P<0.05) were observed in colour, tenderness and juiciness. Meat from birds fed diet 4 had the highest score of 4.11 for aroma while birds fed diet 1 had the lowest score of 3.72. Meat of birds fed diet 1 was scored highest for colour (7.06) while meat from birds fed diet 4 was scored lowest (6.17). Meat from birds fed diet 1 was observed to be the most tender (6.06) while those from birds fed diet 4 was observed as being the least tender (4.67).

Table 4: Attributes of meat from broiler chickens fed β-carotene biofortified cassava based diets

		REPLACEMENT LEVELS OF MAIZE WITH CASSAVA (%)						
		TMS 01/1371			TME 419			
PARAMETERS	Control	25	50	75	25	50	75%	SEM
	1	2	3	4	5	6	7	
Cooking loss (%)	31.22	31.52	30.81	32.02	33.43	33.15	33.60	0.44
Shearforce (kg/cm^3)	5.64^{a}	5.56^{a}	5.62^{a}	4.74^{ab}	5.88^{a}	5.47^{a}	3.65^{b}	0.22
Water holding capacity (%)	56.66	53.85	54.35	55.20	53.58	53.36	54.48	1.44

TMS 01/1371- β-carotene biofortified cassava grit, TME 419- Conventional cassava grit
a, b: means within rows with the same superscript are not significantly (P>0.05) different
SEM: standard error of the mean

There was reduction in meat juiciness with increased inclusion level of TMS 01/1471 grits while juiciness increased with higher inclusion of TME 419. Meat from birds on control was least juicy (4.67). The overall acceptability also reduced with the inclusion level of TMS 01/1371 and increased with inclusion of TME 419. This agreed with documented results (Adeyemo and Sanni, 2013) of the effect of *Aspergilus niger* hydrolyzed cassava peel meal based diets on meat colour, tenderness and juiciness.

Meat colour is a very important quality attribute which determines appearance of meat and plays an important role in consumer acceptance of a product. Early report (Ewa *et al*., 2005) revealed that vitamins added to feed did not have a clear effect on meat acidity and colour, although redness was more favourable. Other workers (Monahan *et al*., 1992; Kirchheim *et al.*, 2001) reported that natural antioxidant added to feed stabilizes meat colour. Asides from being consonant with the result of β-carotene content of the corresponding experimental treatments, the meat colour could also be attributed to other factors which include myoglobin content, chemical structure of haeme, and pH of meat (Fletcher, 2002). Myoglobin content is mainly influenced by bird species and age as well as muscle type, whereas pH of animal muscles is associated with their biochemical state at slaughter and the advancing rigor mortis (Dziadek *et al*., 2002; Fletcher, 2002). Colour could also be attributed to weight of birds. Heavier birds (those with a thicker layer of breast muscles) were reported (Bianch and Fletcher, 2002; Bianchi *et al*., 2006) to have a darker colour of breast muscles compared to lighter birds. There was however no significant difference in overall acceptability and flavour of the chickens across the groups contrary to documented result (Adeyemo and Sanni, 2013).

Table 5: Organoleptic properties of meat of broilers fed β-carotene bio-fortified cassava based diets

		REPLACEMENT LEVELS OF MAIZE WITH CASSAVA (%)						
		TMS 01/1371			TME 419			
PARAMETERS	Control	25	50	75	25	50	75%	SEM
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	
Aroma	3.72	4.28	3.94	4.11	4.06	4.06	4.33	0.182
Colour	7.06^{a}	6.22^{ab}	6.94^{ab}	6.17^{ab}	6.39^{ab}	6.28^{ab}	5.94^{b}	0.116
Tenderness	6.06^{ab}	4.83^{c}	4.83^{c}	4.67^{c}	5.00^{abc}	5.50^{abc}	5.83^{abc}	0.160
Juiciness	4.67^{c}	5.11^{abc}	4.94^{abc}	4.77^{bc}	5.00^{abc}	5.50^{abc}	6.06^{ab}	0.155
Flavour	4.33	4.67	4.78	4.89	5.11	5.06	5.17	0.175
Overall acceptability	5.00	5.50	5.22	5.11	5.61	6.06	6.22	0.146

TMS 01/1371- β-carotene biofortified cassava grit, TME 419- Conventional cassava grit
a, b, c: means within rows with the same superscript are not significantly (P>0.05) different
SEM: standard error of the mean

The significant differences observed in the tenderness and juiciness could be due to several factors; in the mouth, textural properties are not independent of other characteristics of meat, including water-holding capacity and fat content, as they contribute to the necessary lubrication while chewing (Juarez *et al*., 2015). It has also been reported (Cross *et al*., 1986) that juiciness of meat was directly related to the intramuscular lipid and moisture content. In combination with

water, the melted lipids constitute a brooth which when retained in the meat is released upon chewing (Omojola and Adesehinwa, 2007).

Tenderness is regarded as the most important sensory attribute affecting meat acceptability (Cross *et al*., 1986; Quali, 1990; Warkup *et al*., 1995). As stated (Smulders *et al*., 1991; Warkup *et al*., 1995), meat tenderization is a multifactorial process dependent on a number of biological and environmental factors. Intramuscular fat content (Nishimura *et al.,* 1999), as well as the rate and extent of *post-mortem* energy metabolism (Thompson *et al*., 2006) indirectly influence meat tenderness. Thus, multiple interactions between these systems determine the final rate and extent of tenderization, making it difficult to separate the effects of individual factors (Juarez *et al.,* 2015). Additionally, other pre- and post mortem factors can impact on meat tenderness and juiciness. Hence the difference in the tenderness and juiciness of meat from this study could be due to several factors aside diets fed to birds.

The coefficients of correlation of tenderness, juiciness, ether extract and water holding capacity of meat from broilers fed cassava grits based diets is shown in Table 6. Relationship between tenderness and juiciness was positive and highly significant ($r=0.684$; $P<0.01$) while the relationship between tenderness and ether extract ($r=0.032$; $P>0.05$), tenderness and water holding capacity ($r=0.173$; $P>0.05$) were positive but not significant. There was positive but non significant relationships between water holding capacity and juiciness ($r=0.169$; $P>0.05$) and water holding capacity and ether extract ($r=0.087$; $P>0.05$). However, there was also negative non-significant relationship between juiciness and ether extract ($r=-0.051$; $P>0.05$) of meat samples. Meat juiciness is considered to arise from moisture released by meat during chewing and moisture from saliva (Howard, 1976; Christensen *et al.,* 2011), and is influenced not only by meat related factors such as fat content, but also by physiological and psychological factors inherent to individual tasters (Janz and Aalhus, 2002).

Table 6: Correlation coefficients of the different meat attributes of broiler chickens fed β-carotene biofortified cassava grits based diet

	Tenderness	Juiciness	Ether extract	Water holding capacity
Tenderness	1.000			
Juiciness	0.684**	1.000		
Ether extract	0.032	-0.051	1.000	
Water holding capacity	0.173	0.169	0.087	1.000

Table 7 shows the proximate composition and the residual retinol content of meat obtained from the experimental animals. Dietary replacement of maize with cassava grits had no significant effect ($P>0.05$) on proximate composition of meat of broilers. However, replacement of dietary maize with cassava grits had significant effect ($P<0.05$) on the residual retinol (Vitamin A) content of meat of the experimental animals. The retinol values ranged from 251.8 to 479.3 IU/g with meat from birds on diet 4 having the highest value and those from birds on diet 7 having the

lowest (479.30 IU/g and 251.80 IU/g, respectively). Retinol content of meat increased with the replacement of grit of TMS 01/1371 (β-carotene biofortified variety). The increase in meat retinol content could be as a result of increase in the amount of β-carotene absorbed into the muscles of birds fed β-carotene biofortified cassava grits. β-carotene and other provitamin A carotenoids are cleaved in the intestinal mucosa by carotene dioxygenase, yielding retinaldehyde, which is reduced to retinol, esterified and secreted in chylomicrons together with esters formed from dietary retinol (Bender and Mayes, 2003). Chylomicrons transport lipids from the intestine to the adipose, cardiac and skeletal muscle tissues. However, it should be noted that the main sites of β-carotene deposition and accumulation are the adipose tissue in humans and the liver in most animal species; however, substantial amounts can also be found in the corpus luteum of reproducing animals (Kirsche *et al*., 1987; Arikan and Rodway, 2000; Weng *et al*., 2000; Arikan and Rodway, 2001; Chew *et al*., 2001; Schweigert, 2003).

Table 7: Chemical composition of broiler chickens fed β-carotene bio-fortified cassava based diets

Parameters	Control Diet 1	25 Diet 2	50 Diet 3	75 Diet 4	25 Diet 5	50 Diet 6	75% Diet 7	SEM
Dry matter (%)	26.56	27.28	27.60	27.07	26.95	27.65	26.31	0.23
Moisture (%)	73.44	72.72	72.40	72.93	73.65	72.35	73.69	0.23
Protein (%)	22.70	22.69	23.41	23.17	21.70	22.23	22.80	0.29
Ether extracts (%)	2.95	2.53	2.45	2.91	2.73	2.64	2.55	0.08
Ash (%)	3.06	2.81	3.44	3.47	3.07	3.27	3.05	0.11
Retinol (IU/g)	324.31^{e}	331.07^{d}	466.23^{b}	479.30^{a}	256.39^{f}	362.14^{c}	251.80^{g}	17.975

a, b, c,: means within rows with different superscripts are significantly (P<0.05) different.
Trt: Treatment, SEM: standard error of the mean

The thiobarbituric acid reactive substances (TBARS) value of meat of broiler chickens fed β-carotene biofortified cassava based diets is presented in Table 8. The TBARS values increased with storage period; this value is generally regarded as a good indicator of the degree of deterioration of the organoleptic characteristics of meat as a result of oxidation. There were significant differences in the TBARS values on days 7 and 14 with meat from birds fed 75% TMS 01/1371 having the lowest value while meat from those fed TME 419 had the highest. This could be due to the higher β-carotene content in the grits (TMS 01/1371) used and resultant higher β-carotene content in the diet as β-carotene is known to be an important antioxidant that protect the interior of the cell membrane; and vitamins (β-carotene is a provitamin) protects fatty acids and cholesterol from oxidation (Berges, 1999). As stated (Bender, 2003), in addition to its provitamin A role, *β*-carotene is a radical trapping antioxidant and may be nutritionally important in its own right both as an antioxidant and possibly also through direct actions that are independent of retinoid.

The relationship between replacement levels of β-carotene biofortified cassava grit and residual retinol content of broiler chickens meat is shown in Figure 1. The strength of the association between replacement levels of TMS 01/1371 grit and residual retinol content of meat was positive (R^2 = 0.984**.** The regression equation obtained was: y= -0.097x^2 + 12.73x + 73.82. From the equation, the replacement level of TMS 01/1371 grits for optimum meat retinol retention was 66%.

Table 8: Thiobarbituric acid reactive substances of meat of broiler chickens fed β-carotene bio- fortified cassava based diets

	REPLACEMENT LEVELS OF MAIZE WITH CASSAVA (%)							
		TMS 01/1371			TME 419			
Day	Control	25	50	75	25	50	75%	SEM
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	
0	0.0032	0.0034	0.0032	0.0033	0.0034	0.0033	0.0036	0.000064
7	0.0212^{a}	0.0198^{c}	0.0201^{c}	0.0184^{d}	0.0209^{ab}	0.0182^{d}	0.0204^{bc}	0.000121
14	0.0378^{a}	0.0322^{cd}	0.0332^{c}	0.0306^{d}	0.0357^{b}	0.0315^{cd}	0.0329^{c}	0.000290

TMS 01/1371- β-carotene biofortified cassava grit
TME 419- Conventional cassava grit
a, b, c, d: means within rows with the same superscript are not significantly (P>0.05) different
SEM: standard error of the mean

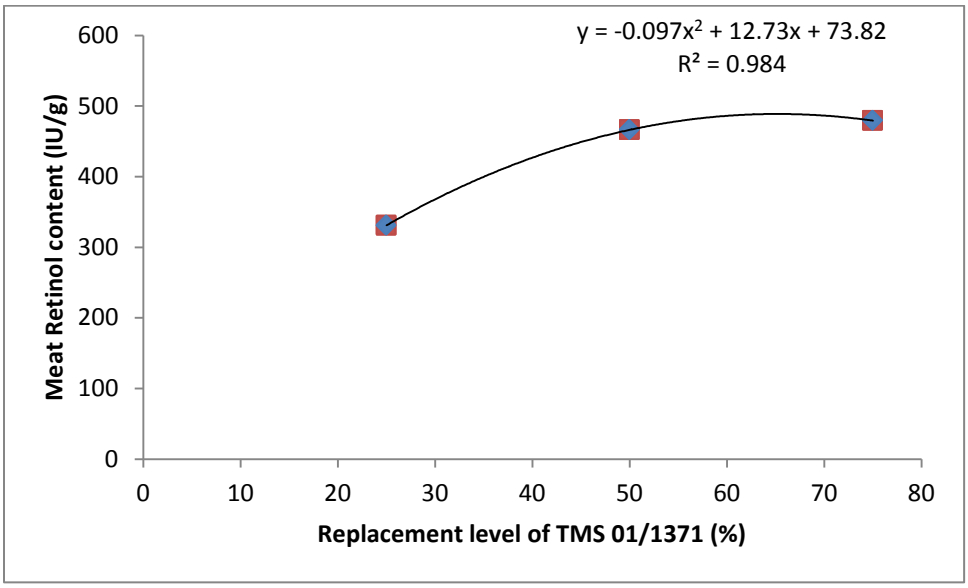


Figure 1: Relationship between replacement levels of β-carotene cassava grit and residual retinol content of meat from broiler chickens

CONCLUSION AND APPLICATION

Dietary maize in broiler chicken rations could be replaced with cassava grits from TME 419 and TMS 01/1371 up to 75% without adversely affecting the meat yield and quality. However, replacement of maize with β-carotene biofortified cassava up to 75% would be assured avenue of improving meat shelf life and oxidative stability of broiler chicken meat.

REFERENCES

Adebayo, K., Abayomi, L., Abass, A., Dziedzoave, N.T., Forsythe, L., Hillocks, R.J., Gensi, R., Gibson, R.W., Graffham, A.J., Ilona, P., Kleih, U.K., Lamboll, R.I., Mahende, G., Martin, A.M., Onumah, G.E., Orr, A.W., Posthumus, H., Sanni, L.O., Sandifolo, V., Westby, A. (2010). Sustainable inclusion of smallholders in the emerging high quality cassava flour value chains in Africa: Challenges for agricultural extension services. *Journal of Agricultural Extension.* 14(1):1-10

Adeyemo, I.A., and Sanni, A. (2013). Physical appearance and organoleptic properties of poultry meat fed *Aspergillus niger* hydrolyzed cassava peel meal based diet. *International Journal of Agricultural Policy and Research.* 1 (6): 166-171

Alais, C. and Linden, G. (1999). Food Biochemistry. Aspen publishers. Maryland, USA. Pp.53-70

AOAC (1990). Official Methods of Analysis of AOAC International. Association of Analytical Communities (AOAC) International, Arlington, VA, USA

AOAC (2000). Official methods of analysis of AOAC International. Association of Analytical Communities (AOAC) International, Arlington, VA, USA

AMSA (1995). Research guidelines for cookery, sensory evaluation and instrumental tenderness measurements of fresh meat. Am. Meat Sci. Assoc. Chicago, IL.

Arikan, S. and Rodway, R.G. (2000). Effects of high density lipoprotein containing high or low beta-carotene concentrations on progesterone production and beta-carotene uptake and depletion by bovine luteal cells. *Animal Reproduction Science*, 62: 253–263

Arikan, S. and Rodway, R.G. (2001). Seasonal variation in bovine luteal concentrations of beta- carotene. *Turkish Journal of Veterinary and Animal Sciences*, 25: 165–168

Awojobi, H.A. and Adekunmi A.A. (2002). Performance of broilers fed graded levels of cassava tuber meal. New Delhi, India: *Indian Council of Agricultural Research*, 72: 1169-1172

Balagopalan, C., Padmaja, G., Manda, S.K. and Moorthy, S.N. (2002). Cassava in food, feed and Industry. *C.R.C. Press Inc*. Bota Raton, Florida 205 pp.

Bender, D. A. (2003). Nutritional Biochemistry of the Vitamins. Second edition. Published in the United States of America by Cambridge University Press, New York. Pp 46

Bender, D. A. and Mayes, P. A. (2003). *Harper's Illustrated Biochemistry*, Twenty-Sixth Edition. The McGraw-Hill Companies, USA. Chapter 44, Pp 475

Berges, E. (1999). Importance of vitamin E in the oxidative stability of meat. Organoleptic qualities and consequences. In: Brufau J. (ed), Tacon A. (ed). Feed manufacturing in the Meditarranean region. *Recent advances in research and Technology, Zaragoza*: CIHEAM, Pp.347-363

Bianchi, M., Fletcher, D.L. (2002). Effects of broiler breast meat thickness and background on colour measurements. *Poultry Science*, 81: 1766-1769.

Bianchi, M., Petracci, M., Cavani, C. (2006). The influence of genotype, market live weight, transportation, and holding conditions prior to slaughter on broiler breast meat color. *Poultry Science*, 85: 123-128.

Bouton, P.E. and Harris, P.V. (1978). Factors Affecting Tensile and Warner-Bratzler Shear Values of Raw and Cooked Meat. *J. Texture Studies*, 9: 395-413

Chew, B.P., Weng, B.B., Kim, H.W., Wong, T.S., Park, J.S. and Lepine, A.J. (2001). Uptake of beta-carotene by ovarian and uterine tissues and effects on steroidogenesis during the estrous cycle in cats. *American Journal of Veterinary Research*, 62: 1063–1067

Christensen M., Ertbjerg P., Failla S., Sañudo C., Richardson R.I., Nute G.R., Olleta J.L. (2011). Relationship between collagen characteristics, lipid content and raw and cooked texture f meat from young bulls of fifteen European breeds. *Meat Science* 87(1):61–65.

Conte-Junior, C.A., Fernandez, M. and Mano, S.B. (2008). Use of carbon dioxide to control the icrobial spoilage of bullfrog meat. In *A. Mendez-Vilas (Ed.), Modern multidisciplincary applied microbiology* (pp 356-361). Weinheim: Wiley-VCH Verlag GmbH & Co. KGaA

Cross, H.R., Quland, P.R. and Seldeman, S.C. (1986). Muscles as Food Ed. P. P. J. Bechtel Academic Press F. L.P., 45-52.

Dziadek, K., Gornowicz, E., Czaja, L. (2002) Relationship between pH value and sensory evaluation of raw breast meat of broilers of different origin. *Roczniki Naukowe Zootechniki*, Supplement 16: 299-303 (in Polish).

Eruvbetine, D., Tajudeen, I.D. Adeosun, A.T. and Olojede, A.A. (2003). Cassava (*Manihot esculenta*) leaf and tuber concentrate in diets for broiler chickens. *Bioresource Technology*, 86: 277 – 281.

Ewa, H., Malgorzata, S. and Jerzy, U. (2005). The effect of high doses of vitamins C, E, and beta-carotene in pigs feed on carcass and meat quality. *Krmiva* 47 Zagreb, 4: 171-177

Fletcher, D. L. (2002). Poultry meat quality. *World Poultry Science Journal*, 58: 131-145

Geesink, G.H., Mareko, M.H.D., Morton, Y.D., and Bickerstaffe, R. (2001). Effects of stress and high voltage electrical stimulation on tenderness of lamb *M. longissimus. Meat Science*, 57: 256-271.

Hamm, R. (1986). Functional properties of the myofibrillar system and their measurements. *In P. J. Bechtel (Ed.), Muscle as food* (pp. 135–199). New York: Academic Press, Inc.

Hedrick, H.B., Aberle, E.D., Forest, J.C., Judge, M.D., Merkel, R.A. (1994). Properties of fresh meat. In; H.B. Hedrick, E.D. Aberle J.C. Forrest, M.D. Judge and R.A. Merkel (eds), Principle of Meat Science. I. A. Dubuque, Kendall/Hunt Publishing Company.123-131

Honikel, K.O. (2004). Water-holding capacity of meat. In M. F. te Pas, M. E. Everts, & H. P. Haagsman (Eds.), Muscle development of livestock animals: *Physiology, genetics and meat quality* (pp. 389–400). Cambridge, MA: CABI Publishing

Howard A. (1976). Psychometric scaling of sensory texture attributes of meat. *Journal of Texture Studies* 7 (1): 95–107.

Huff-Lonergan, E. and Lonergan, S. M. (2005). Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. *Journal of Meat Science*. 7: 194–204.

IITA. (2011). International Institute of Tropical Agriculture. New vitamin A-fortified cassava released in Nigeria, set to improve health of millions. IITA news of December 12, 2011

Janz J. A. M. and Aalhus J. L. (2002). The complexity of measuring beef tenderness using Warner–Bratzler shear methodology for whole muscle samples. In: Nakano T, Ozimek L, editors. *Food Science and Product Technology*. Kerala, India: Research Signpost. pp. 37–64.

Jeffery, A. B. (1983). Principles of water-holding applied to meat technology. *Jour. Sci. Food Agric*. 34:1020–1021

Juárez M, Aldai N., López-Campos Ó., Dugan M.E.R., Uttaro B., and Aalhus J.L. (2015) Beef texture and juiciness. Handbook of Meat and Meat Processing, Second Ed. 9: 177-205

Kirsche, B., Schlenzig, M., Ochrimenko, W.I. and Flachowsky, G. (1987). Influence of beta-carotene supplementation on carotene content of ovaries of heifers. *Archiv für Tierernhrüng*, 37: 995–9.

Kirchheim, V., H.-J. Löhnert, J. Bargholz, A. Schneider, F. Schöne (2001). Effect of dietary vitamin E supplement on pork quality, *Meat Science*. 49: 205-212.

Monahan, F.J., Ashar, A,. Gray, D.J., Buckley, D.J. And Morrissey, P.A. (1992). Influence of dietary vitamin E (alpha-tocopherol) on the color stability of pork chops. *Proceedings of 38th International Congress of Meat Sci. Technol*. Clermont-Ferrand, France. 543-543

Mehaffey, J.M., Pradhan, S.P., Meullenet, J.F., Emmert, J.L. McKee, S.R. and Owens C.M. (2006). Meat Quality Evaluation of Minimally Aged Broiler Breast Fillets from Five Commercial Genetic Strains. *Poultry Science* 85: 902–908.

Ngiki, Y.U., Igwebuike, J.U., Moruppa, S.M. (2014). Effects of Replacing Maize with Cassava Root-Leaf Meal Mixture on the Performance of Broiler Chickens. *International Journal of Science and Technology* 3 (6): 352-362

Ngoka, D.A., Ene, L.S.O., Okpkiri, O.A. and Odurukwe, S.O. (1984). The use of cassava root meal as energy substitute for maize in poultry diets. *Research Bulletin* No. 2 of the NRCRI, Umudike, Nigeria, Pp 12-18

Nishimura, T., Hattori, A. and Takahashi, K. (1999). Structural changes in intramuscular connective tissue during the fattening of Japanese Black cattle: Effect of marbling on beef tenderisation. *Journal of Animal Science.* 77: 93-104

Offer, G., and Knight, P. (1988). The structural basis of water-holding capacity in meat. Part 2: drip losses. In R. Lawrie (Ed.). Developments in meat science. London: *Elsevier Science Publications*. 4: 173–243.

Ogunwole, O.A., Oso, Y.A.A., Omotoso, R.R., Majekodunmi, B.C., Ayinde, B.O. and Oikeh, I. (2013). Performance, carcass characteristics and meat physico-chemical properties of broiler chickens fed graded levels of supplemental ascorbic acid. *Agric. Biol. J. N. Am*., 4(4): 485-495

Ogunwole, O.A., Oladimeji, S.O., Abayomi F.D., Kulakow, P., Iluebbey., and Tewe, O.O. (2015). Effect of β-carotene biofortified cassava grits (*Manihot esculenta* Crantz) based diets on retinol bioavailability and performance of broiler chicks. *Journal of Agricultural Science.* 7 (10):187-197.

Ogunwole, O.A., Idowu, I.A., Lawal, H.O., Oladimeji, S.O., Abayomi, F.D., Mosuro, A.O. and O. O. Tewe**. (**2016). Calcium and phosphorus utilisation by broiler chickens fed β-carotene bio-fortified cassava (*Manihot esculenta* crantz) grits based diets. *Ibadan Journal of Agricultural Research* (Accepted)

Oluyemi, J.A. and Roberts. M. (2000). Poultry Production. Spectrum Books Ltd, Ibadan.

Omojola, A.B. and Adesehinwa, A.O.K. (2007). Performance and Carcass Characteristics of Broiler Chickens Fed Diets Supplemented with Graded Levels of Roxazyme G®. *International Journal of Poultry Science* 6 (5): 335-339

Omole, T.A. (1977). Cassava in the nutrition of layers. Pages 51-55 In: Cassava as animal feed. *Proceedings, Cassava as Animal Feed Workshop*, University of Geulph, 18-20 April 19 Canada. DRC-095e: Otawa

Pensel, N.A. (1990). Influence of experimental conditions on porcine muscle andits effects on oxidation. A thesis, the Ohio State University, Columbu, OH, United States of America

Qiao, M., Fletcher, D.L., Smith, D.P. and Northcutt, J.K. (2001). The effect of broiler breast meat colour on pH, moisture, water holding capacity, and emulsification capacity. *Poultry Science*, 80: 676-678.

Quali, A., (1990). Post-mortem Changes in Muscles Tissue. *J. Muscles Foods*, 1: 129-134.

Rogers, P.J., Goertz, G. E. and Harrison, D. L. 1967. Heat induced changes of moisture in turkey muscles. *Journal Food Science*. 32: 298-304

SAS (2002). SAS Institute, Inc. language: reference, Version 6, 1st Edition. SAS Institute Inc., Cary, North Carolina. USA.

Sante, V., Bielicki, G., Renerre, M. and Lacourt, A. (1991). Postmortem evaluation in Pectoralis Superficialis muscle from two turkey breeds: a relationship between pH and color. *i*n: 37th *International Congress Meat Science*, Kulmbach, Germany. Pages 465-468

Schweigert, F.J. (2003). Research note: changes in the concentration of beta-carotene, alpha-tocopherol and retinol in the bovine corpus luteum during the ovarian cycle. *Archiv für Tierernährung*, 57: 307–310.

Smulders, F.J.M., Vanloack, R. and Ellelenboom, G. (1991). In: The European Meat Industry in the 1999's Ed. F.J.M. Smulders. Audet Nijmogen, pp: 121-129.

Tavarez, M.A., D.D. Boler, K.N. Bess, J. Zhao, F. Yan, A.C. Dilger, F.K. McKeith and J. Killefer, (2011). Effect of antioxidant inclusion and oil quality on broiler performance, meat quality and lipid oxidation. *Poult. Sci*., 90: 92

Tewe, O.O. (2005). Federal Republic of Nigeria, Patents and Decree 1970 (1970 No.60), Patent No RP: 16198

Thompson, J.M., Perry D., Daly, B., Gardner, G.E., Johnston, D.J., Pethick, D.W. (2006). Genetic and environmental effects on the muscle structure response *post-mortem*. *Meat Science* 74(1): 59–65.

Warkup, C.C., S. Marie and Harrington, G. (1995). Expression of Tissue Proteinases and Regulation of Protein Degradation as Related to Meat Quality Ed. A. Quali, D., Demeyer and F. J. M. Smulders. Ecceamst. Ultrechit. The Netherlands, pp: 225-231.

Warris, P.D., and Brown, S.N. (1987). The relationship between initial pH, reflectance and exudation in pig musclee. *Meat Science*. 20: 65 - 72.

Weng, B.C., Chew, B.P., Wong, T.S., Park, J.S., Kim, H.W. and Lepine, A.J. (2000). Beta-carotene uptake and changes in ovarian steroids and uterine proteins during the estrous cycle in the canine. *Journal of Animal Science*, 78: 1284–1290.