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Effects of β-Carotene Biofortified Cassava Grits (*Mahihot esculenta* Crantz) Based-Diets on Retinol Bioavailability and Performance of Broiler Chicks

O. A. Ogunwole[1], S. O. Oladimeji[1], F. D. Abayomi[1], P. Kulakow[2], P. Iluebbey[2] & O. O.Tewe[1]

[1] Agricultural Biochemistry & Nutrition Unit, Department of Animal Science, University of Ibadan, Ibadan, Nigeria

[2] International Institute of Tropical Agriculture, Ibadan, Nigeria

Correspondence: O. A. Ogunwole, Agricultural Biochemistry & Nutrition Unit, Department of Animal Science, University of Ibadan, Ibadan, Nigeria. E-mail: drogunwole@gmail.com

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Abstract

The β-carotene content of five cassava varieties and products as well as β-carotene bioavailability in cassava grit from TMS 01/1371 were undertaken using 240 one-day old Arbor acre broiler strain randomly divided into eight groups of 30 birds each. Each group comprised a triplicate of 10 birds each assigned in a completely randomized design. The eight dietary treatments were: Diets 1 and 8 had yellow and white maize respectively as the main energy source, while diets 2, 3 and 4 had maize replaced with cassava grit from TMS 01/1371 at 25%, 50% and 75%. Diets 5, 6 and 7 also had the maize contents similarly replaced with 25%, 50% and 75% grits from TME 419 respectively. Yellow maize, white maize, grits from TME 419 and TMS 01/1371 contained 238.33, 13.33, 6.67 and 108.33. β-carotene in the peeled fresh tuber of TMS 01/1412 (468.33), unpeeled fresh tuber (425.00), dried peeled tuber (391.67) and dried unpeeled cassava (323.33) were significantly higher ($P < 0.05$) than the corresponding values in TMS 01/1371 (416.67, 371.67, 311.67 and 283.33) and TMS 01/1368 (401.67, 350.00, 295.00 and 258.33). TME 419 cassava and products (peeled fresh tuber, unpeeled fresh tuber, dried peeled tuber and dried unpeeled tuber, garri, garri flour, grit, grit flour, peeling, peels and leaves) contained significantly lower ($P < 0.05$) levels of β-carotene. The FCR of chicks on diet 1 (1.50) was lowest ($P < 0.05$) while those on diet 8 (2.24) was highest. The main and interactive effects of cassava varieties and inclusion levels of grits on all indices of performance were significantly different ($P < 0.05$). Dietary β-carotene only correlated negatively with grits inclusion levels ($P < 0.05$) from TMS 01/1371 ($r = 0.40$). The β-carotene content of the diets when related to the inclusion levels of grits from TMS 01/1371 were both significantly negative linearly and quadratically. Regression equations were: (1) $Y = 15.333 – 0.0530x$ ($R^2 = 0.16$); (2) $Y = 13.667 + 0.147x – 0.003x^2$ ($R^2 = 0.36$) Conclusively, processing methods adopted in this study reduced β-carotene content of cassava grits which may have affected the bioavailability of retinoic acid in broiler chicks'.

Keywords: carotenoids, chick liver assay, provitamin bioavailability, retinoic acid retention

1. Introduction

Carotenoids are natural pigments which are responsible for yellow to red colour observed in plants and vegetables (Mortensen, 2006). Carotenoids are important for its various roles in human and animals, these include immune functions, decrease in the risk of disease and antioxidant function (Johnson, 2002; Rao & Honglei, 2002; Hinds et al., 1997). There are over 700 carotenoids (Junpatiw et al., 2013); one of which is the β-carotene. β-carotene can be metabolized to vitamin A through the action of the enzyme 15-15 monooxgenase. β-carotene provides 66% of vitamin A in the diets of humans in the developing countries (Rasaki & Abimbola, 2009; Ayasan & Karakozak, 2010).

Vitamin A deficiency is of global health significance in under-privileged communities of the world (Ajaiyeoba, 2001; Mama Project, 2010). Sommer et al. (1983) established that vitamin A deficiency increased the risk of childhood morbidity and mortality in humans and reduced production in animals (Beach, 1923). The increased vitamin A deficiency has led to development of food fortification to correct the underlying low intake of vitamin A (UNICEF, 2007).

The erstwhile vitamin A deficiency in sub-Saharan Africa was due to poor intake of provitamin A (Tee, 1995). Cassava products are among the most consumed foods, its tuber products are major sources of nutrients to human and animals (Tee, 1995; Ayasan, 2010). The International Institute of Tropical Agriculture in their stride at reducing the prevalence of avitaminosis A in Sub-saharan Africa recently announced (IITA, 2011) cassava varieties widely acclaimed to be high in β-carotene (TMS 01/1368, TMS 01/1371 and TMS 01/1412). However, in obtaining products from cassava for humans and animals use, cassava must undergo various processing methods that could result in the losses of most of the acclaimed carotenoids (Pinheiro San'Ana et al., 1998a; Idah et al., 2010).

Cassava grit is a product of cassava patented in Nigeria (Tewe, 2005) which is normally used as energy ingredient in the diet of animals. Reports (Adegbola & Asaolu, 1985; Bamgbose et al., 2011; Sarkiyayi & Agar, 2010) have been on the proximate composition of various cassava products and by-products with scanty documentation (Aniedu & Omodamiro, 2012) on the carotene profile. The level of carotene in yellow cassava varieties and products is also yet to be documented. There is therefore the need to quantify the carotene content of cassava products and also to determine the bioavailability of β-carotene in cassava grit for broiler production. Therefore, this study was aimed at determining the β-carotene content of five varieties of cassava and products as well as the bioavailability of β-carotene in cassava grits for broiler chicks.

2. Materials and Methods

2.1 Experimental Site

The experiment was carried out at the Poultry Unit, Teaching and Research Farm, University of Ibadan, Ibadan, Nigeria located on latitude $7^o20'$N, longitude $3^o50'$E, and 200 m above the sea level, in tropical rain forest vegetation zone. The laboratory analyses were carried out at the Department of Animal Science, University of Ibadan.

2.1 Test Materials

Tubers from five cassava varieties (TME 419, TMS 01/1368, TMS 01/1371, TMS 07/0593, and TMS 01/1412) and their leaves at 12 months of age were obtained from the International Institute of Tropical Agriculture, Ibadan, Nigeria. Products and by-products from the 5 cassava varieties were prepared and processed from the cassava tubers for proximate and beta-carotene content determination. A sufficient quantity of cassava grits was processed from two cassava varieties TME 419, the conventional variety and TMS 01/1371 notable for β-carotene.

2.2 Collection and Processing of Test Materials

Leaves of cassava with no evidence of structural, insect and microbiological damage were randomly sampled from each cassava variety plot and then oven dried at 65 ^oC. Cassava peels were obtained from respective tubers. Tubers were water-cleansed and then carefully sliced by sloughing the covering to reveal the cream or whitish inner root skin colour. Cassava peelings were obtained from cassava roots by mechanically peeling the ring-like covering of the cassava tubers. Cassava garri flour was the solid fibrous residue that remained after the water content has been extracted from the grated peeled tubers which was then oven dried at 65 ^oC.

Cassava grits flour was processed from the whole tuber following the steps; weighing, washing, detailing, grating, bagging and pressing and oven dried at 65 ^oC as described (Tewe, 2005). Cassava grit was processed from the respective tubers as documented (Tewe, 2005). The processed cassava grit was thereafter used as test samples in formulating experimental diets.

2.3 Experimental Animal

A total of 240 one-day Abor Acre broiler chicks of 59.7±2.6 from Amo Hatchery, Awe, Oyo, Nigeria, was used for the study. The chicks were randomly distributed to eight dietary treatments. Each treatment was in triplicate of ten broilers per replicate. Birds were raised in a deep litter with separate feeder and water trough. Feed and water were given *ad libitum*, the offered and residual feeds were weighed.

2.4 Experimental Diets

Test cassava grit from TMS 01/1371 and TME 419 were each incorporated to replace yellow maize on weight for weight basis at 25, 50 and 75%. Other diets were the yellow maize based diet (T_1) as the positive control and negative control (T_8) which also contained white maize as well as liquid paraffin at 5 g/Kg diets.

Table 1. Gross composition of the experimental diet (g/100g)

Ingredients	Inclusion Level of Cassava Grits							
	Diet 1	TMS 01/1371			TME 419			Diet 8
		(25%)	(50%)	(75%)	(25%)	(50%)	(75%)	
Yellow Maize	50.00	37.50	25.00	12.50	37.50	25.00	12.50	0.00
White Maize	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00
TME 419	0.00	0.00	0.00	0.00	12.50	25.00	37.50	0.00
TMS 01/1371	0.00	12.50	25.00	37.5	0.00	0.00	0.00	0.00
Soybean meal (42% CP)	35.9	39.00	41.50	43.14	39.5	42.00	44.00	35.90
Wheat offal	8.24	5.14	2.64	1.0	4.64	2.14	0.14	8.24
DL-Methionine	0.20	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	0.10
Oyster shell	1.00	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	0.00
Fried Palm oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50
Dicalcium phosphate	1.50	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	0.25
Salt	0.25	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	0.06
TOTAL	100	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	3080.39
Crude Protein (%)	20.97	20.88	20.64	20.19	20.93	20.61	20.17	20.97
Methionine (%)	0.52	0.51	0.50	0.49	0.52	0.51	0.49	0.52
Lysine (%)	1.30	1.33	1.36	1.37	1.34	1.37	1.38	1.30
Available Phosphorus (%)	0.52	0.52	0.52	0.51	0.52	0.52	0.51	0.52
Calcium (%)	0.97	1.00	1.03	1.05	1.00	1.03	1.05	0.97

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.

3. Data Collection

3.1 Performance Characteristics

The feeding trial lasted 14 days, during which feed consumption by the experimental chicks were quantified on daily basis. The quantity of feed offered and those not consumed were recorded. The chicks were weighed at the start of the experiment and subsequently on weekly basis. The weight gain was calculated as the difference in the initial and final weights. Feed intake was estimated as the difference in the total weight of feed offered daily and the left over while the feed conversion ratio was calculated as: Total feed intake/weight gained by the chicks

3.2 Chemical Analysis

The proximate analyses of cassava, products and experimental diets were undertaken according to AOAC (1995). β-carotene (µg/100g) concentration of fresh cassava tuber, cassava products and by-products (grits, garri, pulp, leaf, peelings, peels, and the experimental diets) were determined spectrophotometrically (AOAC, 2005) and the β-carotene calculated as:

$$\beta - carotene(\mu g / 100\ g) = \frac{Absorbance\ of\ sample \times Average\ Gradient \times Dilution\ Factor}{10000} \tag{1}$$

$$Dilution\ Factor = \frac{Volume\ of\ Solvent}{Sample\ Weight} \tag{2}$$

3.3 Vitamin A Assay

At week 2, two birds per replicate were randomly selected, sacrificed and carefully dissected to harvest the liver which was immediately protected from light, chilled and thereafter analysed spectrophotometrically for vitamin A (retinol) concentration (AOAC, 1990). Vitamin A (µg/g) as retinol was calculated using the formula:

$$\frac{Absorbance\ of\ standard}{Absorbance\ of\ sample} \times \frac{Conc.\ of\ standard}{1} \tag{3}$$

3.4 Statistical Analysis

Data were subjected to analysis of variance in a complete randomized design using (SAS, 2002). Data were also subjected to correlation and regression analyses at $\alpha_{0.05}$.

4. Results

4.1 Proximate and β-Carotene Composition of the Test Material

β-carotene content of cassava grits from TME 419, TMS 01/1371, yellow maize and white maize are shown in Table 2. Results showed that there were significant variations ($P < 0.05$) in the β-carotene of maize and grits. Yellow maize recorded the highest β-carotene value of 238.33 µg/100 g while cassava grits from TME 419 was lowest with β-carotene value of 6.67 µg/100 g.

The β-carotene content (µg/100 g) of tubers and cassava products from the five cassava varieties are shown in Table 3. Results showed that there were significant variations ($P < 0.05$) in the values of β-carotene of the entire cassava tuber and products from different cassava varieties. Peeled cassava tuber of TMS 01/1412 had significantly higher ($P < 0.05$) β-carotene (468.33 µg/100 g) content while cassava grit flour and peels from TME 419 were lower (3.33 µg/100 g) ($P < 0.05$) compared to others.

TMS 01/1412 cassava tuber and products recorded the highest β-carotene while the lowest level was recorded for cassava varieties from TME 419 when compared to other varieties. β-carotene composition in peeled fresh tuber, garri, garri flour, grit, grit flour, peelings, peels and leaves of both TMS 01/1371 and TMS 01/1368 were not significantly different ($P > 0.05$).

Table 2. β-carotene content of cassava grits and maize

Sample	β-carotene µg/100 g
Yellow Maize	238.33^{a}
White Maize	13.33^{c}
Cassava Grit from TME 419	6.67^{c}
Cassava Grit from TMS 01/1371	108.33^{b}
Standard error of mean	28.34

Note. ^{abcde} Means in the same row with different superscript differ significantly ($P < 0.05$).

Table 3. β-carotene content of tuber and products from five different cassava varieties (μg/100 g)

Parameters	TMS 01/1412	TMS 01/1371	TMS 01/1368	TMS 07/0593	TME 419	SEM
Peeled Fresh tuber	468.33^{a}	416.67^{b}	401.67^{b}	128.33^{c}	31.67^{d}	46.82
Unpeeled Fresh Tuber	425.00^{a}	371.67^{b}	350.00^{c}	96.67^{d}	26.67^{e}	42.93
Dried peeled tuber	391.67^{a}	311.67^{b}	295.00^{c}	88.33^{d}	16.67^{e}	38.24
Dried unpeeled cassava	323.33^{a}	283.33^{b}	258.33^{c}	56.67^{d}	13.33^{e}	33.85
Garri	106.67^{a}	91.67^{b}	86.67^{b}	31.67^{c}	6.67^{d}	10.32
Garri flour	41.67^{a}	35.00^{ab}	30.00^{b}	11.67^{c}	1.67^{d}	4.15
Grit	133.33^{a}	108.33^{c}	118.33^{b}	51.67^{d}	6.67^{e}	12.7
Grit flour	58.33^{a}	45.00^{b}	41.67^{b}	18.33^{c}	3.33^{d}	5.34
Peelings	36.67^{a}	23.33^{b}	20.00^{b}	6.67^{c}	5.00^{c}	3.15
Peels	35.00^{a}	25.00^{b}	20.00^{b}	8.33^{c}	3.33^{c}	3.11
Leaves	30.00^{a}	21.67^{b}	20.00^{b}	11.67^{c}	5.00^{d}	2.43

Note. ^{abcde} Means in the same row with different superscript differ significantly (P < 0.05); SEM: Standard Error of Mean.

4.2 Performance of Chicks

Performance characteristics of broiler chickens fed cassava grits based diets are shown in Table 4. There were significant differences (P < 0.05) in the final weight of birds on diet 1 which had the highest final weight (408.64 g) while those on diet 8, the least final weight (192.75 g). Significant differences (P < 0.05) were also recorded in total weight gain and daily weight gain. Chicks on Diet 1 had the highest total weight gain of 353.67 g and daily weight gain of 25.26 g followed closely by dietary treatment with 50% inclusion of cassava grit from TMS 01/1371 with 300.31g of total weight gain and 21.45 g of daily weight gain. The least total weight gain (132.45 g) and daily weight gain (9.46 g) was recorded in chicks on diet 8.

The total feed intake and daily feed intake of birds were significantly different (P < 0.05) with chicks on diet 1 having highest total feed intake (531.50 g) and daily feed intake (37.96 g) while those on diet 8 had the lowest total feed intake (296.13 g) and daily feed intake (21.15 g) per birds. The feed conversion ratio (FCR) among experimental chicks were significantly different (P<0.05), Chicks on T1 had lowest FCR of 1.50 while those on diet 8, the highest.

The main effect of cassava grit varieties and level of grit inclusion on performance of broiler chicks are shown in Table 6. Results showed that there were significant variations (P < 0.05) in the values obtained for all performance indices (final weight, total weight gain, daily weight gain, total feed intake, daily feed intake and FCR), Cassava grit from TMS 01/1371 as well as the chicks on 50% inclusion had overall favourable effect on performance indices measured in this study.

Table 4. Performance characteristics of broilers fed cassava grit based diet

Parameters	Inclusion Level of Cassava Grits								
	Diet 1	TMS 01/1371			TME 419			Diet 8	SEM
		25%	50%	75%	25%	50%	75%		
Initial wt (g)	54.97	63.47	59.90	61.83	58.97	57.43	61.30	60.30	0.75
Final wt (g)	408.64^a	342.25^b	360.21^b	333.71^b	212.03^c	350.52^b	341.09^b	192.75^c	14.94
TWG (g)	353.67^a	278.79^b	300.31^b	271.87^b	153.06^c	293.09^b	279.79^b	132.45^c	15.09
DWG (g)	25.26^a	19.91^b	21.45^b	19.42^b	10.93^c	20.94^b	19.99^b	9.46^c	1.1
TFI (g)	531.50^a	456.67^b	465.73^b	476.21^b	352.92^c	473.32^b	480.22^b	296.13^d	15.41
DFI (g)	37.96^a	32.62^b	33.27^b	34.02^b	25.21^c	33.81^b	34.30^b	21.15^d	1.1
*FCR	1.50^c	1.64^c	1.56^c	1.76^{bc}	2.45^a	1.62^c	1.72^{bc}	2.24^{ab}	0.1

Note. *: Means no unit; ^{abcde}: Means in the same row with different superscript differ significantly (P < 0.05); FCR: Feed Conversion Ratio; Initial wt: initial weight; Final wt: Average final weight; TWG: Average total weight gain; DWG: Average daily weight gain; TWI: Average total feed intake; DFI: Average daily feed intake; SEM: Standard Error of Mean; TME 419: Cassava grit from cassava varieties TME 419; TMS 01/1371: Cassava grit from cassava varieties TMS 01/1371.

Table 5. The interactive effect of cassava grit varieties and inclusion levels on performance of broiler chicks

Parameters	Inclusion Level of Cassava Grits						
	TMS 01/1371			TME 419			SEM
	25%	50%	75%	25%	50%	75%	
Initial wt (g)	63.47	59.90	61.83	58.97	57.43	61.30	1.83
Final wt (g)	342.25^a	360.21^a	333.71^a	212.03^b	350.52^a	341.09^a	11.70
TWG (g)	278.79^a	300.31^a	271.87^a	153.06^b	293.10^a	279.79^a	12.20
DWG (g)	19.91	21.45^a	19.42^a	10.93^b	20.94^a	19.98^a	0.87
TFI (g)	456.67^a	465.73^a	476.21^a	352.92^b	473.32^a	480.23^a	12.27
DFI (g)	32.62^a	33.27^a	34.05^a	25.21^b	33.81^a	34.30^a	0.88
*FCR	1.64^a	1.56^a	1.76^a	2.45^b	1.62^a	1.72^a	0.21

Note. *: Means no unit; ^{abcde}: Means in the same row with different superscript differ significantly (P < 0.05); FCR: Feed Conversion Ratio; Initial wt: initial weight; Final wt: Average final weight; TWG: Average total weight gain; DWG: Average daily weight gain; TWI: Average total feed intake; DFI: Average daily feed intake; SEM: Standard Error of Mean; TME 419: Cassava grit from cassava varieties TME 419; TMS 01/1371: Cassava grit from cassava varieties TMS 01/1371.

Table 6. The main effect of Grit varieties and level of inclusion on performance of broiler chicks

Parameters	Grit varieties		SEM	Level of Inclusion			SEM
	TMS 01/1371	TME 419		25%	50%	75%	
Initial wt (g)	61.73	59.23	1.06	612.20	586.70	615.70	0.79
Final wt (g)	345.39^a	301.21^b	6.75	277.14^b	355.37^a	3374.00^a	12.88
TWG (g)	283.66^a	241.98^b	7.04	215.92^b	296.70^a	275.83^a	12.83
DWG (g)	20.30^a	17.30^b	0.50	15.40^b	21.20^a	19.70^a	0.92
TFI (g)	466.20^a	435.49^b	7.08	404.80^b	469.52^a	478.21^a	11.57
DFI (g)	33.30^a	31.10^b	0.51	28.9^b	33.54^a	34.16^a	0.83
*FCR	1.70^a	1.90^a	0.12	2.10^a	1.59^a	1.74^a	0.10

Note. *: Means no unit; ^{abcde}: Means in the same row with different superscript differ significantly (P < 0.05); FCR: Feed Conversion Ratio; Initial wt: initial weight; Final wt: Average final weight; TWG: Average total weight gain; DWG: Average daily weight gain; TWI: Average total feed intake; DFI: Average daily feed intake; SEM: Standard Error of Mean; TME 419: Cassava grit from cassava varieties TME 419; TMS 01/1371: Cassava grit from cassava varieties TMS 01/1371.

4.3 Dietary β-Carotene and Chick Liver Retinol Composition

Dietary β-carotene and chicks liver retinol (μg/g) of chicks are shown in Table 7. Significant differences (P<0.05) were recorded for β-carotene content of the experimental diets. β-carotene content of experimental diets (μg/100g) were 13.33, 10.00, 13.33, 16.67, 6.67, 10.00, 11.67 and 3.33 for diets 1, 2, 3, 4, 5, 6, 7 and 8 respectively. The liver retinol (μg/g) (9.69, 9.57, 10.25, 9.93, 9.89, 9.97, 10.04 and 9.74 for chicks on diets 1, 2, 3 4, 5, 6, 7 and 8 respectively) were not significantly different (P>0.05)

Table 7. β-carotene in the Experimental Diets and Retinol Content of Chick Liver (μg/g)

Treatment	β-carotene (μg/100g)	Liver retinol (μg/g)
Diet 1	13.33^{ab}	9.69
Diet 2	10.00^{bc}	9.57
Diet 3	13.33^{ab}	10.25
Diet 4	16.67^{a}	9.93
Diet 5	6.67^{dc}	9.89
Diet 6	10.00^{bc}	9.97
Diet 7	11.67^{abc}	10.04
Diet 8	3.33^{d}	9.74
SEM	0.97	0.10

Note. SEM: Standard Error of Mean; Diet 2 = 25% TMS 01/1371; Diet 3 = 50% TMS 01/1371; Diet 4 = 75% TMS 01/1371; Diet5 = 25% TME 419; Diet 6 = 50% Diet 7 = TME 419 75% TME 419; ^{abcde}: Means in the same row with different superscript differ significantly (P < 0.05).

5. Discussion

Carotenoids such as β-carotene are known to enhance immune system (Navara & Hills, 2003), reduce the risk of degenerative disesases (Cooper et al., 1999) and scavenge the free radicals (Mortensen et al., 1997) due to the antioxidant properties. All yellow cassava varieties investigated contained higher quantity of β-carotene compared with the white varieties which may be indicative of their higher potential antioxidant roles. Eleazu and Eleazu (2012) also noted that white cassava varieties had lower carotenoid when compared with the yellow varieties. β-carotene content from fresh cassava tuber obtained by Aniedu and Omodamiro (2012) ranged from 52.8 μg/100 g for TMS 30572 to 387.6 μg/100 g in NR 07/0326. This result is however similar to those presented in Table 3 for peeled fresh tuber, unpeeled tuber, dried peeled tuber and dried unpeeled cassava but β-carotene content of dried peeled tuber of TMS 01/1412 was closest to fresh root of cassava varieties NR 07/0326.

The β-carotene was highest in fresh peeled tuber of TMS 01/1412 (468.33 μg/100 g) and lowest in cassava peels and cassava grit flour of TME 419 (3.33 μg/100 g). It was however observed that β-carotene content of the sample decreased with processing as earlier suggested (Idah et al., 2010; Pinheiro San'Ana et al., 1998a). Pinheiro San'Ana et al. (1998b) also reported some degrees of α-carotene and β-carotene losses in carrot after cooking. Water cooking without pressure was identified as the most appropriate processing method which provided highest retention of α-carotene, β-carotene and total carotenoid in carrots compared to steam-cooking, water-cooking with pressure and baking. Higher cooking temperature was more effective in reducing losses of carotenoid than absence of water during cooking (Pinheiro San'Ana et al., 1998b). Harrriet and Gretel (1997) however opined that carotenoid losses during cooking was dependent on the type of container used and that food cooked in open container had higher losses regardless of methods.

Rasaki and Abimbola (2009) also reported a value of 93 μg/100 g β-carotene content in white garri sampled from market which differed from garri of white variety of TME 419 in Table 3. This difference could however be adduced to probable production of garri from the different cassava varieties which may include yellow varieties.

The reported β-carotene content of yellow market garri (321 μg/100 g) samples (Rasaki & Abimbola, 2009) contrasted with the corresponding garri prepared from yellow cassava tuber TMS 01/1412, TMS 01/1371, TMS 01/1368 and TMS 07/0593 with the values between 31.67-106.67 μg/100g. This variation would probably be ascribed to palm oil which is habitually added to market garri during production for aesthetic. Palm oil is a notable source of carotenoid (You et al., 2002) and the yellowish taint imparted by its addition has been one of the tools aimed at influencing consumers' choice. This factor may have affected the reported values by earlier authors (Rasaki & Abimbola, 2009). The varied β-carotene content of garri flour and high quality cassava flour produced by Aniedu and Omodamiro (2012) could however be attributed to different processing methods as their high quality cassava flour required sieving of the dried flour, not done in garri flour. Lower β-carotene recorded ($P < 0.05$) in TME 419 (5 μg/100 g) and the corresponding higher value in TMS 01/1412 (30 μg/100 g) were the highest levels obtainable in cassava leaves at 12 months age of harvest as reported (Wobeto et al., 2006).

The FCR of 1.50 recorded by Goodarzi et al. (2013) for starter birds fed control diet was similar to that obtained from broilers on diet 1 (1.50) and those on 50% inclusion level of cassava grit from TMS 01/1371 (1.56). It was observed in Table 6 that birds on 50% inclusion level of both varieties of cassava recorded better performance in terms of weight gain than birds on control diets.

The main effect of inclusion level of both varieties and level of grit inclusion on performance of broiler chicks presented in Table 7 showed that broiler chicks fed 50% inclusion of cassava grit from TMS 01/1371 performed better in terms of weight gain and FCR. Significant differences ($P > 0.05$) were recorded in β-carotene of the diet showed that higher inclusion level of cassava grit from TMS 01/1371 resulted in significant increase in β-carotene content of the experimental diets.

There were no significant differences ($P > 0.05$) in the liver retinol, though chicks fed 50% inclusion of TMS 01/1371 and 75% inclusion level of TME 419 had the highest liver retinol. The closeness in retinol content could however be due to the sufficient amount of vitamin A from the vitamin mineral premix as posited (Higdon, 2005) that conversion of β-carotene to vitamin A decreased when body store of vitamin A is high. The processing methods of grit also resulted in decreased β-carotene content of grit and resultant similarities in dietary β-carotene content except for diet 8 which had 3.33 μg/100 g. The liver retinol obtained in this study was relatively lower compared to 13.22 μg/100 g reported for the liver of chickens by Schindler et al. (1987). This observed variation could thus be attributed to the differences in the age of birds.

Dietary β-carotene negatively correlated only with grits inclusion levels ($P < 0.05$) from TMS 01/1371 ($r = 0.40$). The relationships of β-carotene content of the diets and the inclusions levels of grits from TMS 01/1371 were both negative ($P < 0.05$) linearly and quadratically. The regression equations were:

$$Y = 15.333 - 0.0530x \quad (R^2 = 0.16) \tag{1}$$

$$Y = 13.667 + 0.147x - 0.003x^2 \quad (R^2 = 0.36) \tag{2}$$

6. Summary

Bio-availability of β-carotene in cassava grit from TMS 01/1371 cassava variety and β-carotene content of some selected cassava products were determined. Cassava grit from cassava varieties TMS 01/1371 and TME 419 at various inclusion levels were fed to broiler birds. There were strong indications that cassava grit from TMS 01/1371 was better when compared to TME 419.

The β-carotene determination for cassava tubers and products indicated that tuber from TMS 01/1412 had the highest β-carotene in all the products quantified and TME 419 was least. TMS 01/1412 fresh tuber had the highest β-carotene while grit flour and peels of TME 419 were the lowest.

7. Conclusion

Replacement of maize with up to 75% cassava grit from TMS 01/1371 and TME 419 in broiler ration had no deleterious effect on birds' performance. Also, 50% TMS 01/1371 substitution for maize resulted in better performance indices of broiler chickens in two weeks. Cassava products from yellow cassava varieties have potentials to contribute and assist the vitamin A status of animals.

8. Recommendations

The following recommendations were made:

- Cassava grits can partially replace maize up to 50% percent without any deleterious effect.
- Labour saving production and processing of cassava grits need to be developed.
- There is the need for increased awareness on the use of yellow cassava grit in poultry industry.
- There is the need for the development of high dry matter cassava tuber.
- Production and processing of β-carotene cassava grit should be done in a less exposed environment for better retention.

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