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Research Article

Variation among *gari* samples of some yellow cassava (*Manihot esculenta* Crantz) varieties for change in color during storage

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Abstract

Carotenoids in bio-fortified *gari* are degraded by light and oxidation during storage resulting in fading of their yellow color. In this study, *gari* from yellow-root (bio-fortified) cassava varieties (YCVs) were evaluated for color change during storage in two seasons. About 400 g of fresh *gari* samples of five YCVs (IITA-TMSI011368, IITA-TMSI011371, IITA-TMSI011412, IITA-TMSI070539 and IITA-TMS-I070593) and white-root variety (TMEB419-check) were packaged in transparent plastics to ensure exposure to light. The samples were evaluated monthly for color change using a chart with a scale of 1 (white) to 8 (pink) for 12 months in each season. Data collected were subjected to ANOVA, descriptive and correlation analyses. Reduction in yellow color intensity was observed among the yellow *gari* samples in the first month from average of 4.40 to 3.53 representing about 20% decrease. At 12 months after processing, varieties IITA-TMSI011368 and IITA-TMSI011371 had the highest (68%) and least (58%) yellow pigment retention, respectively. There was significant variation among the varieties for *gari* color change and yellow pigment retention over the storage period. Therefore, carotenoid content in bio-fortified *gari* depends on the cassava variety and storage period. These factors should be considered in future breeding program to improve cassava for carotenoid content.

Introduction

Cassava roots are predominantly carbohydrate dense [1], but contain little protein, fat, and some minerals and vitamins [2,3]. Therefore, cassava consumers have high chances of experiencing inadequate vitamin A intake [4]. This is sequel to the fact that the requirement for this vitamin can only be satisfied either by animal food products containing preformed Vitamin A or plant food products containing pro-vitamin A carotenoids [5,6]. Thus, bio-fortification of cassava with pro-vitamin A carotenoids can potentially reduce vitamin A deficiency in low-income countries [7] where cassava is a staple food.

Cassava is usually processed into variety of products including *gari* which accounts for about 70% of the total processed products obtained from cassava in West Africa [8-11]. *Gari* constitutes a major part of the dietary intake of cassava products in Africa, Southeast Asia, and Brazil [12-16]. Millions of both rich and poor Nigerians have also adopted *gari* as a high energy staple food sequel to its availability all year round, long shelf-life and multiplicity of use [17]. Thus, being the highest consumed cassava product in Nigeria, *gari* will be a viable vehicle for the introduction of yellow cassava to the populace [18].

Carotenoids in plant are depicted by varying shades of yellow or orange color [19]. The intensity of the root color had been shown to be highly correlated with carotenoid content making it feasible to use color to estimate carotenoid content [15,20-23]. Njenga, *et al.* [24] reiterated that 98% of the variability in cassava carotenoid content can be explained by the variability in root color. The *gari* produced from bio-fortified yellow root cassava varieties is very similar in color to *gari* made with added crude palm oil [25] and rich in carotenoids thus making it a good and cheap source of vitamin A [26]. In addition, the yellow *gari* produced from yellow root cassava varieties may also have additional advantage over the one from white root varieties (with palm oil added) in the area of uniformity of the yellow color and ability to store for longer period without going rancid.

Pro-vitamin A carotenoids (the predominant carotenoid present in bio-fortified yellow *gari*) are chemically unstable molecules that can be degraded during typical processing and storage due to the sensitivity of carotenoids to physical factors such as light, heat, oxygen, food enzymes or their interaction [27-29], hence, retention of carotenoids during processing and storage is still a challenge. Although UcheChukwu-Agua, *et al.* [10] asserted that packaging materials influenced the carotenoid retention and hence yellowness of stored bio-fortified cassava flour they evaluated, strong genotypic effect on level of retention of carotenoids in stored products was also reported by Bechoff, *et al.* [30]. Furthermore, Bechoff, *et al.* [15] elucidated that storage condition is a main determinant of the final characteristics and composition of cassava products.

Although the detrimental effect of light exposure on stored product quality had been reported [15,31-33], there is dearth of information in literature on the effect of exposure to light during long term storage on the color (measure of β-carotene content) of *gari* from newly released yellow cassava varieties in Nigeria [34]. Hence, the need to evaluate *gari* from these varieties for change in color (fading of yellow pigment) due to exposure to light during storage. The objective of this study was therefore to determine the effect of storage duration on color of bio-fortified *gari* exposed to light during storage.

Materials and methods

Fresh roots of five yellow cassava varieties (IITA-TMS-I011368, IITA-TMS-I011371, IITA-TMS-I011412, IITA-TMS-I070593 and IITA-TMS-I070539) and one white root variety (TMEB419) used as check were harvested at 12 months after planting from the experimental plot of Department of Crop and Horticultural Sciences, University of Ibadan in each season (2016 and 2017). About 10 kg of wholesome storage roots of each variety were selected from plots in the three replicates of the experiment. The storage roots from each replicate for each variety were processed into *gari* using the procedure described by James, *et al.* [35] within 24 hours of harvesting. About 400 g of each of the *gari* samples in three replicates was packaged in white transparent plastic container to ensure the *gari* was preserved from atmospheric moisture but exposed to light. The treatments were arranged on open shelf in the Crop Utilization Laboratory of Department of Crop and Horticultural Sciences, University of Ibadan using completely randomized design. The experiment was carried out in 2016 and repeated in 2017.

Due to the fact that carotenoids are denoted with yellow or orange pigments which contribute to the color of bio-fortified *gari* [36], the *gari* color was used as a measure of carotenoid level in the *gari* samples evaluated in this study. Hence, each *gari* sample was scored for color immediately after processing (initial sample color) and thereafter on monthly basis using a color chart (Figure 1) with a scale of 1-8 where 1 = white and 8 = pink [37] for a period of 12 months. During scoring, each *gari* sample was thoroughly mixed to ensure a representative sample was used for the scoring. Some of the *gari* sample was then placed on the color chart for scoring. The *gari* sample used for the scoring was returned to the container immediately to ensure the same volume of *gari* was stored in each container throughout the period of the experiment. The data collected were subjected to descriptive analysis using Microsoft excel and correlation analysis as well as analysis of variance using Statistical Analysis Software (Version 9.0). Significantly different means were separated using LSD at 5% level of probability.

Results

The *gari* samples (immediately after processing) of the six cassava varieties evaluated in this study for change in color during storage are shown in Figure 2. The color of the samples from the five yellow root varieties ranged from light yellow (score of 4) to yellow (score of 5) while that of the white root check variety was light cream in color (score of 2) and not white, just like the root tissue it was obtained from.

Variety, season, storage duration (period) and interaction among them had significant effect on changes in color of the stored gari samples (Table 1). The color scores of the five bio-fortified *gari* decreased with increase in storage duration across the two seasons with the color scores dropping sharply

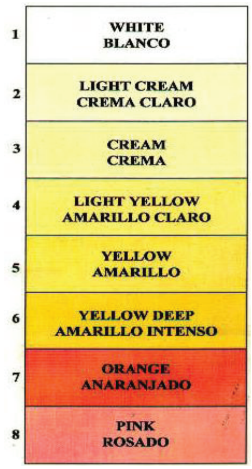

Figure 1: Chart for scoring *gari* color (Source: IITA, 1990 [37]).

Figure 2: *Gari* samples of six cassava varieties immediately after processing.

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from average of 4.40 (4.2 - 4.5) to 3.53 (3.3 - 3.8) representing about 20% decrease in the total carotenoid content of the *gari* samples in the first month (Figure 3). Subsequently, the highest decrease in average color score was about 5% at 5, 10 and 11 months after processing (MAP) (Figure 3). *Gari* sample from the check variety TMEB419 had significantly lower pigment color over the 12 months of storage (Figure 3). Significant variation was observed for the *gari* samples between initial stage and first MAP; fourth and fifth; ninth and tenth; and tenth and eleventh MAP across the two seasons (Table 2). Also, significant difference in color score was observed between *gari* of each of the YCVs and that of TME 419 from 1 to 12 MAP and among *gari* of the five YCVs at 1, 11 and 12 MAP (Table 3). *Gari* sample of variety IITA-TMS-I011412 attained stability in carotenoid content (no further decrease in *gari* color) earlier (5 MAP) than *gari* of other four bio-fortified varieties which attained stability only at 11 MAP (Table 3). At 12 MAP, the least color score of 2.5 was observed in variety IITA-TMS-I01371 while the highest value of 3.0 was recorded in varieties IITA-TMS-I070539 and IITA-TMS-I01412 (Table 3). Over the 12 months of storage, the highest percentage yellow pigment (color) retention of 68% was recorded in variety IITA-TMS-I011368; IITA-TMS-I070539 and IITA-TMS-I011412 had 67% each while the least retention percentage of 58% was observed in variety IITA-TMS-I011371 (Table 3). It is noteworthy that these three varieties (IITA-TMS-I011368, IITA-TMS-I070539 and IITA-TMS-I011412) with high yellow pigment retention percentage also had higher pigment color score (ranging from 2.8 - 3.0) than the other two varieties at 12 MAP (Table 3). Correlation among the varieties for change in *gari* color over the storage period was positive and significant (Table 4).

Table 1: Combined analysis of variance for change in *gari* color during storage at Ibadan in 2016 and 2017.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Period	12	50.6752137	4.2229345	103.02	<.0001
Rep	2	2.9529915	1.4764957	36.02	<.0001
Season	1	29.2500000	29.2500000	713.59	<.0001
Variety	5	106.1645299	21.2329060	518.00	<.0001
Period*Rep	24	2.1581197	0.0899217	2.19	0.0029
Season*Period	12	4.4444444	0.3703704	9.04	<.0001
Period*Variety	60	16.5299145	0.2754986	6.72	<.0001
Season*Rep	2	1.3205128	0.6602564	16.11	<.0001
Rep*Variety	10	4.8162393	0.4816239	11.75	<.0001
Season*Variety	5	9.6346154	1.9269231	47.01	<.0001
Season*Period*Rep	24	3.2350427	0.1347934	3.29	<.0001
Period*Rep*Variety	120	8.4059829	0.0700499	1.71	0.0018
Season*Period*Variety	60	5.1709402	0.0861823	2.10	0.0003
Season*Rep*Variety	10	7.5256410	0.7525641	18.36	<.0001
Error	120	4.9188034	0.0409900		
Corrected Total	467	257.2029915			

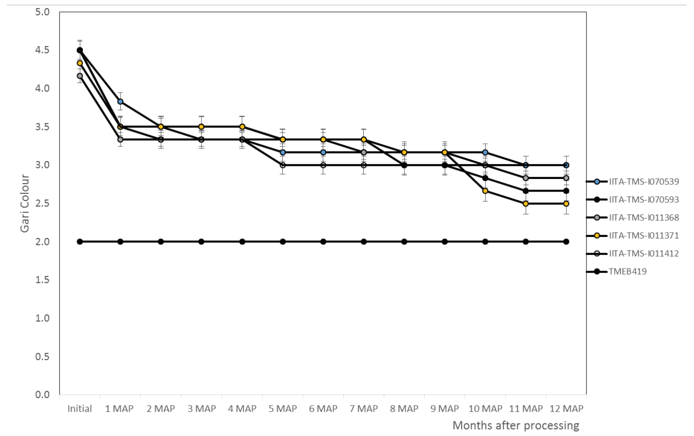

Figure 3: Color scores of *gari* samples of six cassava varieties at different duration in storage in Ibadan in 2016 and 2017.

Table 2: Mean effect of storage duration on color of *gari* from six cassava varieties exposed to light during storage for 12 months.

Month(s) after processing	Mean color score
Initial	4.00a
1	3.28b
2	3.19bc
3	3.17c
4	3.17c
5	3.03d
6	3.03d
7	3.00de
8	2.92e
9	2.92e
10	2.78f
11	2.67g
12	2.67g

* Means with different letters are significantly different from each other.

Discussion

Degradation of carotenoids compounds resulting in loss of yellow color is a major challenge in maintaining the health benefits of high carotenoid products [38]. This is due to the vulnerability of double bond in carotenoids carbon chain to chemical reactions induced by oxygen, light and heat during processing or storage [39,40]. The varietal variation in *gari* color across the storage duration suggests that rate of loss of carotenoid in bio-fortified *gari* samples may not be uniform among the varieties over time. Sharp reduction in *gari* color at 1 MAP indicates that most of the losses due to exposure to light occurred within the first month after processing, hence, short time storage before consumption may not prevent substantial loss in carotenoid content of *gari* samples from yellow root cassava varieties due to exposure to light. These observations corroborate the previous submissions of some authors who reported highest carotenoid degradation of some stored bio-fortified cassava products after few weeks of storage [15,31,41].

The increase in yellow color fading of the stored bio-fortified yellow *gari* samples with increase in storage duration affirmed the previous submission of Oliviera, *et al.* [41] that oxidation process resulting in carotenoid degradation is not interrupted during storage. Hence, the observed yellow pigment degradation with increase in storage period. The report of UcheChukwu-Agua, *et al.* [10] also indicated that oxidation and degradation of yellow pigment in bio-fortified cassava is responsible for decline of yellowness of stored bio-fortified cassava products. The observed decrease in yellowness of the bio-fortified *gari* in this study, most especially within the first month, could be assumed to be equivalent to huge loss of carotenoids in the *gari* samples.

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Table 3: Variation among *gari* samples of six cassava varieties during storage for color stability in two seasons at Ibadan, Nigeria.

Variety	Initial	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	9 MAP	10 MAP	11 MAP	12 MAP	Yellow pigment retention
IITA-TMS-I070539	4.5	3.8	3.5	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.0	3.0	67%
IITA-TMS-I070593	4.5	3.5	3.5	3.5	3.5	3.3	3.3	3.3	3.0	3.0	2.8	2.7	2.7	59%
IITA-TMS-I011368	4.2	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.0	2.8	2.8	68%
IITA-TMS-I011371	4.3	3.5	3.5	3.5	3.5	3.3	3.3	3.3	3.2	3.2	2.7	2.5	2.5	58%
IITA-TMS-I011412	4.5	3.5	3.3	3.3	3.3	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	67%
TMEB419	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	NA
LSD	0.59	0.30	0.47	0.36	0.36	0.42	0.42	0.42	0.51	0.51	0.51	0.30	0.30	

*MAP: Months After Processing; NA: Not Applicable; Grey, orange, yellow, green and blue color s indicate duration of successive *gari* color decline and stability during storage, LSD: Least Significant Difference.

Table 4: Pearson correlation coefficients for *gari* color during storage at Ibadan in 2016 and 2017 (*n* = 18).

	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	9 MAP	10 MAP	11 MAP	12 MAP
Initial	0.972***	0.964***	0.959***	0.959***	0.890***	0.890***	0.884***	0.831***	0.831***	0.756**	0.751**	0.751**
1 MAP		0.951***	0.940***	0.940***	0.869***	0.869***	0.871***	0.846***	0.846***	0.790***	0.779***	0.779***
2 MAP			0.981***	0.981***	0.914***	0.914***	0.909***	0.858***	0.858***	0.754**	0.685**	0.685**
3 MAP				1.000***	0.914***	0.914***	0.905***	0.840***	0.840***	0.711**	0.674**	0.674**
4 MAP					0.914***	0.914***	0.905***	0.840***	0.840***	0.711**	0.674**	0.674**
5 MAP						1.000***	0.975***	0.858***	0.858***	0.752**	0.630**	0.630**
6 MAP							0.975***	0.858***	0.858***	0.752**	0.630**	0.630**
7 MAP								0.870***	0.870***	0.744**	0.596**	0.596**
8 MAP									1.000***	0.885***	0.701**	0.701**
9 MAP										0.885***	0.701**	0.701**
10 MAP											0.888***	0.888***
11 MAP												1.000***

*MAP= Months after processing; ** and *** implies significant at 0.01 and 0.001 levels of probability.

The record of higher yellow pigment color scores and pigment retention percentage from varieties IITA-TMS-I011368, IITATMS-I070539 and IITA-TMS-I011412 implies better stability of carotenoid in the *gari* from these three varieties after long term storage which should translate to better nutritional benefit for end users of such products. *Gari* has been identified as one of the most popular cassava products consumed in Africa, Southeast Asia and Brazil [9,13,16,37,42] as over 70% of total cassava produced in West African countries including Nigeria is processed into 7 million - 10 million tonnes of *gari* annually. Efforts to ensure that the large population depending on *gari* in these regions get optimum benefit from the product can therefore not be overemphasized. Future breeding work to improve cassava for carotenoid content should put into consideration the retention percentage of the micronutrient in the products during storage, most especially when such products cannot be totally shielded from light. This is sequel to the fact that detrimental effect of exposure to light on quality of stored products had been reported [15,31-33] which was also validated in this investigation. The observations of significant effect of storage duration and variety on *gari* color change are in agreement with the submission of Uchechukwu-Agua, *et al.* [10] who attributed changes in yellow color of stored bio-fortified cassava flour to the length of storage and cultivar differences. Also, varietal influence on the carotenoid content of some stored bio-fortified cassava samples was reported in other previous studies [28,30,41]. The record of significantly lowest pigment color from *gari* sample from the check variety TMEB419 over the 12 months of storage suggests that end-users of *gari* from the yellow root varieties have access to more carotenoids regardless of the storage period within a year. The significant correlation observed among the varieties for change in *gari* color over the storage period indicates that the fading of yellow color of the *gari* samples (varieties) followed similar trend over time, hence, response of the gari samples to light exposure at a particular storage period could be reliably predicted using observations at other periods.

Conclusion

Gari samples from five yellow and one white root cassava varieties were evaluated at Ibadan in 2016 and 2017 for fading in color (loss of carotenoid) over storage time of twelve months in each year. Continuous degradation of carotenoids (as depicted by yellow color depletion) was observed in all the bio-fortified *gari* samples from the yellow root varieties over the storage period with variety IITA-TMS-I011412 attaining stability about six months ahead of others. Loss of 32% to 42% of the yellow pigment color of the bio-fortified yellow *gari* observed in this study shows the need for laboratory quantification of carotenoid content in the stored *gari* over time to ascertain the actual loss. The observed rapid reduction in yellow pigment color of the bio-fortified *gari* samples in the first month of storage calls for the need to identify better storage methods to minimise loss of the micronutrients during storage. The information gathered in this study can be harnessed in future breeding programmes and storage processes to ensure that the amount of carotenoid available in bio-fortified *gari* is sufficient to meet the nutritional requirement of the consumers.

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