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Variation in Total Carotenoid Content of *Gari* from Yellow Root Cassava (*Manihot esculenta* Crantz) Varieties during Prolonged Storage

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ABSTRACT: *Agronomic characteristics of some novel yellow root cassava varieties (YRCVs) released in Nigeria in 2011 and 2014 were investigated during their development but there is paucity of information on the stability of total carotenoid content (TCC) in their products during storage, hence this study. Gari from three YRCVs (IBA011368, IBA070593 and IBA070539) and a white root variety (TMSI30572) as control were stored under daylight and dark conditions for 1 year. The samples were scored for colour on a scale of 1 (white) to 8 (pink) and analysed for TCC following standard procedures at 0, 3, 6, 9 and 12 months after storage (MAS). Data on TCC were subjected to analysis of variance at* $\alpha_{0.05}$ *and correlation was done between gari colour and TCC. Variety, season and storage duration effects were significant for TCC. Gari from white root had no TCC. The TCC of the bio-fortified gari samples reduced from between 7.49 µg/g (IBA011368) and 15.19 µg/g (IBA070593) at initial stage to 1.65 µg/g (IBA070539, daylight condition) and 2.09 µg/g (IBA070593, dark condition) at 3 MAS. Over the 12 months storage period, IBA070593 and IBA011368 had the least (7%) and highest (18%) percentage retention, respectively. Notably, colour and TCC of the gari samples were positively correlated under each storage condition.*
KEYWORDS: Bio-fortified *gari*, *Gari* colour, *Gari* storage condition, *Gari* storage duration, Total carotenoid content, Yellow root cassava varieties

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) plays a major role in the national food security because most Nigerians depend on it for their daily source of energy. Howbeit, majority of the available cultivars of cassava are deficient in carotenoids (Gomes *et al*., 2016). This predisposes consumers to Vitamin A Deficiency and prompted the development of bio-fortified yellow root cassava varieties (YRCVs) with enhanced total carotenoids content (TCC) (Ceballos *et al*., 2012). Yellow root cassava varieties have the potential to combat vitamin A deficiency when consumed. However, cassava is rarely eaten raw but processed prior to consumption to enhance diversity in products, increase its shelf life, detoxify the roots and improve their quality. Prominent among cassava products is *gari* which takes up about three quarter of processed cassava in Nigeria and West Africa at large (Otekunrin and Sawicka, 2019).

Following *gari* production, most unconsumed batch are stored for future consumption or sale for duration of 180 to 365 days. Condition under which food is stored had been reported to influence its nutritional quality (Akpe *et al*., 2010). Premium health-related nutritional constituent of bio-fortified yellow *gari* is its TCC. Meanwhile, stability of TCC in bio-fortified *gari* during storage is relatively poor due to dual bonds in molecular structure of carotenoids and their high sensitivity to prevailing environmental conditions like light, heat and oxygen (Bechoff *et al.*, 2017). Prolonged storage of *gari* after processing cannot be avoided due to glut arising from massive production at harvest and other factors relating to demand and supply of the product. Also, farmers devote more time to cultivation during rainy season thereby harvesting and processing more of the cassava roots during dry season when it is also more convenient to process the roots. The fact that moisture content of cassava is higher at early stage of rainy season further discourages processing of the roots during this period except when unavoidable. Thus research into suitable storage conditions for enhanced TCC retention in bio-fortified yellow *gari* during prolonged storage had been of great interest in recent times.

Olasanmi *et al*. (2022) noted that the yellowness (which depicts TCC) of *gari* from YRCVs decreased with increase in storage duration during a one year storage, under condition of exposure to light. A further research on this subject by Udemba *et al*. (2023) which involved comparative evaluation of yellowness of bio-fortified *gari* under conditions of exposure to light and darkness revealed significantly better colour retention of bio-fortified *gari* under the latter storage condition. Six (6) YRCVs were released in Nigeria between the years 2011 and 2014. Howbeit, there is no information on TCC stability potential of *gari* from these YRCVs during prolonged storage which is typical of the Nigeria *gari* distribution chain. To the best of our knowledge, no published research has also reported the relationship between the colour and TCC of *gari* from these YRCVs during prolonged storage. Information relating to TCC retention capacity of *gari* from these YRCVs during long term storage can help to set breeding target right; in varietal selection for propagation; and make decision on appropriate storage facilities for these bio-fortified *gari* across value addition and distribution chains (which are very important components of the farming system). Also, understanding the possible relationship between the TCC and colour of these bio-fortified *gari* might be an easy and cost effective way of predicting their TCC in the absence of sophisticated equipment or technical know-how. Hence, the need to quantify the variation in TCC of *gari* from these YRCVs during prolonged storage and establish the relationship between their TCC and colour under the two aforementioned storage conditions necessitated this study.

MATERIALS AND METHODS

The fresh storage roots (FSRs) of three YRCVs (IBA011368, IBA070539 and IBA070593) and a white root variety (TMSI30572) as control were harvested from the site of experiment of the Department of Crop and Horticultural Sciences, University of Ibadan with the coordinate Latitude N 007°27.134' and Longitude E 003°53.425', 1 year after planting. The roots were converted into *gari* at the processing unit of International Institute of Tropical Agriculture, (IITA) Ibadan following the procedure described by James *at al*. (2012). Subsequently about 5 kg of the *gari* samples were packaged in triplicates in transparent buckets which enhanced light penetration into the packaged *gari* and served as condition of exposure to light. Similar samples of *gari* were packaged in blue buckets wrapped in double black polythene bags (to ensure total barrier to light rays) and was the dark condition. These samples were stored for 1 year in a 4 × 2 factorial experiment using randomised complete block design. Immediately after processing and at interval of three months for duration of 1 year, the colour and total carotenoid content of the *gari* samples were determined using colour chart (Plate 1) and method described by Bioanalyt (2014), respectively. The experiment was repeated in the second season. Data on TCC were subjected to analysis of variance at $\alpha_{0.05}$ and regression analysis. Correlation between colour and TCC of the *gari* samples under the two storage conditions across the storage duration of evaluation were determined.

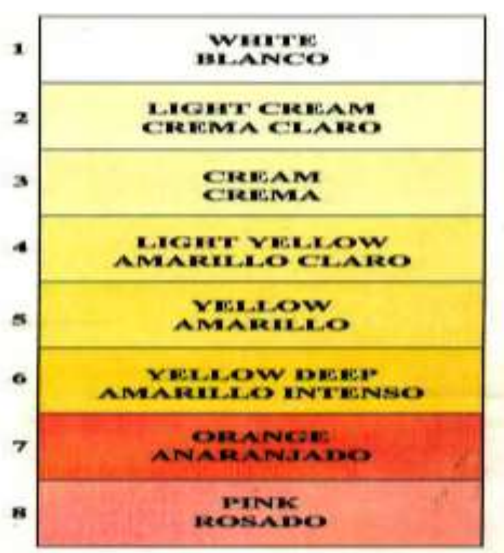

Plate 1: Chart for scoring *gari* colour (Source: IITA, 1990)

RESULTS

Season, variety, storage duration, interaction of storage duration × variety, season × variety and storage duration × season × variety significantly influenced TCC of the *gari* during storage (Table 1). Worthy of note is the fact that the check variety TMSI30572 had 0 µg/ g (Table 2). Conversely, immediately after processing in both seasons, TCC in fresh bio-fortified *gari* from variety IBA070593 (16.58 µg/ g; 13.79 µg/ g) was significantly higher than other samples (Table 2). A sharp decrease in TCC of all *gari* samples from YRCVs was however observed during 3 months storage duration in both storage conditions (Table 2 and Figure 1). This notable TCC decline ranged between 74% (IBA011368) and 89% (IBA070593); and 75% (IBA011368) and 84% (IBA070593) for samples stored under daylight condition in years 2019 and 2020, respectively. Under the dark condition, the reduction in TCC of the *gari* samples at 3 MAS ranged between 73% (IBA011368) and 88% (IBA070593) in 2019 and between 75% (IBA011368) and 84% (IBA070593) in 2020. The TCC of *gari* from varieties IBA070593 and IBA011368 stored under dark condition, though highest from 3 to 6 MAS and 9 to 12 MAS, respectively, were only significantly different from mean TCC of *gari* from variety TMSl30572 (Figure 1). Notably, 12 months after storage under daylight condition, *gari* from IBA070593 (which had the highest TCC immediately after processing) and IBA011368 (with least initial TCC) retained the least (7%) and highest (18%) percentage of TCC over the storage period, respectively. Similar trend was recorded under the dark condition but with higher percentage TCC retention of 9% and 19% in *gari* from IBA070593 and IBA011368, respectively. The dark condition was responsible for 94.1%, 49.7% and 40.8% reduction in TCC of *gari* from IBA070593, IBA070539 and IBA011368, respectively over the storage period (Figure 1). About 96.4%, 50.0% and 42.0% decline in TCC of *gari* from IBA070593, IBA070539 and IBA011368, respectively could be accounted for by condition of exposure to light (Figure 1). Although storage condition effect was not significant for *gari* TCC, higher TCC was recorded for samples stored under dark condition (Table 3). Also, *gari* stored in the first season retained significantly higher mean TCC (3.36 µg/g) over the storage period than the second (3.00 µg/g) (Table 3). The TCC of *gari* stored under both conditions correlated positively with its colour from initial stage to 12 MAS (Table 4).

Table 1: The combined analysis of variance for total carotenoid content of *gari* from four cassava varieties exposed to daylight and darkness conditions for 1 year in 2 seasons

Sources of variation	Total carotenoid content		
	Degree of freedom	Mean square	Sum of squares
Replication	2	0.01	0.02
Storage condition	1	0.13	0.13
Storage duration	4	418.09***	1672.37
Season	1	1.22***	1.22
Variety	3	201.87***	605.60
Duration × condition	4	0.03	0.12
Condition × season	1	0.03	0.03
Condition × variety	3	0.09	0.28
Duration × season	4	0.85***	3.39
Duration × variety	12	74.11***	889.26
Season × variety	3	1.60***	4.79
Duration × condition × season	4	0.01	0.06
Duration × condition × variety	12	0.03	0.41
Condition × season × variety	3	1.95**	0.02
Duration × season × variety	12	0.03	23.40

** and *** implies significant at $\alpha_{0.01}$ and $\alpha_{0.001}$, respectively

Table 2. Total carotenoid content (µg/g) of *gari* (from four cassava varieties) before, during and at the end of storage in two years

Variety	2019 season					2020 season				
	Months after storage									
	0	3	6	9	12	0	3	6	9	12
	Daylight condition									
IBA070593	16.58	1.82	1.58	1.22	1.20	13.79	2.12	2.09	1.54	1.43
IBA070539	8.52	1.46	1.46	1.43	1.05	8.72	1.84	1.73	1.64	1.32
TMSl30572	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IBA011368	6.86	1.73	1.73	1.64	1.13	8.13	2.07	1.97	1.94	1.52
*LSD ($p<0.05$)	0.24	0.56	0.20	0.22	0.56	0.24	0.36	0.98	0.42	0.19
	Dark condition									
IBA070593	16.58	1.94	1.64	1.43	0.84	13.79	2.24	2.07	1.79	1.64
IBA070539	8.52	1.76	1.67	1.52	1.11	8.72	2.24	1.84	1.70	1.61
TMSl30572	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IBA011368	6.86	1.82	1.52	1.46	1.31	8.13	2.07	1.97	1.82	1.57
*LSD ($p<0.05$)	0.24	0.25	0.17	0.21	0.56	0.24	0.64	0.62	0.54	0.46

* LSD: least significant difference

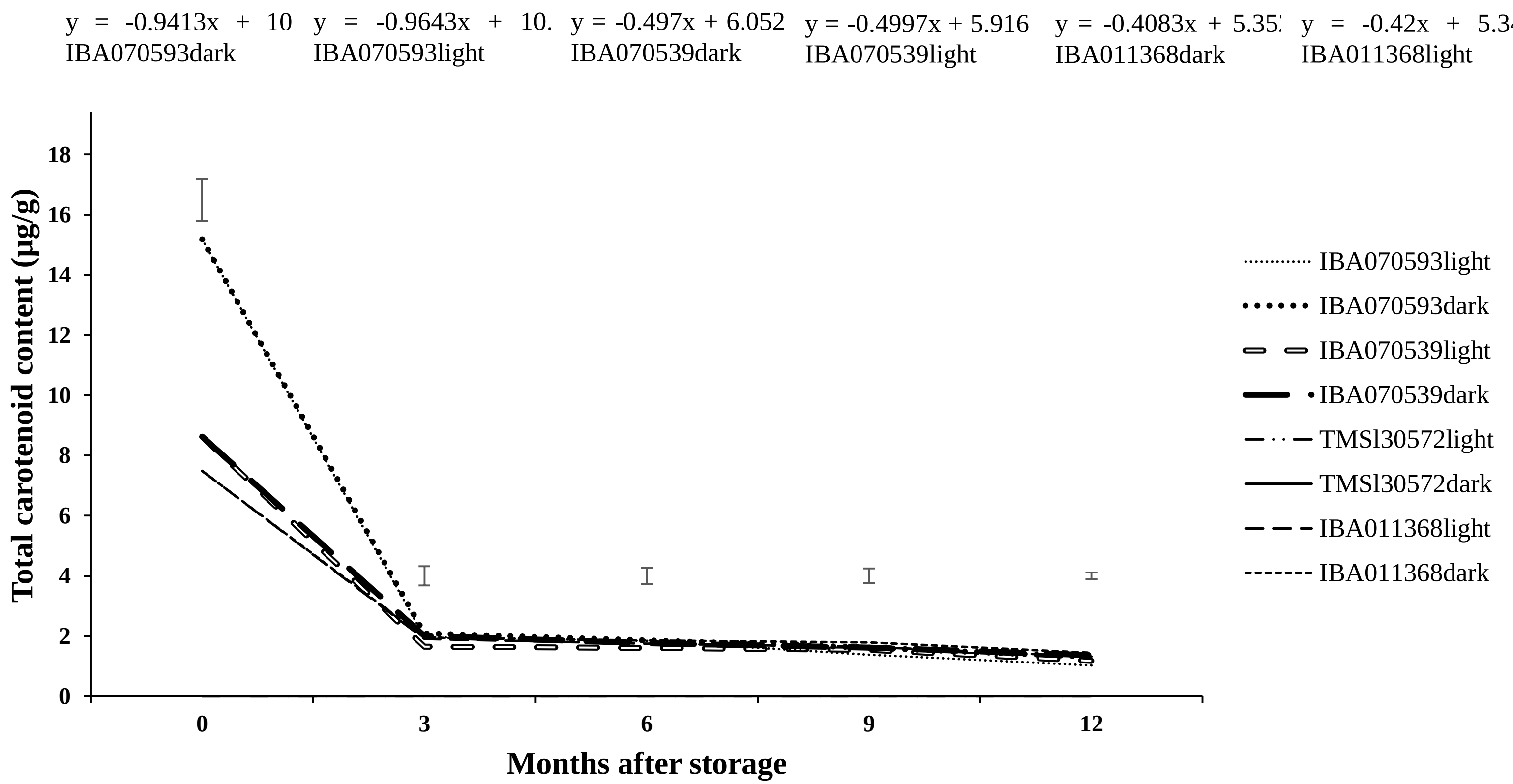

Figure 1. Mean total carotenoids content (µg/g) of *gari* (from four cassava varieties) before, during and at the end of storage under daylight and darkness conditions for 1 year in 2 seasons and their regression equations

Table 3. Mean effect of storage condition and season on total carotenoid content of *gari* (from four cassava varieties) stored under daylight and darkness conditions for 1 year in 2 seasons

Sources of variation	Total carotenoid content (µg/ g)
Storage condition	
Daylight	2.53
Dark	2.58
*LSD (p<0.05)	0.11
Season	
First	2.48
Second	2.63
*LSD (p<0.05)	0.11

*LSD: Least significant difference

Table 4. Pearson coefficient of correlation between colour and total carotenoid content of the stored *gari* samples under the two storage condition (N=24)

Months after storage	Storage condition	Pearson correlation coefficients
0		0.839
3	Daylight	0.808
	Darkness	0.814
6	Daylight	0.701
	Darkness	0.823
9	Daylight	0.313
	Darkness	0.359
12	Daylight	0.124
	Darkness	0.379

DISCUSSION

Storage is an expedient integral component of *gari* production due to glut at peak of cassava harvest season and long distribution chain. Meanwhile, efforts invested in developing yellow roots cassava varieties can only be justified if substantial amount of TCC is retained in products like *gari* after typical storage activities. The present observation of decrease in bio-fortifed *gari* TCC and yellowness over the storage duration might be linked to degradation of carotenoid pigment in the samples. The presence of double bond in carbon chains of carotenoids makes them unstable and prone to loss from food during postharvest handling activities (Mezzoro and Ferreira, 2016). Also, β-carotene which constitutes the highest percentage of carotenoid in YRCVs degrades easily when exposed to light, oxygen and heat (Bechoff *et al.*, 2009; Ceballos *et al*., 2013). Thus, significant huge loss of TCC from the bio-fortified *gari* samples shortly after storage was simultaneously initiated by the great surface area of *gari* (sequel to small granular size) which increased the area of exposure of the *gari* granules to carotenoid-degrading factors like oxygen and light during storage (Mezzomo and Ferreira, 2016). Also, Osagie *et al*. (2017) opined that fermentation softens the tissue of cassava during *gari* production and reduce the ability of bio-fortified *gari* to retain carotenoid for long duration during storage.

The rapid TCC loss from bio-fortified *gari* within 12 weeks of storage aligns with the previous observation of Olufunmilola *et al*. (2020), Olasanmi *et al*. (2022) and Udemba *et al*. (2023) who recorded significantly high loss of TCC and yellowness of *gari* from YRCVs within the first few weeks of storage. However, varietal difference in the rate of decline of *gari* TCC observed in this study highlights the effect of genetic variability on stability of TCC in bio-fortified *gari* during storage. This observation corroborates the previous finding of Bechoff *et al.* (2017) during storage of *gari* from YRCVs. Record of highest TCC in sample from IBA011368 (with the least TCC immediately after processing) at 12 MAS suggests that TCC of bio-fortified *gari* after long term storage is a function of the variety's carotenoid stability potential and not the initial TCC of the sample. Low percentage retention of TCC in bio-fortified *gari* samples from about 2 months of storage indicates that increasing concentration of TCC in bio-fortified cassava varieties might not ensure delivery of sufficient TCC to final end users. This poses a great challenge to eradication of vitamin A deficiency through pro-vitamin A bio-fortification of cassava as the crop is rarely consumed raw, hence, the need to focus research on improving traits of bio-fortified cassava varieties that enhances carotenoid retention during post harvest handling including storage.

The degree of permeability of packaging materials to prevailing environmental conditions had been reported to determine the extent of deviation in proximate composition of food produce during storage (Akpe *et al*., 2010). Specifically, some authors noted that incidence and intensity of light during storage of foods with high TCC determines the extent of β-carotene degradation and consequently yellow colour retention (Udemba *et al*., 2023). Though the two storage conditions had significantly comparable effects on TCC of the bio-fortified *gari*, record of lower TCC retention in samples exposed to light indicates better caroteniod preservation capability of the dark condition sequel to its ability to screen light entry into the stored samples. Earlier, Uzomah *et al*. (2006) submitted that exposure of food products to light is responsible for decline in their carotenoid content. The observed degradation of TCC in *gari* samples stored under dark condition despite its ability to create barrier against light penetration may be due to auto-oxidation of β-carotene inherent in the *gari* samples (Kaur *et al.,* 2013). This affirms the claim of Oliviera *et al*. (2010) that oxidative degradation of carotenoid in food does not cease during storage. Moreover, it is also consistent with the analogous observation of Osagie *et al*. (2017) who noted incessant decline of TCC in some *gari* from YRCVs stored in dark containers. At 12 months after storage, availability of TCC in bio-fortified *gari* in comparison to samples from white root check which had no TCC implies that *gari* from the former can proffer better health benefits than the latter when consumed within 12 months of storage.

Significant seasonal variation recorded for TCC of *gari* during storage might be due to difference in the initial concentration of TCC in the *gari* samples in the two years. This finding validates the earlier submission of Lee and Coates (2003) who noted that carotenoids in food vary in their extent of stability even within the same variety. Positive correlation between TCC and colour of the *gari* samples under the two storage conditions across all storage duration indicates that colour of the bio-fortified *gari* samples can be used to predict its TCC at any storage duration (within 12 months) under both storage conditions. This observation is analogous to the finding of Blagbrough *et al*. (2010) though with fresh storage root of YRCVs. This suggests that the finding of Ceballos *et al*. (2017) that pigmentation of cassava parenchyma is closely linked to carotenoids content also applies to *gari*. This implies that colour charts can be used by scientists and stakeholders in *gari* value addition and distribution chain to make quick decision on TCC status of bio-fortified yellow *gari* during storage in the absence of sophisticated equipment and technical know-how.

IMPLICATION TO RESEARCH AND PRACTICE

Information generated from this study can help stakeholders in cassava breeding, production and value addition to set breeding target appropriately, improve traits of bio-fortified cassava varieties relating to carotenoid stability, select the right varieties of bio-fortified cassava for propagation and *gari* production; and make appropriate decision on condition and duration of storage of bio-fortified *gari* for optimum health benefit. The colour of *gari* from yellow root cassava varieties can also be used by them as quick, easy and cost effective tool for predicting TCC of the bio-fortified *gari* during prolonged storage in the absence of sophisticated equipment or technical know-how.

CONCLUSION

From an overview of this study, it can be concluded that bio-fortification of cassava can only be successful when the carotenoid stability potential of its products including *gari* is improved. Bio-fortified *gari* should therefore not be stored beyond three months but should be consumed shortly after processing in order to harness its optimum health benefit. *Gari* from yellow root cassava variety IBA011368 had better TCC stability capacity than the other bio-fortified *gari* samples during one year storage. However, storage of bio-fortified *gari* under dark condition can enhance retention of its TCC better than exposure to light although this might not totally inhibit TCC degradation.

FUTURE RESEARCH

Concerted effort should be given to study the trend of changes in TCC of the bio-fortified *gari* at shorter interval (about 3 days interval) for the first three months of the ineluctable salient TCC degradation.

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