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Research Article

Influence of exposure to light and storage period on color changes in *gari* produced from bio-fortified cassava (*Manihot esculenta* Crantz) varieties

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Keywords: Bio-fortified *gari*; Carotenoid content; Color changes; Exposure to light; Yellow root cassava

Abstract

Light degrades carotenoids and thus the color of bio-fortified *gari* during storage. This study was therefore conducted to evaluate the effect of exposure of bio-fortified *gari* to light during storage on its color. *Gari* samples obtained from the processing of fresh storage roots of three yellow root cassava varieties (TMSI011368, TMSI010593, and TMSI010539) and a white root variety (TMS30572) as check were packaged in three replicates in transparent white plastics containers (light condition) and blue plastics containers wrapped in black polythene bags (dark condition). These were stored on an open shelf in the laboratory in a 4 × 2 × 13 factorial experiment in a randomized complete block design. Immediately after processing and monthly for 12 months, the *gari* samples were evaluated for color using a scale of 1 (white) to 8 (pink). The result showed that yellowness of the *gari* from bio-fortified cassava varieties decreased over the storage period from 5.5 (TMS010539) immediately after processing to 2.5 (TMS010593, under both storage conditions) at 12 Months After Storage (MAS). The change was significantly ($p < 0.05$) influenced by variety, storage duration and storage condition. *Gari* from varieties TMSI011368 and TMSI010593 had the least (38.3%) and highest (50.2%) percentage reduction in yellowness, respectively at the end of the storage period (12 months). Across the storage period, the mean color of *gari* samples stored in the dark condition (3.37) was significantly higher than the mean color of *gari* samples exposed to light (3.22). Therefore, the proper selection of cassava variety and the use of packaging containers that screen light from bio-fortified *gari* during storage can best preserve its color and ensure the availability of a reasonable amount of carotenoids to consumers after long-term storage (12 months).

Introduction

Gari is a creamy-white, toasted, partially gelatinized, free-flowing granular flour made from cassava roots [1,2]. It has a slightly sour and acidic taste. Babatunde [3] reiterated that over 70% of total cassava produced in West African countries including Nigeria is processed into 7 - 10 million tonnes of *gari* annually. In Nigeria and many African countries, *gari* is eaten in different forms either as a snack or a full meal [4]. Recently, the development of bio-fortified varieties of cassava that contain significant levels of provitamin A carotenoids had resulted in the production of bio-fortified *gari* with an appearance similar to *gari* made with palm oil [2,5]. In practice, a child who consumes 100g of bio-fortified *gari* daily would have his/her vitamin A daily nutritional requirements met [6].

The majority of *gari* produced by processors are rarely consumed immediately after processing but are stored. Storage of *gari* is also practiced at commercial and household levels. The period of storage is on average around 6 months, but some people can store for up to a year. Storage conditions of food products had been reported to determine the final characteristics and composition of the food product [2]. Globally, major and minor carotenoid compounds degrade during storage at ambient temperature. Also, the vitamin A activity of bio-fortified cassava products decreases sharply during storage [7,8]. Since carotenoid pigments in food are denoted by varying shades of color yellow [9], degradation of carotenoid in food results in a reduction of food yellowness and loss of nutritional values [10]. Moreover, a strong and positive correlation between the intensity of the yellow color of cassava

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root and its total carotenoid content had been established by several authors [2,11-13]. Njenga, et al. [14] reiterated that 98% of the variability in the carotene content of cassava can be explained by the variability in root color. This is the sequel to the fact that the extent of the pigmentation of the parenchyma of cassava root is closely linked to its carotenoid content [15].

Uchechukwu-Agua, et al. [9] noted that color variation (and subsequently carotenoid variation) observed during the storage of cassava products can be accredited to the length of storage and cultivar differences. Also, the stability of carotenoids present in food products had been demonstrated to be influenced by factors such as the presence of oxygen, exposure to light and heat, type of food matrix as well as the type and physical form of carotenoid compounds [16-18]. The carotenoids in dehydrated foods like *gari* are most likely to undergo degradation during storage because of their great surface area and porosity which increases their exposure to oxygen and light [19]. Understanding how carotenoids (which can be depicted by the yellow color) of bio-fortified *gari* degrade during storage is critical because it will affect its nutritional impact. This knowledge can help processors, sellers, and consumers of bio-fortified *gari* adjust their storage methodology for enhanced carotenoid preservation. Hence, this study was conducted to determine the effect of light and darkness on the color of bio-fortified *gari* during long-term storage.

Materials and methods

Fresh storage roots of three varieties of yellow root cassava (TMS011368, TMS010593, and TMS010539) and one white root variety (TMS30572) as a check (harvested at 12 months after planting) were processed into *gari* using the stepwise procedure described by James, et al. [20]. About 500 g of each *gari* sample in triplicate were packaged in white transparent plastic containers (exposure to light treatments) and blue plastic containers wrapped in black polythene bags (to screen light and prevent exposure of samples to light). All the treatments were placed on an open shelf and evaluated immediately after processing and monthly for a period of 12 months for color changes using the color chart developed by IITA [21] (Figure 1) where 1: white and 8: pink. Data collected were subjected to descriptive statistics and analysis of variance using SAS version 9.0 and significantly different means were separated using LSD and DMRT as appropriate at a 5% level of probability.

Results

The result presented in Table 1 shows that varietal, storage condition, storage duration, and interaction of variety × storage condition × season; storage duration × storage condition × season effects were significant for the color of *gari* in this study. The yellow color of all the bio-fortified *gari* samples decreased with increase in storage duration across the two storage conditions while the color of *gari* from white root increased (Figures 2 and 3). There was no significant difference in color scores of *gari* from the three bio-fortified yellow root cassava varieties at each storage duration under both daylight and dark conditions. However, the color of the bio-fortified *gari* changed from a score of 5.5 (TMSI010539) at 0 months after storage (MAS) to 2.5 (TMSI010593, under both light and dark conditions) at 12 MAS (Figures 2 and 3). During storage,

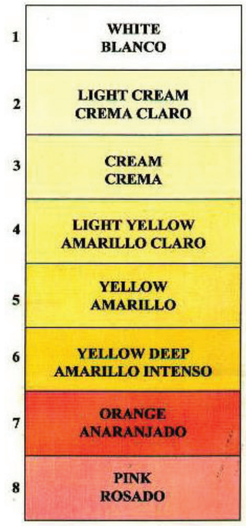

Figure 1: Chart for scoring *gari* color [21].

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

Sources of variation	DF	Type III SS	Mean Square	F Value	Pr> F
Condition	1	3.39	3.39	30.33	< 0.0001
Period	12	244.06	20.34	181.91	< 0.0001
Rep	2	5.84	2.92	26.10	< 0.0001
Season	1	0.06	0.06	0.52	0.4731
Variety	3	355.25	118.42	1059.14	< 0.0001
Period*Condition	12	2.86	0.24	2.13	0.0153
Condition*Rep	2	0.54	0.27	2.42	0.0906
Condition*Season	1	14.16	14.16	126.65	< 0.0001
Condition*Variety	3	1.87	0.62	5.56	0.0010
Period*Rep	24	3.29	0.14	1.23	0.2182
Period*Season	12	18.69	1.56	13.93	< 0.0001
Period*Variety	36	89.08	2.47	22.13	< 0.0001
Season*Rep	2	8.34	4.17	37.28	< 0.0001
Rep*Variety	6	58.36	9.73	86.99	< 0.0001
Season*Variety	3	0.69	0.23	2.04	0.1078
Period*Condition*Rep	24	1.33	0.06	0.50	0.9784
Period*Condit*Season	12	4.84	0.40	3.61	< 0.0001
Period*Condit*Variety	36	3.05	0.08	0.76	0.8414
Condition*Season*Rep	2	0.96	0.48	4.31	0.0143
Condition*Rep*Variety	6	0.63	0.10	0.93	0.4725
Condit*Season*Variety	3	5.61	1.87	16.72	< 0.0001
Period*Season*Rep	24	5.04	0.21	1.88	0.0089
Period*Rep*Variety	72	14.19	0.20	1.76	0.0006
Period*Season*Variety	36	15.73	0.44	3.91	< 0.0001
Season*Rep*Variety	6	53.19	8.86	79.29	< 0.0001
Error	282	31.53	0.11		
Corrected Total	623	942.56			

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variation in the color of *gari* from the white variety ranged from 1.7 (0 MAS) to 2.0 (under both storage conditions) at 12 MAS (Figures 2 and 3). An appraisal of the trend of color changes showed that the decrease in the yellow color of *gari* from the initial (immediately after processing) (4.38) till one month (4.27) in storage was not significant (Table 2). Subsequently, a significant difference was observed in a decrease of yellow color intensity of the stored *gari* samples across all months of storage except from 4 (3.46) to 6 (3.33) months; between 8 (2.88) and 9 (2.77) and 11 (2.52) and 12 (2.44) months of storage (Table 2). The mean color score of *gari* samples stored under dark condition (3.37) was significantly higher than the value recorded for samples exposed to light (3.22) over the storage period (Table 3). Towards the end of storage (12 MAS) bio-fortified *gari* from TMSI011368 and TMSI010593 stored under dark conditions attained stability in carotenoids content (depletion of the color of *gari* stopped) at 9 and 10 MAS, respectively (Figure 4). *Gari* samples from these two varieties exposed to light attained stability at 11 MAS (Figure 4). Notably, *gari* from TMSI011368 had the highest carotenoid content (depicted by the highest color of 2.8) at stability (towards the end of storage) in both storage conditions, though it had the least yellowness score immediately after processing (4.7) among the bio-fortified yellow *gari* (Figure 4). Carotenoids in *gari* from variety TMSI010539 became stable at 11 MAS in both storage conditions (Figure 3). Percentage change in color intensity of the *gari* samples after 12 months of storage followed

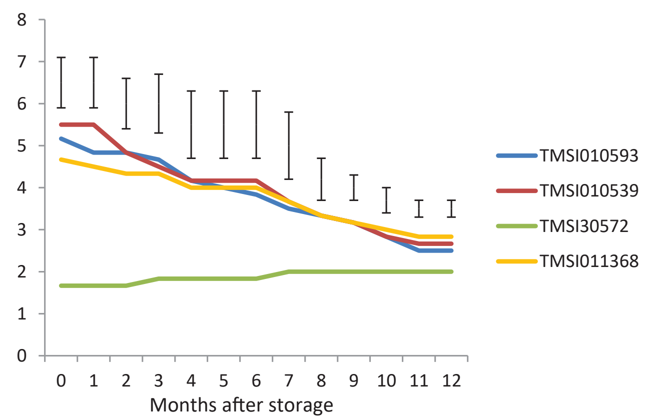

Figure 2: Color scores of *gari* samples stored under dark conditions for two seasons in Ibadan, Nigeria.

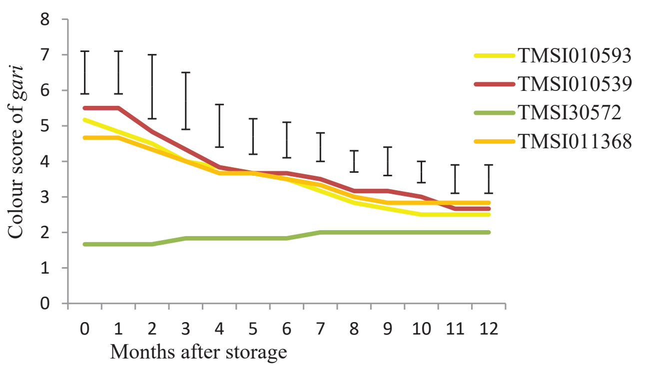

Figure 3: Color scores of *gari* samples exposed to light during storage for two seasons in Ibadan, Nigeria.

Table 2: Mean effect of storage duration on the color of *gari* stored under two conditions for two seasons.

Storage Duration (Months)	Mean Color Score
0	4.38a
1	4.27a
2	3.98b
3	3.73c
4	3.46d
5	3.40d
6	3.33d
7	3.10e
8	2.88f
9	2.77f
10	2.63g
11	2.52gh
12	2.44h

This means with the same letter is not significantly different.

Table 3: Effect of storage conditions on the color of *gari* stored for 12 months in two seasons.

Storage condition	Mean color score
Dark condition	3.37
Light condition	3.22
LSD ($p < 0.05$)	0.13

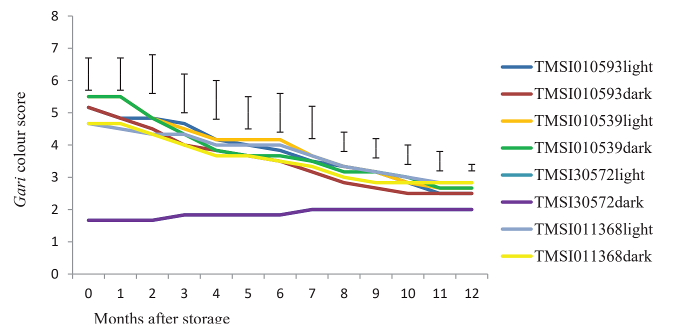

Figure 4: Change in color of *gari* stored under daylight and dark conditions for 12 months in two seasons.

the order of TMSI010593 (50.22%) > TMSI010539 (50.04%) > TMSI011368 (38.25%) > TMSI030572 (19%) (Table 4).

Discussion

Carotenoids are denoted with yellow or orange pigments which contribute to the yellow color of bio-fortified yellow *gari* [22]. The observed decrease in yellowness of bio-fortified *gari* samples (stored in both storage conditions) with an increase in storage duration corroborates the earlier findings of Olasanmi, et al. [23] who observed a progressive decrease in yellowness of bio-fortified *gari* samples exposed to light during storage. Also, Uchechukwu-Agua, et al. [9] reiterated that oxidation, degradation of yellow pigment of bio-fortified cassava product, and length of storage were responsible for the decline of its yellowness. Carotenoid degradation (depicted by yellow color degradation) is an oxidative process that is not

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Table 4: Percentage change in color intensity of *gari* during storage in light and dark conditions for two seasons.

Variety	Percentage change in color intensity
IITA-TMSI010593	50.22
IITA-TMSI010539	50.04
IITA-TMSI011368	38.25
TMSI030572	19.00

interrupted during storage [24]. This is due to the double bond in the carotenoid carbon chain which makes them susceptible to chemical reactions induced by oxygen, light, and heat during processing or storage [25,26]. Thus, increase in storage duration led to augmented degradation of yellow pigment (contained in the *gari* samples) and consequently decrease in yellowness of *gari*. Degradation of carotenoids content during storage is a major challenge in maintaining the health benefit of high carotenoid products [27]. The present finding of an increase in the color of *gari* from white root during storage agrees with the earlier submission of Uchechukwu-Agua, et al. [9], who reported similar observations from the storage of flour from white root cassava variety and attributed the increase in color score to the effect of oxidation during storage. The record of lower color retention for *gari* samples stored under light condition highlights the effect of the permeability of packaging material to light on the quality of stored products as observed by Olasanmi, et al. [23]. Exposure of food products to light during storage had been reported to have a detrimental effect on food quality [28]. Specifically, reports in the literature indicated that the decline in the carotene content of some stored food products can be accounted for by exposure to light [2,29,30]. Conversely, the dark condition created a better barrier to light penetration which resulted in higher color retention in bio-fortified *gari*. Howbeit, the observation of a yellow color decline in *gari* samples stored under dark conditions confirms the earlier findings of Oliveira, et al. [24] and Osagie, et al. [31] who observed continuous degradation of carotenoids of some bio-fortified cassava products during storage in the absence of light. This can be attributed to the auto-oxidation of anthocyanin and β-carotene in the bio-fortified products as opined by Kaur, et al. [10].

The finding of no significant seasonal variation in the color of the *gari* over the storage period suggests that changes in the color of the *gari* in the two seasons of evaluation followed the same trend. The observation of significant effect of variety on the color of *gari* is consistent with the separate submissions of Chavez, et al. [32]; Oliveira, et al. [24] and Olasanmi, et al. [23] who reported a significant varietal influence on color and carotenoid content of stored bio-fortified cassava products including *gari*. However, the absence of significant difference in the color of the three bio-fortified *gari* samples at each storage duration, suggests that changes in carotenoid content of the bio-fortified *gari* samples at each duration of storage were comparable. The low pigment color of *gari* from the white root check variety throughout the period of this study indicates that bio-fortified *gari* can still supply some reasonable quantity of carotenoid even after long-term storage and thus a good panacea for vitamin A deficiency when consumed. After 12 months of storage, the record of highest and least percentage color reduction from *gari* of varieties TMSI010593 and TMSI011368, respectively (among the bio-fortified *gari* samples) implies that degradation of carotenoid pigment was fastest in *gari* samples from variety IITA-TMSI010593 and least in TMSI011368. This connotes better stability of carotenoid in *gari* from variety TMSI011368 among the bio-fortified *gari* samples and better nutritional composition for end users after long-term storage. This finding affirms the observation of Olasanmi, et al. [23] from a separate study who noted that *gari* samples from cassava variety TMSI011368 had the highest color retention after 1year storage period for two seasons when compared to *gari* samples from other varieties. This observation of best color retention in *gari* of variety TMSI011368 which had the lowest initial color score after processing (among the yellow *gari*) suggests that carotenoid retention capacity (depicted by yellow color intensity) of *gari* is not a function of the initial carotenoid content but the inherent carotenoid stability property of the cassava variety.

Conclusion

Degradation of carotenoids (depicted by fading of yellow color) during food storage limits the optimization of nutritional benefit of bio-fortified cassava products. Based on the outcome of this study, it can be concluded that the color of bio-fortified *gari* can be significantly influenced by cassava variety and storage condition and duration. Although a decline in yellowness of bio-fortified *gari* was observed under both light and dark conditions, the achievement of better color preservation under the dark condition makes it a better option for long term storage of bio-fortified *gari* obtained from yellow root cassava varieties with high carotenoid stability during storage.

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