Asian Journal of Advances in Agricultural Research

Volume 23, Issue 2, Page 11-19, 2023; Article no.AJAAR.105647
ISSN: 2456-8864

Tandem Effect of Bio-Fortification on Dry Matter Content and *Gari* Yield of Some Yellow Root Cassava (*Manihot esculenta* Crantz) Varieties

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI:10.9734/AJAAR/2023/v23i2457

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/105647

Original Research Article

Received: 19/08/2023
Accepted: 31/08/2023
Published: 08/09/2023

ABSTRACT

Bio-fortification of cassava increased its total carotenoid content (TCC) but may have boomerang effect on key quality traits of cassava like dry matter content (DMC). Meanwhile, DMC of cassava reflects its true biological and product yield. Therefore, this study was conducted to determine the relationship between TCC of some novel yellow root cassava varieties (YRCVs) and each of DMC and *gari* yield. Three bio-fortified YRCVs (IBA070593, IBA070539 and IBA011368) and a white root variety (TMSI30572) as check were harvested 12 months after planting. The TCC (µg/g) and DMC (%) of the fresh storage roots were determined following standard procedures. Subsequently, the fresh storage roots were processed into *gari* and *gari* yield (t/ha) was estimated. Data collected were subjected to descriptive statistics, analysis of variance at 5% level of probability and

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correlation analysis. The check variety lacked TCC but had significantly higher DMC (34.34%) and *gari* yield (3.40 t/ha) than other varieties except variety IBA070593 for DMC (33.95%). Total carotenoid content of the bio-fortified cassava varieties ranged between 7.81 µg/g (IBA011368) and 10.23 µg/g (IBA070593). Among the YRCVs, IBA070593 consistently had the highest DMC (33.95%) and *gari* yield (3.2 t/ha) while IBA070539 had least values of 24.63% and 2.2 t/ha, respectively. The TCC of the fresh storage roots correlated negatively with DMC (-0.22) and *gari* yield (-0.22). Notably, IBA070593 had a good combination of high TCC, DMC and *gari* yield, hence, it can deliver high *gari* yield and TCC to processors and consumers, respectively. Propagation of variety IBA070593 is therefore encouraged because it can offer the triple benefits of food, nutritional and financial security.

Keywords: Dry matter content; fresh storage roots; gari yield; total carotenoid content; yellow root cassava varieties.

1. INTRODUCTION

Cassava is an important food and industrial crop grown principally for its starchy fresh storage root. It has high yield potential under good conditions and performs better than other crops under sub-optimal conditions [1]. Hence, it is called Africa's food insurance sequel to its reliable yields even in the face of drought, low soil fertility, low management intensity; and resilience to face the effects of climate change [2-5]. Millions of people in tropical countries depend on cassava for their daily calorie intake [6,7]. An estimate of two out of five Africans in both urban and rural areas utilise the crop as a major source of daily energy when compared to other staples. In Nigeria, about 160 million of the country's residents eat cassava in diverse forms at least once a day [8, 9]. This drought tolerant crop can also be stored in the ground and harvested when needed thereby providing households with an alternative when the harvest of other crops fails [10]. The high level of dependence of farming families and several Nigerians on cassava and its products makes them vulnerable to vitamin A deficiency (VAD). This is sequel to the absence of provitamin A carotenoids (PVACs) in most cultivated varieties [11,12].

Globally, the prevalence of VAD had been mitigated through nutrition education on the benefit of breastfeeding, consumption of foods rich in PVACs by children, immunization of children (6-59 months) with high doses of vitamin A at interval of 6 months, dietary diversification and food fortification [13,14]. In Nigeria, all these measures have been utilised but little report exists on the effect of these measures in eradicating VAD in the country [15]. Fortification programs are limited by technical issues associated with installation and maintenance of fortification machinery, non-compliance with fortification standards given by the Standard Organization of Nigeria as well as instability of fortificants during distribution and storage of fortified products [16-18]. Furthermore, many people are ignorant of the existence of food fortification, thus the rate at which fortified products are consumed is low. This prompted the bio-fortification of some staples including cassava as a cost effective and efficient means of combating VAD among deficient, poor and rural people who have limited access to other intervention measures. Bio-fortification of cassava enhanced the total carotenoid content of its fresh storage roots and changed its colour to yellow. This performs dual roles of reducing the rate of malnutrition among vitamin A deficient people and provides an efficient way of sustaining the enhanced nutritional condition. Meanwhile, the impact of any agricultural technology depends on the extent and scale of its adoption [19].

Notably, dry matter content of cassava is a vital trait of premium economic importance to farmers and processors. It influences adoption of new varieties as it directly determines product yield and consequently profitability [20, 10]. Specifically, *gari* yield of cassava varieties is linked to their dry matter content [21]. Rabbi et al. [22] and Bechoff et al. [23] reiterated that there appear to be a physical and genetic link between dry matter and carotenoid contents of cassava roots. Earlier, Graham et al. [24] averred that enhancing the β-carotene (highest carotenoid constituent of yellow root cassava varieties) content of cassava has no negative impact on its yield potential. Meanwhile, there exist conflicting reports in literature on influence of bio-fortification of cassava on its dry matter content. Beyeneet al. [25]; Bechoff et al. [23]; Peprah et al. [26] and De Carvalho et al. [27] reported inverse relationship between dry matter and carotenoid contents of some yellow root cassava varieties. Conversely, Sánchez et al. [28] and Ceballos et al. [29] observed positive relationship between TCC and DMC of some bio-fortified cassava genotypes. Sanchez et al. [30] and Ceballos et al. [31], after working on some cassava genotypes submitted that no correlation exist between DMC and TCC of cassava. Good understanding of the relationship between these two traits is therefore important in developing bio-fortified cassava germplasm with adequate levels of DMC.

Processing is an expedient integral component of cassava production system sequel to short shelf life of cassava fresh storage roots after harvest. Notably, in Nigeria and in West Africa at large, cassava processing focuses chiefly on *gari* production with only 30% of processed fresh storage roots devoted to other products. Some bio-fortified yellow root cassava varieties were released in Nigeria in 2011 and 2014. Limited information exists on the relationship between their total carotenoid content and each of their dry matter content and *gari* yield. Moreover, cassava yield, dry matter content and total carotenoid content are strongly influenced by interaction of genotype × environment. Therefore, this study was conducted to evaluate the dry matter content and *gari* yield of some elite yellow root cassava varieties (planted in an alfisol in Ibadan, South west Nigeria) in tandem with their total carotenoid content.

2. MATERIALS AND METHODS

The field experiments were conducted in 2018 and 2019 at the experimental site of the Department of Crop and Horticultural Sciences, University of Ibadan with the coordinate of Lat. N 007°27.134' and Long. E 003°53.425'. Previously, Orimoloye et al. [32] classified the soil at the site as alfisol. Using randomized complete block design, three of the six yellow root cassava varieties released in Nigeria between 2011 and 2014 (IBA070593, IBA070539 and IBA011368) and a white root variety (TMSI30572) were planted each in a plot of 30 m^2 at a spacing of 1 m × 1 m. The experiment was replicated three times. Twelve months after planting, the fresh storage roots were harvested and analysed for total carotenoid content following the procedure described by Bioanalyt [33]. About 5 g of each sample was weighed into a mortar and macerated using a pestle. The macerated samples were made into slurries by mixing with 20 mL of distilled water. These were transferred to graduated falcon tubes and shaken vigorously to create uniform mixture. With the aid of syringes, 0.4 mL of the slurry samples were transferred into reagent vials. The vials were shaken thoroughly for 10 seconds (to create uniform mixture) and then allowed to stand for about 5 minutes. The absorbance of each sample was read on the i-check device. The formula below was used to estimate the TCC of each sample:

Total carotenoid content = Dilution factor × Absorbance value

The dry matter content of each variety was also evaluated by weighing 100 g of chopped fresh storage roots. Subsequently, it was oven-dried at 105ºC for 72 hours and the dry weight was determined. The dry matter content was estimated using the formula:

$$\text{Dry matter content (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times \frac{100}{1}$$

Subsequently, the fresh storage roots of each variety (in their replicates) were processed into *gari* at the processing unit of the International Institute of Tropical Agriculture (IITA), Ibadan following the procedure described by James et al. [34]. The fresh storage roots were peeled with stainless steel knives, rinsed with portable clean water and grated mechanically with the aid of a petrol-powered rotating grating machine. The grated mashes were packed into woven bags, placed inside plastic buckets and left to ferment for 48 hours. Subsequently, the bags containing the grated mashes were arranged in metallic rack and pressed using hydraulic jack to enable simultaneous pressing and fermentation of the cassava mashes for 24 hours. The pressed mashes were pulverized using the grater and garified in rectangular pans (heated by firewood) made from stainless steel iron with chimney. The *gari* yield was estimated after garification. All data were subjected to descriptive statistics, analysis of variance and correlation analysis. Significant means were separated using least significant difference at 5% level of probability.

3. RESULTS

The effect of variety, season and variety × season on total carotenoid content, dry matter content and *gari* yield of the four cassava varieties were significant (Table 1).

Table 1. Combined analysis of variance for effect of variety and season on total carotenoid content, dry matter content and *gari* yield of four cassava varieties

Sources of variation	Degree of freedom	Total carotenoid content		Dry matter content		*Gari* yield	
		Sum of squares	Mean squares	Sum of squares	Mean squares	Sum of squares	Mean squares
Variety	3	366.25	122.08**	16.10	133.91***	5.03	1.68**
Season	1	5.78	5.78**	401.74	16.11*	1.92	1.92**
Variety × season	3	17.94	5.94**	166.73	55.58**	11.99	4.00**

, ** and * implies significant at 0.05, 0.01 and 0.001 levels of probability, respectively*

The total carotenoid content in fresh storage root of IBA070593 was highest (10.23 µg/g) and differed significantly from other varieties (Fig. 1). Conversely, the check variety (TMSI30572) had 0 µg/g total carotenoid content but significantly higher dry matter content (34.34%) and *gari* yield (3.40 t/ha) than all bio-fortified cassava varieties with the exception of IBA070593 for dry matter content (Figs 1 to 3). The range of the dry matter content and *gari* yield of the yellow root cassava varieties were between 24.63% (IBA070539) and 33.95% (IBA070593) and 2.20 t/ha (IBA070539) and 3.20 t/ha (IBA070593), respectively (Figs 2 and 3). The dry matter content and *gari* yield of the bio-fortified cassava varieties were relatively lower than the white root variety by percentages ranging between 1.14 and 28.28 and 5.88 and 35.29, respectively. Notably, the percentage difference in the two traits was independent of the magnitude of their total carotenoid content. Howbeit, total carotenoid content in the fresh storage roots correlated negatively with dry matter content (-0.22) and *gari* yield (-0.22) while strong positive correlation (0.69) was observed between dry matter content and *gari* yield (Table 2).

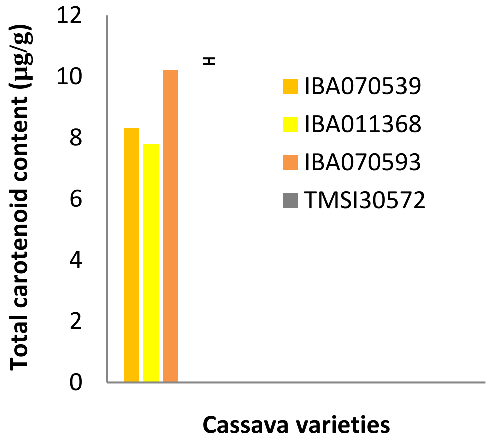

Fig. 1. Total carotenoid content (µg/g) of three yellow root cassava varieties and a white root variety harvested 12 months after planting

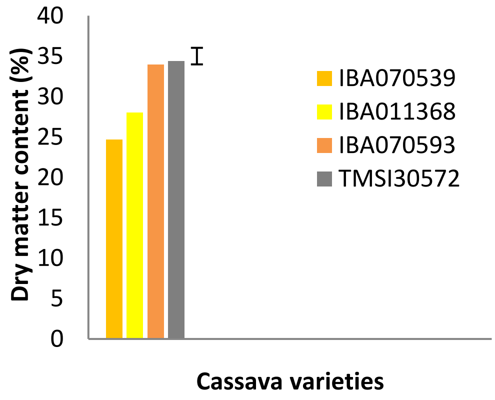

Fig. 2. Dry matter content (%) of three yellow root cassava varieties and a white root variety harvested 12 months after planting

4. DISCUSSION

Bio-fortification of cassava can address the nutritional security of farmers and Nigerians at large. To enhance better adoption of the yellow root cassava varieties by farmers and processors who ultimately determine the availability of cassava products in the market, there is need for adequate information on effect of increase in carotenoid content on dry matter content and *gari* (most consumed product of cassava) yield.

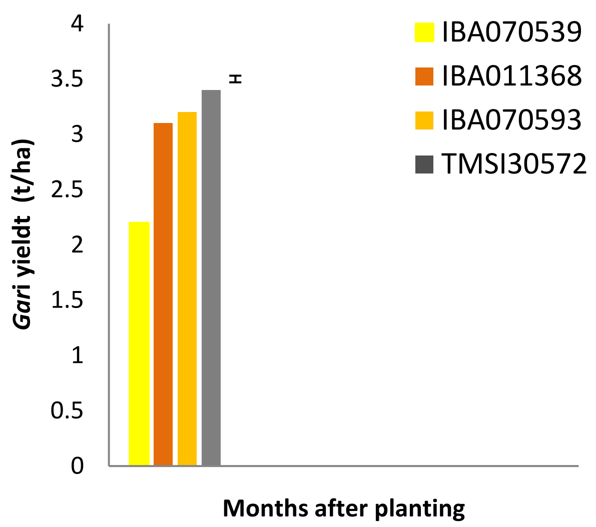

Fig. 3. *Gari* yield (t/ha) of three yellow root cassava varieties and a white root variety harvested 12 months after planting

Table 2. Pearson correlation coefficients for relationship between total carotenoid content of four cassava varieties and each of dry matter content and *gari* yield (N=24)

	Total carotenoid content	Dry matter content
Dry matter content	-0.22	
Gari yield	-0.22	0.69

The significant varietal difference in total carotenoid content, dry matter content and *gari* yield of the cassava varieties highlight the impact of genetic variation on these traits. This finding corroborates the analogous observations of Adetoro et al. [35]; Eyinla et al. [36] and Enesi et al. [37] from separate researches on cassava. The dry matter content of cassava varieties evaluated in this study contradicts the observation of De Oliveira et al. [38] who reported significantly comparable dry matter content for four cassava varieties they evaluated in their study. This discrepancy may not be unconnected to difference in cassava varieties evaluated in the two studies. The absence of carotenoids in white root check validates the earlier assertion of Gomes et al. [11] on most available white cultivars of cassava that they are devoid of carotenoid. This shows the vulnerability of farming families and households that depend on such varieties to VAD.

Vitamin A deficiency weakens the immune system and increase vulnerability to diseases and total or partial blindness. Nigeria was reported to have engaged over four millions farmers in cassava production [39]. Since good sight and healthy body are required for farming activities, VAD has the potential of reducing population of farmers in the country. Consequently, this poses a threat to national food security since the rural communities are the food basket of the nation, producing largest proportion of food in the country from their subsistent farm holdings. Bio-fortification of cassava is therefore appropriate, has itis the major staple of several Nigerians including farmers [40]. The enhanced total carotenoids content of the yellow root cassava varieties is evident in their yellowness and high carotenoid content in comparison to the check variety (Plate 1). This provides a means of making provitaminA carotenoids available to rural communities (at no extra cost) who might not be able to access or afford other VAD intervention measures like fortified food and supplements [40].

Plate 1. Fresh storage roots of white root (TMSI30572) and three bio-fortified yellow root (IBA070539, IBA011368 and IBA070593) cassava varieties

The dry matter content of cassava reflects its moisture content and simultaneously food, feed or industrial product yield.

The dry matter content of the four cassava varieties is within the range of 14.07% and 52.67% recorded by Peprah et al. [26] and De Carvalho et al. [27] for some cassava varieties including yellow root cassava varieties. Higher dry matter content of the white root check (TMSI30572) in comparison to the bio-fortified varieties aligns with the previous analogous observation of Bechoff et al. [41]. However, absence of significant difference between the dry matter content of varieties TMSI30572 and IBA070593 (which had the highest total carotenoid content) contradicts the submission of Rabbi et al. [22] and De carvalho et al. [22] who averred that achieving the combined attributes in African cassava germplasm had proven difficult. Conversely, the finding of IBA070593 combining high TCC and DMC affirms the earlier observations of Ceballos *et al*. [29]. The dry matter content of varieties TMSI30572 and IBA070593 are classified as high because the values are greater than 30% benchmark set by Braima et al. [42].

After processing, the quantity of *gari* obtained from cassava (*gari* yield) is of utmost economic importance to farmers and processors. *Gari* yield determines processors' profit and future demand for any newly released cassava variety for *gari* production [10, 20]. The lower *gari* yields of bio-fortified varieties when compared to that of white root check variety can be explained by the submission of Duah [43] who noted that yellow root cassava varieties tend to yield lower quantity of *gari*in comparison to conventional white cultivars due to their lower dry matter content. Lower dry matter content and resultant reduced *gari* yield of yellow root cassava varieties might result to their lower acceptability by processors [10, 20]. Howbeit, variety IBA070593 can offer the triple benefits of nutritional, food and financial security by providing enhanced provitamin A carotenoids; higher dry matter content and *gari* yield than other bio-fortified cassava varieties. It also has superior nutritional advantage over the white root variety though their dry matter content was significantly comparable.

The observed significant seasonal variation for the three traits suggests that the total carotenoid, dry matter content and consequently *gari* yield of the cassava varieties were influenced by possible variation in environmental conditions in the two seasons. Specifically, Bechoff et al. [23] submitted that seasonal variation depicts what happens in typical life scenario. This is sequel to the fact that cassava as well as other crops is exposed to diverse annual weather and environmental conditions which cannot be replicated in subsequent years. The significant effect of variety × season is in tandem with the observation of Peprah et al. [26] for dry matter content of some cassava but contradicts the report of the authors for their total carotenoid content.

Graham et al. [24] claimed that enhancing the β-carotene content of cassava has no negative impact on its yield potential. However, Rabbi et al. [22] and Bechoff et al. [23] established that there is physical and genetic link between dry matter and carotenoid content of cassava roots. The relationship between these two traits is important in developing bio-fortified cassava germplasm with adequate levels of dry matter content. The observed inverse relationship between total carotenoid and dry matter contentof the four cassava varieties suggest that bio-fortification increased the moisture content in the fresh storage roots of the cassava varieties. This finding is consistent with the compendium of several reports from some authors that cassava germplasm in Africa show existence of negative correlation between these two traits [44, 25, 23, 26 and 27] but negates the observations of Ceballos et al. [29] who recorded a combination of high total carotenoid and dry matter content for cassava. Notably, the correlation coefficients of -0.22 falls within the range of -0.22 and -0.59 documented previously in literature for some cassava varieties bio-fortified with PVACs [45, 44, 46, and 22]. The fact that the order of magnitude of TCC was not in tandem with the order of dry matter content in the cassava varieties implies that effect of bio-fortification on the dry matter content and consequently *gari* yield of each bio-fortified cassava variety was dependent on genetic make-up of the variety and not the quantity of total carotenoid in its fresh storage root. Positive correlation between dry matter content and *gari* yield reported in this study further corroborates earlier submission that *gari*yield of cassava varieties is a function of their dry matter content [22]. This highlights the need to improve the dry matter content of these bio-fortified cassava varieties in order to enhance their *gari* yield, acceptance and economic return to farmers and processors.

5. CONCLUSION

The bio-fortified cassava varieties have enhanced total carotenoid content butlower dry matter content and consequently *gari* yield than the white root variety which was devoid of carotenoid. The effect of enhanced total carotenoid content of the bio-fortified cassava varieties on these two traits was variety dependent. Variety IBA070593 had a good combination of high total carotenoid and dry matter content. The *gari* yield of this variety was also the highest among the bio-fortified varieties. Variety IBA070593 has prospect for food and nutritional security. It is therefore recommended for propagation and *gari* production. However, the dry matter content of all the yellow root cassava varieties should be improved to enhance their propagation by farmers who use preference of processors as a key driver for varietal adoption.

ACKNOWLEDGEMENT

The authors wish to appreciate the HarvestPlus Project and the Cassava Breeding Unit staff of IITA, Ibadan for providing the support for the total caronoid analysis.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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