Tandem effect of bio-fortification on Dry matter content and *gari* yield of some yellow root cassava varieties

Abstract

Bio-fortification of cassava increased its total carotenoid content (TCC); and may have boomerang effect on key quality traits of cassava like dry matter content (DMC). Meanwhile, dry matter content 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 dry matter content and *gari* yield. Three bio-fortified YRCVs (TMSl010593, TMSl011368 and TMSl010539) and a white root variety (TMSl30572) 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 analysis of variance at 5% level of probability and 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 TMSl010593 for DMC (33.95). Notably TMSl010593 had a good combination of high TCC and DMC. Relative percentage reduction in dry matter content and *gari* yield of the bio-fortified cassava varieties sequel to bio-fortification ranged between 1.14 (TMSl010593) and 28.28% (TMSl010539) and 5.88 (TMSl010593) and 35.29% (TMSl010539), respectively. The TCC of the fresh storage roots correlated negatively with DMC (-0.22) and *gari* yield (-0.22). Traits relating to DMC of yellow roots cassava varieties should be improved to enhance adoption and profit index of stakeholders in cassava production value chain.

Keywords: Dry matter content, Fresh storage roots, *Gari* yield, Total carotenoid content, Yellow root cassava varieties

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 (Osagie *et al*., 2017). 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 (Jarvis *et al*., 2012; Murpakati and Tanyaniwa, 2017). Millions of people in tropical countries depend on cassava for more than 25% of their daily caloric intake (Onyenwoke and Simonyan, 2014). 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 100 millions of the country's residents eat cassava in diverse forms at least 365 times in a year (Njoku and Muoneke, 2008). This drought resistant crop can also be stored in the ground and harvested when needed. Thus, providing households with an alternative when the harvest of other crops fails (Chantapransan and Wanapat, 2003; Aerni, 2006; Abdullahi *et al*., 2014). The high level of dependence of farming families and several Nigerians on cassava and its products makes them vulnerable to vitamin A deficiency (VAD) sequel to the absence of provitamin A carotenoids (PVACs) in most cultivated varieties (Gomes *et al*., 2016).

Globally, the prevalence of VAD had been mitigated through nutrition education on the benefit of breastfeeding, consumption of foods rich in PVAC by children, immunization of children (6-59 months) with high doses of vitamin A at interval of 6 months, dietary diversification and food fortification (Ortiz *et al*., 2011; Njoku *et al.*, 2011; Aniedu and Omodamiro, 2012). In Nigeria, all these measures have been utilized but little report exists on the effect of these measures in eradicating VAD in the country (Ilona *et al*., 2017). 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 (Darnton-Hill and Nalubola, 2002; Sanusi and Akinyele 2006; Uchendu *et al*., 2012; Ogunmoyela *et al*., 2013; Timotijevic and Timmer, 2013). Furthermore, Sanusi and Akinyele (2006) discovered that 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 cassava as a cost effective and efficient mean of combating VAD among deficient, poor and rural Nigerians 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 (Graham *et al*., 2001).

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 (Dixon *et al*., 2008; Teye *et al*., 2011). Specifically the differences in *gari* yield of some cassava varieties was linked to variation in their dry matter content (Amoah *et al*., 2010). Akinwale *et al*. (2010) and Bechoff *et al*. (2018) reiterated that there appear to be a genetic link between dry matter and carotenoid content of cassava roots. Earlier Graham *et al*. (2001) 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. Chimaobi *et al*. (2012), Failla *et al*. (2012) and Bechoff *et al*. (2018) reported inverse relationship between dry matter and carotenoid content of some yellow root cassava varieties. Conversely, Sánchez *et al*. (2010); Egesi *et al*. (2012); and Ceballos *et al.* (2013) observed positive relationship between TCC and DMC of some bio-fortified cassava. Ceballos *et al*. (2017) after working on hundreds of cassava genotypes submitted that no correlation exist between DMC and TCC of cassava. Understanding the relationship between these two traits is 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 shelflife of cassava fresh storage roots after harvest. Notably, in Nigeria and in west Africa at large cassava processing focuses chielfly on *gari* production with only 30% of harvested fresh storage roots devoted to other products. Some bio-fortified yellow root cassava varieties were released in Nigeria in the years 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 (including dry matter content) and total carotenoid 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.

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*. (2019) classified the soil at the site as alfisol. Using randomized complete block design, either of three yellow root cassava varieties (TMSl010593, TMSl011368 and TMSl010539) among the six released to Nigeria between 2011 and 2014 or a white root variety (TMSl30572) was planted per plot (30 m^2) using a spacing of 1 m × 1 m and replicated thrice. Twelve months after planting, the fresh storage roots were harvested and analysed for total carotenoid content by following the procedure described by Bioanalyt (2014). 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 well label 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 105 ºC 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* following the procedure described by James *et al*. (2012). 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.

Result

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). The total carotenoid content in fresh storage root of TMSl010593 was highest (10.23 µg/ g) and differed significantly from other varieties (Figure 1). Conversely, the check variety (TMSl30572) 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 TMSl010593 for dry matter content (Figures 1 and 2). The range of the dry matter content and *gari* yield of the yellow root cassava varieties were between 24.63% (TMSl010539) and 33.95% (TMSl010593) and 2.20 t/ ha (TMSl010539) and 3.20 t/ ha (TMSl010593), respectively (Figures 1and 2). Bio-fortified cassava varieties TMSl010593 and TMSl010539 had the least and highest relative percentage reduction in dry matter content and *gari* yield which ranged between 1.14 and 28.28% and 5.88 and 35.29%, respectively (Table 2). Notably, the percentage reduction 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) (Tables 3). Conversely, strong positive correlation (0.69) was observed between dry matter content and *gari* yield (Table 3).

Table 1: Combined analysis of variance for effect of variety and season on total caroteniod 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

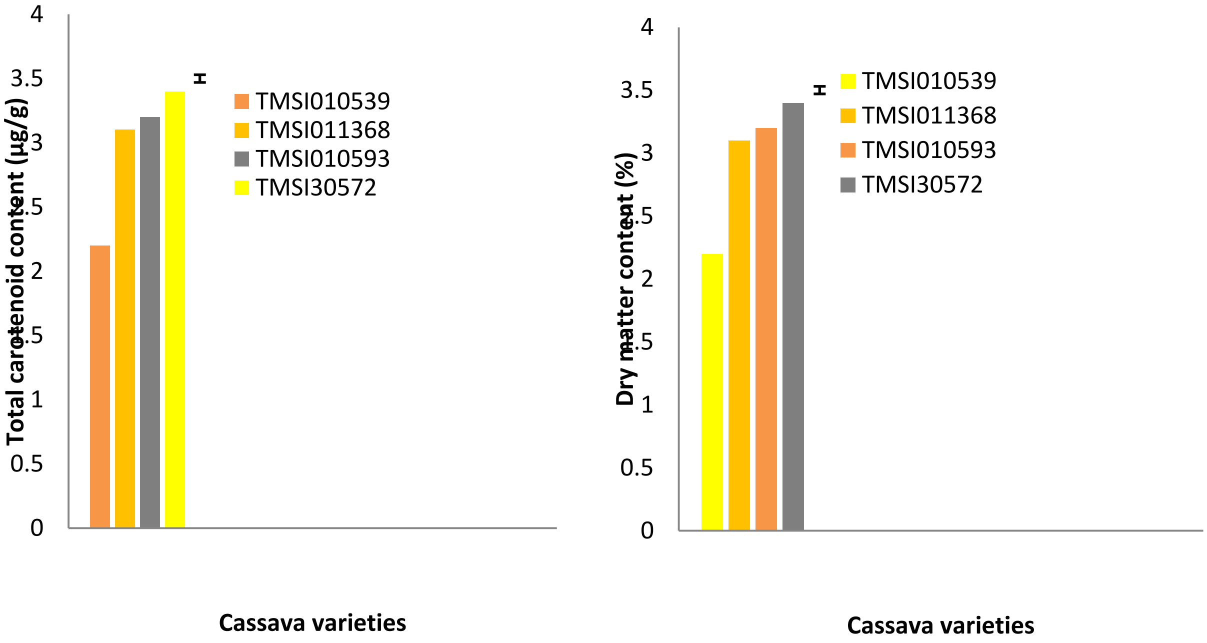

Figure 1: Total carotenoid and dry matter content of three yellow root cassava varieties and a white root variety harvested 12 months after planting

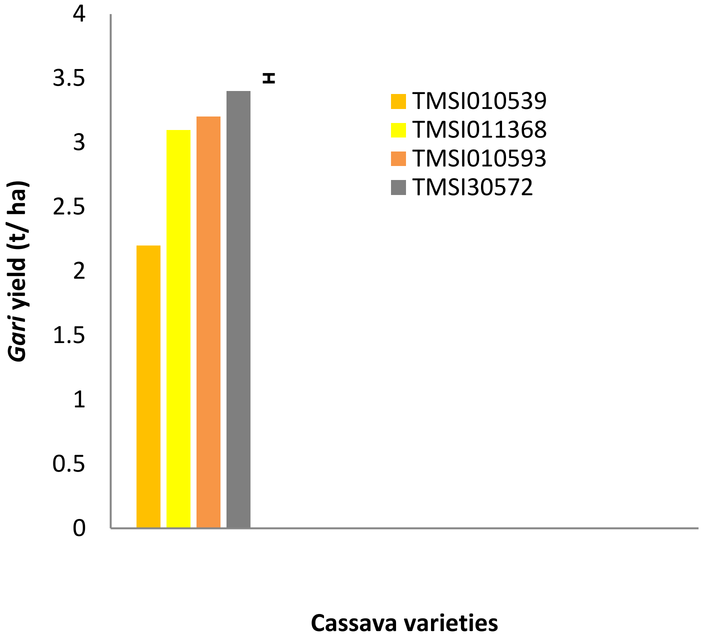

Figure 2: *Gari* yield (t/ha) of three yellow root cassava varieties and a white root variety harvested 12 months after planting

Table 2: Percentage reduction in dry matter content and *gari* yield of bio-fortified cassava varieties in relative to white root check

Varieties	Dry matter content	*Gari* yield
TMSl010539	28.28	35.29
TMSl011368	18.40	8.82
TMSl010593	1.14	5.88
TMSl30572	0	0

Table 3. Pearson correlation coefficients for relationship between total carotenoid content of four cassava varieties and each of dry matter content and *gari* yield

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

Discussion

Although bio-fortification of cassava can addresses the nutritional security of farmers and Nigerians at large, complementing information on its boomerang effect on dry matter content and *gari* yield can enhance better adoption of yellow root cassava varieties by farmers and processors, who ultimately determine the availability of cassava products in the market. 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 Amoah *et al*. (2010); Adetoro *et al*. (2018) and Eyinla *et al*. (2019) from separate researches. Conversely, the result on dry matter content contradicts the observation of De Oliveira *et al*. (2015) who reported significantly comparable dry matter content for four cassava varieties they evaluated in another study. This discrepancy may not be unconnected to difference in cassava varieties evaluated in the two studies. The absent of carotenoids in white root check validates the earlier assertion of Gomes *et al*. (2016) on most available cultivars of cassava. This shows the vulnerability of farming families to VAD since they are the primary consumers of their farm produce. Vitamin A deficiency weakens the immune system and increase vulnerability to diseases and total or partial blindness. 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 it is the major staple of several Nigerians including farmers. The enhanced total carotenoids content of the yellow roots 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 provitamin A carotenoids available to rural communities (at no extral cost) who might not be able to access or afford other VAD intervention measures like fortified food and supplements.

Plate 1: Fresh storage roots of white root (TMSl30572) and three bio-fortified yellow root (TMSl010539, TMSl011368 and TMSl010593) cassava varieties (from left to right)

The dry matter matter content of cassava reflects its moisture content and simultaneously food, feed or industrial product yield. (Aniedu and Omodamiro, 2012). Higher dry matter content of the white root check (TMSl30572) in comparison to the bio-fortified varieties aligns with the previous analogous observation of Bechoff *et al*. (2015). However, absence of significant difference between the dry matter content of varieties TMSl30572 and TMSl010593 (which had the highest total carotenoid content) contradicts the submission of Chimaobi *et al*. (2012) who asserted that achieving the combined attributes in cassava had proven difficult in Africa. Conversely, this finding affirms the earlier observations of Egesi *et al*. (2006) and Ceballos *et al* (2013). Notably, the dry matter content of varieties TMSl30572 and TMSl010593 are classified as high because they are greater than 30% as recommended by Braima *et al*. (2000). Meanwhile, the four cassava varieties had dry matter content that was within the range of 14% and 48% recorded by Sánchez *et al*. (2009) for 4044 cassava varieties but the dry matter content of the three yellow root cassava varieties were higher than the average dry matter content of 23% recorded by Njenga *et al*. (2010) for 129 bio-fortified cassava varieties.

After processing the quantity of *gari* obtained from cassava (*gari* yield) is of utmost economic importance to farmers and processor. *Gari* yield (GY) determines processors' profit and future demand for any newly released cassava variety for *gari* production. The lower yields of bio-fortified *gari* samples when compared to the white *gari* yield can be explained by the submission of Duah (2016) 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. Importantly, Bechoff *et al*. (2015) averred that the lower dry matter content and resultant reduced *gari* yield of yellow root cassava varieties might result to their lower acceptability by processors. The *gari* yield of the yellow root cassava varieties were lower than the range between 23-25% recorded by Adetoro *et al*. (2018) for some bio-fortified cassava varieties.

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. This finding corroborates the observation of Sobowale *et al*. (2010) and Becchoff *et al.* (2018) who evaluated some cassava varieties in different research. Specifically, Becchoff *et al*. (2018) submitted that the seasonal variation is more representative has it depicts what happens in typical life senerio. This is sequel to the fact that cassava as well as other crops as 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 Marova *et al*. (2012) who noted that the interaction of environment and genes significantly influenced the total carotenoid and dry matter content of some cassava.

Graham *et al*. (2001 claimed that enhancing the β-carotene content of cassava has no negative impact on its yield potential. However, Akinwale *et al*. (2010) and Bechoff *et al*. (2018) established that there exist genetic link between dry matter and carotenoid content of cassava roots. The relationship between these two traits is important in developing biofortified cassava germplasm with adequate levels of dry matter content. The observed inverse relationship between total carotenoid and dry matter content of 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 submissions of Chimaobi *et al*. (2012); Failla *et al*. (2012) and Bechoff *et al.* (2018) but negates the observations of Egesi *et al*. (2006) and Ceballos *et al*. (2013) who recorded a combination of high total carotenoid and dry matter content from different studies on cassava. Failla *et al*. (2012) opined that low dry matter content of bio-fortified cassava varieties rends the varieties moist and less acceptable. 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. Variation in rate of decline of dry matter content of bio-fortified varieties in relation to white root suggests that the varieties responded differently to bio-fortification with PVACs. The least relative percentage reduction in dry matter content of variety TMSl010593 despite its highest total carotenoid content highlights its dry matter stability following bio-fortification. Positive correlation between dry matter content and *gari* yield suggests that the yield of *gari* from the cassava varieties was a function of their dry matter content. This highlights the need to improve the dry matter content of these bio-fortified cassava varieties in order to enhance their *gari* yield and economic return to farmers and processors.

Conclusion

Bio-fortification enhanced the total carotenoid content of the yellow root cassava varieties but reduced their dry matter content and consequently *gari* yield when compared to the white root 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 TMSl010593 had a good combination of high total carotenoid content and dry matter content. The *gari* yield of this variety was also the highest among the bio-fortified varieties. Variety TMSl010593 has prospect for food and nutritional security. It is therefore recommended for propagation and *gari* production.

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