THE INFLUENCE OF DAYS AFTER PLANTING ON ROOT YIELD AND QUALITY OF ORANGE- AND PURPLE-FLESHED SWEETPOTATO (*Ipomoea batatas* (L.) Lam) CULTIVARS ASSESSED IN THE NORTHERN REGION, GHANA

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Abstract

Time to harvest sweetpotato is very important in determining root quality. The focus of this investigation was to assess the appropriate time to harvest orange-fleshed sweetpotato (denoted OFSP1, OFSP2, & OFSP3) and purple-fleshed sweetpotato (PFSP) cultivars. OFSP1, a released variety in Ghana, was compared with OFSP2, OFSP3 and PFSP for storage root quality parameters. OFSP2 and PFSP are new cultivars introduced to Ghana by Tuskegee University, while OFSP3, is a landrace. The study was carried out at the Savanna Agricultural Research Institute (SARI), Nyankpala, Ghana in August, 2013. The design was 4x4 factorial in a randomized complete block design. Four harvesting times, denoted by days after planting (DAP): 65, 95, 125 and 155, were assessed to establish the root quality parameters. Standard agronomic practices for sweetpotato cultivation were employed in this study. Storage root quality indices including storage root yield was quantified gravimetrically, while, β-carotene, dry matter, and starch were determined using near infrared reflectance spectroscopy. The highest root yield of 28.20 tha^{-1} was obtained at 125 DAP as compared to 65, 95 and 155 DAP, in the range of 5.77 to 19.34 tha^{-1}. Considering all the sweetpotato cultivars, OFSP1, on the average, had significantly ($p < 0.05$) the highest storage root yield (19.50 tha^{-1}) β-carotene (31.50 mg 100 g^{-1}), and sucrose (15.42 mg 100 g^{-1}). The PFSP recorded the highest dry matter (38.67 g 100 g^{-1}) and starch (67.59 g 100 g^{-1}), but was devoid of β-carotene. Roots harvested at 155 DAP had the highest β-carotene, about 18.50 mg 100 g^{-1} but only marginally different from the16.00 mg 100 g^{-1} of β-carotene in roots harvested at125 DAP. Roots harvested at 65 DAP had the least β-carotene concentration, 12.60 mg 100 g^{-1}. The four cultivars investigated in this study could be harvested at 125 DAP. The OFSP2, and PFSP cultivars could be considered as food crops in Ghana, especially in Northern Ghana.

Introduction

The prevalence of vitamin A deficiency (VAD) among infants and young children in sub-Saharan Africa is 44%, being two-fold higher than the category of being "severe" (World Health Organization, 2009). This situation is mainly due to poor intake of vitamin A-rich food. Most children affected by VAD experience poor growth and blindness (WHO, 2009). Many lives of children are lost in most sub-Saharan African countries as a result of VAD (Humphrey et al., 1992). In Ghana, the prevalence of VAD among children under five is as high as 76% (WHO, 2000).

Several efforts have been made to combat VAD. An example is the promotion of the consumption of meat, fish, eggs and other processed food products (Low et al., 2001). Additionally, United Nations Children Education Fund (UNICEF) introduced vitamin A capsules which are administered every six months at health centres (de Wagt, 2001). The limitation of the animal and animal-based product approach is that they are not readily available and the proportion consumed per meal is relatively small compared to the major staples like cereals, roots and tuber crops.

One major food crop that could complement the vitamin A supplementation in Africa to reduce the VAD menace is the orange-fleshed sweetpotato (OFSP). This variant of sweetpotato compared with the white-cream and yellow-fleshed cultivars contains a significant amount of β-carotene, which is a pro-vitamin A (Carey et al., 1999; Hagenimana and Low, 2000; Low et al., 2001, 2007). Consumption of 100 g of boiled and mashed OFSP cultivars, usually those with intense orange colour, could meet the daily vitamin A requirement of children less than five years old (Attaluri and Campilan, 2010; Carey et al., 1999). Apart from mashing, OFSP could also be used as a complementary food for infants, mostly in low-income countries (Amagloh, 2012). On the other hand, the purple-fleshed sweetpotato (PFSP) cultivars are well known to contain anthocyanins (Islam et al., 2002; Steed and Truong, 2008), which could be used to arrest cancer cells growth (Lim et al., 2013).

In Ghana, there is only one released OFSP variety, Apomuden (denoted as OFSP1 in this study). The Sustainable Technologies for Orange and Purple Sweetpotatoes (STOPS) project, led by researchers from Tuskegee University, USA, identified the gaps in the value chain from production, processing, product development to consumption of OFSP and PFSP aimed at addressing VAD and improving the health and nutritional status of the vulnerable population in rural communities of Ghana. This project introduced OFSP and PFSP cultivars to Ghana, but they are yet to be evaluated for agronomic traits. This study, therefore, assessed the root quality of these introduced sweetpotato cultivars to set the background information required for extensive research for their evaluation for release as varieties in Ghana.

The objective of the study was to assess the root quality (storage root yield, β-carotene, dry matter, starch, fructose, glucose and sucrose) from OFSP2, OFSP3 and PFSP in comparison with OFSP1 as affected by different days after planting (DAP).

Materials and Methods

Experimental site and design

This study was carried out on the research fields at the Council for Scientific and Industrial Research-Savanna Agricultural Research Institute (CSIR-SARI), Nyankpala, Ghana. The research field is characterised by sandy loam soil, with average minimum and maximum temperatures of 23°C and 34°C during the study period, which was the growing season of 2013. The relative humidity for the period ranged between 56% and 79%.The annual total rainfall recorded was 1079 mm.

The experimental layout was 4×4 factorial in a randomised complete block design, with three replications. The main plots were made up of 4 rows of ridges, each measuring 12 m long. The ridges were made using spacing of 1 m apart. The main plots were split into 4 subplots, representing the 4 harvest dates. The trial was laid in 3 replications.

Cultivar description, planting and harvesting regimes

OFSP1, as mentioned earlier, is the only released OFSP variety in Ghana with deep orange colour of the flesh. OFSP2 and PFSP are respectively pale orange- and purple-fleshed sweetpotato variants introduced to Ghana on the STOPS Project described above. OFSP3 is a farmer variety grown in the Kumbungu District, Northern Region, Ghana, but its flesh colour is yellow with deep orange patches. Figure 1 below shows the cultivars investigated in this study.

After ploughing and preparation of ridges, vine cuttings of each cultivar were planted on top of the ridges using a spacing of 0.30 m within rows, each vine cutting (with at least 4–5 nodes) was planted by burying 2–3 nodes into the soil.Data were collected on the plant stands in the two middle rows of each subplot. The four cultivars (Figure 1) of sweetpotato served as the main plots, upon which the 4 different harvesting dates after planting, denoted as 65, 95, 125 and 155 DAP were randomly assigned to the experimental treatments considered. All cultural practices for sweetpotato cultivation were observed, except soil amendment.

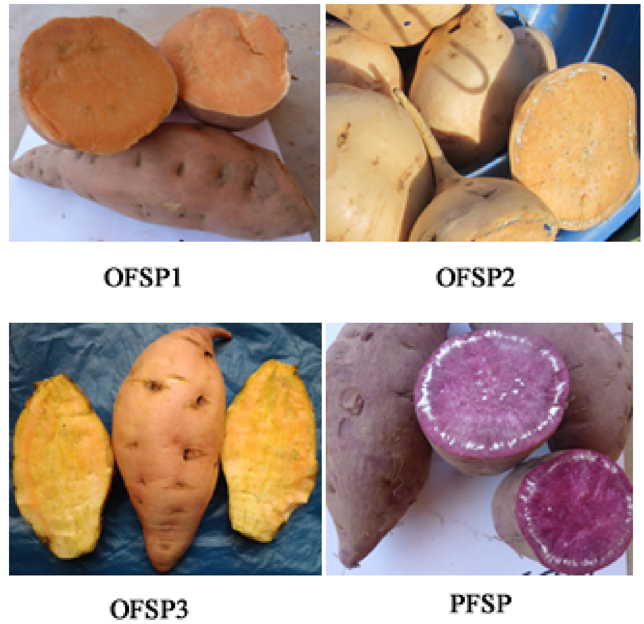

Figure 1. The sweetpotato cultivars evaluated in the study

OFSP1:Apomuden, a released OFSP variety in Ghana

OFSP2: Pale orange-fleshed sweetpotato variant introduced to Ghana through the STOPS project

OFSP3: Farmer sweetpotato variety grown in the Kumbungu District, Northern Region, Ghana

PFSP: Purple-fleshed sweetpotato variant introduced to Ghana through the STOPS project

Root yield

After each harvest, all marketable roots were washed with running water and weighed using a top pan weighing scale (Camry TNO 1215169). Root yield (tha^{-1}) was calculated using Equations 1 and 2.

$$kgha^{-1} = \frac{10,000}{Area\ harvested} \times Root\ yield\,(kg) \tag{1}$$

where $kgha^{-1}$: kilogram per hectare.

$$Metric\,ton\ per\ hectare(tha^{-1}) = \frac{Kilogram\ per\ hectare}{1,000} \tag{2}$$

Compositional Analysis:

β-carotene, dry matter, starch, fructose, glucose and sucrose

Near Infrared Reflectance Spectrometer was used as reported elsewhere (Shenk andWesterhaus,1993) for the nutritional analysis. A maximum of 3 roots, categorised as small, medium and large, were purposely sampled for the compositional analyses. These selected roots were packed into brown paper bags immediately after harvest and transported to the laboratory for analysis. The sampled roots were washed with running water, and peeled, then further washed in deionised water, quartered longitudinally with a stainless steel kitchen knife and sliced into smaller pieces using a potato slicer to get a homogenous sample.

Approximately 50 g of the sliced roots per cultivar were placed in separate zip locked bags and frozen at -20°C prior to freeze-drying. The frozen samples were freeze-dried for 72 hours using the TK-118 Vacuum Freeze-Dryer. The freeze-dried samples were crushed into smaller sizes manually, and milled into flour using a stainless steel mill (3383-L70, Thomas Scientific, Dayton Electric Manufacturing Company Limited, Niles, IL 60714, USA) and sieved through a 60 mm mesh screen. The flour from the mill was collected in zip locked bags, and 5g of each samples were placed into cuvettes and loaded into the XDS Rapid Content Analyzer to scan for β-carotene, dry matter, starch, fructose, glucose and sucrose.

Statistical Analysis

All the data generated were subjected to analysis of variance (ANOVA) using Minitab ® 16.2.2 (Minitab Inc., State College, PA, USA). Treatments were the cultivars and the four harvest intervals (65, 95, 125 and 155 DAP) were the blocking factor. Treatments were separated using the Tukey's studentised range test at ($p < 0.05$) to determine significant levels. Results were presented in Figures.

Results

Root yield

Generally, storage root yield increased from 5.77 tha^{-1} at 65 DAP to 28.11 tha^{-1} at 125 (Figure 2). There was a decline in all the cultivars except the PFSP cultivar that had the same storage root yield at 155 DAPas it had at 125 DAP, that was 23.56 tha^{-1}.

All the cultivars had the highest storage root yield at 125 DAP. Among the cultivars, OFSP1 recorded the highest root yield of 28.20 tha^{-1} at 125 DAP. The least root yield of 14.88 tha^{-1} was observed with OFSP3.

β-carotene

Figure 3 shows the accumulation of β-carotene concentration in sweetpotato roots was significant (p = 0.01) and increased with DAP. The PFSP was completely devoid of β-carotene.

For the three OFSP cultivars, the β-carotene concentrations, on the average, significantly increased consistently from 16.84 to 24.74 mg 100 g^{-1} from 65 to 125 DAP ($p < 0.05$). Similarly, there were significant differences among the cultivars. For the three OFSP cultivars, OFSP1 had the highest β-carotene content of 31.5 mg 100 g^{-1} followed by OFSP2 with 20.6 mg 100 g^{-1}. OFSP3, the farmer cultivar, had the least β-carotene content at all the DAPs considered.

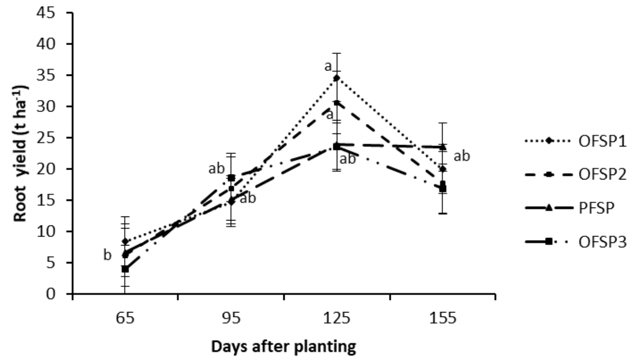

Figure 2. Storage root yield as influenced by days after planting among four sweetpotato cultivars

Values are means of triplicate ± standard error of means

Means with the same letters are not significantly different ($p > 0.05$)

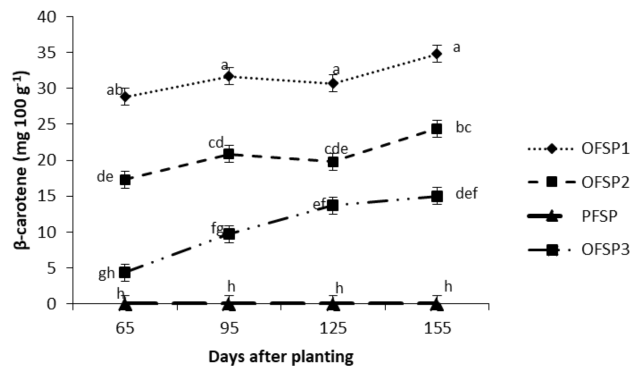

Figure 3. *beta*-carotene content in storage roots as influenced by days after planting among four sweetpotato cultivars

Values are means of triplicate ± standard error of means

Means with the same letters are not significantly different ($p > 0.05$)

Dry matter

Dry matter for OFSP1 and OFSP2 increased with harvest time up to 125 DAP and declined at 155 DAP. PFSP and OFSP3 did not follow this trend. For these cultivars, after 95 DAP there was a decline in percentage dry matter (Figure 4). Dry matter observed at 125 DAP was high (34%) compared with 95 (33%), 65 (31%) and 155 (29%) DAP, respectively (Figure 4). There were also significant differences among the cultivars. The PFSP had the highest dry matter content of 39%. OFSP3 and OFSP2 recorded 36% and 28%, respectively. The cultivar with the least dry matter content of 24% was OFSP1. These results further show that, overall, there is no appreciable increase in percent dry matter beyond 95 DAP.

Starch

As shown in Figure 5, there were significant differences (p = 0.01) in starch content among the DAP. It increased from 62% to 65% from 65 to 95 DAP.

Starch content then decreased to 63% at 125 DAP. It further declined to 58% at 155 DAP. Among the cultivars, there was

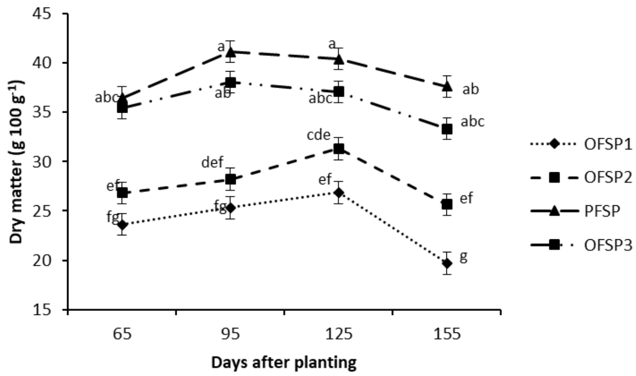

Figure 4. Dry matter content of storage roots as influenced by days after planting among four sweetpotato cultivars

Values are means of triplicate ± standard error of means.
Values followed by different lowercase superscript letters are significantly different (p = 0.01)

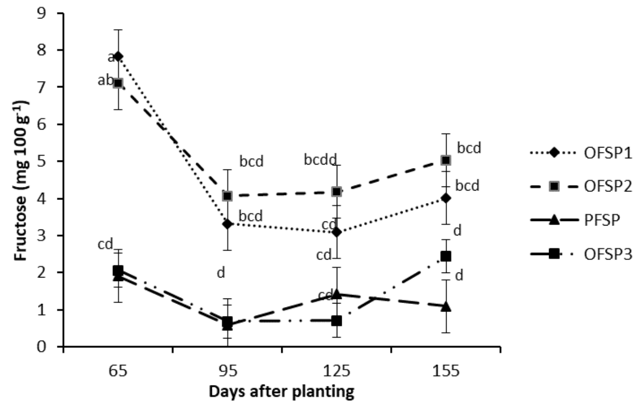

Figure 6. Fructose level in storage root as influenced by days after planting among four sweetpotato cultivars

Values are means of triplicate ± standard error of means
Means with the same letters are not significantly different (p > 0.05)

significant difference at (p = 0.01). PFSP had the highest starch content of 68%. OFSP3 and OFSP2 recorded 66% and 60% respectively. The cultivar with the least starch content was OFSP1 with 54%.

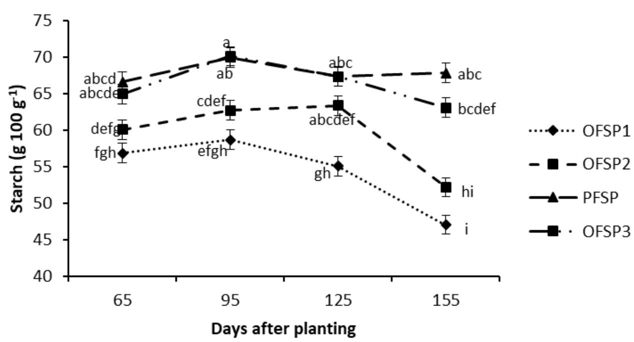

Figure 5. Starch content in storage rootas influenced by days after planting among four sweetpotato cultivars

Values are means of triplicate ± standard error of means
Means with the same letters are not significantly different (p > 0.05)

Fructose

Figure 6 shows that fructose content was significantly affected (p = 0.01) among DAP. It was observed to be 4.2 mg 100 g^{-1} at 65 DAP. Fructose content then declined to 2.2 and 2.1 mg 100 g^{-1} at 125 and 95 DAP respectively. Among the cultivars, OFSP1 recorded 5.1 mg 100 g^{-1}, being the highest, followed by OFSP2 with 4.6 mg 100 g^{-1}. OFSP3 recorded a fructose content of 1.5 mg 100 g^{-1} while PFSP had the lowest of 1.2 mg 100 g^{-1}.

Glucose

The trend observed in glucose was similar to fructose as shown in Figure 7. Glucose content observed was 8 mg 100 g^{-1} at 65 DAP. It then declined to 3.7 and 3.3 mg 100 g^{-1} at 95 and 125 DAP respectively. At 155 DAP, glucose content increased to 5.8 mg 100 g^{-1}. Among the cultivars, glucose content was significantly different (p = 0.01). OFSP2 and OFSP1 recorded high glucose content of 7.6 and 7.3 mg 100 g^{-1} respectively. The cultvars with the lowest glucose content, PFSP and OFSP3 recorded 3.9 and 3.4 mg 100 g^{-1} respectively.

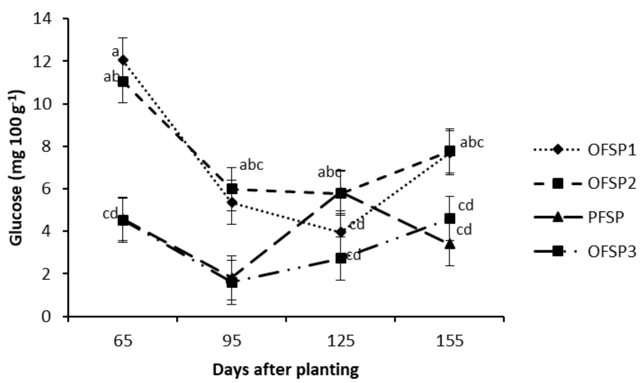

Figure 7. Glucose level in storage root as influenced by days after planting among four sweetpotato cultivars

Values are means of triplicate ± standard error of means
Means with the same letters are not significantly different (p > 0.05)

Sucrose

The highest sucrose content was 16.2 mg 100 g^{-1} observed at 155 DAP (Figure 8). At 125 and 95 DAP sucrose content was 14.2 and 12.5 mg 100 g^{-1} respectively.
It was lowest (7.9 mg 100 g^{-1}) at 65 DAP. Among the cultivars, OFSP1 recorded the highest sucrose content of 15.4mg 100 g^{-1}. OFSP2 and OFSP3 recorded 12.3 and 11.99 mg 100 g^{-1} respectively. The least sucrose content of 11.2 mg 100 g^{-1} was observed in PFSP.

Discussion

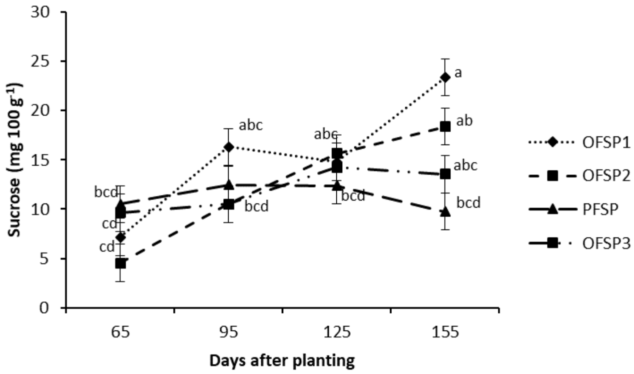

Figure 8. Sucrose level in storage root as influenced by days after planting among four sweetpotato cultivars

Values are means of triplicate ± standard error of means

Means with the same letters are not significantly different ($p > 0.05$)

Storage root yield

Generally, root yield increased regardless of cultivar used up to 125 DAP but declined thereafter. Ironically, 155 DAP did not record the highest storage root yield in this study as reported by Noda et al. (1997) that high root yield was obtained as long as they remained in the ground. However, the findings of this study confirm other studies that the highest storage root yield was observed at 120 DAP (Alcoy et al., 1993; Mitra et al., 2010). The decrease in storage root yield in this study may not be physiological, but rather physical, due to weevil infestation. This infestation increases with maturity as a result of soil cracks due to bulking; as the soil cracks, the weevils are able to get access to the exposed storage roots. This suggests that a delay in harvesting some cultivars leads to a decrease in root yield (Alcoy et al., 1993).

Among all the cultivars investigated, the similar storage root yield for PFSP cultivar at both 125 and 155 DAP may suggest that it may be more resistant to weevil damage than the others.

β-carotene

β-carotene content increased significantly with harvest time. However, it was observed in other studies by Mitra et al. (2010) that β-carotene content declined after 105 DAP in some sweetpotato cultivars. Other results also corroborated this trend, when Carey et al. (1999) and K'osambo et al. (1999) conducted studies and observed β-carotene decline after 140 DAP in some sweetpotato cultivars. These could be attributable to cultivar differences.

PFSP cultivar was devoid of β-carotene, being contrary to the findings of Grace et al. (2014) that NCPUR06-020PFSP cultivar showed an amount of 1.0 μg/g of β-carotene content at harvest and decreased to 0.5 after being stored for eight months. Among the OFSP cultivars, it was OFSP1 that had the highest β-carotene content and OFSP3 the lowest. OFSP2 had a relatively low level of β-carotene. This variation in β-carotene content was expected among cultivars as has been observed in similar studies (Carey et al., 1999; Woolfe, 1992).

Dry matter

The current results support earlier findings that dry matter content was high at 120 DAP (Mitra et al., 2010). The low dry matter content observed at 155 DAP could be due to weevil damage on roots as suggested by other researchers (Alcoy et al., 1993; Mitra et al., 2010) because the number of wholesome storage roots to sample is limited. The higher dry matter content of PFSP than the OFSP cultivars observed in this study lend support to earlier studies (Grace et al., 2014; Steed and Truong, 2008). The current study showed that cultivars with high β-carotene content tend to have low dry matter content.

Starch

Mitra et al. (2010) and Woolfe (1992) opined that starch content in storage roots will continue to increase as it remains in the ground. Thus, maximum starch content was expected at 155 DAP as compared with the earlier harvest. The present finding does not support this suggestion as starch content started to decline from 95 to 155 DAP. It rather confirms other previous findings of Reynolds et al. (1994) that starch accumulation in sweetpotato roots ceases after some period of growth. The trend of starch content among the cultivars was not different from that of the dry matter. This agrees with previous findings that cultivars with good dry matter content perform well with respect to starch accumulation (Mitra et al., 2010).

The data on β-carotene, dry matter and starch levels tend to support earlier studies that there was a direct correlation between dry matter and starch, but both have an inverse relation with β-carotene as starch and β-carotene are formed in the same plastids.

Fructose, glucose and sucrose

The decrease in the monosaccharides (fructose and glucose), and the increase in sucrose (disaccharide) was reported in another study (Adu-Kwarteng et al., 2014). It appears that the monosaccharides were converted to disaccharide as the storage roots matured as suggested by other workers (Adu-Kwarteng et al., 2014; Reynolds et al., 1994). The present findings were contrary to a previous report that cultivars with good dry matter tend to give high sugar content (Adu-Kwarteng et al., 2014).

Conclusion

OFSP1 had the highest β-carotene, sucrose and root yield when evaluated. Fructose was high in OFSP2. The PFSP recorded the highest dry matter and starch. It was however devoid of β-carotene. Among DAP, β-carotene was highest at 155 and the least was 65 DAP. The highest root yield was observed at 125 DAP as compared to 65, 95 and 155 DAP. The cultivars could be harvested at 125 DAP since that harvest time recorded good root yield and β-carotene content. OFSP2, OFSP3 and PFSP produced good quality roots and could be released as food crops in Northern Ghana.

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References

Adu-Kwarteng, E., Sakyi-Dawson, E. O., Ayernor, G. S., Truong, V.-D., Shih, F. F., and Daigle, K. (2014). Variability of sugars in staple-type sweetpotato *(Ipomoea batatas)* cultivars: the effects of harvest time and storage. *International Journal of Food Properties*, 17(2):414–417.

Alcoy, A., Garcia, A., Baldos, D., Robles, R., Cuyno, R., et al. (1993). Influence of planting material and time of harvest on plant to plant yield variability of sweet potato (ipomoea batatas (l.) lam). *Philippine Journal of Crop Science*, 18(3):190–193.

Amagloh, F. K. (2012). *Sweetpotato-based complementary food for infants in Ghana: a thesis presented in fulfilment of the requirements for the degree of Doctor of Philosophy in Human Nutrition*. PhD thesis, Massey University, Palmerston North, New Zealand.

Attaluri, S. and Campilan, D. (2010). Orange-fleshed sweetpotatoes for improved health and nutrition in Orissa. Bhubaneswar, Orissa, India.

Carey, E., Oyunga, M., K'osambo, L., Smit, N., p' Obwoya, C., Turyamureeba, G., Low, J., and Hagenimana, V. (1999). Using orange-fleshed sweetpotato varieties to combat vitamin A deficiency and enhance market opportunities for smallholder farmers in Sub-Saharan Africa. In Akorodan, M. O. and Teri, J. M., editors, *Food security and derversification in SADC countries: The role of casava and sweetpotato*, 17-19 August,1998, Pamodzi Hotel, Lusaka, Zambia.

de Wagt, A. (2001). Vitamin A deficiency control programs in Eastern and Southern Africa: A UNICEF perspective. *Food and Nutrition Bulletin*, 4(22):8–9.

Grace, M. H., Yousef, G. G., Gustafson, S. J., Truong, V.-D., Yencho, G. C., and Lila, M. A. (2014). Phytochemical changes in phenolics, anthocyanins, ascorbic acid, and carotenoids associated with sweetpotato storage and impacts on bioactive properties. *Food Chemistry*, 145:717–724.

Hagenimana, V. and Low, J. (2000). Potential of orange-fleshed sweet potatoes for raising vitamin A intake in Africa. *Food and Nutrition Bulletin*, 21(4):414–418.

Humphrey, J., West Jr, K., and Sommer, A. (1992). Vitamin A deficiency and attributable mortality among under-5-year-olds. *Bulletin of the World Health Organization*, 70(2):225.

Islam, M. S., Yoshimoto, M., Terahara, N., and Yamakawa, O. (2002). Anthocyanin compositions in sweetpotato (*Ipomoea batatas* L.) leaves. *Bioscience, Biotechnology, and Biochemistry*, 66(11):2483–2486.

K'osambo, L., Carey, E., Misra, A., Wilkes, J., and Hagenlmana, V. (1999). Influence of age, farming site, and boiling on pro-vitamin A content in sweet potato (*Ipomoea batats* (L.) Lam.) storage roots. *Journal of Food Technology in Africa*, 4:77–84.

Lim, S., Xu, J., Kim, J., Chen, T.-Y., Su, X., Standard, J., Carey, E., Griffin, J., Herndon, B., Katz, B., et al. (2013). Role of anthocyanin-enriched purple-fleshed sweet potato p40 in colorectal cancer prevention. *Molecular Nutrition & Food Research*, 57(11):1908–1917.

Low, J., Walker, T., and Hijmans, R. (2001). The potential impact of orange-fleshed sweet potatoes on vitamin A intake in Sub-Saharan Africa. In *A paper presented at a regional workshop on food based approaches to human nutritional deficiencies*, pages 9–11.

Low, J. W., Arimond, M., Osman, N., Cunguara, B., Zano, F., and Tschirley, D. (2007). A food-based approach introducing orange-fleshed sweet potatoes increased vitamin A intake and serum retinol concentrations in young children in rural Mozambique. *The Journal of Nutrition*, 137(5):1320–1327.

Mitra, S., Tarafdar, J., and Palaniswami, M. (2010). Impacts of different maturity stages and storage on nutritional changes in raw and cooked tubers of orange-fleshed sweet potato *(Ipomoea batatas)* cultivars. *ActaHorticulturae (ISHS)*, 858:205–212.

Noda, T., Takahata, Y., Sato, T., Ikoma, H., and Mochida, H. (1997). Combined effects of planting and harvesting dates on starch properties of sweet potato roots. *Carbohydrate Polymers*, 33(2-3):169–176.

Reynolds, L., Rosa, N., and McKeown, A. (1994). Effects of harvest date on certain chemical and physical characteristics of sweet potato grown in southwestern Ontario. *Canadian Journal of Plant Science*, 74(3):603–606.

Steed, L. and Truong, V.-D. (2008). Anthocyanin content, antioxidant activity, and selected physical properties of flowable purple-fleshed sweetpotato purees. *Journal of Food Science*, 73(5).

Woolfe, J. A. (1992). *Sweet potato: an untapped food resource*. Cambridge University Press.

World Health Organization (2000). Nutrition for Health and Development: A global agenda for combating malnutrition. France.

World Health Organization (2009). *Global prevalence of vitamin A deficiency in populations at risk 1995-2005: WHO global database on vitamin A deficiency*. Geneva: World Health Organization.