https://dx.doi.org/10.4314/gjas.v56i1.2

Yield, biochemical properties and cooking quality traits of sweet potatoes (*Ipomoea batatas*) as affected by Nitrogen and Potassium Fertilizer rates

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ABSTRACT

This study evaluated the effects of mineral fertilizer rates on biochemical properties, cooking quality traits and root yield of sweetpotatoes. The experimental design was 4 x 4 factorial in randomized complete block with three replications. The treatment factors were four varieties of sweetpotato (*Ligri, Bohye, Dadanyuie* and *Apomuden)* and four fertilizer amendments (T1: 30-30-30 kg /ha NPK, T2: 30-30-60 kg NPK+50 kg Muriate of Potash, T3: 30-30-90 kg/ha NPK+ 100 kg Muriate of Potash and T4: Control (No fertilizer). Results showed that the fertilizer rates did not influence root yield but variety had significant difference (P<0.05). *Apomuden* recorded the highest average root yield of 14.5 t/ha which was significantly higher than *Ligri* 5.1 t/ha. *Ligri* recorded the highest dry matter and sugar contents of 34.63% and 67.98% respectively while *Apomuden* recorded the lowest dry matter content and starch content of 23.75% and 50.00% respectively. However, it recorded appreciable amount of beta-carotene and sugar contents of 32.38 mg/100g and 28.04% respectively. There were significant variety × location interactions effect (P < 0.05) on average root yield and biomass yield. The significant varietal response observed in this study implies that choice of variety is an important factor to consider in sweetpotato production.

Keywords: Food security; malnutrition; yield; cooking quality traits; biochemical traits; sweet potatoes

Original scientific paper. Received 20 Aug 2020; revised 28 Apr 2021

Introduction

Malnutrition caused by deficiency of vitamin A is a widespread phenomenon among many people in sub-Saharan Africa, including Ghana. This is because most of the cereals and the root and tuber crops consumed have low vitamin A (Obeng-Bio, 2018). A considerable proportion of the people, therefore, do not have access to nutritionally adequate food to guarantee healthy living (Waha *et al.,* 2018). The quality of protein in food consumption in Ghana is low resulting in high mortality of children under five years due to undernutrition (FAO, 2009; GFSI, 2012). In addition, majority (<40%) of the people cannot afford alternative protein sources such as animal products and vitamin A supplementation. There is an urgent need to identify alternative food sources that can provide essential vitamins (vitamin A) to achieve better nutritional status for the population. CSIR-Crops Research Institute (CSIR-CRI) in collaboration with its partners have developed a couple of high-yielding, early maturing and vitamin-rich varieties of sweetpotato (Baafi *et al.,* 2016). The potential exists to include high-nutrient sweetpotatoes like orange-fleshed varieties in the diet of the people as an alternative staple food source to curb malnutrition.

Sweetpotato (*Ipomoea batatas)* ranks fifth most important food crop in developing countries (Hoppenstedt *et al.,* 2017). In sub-Saharan Africa, it is the third most important root crop after cassava and yam (Ewell & Mutuura, 1994). It has high nutrient content which, outranked most carbohydrate foods in terms of vitamins, minerals, protein, and energy content (Onuh *et al.,* 2005). The crop has become one of the most promising sources of beta-carotene especially the orange fleshed varieties that have high Vitamin A content (Neela & Fanta, 2019). The crop is also used to make snacks and desserts such as pies, puddings, biscuits, cakes, crisps, mandazis and chapatis (Dumbuya *et al.*, 2016). Despite all these benefits, root yield of sweetpotatoes remains low (7 kg/ha) as against the potential yield of 18 to 24 kg/ha in Ghana (CRI, 2000).

The use of soil amendments such as fertilizer to increase crop productivity is very critical. Research has shown that field experiments using soil amendments improved the yield of sweet potatoes without compromising on quality (Brobbey, 2015; Ennin *et al.,* 2007). Nitrogen and potassium are important factors affecting yield and nutrient composition of root tubers, especially sweetpotatoes (Kareem, 2013). Nitrogen application on sweet potatoes was shown to linearly increase dry matter, carotenoid and protein contents of sweetpotatoes (Constantin *et al.,* 1984). Nitrogen and potassium fertilizers are important for sweet potato in most depleted soils in the tropics, but whether application rates could affect the biochemical properties and cooking quality traits is unknown. Human health throughout the food value chain is of great concern as consumers have become health conscious. This study therefore, seeks to evaluate the effect of mineral fertilizer rates on biochemical properties, cooking quality traits and root yield of the improved sweetpotato varieties.

Materials and Methods

Experimental Site

The study was conducted in May, 2016 at CSIR-Crops Research Institute experimental field at Fumesua (6°45'00.58" N; 1°31'51.28" W) in the semi-deciduous forest zone and Ejura (7°24'46.73" N; 1°24'00.76"W) in the forest-savannah transition zone during the major raining season. The rainfall pattern in the two study areas is bimodal with major (April-July) and minor (September-November). Detailed soil physico-chemical properties, agroclimatic conditions and cropping history of the study area can be found in Darko *et al.* (2020).

Experimental Design

The experiment design was 4 x 4 factorial in randomized complete block, with three replications. The four varieties of sweet potato used were *Ligri, Bohye, Dadanyuie* and *Apomuden* and four fertilizer amendments were T1: 30-30-30 kg /ha NPK; T2: 30-30-60 kg NPK+50 kg Muriate of Potash; T3: 30-30-90 kg/ha NPK+ 100 kg Muriate of Potash and T4: Control (No fertilizer applied), where T1 to T4 represent treatments.

Land preparation
Field preparation included slashing, ploughing and harrowing with a tractor and the plots were prepared into ridges using hoes and garden lines. Each plot measured 4 × 4 m with 1 m space between rows and 0.3 m within rows. The length of a ridge was 4 m long, giving 12 plants per ridge.

Planting materials
Planting materials were obtained from Root and Tuber Division of CSIR-Crops Research Institute, Fumesua. Multiplication of the vine was done eight weeks prior to planting. Vine cutting used was 30 cm long having four or five nodes and planting was done manually.

Fertilizer application
The fertilizers used were NPK 15-15-15 and Muriate of Potash (60% K_2O). Fertilizer application of 200 kg NPK/ha 15-15-15 (30-30-30 kg/ha NPK) was manually applied four weeks after planting on all the plots except the control. The second application was done eight weeks after planting as top dressing, using the sole potassium fertilizer (Muriate of Potash, 60% K_2O) where 30 kg and 60 kg of sole muriate of potash was added to treatments 2 and 3 increasing the number of potassium contents.

Soil Sampling and Analysis
Initial soil samples for analysis of physical and chemical properties were collected at 0-15 cm and 15-30 cm depth with the aid of a soil auger. The soil pH was measured using glass electro-calomel with a pH-meter on a 1:2.5 soil/water suspension (Daniels, 2016). Soil organic carbon was determined using the Walkley-Black method (Daniels, 2016). Total nitrogen was determined by the Kjeldahl digestion and distillation procedure (Daniels, 2016). Bray and Kurtz's method no.1 extract and Nelson and Sommers were used to determine the available phosphorus (Daniels, 2016). Potassium and sodium were determined by flame photometer procedure, whereas calcium and magnesium were determined by using ethylene diamine tetra acetic acid titration (Miller & Arai, 2017).

Root yield
The root yield was determined by harvesting all the plants within the middle rows that were tagged. The harvested plants were counted, weighed and extrapolated per hectare using the equation below:

$$\text{Root yield(kg/ha)} = \frac{\text{Root yield}}{\text{Area}} \text{x} 10{,}000\,\text{m}^2 \quad [1]$$

Biomass yield
The above-ground biomass was computed using Equation 2

$$\text{Biomass yield} = \frac{\text{Weight of biomass (kg)}}{\text{Area}} \text{x } 10{,}000 \quad [2]$$

Biochemical traits and sensory parameters
The biochemical traits determined were starch, beta-carotene, dry matter, zinc, iron, protein and sugar contents. Texture, taste and consistency were determined during the sensory evaluation.

Samples preparation and Biochemical analysis
Samples were selected from the tagged plants per plot to determine the biochemical and cooking quality traits. The samples were washed with clean water to remove debris of soil and root hairs and stored on shelves for 24 hours to drain excess water. They were peeled and cut into four equal parts longitudinally. The two opposite quarters of the peeled storage roots were sliced into pieces of 50 g fresh sample weighted into a polyethylene envelope for each treatment. The samples were frozen at -28^{o}C for 24 hours and later sent to the vacuum freeze dryer kept at low pressure (+1.9 - 5 torr)

and low temperature (-35- 53° C) and freeze-dried for 72 hours. The freeze-dried samples were milled using the Wiley Mini Mill.

Near-Infrared Reflectance Spectrophotometer (NIRS) machine was used for the nutritional analysis. An XDS rapid content analyzer instrument made in Sweden with serial number 3013-0902 was used to scan the milled samples in the cuvettes. Approximately, 2 g of the milled samples of each treatment were placed in the Iris adaptor. The Infrared light passes through the samples to give all the biochemical or nutrient levels in the samples. These were used for the determination of biochemical traits (Tumwegamire *et al.,* 2011) at the Quality and Nutrition Laboratory of the International Potato Centre (CIP) at CSIR-Crops Research Institute, Fumesua.

Cooking quality assessment (Sensory evaluation)

Boiled storage roots were assessed by 20 farmers and field staff to evaluate the cooking quality traits such as texture, taste, and consistency. This is to ascertain the effects of fertilizer on boiled storage root of the improved sweetpotato varieties. Ten harvested disease-free storage roots of similar sizes were selected for the sensory evaluation. The scale range used for the traits assessment ranged from 1- 3 as shown in Table 1.

TABLE 1
Scale used to assess cooking quality

	Scale 1	*Scale 2*	*Scale 3*
Texture	Dry	Just about right	Moist
Taste	Sweet	Just about right	Not sweet
Consistency	Hard	Just about right	Soft

Source: (Stone, 2012)

Statistical Analysis

Two-way analysis of variance (ANOVA) was performed to test the differences among varieties and fertilizer rates using Genstat statistical package version 12. Treatment means were separated using least significance differences (LSD) at $P < 0.05$ probability level.

Results and Discussion

Yield and yield components

There were significant interactions ($P < 0.05$) between variety and location in root and biomass yield (Table 2). Treatment factors, with exception of fertilizer, had significant influence on yield and yield components. *Apomuden* had the highest root yield (14.5 t// ha) while *Dadanyuie* had the lowest (5.1 t/ha) root yield across locations. Yield is dependent on the inherent genetic potential of the variety and the environmental conditions (Bryan *et al.,* 2013). Better climatic conditions and genetic characteristics of the varieties contributed to the yield performance. Therefore, the differences in yield observed at different locations could be attributed to differences in agro-climatic conditions such as rainfall variation, temperature and relative humidity.

TABLE 2
Effect of varieties by locations interactions on yield and yield component of sweet potatoes

Varieties	*Locations*	*Root yield (t/ha)*	*Biomass (t/ha)*
Apomuden	Ejura	16.2	32.6
Apomuden	Fumesua	12.9	20.0
Bohye	Ejura	8.3	21.6
Bohye	Fumesua	8.0	20.5
Dadanyuie	Ejura	5.8	18.4
Dadanyuie	Fumesua	4.4	12.0
Ligri	Ejura	13.5	25.4
Ligri	Fumesua	6.8	11.4
Lsd (5%)		**5.6**	**4.2**
CV (%)		**51.9**	**36.6**

Biochemical properties Dry matter, starch and sugar contents

The result shows that *Ligri* had higher dry matter (34.63%) and starch content (65.87%) contents compared with *Apomuden*, which recorded 25.44% and 49.20% at Ejura (Table 3). Varietal effect was observed with *Dadanyuie* which recorded the highest dry matter content of 33.16% and *Apomuden* with the lowest dry matter yield of 21.06% (Table 3) at Fumesua. *Apomuden* had the highest sugar content (27.49%) while *Ligri* had the lowest sugar content of 16.15% in Ejura. Similar results were recorded at Fumesua, but the starch content for *Ligri* and *Apomuden* were the lowest (Table 3). The variation in the dry matter, starch and sugar content among the sweetpotato varieties can be attributed to the differences in the genetic composition and environmental influences. The average dry matter content in sweetpotatoes is about 30% (Woolfe, 1992), but varies widely depending on variety, climate, soil and cultivation practices. The high dry matter content signifies more carbohydrates and, consequently, a higher energy content (Gichuhi *et al.,* 2014). High dry matter content promotes better marketing appeal, improves the shelf life and makes a better competitor in the food and starch industry. Dry matter content is used as a selection index for trait such as starch content and cooking quality among root and tuber crops.

The significant differences between starch contents of the varieties at the two locations might be explained in terms of differences in cultivar and climatic variations. Metabolic activity is temperature-dependent for the formation of starch-based on the cultivar. Similar to the results of this study, Brobbey (2015), observed that the amount of glycosides (sugar) found in cellular and ligneous membranes of sweet potato vary largely with the cultivars. This could explain the differences in sugar content among the varieties studied.

The fertilizer applied did not have any significant effect on biochemical properties measured in this study. This could be as a result of genotypic and environmental variation. The fertilizer could also be on a low side to have effect on the sweetpotato. It could also be attributed to intermitted rainfall pattern during the growing period. However, the application of fertilizer has been reported to influence the nutrient content of sweetpotato, especially the mineral content (Gichuhi *et al.,* 2014). Several authors have reported an increased concentration of minerals in the sweetpotato leaves and roots with the increased application of fertilizer (Agbede, 2010).

TABLE 3

Effect of fertilizers on dry matter, sugar and starch at Fumesua and Ejura

Treatments	***Dry matter (%)***		***Sugar (%)***		***Starch (%)***	
	Ejura	***Fumesua***	***Ejura***	***Fumesua***	***Ejura***	***Fumesua***
Varieties						
Ligri	34.63	31.82	16.15	13.26	65.87	70.09
Bohye	31.04	30.48	16.30	14.97	61.98	66.50
Dadanyuie	31.87	33.16	17.09	14.22	62.52	69.62
Apomuden	25.44	21.06	27.49	28.60	49.20	50.61
LSD (5%)	**1.08**	**1.58**	**1.45**	**2.27**	**1.55**	**2.52**
Fertilizer						
30-30-30	31.82	29.34	18.56	17.69	61.20	64.89
30-30-60	30.66	29.11	19.82	17.49	59.09	64.65
30-30-90	30.47	28.74	19.32	17.96	59.77	63.91
0- 0 -0	30.05	29.33	19.32	17.91	59.09	63.38
Lsd (5%)	NS	**NS**	NS	**NS**	NS	**NS**
CV	**4.21**	**6.52**	**9.04**	**15.36**	**3.11**	**4.72**

Beta-carotene, Protein, Iron and Zinc Content

The nutritional composition of tuber in terms of beta-carotene, protein, iron and zinc contents at harvest was not affected by fertilizer application. Beta-carotene in *Apomuden* was highest amongst the varieties and *Dadanyuie* recorded the least. Except for *Apomuden,* all the varieties recorded statistically similar values in most of the nutritional composition. *Dadanyuie* had the highest protein content of 6.65 mg/100 g in Ejura while all the others were statistically similar. At Fumesua, *Ligri* recorded the highest protein content; the rest were statistically the same. *Apomuden* variety also recorded the highest iron and zinc content at both locations. The significant differences in beta-carotene content of sweetpotato evaluated could be due to differences in cultivars and climatic factors. According to literature (Grace *et al.,* 2014; Wu *et al.,* 2008), the amount of vitamin A found in sweet potato is quite wide and that the range of values within a specific vitamin depends primarily on the genetic composition of the cultivar, but there is strong interaction with management and environmental factors.

Apomuden had higher beta-carotene than the other varieties. Thus, there is a scope for *Apomuden* for increasing the vitamin A intake in Ghana. The results agree with findings by (Rose & Vasanthakaalam, 2011), who reported that traditionally the white flesh varieties of sweetpotato are low in vitamin A (beta-carotene), as compared with the orange flesh varieties. Sweetpotato with appreciable amount of beta-carotene has the ability to increase blood levels and also helps to neutralize free radicals and reduce harmful substances that can increase the risk of several types of cancers (Islam *et al.,* 2003; Woolfe, 1992).

In this study, fertilizer application did not have any observable effects on beta-carotene. This contradicts the findings of other authors (Ali, 2019) who observed that N and P increased the carotene content of tuber roots during bulking and affect the unit weight of tuberous roots.

Protein content of many households in Ghana is derived mostly from foods of plant origin. The typical total protein content of sweet potato is as low as 1.5% fresh weight and as high as 5% dry weight. However, it is superior to other roots and tubers, such as cassava, but may be inferior to cereals (Woolfe, 1992). The high protein content observed under some of the varieties in this study is significant since the inclusion of such varieties in the diet would help curb malnutrition.

In general, the white varieties, (*Ligri* and *Dadanyuie*) recorded the highest amount of dry matter and starch contents but contained very low amounts of sugar and beta-carotene. The orange-flesh varieties *Bohye* and *Apomuden* in particular recorded the highest amount of beta-carotene and sugar contents but have low dry matter and starch content. The results are in line with findings by researchers (Aina *et al.,* 2009; Baafi *et al.,* 2016), who noticed positive association between sugar and beta-carotene and high dry matter and starch contents.

TABLE 4

Effect of fertilizer on biochemical properties at Fumesua and Ejura

Treatments	***Beta-carotene(mg/100g)***		***Protein (mg/100g)***		***Iron (mg/100g)***		***Zinc (mg/100g)***	
	Ejura	***Fumesua***	***Ejura***	***Fumesua***	***Ejura***	***Fumesua***	***Ejura***	***Fumesua***
Varieties								
Ligri	0.00	0.00	5.64	5.77	2.14	2.02	1.17	1.16
Bohye	0.92	2.32	5.36	4.55	2.38	2.03	1.26	1.06
Dadanyuie	0.00	0.00	6.65	4.70	2.57	1.94	1.48	1.05
Apomuden	30.72	34.05	5.14	4.63	2.65	2.53	1.58	1.51
LSD (5%)	**0.91**	**1.52**	**0.91**	**0.61**	**0.19**	**0.16**	**0.4**	**0.10**
Fertilizer								
30-30-30	7.46	8.97	5.48	4.82	2.35	2.09	1.32	1.18
30-30-60	7.59	8.98	5.78	5.07	2.50	2.14	1.41	1.22
30-30-90	8.10	9.15	5.57	4.96	2.41	2.16	1.35	1.22
0- 0 -0	8.49	9.26	5.96	4.80	2.48	2.12	1.43	1.16
Lsd (5%)	NS	**NS**	NS	**NS**	NS	**NS**	NS	**NS**
CV	**13.9**	**20.1**	**19.3**	**15.1**	**9.6**	**9.0**	**12.2**	**10.2**

Sensory evaluation

The results obtained from the assessment of cooking quality traits of boiled storage root are presented in Figure 1-3. The taste tests by participants mainly farmers reveal that fertilizer application to sweetpotato do not have any negative effect on tuber cooking quality but, rather, it depends on individual varietal characteristic. *Dadanyuie* had good dry texture and excellent taste followed by *Ligri* while *Apomuden* had the lowest (Figure 1 & 2). The trend of the results indicates that the white varieties had dry texture and sweet taste compared with the orange fleshed varieties. With the exception of *Apomuden*, which had the lowest rating for consistency, other varieties obtained high score for consistency (Figure 3). A variety with high dry matter content has excellent taste, texture or consistency than varieties with low dry matter.

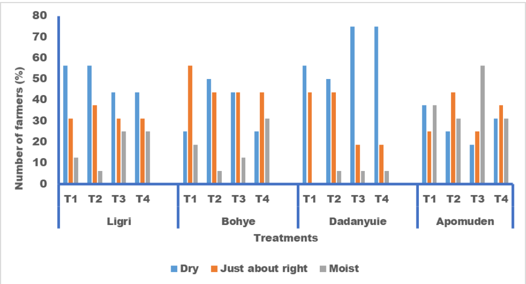

Fig. 1: Effect of fertilizer on texture of boiled sweetpotatoes

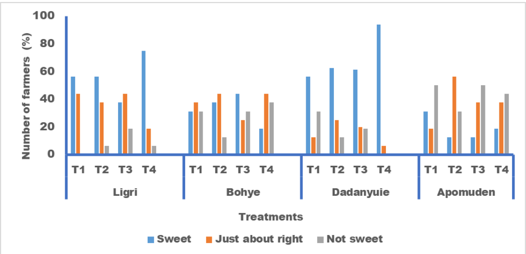

Fig. 2: Effect of fertilizer on taste of boiled sweetpotatoes

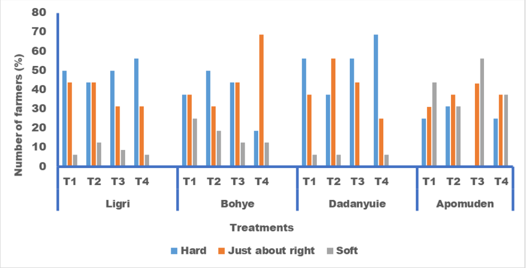

Fig. 3: Effect of fertilizer on consistency of boiled sweetpotatoes

Conclusion

The results obtained in this study showed significant varietal influence on root yield of sweetpotatoes across locations. Application of fertilizer did not influence chemical composition (ß-carotene, starch, protein, zinc) and cooking quality (taste, texture, and consistency) traits of the sweetpotatoes. Also, it was found that the individual varietal characteristic determined their cooking quality traits. The highest content of ß-carotene and protein was obtained under *Apomuden* and *Bohye* respectively. *Ligri* obtained high dry matter and starch content. The variation in ß-carotene and other chemical compositions of the sweetpotato varieties can be useful in influencing sweetpotato research, production, and consumption with the view to curbing malnutrition challenges.

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