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Altered fruit eating quality in tissue culture derived off-type banana (*Musa* spp.)

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ABSTRACT
Objective: Somaclonal variation with desirable agronomic performance has extensively been reported but studies on eating qualities of such off-type banana are limited. This study was conducted to determine eating qualities of an in vitro derived off-type banana (Musa AAA East Africa) cv. 'Uganda' with tolerance to black sigatoka disease and a high yielder.
Methodology and Results: Uncooked and cooked mature green fruits of the off-type banana were compared with those of the popular cooking banana cv. 'Mshale' (AA Pisane Lilin) and cv. 'Uganda' based on laboratory analysis and taste interviews. Similarly, ripe fruits of the off-type banana were compared with those of the popular dessert banana cv. 'Mtwike' (AAA Cavendish cv. Grande naine) and cv. 'Kisukari' (AAB/AB Silk) based on laboratory analysis and taste interviews. Results showed that the uncooked green mature fruits of the off-type banana had higher ($P < 0.05$) calorific value but its cooked meal was the least ($P < 0.05$) accepted by the taste panelists on grounds that it was hard, less sweet and less aromatic. On the other hand, ripe fruits of the off-type banana were the sweetest with the most attractive peel colour but yet the least accepted by the taste panelists for their sweetness had a fast satiating effect. The poor acceptability of the off-type banana for both cooked and ripe fruit consumption was due to differential proportions of soluble solids caused by altered fruit ripening.
Conclusion and application: The undesirable quality of the off-type banana limits not only its adoption by farmers but also the use of somaclonal variation as a source of genetic improvement of banana cv. 'Uganda'. However, as a consequence of increased sweetness, the off-type banana fruits have the potential for use as sweetener in diet drinks, ice creams, chewing gums and cough syrups.
Key words: Eating quality, physicochemical properties, In vitro induced off-type banana

INTRODUCTION
Bananas are consumed in a cooked form (popularly known as 'matoke'), roasted/fried form and ripe form (known as dessert) (Simmonds, 1966; Sebasigari, 1987). The most important eating qualities of cooked banana are taste, texture, softness, pulp yellowness and aroma (Ssemwanga and Thompson, 1994; Ssemwanga, 1995). The main sensory qualities of ripe fruits are pulp sweetness and peel yellowness (Smith *et al*., 1999; Salvado *et al*., 2007). Organoleptic quality is among the major banana attributes affecting the acceptability of new banana cultivars by farmers, traders and consumers in East Africa (Ssemwanga and Thompson, 1994; Ssemwanga *et al*., 2000; Gold *et al*., 2002). For instance, some agronomically potential new banana cultivars have been rejected by traders and consumers due to unacceptable market and eating qualities (Ssemwanga *et al*., 2000). For instance, newly introduced ABB cooking banana cultivars and new

hybrids of African plantains were initially rejected by consumers in Nigeria on grounds they were not tastier than the traditionally eaten plantain cultivars (Vuylsteke, 2001). A wide range of agronomically suitable somaclonal variation has been reported (Trujillo and Garcia, 1996; Vuylsteke, 2001; Nwauzoma *et al*., 2002). For instance, a tissue culture derived off-type banana with tolerance to yellow sigatoka disease (*Mycosphaerella musicola*) has been reported (Trujillo and Garcia, 1996). Similarly, *in vitro* derived off-type of true horn plantain had more fertile flowers and out-yielded the true-to-type plantain (Vuylsteke, 2001). A tissue culture derived off-type banana cv. 'Uganda' was resistant to black sigatoka disease and had higher yield than its true-to-type parent (Msogoya *et al*., 2011). However, eating qualities of this off-type banana have not been reported to support their potential for an adoption by farmers. The objective of this study was to evaluate the fruit eating quality of the *in vitro* derived off-type banana cv. 'Uganda' based on physico-chemical properties and taste interview.

MATERIAL AND METHODS

Description of study materials*: Banana* fruits used for this study were obtained from the banana germplasm collection at Sokoine University of Agriculture. Eating quality of cooked meal of the off-type banana was compared with the popular cooking banana cv. 'Uganda' (i.e. true-to-type parent of the off-type banana) and cv. 'Mshale' (AA Pisane Lilin). Conversely, the quality of the off-type banana for dessert fruit consumption was compared with the popular dessert banana cv. Mtwike (AAA Cavendish cv. Grande naine) and cv. Kisukari (AAB/AB Silk). Banana bunches were harvested at a green mature stage when fruits had lost cross-section angularity (Samson, 1986).

Figure 1: Left: view of the ripe fruits of the off-type banana and Right: view of ripe fruits of banana cv. Grande naine.

Quality of banana for cooked meal consumption: Mature green fruits of the off-type banana (treatment) and popular cooking banana cv. 'Uganda' and cv. 'Mshale' were used as controls. A treatment was replicated three times with each replicate consisting of 4 bunches. The quality of the off-type banana for cooked meal consumption was assessed based on physicochemical properties of uncooked fruits and taste interviews of cooked fruits (Ssemwanga and Thompson, 1994; Ssemwanga *et al*., 2000). The physicochemical properties namely fruit pulp softness, dry matter and total soluble solids contents were determined from 20 fruits in three replications according to Msogoya *et al*. (2011). Mature green fruits were used to prepare a cooked meal using the main culinary method in Morogoro urban area (Msogoya, 2007). The eating quality of the cooked meal was evaluated using 30 best taste panelists (i.e. people who are accustomed to eating cooked banana meal) based on softness, sweetness, aroma and acceptability (Ssemwanga *et al*., 2000). A 5-scale system was used with number one and five in the scale meaning 'not' and 'very' soft, sweet, aromatic and acceptable, respectively.

Quality of off-type banana for ripe fruit consumption*:* Bunches of green mature fruits of the off-type banana and popular dessert banana cv.

'Mtwike' and cv. 'Kisukari' were dehanded and the hands stored in the Horticulture postharvest laboratory for ripening under natural conditions at minimum and maximum temperatures of 25 and 31 °C and relative humidity of 60 and 70 %, respectively. A treatment was replicated three times each replicate consisting of 4 bunches. The eating quality of ripe off-type fruits was assessed based on physicochemical properties and taste interviews of dessert banana fruits (Morton, 1999). Ten hands at a ripe yellow stage each of the off-type, cv. Mtwike and Kisukari were used for fruit evaluation (Figure 1). Physico-chemical properties were taken from fruits at a full yellow ripe stage based on dry matter content and total soluble solids contents according to Msogoya et al. (2011). On the other hand, yellow ripe fruits were used to assess the eating quality using 30 best taste panelists (i.e. people who traditionally eat ripe banana) based on fruit peel attractiveness, pulp sweetness, softness and acceptability. A 5-scale system was used with number one and five meaning 'not' and 'very' attractive peel colour, sweet, soft and acceptable, respectively.

Data analysis: Data analysis was performed using 'SPSS 15.0 computer software (SPSS, 2006). The data were subjected to analysis of variance ($P < 0.05$) and multiple means comparison was performed based on Tukey honest significant difference (Tukey-HSD) test ($P < 0.05$) (Zar, 1997).

RESULTS

Quality of off-type banana for cooking purpose: The uncooked green mature fruits of the off-type banana were significantly harder ($P < 0.05$) with a penetration force of 12.4 kg/cm^2 compared with 8.9 kg/cm^2 of the true-to-type banana cv. 'Uganda' (Table 1). Similarly, the uncooked green mature fruits of the off-type banana had higher ($P < 0.05$) dry matter content of 33.7 % than those of cv. 'Uganda' with 21.1 %. Conversely, the mature green fruits of the off-type banana had significantly lower ($P < 0.05$) total soluble solids content of 3.6 % compared with 4.2 and 5.7 % of cv. 'Uganda' and cv. 'Mshale', respectively.

Table 1: Mean softness, dry matter and soluble contents of uncooked green mature fruits of the off-type banana in comparison with those of the true-to-type cv. 'Uganda' and popular cooking banana cv. 'Mshale'.

Banana type	Pulp softness (kg/cm^2)	Fruit dry matter content (%)	Pulp TSS content (%)
Off-type	$12.4^b \pm 0.2$	$33.7^b \pm 0.1$	$3.6^a \pm 0.2$
Cv. 'Uganda'	$8.9^a \pm 0.2$	$21.1^a \pm 0.2$	$4.2^b \pm 0.1$
Cv. 'Mshale'	$12.5^b \pm 0.1$	$36.7^b \pm 0.4$	$5.7^c \pm 0.2$

a,b,c: Means bearing the same superscript letter within the column are insignificantly ($P < 0.05$) different according to Tukey-HSD test. ±SE: standard error of the mean (n = 30).

The respondents found that the cooked meal of green mature off-type banana was significantly less ($P < 0.05$) soft with an average score of 2.5 compared with 4.3 of cv. 'Uganda' (Table 2). The cooked meal of the off-type banana was also less ($P < 0.05$) sweet and less aromatic with scores of 2.7 and 2.0 compared with 3.4 and 3.5 of cv. 'Uganda' and 4.2 and 4.0 of cv. 'Mshale', respectively. The taste panellists disliked the cooked meal of the off-type banana with an overall acceptability score of 2.5 compared with scores of 4.0 and 4.2 of cv. 'Uganda' and cv. 'Mshale', respectively.

Table 2: Mean taste panel scores of cooked meal of mature green fruits of the off-type banana compared with those of the true-to-type cv. 'Uganda' and cv. 'Mshale'.

Type of banana	Softness	Sweetness	Aroma	Acceptability
Off-type banana	$2.5^a \pm 0.1$	$2.7^a \pm 0.3$	$2.0^a \pm 0.1$	$2.5^a \pm 0.3$
Cv. Uganda	$4.3^b \pm 0.1$	$3.4^b \pm 0.1$	$3.5^b \pm 0.2$	$4.0^b \pm 0.2$
Cv. Mshale	$1.9^a \pm 0.2$	$4.2^c \pm 0.2$	$4.0^c \pm 0.2$	$4.2^b \pm 0.1$

a,b,c: Means bearing the same superscript letter within the column are insignificantly ($P < 0.05$) different according to Tukey-HSD test. ±SE: standard errors of the mean (n = 30).

Quality of off-type banana for ripe fruit consumption: The ripe fruits of the off-type banana had significantly higher ($P < 0.05$) dry matter of 33.7 % compared with 27.4 % of cv. 'Kisukri' (Table 3). The TSS content of the off-type banana was comparable to those of cv. 'Mtwike' and cv. 'Kisukari'.

Table 3: Mean dry matter and soluble contents of the off-type fruits compared with the true-to-type cv. 'Uganda' and popular dessert banana cultivars.

Banana type	Dry matter content (%)	Total soluble solids content (%)
Off-type banana	$32.2^{b} \pm 0.1$	$21.9^{a} \pm 0.0$
Cv. Mtwike	$32.8^{b} \pm 0.5$	$21.9^{a} \pm 0.3$
Cv. Kisukari	$27.4^{a} \pm 0.2$	$22.0^{a} \pm 0.3$

a, b: Means bearing the same superscript letter within the column are insignificantly ($P < 0.05$) different according to Tukey-HSD test. ±SE: Standard error of the mean (n = 30).

The ripe fruits of off-type banana had significantly more ($P < 0.05$) attractive peel colour with a mean score of 4.6 whereas those of cv. 'Mtwike' and cv. 'Kisukari' had scores of 2.8 and 3.2, respectively (Table 4). Moreover, the ripe fruits of the off-type banana were the sweetest ($P < 0.05$) with a score of 5.0 in comparison to those of cv. 'Mtwike' and cv. 'Kisukari' with scores of 4.1 and 4.3, respectively. However, the off-type fruits were the least ($P < 0.05$) accepted by the taste panelists with a score of 2.0 compared with 3.7 and 4.2 of cv. 'Mtwike' and cv. 'Kisukari', respectively.

Table 4: Mean taste panel scores of the ripe off-type banana fruits in comparison with the popular dessert banana cultivars in Tanzania.

Banana type	Fruit peel attractiveness	Pulp sweetness	Acceptability
Off-type	$4.6^{b} \pm 0.1$	$5.0^{b} \pm 0.1$	$2.0^{a} \pm 0.1$
Cv. Mtwike	$2.8^{a} \pm 0.1$	$4.1^{a} \pm 0.1$	$3.7^{b} \pm 0.1$
Cv. Kisukari	$3.2^{a} \pm 1.0$	$4.3^{a} \pm 0.1$	$4.2^{b} \pm 0.1$

a, b: Means bearing the same superscript letter within the column are insignificantly ($P < 0.05$) different according to Tukey-HSD test. ±SE: standard error of the mean (n = 30).

DISCUSSION AND CONCLUSION

The reduction in softness, sweetness and aroma of the cooked meal of the off-type banana was probably due to the low TSS content. The influence of soluble sugars, citrates and aromatic compounds on fruit taste, texture and aroma has been reported (Bugaud *et al*., (2006). The low TSS content of this off-type banana was due to a slow fruit ripening as earlier reported by Msogoya *et al*. (2011). The loss in fruit taste caused by a slow fruit ripening has also been reported in irradiation treated banana, oranges, mandarins and tangerines (Salunkhe, 1961; Ladaniya, 2008).

The ripe off-type banana fruits were the sweetest compared with those of cv. 'Mtwike' and cv. 'Kisukari' despite equal TSS contents. The increased sweetness of the off-type fruits was possibly due to the presence of specific natural sugars such as sorbitol which is several times sweeter than sucrose (Lee *et al*., 1970). A high sucrose concentration above 15% (w/v) has been reported to increase sorbitol formation in fruits (Doelle *et al*., 1990). Conversely, a reduction of sorbitol synthesis in apple leaves through genetic transformation has been used a strategy to improve the fruit taste (Teo *et al*., 2006).

The off-type fruit peel had most intense yellow coloration in comparison with those of cv. 'Mtwike' and cv. 'Kisukari'. The increased yellow intensity in the fruit peel of the off-type banana was probably due to a high concentration of sucrose in a peel. A high sucrose concentration has been reported to accelerate yellow colour pigmentation in banana and apple fruits through promoting carotenoid accumulation in the peel while *in vivo* incubation with glucose or fructose of detached pieces of banana peel impairs their degreening (Igleseas *et al*., 2001; Teng *et al*., 2005; Yang *et al.,* 2009). Similarly, low temperatures increase the intensity of yellow colouration on the fruit peel by slowing down fruit ripening, increasing sucrose accumulation in the peel and promoting synthesis of anthocyanin (Saure, 1990; Yang *et al.,* 2009; Marais *et al*., 2001). Ethylene has also been reported to initiate rapid anthocyanin accumulation in a peel during ripening of apple fruits (Awad and de Jager, 2002).

It is concluded that the off-type banana is undesirable for both cooked meal and ripe fruit consumption due to differential proportions of soluble solids caused by altered fruit ripening. This undesirable quality has a potential to limit the adoption of the off-type banana by farmers despite its tolerance to black sigatoka disease and high yield. Furthermore, the undesirable eating quality of the off-type banana handicaps the use of somaclonal variation as a source of genetic improvement of banana cv. 'Uganda'. Yet as a result of increased sweetness, the ripe fruits of the off-type banana have the potential for use as sweetener in diet drinks, ice creams, chewing gums and cough syrups.

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