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Full Length Research Paper

Evaluation of cyanogenic potential and organoleptic properties in cassava *(Manihot esculenta* Crantz.*)* roots of improved varieties in Côte d'Ivoire

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Fourteen cassava varieties (13 new improved cassava varieties and 1 local variety control) harvested at maturity in Côte d'Ivoire, were analysed for their cyanogenic potential of cassava root parenchyma with a picrate kit and organoleptic properties after boiling. Quantitative estimation of cyanogenic potential for cassava varieties was carried out by comparing the colour of picrate paper against those of known standard. The total cyanogens content of five improved varieties (98/2101, 98/0505, 98/0002, 96/1632 and TME419 with 9.1, 14, 10.5, 16.6 and 13.3 mg HCN kg^{-1} root fresh respectively) was significantly lower than that for the local variety control (ANADER2 with 36.2 mg HCN kg^{-1} root fresh) ($p < 0.05$). However, cyanogens levels in all cassava varieties were ranging from 9.1 to 36.2 mg HCN kg^{-1} root fresh, therefore, inferior to 50 mg HCN kg^{-1} root fresh, the safe level. All cassava varieties cooked, mealiness and melting qualities appear to be under genetic control. There were significant differences ($p < 0.05$) in the mealiness index between two improved varieties (98/0002 (1.8) and TME7 (1.7) and the local variety (ANADER2 (1.3). Results showed a strong correlation between mealiness and melting (R^2 = 0.91), accordingly, melting could be predicted from mealiness.

Key words: Cassava, improved varieties, cyanide, safe levels of cyanogens, mealiness, melting, Côte d'Ivoire.

INTRODUCTION

Cassava (*Manihot esculenta*, Crantz) is one of the most important root crops in tropical countries. In Côte d'Ivoire, it is the major food crop after yam (2'800'000 tons/year) with an annual production of 2'110'000 tons (FAO, 2009). Cassava roots are consumed in several forms, including boiled in water or after processing into fried products such as flour (from dried chips) or into fermented pastes (*placali*), or *attiéké* (couscous). Several studies conducted in Africa have shown that farmers are reluctant to adopt single-use varieties and would prefer multipurpose varieties, which they can use for direct consumption as well as for processing (Ngeve, 1998). So, such varieties will have to be developed in order to increase the field production and local consumption.

The plant, including its storage root, contains a small amount of lotaustralin (methyl linamarin) and the linamarin as the principal cyanogenic glucoside. Hydrolysis of

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this compound results in the release of HCN (Yeoh et al., 1998). In so-called sweet cassava, the parenchyma contains only a small amount of cyanogens, therefore after peeling, these roots can be safely eaten in some areas of Côte d'Ivoire such as the western part of the country. The taste of cassava is very largely due to linamarin (King and Bradbury, 1995). Cultivars with less than 50 mg CG kg^{-1} fresh weight in roots are considered "sweet". Above this level, cassava roots are considered "bitter" (Ceballos et al., 2004). Consumption of cassava that contains large amounts of cyanogens may cause cyanide poisoning with symptoms of vomiting, nausea, stomach pains and diarrhea (Akintonwa et al., 1994). Cyanide intake from cassava exacerbates goiter and cretinism in iodine deficient areas (Delange et al., 1994).

To develop high-yielding, disease-resistant cassava varieties adapted to the needs of consumers, the Swiss Centre for Scientific Research (SCSR) imported 200 improved cassava varieties in true cutting and *vitro*-plant form from the breeding programme of the International Institute of Tropical Agriculture (IITA), Nigeria in 1998. After 4 years of variety development, several improved varieties were distributed to growers. Surprisingly, only a limited number of these varieties were adopted (Bakayoko, 2007). The results of surveys conducted to understand the reasons for this limited adoption showed that many consumers preferred mealy and boil-and-eat types. Boiled cassava is one of the most used forms of consumption in rural area. It is prepared by peeling, cutting and boiling fresh cassava roots. The main quality attributes of boiled cassava are mealiness and melting, both of them should be high. Tuber quality is a very important criterion for the acceptance of varieties by farmers and consumers. Also, the sensory quality of cassava roots is an important factor for the acceptance of new improved cultivars by farmers (Safo-Kantaka et al., 2002).

Differential behaviour of cassava varieties for multiple uses and for production (such as the impact of water stress on fresh tuber yield and dry matter content of cassava, the organic manure and cassava productivity) has been reported (Bakayoko, 2007). In this study, when cassava was harvested at 15 months, roots yields and dry matter contents in cassava roots were high. The mean cassava yield in tuberous roots was quite high (about 43 t/ha) with an average dry matter content of 35.45%. The aim of this study was to assess the cyanide contents of fresh roots and the organoleptic properties of boiled cassava roots from 14 promising new improved varieties harvested at maturity (at 15 months after planting) in Côte d'Ivoire.

MATERIAL AND METHODS

Material

Thirteen improved cassava varieties (96/1632, 97/4763, 97/4769, 97/3200, 97/0162, 98/0510, 98/2132, 98/0505, 98/2101, 98/0002, 98/0581, TME7 and TME419) IITA (International Institute of Tropical Agriculture) in Ibadan, Nigeria introduced to Côte d'Ivoire in June 2002 and one (1) local cultivar control (Anader2) were used as planting material. The local variety is well appreciated by the local populations, and it was considered as control group. Experiments were carried out in the experimental field (altitude 150 m, 06° 40´N, 05° 09´W) of the Swiss Centre for Scientific Research, in Bringakro, located at 180 km in the North from Abidjan (Côte d'Ivoire). The trial was established as a split plot design with planting period as the main plot and variety as the subplot. Both main and subplots were arranged into randomized complete blocks in 4 replications. The basic plots were single rows of 40 plants; making a basic plot size of 40 m^2. Planting was done on ridges spaced 1 m apart. 40 mature stem cuttings about 15-20 cm long, were hand planted on the crests of ridges on June 06^{th}, 2002, then, at the same dates in 2003. No fertilizers, herbicides or plant protection measures were applied. The roots were harvested 15 months after planting and immediately transferred to the laboratory, where they were stored and analyzed within 1-3 days. This is in the line with common practice in Côte d'Ivoire where cassava roots are stored for 1-3 after harvest before utilization.

Cyanide determination

Cassava fresh root slices samples were analyzed for total cyanogens using the picrate kit method (Bradbury et al., 1999). The dipstick involved a piece of linamarase-impregnated paper (Whatman 17 Chr, 10 × 10 mm) and an alkaline picrate (Whatman 3 mm paper) on a plastic strip measuring 10 × 50 mm. For each sample preparation, ten replicate extractions per root slices were prepared. For preparation of the root extract, 1 g roots were homogenized in 10 ml 0.1 M H_3PO_4 and the homogenate was filtered through Whatman No. 1 filter paper. The filtrate was mixed with 0.1 ml 2 M H_3PO_4 in a glass test measuring 100 × 15 mm. An enzyme-based dipstick was inserted and the test tube was immediately sealed airtight with a rubber stopper. For root slices, a 10-15 mm thick section was cut from the middle portion of the peeled cassava root. A disc was then removed from the parenchyma tissue between the centre and periphery of this section of the cassava root. The root slice was weighed directly into glass test tube containing 0.5 ml water. An enzyme-based dipstick was then inserted and the test tube sealed airtight with a rubber stopper. All the tubes were left at room temperature (25 - 30°C). The picrate paper was then soaked in 2.5 ml water to elute the colour and its absorbance read at 510 nm. The cyanogenic potential was expressed as mg HCN/kg root using linamarin as the reference compound. The picrate method made that it is possible to classify the varieties according to their potential cyanogenic. The results were obtained according to three categories: low (< 50 mg HCN eq/kg fresh root), moderate (50 - 100 mg HCN eq/kg fresh root) and high cyanogenic potential (> 100 mg HCN eq/kg fresh root) (Bourdoux et al., 1982; Ceballos et al., 2004).

Sensory evaluation

Healthy cassava tubers were selected from each variety, peeled and cut with a kitchen knife into roughly uniform-sized slices of approximately 30 g. Only the mid-portions of the tubers were used to avoid variation caused by differential flesh coloration. Ten root pieces of about 7 cm length and 6 cm diameter were immersed in enamel pots with 500 ml of tap boiling water on a gas stove and left to cook during 30 min. Mealiness was determined from 10 average-sized boiled roots selected at random, one from each block.

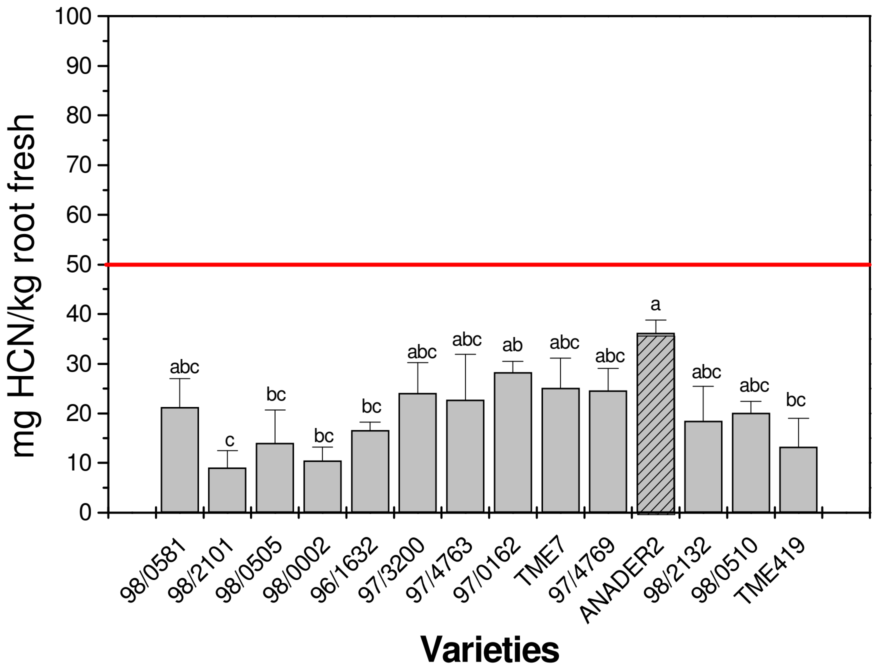

Figure 1. Cyanogenic potential of cassava varieties. Errors bars are SE, histograms surmounted by different letters are significantly different at $p < 0.05$.

Mealiness was judged with fingers by eight experienced panelists using a scale of 1-3, where: 1= fairly mealy, 2= moderately mealy, 3= very mealy (Ngeve, 2003).

Melting was also determined in the same conditions for softness using a toothpick to assess if roots were easily chewable or not. This score has been always used by Ngeve in 2003.

Statistical analysis

The data were subjected to analysis of variance (linear model with interactions) by SAS® software (SAS Institute Inc, Cary, NC, the USA). When the effects were significant, means were compared using Student-Newman-Keuls method (Dagnelie, 2003).

RESULTS

Total cyanide contents in fresh roots

Using fresh roots, the cyanogenic potential of cassava varieties ranged from 9.1 (98/2101) to 36.2 mg HCN kg^{-1} root fresh (ANADER2 which is the local variety control) (Figure 1). There was a significant difference ($p < 0.05$) in the average total cyanogens between five improved varieties (98/2101, 98/0505, 98/0002, 96/1632 and TME419 with 9.1, 14, 10.5, 16.6 and 13.3 mg HCN kg^{-1} root fresh respectively) and the control (ANADER2 with 36.2 mg HCN kg^{-1} root fresh). However, cyanogens levels in all cassava varieties were inferior to 50 mg HCN kg^{-1} root fresh.

Evaluation of boiled cassava

After boiling in water, mealiness index ranged from 1 for 98/2132 and 98/0510 to 1.8 for 98/0002. There were significant differences ($p<0.05$) in the mealiness index between two improved varieties (98/0002 (1.8) and TME7 (1.7)) and the local variety (ANADER2 (1.3)) (Figure 2).

In the evaluation of melting index, scores ranged from 1 (for 98/2132 and 98/0510) to 1.6 (for 98/0002 and TME7). There were significant differences ($p < 0.05$) in the mean quality attribute for melting index of the varieties (Figure 3).

The melting index of boiled cassava roots was very significantly correlated with the mealiness index ($p < 0.001$, $R^2 = 0.91$; Figure 4). The melting index could thus be predicted from the mealiness index of boiled cassava according to the formula:

Melting index = 0.18 mealiness index + 0.81

There was no year effect on the cyanogenic potential and organoleptic properties in cassava varieties. At each year the degree of mealiness and melting and the cyanogens levels in cassava did not vary with the variety.

DISCUSSION

There was statistical difference ($p < 0.05$) in the cyanogenic

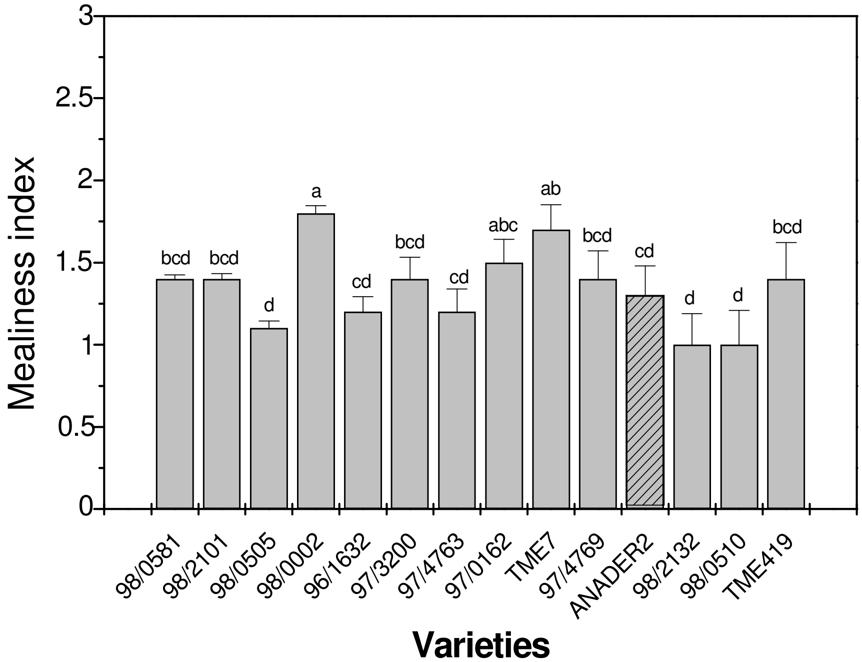

Figure 2. Mealiness index of cassava varieties. Errors bars are SE, histograms surmounted by different letters are significantly different at $p < 0.05$.

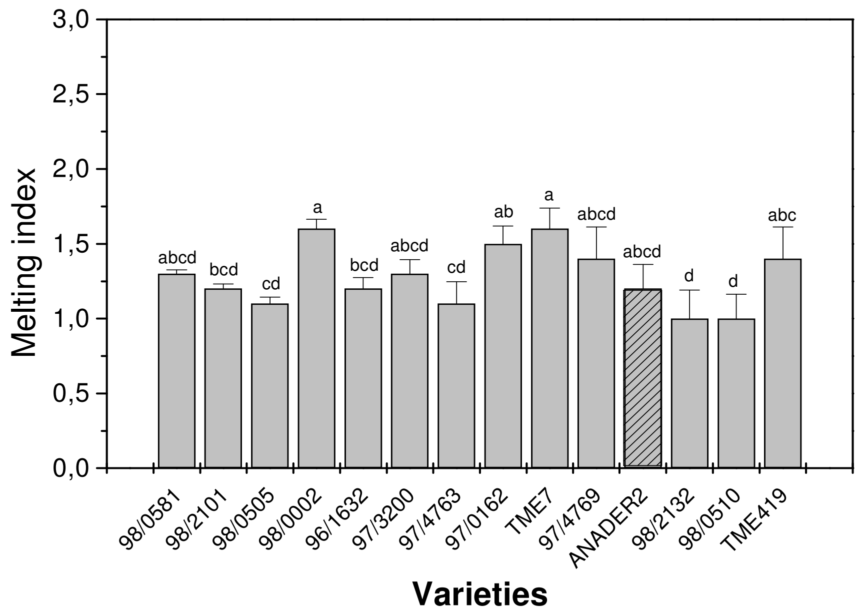

Figure 3. Melting index of cassava varieties. Errors bars are SE, histograms surmounted by different letters are significantly different at $p < 0.05$.

genic potential for cassava varieties. Therefore, the total cyanide content of cassava parenchyma is dependent on the cultivar (Cardoso, 2005). However, all were below the 50 mg HCN kg-1 recommended safe level (Bourdoux et al., 1982; Ceballos et al., 2004). Although there is a continuous distribution of total cyanide levels in cassava parenchyma, cassava roots have been categorised as either sweet or bitter based on taste (Cardoso, 2005). The

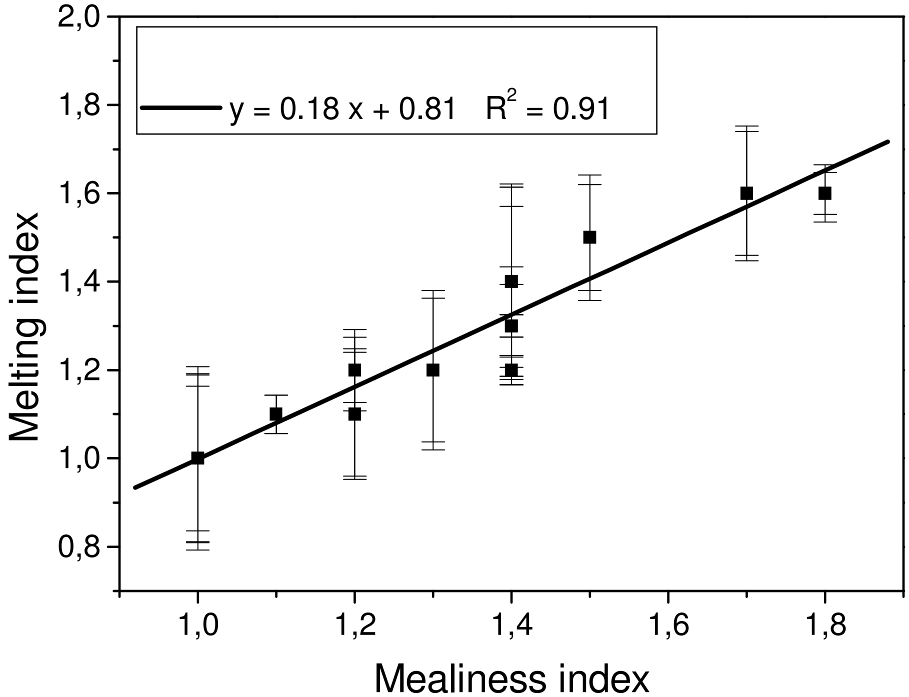

Figure 4. Relationship between melting and mealiness index of cassava varieties. Error bars are SE. Regression equation: y = 0.18 x + 0.81; R^2 = 0.91 ($p < 0.001$).

The bitterness is largely due to linamarin (Cardoso, 2005). The samples collected in this study would be sweet cassava varieties for the taste. However, according Padonou et al. (2005), this may be linked to the higher soluble sugar content of bitter cultivars, which may mask their bitterness.

In this study, some improved varieties were most mealy than local variety because cassava breeders select for high root yields, high dry matter content, high root mealiness and short cooking duration (Ngeve, 2003). An improved variety should have all these attributes to be readily acceptable for farmers and consumers in Côte d'Ivoire where boil-and-eat varieties are preferred. Since high mealiness index is important for processing, it is important for indices for its determination to be developed. Therefore, it can be used earlier in the selection cycle to develop varieties acceptable to consumers.

This study showed that the melting index of boiled cassava roots was positively correlated with mealiness index. The melting index could thus be predicted from the mealiness index of boiled cassava.

This confirms the observation that melting attribute and storage mealiness are related. The work carried out by Padonou et al. (2005) on the cassava roots showed that sweet cultivars had a significantly lower firmness that bitter ones. It is generally held that tuber mealiness is due to cell breaking on chewing (Padonou et al., 2005). Accordingly, if the cohesion force between cells is higher, then, the sensory mealiness is lower. It should be noted, however, that many other publications reported a positive correlation between potato mealiness and resistance to deformation, resulting in a rejection of the cell wall separation theory (Warren and Woodman, 1974).

Concerning the mealiness, the mean scores were always lower than 2. The findings of Padonou et al. (2005) reported that this may be linked to the presence of residual cell walls in the boiled root slices, which can limit the swelling of starch trapped within the cell structure.

Conclusion

This study showed the lower total cyanogens content in some improved cassava varieties compared to the local variety. Furthermore, for some varieties, the mealiness and melting attributes are highest. Some varieties that could be used for quality improvement (such as mealiness and cyanogenic potential) could also be introduced directly to farmers. Mealiness appeared to be related to melting after boiling.

More investigation needs to be carried out to determine the exact role of the environment (soil, rainfall and length of dry and rainy seasons, various cycles of planting) on the cyanogenic potential of cassava roots, mealiness and melting quality of these improved cassava varieties.

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