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Evaluating Bananas and Plantains Grown in Cameroon as a Potential Source of Carotenoids

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ABSTRACT

Strategies based on the utilisation of cultural and locally consumed foods seem essential for identifying solutions to reduce micronutrient malnutrition in Cameroon and other developing countries. Vitamin A deficiency and associated chronic diseases have recently worsened in many African countries where bananas and plantains are staple foods. The aim of this study is to identify yellow- and orange-fleshed banana and plantain cultivars in the *Centre Africain de Recherches sur Bananiers et Plantains de Njombé* (CARBAP) collection that contain significant levels of total carotenoids, as well as to evaluate the effect of ripening and boiling on their total carotenoid retention. Two types of colour fan were used for germplasm screening as a proxy for carotenoid content of 104 *Musa* accessions. Unripe, starting to ripe, ripe and fully ripe fruits of *Musa* cultivars sourced from the CARBAP collection in Cameroon were analysed for their total carotenoid levels by UV-VIS spectrophotometry at 450 nm. The results showed that 'Manameg red' (AAA), 'Hung tu' (AA) and 'Enar' (AA), three accessions from PNG, had the highest total carotenoid contents among all the *Musa* types (plantains, cooking and dessert bananas as well as plantain hybrids) analysed. During post-harvest maturation and processing (boiling), the total carotenoids content of *Musa* pulps vary significantly with genotypes. The yellow or orange fleshed carotenoid-rich *Musa* varieties could be considered for promotion to contribute to the alleviation of vitamin A deficiency and associated chronic diseases in target communities.

Keywords: *Musa*, processing, ripening, total carotenoid

INTRODUCTION

According to the World Bank, economists and public health specialists, micronutrients are among the best bets to stimulate development in poor countries (World Bank 2006). Micronutrients have proven to be essential for chemical processes that ensure the survival, growth and functioning of vital human systems. Apart from well-known functions in vision, vitamin A has been implicated in several other physiological processes including spermatogenesis, fetal development, immune response, and growth. Studies suggest that around one million children under the age of five die each year from the effects of vitamin A deficiency (World Bank 2006). Also, at current prevalence levels, vitamin A deficiency accounts for 9 and 13% of child and maternal deaths, respectively (Sanghvi *et al*. 2007). Strategies based on the utilisation of culturally-significant and locally consumed foods are essential for identifying solutions to reduce micronutrient malnutrition in urban and rural populations in West and Central Africa.

Bananas and plantains are grown widely throughout the humid tropics and are major staple foods for many people in developing countries especially in sub-Saharan Africa, with annual production being in the region of 26 M tonnes, of which only some 0.3 M tonne is exported (FAO 2006). These fruits are an important source of dietary minerals and vitamins as well as calories, and the wider use of micronutrient-rich *Musa* varieties has the potential to have a significant long-term beneficial impact on the population health in these areas. The occurrence of banana and plantain varieties with naturally orange-coloured fruit flesh is an indication that these varieties could be an important source of dietary pro vitamin A carotenoids (Englberger *et al*. 2003a). However, there is little published information on the variability in micronutrient content of bananas and plantains. Recent studies have investigated methods for sampling banana fruit and the efficient quantification of fruit pro vitamin A carotenoids using High Performance Liquid Chromatography (HPLC), and initial data point to significant variability in fruit pulp micronutrient contents (Davey *et al*. 2006, 2007). Thus, it is important to initiate activities to identify banana and plantain cultivars with high levels of provitamin A and other carotenoids and encourage their production and consumption in regions of vitamin A deficiency.

The aim of this study was to screen selected banana and plantain cultivars available at the CARBAP *Musa* collection, selecting on the basis of high yellow- and orange-flesh coloration, and to evaluate the effect of storage and processing on their total carotenoid content as a contribution to understanding the potential impact of high-micronutrient banana and plantain to address micronutrient deficiencies in sub-Saharan Africa.

MATERIALS AND METHODS

All fruit samples were obtained from the *Musa* germplasm collection maintained by *CARBAP*, *Njombé*, Cameroon. CARBAP has the richest collection of traditional cultivars from the West and Central African region; predominantly plantain cultivars. It also holds a representative collection of banana cultivar diversity worldwide, with particularly significant collections from East Africa, Papua New Guinea and the Pacific, as well as a selection of improved hybrids and breeding lines from CARBAP and other banana breeding programmes. Fruits were obtained from healthy, non-diseased plants of the same age cultivated under standard field conditions. Each genotype (variety) was represented by at least

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Fig. 1 Longitudinal section of unripe fruits of 'Batard' (left), a plantain and 'Enar' (right) a cooking banana.

five identical plants (clones) planted at a density of one plant per 6 m^2. Fruits were harvested when at least one finger of the first hand on the bunch showed signs of ripening or yellowing. All fruits were harvested at stage 1 and transported to the *Post Harvest Technology Laboratory* of CARBAP at Njombé for analysis from June to November 2006.

Three inner fruits of 104 cultivars from the first, median and last hands were cut longitudinally (**Fig. 1**) and compared to two colour fans; one based on the flesh colour variation in potato, developed on the initiative of the CGIAR HarvestPlus Challenge Programme, and the other based on egg yolk colour variation developed by DSM.

The two inner, middle fruits from the second and third hands of the same bunch were peeled and the pulps were quartered, weighed, frozen at -20°C and lyophilised for 24 hours before being ground to a fine powder. The total carotenoids were determined according to methods published in Rodriguez-Amaya and Kimura (2004). The pulverized lyophilised matter was extracted in cooled acetone and transferred in petroleum spirit for colorimetric analysis. The absorbance of the clarified extracts was determined at 450 nm using a SHIMADZU UV Mini 1240 spectrophotometer. Three replications were carried out for each experiment and the results expressed as average ± standard deviation (µg/g of fresh matter).

Also, fruits from the 2nd and 3rd hands of 'Batard' (AAB plantain cultivar), 'Grande naine' (AAA, Cavendish dessert banana cultivar) and 'Popoulou CMR' (AAB, Maia Maoli/Popoulou cooking banana) cultivars were kept at ambient temperature (23-26°C) in the laboratory in order to study the effects of post-harvest maturation. The ripening stage was estimated based on the peel colour as described by Dadzie and Orchard (1997). According to this scale, stage 1 = unripe; stage 3 = starting to ripen; stage 5 = ripe; stage 7 = fully ripe; and stage 9 = overripe. At each stage, fruits were peeled and the pulps were quartered, weighed, frozen at -20°C and lyophilised for 24 hours before being ground to a fine powder. The total carotenoid contents were determined as described above. Each experiment was repeated three times and the results expressed as µg/g fresh matter.

The influence of a typical cooking method (boiling) on total carotenoid content of 'Batard' was investigated under controlled conditions. Both peeled and unpeeled pulps (i.e. the entire fruits) from the 2nd and 3rd hands of the same bunch were boiled respectively for 30 and 40 mins. The cooled pulps obtained at each cooking time were then quartered, weighed, frozen at -20°C and lyophilised for 24 hours before being ground to fine powder. The total carotenoids content of the pulverized lyophilized matter was determined using spectrophotometry as described above. Three replications were carried out for each experiment.

Finally, all data were analysed statistically using SPSS statistical software (version 10.2 for Windows). ANOVA and mean comparisons by the SNK test ($P \leq 0.05$) were performed.

RESULTS AND DISCUSSION

Sixteen cooking bananas, 21 dessert bananas, 47 plantains, five plantain hybrids and 15 Papua New Guinea (PNG) cultivars were evaluated for their flesh colouration. **Table 1** shows results of some selected cultivars from each of the *Musa* types. Of all these *Musa* types, the cultivars from PNG 'Hung tu' (AA) and 'Manameg red' (AAA) pulps scored highest orange colour compared to plantains, dessert bananas, plantain hybrids and cooking bananas using the two colour fans. In general, plantain and cooking bananas

Table 1 Pre-screening *Musa* cultivars for provitamin A using colour charts.

Musa types	Genotypes	Harvest Plus colour fan	DSM yolk colour fan	Time of harvest of fruits (days after flowering)
Plantains				
French sombre	AAB	RHS 9/2 - 1355U	9	93
Batard	AAB	RHS 9/2 - 1355U	9	85
Ebang	AAB	RHS 9/2 - 1355U	9	83
Makemba noir	AAB	RHS 9/2 - 1355U	9	90
Apantu	AAB	RHS 9/3 - 7507U	7	91
3 hands planty	AAB	RHS 9/3 - 7507U	7	92
Ihitism	AAB	RHS 9/3 - 7507U	7	83
Agbagba	AAB	RHS 9/3 - 7507U	7	79
Cooking bananas				
Topala	AA	RHS 9/2 - 1355U	9	87
Popoulou	AAB	RHS 9/2 - 1355U	9	75
Pelipita	ABB	RHS 9/3 - 7507U	7	140
Dessert bananas				
Grande naine	AAA	RHS 5/3 - 7401U	3	78
Figue famille	AAB	RHS 5/3 - 7401U	3	139
Pisang pipit	AA	RHS 3/3 - 1205U	1	88
Plantain hybrids				
CRBP 39	AAAB	RHS 9/3 - 7507U	7	100
CRBP 755	-	RHS 9/3 - 7507U	7	180
Cultivars from Papua New Guinea				
Manameg red	AAA	RHS 9 - 137U	13	80
Hung tu	AA	RHS 9 - 137U	13	60
Wikago	AA	RHS 9/3 - 7507U	7	62

Low score (1 or RHS 3/3 – 1205U) = less orange colour
Higher score (13 or RHS 9 – 137U) = more orange colour

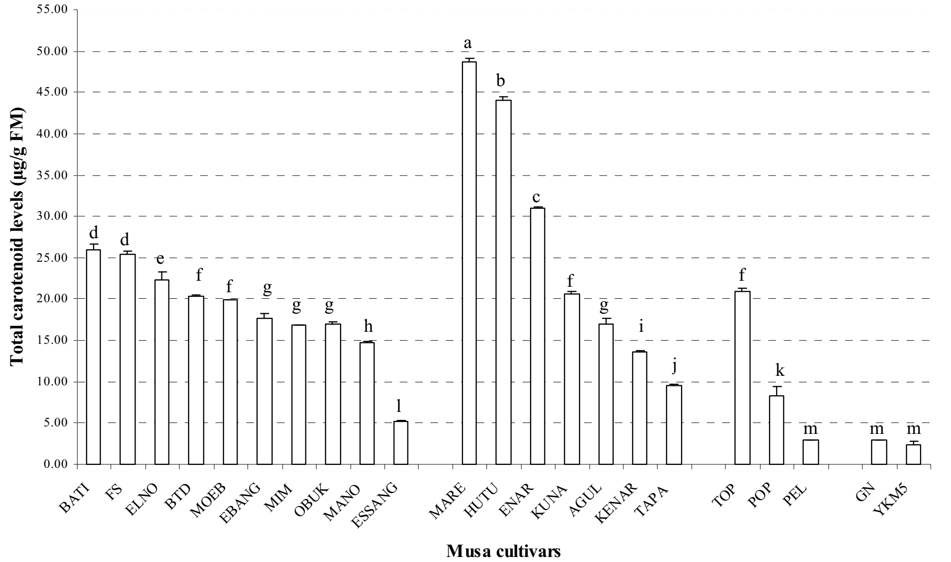

Fig. 2 Total carotenoid content (µg/g fresh matter) of selected unripe raw *Musa* cultivars. Plantain: BATI: Banane tigrée; FS: French sombre; ELNO: Elat noir; BTD: Batard; MOEB: Moto ebanga; MIM: Mimbomena; OBUK: Obubit ukom; MANO:Makemba noir; Cultivars from PNG: MARE: Manameg red; HUTU: Hung tu; KUNA: Kunaimp; TAPA: Tapatuput; Cooking bananas: TOP: Topala; POP: Popoulou CMR; Dessert bananas: GN: Grande naine; YKM5: Yangambi km5

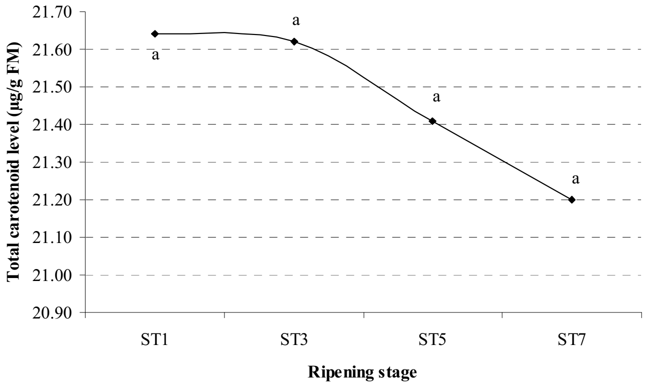

Fig. 3 Influence of post harvest maturation on plantain pulps (cv. 'Batard'). DAH = number of days after harvest. ST1: 0 DAH, ST3: 3-4 DAH, ST5: 5-6 DAH, ST7: 7-9 DAH.

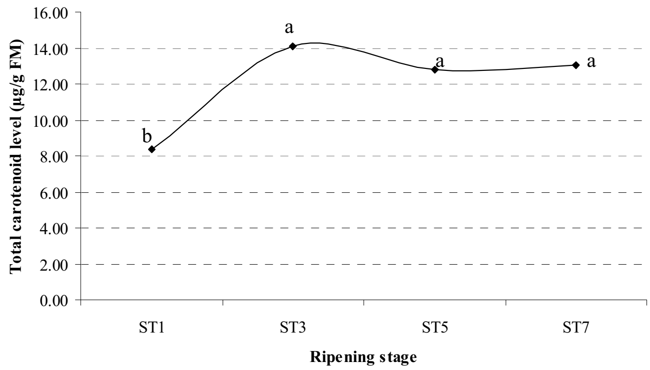

Fig. 5 Influence of post harvest maturation on cooking banana pulps (cv. 'Popoulou CMR'). DAH = number of days after harvest. ST1: 0 DAH, ST3: 2-3 DAH, ST5: 3-4 DAH, ST7: 7-8 DAH.

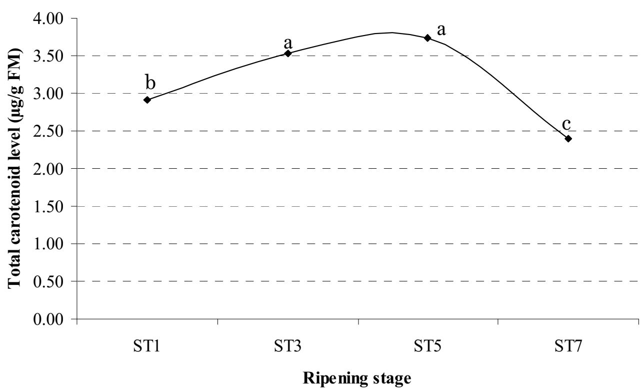

Fig. 4 Influence of post harvest maturation on dessert banana pulps (cv. 'Grande naine'). DAH = number of days after harvest. ST1: 0 DAH, ST3: 2-3 DAH, ST5: 4-5 DAH, ST7: 6-7 DAH.

had more orange flesh than dessert bananas. No significant difference of colour was observed between the fruits from the various hands of the bunch. However, colour evaluation using colour fans is a difficult and subjective task and the range of colour shades in the available colour fans, being designed for other food crops, only have a limited application to banana and plantain. The use of a colorimeter could provide more precise results.

Among the 104 *Musa* cultivars pre-screened with colour fans investigated, 17 and 5 accessions with high and low orange colour flesh respectively were analysed for their total carotenoids content using spectrophotometry. The levels ranged from 2.32 µg/g (lower level) to > 20.00 µg/g fw in 9 of these 22 cultivars (**Fig. 2**). PNG and plantain varieties with yellow- or orange-fleshed pulp exhibit higher values for total carotenoids than the cream-fleshed dessert banana. The total carotenoid contents of *Musa* varies significantly (P<5%) according to *Musa* types (plantains, cooking and dessert bananas). These results confirm the powerful correlation existing between the colour of *Musa* pulps and total carotenoids content.

Maturation or ripening in fruits and vegetables is usually accompanied by enhanced carotenogenesis (Rodriguez-Amaya 1993). The total carotenoid contents of 'Batard' (plantain cultivar), 'Grande naine' (dessert banana cultivar) and 'Popoulou CMR' (cooking banana cultivar) investigated in this study were also affected by the stage of maturity, but the trends differed according to the cultivar. **Fig. 3, 4** and **5** present the changes observed during ripening. The total carotenoid contents of *Musa* pulps slightly decreased for the plantain cultivar 'Batard', even though not significantly (P<0.05), meanwhile a significant increase of total carotenoids was observed from unripe to ripe stage of dessert banana before decreasing at fully ripe stage. The unripe pulp of Popoulou CMR showed significant lower values of total carotenoids compared to those obtained with start ripe, ripe and fully ripe stage; which were not significantly different. In some matured fruits such as strawberry, red currant and olive 'Picual' variety, carotenoid contents decrease during ripening. However, similar to acerola fruits and olive 'Aberquina' variety, which showed an increase of carotenoid pigments during the ripeness state (Lima *et al.* 2005), this phenomenon did not occur in all the bananas and plantains analysed. For 'Grande naine', no significant difference was observed between unripe, starting to ripe, ripe and fully ripe

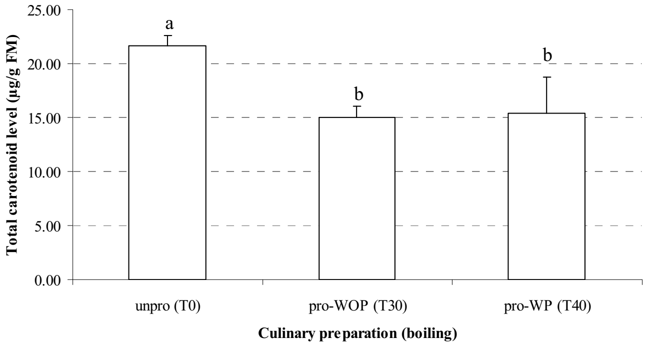

Fig. 6 Effect of boiling 'Batard' pulps with or without peel on total carotenoid level of edible portion. unpro: unprocessed pulps (cooking time: 0 min); pro-WOP (T30): processed pulps without peel (cooking time: 30 min); pro-WP (T30): processed pulps with peel (cooking time: 40 min).

pulps of 'Grande naine'. 'Popoulou CMR' showed an increase in total carotenoid content during post-harvest maturation at ambient temperature and significant difference was observed between unripe 'Popoulou CMR' pulp and its other ripening stages. However, the total carotenoid levels of the 3 cultivars were highly significantly different according to their sub-groups and genotypes.

After boiling the total carotenoids content of unripe 'Batard' pulps decreases (**Fig. 6**). This is probably due to enzymatic or non-enzymatic oxidation and isomerization during heat treatment. The percentage loss after 30-40 mins boiling is between 28-30% being very similar for pulps with or with-out peel. There is no significant difference boiling 'Batard' pulps with or without peels. Considerable retention or loss of carotenoids during processing and storage of food has been reported in numerous papers. However, data are somewhat conflicting and often difficult to interpret because of many reasons such as the description of processing and storage conditions, the difficulty of comparing foods processed differently, etc. (Rodriguez-Amaya 1997).

This study confirms recent findings from other studies of Micronesian banana (Englberger *et al.* 2003a, 2003b, 2006) that yellow- and yellow/orange-fleshed banana cultivars are carotenoid-rich, offering potential for alleviating vitamin A deficiency. Nine among the 22 tested Cameroonian bananas and plantains cultivars with yellow or orange-fleshed fruit contained nutritionally significant levels of total carotenoids; i.e. they can potentially provide at least 50% of daily recommended for a nonpregnant, nonlactating adult woman and for a child 1 to 3 years old allowances (respectively 500 µg and 400 RE/day) within an average meal size (WHO/FAO 2002). These cultivars could be niche-marketed in both industrialised and developing countries as functional foods and play a role in alleviating micronutrient deficiency and chronic disease problems, including cancer, heart disease and diabetes in target communities. Furthermore, they should be of interest to breeding programmes focussed on providing improved varieties for adoption by smallholder farmers, as a means of ensuring that essential micronutrients are delivered as well as high yields to banana-dependent households in developing countries.

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