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Physicochemical Changes during Ripening of Bananas Grown in Cameroon

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ABSTRACT

Physico-chemical changes in the fruits of five and nine cultivars of cooking and dessert banana respectively were determined. The ripening stage was defined in terms of peel colour changes from green to yellow. At harvest, the fruit girth and length as well as the peel thickness vary significantly ($P<0.05$) according to cultivars; cooking bananas exhibiting the highest values respectively (6.00 cm, 27.62 cm and 3.58 mm). During ripening, the peel dry matter content, pulp to peel ratio, total soluble solid and total titratable acidity of the pulp increased (from 8.63 to 24.20 g/100 g, 1.38 to 7.77, 1.27 to 19.3 g/l and 276.3 to 1491 mEq/100 g, respectively) while pulp firmness, pH and dry matter content of the pulps decreased respectively from 3.2 to 0.15 kg/cm², 6.34 to 4.48 and 40.12 to 18 g/100 g. These physicochemical characteristics coupled to pulp colour, fruit girth and length as well as other sensorial parameters are actually used by *Musa* breeders at CARBAP and food processors in Cameroon for the creation and selection of new hybrids with high agronomic performance and accepted by consumers as well as the production of good quality *Musa*-derived foods, respectively.

Keywords: cooking bananas, dessert bananas, harvest, physicochemical parameters, ripening

INTRODUCTION

Dessert and cooking bananas are major starch staple crops of considerable importance in the developing world that are consumed both as an energy yielding food and as dessert. Together with plantains, they provide nearly 70 million people in west and central Africa with more than 200 calories a day (Stover and Simmonds 1987; Tchango Tchango and Ngalani 1998). These very perishable staple food crops constitute the 3rd most important food commodity after rice and cassava in Cameroon. Studies have been carried out in some African countries concerning *Musa* physico-chemical evaluation. Burdon *et al.* (1991) reported the rate of plantain ripening and the changes during ripening for three Nigerian plantain cultivars. Onyejegbou and Ayodele (1995) found that the stage of ripeness of the fruits affects the quality of plantain chips. Collin and Dalnic (1991) and Aboua (1991) described changes in cultivars grown in Ivory Coast and Asiedu (1987) studied those in Malawi. These authors observed a significant increase in the pulp to peel ratio during ripening. In Cameroon, Ngalani *et al.* (1997) evaluated changes in major plantain cultivars grown commercially compared with a dessert banana, 'Grande naine' (AAA group, grown mainly for international trade) and a cooking banana, 'Maduranga' (ABB group, less susceptible to Black Sigatoka disease than plantain and dessert banana). They found that the dry matter contents of the pulp of the analysed plantain cultivars were significantly higher than those of cooking and dessert bananas and that they did not change significantly from stage 1 to stage 7. CARBAP *Musa* collection contains many dessert and cooking banana cultivars that are not well known by population. They could be consumed boiled, pounded after boiling, fried or roasted or as flour according to the ripening stage; but information about their physicochemical changes during ripening is not available in order to stimulate their food and breeding uses as well as to complete their agronomic characterisation. Thus, this study evaluated the evolution of physicochemical parameters of 15 dessert and cooking bananas during their post harvest maturation.

MATERIALS AND METHODS

Materials

Six cooking bananas cultivars: 'Dwarf kalapua' (DK), 'Laknau' (LKN), 'Mnalouki' (MNL), 'Pelipita' (PPT) 'Popoulou' (POP), 'Topala' (TOP) and nine dessert bananas cultivars: 'Banane cochon' (BC), 'Foconah' (FOH), 'Figue rose naine' (FRN), 'Grande naine' (GN), 'Gros michel' (GM), 'IDN 110' (Idn 110), 'Pisang jary buaya' (PJB), 'Pisang mas' (PM), 'Yangambi km5' (Ykm5) from different *Musa* genomic groups were considered. In Cameroon, they are generally eaten as dessert bananas when ripe, cooked or boiled green/unripe and eaten as a vegetable, fried when ripe or unripe to make chips, baked when ripe or green, mashed, etc. (Ngoh Newilah *et al.* 2005a).

Sampling

An experimental plot (with a completely randomised bloc design) was settled in CARBAP. It contained 32 cultivars of *Musa*, each variety being represented by 12 plants divided in 2 bands. Banana bunch was harvested when a ripe fruit appeared on its first hand. In the laboratory, fruits from the second and third hands were randomised, collected and sorted according to external colour of the peel (Dadzie and Orchard 1997) into 4 maturation stages: full green (initial or stage 1), green with yellow points (start ripe or stage 3), yellow with green ends (ripe or stage 5) and entirely yellow with black points (fully ripe or stage 7).

Physico-chemical analysis

The pulp firmness was measured using a manual penetrometer (*Cosse* model) on the 2 halves of a fruit according to Dadzie and

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Table 1 *Musa* fruit characteristics at harvest.

Musa type	Genome	Fruit girth (cm)	Fruit length (cm)	Peel thickness (mm)
Cooking bananas				
Dwarf kalapua	ABB	4.08 ± 0.12 efghi	16.33 ± 0.80 no	3.58 ± 0.14 bcde
Laknau	AAB	4.38 ± 0.08 ef	27.62 ± 0.57 def	3.08 ± 0.10 efgh
Pelipita	ABB	4.87 ± 0.10 cd	18.93 ± 0.70 lmn	3.37 ± 0.12 cdefg
Popoulou	AAB	6.00 ± 0.09 a	19.15 ± 0.62 klmn	2.90 ± 0.10 gh
Topala	AAB	4.85 ± 0.10 cd	23.38 ± 0.66 ghij	3.55 ± 0.11 bcdef
Dessert bananas				
Banane cochon	AAA-EA	4.55 ± 0.08 de	16.58 ± 0.57 no	2.95 ± 0.10 efgh
Foconah	AAB	3.31 ± 0.10 klm	16.44 ± 0.66 no	3.00 ± 0.11 efgh
Figue rose naine	AAA	4.17 ± 0.15 efgh	19.50 ± 0.99 klm	3.25 ± 0.17 cdefg
Grande naine	AAA	3.70 ± 0.09 hijkl	22.09 ± 0.59 ijk	3.22 ± 0.10 defg
Gros michel	AAA	3.26 ± 0.17 lm	19.66 ± 1.14 klm	3.00 ± 0.20 efgh
IDN110	AA	2.79 ± 0.09 no	14.40 ± 0.62 o	2.35 ± 0.10 i
Pisang jary buaya	AA	2.62 ± 0.13 o	21.20 ± 0.88 jkl	2.80 ± 0.15 gh
Pisang mas	AA	3.60 ± 0.09 ijkl	12.20 ± 0.62 o	2.15 ± 0.10 i
Yangambi km5	AAA	3.48 ± 0.09 jkl	14.81 ± 0.59 o	2.31 ± 0.10 i

Means ± standard deviation with the same letters in the same column are not significantly different at P<0.05 (Student Newman Keul's test).

Orchard (1997) and the results were expressed in kg/cm². Fruit length (cm) was determined by measuring the outer curve of individual fruit with a tape from the distal end to the point at the proximal end where the pulp is judged to terminate. Fruit girth or circumference (cm) and peel thickness (mm) were determined by measuring respectively individual fruit with a tape at the widest midpoint of each fruit and peel with a pair of calliper.

Preparation of pulp aqueous extract

At each ripening stage, 15 g of pulp tissues were collected from the medium part of the fruit and grinded within 2 min in an electric blender with 45 ml distilled water. The pulp juice was obtained after filtration using Whatman No. 1 paper.

Refractive index of pulp juice (RI)

A single drop of the filtrate is placed on the prism of a refractometer (REF 113, Brix range from 0–32% at 20°C) that is finally pointed towards a light source and the percentage of total soluble solids is obtained by multiplying the recorded value by three. % TSS (g/l) = 3IR – 0.8.

pH and total titratable acidity (TTA)

pH of the pulp juice was measured with a bench top pH meter (Inolab, pH level 2), while total titratable acidy was ascertained manually by titration with 0.1 N sodium hydroxide until the phenolphthalein indicator just changes pink/red. The results are expressed as milliequivalent per 100 g sample in terms of malic acid, which is the predominant acid present in bananas and plantains (Josylin 1970):

C_{ATT} (mEq/100 g) = (400/11) x $V_{NaOH\ 0.1\ N}$

Peel and pulp dry matter content

Dry matter content was determined by oven drying at 105°C for 24 h of a known quantity of peel or pulp.

Statistical analysis

Three replications on at least five individual samples from different bunches per cultivar were analysed for each parameter. Analysis of variance was performed using the statistical package, SAS version 8.2 for Windows (SAS 2001). The means were compared at P<5% using the Student Newman Keul's test.

RESULTS AND DISCUSSION

The most significant visual changes in the morphological characteristics of the fruit during maturation occur in the size, shape, length and circumference of the fruit as bunches advance in age. Fruit maturity is usually related to the diameter or grade of the fingers; hence an estimate of the bunch maturity can be made. **Table 1** indicates the fruit girth and length as well as the peel thickness at harvest of all the *Musa* cultivars analysed in this study, cooking bananas showing high values compared to dessert bananas. Fruit girth was higher in 'Popoulou' and 'Topala' exhibited the highest fruit length meanwhile 'Dwarf kalapua' had the thickest peel, although some cultivars had statistically similar fruit lengths, fruit girths and peel thicknesses. The values for 'Grande naine', mainly grown for international trade are not significantly different from those obtained by Ngalani *et al.* (1997). The slight difference may be due to variations that occur during experimental plot follow-up. Also, soils, planting calendar and climatic changes from flowering to harvest may have effects on fruit filling thus on its length and girth.

Unlike peel thickness, fruit girth and length that were measured only at harvest (ripening stage 1) other parameters were evaluated during ripening. The disappearance of peel green colour and the corresponding increase in yellowing of the peel during ripening are the obvious manifestations in bananas.

Pulp to peel ratio

The pulp to peel ratio of all the *Musa* cultivars analysed was higher than 1 at harvest although 'Popoulou' exhibited highest value: 3.43. This ratio increased significantly from 1 to at least 2.5 at fully ripe stage, 'Pisang mas' and 'Popoulou' pulps weighing about 8 times more than their peels (**Figs. 1, 2**). The same trends were observed during investigations on some plantains cultivars: 'French clair', 'Rose d'Ekona', '2 hand planty', 'Big ebanga' and 'Bâtard' grown in Cameroon; 'Afôtô' and 'Orishele' grown in Ivory Coast; 'Obino l'Ewai', 'Ubok Iba' and 'Agbagba' as well as a non specific cooking banana grown in Nigeria (Ngalani *et al.* 1998; Aboua 1991; Collin and Dalnic 1991; Burdon *et al.* 1991; Onyejegbou and Ayodele 1995). Pulp to peel ratio is a good and consistent index of ripening of bananas. Changes in pulp to peel ratios during ripening indicate differential variations in moisture content of the peel and pulp. The increase during post harvest maturation is related to sugar concentration in the two tissues; there is a rapid increase in the sugar concentration in the pulp compared to the peel thus contributing to a differential change in osmotic pressure. Furthermore, the peel loses water both by transpiration to the atmosphere and also to the pulp by osmosis; thereby contributing to an increase in the fresh weight of the pulp as the fruit ripens.

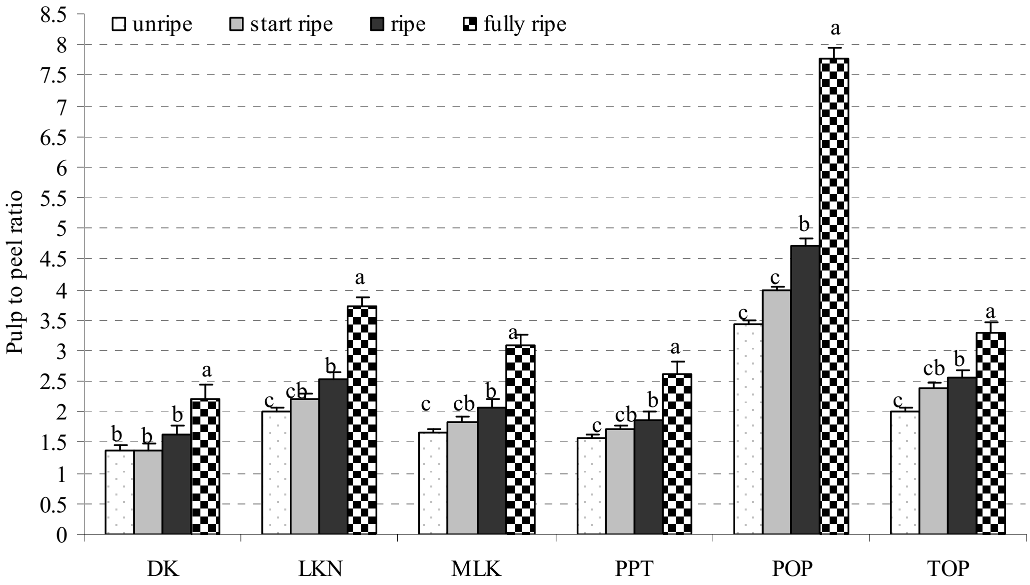

Fig. 1 Changes in pulp to peel ratio during ripening of cooking bananas. Means ± standard deviation with the same letters are not significantly different at P<0.05 (Student Newman Keul's test). DK: Dwarf kalapua; LKN: Laknau; MLK: Mnalouki; PPT: Pelipita; POP: Popoulou; TOP: Topala.

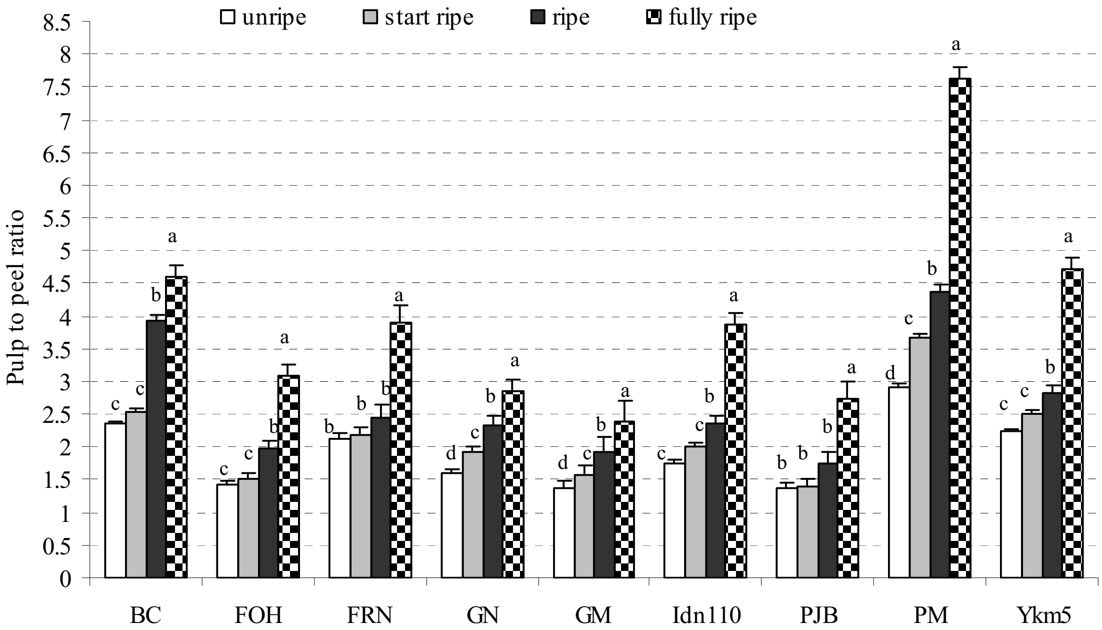

Fig. 2 Changes in pulp to peel ratio during ripening of dessert bananas. Means ± standard deviation with the same letters are not significantly different at P<0.05 (Student Newman Keul's test). BC: Banane cochon; FOH: Foconah; FRN: Figue rose naine; GN: Grande naine; GM: Gros michel; Idn110: IDN 110; PJB: Pisang jary buaya; PM: Pisang mas; Ykm5: Yangambi km5.

Pulp firmness

At harvest the pulp firmness of each banana cultivar was higher than 2 kg/cm², 'Pelipita' and 'Pisang jary buaya' exhibited the maxima values (3.17 and 3.2kg/cm²). The pulp hardness slightly differed according to *Musa* cultivars analysed although some significant differences were observed (P<0.05). Generally, pulp firmness of most bananas does not change significantly during early stage of maturation but as ripening progresses considerable variation occur. During post harvest maturation, the pulp firmness of all the studied bananas decreased, 'Gros michel' exhibited the lowest value 0.15 kg/cm² (**Figs. 3, 4**). The loss of pulp firmness observed during ripening varies with cultivar. The same phenomenon was observed with some *Musa* cultivars grown in Cameroon, Cote d'Ivoire and Nigeria (Ngalani *et al.* 1998; Aboua 1991; Collin and Dalnic 1991; Burdon *et al.* 1991; Onyejegbou and Ayodele 1995). The same trend (loss of firmness) was also reported for some white and red guava varieties during ripening (Bashir and Abou-Goukh 2003). The loss of hardness is often inversely related to ripening implying that as ripening progressed, pulp firmness declined. It has been associated to three processes – breakdown of starch to form sugar – breakdown of the cell walls or reduction in the middle lamella cohesion due to solubilisation of pectic substances (Palmer 1971; Smith *et al.* 1989) – movement of water from the peel to the pulp due to osmosis process. Under normal storage conditions, bananas undergo significant textural transformations as they pass through the ripening process.

Total soluble solids

Fruits including banana contain many compounds, which are soluble in water such as sugars, acids, vitamin C, amino acids and some pectins. These compounds form the soluble solids content of the fruits. At harvest, the total soluble solids contents of banana pulps were between 1 and 2.3 g/l; during ripening of all the *Musa* studied, these values increased 3 to 7 times, 5 to 11 times and 6 to 16 times depending on cultivars and respectively at ripening stage 3, 5 and 7 (**Figs. 5, 6**). A dessert banana 'IDN110' exhibited the

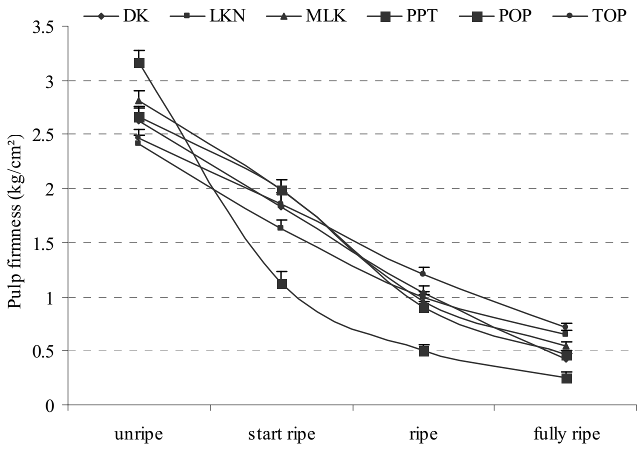

Fig. 3 Changes in pulp firmness during ripening of cooking bananas. Means ± standard deviation with the same letters are not significantly different at P<0.05 (Student Newman Keul's test). DK: Dwarf kalapua; LKN: Laknau; MLK: Mnalouki; PPT: Pelipita; POP: Popoulou; TOP: Topala.

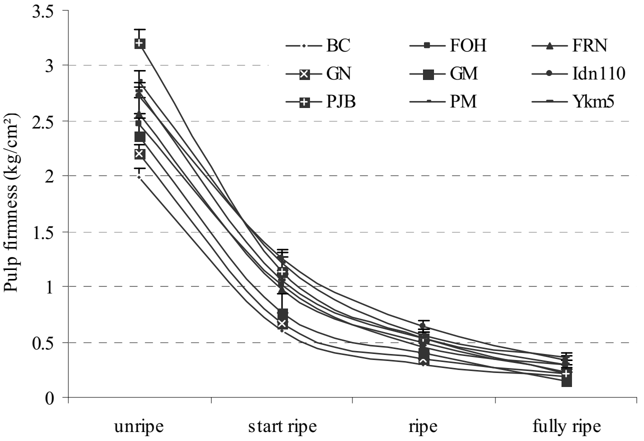

Fig. 4 Changes in pulp firmness during ripening of dessert banana cultivars. Means ± standard deviation with the same letters are not significantly different at P<0.05 (Student Newman Keul's test). BC: Banane cochon; FOH: Foconah; FRN: Figue rose naine; GN: Grande naine; GM: Gros michel; Idn110: IDN 110; PJB: Pisang jary buaya; PM: Pisang mas; Ykm5: Yangambi km5.

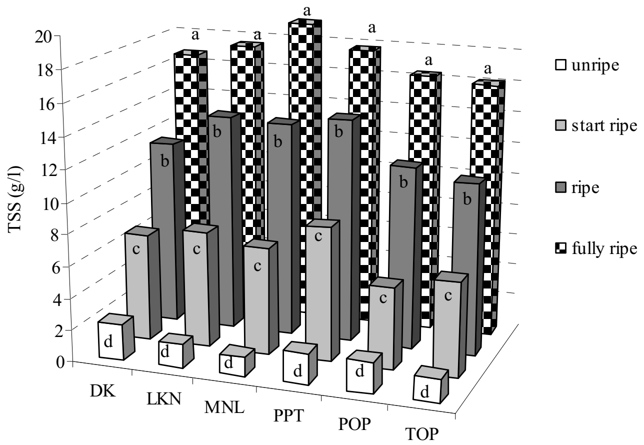

Fig. 5 Pulp total soluble solid concentrations during ripening cooking banana cultivars. Means ± standard deviation with the same letters are not significantly different at P<0.05 (Student Newman Keul's test). DK: Dwarf kalapua; LKN: Laknau; MLK: Mnalouki; PPT: Pelipita; POP: Popoulou; TOP: Topala.

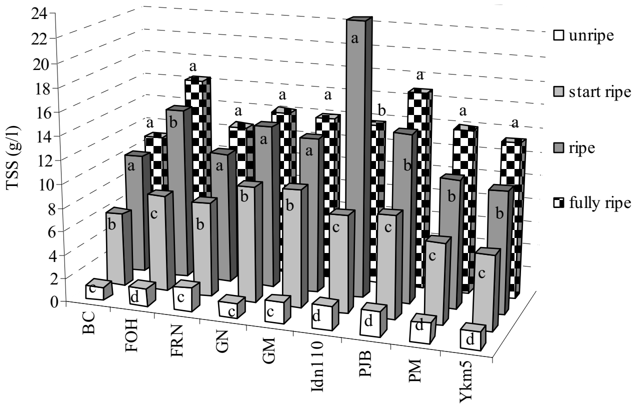

Fig. 6 Pulp total soluble solid concentrations during ripening of dessert banana cultivars. Means ± standard deviation with the same letters are not significantly different at P<0.05 (Student Newman Keul's test). BC: Banane cochon; FOH: Foconah; FRN: Figue rose naine; GN: Grande naine; GM: Gros michel; Idn110: IDN 110; PJB: Pisang jary buaya; PM: Pisang mas; Ykm5: Yangambi km5.

highest and maximum value 23.26 g/l at stage 5 compared to other bananas. Since total soluble solids or sugars contents in bananas significantly increase during ripening as they mature and ripen, it can be a useful index of maturity. Same phenomenon was reported for other *Musa* varieties studied by Ngalani *et al.* (1998) and Collin and Dalnic (1991) although the values were low compared to those obtained in the present study. A highly negative correlation exists between TSS and pulp firmness (**Table 2**).

pH and total titratable acidity

Assessment of pH and titratable acidity of bananas are primarily used to estimate consumption quality and hidden attributes. At harvest, peel pH of all the studied bananas ranged between 5.38 and 5.94 except those of DK and PPT with respectively 6.07 and 6.21 (**Table 3**). Slight differences in peel pH (not often significant) were observed between analysed bananas. During ripening many trends were observed, some cultivars were characterised by – a complete decrease from green to entire yellow peel (DK) – others by a decrease then increase at fully ripe fruit (PPT, TOP) – some by an increase, decrease then finally increase at stage 7 (FOH) – meanwhile others by a continuing increase of peel pH (POP). The screening of *Musa* peels according to their pH parameter is of great importance in Cameroon because of its use as a sauce stabiliser (Ngoh Newilah *et al.* 2005b). **Table 4** presents changes in pulp pH during post harvest maturation. Unripe pulp pH is always higher than

Table 2 Some correlation coefficients between *Musa* physicochemical parameters.

Musa type	pu/pe – puDMC	TTA – pH pu	TSS – firmness
Cooking bananas			
Dwarf kalapua	- 0.379 (0.067)	- 0.916 (0.000)	- 0.970 (0.000)
Laknau	- 0.611 (0.000)	- 0.927 (0.000)	- 0.937 (0.000)
Mnalouki	- 0.618 (0.000)	- 0.927 (0.000)	- 0.955 (0.000)
Pelipita	- 0.745 (0.000)	- 0.913 (0.000)	- 0.927 (0.000)
Popoulou	- 0.601 (0.000)	- 0.951 (0.000)	- 0.919 (0.000)
Topala	- 0.559 (0.000)	- 0.967 (0.000)	- 0.932 (0.000)
Dessert bananas			
Banane cochon	- 0.617 (0.000)	- 0.943 (0.000)	- 0.937 (0.000)
Foconah	- 0.509 (0.001)	- 0.876 (0.000)	- 0.944 (0.000)
Figue rose naine	- 0.543 (0.029)	- 0.834 (0.000)	- 0.953 (0.000)
Grande naine	- 0.477 (0.001)	- 0.792 (0.000)	- 0.940 (0.000)
Gros michel	- 0.763 (0.003)	- 0.879 (0.000)	- 0.985 (0.000)
IDN110	- 0.220 (0.171)	- 0.863 (0.000)	- 0.341 (0.030)
Pisang jary buaya	- 0.748 (0.000)	- 0.934 (0.000)	- 0.947 (0.000)
Pisang mas	- 0.368 (0.019)	- 0.826 (0.000)	- 0.912 (0.000)
Yangambi km5	- 0.662 (0.000)	- 0.917 (0.000)	- 0.908 (0.000)

Values in parenthesis represent probabilities of the correlation coefficient
pu/pe: pulp to peel ratio; DMCpu: pulp dry matter content; TTA: total titratable acidity; pHpu: pulp pH; TSS: total soluble solids

Table 3 *Musa* peels pH changes during ripening.

***Musa* Type**	**Stage 1 (unripe)**	**Stage 3 (start ripe)**	**Stage 5 (ripe)**	**Stage 7 (fully ripe)**
Cooking bananas				
Dwarf kalapua	6.07 ± 0.06 ab	5.86 ± 0.07 abcde	5.78 ± 0.07 bcdefgh	5.78 ± 0.07 efghij
Laknau	5.88 ± 0.04 bcdef	5.86 ± 0.05 abcde	5.90 ± 0.05 ab	6.23 ± 0.05 b
Mnalouki	5.65 ± 0.05 cdefgh	5.65 ± 0.05 cdefgh	5.56 ± 0.05 fghi	5.75 ± 0.05 fghij
Pelipita	6.21 ± 0.06 a	6.10 ± 0.06 a	6.00 ± 0.06 ab	6.43 ± 0.06 a
Popoulou	5.73 ± 0.05 cdefg	5.79 ± 0.05 bcdef	5.81 ± 0.05 bcdefg	6.03 ± 0.05 bcdef
Topala	5.92 ± 0.05 bcd	5.77 ± 0.06 bcdef	5.46 ± 0.05 hi	5.65 ± 0.05 hij
Dessert bananas				
Banane cochon	5.56 ± 0.04 fgh	5.36 ± 0.05 h	5.39 ± 0.05 i	5.56 ± 0.05 j
Foconah	5.64 ± 0.05 cdefgh	5.70 ± 0.06 bcdefg	5.57 ± 0.05 efghi	5.90 ± 0.05 cdefghi
Figue rose naine	5.71 ± 0.08 cdefg	5.78 ± 0.09 bcdef	5.68 ± 0.08 cdefghi	5.92 ± 0.08 cdefgh
Grande naine	5.49 ± 0.05 gh	5.47 ± 0.05 fgh	5.64 ± 0.05 cdefghi	5.75 ± 0.05 fghij
Gros michel	5.38 ± 0.09 h	5.60 ± 0.10 cdefgh	5.68 ± 0.10 cdefghi	5.86 ± 0.10 defghij
IDN110	5.90 ± 0.05 bcde	5.90 ± 0.05 abcd	5.85 ± 0.05 abcdef	6.06 ± 0.05 bcde
Pisang jary buaya	5.86 ± 0.07 bcdef	5.56 ± 0.08 defgh	5.54 ± 0.07 ghi	6.02 ± 0.07 bcdefg
Pisang mas	5.49 ± 0.05 gh	5.75 ± 0.05 bcdef	5.91 ± 0.05 abc	6.13 ± 0.05 bcd
Yangambi km5	5.94 ± 0.05 bc	6.00 ± 0.05 ab	5.88 ± 0.05 abcd	6.10 ± 0.05 bcd

Means ± standard deviation with the same letters in the same column are not significantly different at P<0.05 (Student Newman Keul's test).

Table 4 *Musa* pulp pH changes during ripening.

***Musa* Type**	**Stage 1 (unripe)**	**Stage 3 (start ripe)**	**Stage 5 (ripe)**	**Stage 7 (fully ripe)**
Cooking bananas				
Dwarf kalapua	6.34 ± 0.07 a	5.10 ± 0.08 b	4.74 ± 0.04 c	4.58 ± 0.05 d
Laknau	6.21 ± 0.05 a	4.87 ± 0.05 b	4.60 ± 0.02 c	4.57 ± 0.03 c
Mnalouki	6.07 ± 0.05 a	5.07 ± 0.06 b	4.59 ± 0.03 c	4.54 ± 0.04 c
Pelipita	6.13 ± 0.06 a	4.99 ± 0.07 b	4.73 ± 0.03 b	4.74 ± 0.04 b
Popoulou	6.08 ± 0.05 a	5.28 ± 0.06 b	4.77 ± 0.03 c	4.65 ± 0.04 c
Topala	5.88 ± 0.06 a	4.93 ± 0.06 b	4.56 ± 0.03 c	4.48 ± 0.04 c
Dessert bananas				
Banane cochon	5.62 ± 0.05 a	4.78 ± 0.05 b	4.66 ± 0.02 c	4.83 ± 0.03 b
Foconah	5.62 ± 0.06 a	4.57 ± 0.06 bc	4.46 ± 0.03 c	4.69 ± 0.04 b
Figue rose naine	5.42 ± 0.09 a	4.76 ± 0.10 b	4.77 ± 0.05 b	5.54 ± 0.06 a
Grande naine	5.65 ± 0.05 a	4.82 ± 0.06 d	4.96 ± 0.03 c	5.15 ± 0.04 b
Gros michel	5.46 ± 0.10 a	4.74 ± 0.11 c	4.88 ± 0.05 c	5.28 ± 0.07 b
IDN110	5.50 ± 0.05 a	4.87 ± 0.06 c	4.77 ± 0.03 c	5.25 ± 0.04 b
Pisang jary buaya	5.55 ± 0.08 a	4.52 ± 0.09 b	4.33 ± 0.04 c	4.59 ± 0.06 b
Pisang mas	5.67 ± 0.05 a	5.04 ± 0.06 c	5.00 ± 0.03 c	5.32 ± 0.04 b
Yangambi km5	5.51 ± 0.05 a	4.79 ± 0.06 c	4.69 ± 0.03 d	5.18 ± 0.04 b

Means ± standard deviation with the same letters in the same row are not significantly different at P<0.05 (Student Newman Keul's test).

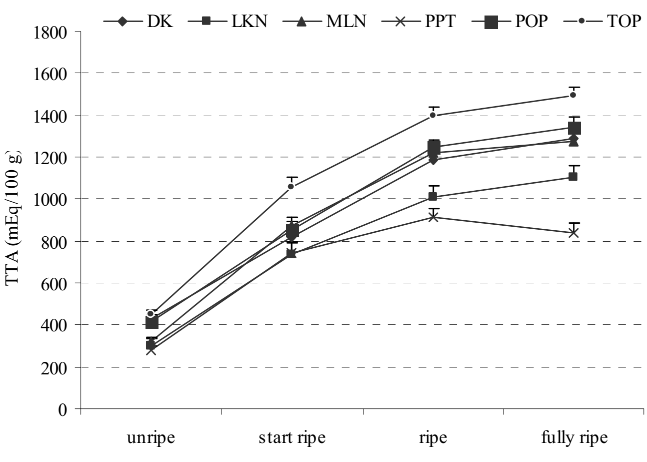

Fig. 7 Changes in total titratable acidity (TTA) during ripening of cooking bananas. Means ± standard deviation with the same letters are not significantly different at P<0.05 (Student Newman Keul's test). DK: Dwarf kalapua; LKN: Laknau; MLK: Mnalouki; PPT: Pelipita; POP: Popoulou; TOP: Topala.

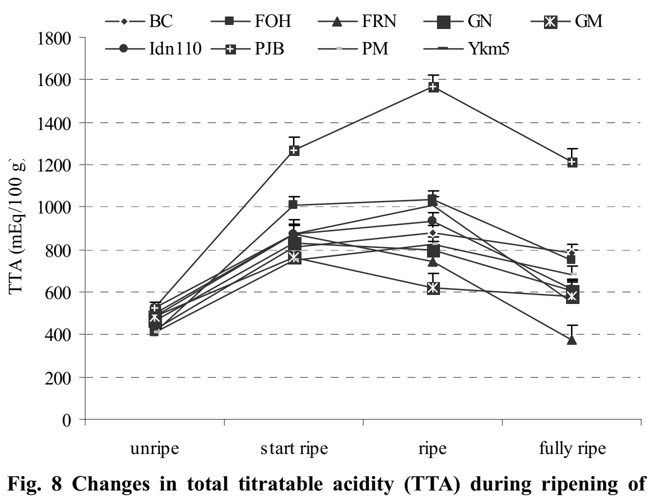

Fig. 8 Changes in total titratable acidity (TTA) during ripening of dessert bananas. Means ± standard deviation with the same letters are not significantly different at P<0.05 (Student Newman Keul's test). BC: Banane cochon; FOH: Foconah; FRN: Figue rose naine; GN: Grande naine; GM: Gros michel; Idn110: IDN 110; PJB: Pisang jary buaya; PM: Pisang mas; Ykm5: Yangambi km5.

that of green peel for the same cultivar. At harvest, pulp pH ranged between 5.42 and 6.34. These values significantly decreased during ripening and reached 4.57 to 5.54 at fully ripe stage. Similar results were reported for some *Musa* cultivars in Africa (Ngalani *et al.* 1998; Aboua 1991; Collin and Dalnic 1991; Burdon *et al.* 1991; Onyejegbou and Ayodele 1995). The pulp pH decline has been attributed to the high production of malic acid during ripening. A highly negative correlation exists between pulp pH and total titratable acidity (**Table 2**). Cooking and dessert bananas analysed are characterised by a decrease in pulp pH and increase in total titratable acidity (TTA) as fruit advance in age. At harvest 'Topala' (448 meq/100 g) and 'IDN110' (527 meq/100 g) exhibited maximum values of TTA.

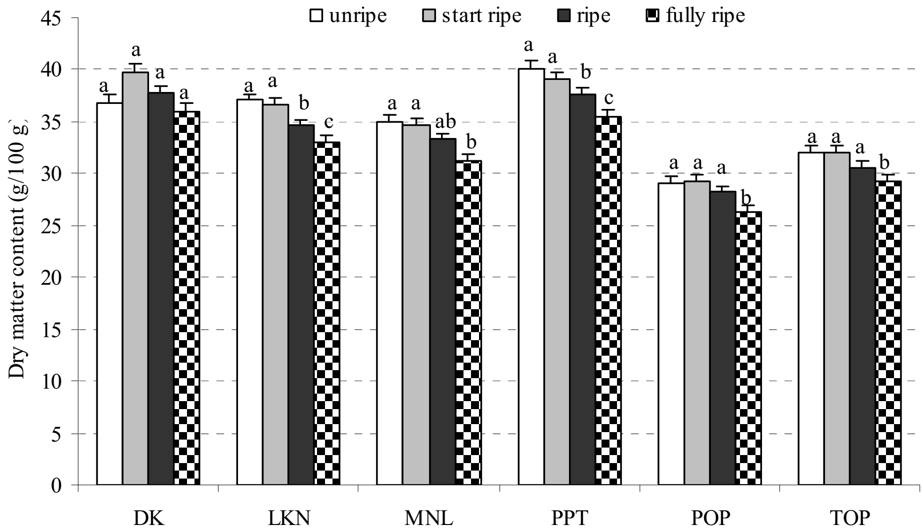

Fig. 9 Changes in pulp dry matter contents during ripening of cooking bananas. Means ± standard deviation with the same letters are not significantly different at P<0.05 (Student Newman Keul's test). DK: Dwarf kalapua; LKN: Laknau; MLK: Mnalouki; PPT: Pelipita; POP: Popoulou; TOP: Topala.

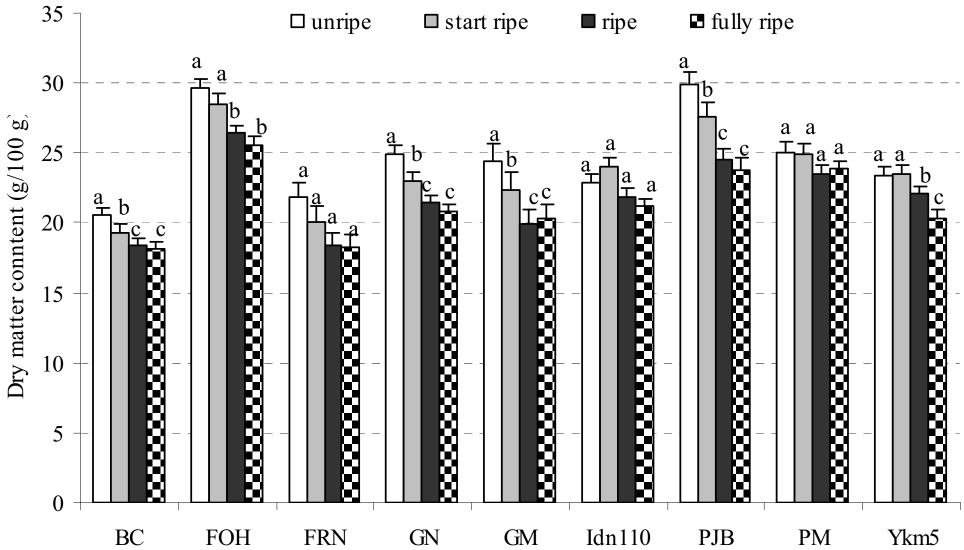

Fig. 10 Changes in pulp dry matter contents during ripening dessert bananas. Means ± standard deviation with the same letters are not significantly different at P<0.05 (Student Newman Keul's test). BC: Banane cochon; FOH: Foconah; FRN: Figue rose naine; GN: Grande naine; GM: Gros michel; Idn110: IDN 110; PJB: Pisang jary buaya; PM: Pisang mas; Ykm5: Yangambi km5.

During ripening TTA content of cooking bananas keep on increasing 3 to 4 times at stage 7 (**Fig. 7**) meanwhile that of dessert bananas increased up to a maximum value between stage 3 and 5, then decreased in fully ripe pulps but never reached the initial values (**Fig. 8**). Significant differences were observed between TTA content of unripe and fully ripe pulps of all the *Musa* varieties analysed. The phenomenon (increase of TTA content up to a pick then slightly decrease) observed in bananas is similar to many fruits such as guava and mango during post harvest maturation (Abou-Goukh and Abu-Sarra 1993; Bashir and Abou-Goukh 2003). The increase during ripening has been attributed to the production of acid compounds (malic and citric for *Musa* sp.) responsible for the taste.

Dry matter content

Peel and pulp dry matter contents of banana are important post-harvest quality attributes in the assessment of fruit maturation. The dry matter contents of the pulp of all cooking banana cultivars were significantly higher (P<0.05) than those of dessert bananas (**Figs. 9, 10**). 'Pelipita' exhibited the highest value at harvest (40 g/100 g fw). During ripening, the dry matter content of banana pulps decreased from stage 1 to 7 but did not change significantly. **Table 5** presents *Musa* peel dry matter content. High rate of respiration accompanied by water loss that occurs in banana during ripening, particularly at climacteric stage causes a net reduction in the proportion of the fruit dry matter. Compared to the pulps, banana peels showed different trends during post harvest maturation, increasing significantly from green to completely yellow colour. The lack of significant change in the dry matter of the pulp of all the cultivars and the increase in that of the peel corroborate the results and trends of some *Musa* cultivars investigated by Ngalani *et al.* (1998), Aboua (1991), Collin and Dalnic (1991), and Burdon *et al.* (1991).

CONCLUSION

All the physicochemical parameters analysed at harvest vary according to banana cultivars. Significant differences and different variation trends have been observed during ripening of dessert and cooking bananas. Physicochemical characteristics evaluated in this study are important post harvest quality criteria in *Musa* screening and breeding. Dry matter content for example provide banana breeders with information in determining whether increased yield is due to higher water content or to genuine increase in harvest weight. It is also an important parameter for processing

Table 5 Changes in *Musa* peel dry matter contents during ripening.

Musa **types**	**Stage 1 (unripe)**	**Stage 3 (start ripe)**	**Stage 5 (ripe)**	**Stage 7 (fully ripe)**
Cooking bananas				
Dwarf kalapua	14.39 ± 0.59 a	14.70 ± 0.52 a	14.89 ± 0.64 abc	16.22 ± 1.12 bcdefg
Laknau	11.28 ± 0.41 bcdef	12.12 ± 0.37 bcdefg	12.06 ± 0.45 defg	16.27 ± 0.79 bcdefg
Mnalouki	11.14 ± 0.45 bcdef	11.59 ± 0.40 defghi	12.03 ± 0.49 defg	15.86 ± 0.87 bcdefg
Pelipita	11.32 ± 0.51 bcdef	12.16 ± 0.45 bcdefg	13.35 ± 0.55 bcdef	19.27 ± 0.97 bc
Popoulou	9.89 ± 0.45 defg	9.80 ± 0.40 ghij	11.39 ± 0.49 fg	18.20 ± 0.87 bcde
Topala	10.37 ± 0.48 cdefg	12.80 ± 0.43 abcdef	14.28 ± 0.52 abcde	18.11 ± 0.92 bcde
Dessert bananas				
Banane cochon	11.44 ± 0.41 bcde	13.02 ± 0.37 abcde	14.36 ± 0.46 abcde	17.73 ± 0.79 bcde
Foconah	10.36 ± 0.48 cdefg	10.76 ± 0.43 efghi	11.95 ± 0.52 defg	18.38 ± 0.92 bcd
Figue rose naine	10.08 ± 0.72 defg	10.84 ± 0.64 efghi	10.24 ± 0.79 gh	13.79 ± 1.38 defg
Grande naine	9.56 ± 0.43 efg	9.90 ± 0.38 ghij	10.79 ± 0.47 fgh	12.54 ± 0.83 fg
Gros michel	9.51 ± 0.83 efg	10.78 ± 0.74 efghi	10.46 ± 0.91 gh	14.57 ± 1.59 cdefg
IDN110	10.25 ± 0.45 defg	10.81 ± 0.40 efghi	11.70 ± 0.49 efg	20.21 ± 0.87 b
Pisang jary buaya	11.59 ± 0.64 bcde	12.08 ± 0.57 bcdefg	12.36 ± 0.70 cdefg	17.58 ± 1.23 bcdef
Pisang mas	9.99 ± 0.45 defg	11.96 ± 0.40 cdefgh	14.46 ± 0.49 abcd	24.20 ± 0.87 a
Yangambi km5	8.63 ± 0.43 fg	10.06 ± 0.38 ghij	10.13 ± 0.47 gh	16.84 ± 0.83 bcdef

Means ± standard deviation with the same letters in the same column are not significantly different at $P<0.05$ (Student Newman Keul's test).

quality. Acids make an important contribution to the post harvest quality of the fruit, as taste is mainly a balance between sugar and acid contents. Data from this study will be reported to the *Musa Germplasm Information System* of Bioversity International in order to be shared worldwide. Further studies including nutritional aspects, sensorial and microbial analysis as well as effects of processing on the fruit composition will be carried out involving more dessert and cooking bananas from CARBAP *Musa* collection.

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