Field Scientific Report

Participatory Processing Diagnosis of Boiled Plantain in Cameroon

Understanding the Drivers of Trait Preferences and the Development of Multi-user RTB Product Profiles, WP1, Step 3

Njombé, Cameroon, September 2019

Gérard NGOH NEWILAH, Centre Africain de Recherches sur Bananiers et Plantains (CARBAP), Njombé, Cameroon

Cédric KENDINE VEPOWO, CARBAP, Njombé, Cameroon

Annie TAKAM NGOUNO, University of Dschang, Dschang, Cameroon

Alexandre BOUNIOL, Centre de coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Montpellier, France (Validator)

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Ethics: The activities, which led to the production of this document, were assessed and approved by the CIRAD Ethics Committee (H2020 ethics self-assessment procedure). When relevant, samples were prepared according to good hygiene and manufacturing practices. When external participants were involved in an activity, they were priorly informed about the objective of the activity and explained that their participation was entirely voluntary, that they could stop the interview at any point and that their responses would be anonymous and securely stored by the research team for research purposes. Written consent (signature) was systematically sought from sensory panellists and from consumers participating in activities.

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Alexandre BOUNIOL	28/04/2020
Final validation by:	
Alexandre BOUNIOL (CIRAD)	28/04/2020

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ABSTRACT

Participatory Processing Diagnosis for boiled plantain in Cameroon

Cameroon (Bafoussam & Douala)

September 2019

Gérard NGOH NEWILAH, University of Dschang, Dschang – Cameroon / CARBAP – Cameroon

Cédric KENDINE VEPOWO, CARBAP, Njombé, Cameroon

Annie TAKAM NGOUNO, University of Dschang, Dschang – Cameroon

Within the framework of the RTBfoods project, processing demonstrations were carried out in order to understand processors' demand for quality characteristics of plantain while processing different varieties. This activity was executed between the 4th and 9th September 2019 in Bafoussam (1 521 m above sea level (asl)) and Douala (13 m asl) with a total of six (06) processors (three per town). Processors were asked to boil plantains on-site using our tools and four (4) plantain varieties. These plantain varieties were of three (3) kinds: (i) a variety considered to be good, corresponding to the local variety frequently used by the processor in his/her restaurant; (ii) two intermediate quality varieties (*Batard* and *Big ebanga*), and (iii) one poor variety (a plantain-like hybrid), *CARBAP K74*. It was revealed that boiled plantain is obtained after a series of five (5) preparation steps which vary depending on whether processors cook with or without peel. During processing, *Big ebanga* presented the highest "peeling + scraping" yield (51.08-52.55 % wet basis (w.b)), while local varieties had the least values (44.88-45.31 % w.b). Cooking yield was highest for *Batard* and *Big ebanga* (59.35-61.35 % w.b) and least for local varieties (53.59-54.67% w.b) in both towns. Irrespective of the towns, *Big ebanga* presented an overall process yield greater than 30% (w.b). Dry matter content of raw plantain pulps revealed values ranging between 30.0 and 41.7 % (w.b) with *CARBAP K74* having the lowest values. High-quality boiled plantain should be attractive, wet, soft in the mouth with a good/plantain taste; while poor or bad quality boiled plantain is pale in color, with a taste of sap or banana and is hard in the mouth. Of all the varieties, *Batard* and *Big ebanga* were preferred most by the processors, while *CARBAP K74* was liked least. This study suggests that the plantain-like hybrid, *CARBAP K74*, despite its intermediate cooking and "peeling + scraping" yields, is not suitable for boiling unlike *Batard* and *Big ebanga* which not only presented higher cooking yields, but are also preferred by processors with greater dry matter contents.

Key Words: Boiled plantain, plantain processing, unripe plantain, plantain cultivars, plantain like hybrid, quality characteristics, yield, dry matter content, Cameroon

1 STUDY CONTEXT AND GENERAL OBJECTIVES

The knowledge of quality crop characteristics important to end-users are necessary for the development of hybrids that will be adopted. In this respect, the RTBfoods project in its Work package 1, through a methodology developed by Forsythe *et al.*[1], aims at determining traits of importance to users along the food chain, in order to develop food product profiles that support breeding and selection decisions. During the implementation of this methodology, step 2: Gendered Food mapping, revealed interesting insights that need to be completed with steps 3 and 4 of the methodology for the development of the product profile.

The current document focuses on step 3 of the methodology: Participatory Processing Diagnosis and Quality Characteristics, whose objectives are to:

- conduct participatory processing diagnoses of plantain with restaurant cooks;
- understand processors' demand for quality characteristics of plantain while processing different varieties.

2 METHODOLOGY

2.1 Study Area

Processing demonstrations were done with selected processors in the towns of **Douala** (04°03′N 009°41′E, 13 m asl) and **Bafoussam** (5°28′N 10°25′E, 1 521 m asl) from the 4th to 9th September 2019. These processors gave their approval during a preliminary field visit carried out from the 09th to 12th August 2019. For these processing demonstrations, three (3) processors per town were needed. These activities were done at their working place using our tools. An entire day was needed to complete processing demonstrations with each processor.

2.2 Raw Material Choice

Processing diagnoses were carried out using four cultivars: (i) a cultivar considered to be good, corresponding to the local cultivar frequently used by the processor in his/her restaurant; (ii) two intermediate quality cultivars (*Batard* and *Big ebanga*), harvested from CARBAP's experimental plots in Njombé; and (iii) one poor cultivar, *CARBAP K74* (a CARBAP-CIRAD co-ownership plantain-like hybrid created in Cameroon) harvested from CARBAP experimental plot in Bansoa

It should be recalled that during the implementation of this activity, only unripe plantain pulps (pulps of plantain fruits that are green) were boiled in order to avoid ripening stage variability.

[1] Forsythe, L., Tufan, H., Bouniol, A., Kleih, U., & Fliedel, G. (2021). An interdisciplinary and participatory methodology to improve user acceptability of root, tuber and banana varieties through development of food product profiles quality characteristics. *International Journal of Food Science and technology*; Special Issue: Consumers have their say: assessing preferred quality traits of roots, tubers and cooking bananas, and implications for breeding, 56 (1), submitted manuscript.

1st Processor

Photo 1. Long fingers plantain

2nd Processor

Photo 2. Short fingers plantain *(Kelong mekintu)*

3rd Processor

Photo 3. Big fingers plantain *(Matumb)*

Figure 1: Photos of local varieties used by processors in Bafoussam

Medium varieties

Photo 4. Bunch of *Batard cv.*

Photo 5. Bunch of *Big ebanga cv.*

Bad variety

Photo 6. Bunch of *CARBAP K74 cv.*

Figure 2: Photos of medium and bad varieties used by processors in Bafoussam

4th Processor

Photo 7. Plantain from the West region

5th Processor

Photo 8. Bunch of *Moundja cv.*

6th Processor

Photo 9. Bunch of *Moundja cv.* from Deido market

Figure 3: Photos of local varieties used by processors in Douala

Medium varieties

Photo 10. Bunch of *Batard cv.*

Photo 11. Bunch of *Big ebanga cv.*

Bad variety

Photo 12. Bunch of *CARBAP K74 cv.*

Figure 4: Photos of medium and bad varieties used by processors in Douala

2.3 Product Profile Processing

For these processing demonstrations, processors were asked to prepare plantain using three (3) fruits from each bunch and in separate pots. These fruits were gotten either from the second or third hands of the plantain bunches since they are the most representative ones.

The processing steps involved in obtaining boiled plantain are:

Step 1. Detaching fruits from the bunch

Fruits are either detached from the bunch using a knife to cut the peduncle resulting into a fruit without peduncle or detached by pulling up in order to obtain the entire fruit. After detaching the fruits from the bunch, they were first weighed before the next step.

Step 2. Fruit washing

Fruits are washed using clean water in a basin in order to remove dirt and other impurities before peeling.

Step 3. Fruit peeling

Depending on the cooking mode, the plantain fruit can be peeled using a knife when cooked without peel. During this process, the operator avoids cutting the pulp with a worn-out tool. A sharpened stick or bamboo could also be used for the same purpose. The obtained pulp is either scraped or not, then kept in water at ambient temperature in order to avoid enzymatic browning. Sometimes, the pulp (whether scraped or not) is introduced directly into the boiling water in a pot placed on the fire source. When cooked with peel, plantain fruits are not peeled, they are simply washed and cooked.

Step 4. Pulp scraping

This process is usually done either before cooking (plantain is boiled without peel) or after cooking (plantain was boiled with peel). After peeling the raw or boiled fruit, a knife or a sharpened stick/bamboo is used to scrape or clean off the thin skin of the pulp. Restaurant cooks indicated that this process improves the appearance of the boiled plantain (*it should look shiny*).

Step 5. Boiling

Whether boiled without peel or with peel, two possibilities are offered:

(i) The pulp (scraped or not) or the entire fruit is introduced in a pot containing water before carried to the heat source (here a gas cooker),
(ii) The pulp (scraped or not) or the entire fruit is introduced directly into the boiling water in a pot placed on the gas cooker.

The volume of water used, and the boiling time were processor-dependent. The end of the boiling process was assessed by the change in colour of the peeled fruits, the splitting of peels of the unpeeled fruits, the release of a characteristic plantain odour, etc. When boiling was complete, the boiled fruits were weighed, and the remaining water was measured. Fruits that were boiled with peels were also weighed once they were scraped. Samples of plantain both raw (entire fruits) and boiled (15-45g) were conditioned for laboratory analyses, this in order to measure parameters such as dry matter content, pH, total titratable acidity and total soluble solids.

Before and during processing demonstration, a series of measurements were done. They include:

- **Fruits' weight**: After detaching fruits from the bunch, the weight of three (3) fruits per cultivar was measured using a balance load-cell. When boiling was over, their weight was measured once more to ease the calculation for the change in weight. These measurements were expressed in grams (g);
- **Weight of waste**: Once the fruits were peeled and eventually scraped, their weight was measured and expressed in grams (g);
- **Peeling, scraping and cooking times**: these operations were measured using a stopwatch and were expressed either in seconds (s) or in minutes (min). At the beginning of each operation, the

stopwatch was started. Once the operation was over, the stopwatch was stopped, and the time of the operation was recorded;

- **Quantity of water used for boiling**: with a 2,000 mL measuring cylinder, the quantity of water to be used for boiling by the operators was measured and poured into the cooking pot. When boiling was done, using the same measuring cylinder, the remaining water was quantified;
- **Peel and pulp thickness**: after peeling of the fruits, they were cut transversely at the midpoint, and the peel and pulp thicknesses were measured with a pair of callipers and expressed in millimetres (mm);
- **Fruit's girth**: this was determined by measuring individual fruit with a tape at the widest midpoint of each fruit. This was expressed in centimetres (cm);
- **Fruit firmness**: using a hand-held force gauge (PCE-FM 200), the firmness of the pulp was determined. After cutting the fruits transversely at their midpoint and placing them on a flat surface, the force required to penetrate 1 cm of pulp tissue with a 6 mm diameter cylindrical probe was measured and expressed in kilogram force (kgf);
- **Bunch weight**: this was measured using a spring balance. A rope was first tied on the bunch to be weighed. This rope was then lifted using a spring balance such that the bunch was suspended in the air. The weight of the bunch was then recorded and expressed in kilograms (kg).

2.4 Statistical Analyses of data

XLSTAT 2014 Software was used to analyse all the data. Results are presented as means ± standard deviation. Statistical analyses were done using One-way ANOVA to determine the significant differences in the values at $P<0.05$ (Student Newman Keul's Test).

3 RESULTS & DISCUSSION

3.1 Raw Material Characteristics

Raw material characteristics measured during processing demonstrations include bunch weight, peel and pulp thicknesses, fruit length, fruit girth, etc. An overview of these characteristics is portrayed in table 1.

Table 1: Overview of the physical characteristics of raw material

Towns	Raw material	Bunch weight (kg)	Peel thickness (mm)	Pulp thickness (mm)	Pulp firmness (kgf)	Fruits length (cm)	Fruits girth (cm)
Bafoussam	*Long fingers plantain*	27.00	4.75	34.25	3.89	28.00	14.50
	Short fingers plantain	23.50	3.95	32.61	6.24	20.35	14.45
	Big fingers plantain (Matumb)	13.00	2.86	30.74	5.94	20.50	13.40
	Batard	36.00	3.49	36.97	4.17	29.00	14.00
	Big ebanga	12.00	4.41	37.05	3.95	28.50	14.00
	CARBAP K74	22.00	3.20	34.29	3.92	20.00	12.50
Douala	*Plantain from the West region*	21.00	4.04	34.25	5.12	22.00	12.45
	Moundja	9.00	4.20	30.04	5.56	24.50	13.25
	Moundja	14.00	3.63	29.01	5.51	25.25	13.25
	Batard	15.00	3.28	36.69	5.35	22.00	14.50
	Big ebanga	17.00	4.11	39.08	4.65	30.30	16.00
	CARBAP K74	14.00	3.30	26.80	4.66	18.00	11.50

From these results, varieties in Bafoussam weighed more than those in Douala, with the highest weight been attributed to *Batard* (36 kg), while *Moundja* (local variety in Douala) weighed 9 kg. The weights attributed to these bunches are highly impacted by the size of their peduncles. Thus, the fact that a variety weighs more than another does not reflect the weight of the fruits taken individually.

“Long fingers plantain” had the highest peel thickness while “Big fingers plantain” had the lowest peel thickness. The thickness of the peel gives an idea of the ease with which plantain could be peeled. Thus, the greater the peel, the easier the peeling.

Pulp thickness varied between 26.80 mm (*CARBAP K74*) and 39.08 mm (*Big ebanga*) depending on localities. This criterion may help to explain some cooking parameters such as cooking time, and the volume of water used.

3.1.1 Weight of plantain fruits

The average weight of plantain fruits used for the processing demonstrations per variety and per town are displayed in the figure below. It should be noted that three (3) fruits were used per variety per processor. Irrespective of the towns, *Big ebanga* and *Batard* had the highest weights comprised between 0.71 and 0.94 kg, unlike *CARBAP K74* that weighed least (0.42-0.50 kg).

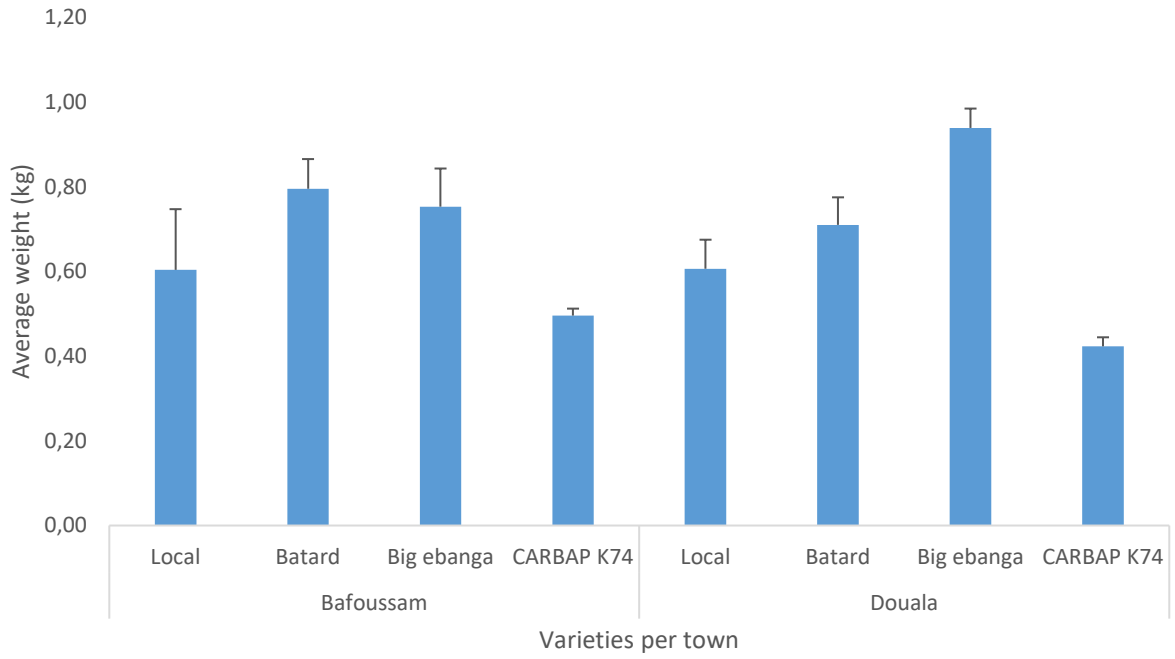

Figure 5: Average weight (kg) of plantain fruits for each variety per town

3.1.2 Raw pulp dry matter contents and firmness

In the course of this activity, dry matter contents and firmness were assessed on raw plantain pulps (table 2). Both parameters were low for the plantain-like hybrid (*CARBAP K74*) unlike the landraces that exhibited higher values.

Table 2: Dry matter contents and firmness of raw plantain pulps per town

Locality	Cultivars	Raw pulp dry matter content (%)	Raw pulp firmness (kgf)
Bafoussam	Local cultivar	39.7 ± 1.9^{ab}	5.4 ± 2.8^{a}
	Batard	41.7 ± 0.0^{a}	4.2 ± 0.0^{b}
	Big ebanga	38.5 ± 0.0^{b}	4.0 ± 0.0^{b}
	CARBAP K74	31.8 ± 0.0^{c}	3.9 ± 0.0^{b}
Douala	Local cultivar	39.4 ± 2.1^{ab}	5.4 ± 0.2^{a}
	Batard	40.9 ± 0.0^{ab}	5.4 ± 0.0^{a}
	Big ebanga	39.1 ± 0.0^{b}	4.7 ± 0.0^{ab}
	CARBAP K74	30.0 ± 0.0^{d}	4.7 ± 0.0^{ab}

Means with the same letters in the same column are significantly different at 5% threshold.

3.1.3 Qualitative information collected on the raw material

While carrying out the processing demonstration, some qualitative information regarding raw plantain were obtained from processors or restaurant cooks.
In fact, it was revealed that, plantain to be boiled should be mature. This maturity implies a variety of assessment methods, among which the colour of pulp observed when a fruit is broken was the most recurrent. This method usually clears the processors' doubts on the maturity stage of plantain, since the colour of the fruit (dark green), the size of the fruits (long fruits) and the presence of dark apices on plantain fruits can be disappointing on the maturity point of view. When the colour of pulp is orange/yellow, the plantain is deemed mature. When this colour is instead white, it is rather immature. Some processors' preference for certain plantain varieties is either due to consumer demands who might prefer short plantain fruits, or to profitability made as longer plantain fruits are beneficial in catering.

3.2 Product Profile Process Description

3.2.1 Unit operations of product profile process

Processing of raw plantain into boiled plantain requires a series of four (4) to five (5) steps that depend either on the cooking mode (with or without peel) or on the processor (a step performed either before or after another one). These steps include: detaching fruits from the bunch, washing, peeling, boiling and scraping (figure 6). The scraping step, as stated by the processors helps in improving the attractiveness of the boiled plantain.

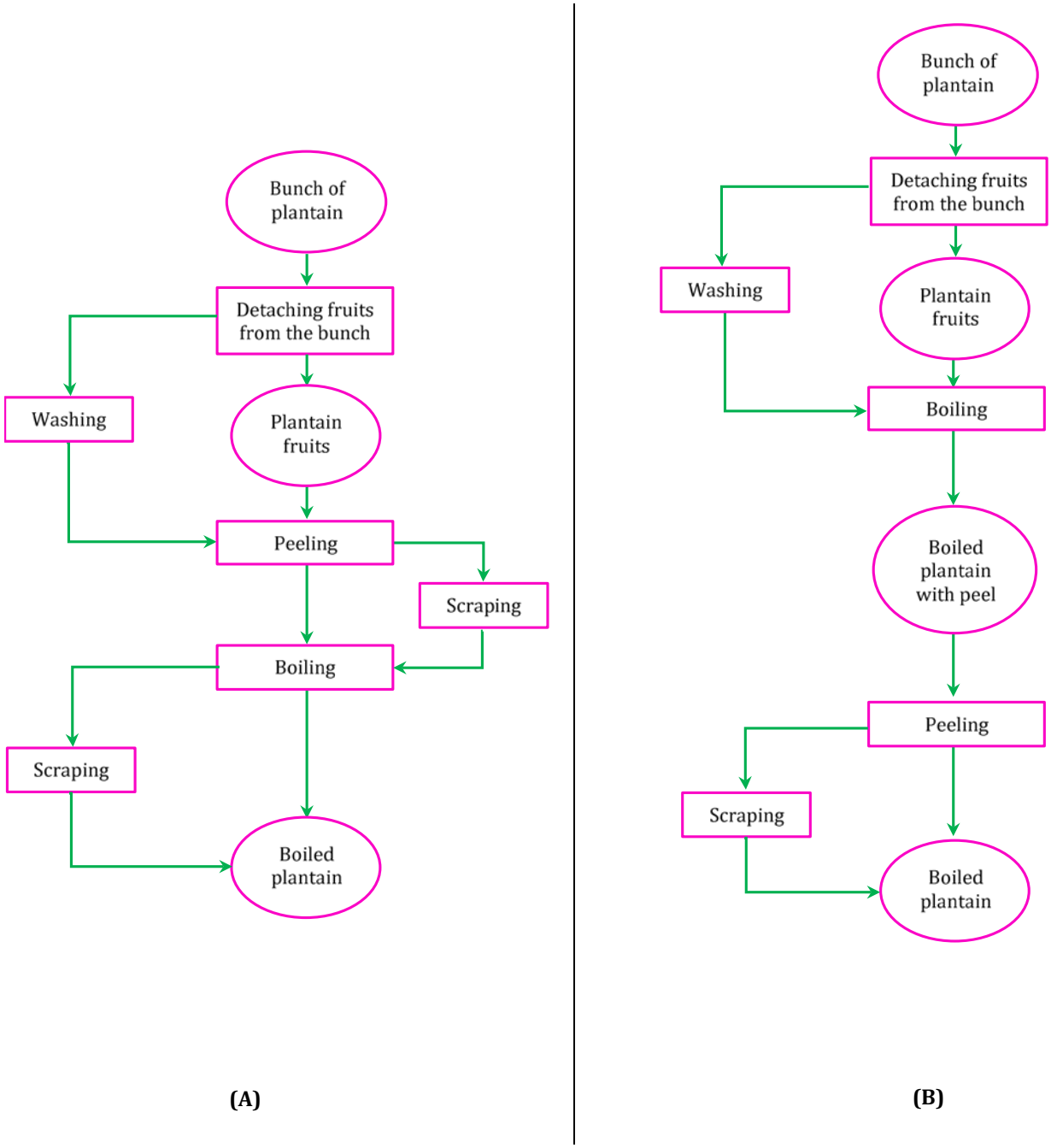

Figure 6: Flow diagram of boiled plantain process without peel **(A)** and with peel **(B)**

3.2.2 Unit operations characterization

Two (2) main unit operations were characterized during processing demonstrations: “Peeling” and “Boiling”, for which the durations were measured. The unit operation “Scraping”, was done by some

processors either before or after cooking. Concerning the yield of the operations, the remains (or wastes) produced during peeling and scraping were combined in order to consider these two steps as one, and hence have the "Peeling + Scraping" yield. The unit operation "cooking" remained unchanged. The yield of a unit operation is calculated as follows:

$$Yield = \frac{Quantity\ of\ processed\ product}{Quantity\ of\ raw\ material} \times 100$$

The productivity of these combined steps was also measured and calculated as the quantity of raw material processed per hour per operator.

Peeling and scraping

Peeling of plantains were performed either before or after boiling depending on the cooking mode. When done after cooking, peeling was easier for the processor to carry out this operation. Unlike peeling, scraping is done to improve the appearance of plantain, but does not condition its edibility since plantains can be consumed without been scraped, but can't be consumed without been peeled or cooked. Thus, peeling and scraping in the course of this study will be considered as a unit operation while taking into consideration the wastes produced by both steps.

Duration

Peeling and scraping times recorded in the course of this study are displayed in tables 3 & 4. *Batard* and *Big Ebanga* presented the highest peeling times especially in Bafoussam. The same constat is observed with scraping times. However, these values are a function the fruits lengths as longer fruits take much time to peel and scrape than shorter ones. Despite these findings, processors acknowledged that *CARBAP K74* was difficult to peel, although its fruits were relatively shorter than others. This could be due to its lower peel thickness compared to the other varieties, as the greater the peel thickness the greater the peeling ability

Table 3: Peeling time (seconds) of the various plantain varieties

Processors	Local cultivar	*Batard*	*Big ebanga*	*CARBAP K74*
BAF_P1	15.5 ± 0.6	20.6 ± 0.7	14.5 ± 0.5	13.7 ± 0.8
BAF_P2	41.1 ± 5.9	21.1 ± 0.4	48.3 ± 5.5	14.3 ± 0.5
BAF_P3	19.7 ± 1.3	34.9 ± 3.9	24.2 ± 3.8	17.7 ± 3.6
DLA_P4	9.4 ± 0.7	9.1 ± 0.5	9.9 ± 0.6	9.8 ± 1.7
DLA_P5	14.6 ± 4.9	18.5 ± 1.9	16.2 ± 2.3	13.5 ± 2.1
DLA_P6	2.0 ± 0.4	2.7 ± 0.7	3.0 ± 0.4	2.4 ± 0.6

BAF=Bafoussam; DLA=Douala; Pn=Processor number (1≤n≤6)

Table 4: Scraping time (seconds) of the various plantain varieties

Processors	Local cultivar	*Batard*	*Big ebanga*	*CARBAP K74*
BAF_P1	28.8 ± 0.2	24.2 ± 0.3	34.6 ± 1.8	23.8 ± 0.5
BAF_P2	43.5 ± 0.7	62.5 ± 10.6	48.5 ± 0.8	49.4 ± 7.8
BAF_P3	31.6 ± 9.0	25.4 ± 3.1	41.4 ± 5.1	20.3 ± 2.9
DLA_P4	17.1 ± 0.7	14.7 ± 0.4	22.2 ± 0.6	14.9 ± 0.6
DLA_P5	12.8 ± 2.9	11.9 ± 0.9	16.3 ± 0.7	10.4 ± 0.5
DLA_P6	10.5 ± 1.6	13.5 ± 0.6	23.5 ± 6.7	9.4 ± 1.8

BAF=Bafoussam; DLA=Douala; Pn=Processor number (1≤n≤6)

Peeling + scraping yield

The peeling + scraping yield observed during these demonstrations varied from 44.55 to 52.67 % (w.b), with no significant difference between the 4 varieties irrespective of the towns (Figure 7).

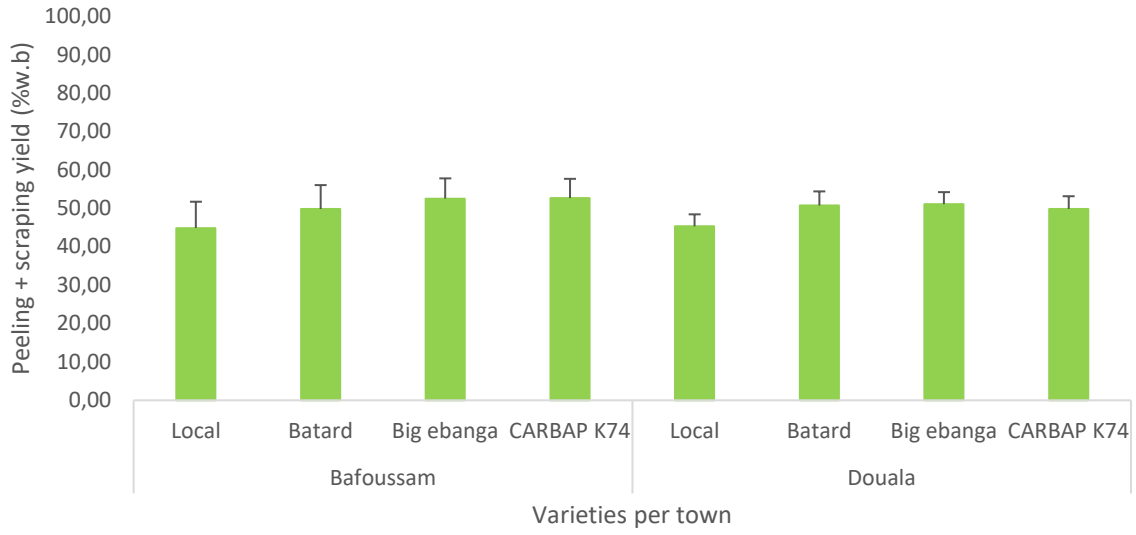

Figure 7: Peeling + scraping yield (% w.b) of the plantain cultivars

Peeling + scraping productivity

The "peeling + scraping" productivity expressed in kilograms of processed raw material is shown in figure 8. This unit operation showed huge discrepancies in both towns, with Douala having the highest productivity for all its cultivars. This can be explained by the fact that in Douala, the sixth (6th) processed plantains with peels unlike the other processors, thereby reducing tremendously the peeling time and eventually the scraping time, compared to other processors. Despite these huge differences, analysis of variance showed no significant difference at 5% threshold.

When taking into account processors' effect on processing as shown in table 5, the highest productivity is observed for the sixth (6th) processor (144.19 Kg of raw plantain processed per hour), while the least productivity is obtained by the second (2nd) processor (28.82 Kg of raw plantain processed per hour). This implies that when cooking plantains with peels, one is more productive when it comes to peeling and scraping unlike when cooking without peels.

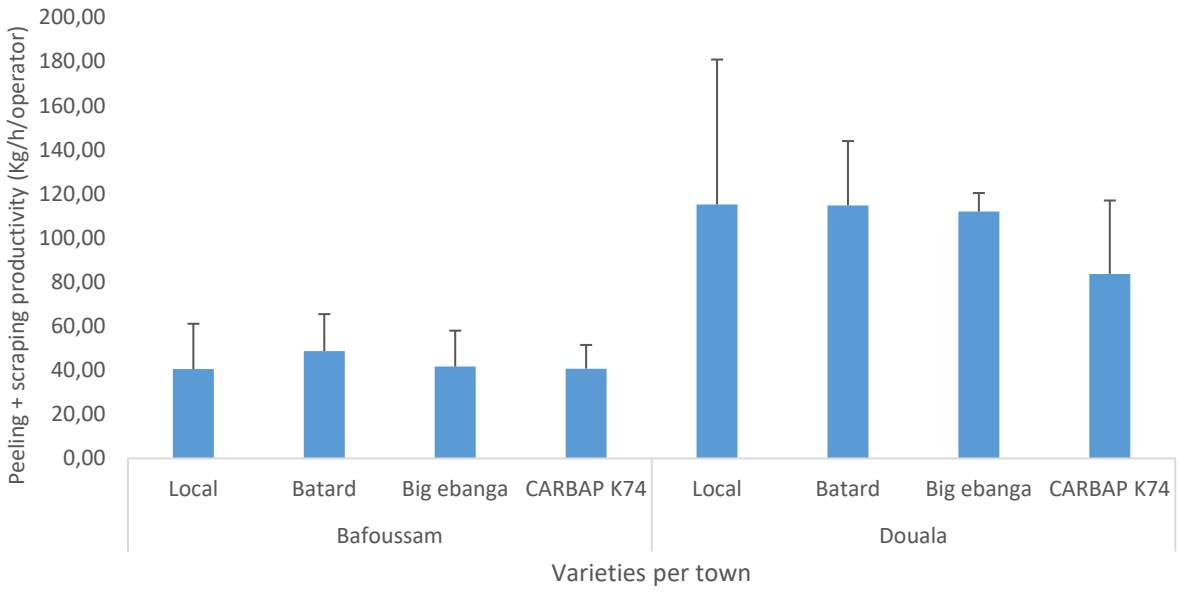

Figure 8: Peeling + scraping yield productivity (Kg of processed raw material/hour/operator) of the plantain cultivars

Table 5: Productivity of the various processors

Processors	Productivity (Kg of processed raw material/hour/operator)
BAF_P1	59.69^{bc}
BAF_P2	28.82^{c}
BAF_P3	40.28^{c}
DLA_P4	91.01^{b}
DLA_P5	84.13^{b}
DLA_P6	144.19^{a}

Means with the same letters in the same column are significantly different at 5% threshold.
BAF=Bafoussam; DLA=Douala; Pn=Processor number (1≤n≤6)

Cooking

Boiling temperature

During processing demonstrations, the boiling temperature of water was measured (see table 6). In fact, this temperature varied from 96.4 °C in the town of Bafoussam to 100.8 °C in the town of Douala. The difference in these values is due to the altitude of these towns. As a matter of fact, Douala is located at 13 m asl, while Bafoussam is located at 1,521 m asl. Since the boiling temperature of water is a function of the altitude of a locality, the higher we go, the lower the boiling temperature.

Table 6: Boiling temperature of water used in cooking plantain fruits

Processors	Boiling temperature (°C)
BAF_P1	96.43 ± 0.05
BAF_P2	96.40 ± 0.00
BAF_P3	96.38 ± 0.05
DLA_P4	100.78 ± 0.05
DLA_P5	100.58 ± 0.05
DLA_P6	100.80 ± 0.00

BAF=Bafoussam; DLA=Douala; Pn=Processor number (1≤n≤6)

Duration

Cooking time in this study refers to the time between which the pot (containing water) is set on fire (with or without the peeled/unpeeled fruit) and that at which cooking is complete. In this respect, results obtained on this parameter are shown in table 7. The sixth processor in the town of Douala had the highest cooking time (60 – 87 minutes). Since this processor cooked her plantains with peels, more time is needed for the water to enter the fruit's pulp as the peel constitute a barrier.

Table 7: Cooking time (minutes) of the various plantain varieties

Processors	Local variety	*Batard*	*Big ebanga*	*CARBAP K74*
BAF_P1	65	64	60	64
BAF_P2	43	41	60	56
BAF_P3	26	26	41	50
DLA_P4	46	44	61	59
DLA_P5	15	15	18	18
DLA_P6	70	87	60	60

BAF=Bafoussam; DLA=Douala; Pn=Processor number (1≤n≤6)

Cooking yield

The cooking yield of the various varieties ranged between 54.67 and 61.35 % w.b, with no significant difference at 5% threshold.

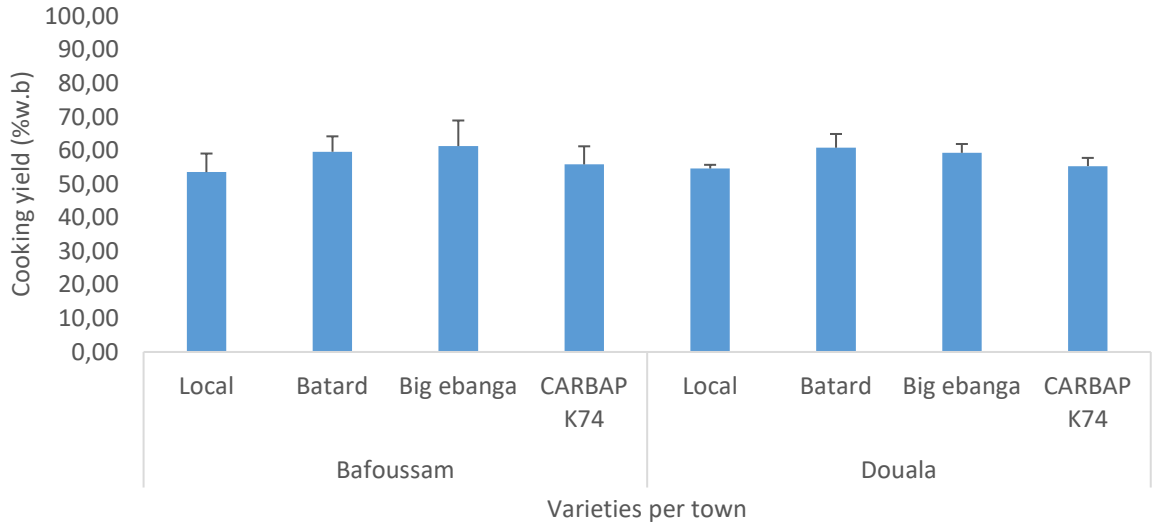

Figure 9: Cooking yield (% w.b) of plantain cultivars

Quantity of water used during boiled plantain preparation

The percentage of water used by the processors during boiling is shown in table 8. This quantity of water does not take into account water loss as vapor during boiling. More than 60% of the initial water is used during boiling by the processors. However, in Douala the second processor used less than 60% of this water to boil the Local variety, *Batard* and *Big ebanga*. This processor also had shorter cooking times, thus the water to be evaporated during boiling was reduced compared to the other processors.

$$Percentage\ of\ water\ used = \frac{Qi - Qr}{Qi} \times 100$$

With *Qi* = Quantity of water put in the pot for boiling
Qr = Quantity of water remaining after boiling

Table 8: Percentage of water used during plantain boiling

Processors	Local variety	*Batard*	*Big ebanga*	*CARBAP K74*
BAF_P1	92.00%	89.88%	74.45%	64.45%
BAF_P2	89.96%	75.19%	77.84%	81.65%
BAF_P3	98.08%	88.74%	100.00%	87.80%
DLA_P4	62.21%	59.88%	88.95%	94.77%
DLA_P5	50.57%	59.77%	59.77%	66.67%
DLA_P6	92.75%	84.07%	76.79%	95.75%

BAF=Bafoussam; DLA=Douala; Pn=Processor number (1≤n≤6)

3.3 Processors' Appreciation of End-product

After processing the various varieties, processors were asked to evaluate their boiled plantains while taking into account their senses and rank the varieties in order of preference.

3.3.1 End-products descriptors

A variety of quality descriptors were given by processors when processing was over. In general, boiled plantain should have an attractive colour and should be soft in the mouth and firm on touching. It should have a natural plantain. The table below highlights some of the descriptors obtained on boiled plantains from these processors.

Table 9: Boiled plantain high- and poor-quality descriptors

Colour		Textural		Taste	
High quality	Poor quality	High quality	Poor quality	High quality	Poor quality
- Bright - Yellowish - Attractive	- White - Pale	- Soft - Supple - Tender - Wet - Mealy - Firm	- Sticky - Dry - Hard	- Plantain taste - Natural taste - Good taste	- Banana taste - Taste of sap

3.3.2 Preferred and non-preferred varieties

Following a preference ranking of plantain varieties by the processors (table 10), *Batard* and *Big ebanga* were most preferred by scoring 17/20, followed by the local cultivars and finally *CARBAP K74*. This suggests that the plantain-like hybrid is not suitable for boiling unlike the other varieties.

Table 10: Overall preference rankings of plantain varieties by different processors

	Preference rankings per processor (1 - 4) *							
	BAFOUSSAM			DOUALA			Sum of individual scores	Overall score
	P1	P2	P3	P4	P5	P6	(1=4, 2=3, 3=2, 4=1)	(/20)
Local cultivar	2	3	3	3	3	1	3+2+2+2+2+4	15
Batard	1	1	4	1	2	2	4+4+1+4+3+3	17
Big ebanga	3	2	2	2	1	3	2+3+3+3+4+2	17
CARBAP K74	4	4	1	4	4	4	1+1+4+1+1+1	9

**1= most preferred and 4= least preferred*
P1 – P6 = Processors in each town (Bafoussam and Douala)

Moreover, an overall analysis of some of the parameters measured on these plantain varieties, using Agglomerative hierarchical clustering (AHC) denotes the presence of three classes (figures 10 & 11): **Class 1** comprising observations from a local cultivar, *Batard* and *Big ebanga*; **Class 2** made only of observations from the plantain-like hybrid *CARBAP K74*, and **Class 3** represented by

observations from some local cultivars and *Batard*. Of these three classes, class 1 and class 2 are different from class 3. This difference is well observed on the profile plot in figure 12. In fact, on this graph, one can observe that fruit thickness, fruit length and dry matter contents are parameters accountable for the differences between these classes. To a lesser extent, the firmness of the pulp could also be taken into consideration. However, peel thickness and pulp pH are parameters that do not vary between these varieties. All these confirm the rankings done by the processors in table 10.

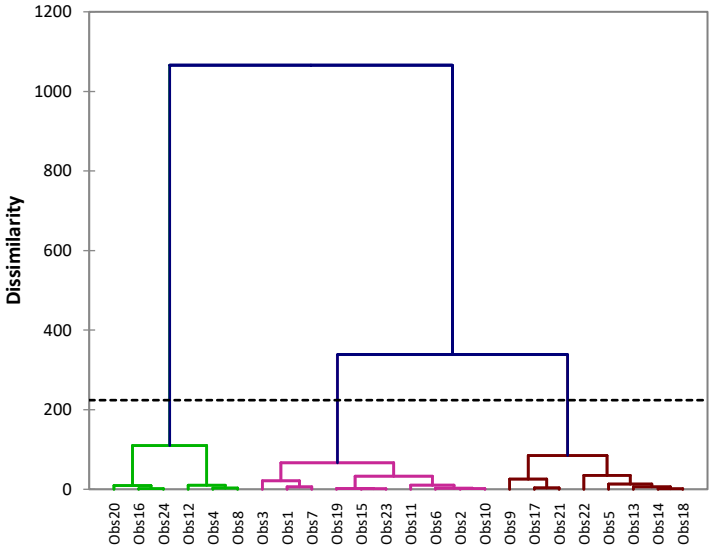

Figure 10: Dendrogram of the various observations

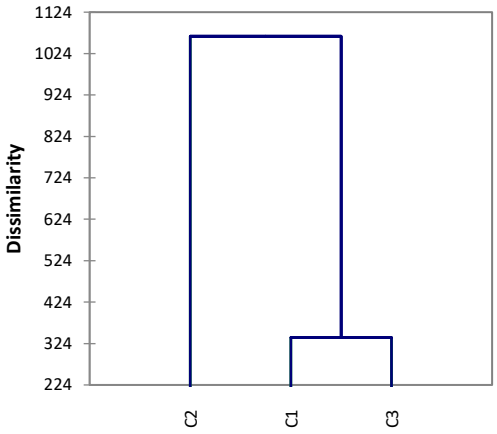

Figure 11: Dendrogram showing the classes obtained

Key:

Varieties	Observations (Obs)					
Local variety	Obs1	Obs5	Obs9	Obs13	Obs17	Obs21
Batard	Obs2	Obs6	Obs10	Obs14	Obs18	Obs22
Big ebanga	Obs3	Obs7	Obs11	Obs15	Obs19	Obs23
CARBAP K74	Obs4	Obs8	Obs12	Obs16	Obs20	Obs24

	Class 1 (C1)
	Class 2 (C2)
	Class 3 (C3)

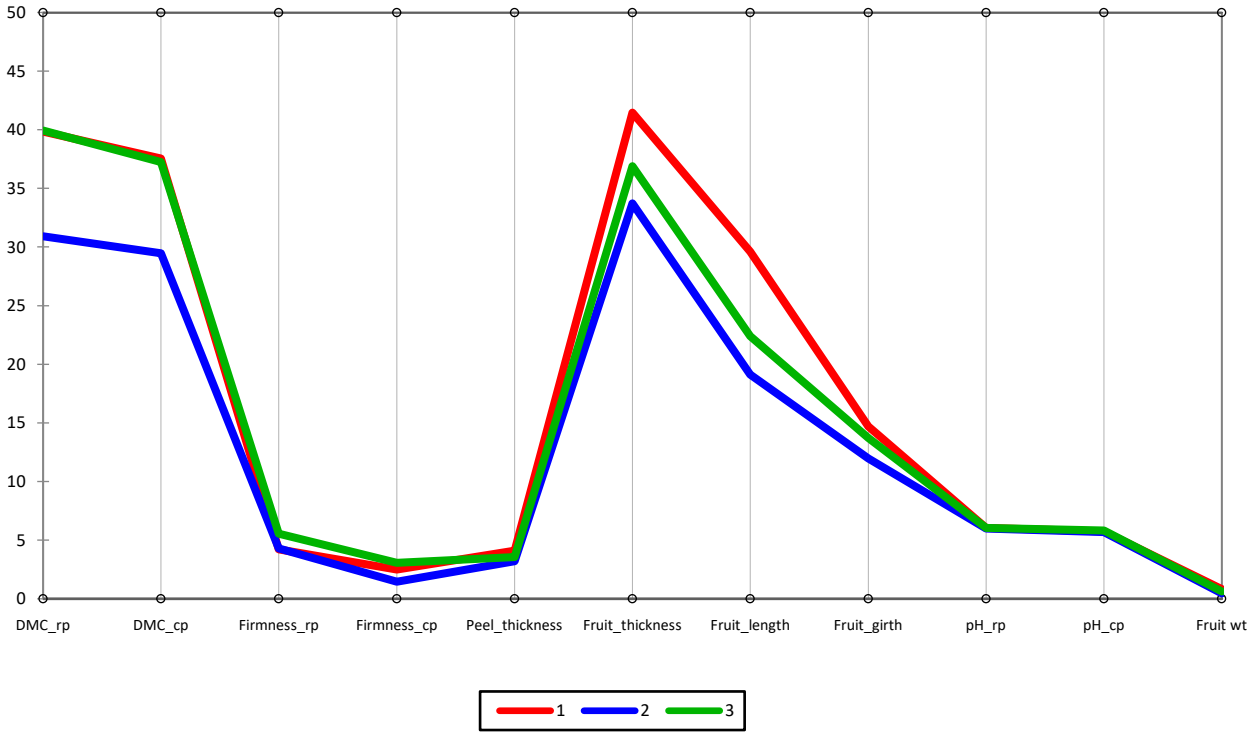

Figure 12: Profile plot of the three (3) classes obtained from the dendrogram

Legend:

	Class 1
	Class 2
	Class 3

DMC_rp: Dry matter content of raw pulp (%); DMC_cp: Dry matter content of cooked pulp (%); Firmness_rp: Firmness of raw pulp (kgf) ; Firmness_cp: Firmness of cooked pulp (kgf); pH_rp: pH of raw pulp; pH_cp: pH of cooked pulp; Fruit wt: Initial fruit weight (kg)

3.4 Global Process Yield

The global process yield per variety is displayed in the table below. This yield ranges between 24.3% for the local variety to 32.48 % for *Big ebanga* (w.b). This variety (*Big ebanga*) had a yield greater than 30% in both towns. This could be attributed to the relatively large size (28.50-30.30 cm) of its fruits alongside its high pulp thickness (37.05-39.08 mm)

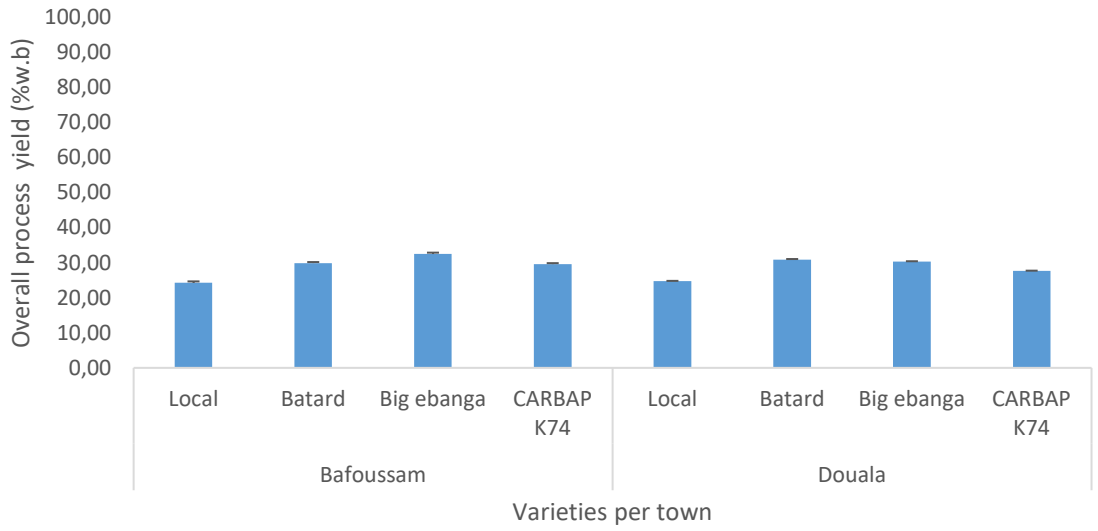

Figure 13: Overall process yield (% w.b) of plantain cultivars

4 CONCLUSION

The objectives of our study were to understand processor's demand for quality characteristics of plantain while processing different varieties and identify the key processing unit operations important in the quality of boiled plantains.

The following remarks can be drawn:

- Processors want plantain that is mature for cooking;
- Boiled plantain is obtained after cooking the pulp either with peel or without peel;
- Boiled plantain needs about five (05) preparation steps that may vary depending on the processors;
- A high-quality boiled plantain should be attractive. It should not be dry or strong in the mouth and should have a good/plantain taste;
- A poor or bad quality boiled plantain is pale in color, with a taste of sap or banana and is hard in the mouth;
- Processors liked the *Batard* and *Big ebanga* varieties compared to other varieties;
- *CARBAP K74* the plantain-like hybrid was liked least, because "*it is like banana and has nothing to do with plantain*" as said by a processor;

Based on the plantain varieties used within the framework of this study, the following outputs were obtained:

- The boiling temperature was comprised between 96.4 °C (Bafoussam) and 100.8 °C (Douala);
- Boiling times of boiled plantains were comprised between 15 and 87 minutes;
- Peeling times were found between 2 and 48 seconds, while scraping times were between 9 and 49 seconds;
- *Big ebanga* had the highest "Peeling + scraping" yield in each town comprised between 51.0-52.55% (w.b), while local varieties had the lowest yields (44.88-45.31% (w.b));
- *Big ebanga* and *Batard* presented the highest cooking yields (59.35-61.35% (w.b)), unlike local varieties having the lowest yields (53.59-54.67% (w.b));

- *Big ebanga* had the highest overall process yield (>30%) in both towns;
- 60 to 100 % of the boiling water was used for boiling plantain by the various processors;

5 APPENDICES

5.1 Appendix 1: Summary Table of Quantitative Data

		Raw material characteristics			Processing quantitative data							
					"Peeling + scraping" unit operation		Cooking unit operation*			End-products	Global process yield	
	Varieties	Weight (g)	Length (cm)	Dry matter (%)	Yield (%)	Productivity (kg/h/op)	Ratio [Qw/Qy]	Cooking time (min)	Yield (%)	Dry matter (%)	Yield (w.b)	Yield (d.b)
BAFOUSSAM	Local	604.00^{cd}	23.0^{b}	39.7^{ab}	44.88^{a}	40.53^{a}		44.67^{a}	53.59^{a}	35.7^{a}	24.30^{a}	67.95^{b}
	Batard	795.67^{b}	29.0^{a}	41.7^{a}	49.83^{a}	48.72^{a}		43.67^{a}	59.67^{a}	39.6^{a}	29.91^{a}	75.79^{ab}
	Big ebanga	753.33^{bc}	29.5^{a}	38.5^{b}	52.55^{a}	41.72^{a}		53.67^{a}	61.35^{a}	35.6^{a}	32.49^{a}	91.44^{ab}
	CARBAP K74	496.00^{de}	20.0^{bc}	31.8^{c}	52.67^{a}	40.77^{a}		56.67^{a}	55.89^{a}	27.9^{b}	29.62^{a}	106.17^{a}
DOUALA	Local	606.67^{cd}	23.9^{b}	39.4^{ab}	45.31^{a}	115.25^{a}		43.67^{a}	54.67^{a}	37.0^{a}	24.80^{a}	67.02^{b}
	Batard	710.33^{bc}	22.2^{b}	40.9^{ab}	50.74^{a}	114.84^{a}		48.67^{a}	60.87^{a}	38.4^{a}	30.92^{a}	80.85^{ab}
	Big ebanga	939.33^{a}	30.8^{a}	39.1^{b}	51.08^{a}	111.97^{a}		46.33^{a}	59.35^{a}	38.2^{a}	30.35^{a}	79.53^{ab}
	CARBAP K74	423.33^{e}	18.2^{c}	30.0^{d}	49.85^{a}	83.72^{a}		44.67^{a}	55.40^{a}	31.0^{b}	27.67^{a}	88.96^{ab}

$^{a, b, c, d, e}$ *indicate membership in significantly different value groups with a P value < 0.05 (Student Newman Keul's Test)*

5.2 Appendix 2: Overview of Quality Traits of Raw Plantain, Plantain during Processing and Boiled Plantain

	Raw product				Cooked product				
	Agronomical characteristics	Technological characteristics at each step of the process			Sensory characteristics				
		Peeling	*Shaping/ washing*	*Example*	When you look at	Texture when you touch	When you smell	Taste (In mouth)	Texture when you chew
High quality traits	- Long plantain fruits - Mature fruits - Yellow or orange pulp colour - Black-edged plantain fruits	Easy to peel	NA	NA	- Presentable - Bright - Attractive - Like ripe plantain - Yellowish colour - Smooth	- Soft - Supple - Tender - Wet - Mealy	NA	- Plantain taste - Natural taste - Good taste -	- Soft - Firm
Low quality traits	- Immature fruits - Spotted plantain fruits - Plantain fruits with small flesh (more peel than pulp)	Difficult to peel	NA	NA	- Pale colour - Red colour - White colour	- Sticky - Dry - Hard	NA	- Banana taste - Taste of sap	- Hard

NA=Not applicable

Institute: Cirad – UMR QualiSud

Address: C/O Cathy Méjean, TA-B95/15 - 73 rue Jean-François Breton - 34398 Montpellier Cedex 5 - France

Tel: +33 4 67 61 44 31

Email: rtbfoodspmu@cirad.fr

Website: https://rtbfoods.cirad.fr/