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ORIGINAL ARTICLE

Physicochemical and sensory evaluation of some cooking banana (Musa spp.) for boiling and frying process

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Abstract Experiments were conducted to study physicochemical properties of four cooking banana varieties (*Cardaba*, *Nijiru*, *Matoke* and *Kitawira*) and to determine their suitability for chips processing and boiling quality. A randomized complete block design with three replications was employed. Pulp to peel ratio, pulp firmness (before and after), total soluble solids, pH, titratable acidity, ascorbic acid, ease of peeling, pulp water absorption, duration of cooking (or boiling) and dry matter are the most important parameters to evaluate the quality of cooking banana including plantain. The different variety affected the fruit physical characteristics significantly ($P \leq 0.05$). The *Cardaba* varieties fruit was found to be the heaviest and the longest. The *Kitawira* and *Nijiru* varieties had the smallest, shortest and thinnest fruit. The *Cardaba* contained 88 % more edible portions per unit fresh weight than the peel. The *Nijiru*, *Matoke* and *Kitawira* contained more pulp weight than peel weight. Most fruit chemical quality parameters were significantly ($P \leq 0.05$) affected by the varieties. Similarly, the boiling and chips qualities were significantly ($P \leq 0.05$) affected by varieties. Among others, the Cardaba variety was found to have high fruit weight, fruit length, fruit girth, fruit volume, total soluble solids, ascorbic acid, dry matter and low total titratable acidity. Thus, *Cardaba* provided the best quality boiled pulp which can serve for diversified culinary purposes. Generally, the *Nijiru*, *Kitawira* and *Matoke* varieties were found to be superior to produce acceptable quality chips. These varieties are recommended for chips development by food processors in Ethiopia.

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Introduction

Banana has several economic values as human food or animal feed (Suresh et al. 2011). Cooking banana production is concentrated in the southern region of Ethiopia and the major produce comes from small scale growers. The average banana production in between 1961 and 2009 production year varied from 60,000 t in 1961 to 240,000 t in 2009. Its production and utilization has many technical, economical and social problems that attract research attention in order to exploit its immense suitability potential. The Ethiopian Institute of Agricultural Research (EIAR) introduced some banana germplasms and the collection of local cooking banana clones. These materials were evaluated by *Worrer*, *Melkassa* and *Jimma* Agricultural Research Centres. Among these, four cooking type banana varieties were released in 2006 by Melkassa Agricultural Research Centre based on their better agronomic performance as well as increased disease resistance. The four cooking type banana varieties released were *Cardaba*, *Kitawira*, *Matoke* and *Nijiru*.

Production and processing of cooking banana in Ethiopia could play a great role in ensuring adequate food supplies to the teeming population, diversification, addressing micronutrient deficiencies in populations, produce raw materials for domestic industries and create employment opportunities. The trend in other countries indicated that the introduction and promotion of banana processing could be an interesting alternative for countries, which have agro-industry development as a key component to underpin the government's agricultural diversification program that exists as primary producer with very poorly developed agro-industry (Davies 1995; Abdul-Rasaq and Lateef 2011).

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Expansion of food industry in the urban areas and the increase in demand for processed foods especially for children, is expected to create demand for banana processing into different final products. Generally, to change the retarded state of development of agro-industry in Ethiopia, as it is being observed on potato chips in different parts of the country, cooking banana chips processing could also play an important role. The processing industry can promote cottage agro-industry for rapidly expanding tourism and provide income generation opportunities for low income group entrepreneurs. Moreover, processing is recognized as a way of preserving fruit. As banana fruit has a limited shelf life, processing is important. Melkassa Agricultural Research Centre in 2006 (MoARD 2006) released four varieties namely *Cardaba* (ABB, Saba banana/2006-MARC/EIAR), *Kitawira* (AAB, 2006-MARC/EIAR), *Matoke* (AAB, 2006-MARC/EIAR), and *Nijiru* (AAB, 2006-MARC/EIAR). The production and utilization of these varieties have been consistantly increasing since 2006 in Ethiopia. Yet the proportion of fruit processed and the suitability of the various varieties to processing is relatively not well known. The existing potential could only benefit the nation if it could be fully exploited through the export of processed banana products, including chips. As was mentioned earlier, all improvement works conducted in Ethiopia, particularly, on banana, focused mainly on selecting promising varieties in terms of high yield, cold tolerance, disease and insect resistance without giving much attention to post harvest and processing quality evaluation (Seifu 2003). Moreover, the improvement efforts would be complete and sustainable, if the breeder materials could be tested for their processing quality in different value added food products such as chips and dried products (Seifu 2003; Chavan et al. 2010). Adeniji et al. (2010) reported that cooking bananas including plantains are used to combat food insecurity in Sub-Saharan Africa. It is estimated that more than 30 % of the banana production are lost after harvest (Adeniji et al. 2010). The losses are mostly due to fast deterioration resulting from the rapid ripening as well as lack of postharvest technologies to be used during storage and transportation. Processing cooking banana and plantain to shelf stable end products can provide appropriate solutions and help to exploit different marketing options. However, very limited scientific information exists on processing of cooking banana including plantains. This study was, therefore, initiated to determine the physicochemical properties of four improved cooking type banana varieties and evaluation of their suitability for boiling and chips processing based on the physicochemical properties and sensory characteristics data obtained in this study.

Materials and methods

Experimental material

Four locally released cooking type banana varieties by Melkassa Agricultural Research Centre in 2006 (MoARD 2006) namely *Cardaba* (ABB, Saba banana/2006-MARC/EIAR), *Kitawira* (AAB, 2006-MARC/EIAR), *Matoke* (AAB, 2006-MARC/EIAR), and *Nijiru* (AAB, 2006-MARC/EIAR) were used for this experiment. The varieties were grown at a spacing of 2.5 m×2.5 m at *Arbaminch-chanomille* substation trial site under rain-fed conditions and supplementary irrigation at every 10 days interval during the dry months. Nutrition of 150 g urea and 70 g diammonium phosphates (DAP) were given to each plant in the orchard. From this experimental orchard, bunches were examined about 3 months before harvest in order to make propping as per the requirement of the plant. Finally, matured fingers were harvested using visual banana maturity indices, hanging bunch and particularly by individual fingers angularity. The harvested bunches were carefully transported to Haramaya University during the night time while the ambient temperature was low. To reduce physiological changes and mechanical damage during transportation of 4–5 h, harvested intact bunches were packed in banana leaves and stacked vertically in a truck cushioned with *teff* straw at its floor and sides. Attempts were made to maintain cool environmental condition by using wetted a truck cover canvas and cool period (night) travel. Freshly harvested bunches were used to conduct the whole experiment.

Sampling and design

The samples were prepared according to the procedure of Senayit and Tiruset (1994). A composite sample of healthy, clean fingers at matured green stage was prepared for each variety from the second and a third hand of the three bunches. Furthermore, the composite samples from each variety was sub-divided into three sets and arranged in a randomized complete block design (RCBD) with three replications. From each sample set, consisting of five fruit, were kept in a freezer at −70 °C, the total soluble solids, total titratable acidity, dry matter and ascorbic acid analyses were carried out within 5 days including freezing periods (Yurena et al. 2006). From each sample set ten sample fruit were randomly taken and arranged for fruit physical quality parameter determinations. Finally, a total of 5 kg sample fruit per replication were kept for utilization aspect evaluation, from which 4.5 kg fruit were used for chips preparation, while the remaining 0.5 kg sample were used for the cooking and boiling quality evaluation.

Chips preparation

Randomly sampled 4.5 kg fruit from each replication were treated separately for chips preparation. The fruit was washed, manually peeled and sliced into 2 mm thick round pieces by a mechanical slicer with an adjustable cutting disc. Furthermore, the slices were washed and dried between cloth towels before frying. The drained slices were weighed and fried in pre-heated palm oil in thermostat controlled deep fryer operating at 170 °C for 4 min. After the chips developed a yellow golden colour, it was removed from the fryer and the oil was drained for 1 min and turned out onto absorbent paper (Diaz et al. 1999). At the end, the chips were further cooled at ambient temperature for one hour to avoid condensation occurrences and packaged in a low-density polyethylene bags for sensory evaluation the next day (Ikoko and Kuri 2007).

Boiled banana preparation

For cooking quality evaluation, sample fruit was washed, peeled and sliced into 1 cm thick round pieces by the slicer. For the cooking quality assessment, 5 pieces of the cut pulp samples were weighed on a balance. The weighed pulp samples were added to a 600 ml beaker containing 300 ml of boiling distilled water at 93 °C (altitude of 1950 m) plus 1 g of salt to improve the taste. Samples were allowed to boil at different time intervals of 5, 10, 15 and 20 min. After boiling for the specified time intervals, samples were quickly emptied on a kitchen sieve to drain the boiling water. The samples were cooled for 10 min at room temperature before each boiled banana slice was subjected to quality evaluation, consistent with the consumption traditions in the region. The sample preparation and the experiments were carried out in the Food Science and Postharvest Technology and Horticulture Laboratories of Haramaya University.

Physical quality analysis

Ten fruit from each set was used for the analysis of physical parameters. All fruit physical quality evaluations were done according to Dadzie and Orchard (1997). Each finger girth and length was measured by tape meter. The volume was measured by water replacement in a water-filled measuring cylinder. Fruit firmness was measured on a fruit slice, cut 1 cm transversely at the midpoint contain both the peel and pulp using a hand held-penetrometer (model FT327, Ferli, Italy). Individual unpeeled pulp samples were placed on a platform table, held firmly in one hand, and the force required to penetrate the 1 cm of pulp tissue, with 6 mm diameter cylindrical probe fitted to the penetrometer, was recorded.

Fruit peel and pulp weight was measured using a beam balance. Furthermore, the specific gravity and the pulp to peel ratio was calculated from collected data. The fruit specific gravity was obtained by simply dividing the fruit weight in air by the fruit volume according to Kushman and Pope (1968). Pulp and peel weight was determined after fingers have been hand-peeled and both peel and pulp were weighed separately using an analytical balance. To calculate pulp to peel ratio, the weight of pulp and peel was used and expressed as a ratio of pulp weight divided by the peel weight. To measure peel and pulp thickness, the fruit was transversely cut at the midpoint and hand peeled. Then, the peel and pulp thickness was measured with a digital micro-calliper.

The cooking quality or suitability to boiling of the banana was assessed using the methods as described by Dadzie and Orchard (1997). The ease or difficulty to peel was ascertained subjectively on matured green cooking banana by peeling each fruit and scoring the ease or difficulty to peel on a 5- point hedonic scale from 1 (very hard to peel) to 5 (ease to peel). In addition to the calculated pulp to peel ratio from the measured values, the pulp thickness was used as easy to peel indices. Prior to cooking, the initial pulp mass, the firmness, the dry matter content and the moisture content of the representative sample was measured. Furthermore, each pulp sample slices was boiled for the treatment periods varying from 5 min to 20 min and cooled for 10 min at room temperature and re-weighed for mass determination. Finally, the cooking quality or suitability to cooking was determined from the percentage water absorption which is calculated as the difference in the weight of the pulp before and after boiling and then expressed as a percentage of the initial weight. After cooking pulp samples for 5, 10, 15 and 20 min, the suitable cooking time was optimized as the time at which the pulp sample is well cooked, i.e. the samples remain firm but not mushy or watery (Dadzie and Orchard 1997). Cooking duration was determined by measuring pulp firmness, water absorption value and with the help of visual observation of the overall visual appearance of the pulp during cooking.

Chemical analysis

Among the chemical properties, total soluble solids (TSS), dry matter (DM), pH, total titratable acidity (TA) and ascorbic acid (AA) were measured according to INIBAP technical guidelines (Dadzie and Orchard 1997; Workneh et al. 2011a and 2011b; Tigist et al. 2011; Awole et al. 2011; Kundan et al. 2011). TSS was measured by blending 30 g of pulp tissue that was taken from the transverse section of the fruit in 90 m1 distilled water for 2 min in a blender (6001x Model No. 31JE35 6x 00777) and the slurry was filtered through filter paper. A single drop of a the filtrate was placed on a prism of calibrated digital hand held refractometer (Misco®, USA) with a degree brix range of 0–32 % and resolutions of 0.2 °Brix at 20 °C with distilled water. The pH value of the filtrate was determined using a pH meter (ELE International, U.K). The TA of filtrate was measured by titrating against sodium hydroxide to the phenolphthalein end point and calculation of the acid present as malic acid (Kotecha and Desai 1995). The loss of weight from fruit dried at 100 °C is attributed to the evaporation of hygroscopical water. An empty container was labelled and weighed on a Mettler Balance and the weight was recorded. Thirty grams of freshly chopped pulp sample was placed in the container and the weight was again recorded. Then, the sample was placed in a draft air oven at 100 °C for 24 h. Finally, the weights of the dry samples were taken. AA content was determined by the 2, 6-dichlorophenol indophenol titration method AOAC (1990).

Sensory evaluation

A total of 44 male and female panellists were used. Each panellist was first briefed with the important sensory evaluation conceptual knowledge. Then, each panellist was presented with a score sheet which was specifically designed for this experiment, a pen, pure water for mouth rinsing and chips samples. Each panellist received and evaluated the same amount of duplicate coded sample chips in a controlled sensory evaluation laboratory with separate boxes for each panellist. The samples were evaluated on the basis of their texture, taste, colour, crispiness and overall acceptability. Furthermore, all panellists scored the samples for each quality feature using a hedonic scoring scale of 1 to 5 on the provided evaluation sheet.

Statistical analysis

The samples from each variety was sub-divided into three categories and arranged in a randomized complete block design (RCBD) with three replications. Data was analyzed with the Statistical Analysis System (SAS Institute Inc., Cary, NC). Comparisons between the sample means were done using the least significant differences (USD) at 5 % significance level (Workneh et al. 2011c and 2011d; Tigist et al. 2011; Awole et al. 2011).

Results and discussion

Physical quality

The characteristics of the cooking type banana varieties (*Cardaba*, *Nijiru*, *Matoke* and *Kitawira*) are presented in Table 1. Fruit width, length and girth varied from 199 cm to

Table 1 Physical and chemical quality characteristics of four cooking varieties and chips sensory quality for four cooking type banana varieties

Variety	Physical parameters (*n*=3)												Chemical quality parameters (*n*=3)				
	FW (g)	FL (cm)	FG (cm)	FV (cm3)	FSG	PLW (g)	PPW (g)	PPR	PLT (cm)	PPT (cm)	FF (Kgf)	Ease of peeling (*n* =44)	TSS (%)	pH	TTA (%)	AA (mg 100 g−1)	DM (%)
Cardaba	199.0^{a}	15.9^{a}	3.50^{a}	206.5^{a}	0.96	69.0^{a}	130.0^{a}	1.9^{a}	0.38	3.8^{a}	8.1	2.7^{b}	1.7	6.3	1.9^{b}	2.3^{a}	29.0^{a}
Kitawira	79.0^{c}	13.5^{b}	2.05^{d}	82.8^{c}	0.96	35.1^{c}	43.9^{c}	1.2^{b}	0.4	2.4^{b}	6.2	3.2^{ab}	1.6	5.8	2.0^{b}	1.4^{c}	25.7^{b}
Matoke	130.3^{b}	16.4^{a}	2.8^{b}	136.8^{b}	0.95	57.7^{b}	72.7^{b}	1.3^{b}	0.45	2.6^{b}	6.7	2.4^{bc}	1.6	5.7	2.7^{a}	1.7^{b}	23.5^{b}
Nijiru	75.0^{c}	12.6^{b}	2.2^{c}	77.5^{c}	0.97	31.9^{c}	43.2^{c}	1.4^{b}	0.4	2.6^{b}	5.8	3.4^{a}	1.5	5.6	2.2^{b}	2.2^{a}	22.9^{b}
Significance	***	**	***	***	ns	***	***	***	ns	***	ns	*	ns	ns	*	***	*
CV%	5.66	5.36	2.54	6.59	3.95	6.23	6.28	4.64	5.69	4.44	13.2	5.22	15.8	6.79	9.59	6.51	6.35

ns, *, **, *** non significant or significant at $P \leq 0.05$, $P \leq 0.01$ or 0.001, respectively; means with the same letter within columns were not significantly different at $P \leq 0.05$

FW fruit weight; *FL* fruit length; *FG* fruit girth; *FV* fruit volume; *FSG* fruit specific gravity; *PLW* peel weight; *PPW* pulp weight, *PPR* pulp to peel ratio; *PLT* peel thickness; *PPT* pulp thickness; *FF* fruit firmness, *TSS* total soluble solids; *TTA* total titratable acidity; *AA* ascorbic acid; *DM* dry matter

75 cm, 16.4 cm to 12.6 cm and 3.4 cm to 2.1 cm, respectively. Accordingly, fruit weight ranges from 129 g (*Cardaba*) to 95 g (*Kitawira*) were reported, while all the varieties recorded equal fruit lengths of 14 cm and diameters of 4 cm.

Variety had a significant ($P \leq 0.001$) effects on most of the fruit physical quality parameters (Table 1). However, no significant ($P \geq 0.05$) difference was observed between the fruit sample peel thickness, specific gravity and firmness of the varieties were recorded. The fruit specific gravity values found in this study agrees with that of Kachru et al. (1995) and Diaz et al. (1999). Out of the four cooking banana varieties considered in this study *Cardaba* had shown the best performance for most physical quality parameters.

On the other hand, there were significant ($P \leq 0.001$) differences between the mean fruit weight, length, girth and volume among the varieties (Table 1). *Cardaba* had 62 % and 60 % more mean fruit weight when compared to the mean fruit weight of *Nijiru* (75 g) and *Kitawira* (79 g), respectively. The fruit weight of *Matoke* (130 g) was found to be 35 % lower than the mean fruit weight of *Cardaba*. *Matoke* and *Cardaba* had statistically ($P \leq 0.05$) the same fruit lengths but were significantly ($P \leq 0.01$) longer than *Kitawira* and *Nijiru*. *Nijiru* and *Kitawira* were 22 % and 17 %, respectively, shorter fruit when compared with the mean fruit length of *Matoke*.

The *Cardaba* variety had the highest mean fruit girth and volume (Table 1). The *Cardaba* had 20 % wider mean fruit girth when compared to the mean fruit girth of *Matoke*. The mean fruit girth of *Nijiru* was found to be 35 % lower than the mean fruit girth of *Cardaba*. Similarly, the *Cardaba* had 169 % higher mean fruit girth when compared to the mean fruit girth of *Kitawira*. The *Cardaba* had 34 % more mean fruit volume when compared to the mean fruit volume of the *Matoke*. The mean fruit volume of the *Nijiru* and *Kitawira* were found to be 62 % and 60 % lower than the mean fruit volume of the *Cardaba*, respectively. This indicates that *Cardaba* had the thickest and bulkiest fruit while, the *Kitawira* and *Nijiru* varieties were characterized by their thin and small fruit. These might have contributed for the higher fruit weight as well as the unusual shape observed in *Cardaba* fruit as compared to that of *Nijiru* and *Kitawira* varieties.

The Cardaba and *Matoke* had the higher values, for fruit weight and length while *Nijiru* and *Kitawira* showed lower values than the reported average fruit weight and length values for the multi-location trial. The higher values obtained for *Cardaba* and *Matoke* could be explained by suitable agro ecological condition for better performance of the two varieties compared to the *Kitawira* and *Nijiru* varieties. This might indicate better adaptability of the former varieties to *Arbaminch-chanomille* area.

There was a significant ($P \leq 0.001$) difference between the pulp to peel ratios of *Cardaba*, *Matoke*, *Nijiru* and *Kitawira* varieties. This result agrees with the findings of Dadzie (1998) who reported a fruit pulp to peel ratio range of 1.1 to 1.7 for four cooking banana and three plantain varieties at the green mature stage. Similarly, Kachru et al. (1995) reported that the pulp to peel ratio for Dwarf Cavendish variety varies between 1.2 and 1.6. This indicates that fruit of the three varieties had 130 % more mean pulp weight when compared with its mean peel weight. According to Dadzie and Orchard (1997), Forster et al. (2003) and Muchui et al. (2010) fruit pulp to peel ratio is the indicator of a more edible portion per unit fresh weight and maturity. Thus, *Cardaba* had 189 % more edible portion of pulp than peel per unit weight of fruit which is about two times more than its peel. Similarly, *Cardaba* had 44 %, 66 % and 67 % more mean fruit pulp mass when compared to the mean fruit pulp mass of *Matoke*, *Kitawira* and *Nijiru* varieties, respectively. This is positively related to the highest fruit mean pulp thickness of *Cardaba* variety compared to *Matoke*, *Nijiru* and *Kitawira*. The positive and significant correlation (r=91; P<0.0001) between pulp to peel ratio and pulp thickness results also revealed the contribution of pulp thickness to higher pulp to peel ratio.

There were no significant ($P \geq 0.05$) differences in peel thickness among the varieties. Pulp thickness results showed significant ($P \leq 0.001$) variations among the evaluated varieties. The mean fruit pulp thickness of *Matoke* and *Nijiru* were found to be 31 % and 32 % lower than the mean fruit pulp thickness of *Cardaba*. Similarly, *Cardaba* had 159 % higher mean pulp thickness when compared with the mean pulp thickness of *Kitawira* fruit. This indicates that *Cardaba* fruit had the thickest pulp and thinnest peel than the other three varieties. Consumers often prefer thicker and bulkier pulp (Dadzie and Orchard 1997; Forster et al. 2003; Muchui et al. 2010). Thus, this result confirms the potential of *Cardaba* to produce larger sized slices for processing into various products such as chips, as well as a more preferable bulkier and thicker boiled pulp.

Total soluble solids

Since the analysis was done at the unripe fruit stage there were no significant ($P \geq 0.05$) varietal differences in terms of TSS (Table 1). Dadzie and Orchard (1997), Ferris et al. (1996) and (1999), Diaz et al. (1999) as well as Muchui et al. (2010) confirmed that the TSS genotypic variation in banana fruit at unripe mature stage was not significant ($P \geq 0.05$). However, the differences became more apparent as fruit ripened (Dadzie 1998). The TSS content was slightly affected by the genetic factor which was found to be 1.5 % and 1.7 % for *Nijiru* and *Cardaba*, respectively (Table 1). This clearly confirm that the sample fruit of the four varieties that were used for the post-harvest characterization and evaluation of chips and boiling quality was at the required maturity stage.

pH and total titratable acidity

Variety had no significant ($P>0.05$) effect on fruit pulp pH values. The TTA value of *Matoke* was significantly higher ($P<0.05$) than that of *Nijiru*, *Kitawira* and *Cardaba* varieties (Table 1). This indicates that *Matoke* contains the highest amount of malic acid in its pulp. According to Dadzie (1998), the high pH level presented in Table 1 corresponded banana fruit at a matured green stage. The TTA values also coincided with the results from of the same author who reported malic acid contents ranging from 1.5 % to 2.5 % at harvest for FHIA-03 cooking banana and three plantain hybrids (FH IA-21, FH IA −22 and Cuerno). This could be used as an indicator of the maturity for banana (Dadzie and Orchard 1997).

The AA content of the *Matoke* variety fruit was found to be significantly ($P<0.001$) higher than the AA content of *Kitawira* variety fruit, but it was significantly lower than that of the *Cardaba* and *Nijiru* varieties fruit (Table 1). The *Cardaba* fruit had 26 % more mean AA content when compared to that of *Matoke*. The mean fruit AA content of *Kitawira* was 40 % lower than the mean fruit AA content of *Cardaba*. Fresh green banana is a good source of vitamin C (Sarathathevy and Ganesharanee 1993). Thus, *Cardaba* and *Nijiru* could be preferably recommended for cultivation and consumption in areas where there is this deficiency.

The plantain and cooking banana are being cooked before use and may be boiled, fried, baked/roasted or dried either intact or after grating or pounding (Dadzie and Orchard 1997). This indicates that fruit of cooking banana varieties are preferred for its diversity of culinary processes rather than its raw consumption. Hence, the most important aspect that should be investigated is the type of variety, product and processing method that could preserve the AA content of the raw fruit in the final product.

Dry matter content

The *Cardaba* variety, had the highest fruit physical properties, had a significantly ($P\leq0.05$) higher dry matter content as compared to the other varieties (Table 1). The values for both dry matter and moisture content of the four cooking banana varieties were in agreement with those that were previously reported for different banana and cooking banana varieties, but were found to be slightly lower than that of plantain. The dry matter result matches with Ferris et al. (1999) who reported 30.4 % for *Cardaba*. *Matoke*, *Nijiru* and *Kitawira* agree with values reported, Agunbiade et al. (2006) and Dadzie (1998). The pulp moisture content of *Matoke*, *Nijiru*, and *Kitawira* varieties were approximately equal and not significantly higher than that of *Cardaba* ($P\leq0.05$).

The *Cardaba* had 11 % more fruit mean dry matter content when compared to the mean dry matter content of *Kitawira*. The mean fruit dry matter content of *Matoke* was found to be 19 % lower than the mean dry matter content of *Cardaba* (calculated from dry matter data in Table 1). Similarly, *Cardaba* had 127 % higher mean fruit dry matter content when compared with the mean dry matter content of *Nijiru* (calculated from dry matter data in Table 1). The higher dry matter content of banana and plantains fruit was the indicator of better cooking quality and storability (Dadzie and Orchard 1996; Ferris et al. 1996; Forster et al. 2003; Muchui et al. 2010). This indicates that the *Cardaba* fruit could produce quality boiled products and have a longer shelf life than the other the varieties. Dry matter also determines the biological value of the crop, which shows the fraction of a harvested crop that is available for processing into food products (Baiyeri et al. 1999). Therefore, considering fruit dry matter analysis during variety evaluation might give a good estimation of the crop acceptability.

Chips sensory quality evaluation

For comprehensive new variety evaluation, assessing the utilization aspects is very crucial. Hence, in this study, to complement the physical and chemical postharvest characterization of green matured fruit of some cooking type banana varieties, sensory evaluation had been considered. Table 2 shows chips sensory quality of the deep fat fried *Cardaba*, *Matoke*, *Nijiru* and *Kitawira* fruit at green matured stage.

Texture

There were no significant differences ($P>0.05$) among the cooking banana varieties in their chips texture (Table 2). The panellists score indicated that the processed chips had very hard to good texture. Willbur and Shairi (1985) reported that specific gravity has a direct relationship to the processing efficiency, texture and yield of chip. Hence, similarity in chips texture score among the varieties could be explained by the non significant difference in specific gravity and firmness of fruit used for chips processing (Table 2).

Taste

The sensory panel also did not detect significant differences ($P>0.05$) among varieties in the chips taste (Table 2). Taste is mainly a balance between the sugar and acid contents (Dadzie and Orchard 1997). Thus, lack of significant difference in chips taste sensory quality can be linked to the similarity in the TSS and pH of the varieties tested (Table 2). Generally, the panelists agreed that chips prepared from the cooking type banana varieties had acceptability of very

Table 2 Sensory quality of chips prepared from four cooking type banana varieties

Variety	Sensory quality (n=44)					
	Texture	Taste	Colour	Crispiness	Overall acceptability	Panellist preference (%)
Cardaba	3.5	3.0	2.8^{c}	2.9^{c}	2.9^{c}	13.0^{c}
Kitawira	3.4	3.6	3.5^{bc}	3.8^{a}	3.5^{ab}	23.0^{b}
Matoke	3.3	3.4	3.6^{ab}	3.7^{ab}	3.5^{ab}	32.0^{a}
Nijiru	3.4	3.6	3.7^{a}	3.9^{a}	3.6^{a}	32.0^{a}
Significance	ns	ns	**	*	**	**
CV%	4.4	7.7	6.2	8.3	5.5	6.1

Each observation is a mean (n=44). *, **, significant at $P \leq 0.05$ or $P \leq 0.01$, respectively. Means with the same letter within columns were not significantly different at $P \leq 0.05$

good to good chips taste. The group of consumer panellists could be taken as good responsibilities for the market potential of cooking banana chips (Dadzie 1998). This indicates that these varieties could produce acceptable chips regarding their taste.

Colour

The colour of the chips is important in the assessment of consumer acceptability. In the sensory studies, the panellists indicated that there were a highly significant colour variations ($P \leq 0.01$) among the evaluated chips samples (Table 2). The chips processed from *Nijiru*, *Matoke* and *Kitawira* obtained similar colour acceptance scores, while *Cardaba* chips scored a significantly lower values than the other three varieties. Mean chips colour preference score indicates that the colour of chips produced from *Nijiru*, *Matoke* and *Kitawira* varieties were good and liked very much by panellists. The *Cardaba* which was superior for most of its fruit physicochemical properties, had been rated as a variety producing inferior coloured chips. This might be due to the slice sticking problem observed in the *Cardaba* fruit pulps. According to Diaz et al. (1996) slices sticking together during frying had great influence on homogenous product processing efficiency. Thus, the lower *Cardaba* chips colour acceptance score by the panellists could be explained by the slice sticking problem that hinder uniform colour development up on frying and visible black core with hole at the centre of the chips disc. This result clearly indicated that screening of new varieties only with physicochemical properties could not be complete without sensory evaluation and that it finally proves consumer acceptance.

Crispiness

In terms of chips crispiness, *Nijiru*, *Matoke*, and *Kitawira* scored significantly ($P<0.05$) higher values than *Cardaba* (Table 2). According to the hedonic scoring scale, chips of the three varieties were crispier than the slightly crispy grade chips processed from *Cardaba*. Sensory evaluation of fried fruit of Musa had shown that the higher the dry matter content, the better the eating quality and storability (Ferris et al. 1996; Dadzie and Orchard 1996). However, *Cardaba* which had higher fruit dry matter and that has expected to give crispier chips than the other varieties within a given frying period, got an inferior crispiness scores. This disagreement could be due to large sized *Cardaba* pulp slices that stick together and create a frying problem during the early frying period. Diaz et al. (1996) highlighted that the frying period from 0 s to 120 s is an initial phase when high mass transfer occur. According to these authors, during the initial frying phase, there will be very intense boiling in the oil bath along with a sharp drop in temperature and fried product water content. The higher mucilage content observed in *Cardaba* pulp than in others could be taken as the probable reason for slice sticking and reduced chips crispiness quality due to comparably higher moisture content in *Cardaba* chip.

Overall acceptability

The *Nijiru*, *Matoke* and *Kitawira* scored equal chips overall acceptability mean scores of 3.5, which is significantly ($P \leq 0.01$) more acceptable than the *Cardaba* chips 2.9 (Table 2). According to the hedonic scoring scale, panellists indicated that chips processed from the three varieties had good to very good overall acceptability scores. Correlation analysis indicated that the overall acceptability of chips was strongly related to taste (r=0.92; $P \leq 0.001$), crispiness (r=0.98; $P<0.001$) and also closely related to colour (r=0.78; $P \leq 0.01$). In other words, although colour of chips contributed to the overall acceptability of the evaluated chip, taste and crispiness were the most influential factors for consumers' processed chips overall quality acceptance .

Generally, panellists scores for overall acceptance for cooking banana chips ranged from good to very good scale. None of the chips samples were rated as poor quality, even chips of *Cardaba* had a good score for overall acceptability (Table 2). This indicates that consumers may not reject cooking banana chips though they are accustomed to potato chip. As it is known, potato chips are common as street sold food and a side item served in quick serve restaurants in most big cities of Ethiopia while banana remained a raw and consumed as fruit at its ripe stage. The observed acceptance score is very supportive evidence for marketing- prospects of banana chips for better income generation than the more perishable raw fruit. Processing could contribute to the reduction of postharvest losses of bananas since utilization commences early at matured green stage and due to reduced produce moisture content than in the raw fruit. Similarly, comments provided by participants suggested that the cooking banana could be an alternative raw material source to the potato for chips processing and that they have on expectation to see banana chips alongside potato chips in near future.

Preference

When the 44 panellists were asked which of the samples they preferred most, 32 % stated that they preferred chips prepared from *Nijiru* or *Matoke* while, 23 % opted for *Kitawira* and 13 % chose *Cardaba* (Table 2). The panellist's preference percentage also confirms the suitability of *Nijiru*, *Matoke* and *Kitawira* varieties for chips processing than *Cardaba*, which is in agreement with the acceptance data presented in Table 2.

Ease of peeling

The ease of peeling was assessed subjectively in the present study. According to Dadzie and Orchard (1997) consumers of green boiled plantain or cooking banana often prefer varieties that are easy to peel. There was no significant ($P>0.05$) difference observed in the mean scores among the cooking banana varieties in the ease of peeling. The slight variation in mean peeling scores indicates that *Matoke* was relatively difficult to peel (2.4) in comparison to easy to peel mean score of *Nijiru* (3.4), *Kitawira* (3.2) and *Cardaba* (2.7) varieties (Table 1). The slightly higher mean peel thickness recorded in *Matoke* may partly explain why it was relatively difficult to peel.

Objective chips quality evaluation

Along with the sensory evaluation done to confirm consumer acceptance, objective quality evaluations were made to obtain data on the storability, nutritional quality retention and profitability of chips. Accordingly, the quality parameters such as chips mass frying yield, dry matter, final moisture content and ascorbic acid loss were studied and presented in Table 1.

Chips mass frying yield

The percentage recovery rate or chips mass frying yield reflects the quantity or percentage of saleable chips obtained after frying (Dadzie 1998). In terms of chips mass frying yield, significant ($P\leq0.001$) differences had been found among the varieties (Table 3). *Kitawira* was found to have significantly ($P<0.001$) lower chips yield as compared with *Cardaba* but higher than both *Nijiru* and *Matoke* chips yield. This indicated that the final amount of chips that was found after frying per a given amount of pulp slice was found to be higher in *Cardaba* which was followed by *Kitawira*. *Nijiru* and *Matoke* comparably yield a smaller amount of chips in mass. Significantly higher fruit pulp dry matter and final chips moisture level of *Cardaba* might have contributed to the higher chips mass frying yield. This can be confirmed from chips mass frying yield is positive correlation with pulp dry matter ($r=0.73$; $P\leq0.01$) and final chips moisture content ($r=0.66$; $P\leq0.05$). Chips recovery rate found in this study strongly agree with Dadzie (1998) but lower than Diaz et al. (1999) chips recovery rate that converges to 0.5 units after frying different plantain varieties for 150 s at 145 °C and 185 °C frying temperature. Mass frying yield falls as frying time increases (Diaz et al. 1999). Hence the lower chips recovery rate result could be explained by longer frying time.

Chips moisture content

Table 3 displays that there was a significant difference ($P\leq0.01$) among the varieties in chips moisture content; *Cardaba* chips contained higher moisture (9.0 %) than *Nijiru* (2.2 %), *Matoke* (4.0 %) and *Kitawira* (2.5 %) after 4 min palm oil deep frying at 170 °C. Literature showed that chips moisture should be less than 10 %, preferably even less than 5 % (Dadzie and Orchard 1997) which is in agreement with results of this study. Totte et al. (1996) stated that the deep fat frying process final products can produce chips with moisture content of lower than 10 % on wet basis.

Table 3 Deep-fat fried chips chemical quality characters of four cooking type banana varieties

Variety	CMFY	CMC (%)	CDM (%)	CAA (mg 100 g^{-1})	AAL (%)	AAP
Cardaba	0.42^{a}	9.0^{a}	91.0^{b}	1.5^{ab}	35.6^{a}	64.4^{c}
Kitawira	0.40^{b}	2.5^{b}	97.5^{a}	1.4^{bc}	13.2^{c}	96.8^{a}
Matoke	0.37^{c}	4.0^{b}	96.0^{a}	1.2^{c}	32.5^{a}	67.5^{c}
Nijiru	0.38^{c}	2.2^{b}	97.8^{a}	1.7^{a}	20.6^{b}	79.4^{b}
Sign	***	**	**	**	***	* **
CV%	0.98	38.4	1.9	8.4	17.3	5.2

Each observation is a mean of replicate experiments ($n=3$). **, ***, significant at $P\leq0.01$or $P\leq0.001$, respectively; means with the same letter within columns were not significantly different at $P\leq0.05$

CMC chips moisture content; *CDM* chips dry matter content; *CAA* chips ascorbic acid; *AAL* ascorbic acid loss; *AAP* ascorbic acid preservation; *CMFY* chips mass frying yield

Diaz et al. (1996) also found chips moisture content that varied from 1.3 % to 8.2 % after plantain slice deep fat frying for 180–240 s at 150 °C–200 °C.

Chips prepared from *Cardaba* variety had significantly ($P\leq0.01$) higher moisture content. The reason for this could be attributed to the fact that the larger diameter pulp slices that stick together during the early frying period limited mass transfer. Water losses were higher during the three first minutes of frying (Adelaide et al. 2007). Farthermore, *Cardaba* slice sticking problem during frying could be explained by excessively higher mucilaginous substance observed particularly in *Cardaba* pulp. On the other hand, *Nijiru*, *Kitawira* and *Matoke* varieties, which were statistically similar in their pulp moisture content also showed similarity in their chips moisture content. Fried chips moisture content, is an important parameter as it is mostly related to chips sensory quality and storability. As it has been reported by many researchers, the moisture content obtained for *Nijiru*, *Kitawira* and *Matoke* chips is in a very acceptable range for acceptability and storability (Almazan 1990; Diaz et al. 1996; Dadzie 1998 and Adelaide et al. 2007). This could be taken as a good reason for the inferior performance of *Cardaba* chips during sensory evaluation. Negative and significant correlation between chips moisture content and sensory quality taste ($r=-0.70$; $P\leq0.01$), crispiness and overall acceptability score ($r=-0.75$; $P\leq0.01$) found in the current work also confirm the strong influence of final chips moisture content on the produce acceptability.

Chips ascorbic acid loss

Regarding AA loss, a highly significant difference ($P\leq0.01$) had been observed among chips processed from the four cooking banana varieties (Table 3). This result showed that there was a variety dependent decline in the AA content decline among the cooking banana varieties processed chips. *Cardaba* and *Matoke* chips lost the highest percentage of AA found in their matured green fruit, while *Kitawira* chips showed the lowest percentage loss. Except, for the high vitamin C preservation observed in *Kitawira* (about 97 %), the values recorded in the other varieties are similar to those reported by Hasse and Weber (2003) (26 % for 20 to 4 potato chips) and by Adelaide et al. (2007) (3 % in plantain slices fried at 130 °C). However, it was much lower than the 54–70 % losses reported by the latter author for plantain slices fried at 170 °C. Suntharalingam and Ganesharanee (1993) reported an AA loss of 65 % during the preparation of flour from banana. The levels of vitamin C remaining in chips after frying are dependent on the temperature of frying, the duration of frying and the thickness of the slices (Adelaide et al. 2007). This discrepancy in the first case might be explained by a longer frying period used since the frying was from 1 min to 10 min, but the authors gave no details on which frying time these values were found. Hasse and Weber (2003) stated that washing was the main AA reduction stage in potato chips processing and also pointed out that intensive slices washing should be proofed for leaching capacity. Hence, the cause of higher ascorbic acid losses in *Cardaba* and *Matoke* might be due to longer washing and draining time to remove excessively higher mucilaginous substance, observed in these varieties.

Boiled banana quality

The cooking quality criterions were linked to some physical fresh fruit cooking quality indices. As was illustrated in fruit physical characteristic evaluation (Table 1) *Cardaba* had significantly ($P\leq0.01$) higher pulp to peel ratio and pulp thickness than the other three varieties. Consumers of boiled cooking banana often prefer thicker and bulkier pulp (Dadzie and Orchard 1997). Thus, to consider pulp to peel ratio and pulp thickness as postharvest fruit quality indices is very important in variety selection for cooking quality. Fruit physical quality investigation indicated that *Cardaba* fruit had the thickest and heaviest pulp than peel amongst the four cooking type banana varieties. This suggests that *Cardaba* fruit had preferable boiling quality than *Nijiru*, *Matoke* and *Kitawira*.

Pulp firmness

The study revealed that there was a significant ($P\leq0.01$) interaction between varieties and boiling time on softening of the cooking banana varieties (Fig. 1a). According to the results obtained, 5 min boiled pulp slices firmness loss of all varieties was significantly ($P<0.01$) higher than pulp slices boiled for 10, 15 and 20 min. The firmness reduction in pulp slices boiled for 5 min ranges from 45 % to 71 % in *Cardaba* and *Matoke*, respectively. Works of similar nature, for example by Dadzie (1998) and Baoxiu et al. (2000) also indicated that pulp firmness reduction by cooking for various periods of time is variety dependent. Dadzie (1998) reported that a variety dependent initial mean firmness loss range of 78 %–28 % for five cooking banana varieties. The mean pulp firmness values (kgf) were significantly ($P\leq0.05$) higher for all varieties before cooking or at zero times (Fig. 1a). But after boiling for various periods of time, there was a significant ($P<0.01$) decrease in the firmness or increase in the softening depending on the variety.

This indicates that varieties were similar in their initial pulp firmness and the observed pulp firmness loss and variations were consequences of cooking. Compared to *Nijiru*, *Kitawira* and *Matoke*, *Cardaba* pulp firmness loss was significantly ($P\leq0.01$) lower throughout the cooking period. After the initial drop in firmness during 5 min

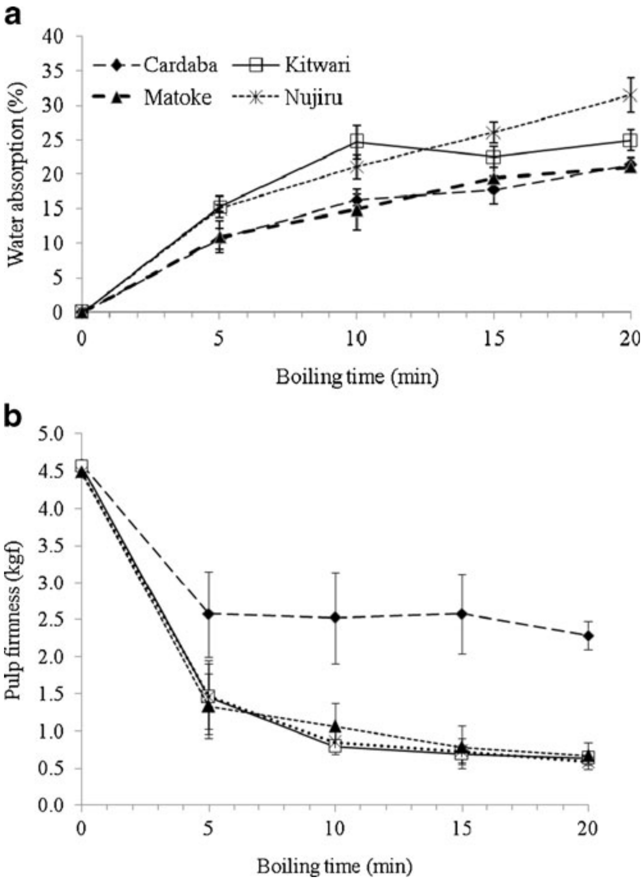

Fig. 1 Changes in pulp firmness (**a**) and water absorption (**b**) during cooking of banana varieties. Each observation is a mean of three replicate experiments (n=3)

boiling, there were no significant changes at $P \geq 0.05$ level of significance in the *Cardaba* pulp firmness when cooked for 10, 15 and 20 min. Hence, even after 20 min boiling the *Cardaba* pulp was found to be significantly ($P \leq 0.01$) firmer than all other varieties pulp boiled for 5 min. The texture and appearance of banana pulp after cooking are particularly important features for consumers (Dadzie and Orchard 1997). Consumers of boiled green plantain or cooking banana usually prefer the pulp to remain firm and crunchy after cooking, rather than too soft and waterlogged. This suggests that the *Cardaba* pulp had more suitable boiling quality than the other evaluated varieties. On the contrary, *Nijiru*, *Matoke* and *Kitawira* varieties had shown further significant pulp firmness reduction by boiling up to 20 min. According to Dadzie (1998), arguments such as remarkable differences in firmness loss is due to inherent differences in cell size and structure, as well as differences in chemical composition before cooking. The softening in fruit as a result of cooking or heating involves a loss of turgor, a series of chemical changes in the cell polysaccharide matrix, along with starch swelling and gelatinisation (Baoxiu et al. 2000).

Water absorption

Fig. 1b shows changes in the percentage of water absorption by *Cardaba*, *Nijiru*, *Matoke*, and *Kitawira* fruit pulps during cooking for 5, 10, 15 and 20 min. In this study, the amount of water absorbed significantly ($P \leq 0.001$) depended on the duration of cooking and the varieties. As stated by Dadzie (1998) cooking bananas absorb some water during cooking which ultimately results in the softening of the pulp. In most of the varieties, the percentage water absorption seemed to increase with the cooking time, but the extent of increase was variety dependent ($P \leq 0.001$). There was nearly 15 % increase in water absorption of *Kitawira* and *Nijiru* after 5 min of cooking, compared to approximately 10 % raise in water absorption in *Cardaba* and *Matoke*. This initial dramatic increase in the percentage water absorption in these varieties marked the onset of pulp softening during cooking.

Studies by other investigators (Dadzie and Orchard 1997; Dadzie 1998; Baoxiu et al. 2000) have shown that absorption of water by cellulose , starch and pectin in the plantain pulp during boiling or cooking induces tissue softening. The authors further indicated that starch granules in the pulp swell and gelatinize, resulting in a hard to soft-jelly textural change. The cellulose does not undergo further change. The pectin is hydrolysed by the hot water and converted into a softer, more soluble form, thus making tissues easier to bite and masticate (Baoxiu et al. 2000). During the cooking period, the percentage water absorption was higher in *Nijiru* and *Kitawira* in comparison to *Matoke* and *Cardaba* (Fig. 1b). This indicates that *Nijiru* and *Kitawira* absorbed more water during cooking and consequently lost more firmness as compared to *Matoke* and *Cardaba*. Further correlation analyses indicated that the percentage water absorption was inversely related to cooked pulp firmness ($r=-0.83$; $P<0.0001$). In other words, the higher the water absorption of the pulp of a particular cultivar during cooking the more boiled pulp gets softer. Despite of the lower amount of water absorption *Matoke* did not maintained its firmness after the boiling.

As shown in Fig. 1a, *Matoke* had lost its firmness in comparable amount with *Nijiru* and *Kitawira*. This suggests that *Nijiru*, *Kitawira* and *Matoke* are less suitable for boiling. In contrast, *Cardaba* had a comparatively low water absorption potential during boiling. This indicates that *Cardaba* had good cooking quality which makes it more suitable for boiling. In agreement with this finding, there are many investigations that confirm suitable boiling quality of varieties that had higher pulp dry matter percentage like *Cardaba* (Almazan 1990; Dadzie and Orchard 1996; Ferris et al. 1996; Dadzie 1998; Baoxiu et al. 2000). Thus, observed lower water absorption quality in the boiled *Cardaba* pulp slices might be related to its higher dry matter contents than that of the *Kitawira*, *Matoke* and *Nijiru* varieties.

Duration of cooking

The boiled pulp from the *Nijiru*, *Matoke* and *Kitawira* varieties were found to be softer, sticky and water soaked even at initial 5 min boiling, whereas *Cardaba* boiled pulp remained firm and crunchy throughout the cooking period. This indicates that relative to *Cardaba*, the three were not sufficiently suitable for boiling quality and no need of evaluation for cooking time. According to the visual observation made during the experiment the cooked pulp of the *Cardaba* started to changed from whitish raw pulp colour to creamy colour after 15 min of boiling. The cooking taste evaluation comments indicated that the *Cardaba* pulp samples that had been boiled for about 5 and 10 min did not taste well cooked. The *Cardaba* pulp start to taste well cooked after 15–20 min of boiling. Hence, 15–20 min seemed to be ideal for the *Cardaba*, since it tasted well-cooked, firm and found to be crunchy.

Conclusion

The results indicated that *Cardaba* had superior values for physical characteristics. *Nijiru* and *Kitawira* had the smallest, shortest, thinnest fruit and the edible portions mass almost equal to peel mass. *Cardaba* had a higher proportion of pulp per unit mass. In terms of green matured fruit the chemical quality was found to be significant amongst the tested varieties. The *Matoke* variety had the highest acid content, the *Cardaba* the highest dry matter and *Nijiru* the highest AA content. Boiling quality parameters, pulp firmness reduction and water absorption were found to be dependent on the variety and boiling time. Even after 20 min' cooking, the mean pulp firmness loss of *Cardaba* was found to be 15 % lower than the mean pulp firmness loss experienced by the remaining three varieties boiled for 5 min. Though *Matoke* showed less water absorption, its quick pulp firmness loss like *Nijiru* and *Kitawira* during cooking and peeling difficulty makes it less preferable when compared to *Cardaba*. *Cardaba* pulp slices remained firm and crunchy. *Nijiru*, *Kitawira* and *Matoke* pulp slices were found to be too soft. Generally, *Cardaba* adhere to both physical and boiling quality standards required for the best boiled product quality. The good cooking qualities of *Cardaba* could be related to its comparatively ease to peel, lower water absorption potential, slightly higher pulp firmness before cooking, higher percentage of pulp dry matter content and pulp to peel ratio. *Nijiru*, *Kitawira* and *Matoke* were relatively watery and produced a softer pulp on cooking, indicating their lower suitability for boiling purposes. Both the sensory and the objective chips quality of green matured fruit pulp sliced in 2 mm thickness and deep-fat fried at 170 °C for 4 min indicated that *Nijiru*, *Kitawira* and *Matoke* varieties were suitable for chips processing. The panellist acceptance score, preference percentage, and higher chips moisture content did not confirm suitability of *Cardaba* variety for chips processing. The panellist acceptance score, preference percentage, objective chips quality and profitability evaluation indicates that *Nijiru*, *Kitawira* and *Matoke* posses better potential for producing a comparably acceptable quality chips than the *Cardaba* variety.

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