RESEARCH PROGRAM ON Roots, Tubers and Bananas

Technical report
Optimization of the harvest stage for reducing cooking banana postharvest losses: a multi-criteria approach targeting matooke end-product

Expanding Utilization of Roots, Tubers and Bananas and Reducing Their Postharvest Losses

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IFAD
Enabling poor rural people to overcome poverty

Nowakunda, Kephas[1]; Olivier Gibert[2], Christophe Bugaud[2] and Kikulwe, Enoch[3]

[1] National Agricultural Research Laboratories, Kampala, Uganda

[2] CIRAD

[3] Bioversity International, Kampala, Uganda

* *Contact person: Enoch Kikulwe (e.kikulwe@cgiar.org)*

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Expanding Utilization of Roots, Tubers and Bananas and Reducing Their Postharvest Losses (RTB-ENDURE) is a 3 year project (2014-2016) implemented by the CGIAR Research Program on Roots, Tubers and Bananas (RTB) with funding by the European Union and technical support of IFAD. http://www.rtb.cgiar.org/endure

The CGIAR Research Program on Roots, Tubers and Bananas (RTB) is a broad alliance led by the International Potato Center (CIP) jointly with Bioversity International, the International Center for Tropical Agriculture (CIAT), the International Institute for Tropical Agriculture (IITA), and CIRAD in collaboration with research and development partners. Our shared purpose is to tap the underutilized potential of root, tuber and banana crops for improving nutrition and food security, increasing incomes and fostering greater gender equity, especially among the world's poorest and most vulnerable populations.

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Acronyms

CIRAD: Centre de Coopération Internationale en Recherche Agronomique pour le Développement

IFH: Interval between flowering and harvest

IITA: International Institute of Tropical Agriculture

masl: Metres above sea level

MBADIFA: Mbarara District Farmers Association

NARL: National Agricultural Research Laboratories

NARO: National Agricultural Research Organisation

Executive Summary

This report presents results of RTB-ENDURE sub-output 1.3; 'Determining appropriate harvest time for the cooking bananas with intrinsic long shelf-life using physical, chemical and sensory attributes' of the cooking banana business case's Output 1, entitled "Increased access of farmers to cooking banana varieties with preferred quality attributes and intrinsic long shelf life traits". The worked aimed at reducing postharvest losses for cooking banana while modulating harvest stage for green life extension. The originality of this investigation was to evaluate the putative impact of fruit stage of harvest onto its potential storage life and eating quality. The optimal harvest stage was evaluated by coupling three antagonist parameters, namely fruit diameter, green life, and eating quality, to optimize harvest stage of the variety Kibuzi in specific edapho-climatic conditions of Rakai and Isingiro districts in southwestern Uganda. A temperature record was considered in both sites between flowering and harvest. The interval between flowering and harvest (IFH) of Kibuzi banana variety was used as a quantitative explanatory variable, and the site location (Rakai at 1270 masl vs Isingiro at 1440 masl) was used as a qualitative one. Since the sites were at different altitudes, two Tynitag temperature data loggers were installed to record temperatures. Fruits size, dry matter, fruit firmness, total soluble solids, titratable acidity and sensory attributes were recorded at four harvest stages: 112, 126, 138, 152 days and 111, 125, 137, 151 days after flowering. The evolution of three parameters; diameter of fruit, green life and overall acceptability of the end-product - Matooke - were simulated for 110 to 155 days range, leading to the identification of a range of optimal harvest ages for variety Kibuzi in Rakai at between 133 to 142 days and 133 to 150 days for Isingiro. The prediction of the optimal harvest stage will remain only valid for the two locations without taking into account thermal sum for establishing a strong relationship between fruit age in degree.days and green life. Given the respective altitudes at Rakai and Isingiro, it implies that the two edapho-climatic conditions were not so different in terms of on field temperature. With some more diverse thermal conditions in the experimental sites (lowland vs highland with at least 3°C needed between sites), the thermal sum concept will be even more precise for the prediction of the optimal harvest stage for bananas, regardless the location site (lowland, highland, with hot or cool local conditions). Such original multi-criteria approach (agro-morphological, physiological traits, and end-product sensory attributes) was relevant for the prediction of the optimal harvest stage, in order to reduce banana postharvest losses during transport and until Matooke preparation by end-users. Such innovative methodology can be applied to some other banana culinary recipes and end-uses.

Introduction

The CGIAR Research Program on Roots, Tubers and Bananas (RTB) is a broad alliance led by CIP jointly with Bioversity International, CIAT, IITA, and CIRAD in collaboration with research and development partners. Our shared purpose is to tap the underutilized potential of root, tuber and banana crops for improving nutrition and food security, increasing incomes and fostering greater gender equity, especially among the world's poorest and most vulnerable populations.

In the cooking banana RTB-ENDURE sub-project, the output 1 entitled “Increased access of farmers to cooking banana varieties with preferred quality attributes and intrinsic long shelf life traits” involved the team composed of NARO, IITA, CIRAD, Bioversity International, Ssemwanga Center, and Kaika. Output 1.3 entitled “Determining appropriate harvest time for the cooking bananas with intrinsic long shelf-life using physical, chemical and sensory attributes” was coordinated by Kephas Nowakunda (NARL) and Olivier Gibert (CIRAD).

Two experiments where designed aiming at reducing postharvest losses for cooking banana while targeting Matooke end-product. The first experiment, designed and carried out under the responsibility of CIRAD, aimed to identify the optimal harvest stage for both extended shelf life and optimum eating qualities. This experiment was implemented by Kephas Nowakunda (NARL) and Christophe Bugaud (CIRAD). The second experiment was designed by NARO to identify the best postharvest treatments (peeled fingers, deeping into water, preservative) to complementary ensure better banana postharvest storage, and optimum eating quality. Findings of the second experiment, under the responsibility of NARO, are not be presented in this report.

Many scientific investigations were earlier carried out on banana (both dessert and cooking types) for evaluating the impact of the harvest stage on fruit weight and green life. However, if the impact of the harvest stage of banana on the eating quality of Matooke is empirically known, no demonstration had been made so far to limit east African highland banana postharvest losses.

Thus, the work aimed at reducing postharvest losses for cooking banana by modulating harvest stage for green life extension. The originality of this investigation was to evaluate the putative impact of fruit stage of harvest onto its potential storage life and eating quality. The optimal harvest stage was evaluated by coupling three antagonist parameters, namely fruit diameter, green life, and eating quality, to optimize harvest stage of the variety Kibuzi in specific edapho-climatic conditions of Rakai and of Isingiro districts in southwestern Uganda. A temperature record was considered in both sites between flowering and harvest. The interval between flowering and harvest (IFH) of Kibuzi banana variety was used as a quantitative explanatory variable, and the site location (Rakai *vs* Isingiro) was used as a qualitative one.

Materials and Methods

Experimental design

After a field-trip and discussion with the NARO team, one experimental design has been developed to optimize harvest stage of the variety Kibuzi produced on two sites, namely Rakai and Isingiro. That made it possible to investigate the putative impact of fruit growth conditions (field temperature, soils, and crop management) onto the potential storage life (green life) and eating quality of banana. Since both sites were apparently not exactly at the same altitude (1440m vs 1270m according to Google Earth), inducing potential different field temperatures, two Tynitag Plus 2 waterproof temperature data loggers (ref. TGP-4017 with -40 to 85°C range) with a built-in sensor were provided to NARO to record the daily temperature on each plot between flowering and harvest. These data loggers were installed between April and July 2016 by Juliet Masawi, MSc fellow of the project, student at University of Makerere in Kampala. With the temperature being recorded for few months, we expected being able to determine the harvest stage on the basis of thermal sum, which permits strong relationship between fruit age measured in degree.days, and green life. The concept of thermal sum was explained by the CIRAD expert, Christophe Bugaud, during his mission at NARO in Uganda in December 2015 (Cf. Annex 1). C. Bugaud was also able to give all needed information for the on-field installation of thermal data loggers as illustrated below in Fig **1**.

Figure 1. On-field thermal data logger installation

The time between flowering and ripening (on tree) has been earlier estimated by Juliet Masawi being about 5 months for the variety Kibuzi. Consequently, four harvest stages were chosen: 112, 126, 138, 152 days and 111, 125, 137, 151 days after flowering for the districts of Rakai and Isingiro, respectively. The one day difference in between allowed harvesting by the same operator in the two sites. It seemed important to ensure a range of 10 to 15 days between each harvest stage. For each harvest stage, five bunches were collected, as illustrated in Figure 2.

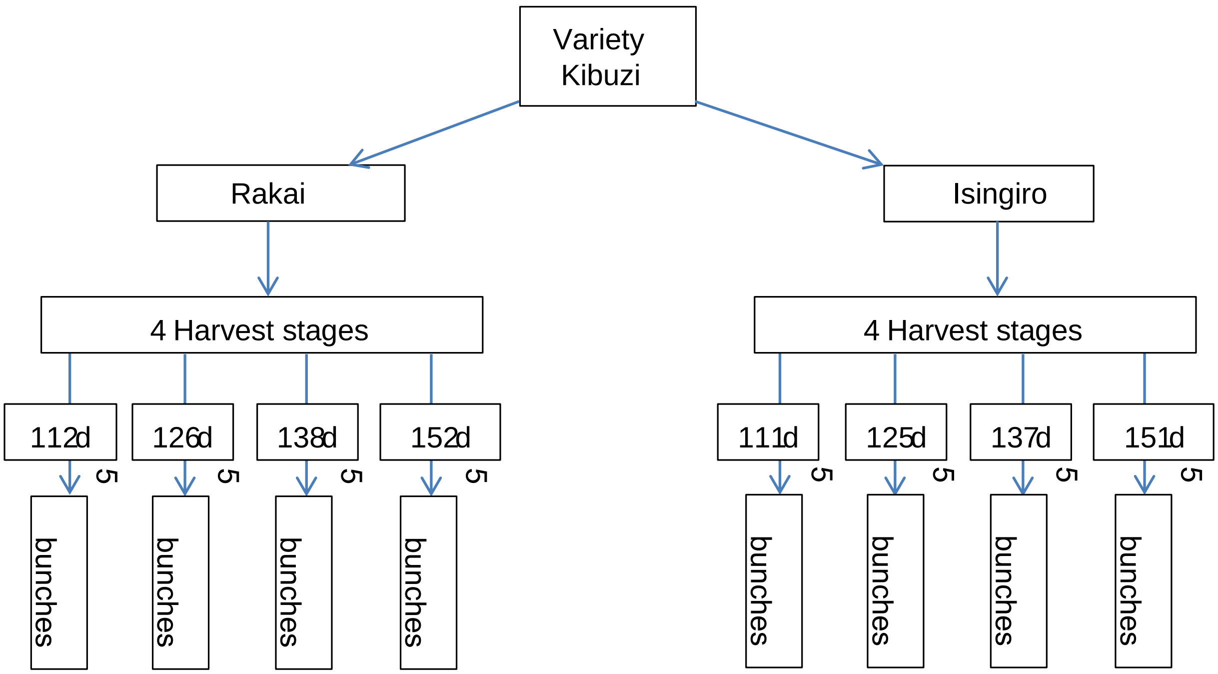


Figure 2. Scheme of the experimental design in the sites of Rakai and Isingiro

Analyses

The optimal harvest stage has been determined on the basis of three objectives:

1. The fruits have not to be too thin (optimal fruit filling). That is important for farmers to sell heavy and attractive bunches;
2. The fruits need sufficient potential life-storage, to allow the reduction of postharvest losses for transporters and retailers;
3. The fruits need high eating quality, to allow sensory attractiveness by the consumers of Matooke, and thus reducing wastes.

The traits that seemed suitable for achieving these objectives were fruits' weight and diameter (1st objective), green life (2nd objective), and level of acceptability by consumers (3rd objective). Furthermore, some other physicochemical analyses were conducted on banana fruits at harvest, and prior to Matooke preparation, to find relevant indicators for the optimal harvest stage. A list of physicochemical parameters has been defined and agreed with partners at NARO, as reported in Table 1.

Table 1.Targeted physicochemical parameters to analyze

	Recommended to be done on fruits at green stage when harvested	Recommended to be done on fruits at green stage prior to matooke preparation	Recommended to be done on the Matooke product
Fruits weight *	X	X[1]	
Fruit diameter *	X		
Dry matter content	X	X	X
Pulp to peel ratio *	X		
Firmness	X[2]	X[2]	X[3]
Titratable acidity *	X		X
Total soluble solids	X	X	X

[1] to evaluate the fruit weight losses during storage

[2] to be done with the thinnest probe of the hand texture analyzer, with preliminary trails

[3] to be done with the cylindrical probe of largest diameter of the hand texture analyzer, with preliminary trials

The analyses were planned according to the preliminary conditions defined and reported by Juliet Masawi (Cf. Annex 2). Unfortunately, practical experimental conditions only allowed to perform the analysis marked with an '*' in Table 1.

For **green life**, one cluster per bunch has been packed into a perforated polyethylene bag (to reduce losses of water) and let into a controlled temperature room (24-25°C). If some fluctuations of the temperature occur, the green life can be computed by using an abacus (Cf. Annex 1 in the thermal sum concept). The green life is relatively easy to estimate, but requires strict precautions. As earlier advised to Juliet Masawi, the following precautions have to be taken into account:

- Fruits have to be checked every 2-3 days.
- If any fruits from any cluster starts to ripen, these need to be immediately removed from the room, to avoid any artificial ripening of the other fruits/clusters due to the presence of ethylene.

The **degree of acceptability** of Matooke has been evaluated using fruits being harvested at the four stages, five days after harvest. The consumer test included 20 consumers in each district. For each sample, smoothness, taste, color, smell, and overall acceptability were scored on a 6-points discrete scale (1 = dislike very much, 6 = like extremely). Consumers were also asked to point out the sample they preferred (Cf. questionnaire in Annex 3). The sensory attributes were also investigated using steam-cooked bananas, since it represents the most popular consumption mode. No information was reported regarding the cooking conditions used (time, temperature) for the preparation of matooke recipe.

Results

Impact of the harvest stage on physicochemical parameters

At first, we investigated the impact of the harvest stage on some physicochemical parameters described in Table 1. Cluster weight, fruit diameter, peel to pulp ratio, green life and titratable acidity were measured.

The impact of harvest stage was investigated using ANCOVA statistical tool (Xlstat, 2016). The interval between flowering and harvest (IFH) was used as a quantitative explanatory variable, and the site location (Rakai *vs* Isingiro) was used as a qualitative explanatory variable. Subsequent models were built to predict physicochemical parameters with IFH and location contributions. Statistical results are reported above in Table 2.

Table 2. Result of the ANCOVA using the five physicochemical parameters

	Cluster weight	Diameter	Peel to pulp ratio	Green life	Titratable acidity
R^2	0.80	0.65	0.52	0.69	0.384
F	73	34	20	42	6.6
P > F	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.006
IFH	142	43	35	79	12
	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.002
Location	4.3	25	5.2	4.0	0.48
	0.044	< 0.0001	< 0.0001	0.054	0.49

As shown above, for the five parameters (weight of cluster, diameter of fruit, pulp to peel ratio, titratable acidity and green life), some significant effects of IFH was observed (with a probability *P* below 1%). As expected, the diameter of the fruits increased with IFH as illustrated in Figure 3.

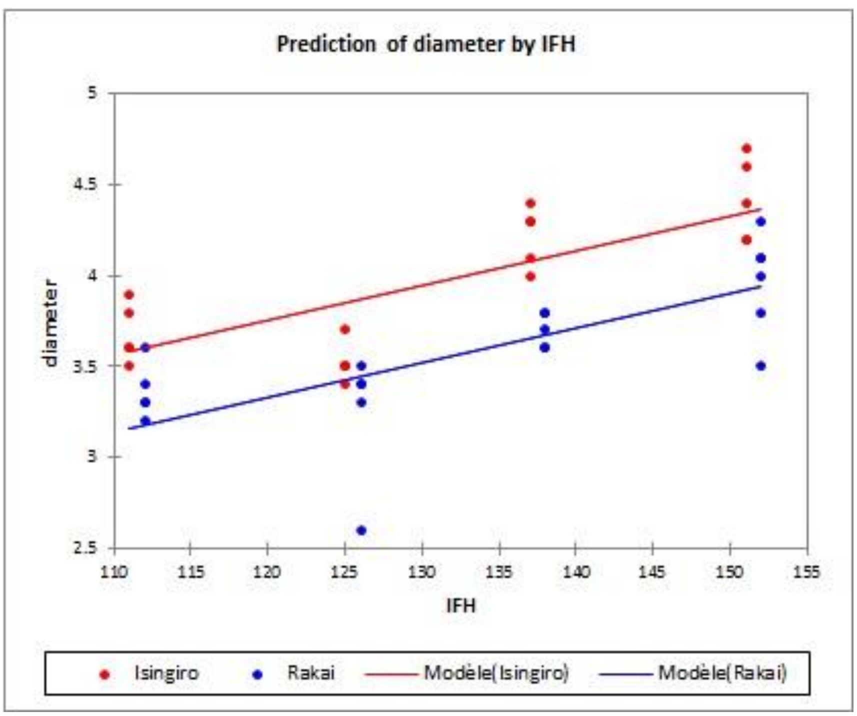


Figure 3. Relationship between diameter and IFH for Kibuzi variety in Isingiro and Rakai

In Isingiro, fruits exhibited higher diameters, which meant that this trait may depend on the local agro-ecological conditions. A subsequent model *(1)* allowed us to accurately predict the diameter, based on experimental data, as follows:

$y = 1.0 + 0.019 \times IFH + 0.42 \times Isingiro\_site$ *(1)*

With *y* the predicted diameter, *IFH* the interval between flowering and harvest, *Isingiro_site* the location site of Isingiro.

The pulp to peel ratio seemed to be negatively affected by IFH as illustrated below in Figure 4.

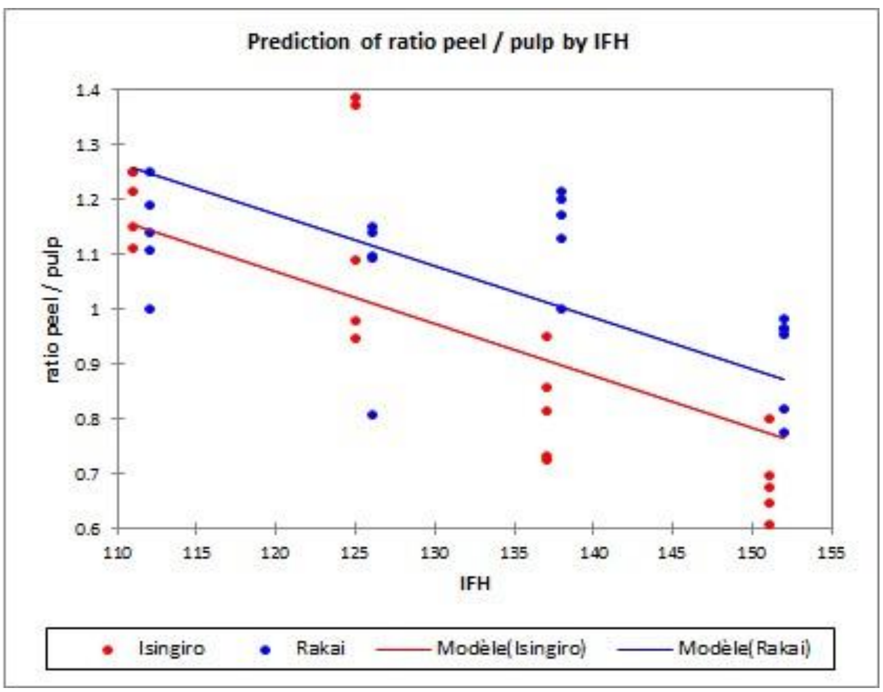


Figure 4. Relationship between pulp to peel ratio for Kibuzi variety in Isingiro and Rakai

In Isingiro, fruits exhibited lower pulp to peel ratios, which suggests that this parameter (like diameter) is dependent of the local conditions. It would be interesting to explore the putative link between this parameter and the thermal sum. A subsequent model *(2)* allowed us to predict the pulp to peel ratio, based on experimental data, as follows:

$y = 2.3 - 0.0094 \times IFH - 0.1 \times Isingiro\_site$ *(2)*

With *y* the pulp to peel ratio, *IFH* the interval between flowering and harvest, *Isingiro_site* the location site of Isingiro.

As expected, the green life was negatively affected by IFH as illustrated in Figure 5. For a given IFH, fruits from Rakai location exhibited a lower green life that those collected in Isingiro, which in turn suggested that the fruits from Rakai exhibited a higher physiological age at harvest. This might be due to the field temperature at Rakai estimated to be higher than that at Isingiro.

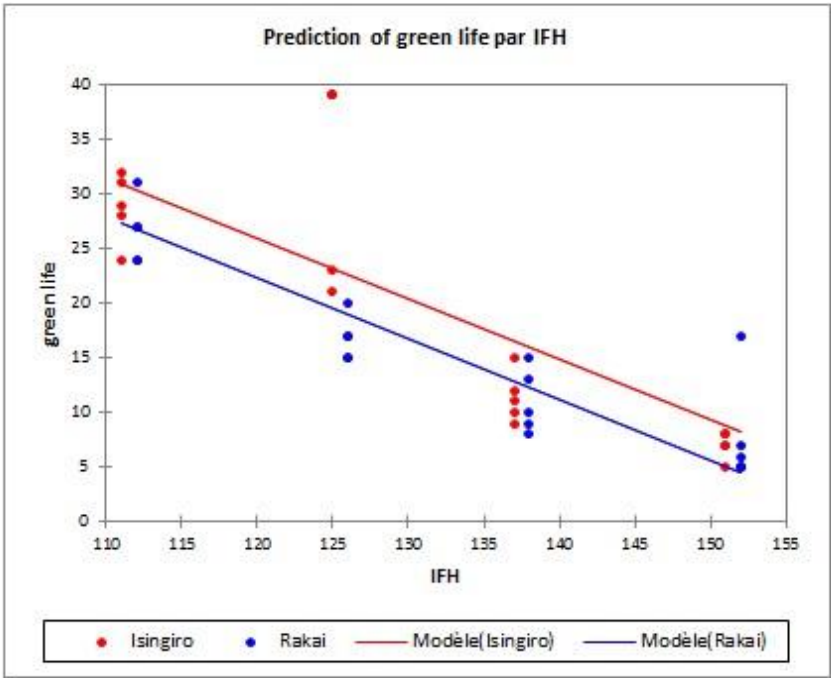


Figure 5. Relationship between green life and IFH for Kibuzi in Isingiro and Rakai

Thermal records at both locations would help to better describe the relationship between green life and IFH by taking into account *degree.days* from thermal sum.

A first stage model *(3)* allowed us to predict the green life, based on the estimation of IFH, as follows:

$$y = 88 - 0.55 \times IFH + 4 \times Isingiro\_site \quad (3)$$

With *y* the green life estimate, *IFH* the interval between flowering and harvest, *Isingiro_site* the location site of Isingiro.

Impact of harvest stage on degree of acceptability

The impact of harvest stage pm consumers' acceptability was also investigated using ANCOVA statistical tool. Once again, the interval between flowering and harvest (IFH) was used as a quantitative explanatory variable, and the site location (Rakai *vs* Isingiro) was used as a qualitative explanatory variable. Subsequent models were built to predict five sensory attributes (smoothness, taste, color, smell, and overall acceptability) based on IFH and location contributions. The ANCOVA showed a significant impact of IFH on the five sensory attributes, as reported in Table 3.

Table 3. Result of the ANCOVA using the five sensory attributes

	Smoothness	Taste	Color	Smell	Accept
R^2	0.26	0.32	0.48	0.23	0.39
F	26	37	72	23	48
Pr > F	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
IFH	48	73	144	46	95
	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Location	3.5	0.05	0.03	0.15	0.09
	0.06	0.81	0.85	0.69	0.75

Except from a slight significant contribution of the location on smoothness (P< 0.065), no significant difference in sensory attributes was observed between locations.

A subsequent model *(4)* allowed us to predict the overall acceptability, based on IFH estimate, as follows:

$y = -4 + 0.06 \times IFH$ *(4)*

With *y* the degree of acceptability on a 1-6 scale, and *IFH* the interval between flowering and harvest.

A complementary internal preference mapping done on overall acceptability (Xlstat, 2016) allowed us to identify the products being mostly accepted by consumers. The higher was IFH, the most appreciated was the resulting Matooke (Figure 6a&b).

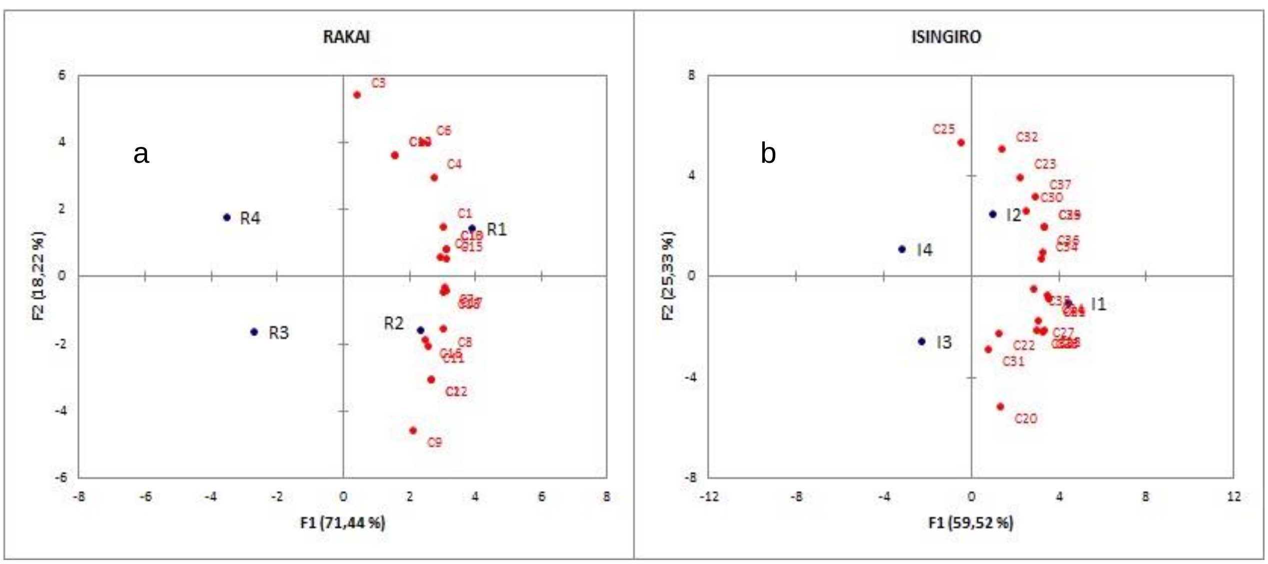


Figure 6. Internal mapping illustrating the preference of consumers at Rakai (a) and Isingiro location (b) for the four products, with an harvest stage at 152 days (R1 and I1), at 138 days (R2 and I2), at 126 days (R3 and I3), and at 112 days (R4 and I4).

Thresholds

We arbitrary established some ranges (threshold) for each parameter as unacceptable / acceptable / optimal, as illustrated in the following **Table 4**.

Table 4. Threshold for fruits, as unacceptable, acceptable, and optimal

	Unacceptable (highlighted in red)	Acceptable (highlighted in orange)	Optimal (highlighted in green)
Diameter of fruit	< 3 cm	3 to 4 cm	> 4 cm
Green life	<10 days	10 to 20 days	> 20 days
Overall acceptability (1-6)	< 4	4 to 5	> 5

Complementary analysis based on temperature records

Given the temperature records, it was possible to compute a partial thermal sum (in degree.days) taking into account the evolution of temperatures in Rakai and Isingiro sites during a 80 days period prior to harvest. Unfortunately, only partial temperature records between flowering and harvest on the two sites were available. In fact, records covered the period from 14th of April to 5th of July with flowering stage occurring between 12th of February and 23rd of March. Therefore, it was not possible to compute the full thermal sum. With a temperature record not available for about two months, we obtained about 752 and 737 degree.days, in Isingiro and Rakai location, respectively. With a shorter period of missing data, it would have been possible to make accurate predictions of the optimal harvest stages in other locations.

On the daily average temperature records basis from 14th of April to 5th of July, some small differences in temperature records were observed between sites as illustrated in Figure 7. The global average thermal records between sites were relatively similar with 21.7 and 21.8°C in Rakai and Isingiro, respectively.

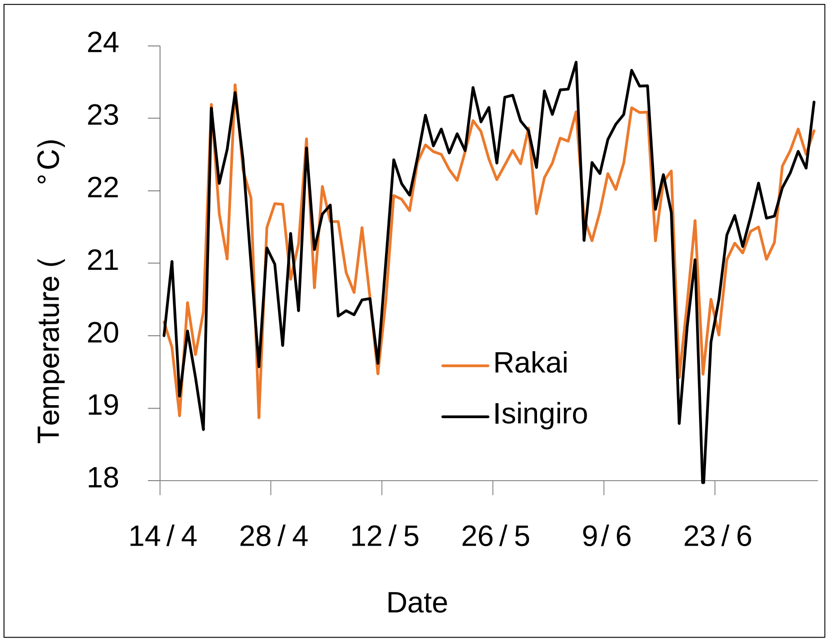


Figure 7. Average daily temperature in Rakai (brown) and Isingiro (black) from 14th of April to 5th of July 2016

It seemed interesting to have a deeper look into the temperature records in both locations. As illustrated in Figure 8, the average monthly temperature (Ẋ) were similar in Rakai and Isingiro locations. The largest difference in average temperatures was observed in July with about 0.5°C difference between locations. However, as illustrated in corresponding error bars, the largest amplitude in temperature was observed in Rakai in June and July with about 30.1 to 31.8°C, respectively. Other average thermal amplitudes remained below 20°C in Rakai and Isingiro. Except from the median temperature in Isingiro in July (above 22°C), all monthly median temperatures were distributed in the 19.2-20.4°C range. In summary, if the hottest temperatures were recorded in June and July in Rakai, the temperature was often higher in Isingiro in July, as illustrated by corresponding monthly average and median records.

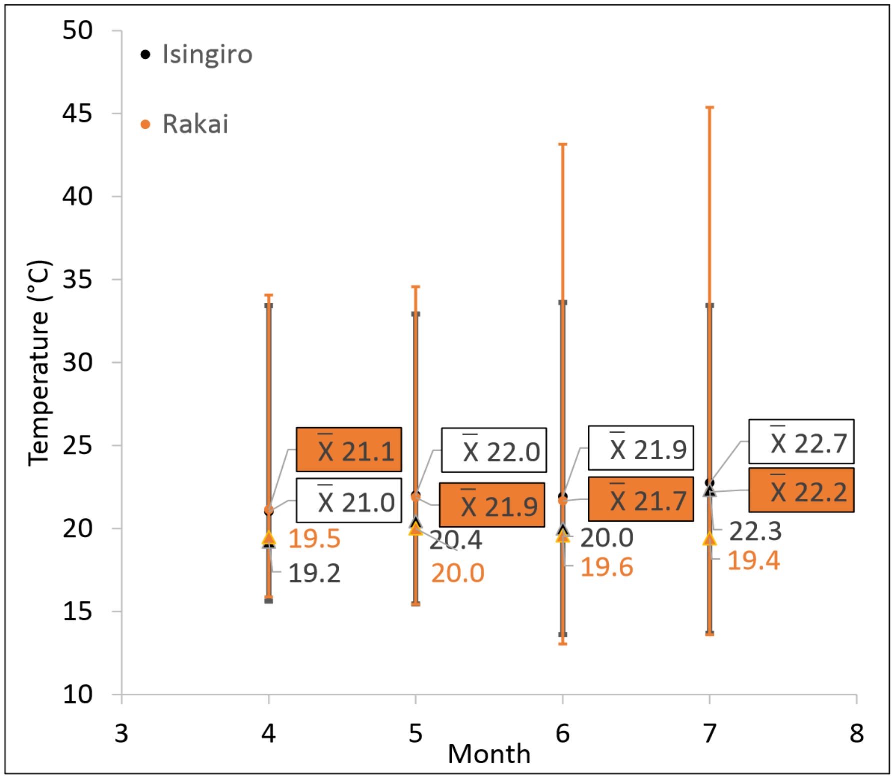


Figure 8. Average monthly temperature in Rakai ($\dot{X}$ in brown) & Isingiro ($\dot{X}$ in black) with corresponding error bars for min and max temperatures, & corresponding average monthly medians from 14^{th} of April to 5^{th} of July 2016

We earlier hypothesized that the field temperature in Rakai might be higher than in Isingiro, to justify that, for a given IFH, fruits from Rakai location exhibited a lower green life (higher physiological age at harvest). Thus, such hypothesis was partially right, since fruits were submitted to higher temperature (even for a shorter period). In such extreme thermal conditions, one can expect fruits having their green life being significantly affected.

Some differences were observed between locations in terms of relationship between green life and interval between flowering and harvest. However, according to Umber et al. (2011), a contrasted temperature of at least 3°C is needed between sites to obtain a significant regression. Given the respective altitudes at the two sites, it implies that the two edapho-climatic conditions were not so different in terms of on-field temperature.

Identifying the optimal harvest stage

From the previous models, we were able to simulate the evolution of the three parameters (diameter of fruit, green life and overall acceptability) for an IFH in the 110 to 155 days range. We were then able to superimpose the corresponding colors according to the established thresholds for each location site.

The following Table 5 illustrates the optimal IFH obtained for the location of Rakai as a compromise solution, by taking into account the diameter, the green life and the overall acceptability of the variety Kibuzi. As optimal harvest stage, only acceptable (orange) or optimal (green) conditions were considered. The unacceptable conditions of harvest were highlighted in red, taking into account the unacceptable overall acceptability and green life.

Table 5. Optimal harvest stages in Rakai based on predicted diameter, green life, and overall acceptability

IFH	Diameter (cm)	Green life (days)	Overall acceptability (1-6)
110	3.1	28	2.6
115	3.2	25	2.9
120	3.3	22	3.2
125	3.4	19	3.5
130	3.5	17	3.8
131	3.5	16	3.9
132	3.5	15	3.9
133	3.5	15	4.0
134	3.5	14	4.0
135	3.6	14	4.1
140	3.7	11	4.4
141	3.7	10	4.5
142	3.7	10	4.5
143	3.7	9	4.6
144	3.7	9	4.6
145	3.8	8	4.7
150	3.9	6	5.0
155	3.9	3	5.3

Thus, we came to the conclusion that the optimal harvest stage was in the 133 to 142 days range for the variety Kibuzi in Rakai site.

Table 6 below shows the optimal IFH obtained for Isingiro.

Table 6. Optimal harvest stages in Isingiro based on predicted diameter, green life, and overall acceptability

IFH	Diameter (cm)	Green life (days)	Overall acceptability (1-6)
110	3.5	32	2.6
115	3.6	29	2.9
120	3.7	26	3.2
125	3.8	23	3.5
130	3.9	21	3.8
131	3.9	20	3.9
132	3.9	19	3.9
133	3.9	19	4.0
134	4.0	18	4.0
135	4.0	18	4.1
140	4.1	15	4.4
145	4.2	12	4.7
150	4.3	10	5.0
151	4.3	9	5.1
152	4.3	8	5.1
153	4.3	8	5.2
154	4.3	7	5.2
155	4.4	7	5.3

Therefore the optimal harvest stage for the variety Kibuzi in Isingiro site was found in the 133 to 150 days range. The prediction of the optimal harvest stage will remain only valid for both location sites without taking into account the thermal sum able to establish a strong relationship between fruit age in degree.days and green life. As earlier suggested by Umber et al. (2011), further investigations need to be conducted at sites with different thermal conditions (lowland and highland), or monitored on one plot basis, for at least a complete year with different thermal periods (contrasted seasons).

Conclusions

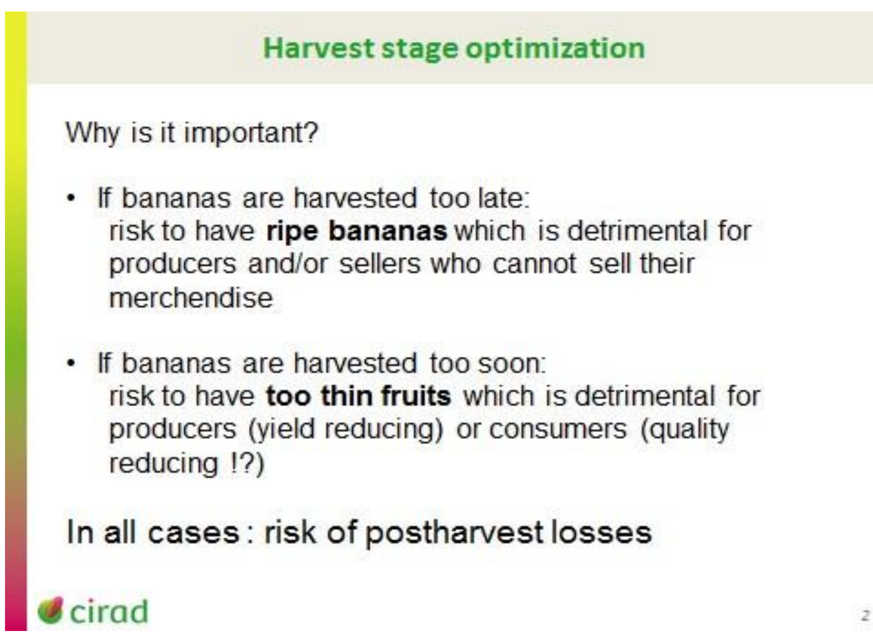
We were able to conduct some on-field experiments to determine the optimal harvest stage for shelf-life extension of the cooking banana Kibuzi variety in two sites and taking into account physical, chemical, and sensory attributes related to matooke end-product.

Given the respective altitudes at Rakai and Isingiro, it implies that the two edapho-climatic conditions were not so different in terms of on field temperature. With some more contrasted thermal conditions for the selection of the experimental sites (lowland *vs* highland with at least 3°C difference needed between sites), the thermal sum concept will be even more precise for the prediction of the optimal harvest stage for bananas beyond the research sites (lowland, highland, with hot or cool local conditions).

Such original multi-criteria approach (agro-morphological, physiological traits, and end-product sensory attributes) was relevant for the prediction of the optimal harvest stage, in order to reduce banana postharvest losses, during transport and until end-users processing into Matooke. Such innovative methodology can be easily applied to some other banana culinary recipes and end-uses.

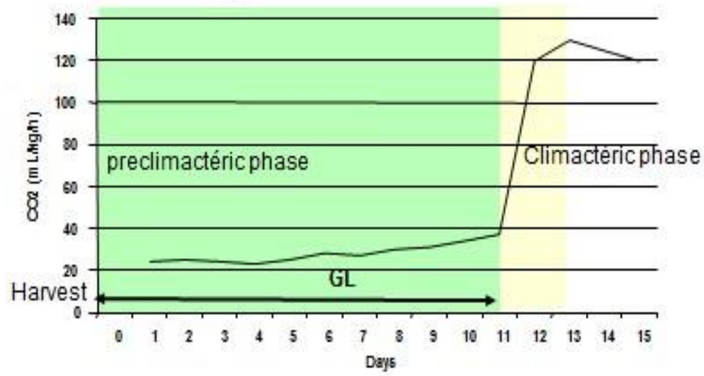
Annexes

Annex 1. Presentation of thermal sum concept by Christophe Bugaud during his mission at NARO in Uganda in December 2015.



Storage life potential: Green Life

GL = Time (in days) between harvest and the apparition of the climacteric peak



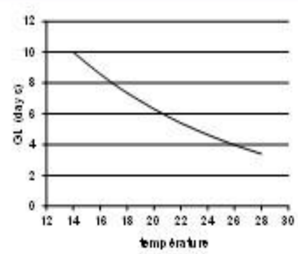
Green life is an indicator of fruit age at harvest

cirad

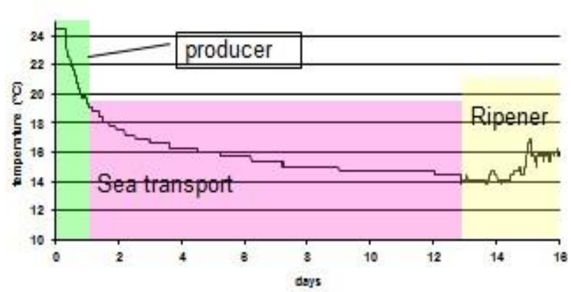
3

Green life and storage conditions

Decreasing relationship between GL and storage temperature: 7-8% / ° C



Final GL depends on storage conditions



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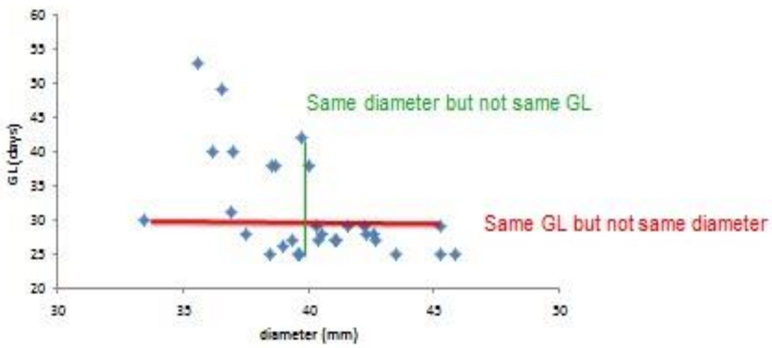
4

Which tools to aid harvest?

Using diameter fruit for harvest?

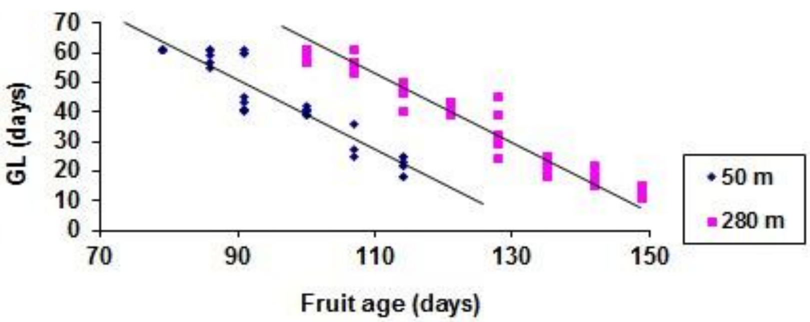


Not relevant for harvest stage optimization!

cirad 5

Which tools to aid harvest?

Using fruit age (in days) for harvest?

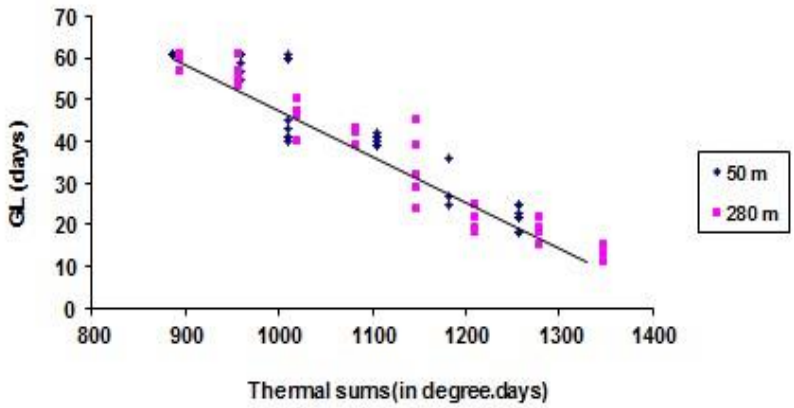


Neccessity of having a referential per site! Not relevant!

cirad 6

Which tools to aid harvest?

Using fruit age (in degree.days) for harvest?



Robust relationship whatever thermal conditions in field: it is a relevant indicator!

cirad 7

Thermal sum concept

Thermal sum: widely used in growth and cropping models to estimate the duration of different development stages

$$Ts = D.(T - Tbase)$$

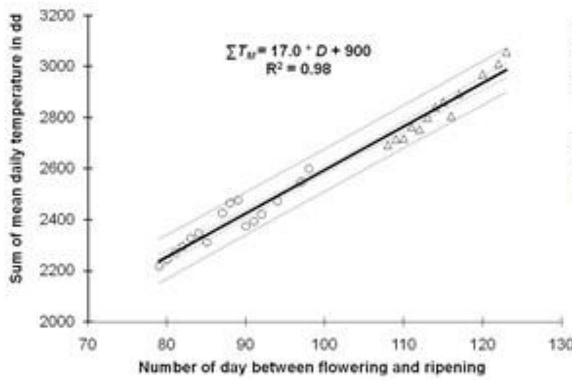
with D number of days,
Tbase the base temperature
And Ts the thermal sum **which remains constant regardless of the season and elevation**

cirad 8

How estimate optimum harvest stage of a new banana

Ts = ∑(Tm -Tbase), with Tm mean daily temperature

∑Tm = D.Tbase + Ts (Y = a.X + b)



First step: identify Tbase

For Cirad916, Tbase = 17° C

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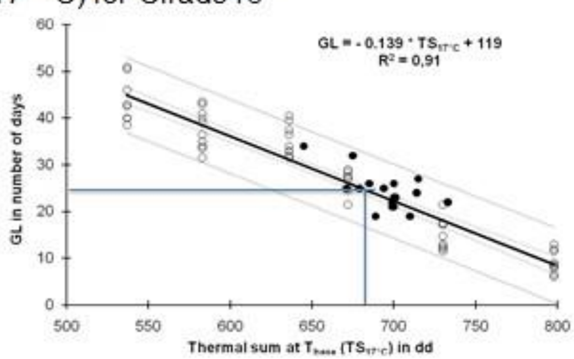
How estimate optimum harvest stage of a new banana

Second step: identify the thermal sum for a given GL

For banana export, GL = 25 days, so Ts = 680 dd (base 17° C) for Cirad916



For Cavendish

Ts = 930 dd (base 14,7° C)

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Weather station

A temperature sensor (Tynitag) was installed in each plot and recorded daily temperature

Suspending the tynitag in the middle of the PVC pipe

Making holes in the bottom of the white PVC pipe

Putting the weather station at about one meter of the banana tree

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What preharvest factors impact GL?

Field temperature	no
Position on the bunch	yes
Bunch trimming	no
Bunch bagging	yes
Water deficit– anoxic stress	no - no
Nematods stress	no
Leaf pruning - Leaf shading	no - no
Sigatoka – Blak leaf streak diseases	yes - yes

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Annex 2. Extract from preliminary Juliet Masawi's report

Determining the physical characteristics of the cooking bananas

For assessment of physical parameters of the study that involve using observing fingers, the first two fingers of the upper row of the second hand will be used throughout the study. The physical characteristics will be determined in the following ways:

Determining the bunch weight (kilograms) of each cultivar by weighing individual bunches with a balance. This weight will be collected to two decimal places.

Determining the weight (kilograms) of the second and third clusters of each harvested bunch.

Determining the circumference (centimeters) and diameter of the fruit to one decimal place by measuring the widest midpoint of selected fruits using a tape measure.

Determining the length (centimeters) to one decimal place of the selected finger on the second cluster by measuring the outer curve of individual fruit with a measuring tape from the distal end to the point at the proximal end where the pulp is judged to terminate.

The pulp and peel weight (grams) will also be determined using a mettler electronic scale. In this case the fingers will be hand peeled; the peel and weight will then be weighed separately. These will also be used to obtain the pulp to peel ratio.

A photograph will be taken to compare the bunch appearance for the four different harvest stages.

Determining the chemical properties of the bananas

Some chemical properties of the bananas harvested at the different stages will be established. For chemical analysis, the first two fingers of the second row of the second hand will be used during the study. For data consistency all fingers to be assessed for chemical properties will be washed in distilled water before carrying out any tests. The chemical parameters to be assessed will include:

(i) Measurement of total titratable acidity

30 grams of pulp tissue (from the transverse section of the banana fruit) in 90 ml of distilled water will be blended in a kitchen blender for 2 minutes and filtered through a filter paper.

25 ml of the above prepared filtrate will be transferred into a 125 ml conical flask.

25 ml of distilled water and 4-5 drops of phenolphthalein indicator will be added into the conical flask. A 25 ml burette will be filled with 0.1 M sodium hydroxide (NaOH) and adjusted to the zero mark after eliminating the bubbles.

The diluted filtrate will be titrated with 0.1 M sodium hydroxide until the indicator just changes pink/red. The titre volume of the NaOH added will be recorded. The results will be expressed (e.g. as milliequivalent per 100 g sample) in terms of the predominant acid present.

The pH will be correlated with the titratable acidity of the cooking bananas at different harvest stages.

(ii) Dry matter and moisture content of the cooking banana

The moisture and dry matter contents of cooking banana will be measured as follows:

An empty container (e.g. foil dish) will be weighed using an electronic balance (± 0.0001) and the weight (X) recorded.

2 grams of pureed fruit will be placed in an oven maintained at 70°C for 48 hours.

The samples will be transferred from the oven into a desiccator and cooled at room temperature.

The samples will be weighed after drying (Z)

The percentage moisture and dry matter content of the sample will be calculated as follows:

Wet weight of sample (P) = 2grams

Weight of dry sample (Q) = Z - X

Moisture content (%) = $(\underline{2 - Q \times 100})/2$

Dry matter content (%) = 100 - (% moisture content)

Determining the green life of the cooking bananas

The green life of the third hand on will be determined. The hands to be used for assessing green life will be treated with a fungicide to protect them against fungal infestation..

40 third hands harvested at different ages and at different sites will be packed in replicated boxes (lined with perforated polyethylene film), transferred and stored in a room maintained at room temperature. Each cluster will be placed in individual polyethylene film. Care will be taken to select a well aerated room to regulate the temperature and relative humidity of the room. This will control water loss of the fruits hence control premature ripening. The temperature of the room will be recorded at a four hourly interval.

After the initial measurements of the above parameters, the above parameters will be assessed after a three days interval till a softening will be detected. Any cluster containing fruits detected to commence softening will be removed from the storage room since the ethylene produced by a fruit would trigger ripening in the rest of the fruits.

Green-life will be calculated as the period (in days) between harvest and commencement of ripening.

Sensory evaluation of the cooking bananas

A hedonic sensory test will be conducted to achieve objective three of the study.

The second and fourth hands of bananas harvested at the different maturity stages will be wrapped separately in banana leaves. The wrapped samples will be marked distinctly to avoid confusing samples harvested at different maturity stages. The bananas will then be steamed in the same saucepan for at least 50 minutes. Steaming bananas in the same saucepan will subject the different samples to the same cooking conditions hence limiting variations that could have been caused by cooking the samples separately.

Samples from the two sites will be assessed separately as sites have different growth conditions like temperature and relative humidity which could cause changes in the acceptability of samples at the same maturity stage. This will give a total of 8 samples which will be grouped into two sets with respect to the site.

Three table spoons of each selected sample will be placed on the disposable plates. The 4 samples (harvest at 60, 75, 90, and 105 days) of the same set will be labeled with four digit codes designed and selected randomly to avoid biasing the consumers. Care will be taken to maintain the same name code for samples of the same age from the same site for all consumers. The Samples will be presented to consumers in a form and temperature at which they are consumed normally. The sensory evaluation will be done by 60consumers; five panelists will evaluate the samples at a given time.

The panelists will sit in a facility that houses a number of individual booths to limit interruption and interaction therefore maximize concentration among panelists. The booths will be cleaned regularly, well ventilated, provided with adequate lighting and equipped with a sink for rinsing. The Samples will be presented to panelists in a form and at a temperature at which they are consumed normally. Panelist will be instructed to drink water or rinse the mouth with water in between samples. The panelists will be given a form which they will fill to express their feelings towards a given product.

Annex 3. Questionnaire for consumers test

National agriculture research laboratories/ Kari

Product: mashed matooke from Rakai district Product code…… ………

Sex of consumer…… ……………………………………………………………

Date of evaluation……………………Time of evaluation………………………

Instructions

You are provided with four samples of mashed cooking bananas. You are requested to test each sample with respect to mouth feel/smoothness, taste, colour, smell /odour and overall acceptability. Please indicate your degree of liking by using the scale provided and the sensory quality parameters as indicated in the table below. After testing one sample just before testing the next sample, please rinse your mouth with the water provided. Beside each sample code please write the figure that best describes your feelings about each sample. Any other comments on quality of given samples are also welcome.

SCALE	MOUTH-FEEL/SMOOTHNESS	TASTE	COLOUR	SMELL/ODOUR	ACCEPTABILITY
6	LIKE EXTREMELY	LIKE EXTREMELY	LIKE EXTREMELY	LIKE EXTREMELY	LIKE EXTREMELY
5	LIKE VERY MUCH	LIKE VERY MUCH	LIKE VERY MUCH	LIKE VERY MUCH	LIKE VERY MUCH
4	LIKE	LIKE	LIKE	LIKE	LIKE
3	LIKE FAIRLY	LIKE FAIRLY	LIKE FAIRLY	LIKE FAIRLY	LIKE FAIRLY
2	DISLIKE	DISLIKE	DISLIKE	DISLIKE	DISLIKE
1	DISLIKE VERY MUCH	DISLIKE VERY MUCH	DISLIKE VERY MUCH	DISLIKE VERY MUCH	DISLIKE VERY MUCH

Table for filling in results using above scale, use figures 1-6

SAMPLE CODE	MOUTH-FEEL/ SMOOTHNESS	TASTE	COLOUR	SMELL/ ODOUR	ACCEPTABILITY
1R					
2R					
3R					
4R					

Which sample do you prefer? ……………………………..

Would you like to write a comment? Please write here ……………………………………