Laboratory Standard Operating Procedure

SOP for Instrumental Texture Characterization of Boiled Plantain

Biophysical Characterization of Quality Traits, WP2

Njombe, Cameroon, August 2022

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

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RTBfoods

WP2: Biophysical Characterization of Quality Traits

SOP: Instrumental Texture Characterization of Boiled Plantain

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ABSTRACT

Boiled plantain is the most frequent form of consumption of plantain in Cameroon as it serves as an accompaniment for a variety of dishes. The assessment of boiled plantain quality traits, therefore, becomes important as new clones fail to be adopted by consumers. This study was designed to elaborate the texture profile of boiled plantain from four genotypes. Softness or rather hardness, is considered an important quality trait for boiled plantain and its perception differs from one consumer to another. Hence, the standardization of the instrumental texture measurement of boiled plantain will help improve its preference by end-users when contrasting genotypes can be rapidly screened by instrumental texture characterization during breeding. This Standard Operating Protocol (SOP) describes the apparatus required for sample preparation and instrumental texture measurements. For Instrumental Texture Profile Analysis (ITPA), a double compression mode with a strain of 30% was considered, while for Penetrometry, a puncture test with a 10mm distance was applied. These measurements were carried out at a temperature range comprised between 55°C and 60°C, with a combination of other parameters (Pre-test speed = 5mm/s, Test speed = 1mm/s, Post-test speed = 5mm/s). The genotypes were well discriminated based on textural attributes. Penetrometry better discriminates analysed genotypes. No significant correlations were found between instrumental textural attributes of boiled plantain, mostly influenced by genotypes. In general, the key attributes of boiled plantain are hardness, chewiness and cohesiveness.

Keywords: Boiled plantain, Quality traits, Genotypes, Texture Profile Analysis, Penetrometry

1 SCOPE AND APPLICATION

This Standard Operating Protocol (SOP) describes the sample preparation and instrumental texture analysis of boiled plantain samples.

The objective of this SOP is to describe how plantain pulps are boiled before texture analysis and to measure boiled plantain texture traits. This SOP has been designed as complementary to the procedure reported by Kouassi *et al.* (2021).

2 REFERENCES

Kouassi, H.A., Assemand, E.F., Gibert, O., Maraval, I., Ricci, J., Thiemele, D.E.F., et al. (2021). Textural and physicochemical predictors of sensory texture and sweetness of boiled plantain. *International Journal of Food Science and Technology* 56(3):1160-70, https://doi.org/10.1111/ijfs.14765

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Rodriguez-Sandoval, E., Fernández-Quintero, A., Sandoval-Aldana, A. and Cuvelier, G. (2008). Effect of Processing Conditions on the texture of reconstituted cassava dough. *Brazilian Journal of Chemical Engineering* 25 (4), 713-722.

Singh, V., Guizani, N., Al-Alawi, A., Claereboudt, M. and Rahman, M. (2013). Instrumental Texture Profile Analysis (TPA) of Date fruits as a function of its physicochemical properties. *Industrial Crops and Products* 50, 866-873.

International Organization for Standardization. (2009). ISO 5492:2008. Sensory analysis – Vocabulary.

3 DEFINITIONS

The definitions of the textural attributes were collected from the above-mentioned references. They were measured by a texturometer using texture profile analysis (TPA) and Penetrometry methods. They include:

Hardness: it is the maximum force required to deform a sample (Bourne, 2002). It directly affects chewiness and gumminess, in texture profile analysis. For penetration, it is the amount of force required to overcome resistance to puncture of the food material.

Fracturability: mechanical textural attribute related to cohesiveness and hardness and to the force necessary to break a product into crumbs or pieces.

Adhesiveness: it is the work required in overcoming the attractive force between a product and the contact surface (Singh *et al*., 2013). After the sample is subjected to deformation, if the surface of the sample is sticky, a negative force will be generated. In the sensory field, it can be interpreted as a sticky mouthfeel.

Springiness: The degree to which food can recover between the end of the first bite and the beginning of the second in the mouth.

Chewiness: mechanical textural attribute related to the amount of work required to masticate a solid product into a state ready for swallowing.

Gumminess: Mechanical textural attribute related to the cohesiveness of a tender product.

Cohesiveness: it is the work required to overcome the internal bonds of a material (Rodriguez-Sandoval *et al*., 2008). Cohesion is defined as the ratio of the positive total area under the second compression and withdrawal cycle to the positive total area in the first compression and withdrawal cycle. Tensile force is a manifestation of cohesion. If a sample is cohesive, the probe is also easier to keep clean. Cohesion is usually tested as a lesser parameter than brittleness, chewiness and adhesion.

Resilience: mechanical textural attribute relating to the rapidity of recovery from a deforming force; and the degree to which a deformed material returns to its original condition after the deforming force is removed (ISO, 2009). It is the ratio of the area of the first withdrawal to the first compression.

Distance at max. force (mm): Distance at which the maximum force occurs during the puncture experiment. It is representative of the firmness of the food material

Area under curve (N.mm): work (energy) required to carry out the puncture test.

4 APPARATUS

a. Gas stoves
b. Aluminium pots (30 cm wide, 16.5 cm high and 4 cm thick)
c. Cooking knives (stainless)
d. Plastic basins
e. Strainers
f. Countdown timer
g. Weighing balance (Precisa XB 1200C, d=0.01g)
h. Double-blade knives (stainless steel)
i. Hollow cylindrical rod (2.9 cm wide and 4.1 cm high) with a plunger
j. Thermometer
k. Vernier Calliper
l. Thermos box
m. Tray
n. Tissue cloth
o. Texture analyser with a load cell able to measure the maximum force of 50kg, cylindrical probe (35 mm) for TPA and a conical Perspex (40^{o}) probe for penetrometry.

Using and managing a texture analyser: The Stable Microsystems ***TA-XTplusC*** Texture analyzer (Serial No: 2-P6-Z10657-01-V0039F99B) is equipped with 5kg and 50kg load cells, a keypad and a computer. The instrument is kept in a cool, dry room, on a level surface with no vibrating instruments in proximity. All necessary cables are connected to a power supply, and the equipment can warm up for at least 30 minutes before starting the analysis. After fitting the appropriate probe, a force calibration is done using a 2kg standard weight if the load cell is 5kg or a 5kg standard weight if the load cell is 50kg. With a sample size 20mm high, the return probe distance is calibrated such that the probe returns to a distance of 35 mm after zero calibration on contact with the platform.

After the analysis, the platform and probes are cleaned with a moist, soft cloth, to avoid staining the platform and the probes.

5 PRODUCT PREPARATION: BOILED PLANTAIN

5.1 Step 1: Fruit selection and Peeling

- Plantain bunches of the various clones were harvested at their optimum physiological maturity (appearance of a ripe fruit on the first or second hand), and fruits at the unripe (green) maturity stage were used.
- Remove the banana clusters from the peduncle, separate the fruits and select fruits from the 2nd and 3rd hands with similar grades (fruit grade >3.5cm). In case of fruit shortage from these hands, fruits can be taken from other hands provided they present similar grades (Figure 1).
- Remove the peel by first cutting along the length of the fruit from the upper tip to the lower end using a sharp knife, and remove the peel with fingers (Figure 2). This operation is done carefully to minimize pulp losses
- Weigh the pulps and briefly soak them in water to minimize browning (Figures 3 and 4).

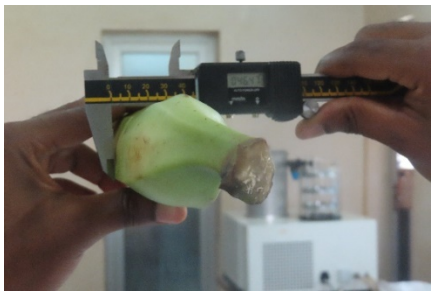


Figure 1. Measuring the fruit grade with callipers

Figure 2. Careful removal of the peel

Figure 3. Weighing of plantain pulps

Figure 4. Soaking of plantain pulps in water

5.2 Step 2: Plantain pulps boiling

- In aluminium pots, boil a quantity of water equivalent to 4 times the initial mass of the pulps previously soaked.
- Once the water is boiling, introduce the pulps and allow to boil for 45 minutes.
- When cooking is done, remove the pulps and drain in a strainer.

NB. *This SOP is written based on using hybrids for which a cooking time of 45 minutes is used. It is recommended to boil landraces at a cooking time of 60 minutes.*

5.3 Step 3. Sample preparation

- The temperature of the drained pulps is recorded after cooking, and the pulps are kept in a thermos box to reduce temperature (from 97°C to 60°C, after 15 minutes of storage) and moisture loss before texture analysis.
- A boiled pulp is removed, put in a tray and cut in the middle section using a double-blade knife (Figure 5).
- A hollow cylindrical rod (2.9 cm wide) is then forced through the cut portion and the extruded pulp is placed on the plate of the texture analyzer for TPA measurements (Figures 6 and 7)
- For penetrometry, the pulp is simply cut (2cm long) with the dorsal side facing the conical probe.

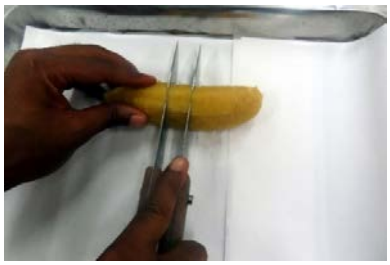


Figure 5. Cutting of the pulp with a double-blades knife

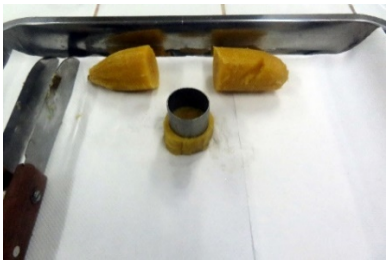


Figure 6. Forcing the hollow rod through the cut portion

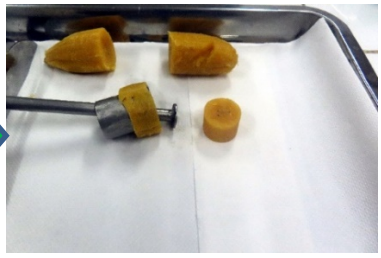


Figure 7. Sample extrusion with a plunger

Important to note:

- The temperature of the water inside the thermos flask should never be below 85°C. Change the water as soon as its temperature is below that threshold;
- Perform sample preparation quickly to minimize cooling such that the temperature of the sample to be tested should be the same as that of samples to be used for sensory analyses (between 55°C and 60°C);
- The same preparation method is used for sensory analysis.

6 TEXTURE MEASUREMENT

Equipment: TA-XTplusC Texture Analyser, Serial Number: 2-P6-Z10657-01-V0039F99B

Method: (i) **TPA:** Double compression

(ii) Penetrometry: Puncture test

Table 1. Texture measurement parameter settings

Parameters	TPA	Penetrometry
Load cell capacity	50kg	
Probe	35mm Diameter Cylinder Probe (P/35)	40º Conical Perspex probe (P/40C)
Pre-test speed	5 mm/s	5 mm/s
Test speed	1 mm/s	1 mm/s
Post-test speed	5 mm/s	5 mm/s
Strain/Distance	30%	10 mm into the sample
Time	5s	not applicable
Trigger force	250g	25g
Temperature at measurement	55 - 60 ºC	55 - 60 ºC

- The texture analyser was switched on using the main switch located at the rear end and the PC was turned on.
- TPA or penetrometry test settings were selected from the library and a project folder was created to recover analysis data.
- The force and probe height were calibrated following the instructions in the operating manual (as described above).
- For TPA, a cylinder of uniform dimension (diameter = 2.9cm, height = 2cm) was placed at the centre of the instrument platform at a temperature range of 55 and 60°C.
- For penetrometry, the pulp (2cm long) is directly placed on the platform
- The analysis was initiated by clicking on the “Run” button on the instrument software.

Figure 8. Sample placement for TPA

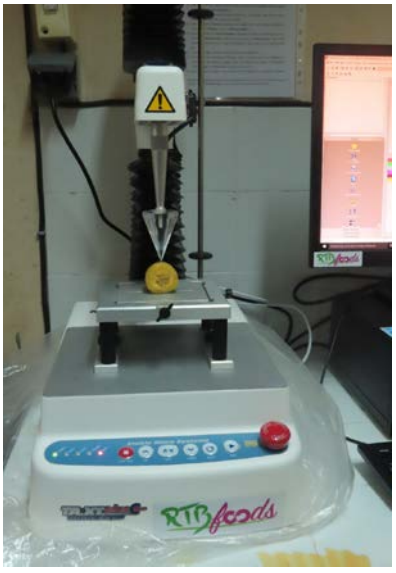


Figure 9. Sample placement for penetrometry

7 EXPRESSION OF RESULTS

Figure 10 is a schematic diagram explaining a TPA profile. A TPA test generally follows a standard sequence.

- ✓ **1st compression:** the probe descends onto the sample, once contact is made, measurement begins and the probe descends at a defined speed, for a set distance or a set strain.
- ✓ **1st withdrawal:** Once the target distance/strain is reached, the probe ascends away from the sample at a typically faster speed for a set distance or a set time.
- ✓ **Wait:** The sample is allowed to recover before the process is repeated.
- ✓ **2nd compression and 2nd withdrawal:** After the waiting time, the second cycle of compression and withdrawal occurs.

Concerning penetrometry, Figure 11 is a representation of the puncture test profile, with parameters such as hardness (F_{max}, maximum force at the peak (unit N, or g)), distance at F_{max} (mm), and area under the curve (shaded in red, units g.mm or g.s, N.mm or N.s)

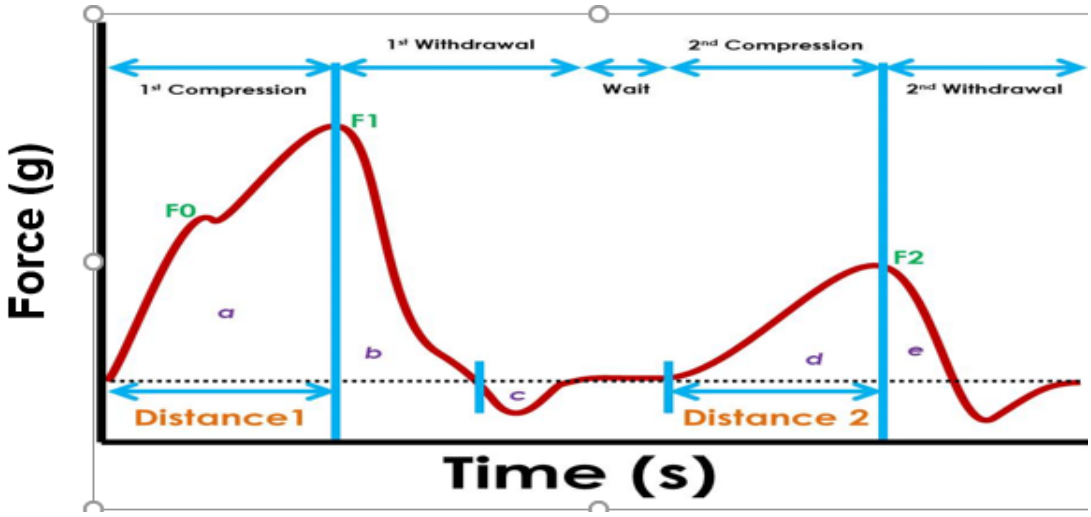


Figure 10. A graph showing the calculation parameters for TPA

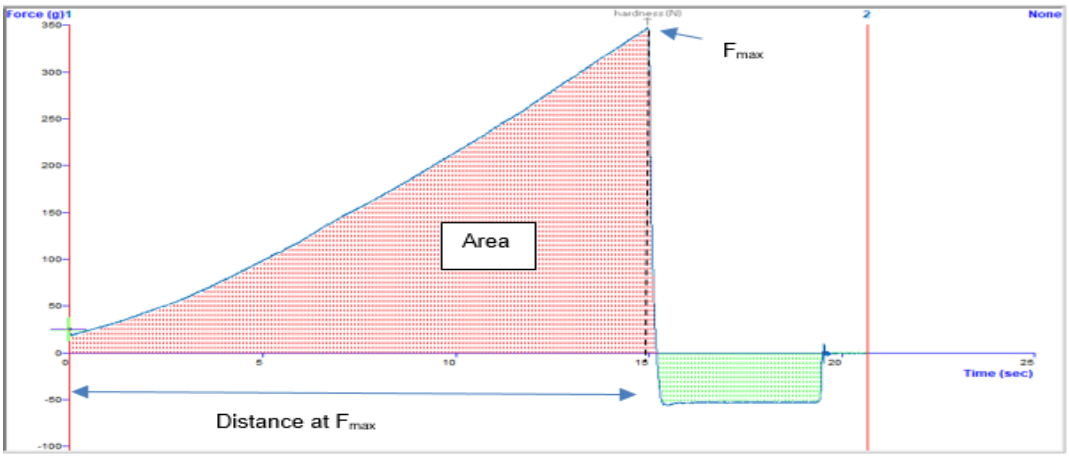


Figure 11. A graph showing the calculation of parameters for penetrometry

7.1 Summary of parameters from texture profile analysis and penetrometry

- **Hardness (g):** The highest peak force measured during the first compression **(F1)**.
- **Adhesiveness (g·s):** The area covered by the first negative peak **(c)**.
- **Cohesiveness (-):** The area underneath the second compression curve divided by the area underneath the first compression curve [**(d+e)/(a+b)**].
- **Springiness (%):** A ratio or percentage of a product's recovery to its original height [**(Distance 2)/(Distance 1)]*100** or **(Time 2/Time 1)*100**.
- **Gumminess (g):** Hardness x Cohesiveness **F1*[(d+e)/(a+b)]**.
- **Chewiness (g):** Hardness x Cohesiveness x Springiness **F1*(Distance 2/Distance 1)*[(d+e)/(a+b)]**.
- **Resilience:** The area under curve after peak force is reached, divided by the area under curve before peak force is reached **(b/a)**.

8 CRITICAL POINTS OR NOTES ON THE PROCEDURE

- Each sample will undergo 2 cooking replicates with at least 8 readings per replicate, to give an estimate of the true value.
- Bringing the probe into contact with the sample surface is a critical step and should be carefully carried out.
- The probe should slightly be above the sample before pressing the 'run' button to start the measurement
- The 5kg load cell is recommended only for penetrometry tests

9 APPENDICES

9.1 Example of data on Instrumental Textural Profile Analysis (TPA) and Penetrometry of Boiled Plantain

Table 2. Characteristics of clones analysed

Name	Type
CARBAP K74	hybrid
PITA 14	hybrid
PITA 21	hybrid
PITA 23	hybrid

Table 3. Statistical accuracy of textural attributes measured by TPA compression method

	Genotype	N	Mean	Std Dev	Std Err	CV
Hardness (g)	CARBAP K74	23	7635.4	1567.2	326.8	21
	PITA 14	25	3356.0	452.5	90.5	13
	PITA 21	27	2929.3	737.7	142.0	25
	PITA 23	21	5992.8	590.4	128.8	10
Resilience (%)	CARBAP K74	23	109.0	18.3	3.8	17
	PITA 14	23	151.1	22.5	4.7	15
	PITA 21	21	212.4	52.8	11.5	25
	PITA 23	21	112.8	19.8	4.3	18
Springiness (%)	CARBAP K74	23	102.0	14.8	3.1	15
	PITA 14	23	86.4	8.6	1.8	10
	PITA 21	21	89.7	11.2	2.4	12
	PITA 23	20	62.2	9.8	2.2	16
Adhesiveness (g.s)	CARBAP K74	23	-132.5	81.3	17.0	-61
	PITA 14	20	-393.6	234.0	52.3	-59
	PITA 21	19	-376.9	249.9	57.3	-66
	PITA 23	20	-1051.4	544.9	121.9	-52
Cohesiveness	CARBAP K74	23	0.2	0.0	0.0	20
	PITA 14	13	0.1	0.0	0.0	23
	PITA 21	7	0.1	0.0	0.0	14
	PITA 23	18	0.1	0.0	0.0	29
Gumminess	CARBAP K74	23	1226.7	442.2	92.2	36
	PITA 14	13	320.4	68.3	19.0	21
	PITA 21	7	300.1	98.8	37.3	33
	PITA 23	18	543.4	179.5	42.3	33
Chewiness	CARBAP K74	23	1235.8	430.3	89.7	35
	PITA 14	13	264.2	62.8	17.4	24
	PITA 21	7	244.0	67.7	25.6	28
	PITA 23	18	337.6	138.5	32.6	41

Table 4. Statistical accuracy of textural attributes measured by penetrometry method

	Genotype	N	Mean	Std Dev	Std Err	CV
hardness (g)	CARBAP K74	5	422.30	50.44	22.56	12
	PITA 14	35	58.50	15.40	2.60	26
	PITA 21	28	49.39	13.42	2.54	27
	PITA 23	17	84.00	29.12	7.06	35
Distance at F max (mm)	CARBAP K74	5	4.31	0.93	0.42	22
	PITA 14	35	6.62	1.87	0.32	28
	PITA 21	27	7.69	1.75	0.34	23
	PITA 23	17	5.53	0.83	0.20	15
Area under curve (g.s)	CARBAP K74	5	4598.42	519.74	232.43	11
	PITA 14	35	384.71	112.46	19.01	29
	PITA 21	28	281.44	73.15	13.82	26
	PITA 23	17	560.66	174.85	42.41	31
Area under curve (g.mm)	CARBAP K74	5	10061.08	1403.22	627.54	14
	PITA 14	35	1060.56	306.47	51.80	29
	PITA 21	28	763.57	198.28	37.47	26
	PITA 23	17	1561.08	491.93	119.31	32

Outliers were not removed. Outliers can be removed statistically

i. Examplary ANOVA and repeatability of instrumental textural attributes

❖ **TPA compression method**

HARDNESS BY Genotype

Oneway Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Genotype	3	361253792	120417931	138.3612	5.57e-34
Error	92	80069037	870315.62		
C. Total	95	441322828			

Connecting Letters Report

Level				Mean
CARBAP K74	A			7635.3519
PITA 23		B		5992.7968
PITA 14			C	3355.9688
PITA 21			C	2929.3489

Levels not connected by same letter are significantly different.

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
CARBAP K74	PITA 21	4706.003	264.7144	4013.35	5398.659	<.0001*
CARBAP K74	PITA 14	4279.383	269.5412	3574.10	4984.669	<.0001*
PITA 23	PITA 21	3063.448	271.4360	2353.20	3773.692	<.0001*
PITA 23	PITA 14	2636.828	276.1453	1914.26	3359.395	<.0001*
CARBAP K74	PITA 23	1642.555	281.5731	905.79	2379.324	<.0001*
PITA 14	PITA 21	426.620	258.9335	-250.91	1104.150	0.3574

HARDNESS BY Cooking replicate

Oneway Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob >
Cooking replicate	1	2203716	2203716	0.4717	4.939e-
Error	94	439119112	4671480		
C. Total	95	441322828			

Connecting Letters Report

Level		Mean
2	A	4977.4262
1	A	4673.3479

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
2	1	304.0783	442.7258	-574.964	1183.121	0.4939

❖ Penetrometry

HARDNESS BY Genotype

Oneway Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Genotype	3	628206.13	209402	462.5200	7.63e-51
Error	81	36672.07	453		
C. Total	84	664878.20			

Connecting Letters Report

Level				Mean
CARBAP K74	A			422.30420
PITA 23		B		83.99900
PITA 14			C	58.49880
PITA 21			C	49.39154

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
CARBAP K74	PITA 21	372.9127	10.33042	345.814	400.0112	<.0001*
CARBAP K74	PITA 14	363.8054	10.17270	337.121	390.4902	<.0001*
CARBAP K74	PITA 23	338.3052	10.82498	309.909	366.7010	<.0001*
PITA 23	PITA 21	34.6075	6.54226	17.446	51.7690	<.0001*
PITA 23	PITA 14	25.5002	6.29026	9.000	42.0007	0.0007*
PITA 14	PITA 21	9.1073	5.39489	-5.044	23.2590	0.3366

HARDNESS BY Cooking replicate

Oneway Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Replicate	1	4275.80	4275.80	0.5372	4.657e-1
Error	83	660602.40	7959.07		
C. Total	84	664878.20			

Connecting Letters Report

Level		Mean
2	A	89.521850
1	A	75.312244

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
2	1	14.20961	19.38672	-24.3498	52.76901	0.4657

The TPA and penetration tests produced accurate measurements. TPA and penetration attributes were generally repeatable. Both methods showed that the genotype were very significantly different from one another by one way ANOVA. Both methods were discriminating for the textural attributes, but penetrometry seem to be more discriminant than TPA. For TPA, hardness, springiness, resilience and chewiness were the most discriminatory attributes. For penetration, hardness and area under curve were the most discriminatory attributes.

ii. Discriminance between genotypes based on instrumental textural profile

PCA

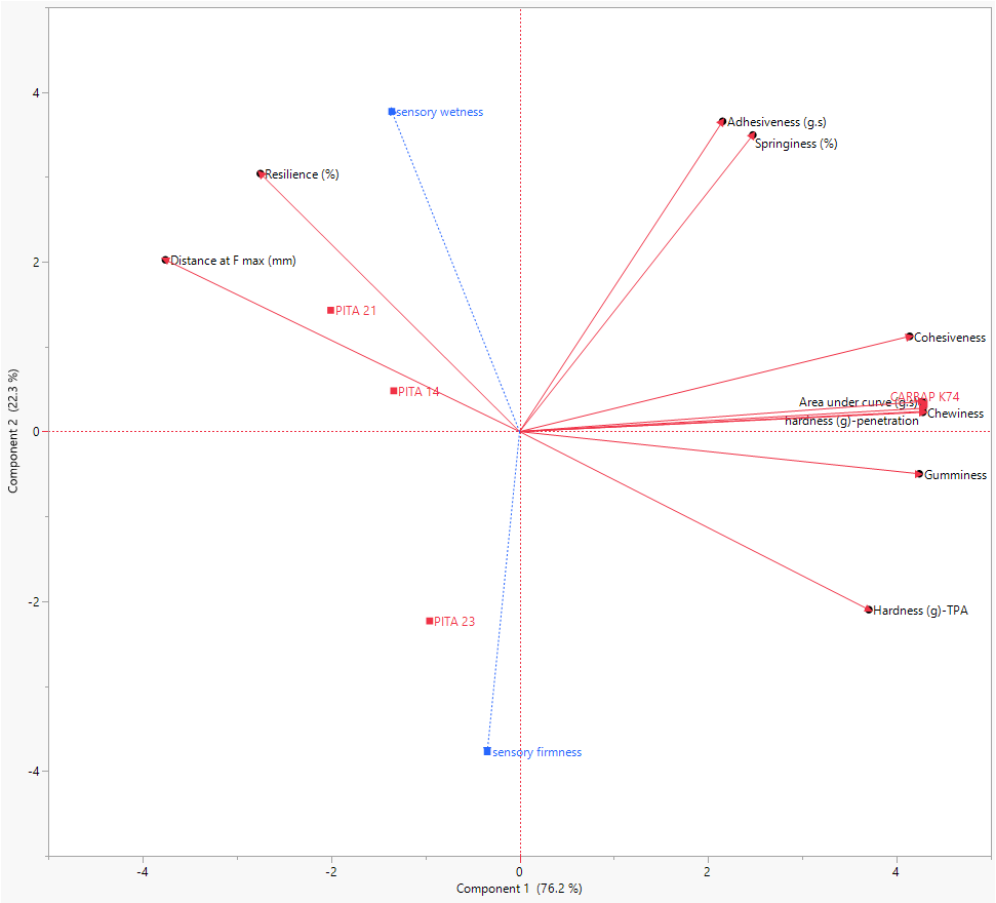
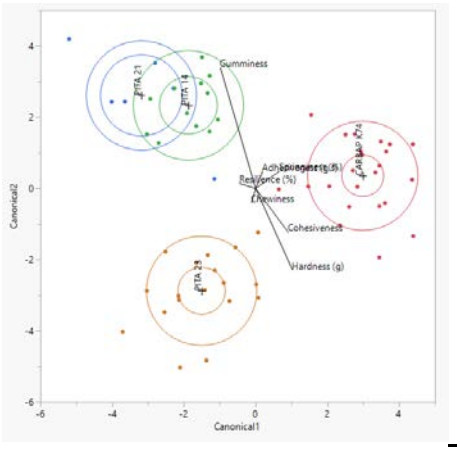


Figure 12. PCA of instrumental + sensory texture of boiled plantain genotypes

By combining both TPA and penetration and sensory texture, the genotypes PITA 14 and PITA 21 are closely related hybrids, and associated with resilience and sensory wetness. Wetness refers to the mouthfeel of moist texture rather than dryness, and influences how chewy the boiled plantain is. The genotype CARBAP K74 is a hybrid associated with cohesive, chewy, hard and gummy texture that is not wet, and is uniquely clustered separate from other genotypes. PITA 23 is associated with sensory firmness. There is a good relationship between hardness TPA and Distance at F_{max}.

Discriminant



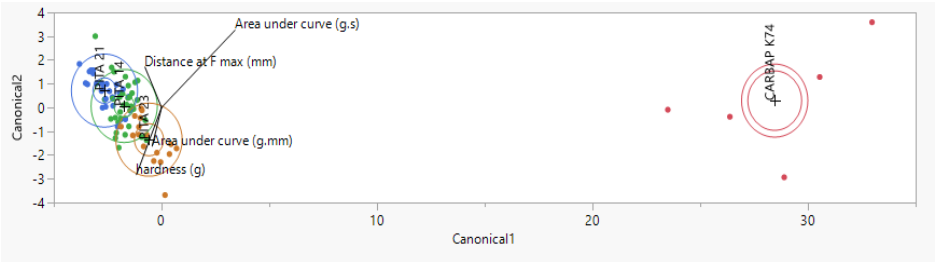


Figure 13. Discriminant for TPA compression

Figure 14. Discriminant for Penetrometry test

Both methods were discriminating between the genotypes, but the genotypes seem to be more discriminated by penetration protocol than the TPA method. For TPA, hardness, springiness, resilience and chewiness were the most discriminatory attributes, For penetration, hardness and area under curve were the most discriminatory attributes. CARBAP K74 is the most discriminant genotype from the other genotypes.

Table 5. Correlation coefficients and probabilities of combined TPA and penetrometry textural attributes

	coefficient												
	Hardness (g)-TPA	Resilience (%)	Springiness (%)	Adhesiveness (g.s)	Cohesiveness	Gumminess	Chewiness	hardness (g)-penetration	Distance at F max (mm)	Area under curve (g.s)	Area under curve (g.mm)	sensory firmness	sensory wetness
Hardness (g)-TPA	1.0000												
Resilience (%)	-0.8609	1.0000											
Springiness (%)	0.0903	0.1867	1.0000										
Adhesiveness (g.s)	-0.0029	0.2370	0.9932	1.0000									
Cohesiveness	0.6970	-0.4478	0.7721	0.7142	1.0000								
Gumminess	0.9224	-0.6832	0.4675	0.3807	0.9159	1.0000							
Chewiness	0.8424	-0.5813	0.6128	0.5350	0.9707	0.9849	1.0000						
hardness (g)-penetration	0.8408	-0.5809	0.6152	0.5378	0.9717	0.9843	1.0000	1.0000					
Distance at F max (mm)	-0.9719	0.9267	-0.1280	-0.0537	-0.7258	-0.9075	-0.8400	-0.8394	1.0000				
Area under curve (g.s)	0.8255	-0.5628	0.6367	0.5609	0.9776	0.9790	0.9995	0.9996	-0.8261	1.0000			
Area under curve (g.mm)	0.8354	-0.5775	0.6228	0.5464	0.9744	0.9824	0.9999	0.9999	-0.8363	0.9998	1.0000		
sensory firmness	0.3000	-0.7107	-0.7285	-0.7172	-0.2821	-0.0272	-0.1572	-0.1573	-0.3951	-0.1779	-0.1607	1.0000	
sensory wetness	-0.6562	0.9308	0.5085	0.5361	-0.0933	-0.3757	-0.2446	-0.2440	0.7294	-0.2222	-0.2396	-0.9153	1.0000
	probability												
Hardness (g)-TPA	<.0001												
Resilience (%)	0.1391	<.0001											
Springiness (%)	0.9097	0.8133	<.0001										
Adhesiveness (g.s)	0.9971	0.7630	0.0068	<.0001									
Cohesiveness	0.3030	0.5522	0.2279	0.2858	<.0001								
Gumminess	0.0776	0.3168	0.5325	0.6193	0.0841	<.0001							
Chewiness	0.1576	0.4187	0.3872	0.4650	0.0293	0.0151	<.0001						
hardness (g)-penetration	0.1592	0.4191	0.3848	0.4622	0.0283	0.0157	<.0001	<.0001					
Distance at F max (mm)	0.0281	0.0733	0.8720	0.9463	0.2742	0.0925	0.1600	0.1606	<.0001				
Area under curve (g.s)	0.1745	0.4372	0.3633	0.4391	0.0224	0.0210	0.0005	0.0004	0.1739	<.0001			
Area under curve (g.mm)	0.1646	0.4225	0.3772	0.4536	0.0256	0.0176	0.0001	<.0001	0.1637	0.0002	<.0001		
sensory firmness	0.7000	0.2893	0.2715	0.2828	0.7179	0.9728	0.8428	0.8427	0.6049	0.8221	0.8393	<.0001	
sensory wetness	0.3438	0.0692	0.4915	0.4639	0.9067	0.6243	0.7554	0.7560	0.2706	0.7778	0.7604	0.0847	<.0001

Significant correlations at 5 % level are highlighted

There were no significant correlations between TPA or penetrometry attributes and sensory texture of boiled plantain. More genotypes should be analysed to derive significant relationships between instrumental and sensory texture.

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