Standard Operating Procedure for Instrumental Textural Characterization of Fried Plantain (Aloco)

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

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ABSTRACT

Plantain is one of the most consumed foods for many people in Africa. As in the fried form also called ***aloco***, it is one of the main ways in which bananas are eaten in Côte d'Ivoire. In this procedure, textural measurements were carried out on fried plantain product in order to develop a standard operating procedure (SOP). This SOP would make it possible to objectively and physically measure the texture of aloco in the laboratory, and use as a tool to discriminate banana genotypes for the purpose of screening populations for advanced breeding.

The SOP describes the procedure for preparing aloco, the required equipment and related accessories, the conditions set for measurement of texture, and the data collection and analysis.

Thirteen (13) cooking banana genotypes (including plantains and banana hybrids) were harvested at the green stage of commercial maturity. Fruits were treated with ethylene gas in order to accelerate the ripening process. The ripening was done at room temperature until they reached the appropriate ripening stage, namely J4 (4 days after ripening induction). The fresh banana pulps were cut in standardized slices before frying at constant temperature of 150°C for 10 min. Puncture (penetration) and double compression TPA tests were conducted on aloco to measure the texture attributes using TA-XTPlusC texture analyser.

Overall, a good repeatability of the puncture and TPA tests was observed with banana genotypes tested at stage J4 at sample temperature of 30°C. ANOVA showed a significant effect of genotype on the puncture and TPA parameters of the aloco. Moreover, it is possible to cluster the genotypes based on their puncture and TPA texture parameters using principal components (PCA). Our data show that the two methods can be used to discriminate the textural properties of aloco prepared from different plantain genotypes. However, we recommend the puncture method for aloco analysis because of its better accuracy, discrimination and repeatability.

Key Words: SOP, aloco, texture profile analysis, puncture, ripening, Musa, hybrid, bananas

1 SCOPE OF THE STUDY

This SOP describes the sample preparation procedure of aloco for textural measurement, texture analyser settings, a methodology for instrumental texture analysis of aloco, and data analysis.

1.1 References

Ebah-Djedji, B. C., Koffi, L. B., Goran-Haddad, P. N., Koné, K., Kouassi, K. S., Traoré, S., & Kouakou, A. (2021). Ability to produce alloco (fried plantain) from some plantain (Musa paradisiaca L. 1753) hybrids. *American Journal of Innovative Research and Applied Sciences*, *13*(4), 488–495.

Kouassi, H. A., Beugre, T. A., Yapi, E. Y., N'goran, P., Deffan, P. K., Diby, Sylvie, N. A., Adiko, C. E. J. R., Forestier-Chiron, N., Bugaud, C., Ebah-Djedji, C. B., & Mbéguié-A-Mbéguié, D. (2022). Sensory Evaluation of Fried Plantain (Aloco). *Agritrop*, *February*, 1–20. https://doi.org/https://doi.org/10.18167/agritrop/00709

2 PREREQUISITE

Setting up and managing a TA-XTPlusC Texture Analyser for textural measurements.

Familiarity with the process of producing aloco.

3 GENERALITY ON ALOCO AND TEXTURE

In Côte d'Ivoire, aloco is obtained after frying the pulp of ripe plantain. The textural quality is one of the major criteria for the acceptability and adoption of this product. In addition, genotype and ripening stage of banana are extremely important criteria which influence aloco textural characteristics. It was therefore essential to develop an objective, mid-throughput instrumental methodology to assess the textural attributes of fried plantain from different genotypes.

4 ALOCO PREPARATION

4.1 Raw material and sampling

Thirteen (13) cooking banana genotypes (*Afoto clair, Afoto sombre, Agnrin, Ameletia, Big ebanga, Corne 1, Corne tacheté, French sombre, N'zoulé, Orishele, Pita 3, Saci and Zakoi*) were used in this study. They were selected because they are contrasted in regard to their physicochemical, organoleptic and technological properties (Ebah-Djedji et al., 2021; Kouassi et al., 2022).

For this study, banana fruits were harvested at mature green stage, treated with ethephon (an ethylene analog) and kept to ripen at room temperature until used for aloco preparation. Fruits selected at the yellow stage, corresponding to four days after ethylene treatment were considered the best samples for textural measurements based on preliminary experiments.

4.2 Preparation of Aloco

Aloco was prepared as described by Kouassi et al. (2022), from standardized slices of fresh banana pulp. The slices of approximately 20 mm in height were obtained using a vegetable cutter (

Figure 1 and

Figure 2**)**.

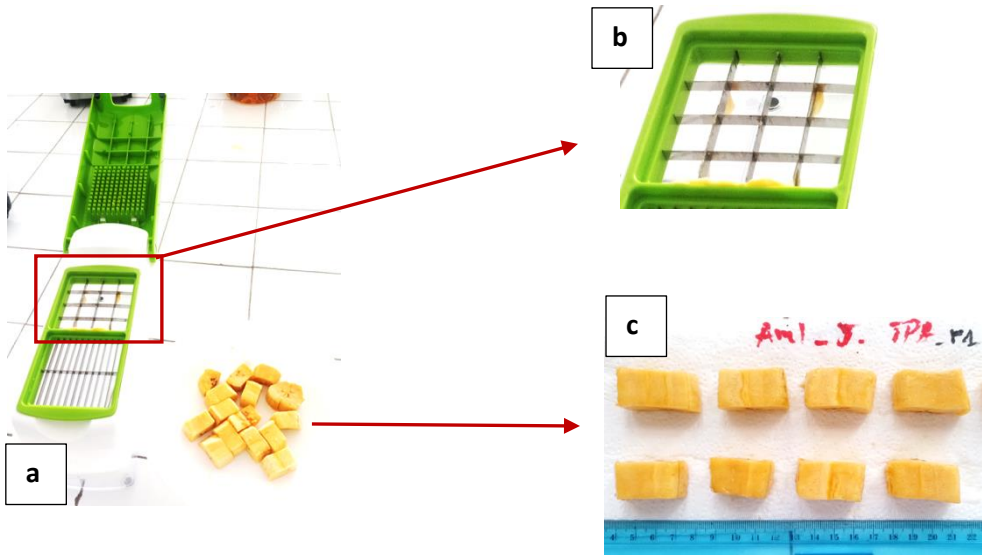

Figure 1: Standardization of slices of fresh banana pulp.

a: vegetable cutter and slices of banana pulp
b: Piece of vegetable cutter blade of ≈20 mm grid
c: Sections of ≈ 20 mm of raw pulp from Ameletia variety

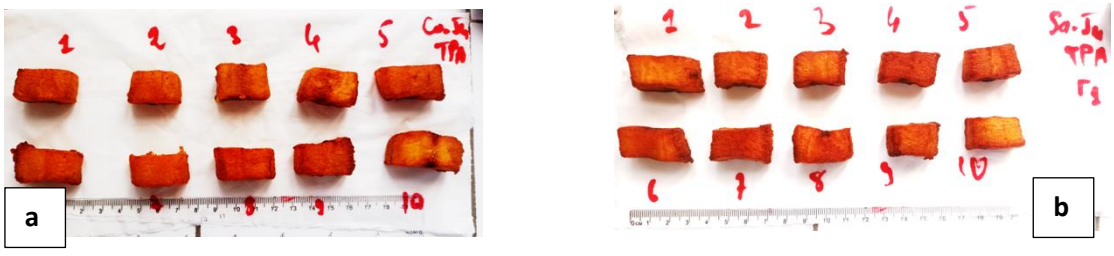

Figure 2: Examples of slices of aloco from Corne 1 (a) and Saci (b) varieties.

5 TEXTURE MEASUREMENTS

5.1 General conditions of the texture measurement of Aloco

The texture of aloco was measured by puncture and by double-compression tests. Measurements were performed on aloco slices individually. For each type of test, texture measurements were performed on at least 8 aloco slices per replicate.

5.2 Apparatus

The textural measurement was performed using a TA-XTPlusC Texture Analyser apparatus (Stable Micro Systems, Ltd., Swantech International SARL, Gennevilliers, France) previously calibrated against the 5kg load cell, at 5g trigger force and distance.

5.3 Temperature control of Aloco slices

The banana slices were fried in a deep fryer at 150°C and the temperature of each slice of aloco was monitored with an infrared thermometer (**Figure 3**) before analysis. The acquisition of texture parameters (puncture test and TPA) was carried out at 30°C.

Figure 3: Checking of aloco slice temperature.

5.4 Puncture test setting

For puncture test of aloco, a 5 mm diameter cylindrical metal probe (surface area ~20 mm^2) penetrated the aloco slice at a constant speed (1 $mm.s^{-1}$) to a depth of 10 mm. The puncture test settings are recorded in **Table 1**. Figure 4 shows the assembly made for the measurement of texture parameters of the aloco slice, while Figure 5 shows a slice of aloco before (a) and after (b) the test.

Table 1: Puncture test settings.

Load cell type	Calibration
Load cell	5 kg
Probe	P/5 (5 mm diameter cylindrical stainless steel (surface area ~20 mm^2)
Test mode	Compression
Pre-test speed	5 $mm.s^{-1}$
Puncture speed	1 $mm.s^{-1}$
Post-test speed	10 $mm.s^{-1}$
Trigger force	0,049 N (5 g)
Puncture depth	10 mm

Figure 4: Measurement of texture of aloco slice by puncture test.

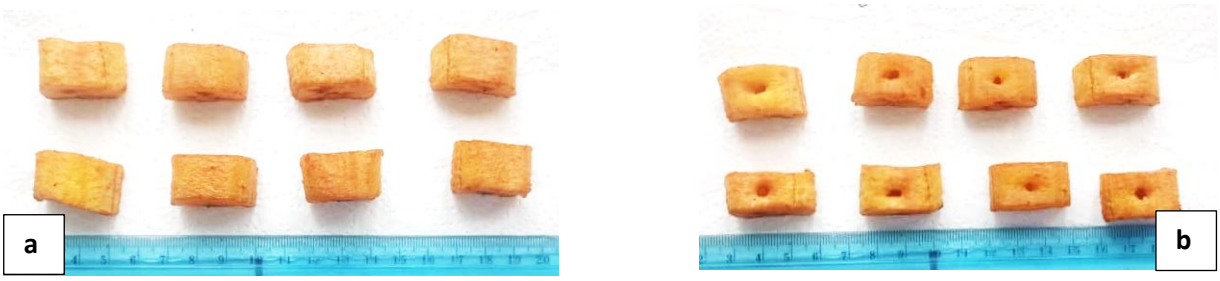

Figure 5: Aloco slices before (a) and after (b) puncture test.

5.5 TPA test settings

Double compression cycle corresponding to 30% strain of sample size was carried out using a cylindrical probe of 50 mm diameter, at a constant speed of 1 $mm.s^{-1}$. All the TPA settings, including sensitivity (trigger force) of the texturometer are described in

Table 2.

Table 2: TPA settings.

Parameters	Calibration
Load cell	5 kg
Probe	P/50 (50 mm diameter cylinder aluminium)
Pré-test speed	10 $mm.s^{-1}$
Test speed	1 $mm.s^{-1}$
Post-test speed	10 $mm.s^{-1}$
Strain	30 %
Time (between cycles)	10 s
Trigger force	0,049 N (5 g)

Figure 6: Measurement of texture of aloco slice by TPA.

6 EXPRESSION OF RESULTS

6.1 Puncture data

An example of a force-time curve of aloco is shown in the **Figure 7**. The curve may also be expressed as a force-distance profile. The maximum force applied during the measurement and other parameters are recorded (**Table 3**). The extraction of quantitative data was carried out from the force/time curve using a macro.

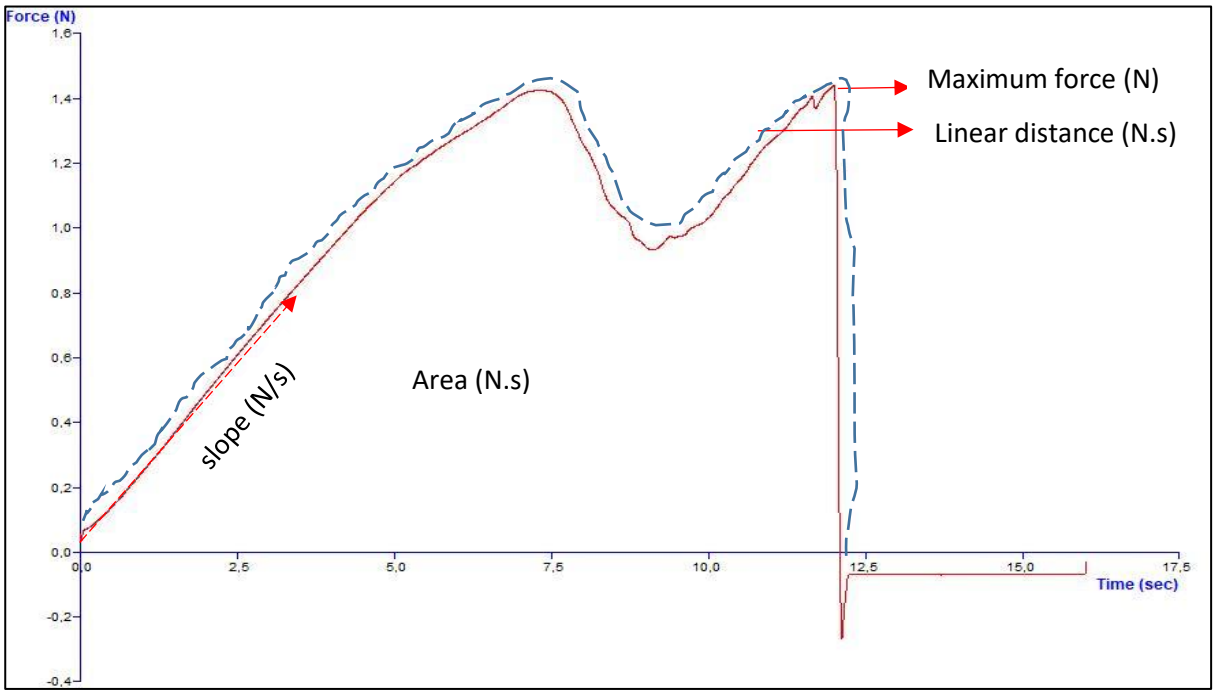

Figure 7: An example of force-time curve of aloco for the puncture test (Corne 1 variety taken at day 4, yellow ripe stage).

Table 3: Puncture test parameters.

Puncture test parameters (unit)	Definition
Maximum force (N)	Maximum puncture force of aloco
Area (N.s)	Area under the force/time curve
Mean force (N)	Average puncture force of aloco
Perimeter / linear distance (N.s)	Length of force/time curve
Slope (N/s)	Slope of the force/time curve

6.2 TPA data

Texture profile of aloco (force-time curves) were recorded by the Exponent Connect software of the instrument integrated with the texture analyzer (**Figure 8**). The extraction of quantitative data was carried out from the force/time curve using macro. Then, TPA parameters were determined (**Table 4**).

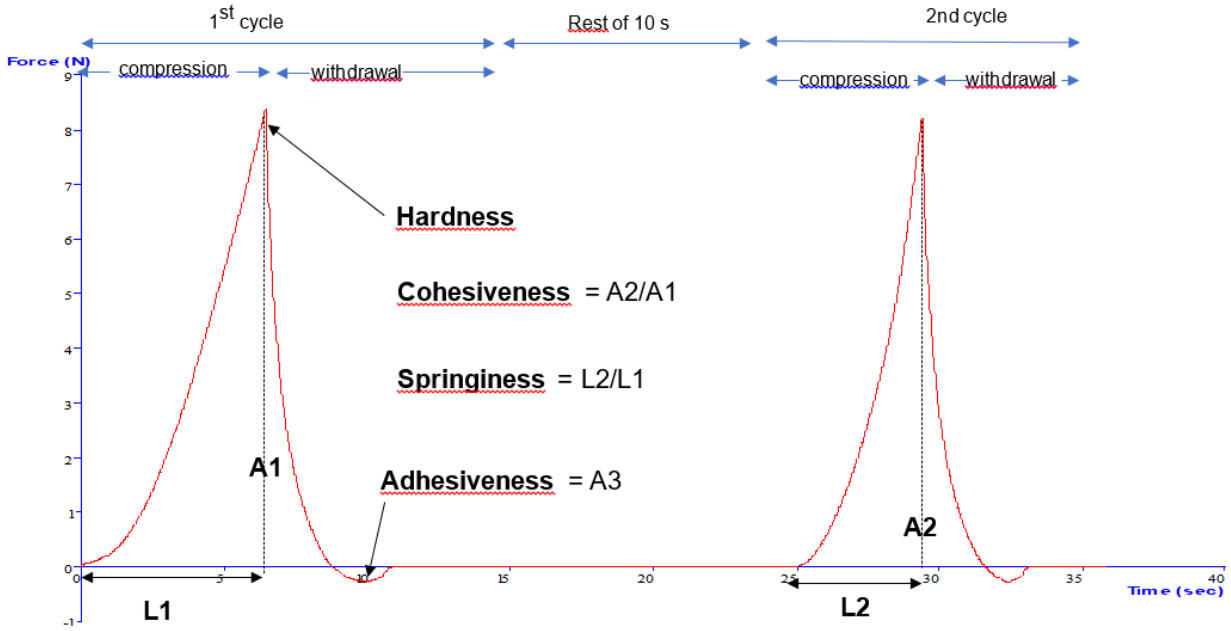

Figure 8: An example of force-time curve of aloco for the TPA test (Corne 1 variety taken at day 4, yellow stage).

Table 4: TPA parameters (per unit area) of Aloco.

TPA Parameters (unit)	Definition
Hardness (N.mm^{-2})	Positive peak force during the first bite divided by the surface area of the Aloco slice
Cohesiveness (% or no unit)	Ratio of the area under the second bite cycle to the area under the first bite cycle
Springiness (% or no unit)	Ratio of the distance travelled during the second descent to the distance travelled during the first descent of the probe
Adhesiveness (N.s.mm^{-2})	Negative area (divided by the surface area of the aloco slice). Absolute values
Resilience (% or no unit)	Ratio of positive area under first withdrawal cycle to the first compression cycle
Gumminess (N.mm^{-2})	Product of hardness and cohesiveness
Chewiness (N.mm^{-2})	Product of gumminess and springiness

6.3 Calculation of surface of Aloco slice

Given that the instrumental texture parameters take into account the real surface area of the sample, the surface of aloco slices were first photographed and the area was estimated using *ImageJ* software version 1.52k (NIH, USA).

6.4 Repeatability

About 4-11 measurements were considered per genotype per replicate run. A variation coefficient of maximum of 30 % is admitted between 2 replicates. Differences among genotypes are significant at $P<0.05$, and repeatability of replicate runs at $P>0.05$.

7 CRITICAL POINTS OR NOTE ON THE PROCEDURE

- Make sure that texture analyzer is switched on at least 15 min before calibration and measurements
- The height of sample should be similar for each test
- Instrumental parameters of TPA must consider the actual surface of the sample
- Samples must be at the same temperature before measurement
- It must be ensured that aloco does not stick to the base of the fryer, and frying is done in excess oil.

8 TEST REPORT

8.1 Descriptive analysis of puncture test

Table 5: Descriptives statistics (Qualitative data).

Variable\Statistique	Nb. of observation	Nb. of modality	Modality	Effectif by modality	Frequency by modality (%)	P value
Genotype	328	10	Afoto clair	17,00	5,18	<0.001
			Afoto sombre	19,00	5,79	
			Agnrin	43,00	13,11	
			Big ebanga	69,00	21,04	
			Corne 1	24,00	7,32	
			Corne tacheté	33,00	10,06	
			French sombre	20,00	6,10	
			Orishele	24,00	7,32	
			Pita 3	35,00	10,67	
			Saci	44,00	13,41	
Type	328	4	F/FC *	44,00	13,41	
			corne	186,00	56,71	
			french	63,00	19,21	
			hybrid	35,00	10,67	

** F/FC: intermediate between French and False horn*

8.2 Principal component analysis (PCA) of aloco after puncture test

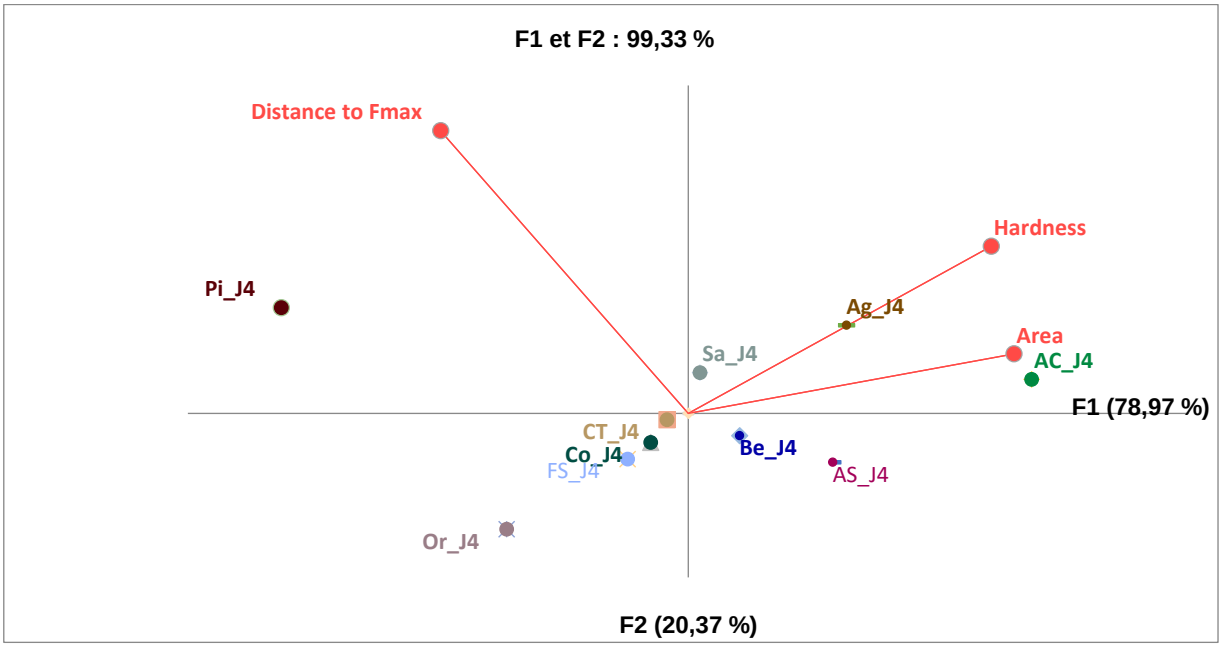

Figure 9: Principal component analyse (PCA) of aloco after puncture test.

***10 Genotypes: AC**: Afoto clair; **AS**: Afoto sombre; **Ag**: Agnrin; **Be**: Big ebanga; **Co**: Corne 1; **CT**: Corne tacheté; **FS**: French sombre ; **Or**: Orishele ; **Pi**: Pita 3; **Sa**: Saci. **Ripening stage**: yellow stage (J4). **Temperature of aloco**: 30°C.*

The PC 1 and 2 accounts for 99.3% of the variation in puncture test data. The genotypes Saci, Agnrin, and Afoto clair were clustered in a component associated with hardness and area (work done to puncture), while Pita was associated with distance to max force. Orishele, French sombre, Corne 1 and Corne tachete situated in component opposite hardness signify softness.

8.3 Descriptive analysis of TPA

Table 6: Descriptives statistics (Qualitative data)

Variable\Statistique	Nb. of observations	Nb. of modality	Modality	Effectif by modality	Frquency by modality (%)	P value
Genotype	241	11	Agnrin	9,000	3,734	<0.001
			Ameletia	13,000	5,394	
			Big ebanga	25,000	10,373	
			Corne 1	36,000	14,938	
			Corne tacheté	8,000	3,320	
			French sombre	16,000	6,639	
			N'zouele	20,000	8,299	
			Orishele	27,000	11,203	
			Pita 3	16,000	6,639	
			Saci	55,000	22,822	
			Zakoi	16,000	6,639	

8.4 Principal component analysis (PCA) of aloco after TPA

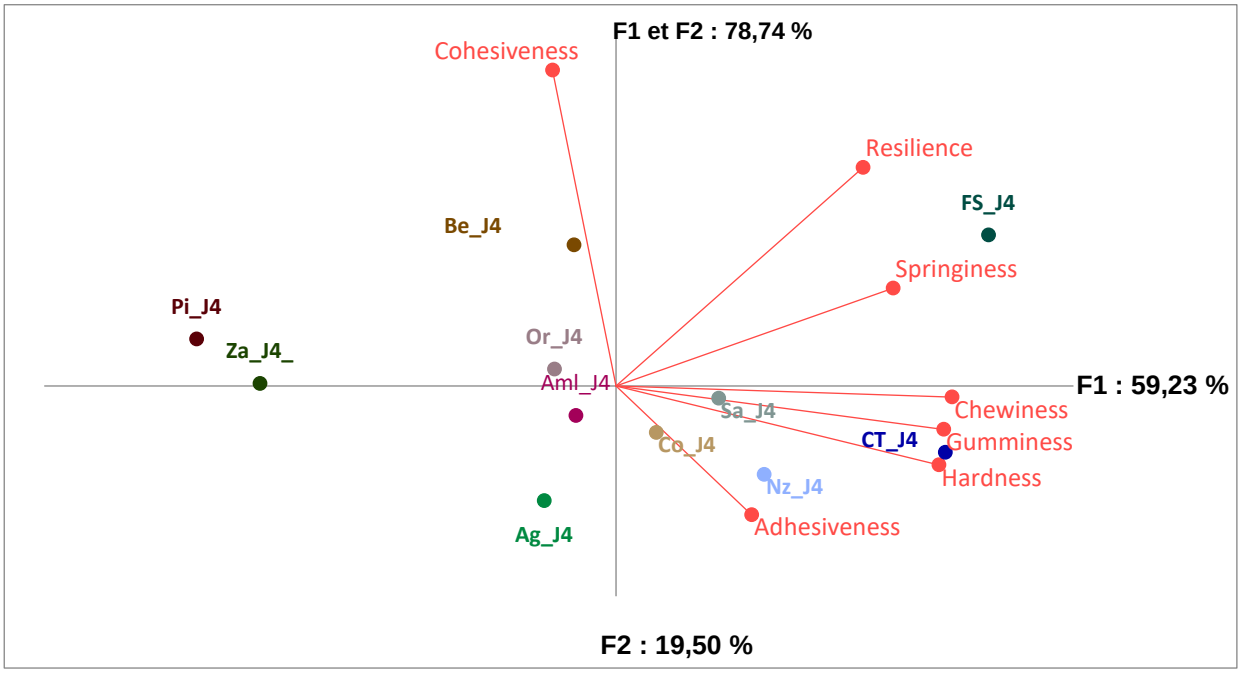

Figure 10: Principal component analyse (PCA) of aloco after TPA.

***11 Genotypes: Ag**: Agnrin ; **Aml**: Ameletia; **Be**: Big ebanga; **Co**: Corne 1; **CT**: Corne tacheté; **FS**: French sombre ; **Nz** : N'zouele; **Or**: Orishele ; **Pi**: Pita 3; **Sa**: Saci; **Za**: Zakoi. **Ripening stage**: yellow stage (J4). T**emperature of aloco**: 30°C.*

PC1 and 2 accounted for 78.4% of the variation in TPA data. The genotype French somber is springy and resilient. Saci, Corne 1, Corne tacheté, N'zouele are most associated with adhesive, hard and chewy texture. The other genotypes were associated mostly with cohesiveness.

The clustering of genotypes in puncture test was different from that of TPA. Principal component analysis (PCA) shows the distribution of the genotypes as a function of the instrumental texture parameters obtained by penetration test (**Figure 9**) and TPA (**Figure 10**). TPA and the penetration test can be used for varietal screening of the aloco because the PCA showed different cluster segregation among the genotypes. Moreover, based on data collected on both puncture and double compression methods, we recommend puncture method for the analysis of aloco due to better accuracy, discriminance among varieties and repeatability between replicate runs.