

# Standard Operating Procedure for Sample Preparation and the Measurement of Texture of Boiled Yam

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# RTBfoods / RTB Breeding



## SOP: Sample Preparation and the Measurement of Texture of Boiled Yam

**Date: 17/10/2024**

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# ABSTRACT

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Boiled yam preparation steps showed variations in the yam pieces size and the cooking procedure; this presumably affect the sensory descriptors and texture analyses of final product. In this context, a standard method for boiled yam preparation and texture analyses was established in previous SOP (<https://doi.org/10.18167/agritrop/00603>) which defined the optimum cooking time (OCT) for each variety and the ideal cooking time (ICT). In the current SOP, the texture analyses are consolidated for robustness. Accordingly, nine varieties were selected based on their contrasting quality characteristics. Yam tuber was cut into three equal sections: proximal, central and distal. After peeling and washing, each usable part (6/10 of length of tuber) is divided, depending on the length, into two semi-cylinder subsections. Cuboid pieces (25 mm x 25 mm x 30 mm) were obtained from the cylinders and were steam-cooked for 38 min (ICT), and then tested at 45 °C by uniaxial texture analysis (penetration and texture profile analysis (TPA) using conical probe P/40C and compression plate (P/75), respectively). Both methods discriminate among the yam genotypes. Validation parameters such as repeatability and reproducibility limits, and two-sample T-test were calculated, proving the robustness of these methods.

**Key Words:** Boiled yam, Repeatability, Penetration test, Texture profile analysis

# 1 SCOPE AND APPLICATION

## 1.1 References

This SOP aims to improve on the one previously developed (<https://doi.org/10.18167/agritrop/00603>) with few changes such as change in sample size and shape. It focuses on validation of penetrometry and TPA tests. Steam cooking is used to avoid disintegration of cooked yam as described in previous SOP (<https://doi.org/10.18167/agritrop/00603>).

## 1.2 Definitions

Yam tubers are cut to the required dimensions and peeled, and then steam-cooked for 38 minutes, before testing by penetration and TPA analyses. Discriminant test, conformity test of standard deviation, limits of repeatability and reproducibility are included. Texture parameters are defined below:

- Maximum Force (Hardness) for penetration test (N or g): Defined as the maximum force at max displacement of the probe in the steam-cooked yam piece as captured in Figure 7.
- Area (work done for penetration) (N.mm or g.mm or N.s or g.s): Defined as the full area under the curve, i.e. between 0 and 10 mm travel distance or 0 and 20 s travel time into the sample as captured in Figure 7. This area represents the work (energy) required to carry out the penetration test.
- As far as TPA is concerned, hardness or firmness is represented by the peak force of the first compression cycle (Figure 8).
- Springiness (% or dimensionless ratio): ability of the sample to return to its initial shape during the time between the 1<sup>st</sup> and 2<sup>nd</sup> compression. It is the ratio of distance (or time) covered for the second compression cycle and distance (or time) covered for the first compression cycle. (Figure 8).
- Adhesiveness (N.mm or g.mm or N.s or g.s): is the work required to be done to separate the sample from probe after compression in the first cycle. It is determined as the negative area under the curve after first compression and withdrawal.
- Cohesiveness (% or dimensionless ratio): is the ratio of total area under curve in second cycle of compression and withdrawal to the total area under curve in first cycle of compression and withdrawal. It can be measured by the level of resistance to disintegration of the product under stress. If the adhesiveness is low compared to the cohesiveness, then the measuring probe will retain no residue and the product will tend to remain compact (Figure 8).
- Gumminess (N): work required to chew the sample before swallowing. It is characteristic of semi-solid products with a low degree of firmness and a high degree of cohesiveness (Figure 8).  
Gumminess = hardness x cohesiveness
- Chewiness (N): work required to masticate the sample before swallowing. It is the product of gumminess and springiness.
- Resilience (dimensionless or %): is the ability of the sample to return to its original geometry after deformation by compression. It is determined as the ratio of area under the curve on withdrawal to the area under the curve on compression in the first cycle of the TPA test.

## 1.3 Principle

The resistance of boiled yam samples to compressive force exerted uniaxially by penetration cone or cylindrical plate as captured by a texture analyzer may be considered to define the texture of boiled yams. The textural parameters measured by the instrument may be correlated with sensory scores obtained by quantitative descriptive analysis. The methods must guarantee repeatability and be able to discriminate among boiled yam from genotypes of contrasting texture.

## 1.4 Reagents

No reagents

## 1.5 Apparatus

- a. Texture analyser (TA-XTPlus, Stable Microsystem).
- b. Conical probe (P/40C) – Perpex
- c. Compression plate (P/75) - Aluminium
- d. Steam cooker with three trays was used with a degree of cooking varying from the low (first tray) to the top (third tray). The first tray was used in our experiment.
- e. Oven (45°C)
- f. Thermometer

# 2 PRODUCT PREPARATION

## 2.1 Sampling and preparation of boiled yam

*Cutting samples into appropriate subsections*

1. Select two or three tubers per genotype and measure their length (L) (15 to 40 cm depending on variety)
2. Cut yam tubers into three sections: proximal, central and distal (Figure 1)
3. After peeling and washing, cut the sections as follows:
  - a. For the proximal and distal parts, 1/10 and 3/10 of the length is cut off from both ends of section and discarded, while for the central part, 2/10 of the length is cut off from both ends of the section and discarded
  - b. 6/10 of each section length (as representative of each part) is suitable to cook.
  - c. Each usable/operational part (6/10) is divided following the length into two subsections (semi-cylinders).



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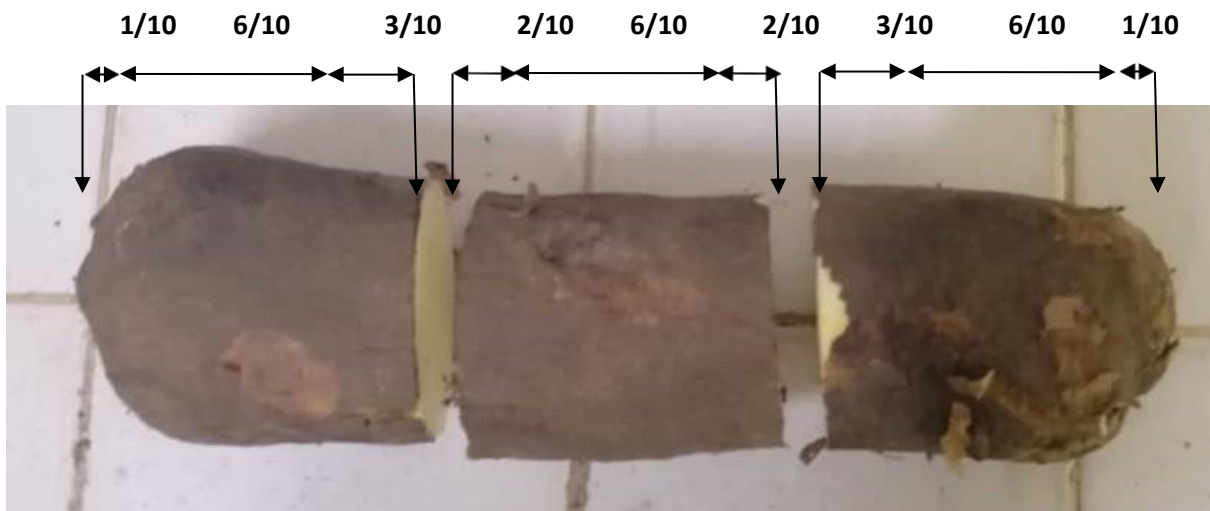


Figure 1 : Yam tuber sections for preparation of samples for texture analysis

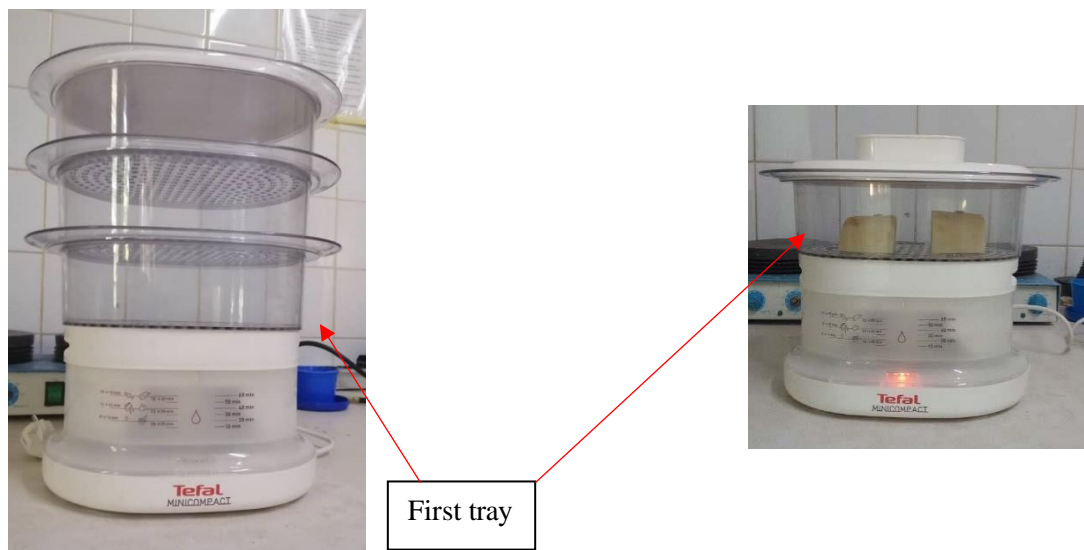


Figure 2 : Steam cooker for boiled yam

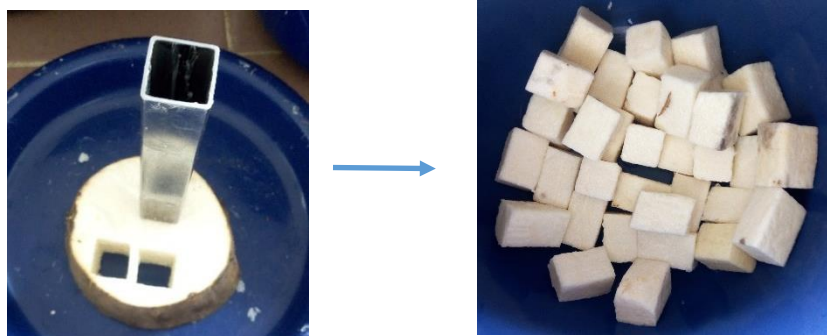
## 2.2 Yam cooking for texture analysis:

### 2.2.1 Penetration test

#### *Preparation of sample for penetration test*

For penetration test, two yam tubers per genotype were used. After preparation as described in section 2.1, cylinders of 30 mm thickness were cut by section, and then test-pieces of 25 mm x 25 mm and 30 mm height were collected from each cylinder using a mold/punch. In total, per section, three to six pieces were steam-cooked for 38 min and evaluated by penetration test.

After cooking, remove the pieces and allow them to stabilize to 45 °C in an oven/incubator before performing the penetration test as indicated in the subsequent step.

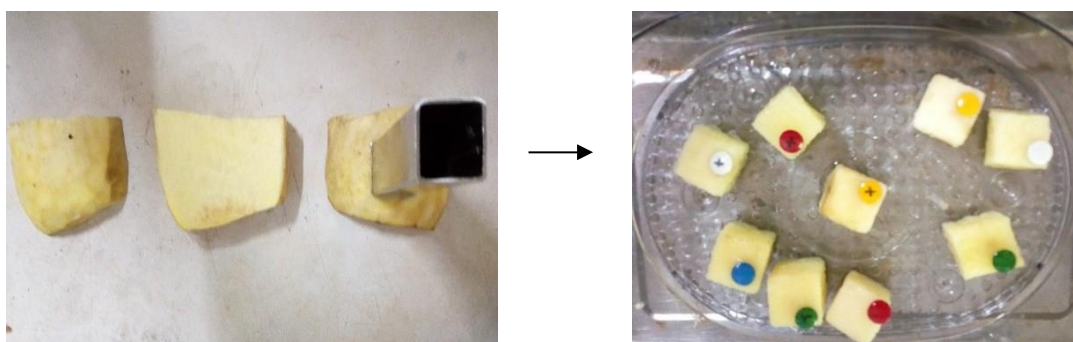


**Figure 3 : Sampling of cuboid pieces (25mmx25mmx30mm) of yam for penetration test**

### 2.2.2 TPA test

*Preparation of sample for texture profile analysis (TPA)*

For texture profile analysis, two yam tubers per genotype were used, yielding six to twelve pieces. TPA test was performed on each piece of 25 mm x 25 mm x 30 mm.



**Figure 4 : Cut yam into cuboid pieces with punch for TPA**

After steam-cooking, remove the pieces and allow them to stabilize to 45°C in an oven/incubator before performing the TPA test in the subsequent step.

### 3 TEXTURE MEASUREMENT CONDITIONS

#### 3.1 Penetrometry test

The penetration test was performed with conical probe P/40C and the settings are shown in Figure 5 and for each piece.

Pre-Test Speed	10 mm/s
Test speed	0.5 mm/s
Trigger force	5 g
Target distance	10 mm
Temperature of test sample	45°C



Figure 5 : Example of penetration test set-up

#### 3.2 Texture profile analysis

The texture profile analysis was performed with compression plate (P/75) and the settings are shown in Figure 6.

Pre-Test Speed	10 mm/s
Test speed	0,5 mm/s
Trigger force	10 g
Strain	25%
Temperature of test sample	45°C



Figure 6 : Texture analysis set-up by TPA

## 4 EXPRESSION OF RESULTS

The penetration results are expressed as hardness (N) and total penetration work (N.sec or N.mm). The typical curve for penetration is presented in Figure 7.

The TPA results are expressed as hardness (N), springiness (no unit, or %), cohesiveness (no unit, or %), gumminess (N) and chewiness (N). The TPA curve is presented in Figure 8.

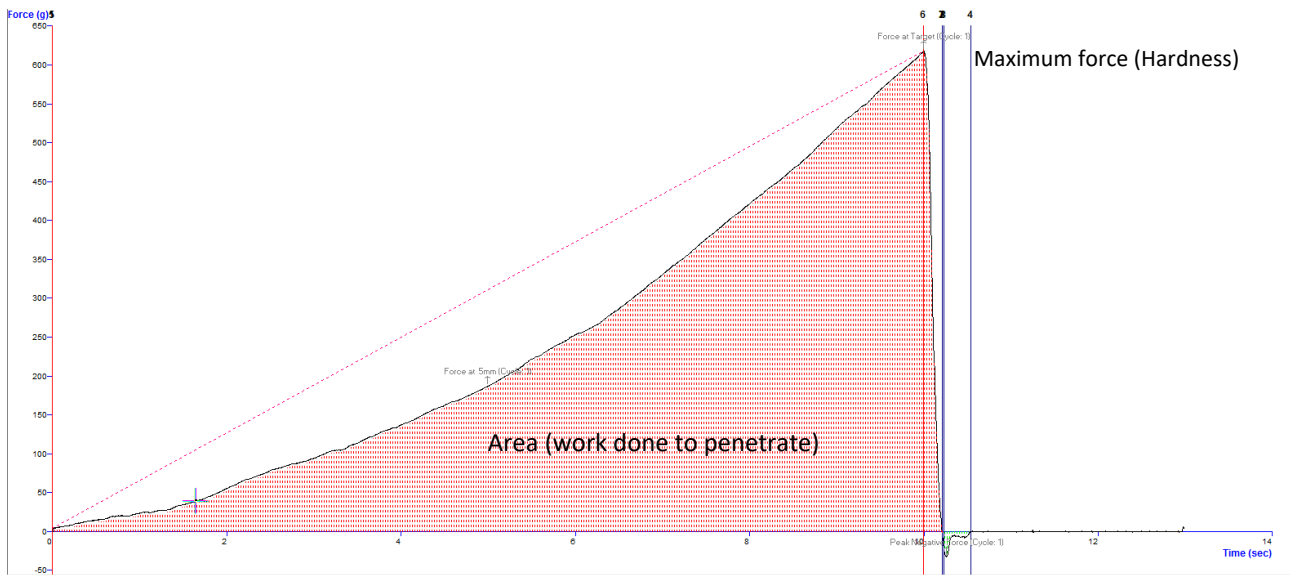


Figure 7: Penetration curve of steam-cooked yam

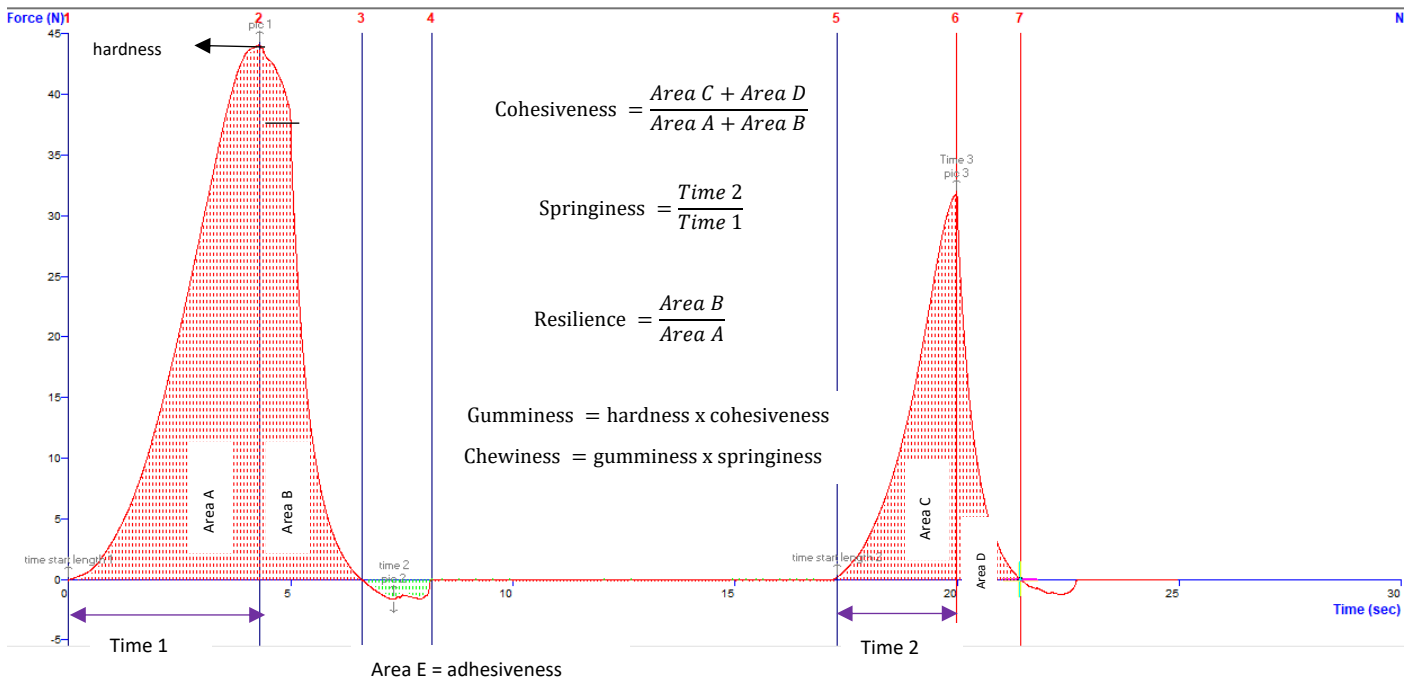


Figure 8: TPA curve of steam-cooked yam

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## 4.1 Discrimination test from data of 2024

**Table 1: ANOVA of textural attribute Hardness (Max force) for the protocols**

- Penetrometry – Max force

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Variety	2	80.199	40.099	57.594	< 0.0001
Section	8	379.331	47.416	68.103	< 0.0001
Variety*Section	16	147.372	9.211	13.229	< 0.0001

- Texture profile analysis (TPA)\_Max force

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Variety	8	69715.713	8714.464	50.290	< 0.0001
Section	2	23576.090	11788.045	68.027	< 0.0001
Variety*Section	16	25554.421	1597.151	9.217	< 0.0001

P value revealed significant effect of varieties, the sections of the tubers.

## 4.2 Repeatability and reproducibility and conformity test (T-test for two samples)

**Table 2: Mean standard deviations from data of 2021 are compared to the ones from 2023 using T-test**

Parameters	2021 assay	2023 assay	T-test for 2 samples
Number of yam varieties	5	9	
Standard deviation of repeatability ( <b>sd</b> )	14.99	12.67	p-value =0.218
Standard deviation of reproducibility ( <b>sr</b> )	5.18	6.04	
Limit of repeatability ( <b>sd*2√2</b> )	14.65	17.10	

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## **5 CRITICAL POINTS OR NOTE ON THE PROCEDURE**

- Sample temperature and size /shape sample should be applied to all boiled yam samples.
- The texture analyzer must be switched on at least 15 min prior to calibration and measurements.
- The texture analyzer must be calibrated for force and distance prior to measurements.
- Ensure to clean the probed after each measurement.

## **6 TEST REPORT**

The test report should include full information about the samples; harvest location, plot number, clone/genotype name and number of replicates.

# APPENDICES

## Annex 1: Varieties

Yam varieties used for second season are: Dodo, Irindou, Agatou, Aga, Kpètè, Moroco, Wété, Efourou and Ofegui.

## Annex 2: Statistical accuracy of texture attributes measured from data of 2024

- **Table 3:** Descriptive statistics on penetration data
- **Table 4:** Descriptive statistics on texture profile analysis

**Table 3 : Descriptive statistics on Penetrometry**

Variety	Section	N	Force (N)				Area (N.s)			
			Mean	Std Dev	Std Err	CV, mean (%)	Mean	Std Dev	Std Err	CV, mean (%)
DODO	Central	4,00	4,86	1,02	0,58	10,51	41,72	5,97	1,16	7,15
DODO	Distal	5,00	4,76	0,54	0,25	5,05	38,80	4,32	0,69	4,98
DODO	Proximal	5,00	4,63	1,10	0,51	10,58	39,23	7,58	1,22	8,65
IRINDOU	Central	2,00	5,59	0,49	0,27	6,20	45,45	1,28	0,25	1,99
IRINDOU	Distal	2,00	4,47	0,31	0,19	4,95	38,37	4,02	0,83	7,40
IRINDOU	Proximal	4,00	5,23	0,87	0,38	8,31	41,76	6,81	1,06	8,16
AGATOU	Central	5,00	4,96	0,33	0,18	2,93	41,29	3,45	0,66	3,74
AGATOU	Distal	3,00	5,28	0,77	0,35	8,45	43,19	8,57	1,35	11,45
AGATOU	Proximal	4,00	4,51	1,01	0,47	11,19	38,98	9,34	1,50	11,99
MOROCCO	Central	4,00	6,43	0,86	0,34	6,70	53,34	8,33	1,14	7,81
MOROCCO	Distal	3,00	6,79	0,26	0,10	2,25	55,23	0,32	0,04	0,33
MOROCCO	Proximal	4,00	9,31	0,91	0,30	4,86	74,37	3,14	0,37	2,11
WETE	Central	5,00	7,81	0,90	0,32	5,17	63,11	5,71	0,72	4,05
WETE	Distal	3,00	7,29	0,32	0,11	2,51	57,58	4,26	0,55	4,27
WETE	Proximal	6,00	8,57	1,12	0,39	5,34	70,12	10,60	1,30	6,17
EFOUROU	Central	6,00	9,18	1,01	0,33	4,47	72,41	5,41	0,64	3,05
EFOUROU	Distal	4,00	7,31	0,63	0,22	4,32	61,67	7,53	0,91	6,10
EFOUROU	Proximal	4,00	10,46	1,55	0,50	7,43	82,69	9,20	1,05	5,57
OFEGUI	Central	5,00	6,62	0,97	0,38	6,55	54,08	7,55	1,03	6,24
OFEGUI	Distal	4,00	5,26	0,24	0,09	2,28	42,25	2,14	0,29	2,53
OFEGUI	Proximal	4,00	13,75	0,98	0,29	3,57	113,93	11,33	1,18	4,97
AGA	Central	5,00	3,37	0,34	0,19	4,55	25,28	3,93	0,78	6,95
AGA	Distal	4,00	3,01	0,45	0,25	7,48	26,01	2,64	0,51	5,07
AGA	Proximal	5,00	4,24	0,49	0,24	5,15	36,34	6,01	1,00	7,39
KPETE	Central	7,00	6,49	0,72	0,29	4,21	51,10	5,77	0,82	4,27
KPETE	Distal	5,00	5,55	0,55	0,23	4,45	44,37	4,35	0,65	4,38
KPETE	Proximal	6,00	7,37	0,91	0,33	5,05	58,54	7,82	1,01	5,45



**Table 4 : Descriptive statistics on texture profile analysis**

Variety	Section	N	Maximum Force, Hardness (N)				Springiness (-)				Cohesiveness (-)			
			Mean	Std Dev	Std Err	CV, mean (%)	Mean	Std Dev	Std Err	CV, mean (%)	Mean	Std Dev	Std Err	CV, mean (%)
DODO	Centrale	5	73,75	10,64	1,24	6,45	0,91	0,13	0,13	6,30	0,26	0,04	0,07	6,22
DODO	Distale	4	63,90	11,96	1,49	9,36	0,77	0,10	0,11	6,21	0,36	0,08	0,13	11,02
DODO	Proximale	4	60,26	7,96	1,01	6,61	0,79	0,12	0,13	7,52	0,29	0,03	0,07	4,99
IRINDOU	Centrale	4	93,43	14,68	1,56	7,86	1,00	0,20	0,20	10,10	0,18	0,01	0,03	3,15
IRINDOU	Distale	3	65,30	9,11	1,00	8,05	0,96	0,26	0,27	15,50	0,10	0,01	0,04	7,39
IRINDOU	Proximale	3	120,53	17,46	1,77	8,36	0,76	0,15	0,16	11,26	0,33	0,08	0,20	13,40
AGATOU	Centrale	5	71,61	17,76	2,64	11,09	0,94	0,18	0,19	8,75	0,19	0,06	0,14	14,30
AGATOU	Distale	4	70,29	18,08	2,28	12,86	0,81	0,12	0,13	7,15	0,26	0,05	0,09	8,84
AGATOU	Proximale	4	46,29	7,93	1,10	8,56	0,89	0,11	0,12	6,45	0,26	0,01	0,02	1,98
MOROCCO	Centrale	4	82,13	7,80	0,85	4,75	0,95	0,13	0,13	6,81	0,17	0,03	0,08	9,55
MOROCCO	Distale	2	93,21	4,84	0,45	3,68	1,02	0,09	0,09	6,45	0,21	0,03	0,08	11,64
MOROCCO	Proximale	3	130,67	33,53	2,99	14,81	0,98	0,16	0,17	9,34	0,19	0,00	0,01	0,91
WETE	Centrale	5	119,53	9,83	0,90	3,68	0,78	0,09	0,10	5,13	0,25	0,06	0,12	11,01
WETE	Distale	4	96,20	15,57	1,50	8,09	0,82	0,11	0,13	6,95	0,23	0,05	0,10	10,94
WETE	Proximale	4	144,60	14,34	1,21	4,96	0,74	0,09	0,10	5,87	0,41	0,11	0,19	13,33
EFOUROU	Centrale	5	113,70	16,81	1,58	6,61	0,73	0,07	0,08	4,34	0,18	0,04	0,09	9,19
EFOUROU	Distale	4	98,62	11,83	1,14	6,00	0,76	0,12	0,14	7,62	0,21	0,04	0,11	10,08
EFOUROU	Proximale	4	165,91	20,27	2,18	6,11	0,65	0,08	0,12	6,10	0,37	0,13	0,30	17,98
OFEGUI	Centrale	5	78,90	18,33	2,59	10,39	0,87	0,12	0,13	6,38	0,24	0,09	0,19	17,27
OFEGUI	Distale	4	60,22	7,06	0,81	5,86	1,11	0,21	0,21	9,53	0,15	0,05	0,12	17,21
OFEGUI	Proximale	5	149,18	10,65	0,87	3,19	0,82	0,09	0,10	4,80	0,29	0,05	0,09	7,59
AGA	Centrale	5	31,71	7,34	1,31	10,36	0,87	0,21	0,22	10,68	0,16	0,03	0,08	8,78
AGA	Distale	4	36,59	7,33	1,14	10,01	0,85	0,08	0,09	4,95	0,20	0,08	0,21	19,03
AGA	Proximale	5	50,93	10,94	1,54	9,60	1,06	0,11	0,10	4,49	0,16	0,03	0,07	8,08
KPETE	Centrale	5	68,50	5,97	0,72	3,90	0,83	0,07	0,08	3,74	0,16	0,05	0,12	13,51
KPETE	Distale	4	59,77	9,09	1,10	7,61	0,96	0,23	0,25	11,92	0,16	0,04	0,10	12,32
KPETE	Proximale	4	119,89	14,92	1,36	6,22	0,67	0,21	0,25	15,48	0,22	0,05	0,12	12,42

**Table 4: descriptive statistics on texture profile analysis (con'd)**

Variety	Section	N	Chewiness (N)				Gumminess (N)			
			Moy	Std Dev	Std Err	CV, mean (%)	Moy	Std Dev	Std Err	CV, mean (%)
DODO	Centrale	5	16,84	1,95	0,48	5,19	18,75	2,86	0,66	6,83
DODO	Distale	4	17,28	4,01	0,96	11,61	22,97	7,08	1,49	15,42
DODO	Proximale	4	11,82	8,21	2,58	34,74	13,97	9,52	2,89	34,07
IRINDOU	Centrale	4	16,82	0,50	0,15	1,49	17,34	3,67	1,11	10,58
IRINDOU	Distale	3	5,35	2,87	1,90	31,01	6,12	1,78	0,52	16,81
IRINDOU	Proximale	3	31,79	11,01	3,73	19,99	37,49	12,65	3,94	19,48
AGATOU	Centrale	5	15,88	3,01	1,26	8,47	17,52	4,67	1,87	11,92
AGATOU	Distale	4	14,54	4,35	1,21	14,95	18,59	7,45	1,84	20,03
AGATOU	Proximale	4	10,81	3,14	0,94	14,52	12,00	2,05	0,58	8,56
MOROCCO	Centrale	4	13,24	2,85	0,73	10,76	14,17	3,62	0,92	12,76
MOROCCO	Distale	2	20,30	6,17	1,30	21,48	19,64	4,23	0,89	15,25
MOROCCO	Proximale	3	24,03	3,14	0,68	7,55	25,13	6,56	1,33	15,08
WETE	Centrale	5	22,97	5,18	1,09	10,08	29,77	8,26	1,52	12,40
WETE	Distale	4	17,89	1,61	0,33	4,50	21,99	3,11	0,57	7,07
WETE	Proximale	4	43,54	11,20	1,88	12,86	60,40	19,24	2,76	15,92
EFOUROU	Centrale	5	14,69	2,99	0,78	9,11	20,58	6,04	1,34	13,12
EFOUROU	Distale	4	16,02	2,94	0,81	9,18	20,19	5,44	1,26	13,46
EFOUROU	Proximale	4	39,06	15,06	3,43	19,28	45,74	36,29	6,86	39,67
OFEGUI	Centrale	5	12,43	9,84	3,19	35,41	15,21	14,31	4,26	42,07
OFEGUI	Distale	4	8,37	1,72	0,56	10,25	7,81	3,10	0,97	19,83
OFEGUI	Proximale	5	35,64	7,61	1,28	9,54	43,52	10,13	1,54	10,41
AGA	Centrale	5	4,35	1,39	0,67	14,29	4,98	0,76	0,34	6,78
AGA	Distale	4	5,85	2,71	1,25	23,19	6,87	3,43	1,52	24,94
AGA	Proximale	5	8,96	3,30	1,12	16,48	8,46	3,04	1,06	16,05
KPETE	Centrale	5	10,70	3,11	1,20	12,99	12,76	3,00	1,06	10,52
KPETE	Distale	4	8,65	2,24	0,75	12,94	9,16	2,03	0,61	11,09
KPETE	Proximale	4	17,00	4,85	1,19	14,26	26,35	8,14	1,60	15,45

**Table 5: (cont'd) Grouping connecting letters report by section and varieties**

▪ **Penetrometry test**

Connecting Letters Report by section

Section	Estimated mean	Err std	Group		Legend
P	7,57	0,13	A		P: Proximal
C	6,14	0,14	B		C: Cental
D	5,53	0,15	C		D: Distal

Levels not connected by same letter are significantly different

Connecting letters report by varieties

Level	Estimated mean	Err std	Group	
EFOUROU	8,99	0,23	A	
OFEGUI	8,54	0,23	A	B
WETE	7,89	0,23	B	
MOROCCO	7,51	0,25	B	
KPETE	6,47	0,20	C	
IRINDOU	5,10	0,31	D	
AGATOU	4,92	0,25	D	
DODO	4,75	0,22	D	
AGA	3,54	0,22	E	

Levels not connected by same letter are significantly different

▪ **Texture profile analysis**

Connecting letters report by section

Section	Estimated mean	Err std	Group	
P	109,19	2,38	A	
C	82,45	2,14	B	
D	70,04	2,53	C	

Levels not connected by same letter are significantly different

Connecting letters report by varieties

Level	Estimated mean	Err std	Group		
EFOUROU	124,27	4,09	A		
WETE	120,11	3,67	A	B	
MOROCCO	102,00	4,57		B	C
OFEGUI	95,41	3,88			C
IRINDOU	89,12	4,91			C
KPETE	83,14	3,80			C D
DODO	67,03	3,88			D E
AGATOU	65,24	4,01			E
AGA	38,70	3,76			F

Levels not connected by same letter are significantly different

Discriminance between varieties based on textural attributes

PCA

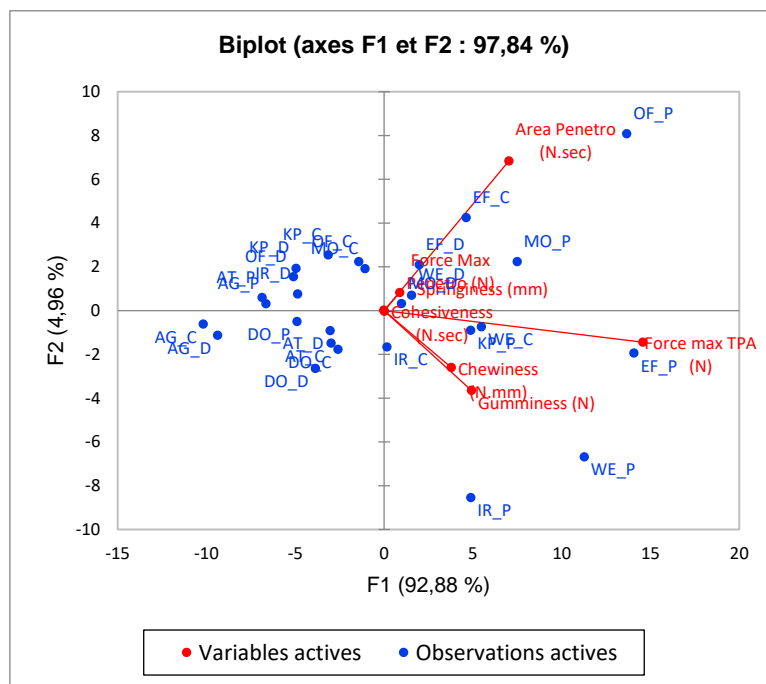


Figure 9: PCA of boiled yam with penetration and texture profile analysis