Laboratory Standard Operating Procedure

SOP for Determination of the Firmness of Cassava Genotypes during Retting using the Hand-held Penetrometer

Biophysical Characterization of Quality Traits, WP2

Umudike, Nigeria, 2023

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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

WPX: Biophysical Characterization of Quality Traits

SOP: Determination of the firmness of Cassava genotypes during Retting using the hand-held Penetrometer

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ABSTRACT

Fufu, a fermented wet paste food product from cassava is a good source of dietary energy and is one of the widely consumed foods in Nigeria and other West African countries. In fufu processing, retting involves the steeping of cassava roots in water for a period of 72 hours. Due to the genetic make-up of different cultivars of cassava, there is variation in the retting abilities of these cassava roots. Therefore, it is of importance to standardize the procedure involved in determining the different retting behaviors of these different cassava cultivars using a hand held penetrometer. This SOP encapsulates the materials required for the standardized procedure, as well as the instrument involved. The protocol for evaluating the retting ability of cassava genotypes was standardized using the hand-held penetrometer by measuring firmness of 42 cassava genotypes (37 breeder's elite clones, 3 released elite clones, 2 landraces) with contrasting root quality attributes during various retting regimes. Data obtained showed that the protocol effectively classified the genotypes into three distinct groups: fast (low firmness), intermediate (intermediate firmness) and slow (high firmness) retting groups.

Key Words: fufu, hand-held penetrometer, retting, SOP, cassava

1 SCOPE AND APPLICATION

The objective of this study is to establish a standard operating procedure (SOP) for determining the retting ability (by measuring firmness) of cassava roots using the hand-held penetrometer.

2 DEFINITIONS

Penetrometer: It is a device that offers rapid and handy assessment of firmness based on a unique output parameter defined by the maximum force to disrupt the tissue (herein named as firmness).

Retting: Process employing the actions of microbes and moisture on intact plants to disintegrate much of the cellular tissues

Firmness: The quality parameter of being hard and cohesive (tight)

G1: Genotype 1

G2: Genotype 2

[A] & [B]: Duplicate readings

3 PRINCIPLES

Fufu is one of the popular fermented products processed from cassava roots. It is widely consumed in Nigeria and other West and Central African countries and it is considered one of the main sources of carbohydrates in the Nigerian diet (Uyor *et al.* 2009). The preparation of *fufu* involves the fermentation of the fresh cassava roots for a period of 72 hours to obtain an intermediate fermented product. Retting (Softening) of cassava roots during the processing of fermented products such as *fufu* is highly influenced by the cassava variety (Nanda and Mathew, 1996) and determines the easy recovery of the released water-insoluble material (starch, fiber strands) during sieving operation.

4 APPARATUS

Hand-held Penetrometer (FHP-802 model, Agriculture Solutions LLC, USA)

5 INSTRUMENTATION

5.1 Operating mode to start the instrument

- Turn on the instrument by pressing the red button on the central part of the instrument. As the instrument is turned on, it will display numerical digits as shown in the Figure 1.

Figure 1 Hand – held penetrometer

5.2 Instrument Calibration

- Hold the tester vertically with the plunger tip hanging in the air. The reading on the display should be '0.0'.
- If the reading on the display is not '0', press the 'ZERO' button. The tester (with a range of 0.5 to 15.0kgf/cm^2, and tip of 3.5mm stainless steel) should read '0.0' when the tip is not pressed.

5.3 Device Operating Instruction

- Select random samples of five peeled and soaked cassava roots of uniform sizes.
- To record the maximum resistance level, press the 'MAX' button until 'Max' shows on the display before taking measurements.
- Hold the cassava root against the hard surface of the tip and slowly force the tip into the cassava pulp at a recommended speed of 5 mm/s.
- Take two readings on the cassava pulp (distal and proximal)
- It should take about three seconds to fully insert the tip up to the inscribed penetration depth indication line.
- Record the reading on display when it is steady
- To take the next measurement, press the 'ZERO' button, and repeat.
- The tester will auto-power off after 5 minutes of inactivity.

6 SAMPLE PREPARATION PROCEDURE

Thirty-seven (37) breeder elite cassava genotypes from AYT, three (3) released elite clones, and two (2) landrace varieties identified during the WP1 survey (a total of 42 NEXTGEN genotypes) were used for the retting ability studies. Uniform-sized (medium-sized root) freshly harvested cassava roots of about 5kg were weighed for each genotype. The roots were peeled and about 4kg of each peeled genotype was weighed into fermenting vessel of uniform size. An equal volume of water (5litres) was poured into each fermenting vessel containing the roots and was allowed to stand for 72 hours.

6.1 Penetration test using a hand-held penetrometer

For each cassava variety, five different roots per genotype were evaluated for firmness (2 penetration readings on opposite sides of each root, resulting in 10 penetrations readings per genotype).

Figure 2 Taking penetrometer readings on the retted cassava (fufu) samples

6.2 Protocol of penetrometer readings and sample codification

- The appropriate codes were used for the samples. The code used for each sample differs from each other to avoid errors due to sample mixing. The codes used in this SOP are as follows:

G1: Root 1 [A] [B]
Root 2 [A] [B]
Root 3 [A] [B]
Root 4 [A] [B]
Root 5 [A] [B]

G2: Root 1 [A] [B]
Root 2 [A] [B]
Root 3 [A] [B]
Root 4 [A] [B]
Root 5 [A] [B]

(Successive genotypes continues…..G3, G4, G5,……..G42).

7 EXPRESSION OF RESULTS

7.1 Penetrometer readings for firmness of retted cassava genotypes at different retting durations

Table 1 Penetrometer readings of firmness (kgF/cm^2) of retted cassava genotypes at 0 h

CODE	ACCESSION NAME	ROOT 1		ROOT 2		ROOT 3		ROOT 4		ROOT 5	
		A	B	A	B	A	B	A	B	A	B
1	NR17C2aF7P008	11.2	7.31	14.6	14.6	14.7	14.7	14.7	14.7	14.6	14.6
2	NR17C2aF62P020	13.8	14.6	14.2	14.5	14.4	14.3	13.9	14.6	14.1	14.6
3	NR17C2aF70P008	14.5	14.5	14.6	14.7	14.6	14.6	14.5	14.5	14.6	14.5
4	NR17C2aF61P007	14	13	9.49	13	11.7	14	10.5	9.87	10.2	12.3
5	NR17C2aF5P026	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6
6	NR17C2aF60P009	14.5	14.5	14.6	14.6	14.5	14.5	14.6	14.6	14.5	14.5
7	NR17C2aF89P028	13.3	11.7	11.7	12.9	7.25	8.17	10.5	10.4	12.6	14.6
8	NR17C2aF79P016	14.2	14.1	14.6	14.6	14.6	14.6	13.6	14	14.6	14.6
9	TMEB419	14.5	14.5	14.6	14.6	14.5	14.5	14.6	14.5	14.5	14.6
10	NR17C2aF16P010	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6
11	NR17C2aF92P001	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6
12	NR17C2aF61P008	14.6	14.6	14.6	14.6	14.5	14.6	14.6	14.6	14.6	14.6
13	NR17C2aF79P005	14.6	14.6	14.6	14.6	14.6	14.6	13.6	14.7	14.6	14.6
14	NR17C2aF16P013	14.6	14.2	13.9	13.7	14.6	14.7	14.5	14.5	14.5	14.5
15	NR17C2aF103P001	14.5	14.5	14.5	14.4	13.5	12.9	14.6	14.5	14.6	14.5
16	NR17C2aF95P003	14.6	14.6	14.6	14.6	14.6	14.6	14.5	14.5	14.6	14.6
17	NR17C2aF91P011	12.2	14.6	14.5	14.6	13.6	14.4	14.6	14.6	14.6	14.5
18	NR17C2aF91P004	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6
19	NR17C2aF7P030	10.1	14.5	14.5	14.5	14.5	14.5	10.6	14.5	14.5	14.5
20	NR17C2aF16P004	14.6	13.9	14.6	14.5	14.5	14.5	14.6	14.6	14.6	14.5

CODE	ACCESSION NAME	ROOT 1		ROOT 2		ROOT 3		ROOT 4		ROOT 5	
		A	B	A	B	A	B	A	B	A	B
21	NR17C2aF39P002	14.5	14.5	14.5	14.5	14.6	14.6	14.5	14.5	14.5	14.5
22	NR17C2aF98P001	6.73	8.44	8.29	14.5	7.33	14.6	14.6	14.6	14.6	14.6
23	NR17C2aF7P067	14.5	14.5	14.5	14.5	14.5	14.5	14.6	14.6	14.5	14.6
24	NR17C2aF12P001	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
25	NR17C2aF97P002	13.6	13.9	14.2	14.5	12.8	14	9.14	14.6	14.2	14.4
26	NR17C2aF61P016	14.1	13.9	14.1	13.6	13.8	14	12.9	14.5	14.5	14.5
27	IITA-TMS-IBA00070	14.5	14.5	14.5	13.4	14.5	14.5	14.5	14.5	14.5	14.5
28	NR17C2aF7P065	14.5	14.6	14.5	14.4	14.3	14.3	13.7	14.5	12.8	14
29	NR17C2aF21P004	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
30	NR17C2aF83P010	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
31	NR17C2aF99P002	14	14.1	13.3	13.4	14.5	14.5	13.5	14.5	13	14.5
32	NR17C2aF62P015	14.5	14.5	14.6	14.6	14.5	14.5	14.5	14.5	14.5	14.5
33	NR17C2aF9P013	14.4	14.5	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6
34	NR17C2aF79P008	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
35	NR17C2aF7P044	13.5	9.41	14.5	14.5	12.5	14.5	14.5	14.5	14.5	14.5
36	NR17C2aF54P010	14.5	14.2	14.5	14.5	14.5	14.5	13.7	14.5	12.3	13.9
37	NR17C2aF27P001	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
38	NR17C2aF91P001	14.6	14.5	14.7	14.6	14.5	14.5	14.6	14.7	14.5	14.6
39	CHENKE	10.9	10.7	14.6	14.6	11.2	7.62	13.3	12.8	12.1	12.6
40	WONONO	13.2	12.7	11.5	12.8	13.2	11.1	12.4	12.8	4.89	8.08
41	1368	6.33	9.01	12.9	13.6	14.6	5.37	13.7	14.7	14.6	9.23
42	TMS980505	14.4	14.6	14.7	14.7	14	14.6	14.6	14.6	14.6	14.6

Table 2 Penetrometer readings of firmness (kgF/cm^2) of retted cassava genotypes at 24 h

CODE	ACCESSION NAME	ROOT 1		ROOT 2		ROOT 3		ROOT 4		ROOT 5	
		A	B	A	B	A	B	A	B	A	B
1	NR17C2aF7P008	14.5	8.1	14.5	13.7	13.7	14.6	14.6	14.6	14.6	14.5
2	NR17C2aF62P020	7.26	6.5	7.01	8.67	6.91	12.3	12.3	9.82	8.52	5.54
3	NR17C2aF70P008	14.5	14.6	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
4	NR17C2aF61P007	14.4	14.5	14.6	14.5	14.5	14.5	14.5	14.5	14.1	14.5
5	NR17C2aF5P026	14.5	14.5	14.6	14.6	14.5	14.5	14.5	14.5	14.5	14.6
6	NR17C2aF60P009	11.7	14.6	14.6	14.5	14.1	12.8	13.7	14.5	14.5	14.5
7	NR17C2aF89P028	8.3	8.65	10.8	14.5	14.5	14.5	9.68	12.4	14.5	12.5
8	NR17C2aF79P016	13.1	12	14.6	14.5	14.6	14.5	14.6	14.7	14.6	14.6

CODE	ACCESSION NAME	ROOT 1		ROOT 2		ROOT 3		ROOT 4		ROOT 5	
		A	B	A	B	A	B	A	B	A	B
9	TMEB419	8.26	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
10	NR17C2aF16P010	14.5	14.5	13.9	14.5	14.5	14.6	14.5	14.5	14.5	14.5
11	NR17C2aF92P001	14.5	14.6	14.5	14.6	14.5	14.5	14.5	14.6	14.5	14.6
12	NR17C2aF61P008	14.5	11.6	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
13	NR17C2aF79P005	14.1	14.6	14.6	14.7	14.7	14.5	14.5	14.5	14.5	14.5
14	NR17C2aF16P013	12.7	14.5	12.9	13.7	14.7	14.5	14.5	14.5	14.5	14.5
15	NR17C2aF103P001	14.6	14.6	14.6	14.6	14.6	14.6	14.5	14.5	11.2	11.1
16	NR17C2aF95P003	14.1	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
17	NR17C2aF91P011	9.65	14.6	9.33	14.6	13.1	14.6	14.6	14.6	14.6	14.6
18	NR17C2aF91P004	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
19	NR17C2aF7P030	13.3	12.4	5.47	6.66	8.26	12.4	14.5	14.5	14.5	14.5
20	NR17C2aF16P004	14.5	14.5	14.5	14.5	14.5	14.5	13.7	14.1	10.3	14.5
21	NR17C2aF39P002	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
22	NR17C2aF98P001	6.41	7.18	2.46	2.96	14.5	14.5	14.6	14.6	13.9	6.5
23	NR17C2aF7P067	14.5	14.5	11.4	10.2	14.5	14.5	14.5	14.5	14.5	14.5
24	NR17C2aF12P001	9.12	8	14.5	14.4	14.5	10.9	12.9	12.6	13.4	12.8
25	NR17C2aF97P002	13.3	12.5	13.9	14.2	8.95	14.6	14.5	14.7	14.5	14.5
26	NR17C2aF61P016	7.63	7.99	14.2	14.5	7.34	10.6	12.8	10.8	14.5	14.6
27	IITA-TMS-IBA00070	13.4	14.5	8.02	14.5	14.5	14.5	14.5	14.5	14.5	12.7
28	NR17C2aF7P065	13.9	14.5	13.8	13.9	14.5	14.5	14.6	14.6	14.1	14.6
29	NR17C2aF21P004	14.5	14.5	14.3	14.5	14.5	14.5	14.5	14.5	14.5	14.5
30	NR17C2aF83P010	13.3	13.5	13.3	12.6	14.2	14.5	13.4	14.5	14.5	14.1
31	NR17C2aF99P002	14.3	14.3	12.9	14.6	14.6	7.65	14.5	14.6	14.1	14.5
32	NR17C2aF62P015	14.6	14.6	14.5	14.5	14.2	14	14.6	14.5	14.5	14.6
33	NR17C2aF9P013	14.5	14.5	14.5	14.6	14.6	14.6	14.5	14.5	14.5	14.5
34	NR17C2aF79P008	9.73	12	10.2	14.5	14.5	14.5	9.57	14.1	14.5	14.5
35	NR17C2aF7P044	6.43	7.322	8.62	7.39	14.5	14.5	14.5	14.5	14.5	14.5
36	NR17C2aF54P010	7.87	10.4	13.8	13.1	13.9	14.6	13.9	13.5	14.5	12.7
37	NR17C2aF27P001	7.36	9.79	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
38	NR17C2aF91P001	13.5	11.8	14.5	14.5	14.5	14.5	14.7	14.5	14.2	13.6
39	CHENKE	7.61	12.4	5.04	4.85	12.3	5.94	4.24	12.6	13.3	12.9
40	WONONO	7.1	5.69	13	14	10.8	3.67	13.6	9.47	14.1	12
41	1368	9.59	7.92	7.96	13.4	14.5	10.2	14.5	13.7	12.3	8.53
42	TMS980505	14.3	14.5	14.5	14.5	14.5	11.8	12.3	14.5	14.7	14.5

Table 3 Penetrometer readings of firmness (kgF/cm^2) of retted cassava genotypes at 48 h

CODE	ACCESSION NAME	ROOT 1		ROOT 2		ROOT 3		ROOT 4		ROOT 5	
		A	B	A	B	A	B	A	B	A	B
1	NR17C2aF7P008	10.1	13.9	6.28	7.82	5.14	5.02	2.6	2.95	3.8	6.04
2	NR17C2aF62P020	1.34	1.25	1.65	1.84	1.13	1.23	1.39	0.8	1.97	2.03
3	NR17C2aF70P008	5	6.01	2.31	2.68	3.84	5.01	3.04	4.99	3.69	4.24
4	NR17C2aF61P007	4.78	2.8	6.51	6.99	4.31	5.16	4.68	6.79	8.46	13.8
5	NR17C2aF5P026	2.75	4.18	2.76	3.1	4.63	14.6	4.46	5.27	4.44	4.84
6	NR17C2aF60P009	2.97	2.28	2.94	2.62	3.57	4.25	3.95	2.82	1.8	1.92
7	NR17C2aF89P028	6.58	5.44	3.62	4.36	3.65	7.37	2.86	3.76	3.96	3.63
8	NR17C2aF79P016	3.18	4.31	3.21	2.82	1.35	1.93	4.31	8.33	7.05	4.73
9	TMEB419	2.49	2.81	2.75	2.56	1.99	0.98	2.7	4.06	5.52	3.45
10	NR17C2aF16P010	2.2	2.84	5.49	4.91	3.59	4.81	3.44	5.39	4.81	5.32
11	NR17C2aF92P001	4.1	2.66	5.53	4.91	3.86	3.66	4.9	5.9	5.8	6.97
12	NR17C2aF61P008	1.51	1.77	3.46	3.05	1.92	1.4	1.89	1.85	1.41	1.61
13	NR17C2aF79P005	1.88	1.87	2.77	2.7	1.02	1.48	2.76	1.49	1.56	0.99
14	NR17C2aF16P013	4.95	4.74	9.76	7.25	8.41	7.51	6.68	7.25	5.63	5.15
15	NR17C2aF103P001	1.39	1.01	5.32	1.73	4.22	3.98	0.8	0.88	2.34	2.59
16	NR17C2aF95P003	6.16	8.82	5.19	6.24	7.01	12	5.58	5.44	6.57	6.15
17	NR17C2aF91P011	2.98	3.5	2.01	2.68	2.45	2.46	2.51	2.48	2.12	2.34
18	NR17C2aF91P004	4.41	3.16	2.85	3.6	2.37	2.89	3.55	3.52	2.09	2.72
19	NR17C2aF7P030	3.84	4.51	2.63	2.62	2.9	2.71	4.01	5.09	4.59	6.54
20	NR17C2aF16P004	3.07	4.54	3.44	3.92	4.32	4.17	4.47	4.28	6.67	6.59
21	NR17C2aF39P002	4.46	5.75	3.76	4.97	5.69	4.18	7.58	7.41	6.03	4.17
22	NR17C2aF98P001	3.72	3.15	4.75	3.3	2.31	2.74	2.57	4.07	3.3	3.55
23	NR17C2aF7P067	4.24	3.27	7.57	14	13.3	14.5	13.7	13.9	8.16	4.09
24	NR17C2aF12P001	3.18	2.96	8.6	5.87	3.37	2.52	6.31	8.01	7.81	14.5
25	NR17C2aF97P002	11	14.5	8.15	14.5	4.06	14.5	6.59	5.87	5.23	5.33
26	NR17C2aF61P016	6.06	4.46	2.58	4.61	3.28	3.69	3.1	3.16	5.09	2.6
27	IITA-TMS-IBA00070	10.1	14.5	9.5	14.5	7.02	8.54	14.5	14.5	5.31	14.5
28	NR17C2aF7P065	14.5	3.21	8.76	6.53	14.5	14.5	14.2	12.6	14	5.98
29	NR17C2aF21P004	4.03	14.6	6.32	14.6	10	14.5	7.08	4.55	8.46	7.73
30	NR17C2aF83P010	14.6	14	9.25	8.61	14.5	14.5	12.8	12.6	12	14.6
31	NR17C2aF99P002	5.49	8.48	5.17	8.22	5.69	7.11	2.68	10.3	6.3	5.78
32	NR17C2aF62P015	3.12	4.99	6.23	5.14	2.54	4.9	4.49	4.68	6.55	3.56
33	NR17C2aF9P013	7.16	8.11	6.7	5.25	14.5	14.5	14.5	14.5	13.6	14.5
34	NR17C2aF79P008	14.3	14.6	1.92	1.7	14.5	14.6	4.61	4.13	5.21	14.5

CODE	ACCESSION NAME	ROOT 1		ROOT 2		ROOT 3		ROOT 4		ROOT 5	
		A	B	A	B	A	B	A	B	A	B
35	NR17C2aF7P044	1.7	4.05	1.57	1.9	2.84	2.47	2.82	2.44	3.85	2.82
36	NR17C2aF54P010	3.67	14	14.3	14.4	14.6	14.5	14.5	14.5	14.5	14.5
37	NR17C2aF27P001	8.8	14.5	14.5	14.5	8.65	12.2	6.14	5.41	2.64	4.14
38	NR17C2aF91P001	5.54	5.01	6.63	5.66	13.7	7.86	10.4	7.77	9.15	3.7
39	CHENKE	1.55	1.92	1.73	1.74	2.01	2.06	2.15	1.68	1.8	2.02
40	WONONO	6.29	9.92	4.12	4.53	2.3	2.95	4.13	6.62	4.09	5.07
41	1368	5.95	8.08	6.95	5.66	4.95	5.52	8.76	5.76	5.25	3.48
42	505	1.03	1.39	1.99	2.09	2.38	2.5	1.37	1.44	2.5	1.69

Table 4 Penetrometer readings of firmness (kgF/cm^2) of retted cassava genotypes at 72 h

CODE	ACCESSION NAME	ROOT 1		ROOT 2		ROOT 3		ROOT 4		ROOT 5	
		A	B	A	B	A	B	A	B	A	B
1	NR17C2aF7P008	3.45	2.04	2.24	2.52	3.05	4.18	2.16	2.4	2.81	2.68
2	NR17C2aF62P020	1.37	0.93	0.79	1.19	1.24	1.35	0.61	0.81	0.75	0.63
3	NR17C2aF70P008	4.19	4.45	3.47	2.87	2.34	2.42	2.26	3.18	2.08	1.53
4	NR17C2aF61P007	2.96	2.55	3.32	2.95	2.29	2.41	2.25	2.46	1.99	2.36
5	NR17C2aF5P026	2.33	1.95	1.09	1.88	2.48	2.64	2.19	2.35	2.12	1.94
6	NR17C2aF60P009	1.9	1.32	2.09	2.39	2.57	3.23	1.96	2.37	1.45	1.52
7	NR17C2aF89P028	1.82	1.82	1.74	1.18	1.83	1.8	1.47	1.61	2.02	1.89
8	NR17C2aF79P016	2.31	2.95	1.76	2.62	2.12	1.92	1.53	2.2	1.43	1.64
9	TMEB419	1.08	1.38	1.89	2.22	1.7	1.66	1.84	1.99	1.77	2.04
10	NR17C2aF16P010	1.36	1.07	1.42	1.96	1.54	2.03	2.34	2.67	2.33	3.73
11	NR17C2aF92P001	1.83	2.01	1.79	1.57	2.14	2.51	3.15	2.44	3.4	3.17
12	NR17C2aF61P008	1.1	1.28	1.95	1.6	1.17	0.91	2.17	1.16	1.62	2.28
13	NR17C2aF79P005	2.31	2.38	2.47	1.96	1.62	1.88	2.38	2.43	3.4	3.17
14	NR17C2aF16P013	2.38	2.43	2.14	1.85	1.29	1.4	3.48	2.85	4.65	4.14
15	NR17C2aF103P001	2.11	2.08	2.27	2.53	0.87	1.64	2.18	2.22	3.42	2.49
16	NR17C2aF95P003	2.71	2.12	1.23	1.01	2.07	2.35	2.81	3.42	3.76	3.32
17	NR17C2aF91P011	1.73	1.96	1.59	2.03	2.37	3.02	2.2	1.79	2.23	1.9
18	NR17C2aF91P004	1.68	1.62	1.6	1.98	1.96	2.11	1.65	1.21	1.35	2.14
19	NR17C2aF7P030	1.74	2.6	1.98	1.34	1.92	1.9	1.93	1.82	2.5	1.91
20	NR17C2aF16P004	1.95	1.03	2.04	2.12	1.63	1.21	2.16	1.22	2.97	2.31
21	NR17C2aF39P002	1.8	2.12	2.15	2.68	4.21	2.79	1.77	1.78	2.57	3.04
22	NR17C2aF98P001	1.63	0.88	1.29	1.63	1.8	1.96	2.5	2.13	1.8	2.04

CODE	ACCESSION NAME	ROOT 1		ROOT 2		ROOT 3		ROOT 4		ROOT 5	
		A	B	A	B	A	B	A	B	A	B
23	NR17C2aF7P067	1.51	2.5	3.78	3.01	2.87	1.85	4.54	3.41	3.97	3.6
24	NR17C2aF12P001	1.83	2.11	2.01	1.69	2.59	3.01	1.88	2.07	4.3	2.88
25	NR17C2aF97P002	1.69	1.1	4.67	5.06	2.32	2.21	3.29	2.4	3.03	3.01
26	NR17C2aF61P016	1.58	1.23	1.31	2.35	2.96	2.75	2.67	2.5	1.89	2.1
27	IITA-TMS-IBA00070	2.82	1.88	5.92	5.91	7.5	6.16	2.45	2.85	3.91	4.98
28	NR17C2aF7P065	2.68	2.26	3.91	3.54	2.75	2.88	3.13	3.32	4.75	5.08
29	NR17C2aF21P004	2.53	2	2.99	3.57	1.66	1.17	2.91	2.21	4.95	4.4
30	NR17C2aF83P010	4.15	3.68	4.13	3.76	3.89	5.18	2.66	3.64	5.42	6.79
31	NR17C2aF99P002	3.14	3.4	5.06	4.97	3.76	5.55	3.07	3.52	4.79	4.43
32	NR17C2aF62P015	1.77	2.32	2.05	2.37	2.67	2.28	1.99	1.97	2.31	2.52
33	NR17C2aF9P013	4.48	5.18	5.13	6.57	3.38	4.35	6	4.38	4.18	4.31
34	NR17C2aF79P008	3.17	2.44	3.03	2.82	3.99	2.78	4.3	3.54	3.26	3.07
35	NR17C2aF7P044	1.63	1.09	1.51	0.76	1.63	2.17	1.91	1.89	1.93	1.95
36	NR17C2aF54P010	3.95	2.77	2.4	2.69	4.28	5.82	4.3	4.08	5.32	5
37	NR17C2aF27P001	2.84	4.04	2.59	2.5	2.91	2.87	2.49	3.33	2.61	2.66
38	NR17C2aF91P001	3.14	3.74	1.56	2.22	2.9	2.14	3.74	4.6	3.25	2.17
39	CHENKE	1.12	0.95	1.11	1.18	1.18	0.94	1.21	0.76	0.83	1
40	WONONO	1.33	0.94	2	1.42	1.08	1.25	2.07	3.07	2.83	3.02
41	1368	1.6	1.38	1.5	1.65	2.21	2.45	0.77	1.31	2.01	2.14
42	TMS980505	1.29	1.16	1.97	1.71	2.3	1.95	1.42	1.5	1.49	2.74

Tables 1 - 4 show the penetrometer readings (in duplicate) of the different cassava genotypes as their retting/softening progresses from 0h to 72h. As retting progresses, there is a reduction in firmness of the cassava roots. The penetrometer readings at 0h (Table1) ranges from 4.9 to 14.7 kgf/cm^2, at 24h (Table 2) it ranges from 2.5 to 14.7 kgf/cm^2, at 48h (Table 3) it ranges from 0.8 to 14.6 kgf/cm^2, while at 72h (Table 4) it ranges from 0.61 to 7.5 kgf/cm^2. Due to some values here close to the maximum limit of 15 kgf/cm^2, we recommend to use a thinner penetration tip or lower test speed. According to Ampe and Brauman (1995), retting of cassava roots during fermentation may be attributed to enhanced activity of pectinolytic and cellulolytic enzymes. This process results in the rupture of the plasmalema of individual cells leading to starch release.

8 CRITICAL POINTS OR NOTES ON THE PROCEDURE

- Ensure that good and healthy fresh cassava roots are selected for the analysis.
- The volume of water for soaking is dependent on the size and quantity of cassava roots used. The volume of water should be enough to completely submerge the roots.

- Before daily use of the instrument, ensure the plunger is pressed and depressed in and out for 10 s to ensure the mechanism functions properly.
- Clean the penetrometer tips after usage before storing.
- To clean, hold the tester with the load shaft pointing down under slowly flowing water for a few seconds, dry it with a towel and allow it to air-dry upright with the shaft still pointing down.

9 APPENDIX

9.1 Example of data on firmness of cassava during the retting duration (0 - 72 h)

Genotype

The genotypes are numbered 1 to 42 for simplicity.

Genotype number	Genotype
1	NR17C2aF7P008
2	NR17C2aF62P020
3	NR17C2aF70P008
4	NR17C2aF61P007
5	NR17C2aF5P026
6	NR17C2aF60P009
7	NR17C2aF89P028
8	NR17C2aF79P016
9	TMEB419
10	NR17C2aF16P010
11	NR17C2aF92P001
12	NR17C2aF61P008
13	NR17C2aF79P005
14	NR17C2aF16P013
15	NR17C2aF103P001
16	NR17C2aF95P003
17	NR17C2aF91P011
18	NR17C2aF91P004
19	NR17C2aF7P030
20	NR17C2aF16P004
21	NR17C2aF39P002
22	NR17C2aF98P001
23	NR17C2aF7P067
24	NR17C2aF12P001
25	NR17C2aF97P002
26	NR17C2aF61P016
27	IITA-TMS-IBA00070
28	NR17C2aF7P065
29	NR17C2aF21P004
30	NR17C2aF83P010
31	NR17C2aF99P002
32	NR17C2aF62P015
33	NR17C2aF9P013
34	NR17C2aF79P008
35	NR17C2aF7P044
36	NR17C2aF54P010
37	NR17C2aF27P001

38	NR17C2aF91P001
39	CHENKE
40	WONONO
41	1368
42	TMS980505

Statistical accuracy of firmness of cassava genotypes during retting

One-way ANOVA of Firmness (Kgf) By Genotype

Retting duration (h)	Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
0	Genotype	41	425.21183	10.3710	6.9090	1.2e-26
24	Genotype	41	1015.8112	24.7759	6.2270	1.32e-23
48	Genotype	41	4203.3936	102.522	15.5203	1.44e-58
72	Genotype	41	322.05735	7.85506	13.3514	1.57e-51

One-way ANOVA of retting firmness as influenced by retting duration (Combined hours)

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Retting time	3	4016.2439	1338.75	367.9806	1.4e-72
Error	164	596.6474	3.64		
C. Total	167	4612.8913			

Means and Std Deviations

Retting duration (h)	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
0	42	13.956333	1.0183821	0.1571398	13.638983	14.273684
24	42	13.26141	1.5740357	0.242879	12.770905	13.751914
48	42	5.7545952	3.2019025	0.4940643	4.7568122	6.7523783
72	42	2.4853333	0.8862876	0.1367571	2.2091467	2.76152

Means Comparisons

Connecting Letters Report

Retting duration (h)				Mean
0	A			13.956333
24	A			13.261410
48		B		5.754595
72			C	2.485333

Levels not connected by same letter are significantly different

Repeatability of retting firmness measurements

Oneway Anova of Firmness (Kgf) By Replicates (root) 0h

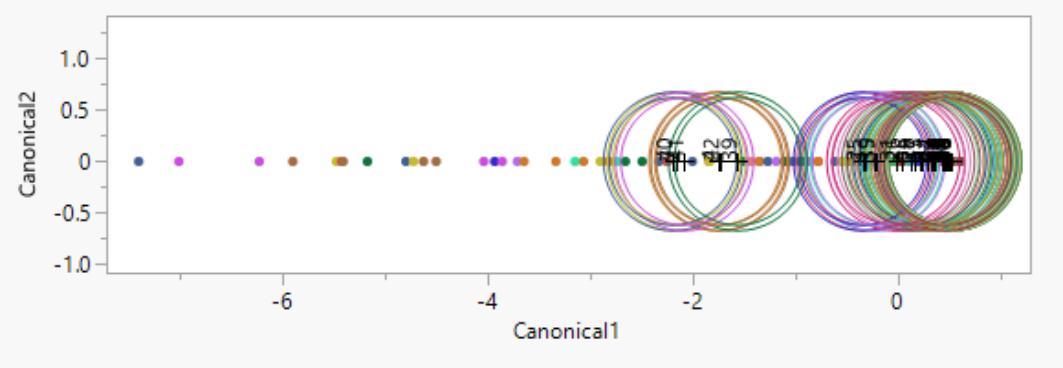
Analysis of Variance

Retting duration (h)	Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
0	Replicates (root)	4	14.66626	3.66657	1.5559	1.852e-1
24	Replicates (root)	4	168.9233	42.2308	7.4551	8.321e-6
48	Replicates (root)	4	19.5002	4.8750	0.3028	8.76e-1
72	Replicates (root)	4	19.09389	4.77347	3.7708	5.02e-3

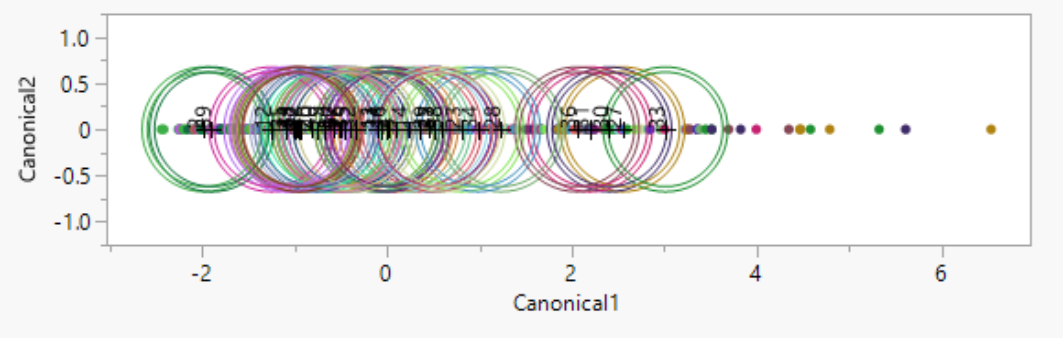
There was significant difference between the firmness of the genotypes at each of the different retting durations, especially at 48h and 72h. There was no significant difference in the firmness of the genotypes at 0h and 24h, probably due to the values been close to maximum limit. There was good repeatability between firmness for replicate measurements at 0h and 48h. Overall, the retting duration had even more significant effect on firmness of cassava than the genotype effect. In addition, the most significant effects of the factors on cassava firmness during retting can be ranked according to genotype > genotype*replicates > replicates.

Discriminance between genotypes and between different retting durations

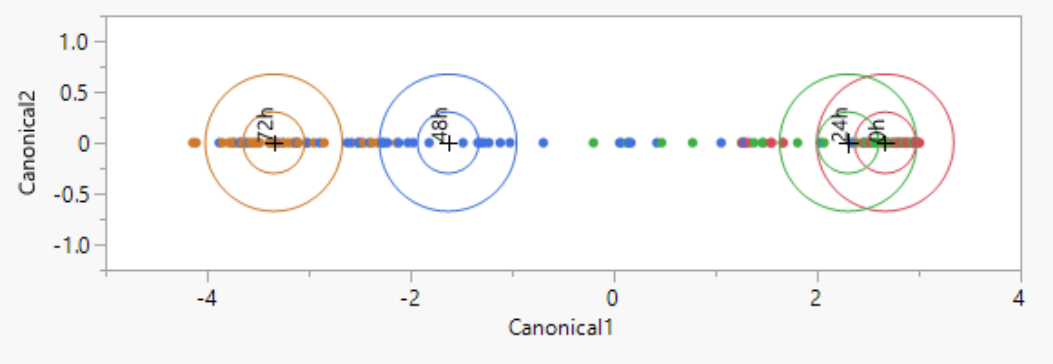
By genotypes (0 h)



By genotypes (72 h)



By retting duration (0 - 72 h)

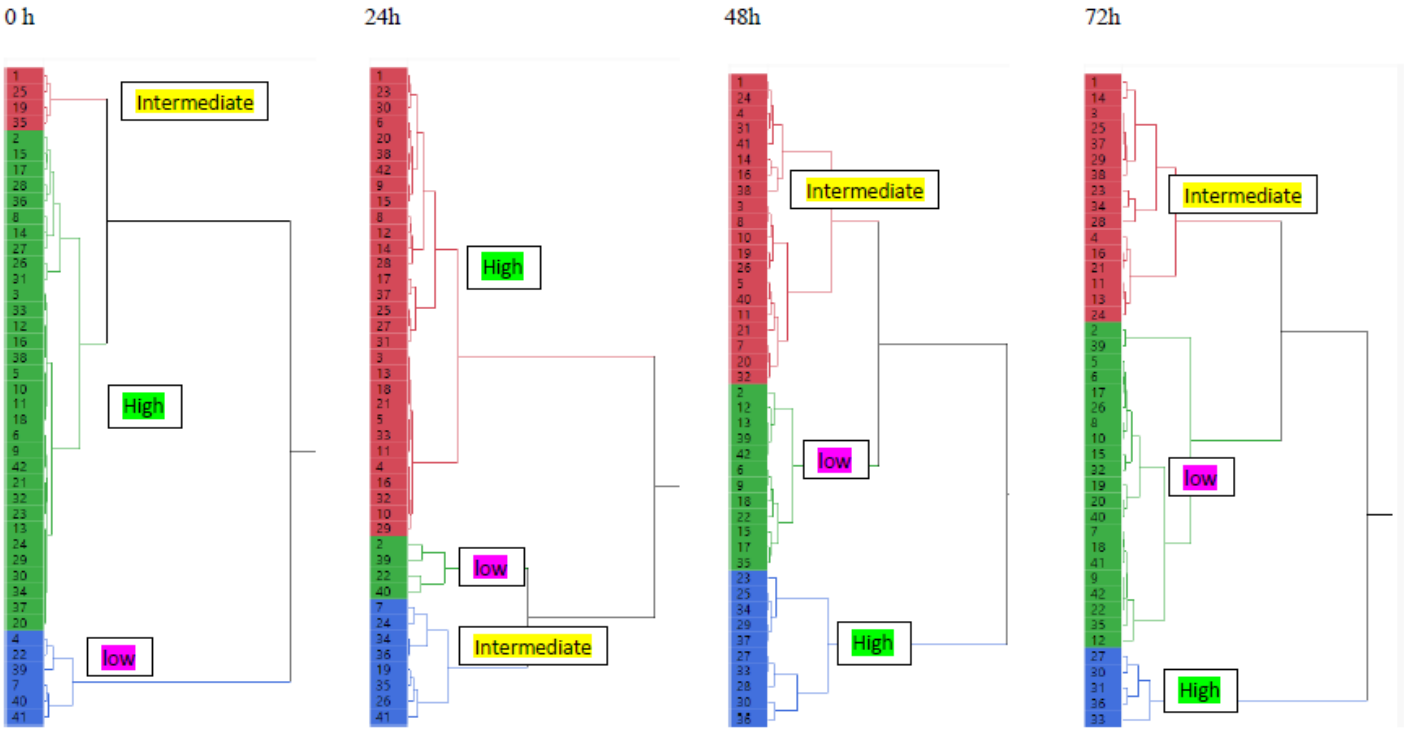


Discriminant canonical charts of 42 cassava genotypes during retting at 0 and 72 h, and between 0 - 72 h

Hierarchical classification

Generally, the proportion of cassava genotypes with low retting firmness increased as retting duration increased. In contrast, the proportion of cassava genotypes with high retting firmness decreased as retting duration increased. This shows that there was significant decrease in firmness during retting, but this is significantly dependent on the genotype.

In addition, there was minor discrimination in firmness of the genotypes at 0 h and 24 h of retting, but the discriminance was very significant at 48 h and 72 h of retting when the firmness decreased very significantly.



Hierarchical classes of cassava genotypes based on firmness during retting at different durations (0 – 72 h) having low (fast retting ability), intermediate (intermediate retting ability) and high (slow retting ability) firmness

In conclusion, the hand-held penetrometer may be useful in discriminating between cassava genotypes as fast, intermediate or slow retting during retting into fufu. However, there may need to be more control over operation of the device especially regarding a regular test speed during measurements.

10 REFERENCES

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