Standard Operating Protocol for Characterization of Extrusion-Texture of Boiled Cassava

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Thierry TRAN, CIAT, Colombia

Andrés ESCOBAR, CIAT, Colombia

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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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RTBfoods / RTB Breeding

SOP: Characterization of Texture-Extrusion of Boiled Cassava

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Written by: Thierry Tran, Andrés Escobar, Alejandra Ospina

For information on this SOP please contact :

- Thierry Tran (thierry.tran@cgiar.org or thierry.tran@cirad.fr)
- Alejandra Ospina (m.a.ospina@cgiar.org)

This document has been reviewed by:

Layal DAHDOUH (CIRAD)	02/12/2019
Oluwatoyin AYETIGBO (CIRAD)	05/04/2022
Christian MESTRES (CIRAD)	17/12/2022

Final validation by:

Oluwatoyin AYETIGBO (CIRAD)	02/01/2023

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ABSTRACT

Cassava is often consumed in the boiled form in Africa, Asia and South America. The food product is easy to prepare by simply boiling in water. Most consumers prefer mealy, sufficiently soft, and easy to cook boiled cassava. The SOP describes the procedures for sampling, sample preparation, boiling, and measurement of extrusion-texture parameters of boiled cassava using a texture analyzer fitted with a 5-blade grid Ottawa cell system. The texture parameters measured are Initial gradient, Maximum force, End force, Area under curve, Linear distance, and End force : Maximum force ratio. The texture parameters were found to be discriminant between the genotypes.

Keywords: boiled cassava, texture-extrusion, SOP, Ottawa cell, trigger force

1 SCOPE AND APPLICATION

This SOP describes the preparation of cassava root samples for boiling tests to measure extrusion texture of boiled cassava using a texture analyzer. This SOP has been developed by building upon previous knowledge and experience of other research teams (from Brazil and Benin in particular), key references of whom are indicated in section 10. The shape and size of the root pieces for boiling are selected to (1) be representative of the pieces of cassava roots typically used for boiling in Colombia; (2) be suitable for the texture-extrusion protocol developed at CIAT for RTBfoods in 2019-2020 (Ottawa cell with 5-blade extrusion grid).

The SOP includes the handling of cassava roots after reception from the field on the day of harvest, preparation of samples for boiling and characterizations (texture), and allocation of identification codes for each sample. Further characterizations such as water absorption, cooking time, closing angle and NIRS of fresh roots and boiled roots are described in separate SOPs.

2 PRINCIPLES AND DEFINITIONS

When roots are delivered from the field by the breeders (RTBfoods Work Package 4) for cooking tests and high-throughput phenotyping (HTPP) analyses (such as Near Infra-Red Spectroscopy, NIRS), they are transformed typically as follows: Washing and peeling; cutting into pieces of appropriate size for boiling; rasping the remaining parts of the root for dry matter and NIRS, and preservation by drying (45°C or lyophilisation) for further analyses (e.g. extraction and characterization of cell wall materials, CWM).

Pieces of cassava roots cut for the boiling experiments are placed in boiling water and subjected to various boiling times depending on the type of analysis. For texture-extrusion, the set of cassava roots pieces is boiled for 18 minutes (T18) for texture measurements. The 18 minutes of boiling allows a comparison of texture across genotypes with discriminative characters, as the roots are not fully cooked and present a wide range of textures depending on the genotype.

For texture analysis, pieces of boiled roots are placed in closed containers (to limit water evaporation) and left to cool exactly 10 minutes after removal from boiling water, placed on the Ottawa texture-extrusion grid (Fig 6 & 7), and pushed through the grid with a piston moving at constant speed (1 mm/s). The force necessary to maintain the speed at 1 mm/s is recorded as a function of the distance travelled. The resulting texture profile of the sample is used to analyse various parameters to characterize the texture of the sample, such as gradient at origin, maximum force, force at end of compression, area under the curve, linear length of the curve, and end force: maximum force ratio.

Remark: This SOP focuses on boiling and texture analysis; however, several biophysical characterizations described in other SOPs (water absorption (WAB), cooking time, dry matter, HCN, NIRS, CWM) form a package to be conducted on the same batch of roots in order to develop HTPP predictions from NIRS data. The high variability that is sometimes observed between roots of the same cassava genotype (and of the same plant in some cases) makes it necessary to conduct all the biophysical characterizations and the HTPP analyses (NIRS) on the same batch of roots, preferably cut in pieces and mixed together so as to obtain homogeneous samples representative of the whole batch.

3 PREREQUISITE

Using and managing a texture analyzer.

4 APPARATUS

a. Texture analyzer with load cell able to measure forces at least 50 kg (the model used for the development of this SOP is a TA-XTPlus by Stable Microsystem) equipped with an Ottawa texture-extrusion cell (A/OTC).
b. Gas cooker with several fires to boil several samples simultaneously. Ensure the room/laboratory has good ventilation and the gas inlet valve is closed when not in use.
c. Large cooking pots (capacity at least 5 litres of water): (1) to enable boiling several root pieces in the same pot, ensuring boiling at the same temperature; (2) to minimize temperature variations upon introduction of the root pieces in the water.
d. Temperature probe or thermometer to check the temperature of boiling water.
e. Heat-resistant trays or containers to hold pieces of roots above the bottom of the cooking pots. The trays should be pierced with holes to ensure unhindered flow of the water within the cooking pot and homogeneous temperature.
f. Plastic boxes with lids to store the boiled pieces of cassava before texture analysis.
g. Chronometer.

5 PRODUCT PREPARATION: BOILED CASSAVA

5.1 Sampling and preparation of cassava roots

Select at least three roots per genotype as follows: Minimum length 25 cm (Fig 1) and minimum diameter 5.5 cm (Fig 2). These dimensions are important to be able to cut pieces of suitable size for boiling (Fig 3), and to prepare samples for NIRS analysis from the same root.

Remark: To carry out multiple analyses (texture, water absorption, NIRS, dry matter, etc.) of the same genotype, a minimum of nine roots is necessary to capture the variability of cooking behaviour. In particular, texture analysis requires at least three roots, and WAB/optimum cooking time measurements require six roots. If more roots of suitable size are available, it is recommended to use them and increase the number of samples and representativeness of the results.

Figure 1: Minimum length of cassava root: 25 cm

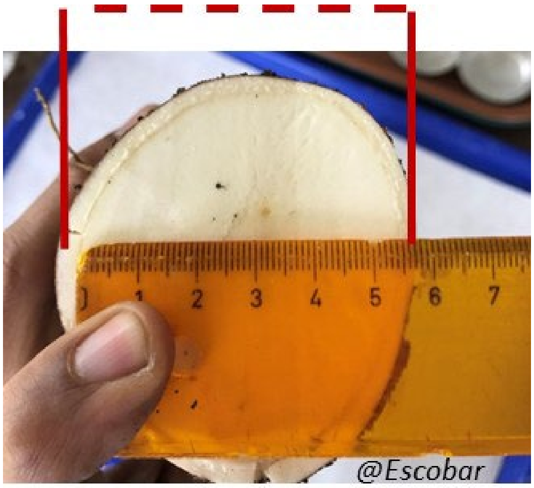

Figure 2: Minimum diameter 5.5 cm

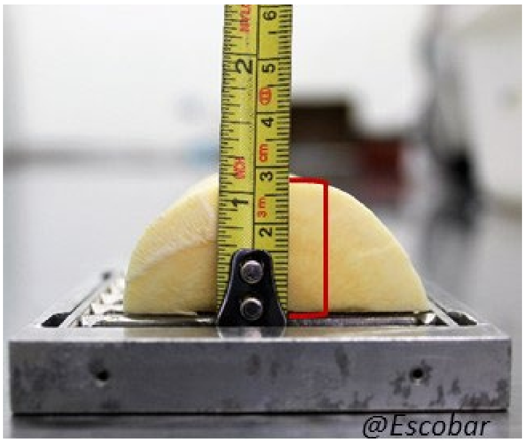

Figure 3: Minimum radius 2.5 cm for texture test

5.2 Preparation of root pieces for boiling

After washing and peeling the roots, divide each root as follows:

For texture analysis, select at least three roots, and cut six pieces per root in the shape of half cylinders, about 6 cm long and 5.5 cm diameter (Fig 2, 3 and 4). For better representativeness, and if enough roots are available, cut half-cylinders from more than three roots, e.g. use six roots and cut three half-cylinders from each root (see also Tran et al., 2021). If several lab analyses are to be carried out concurrently (e.g. texture, NIRS, water absorption, etc.), even more roots can be used so as to produce homogeneous batches of root pieces for each analysis, all comparable among each other and representative of the genotype (see example on figure 5 in the case of 12 roots distributed among five lab analyses).

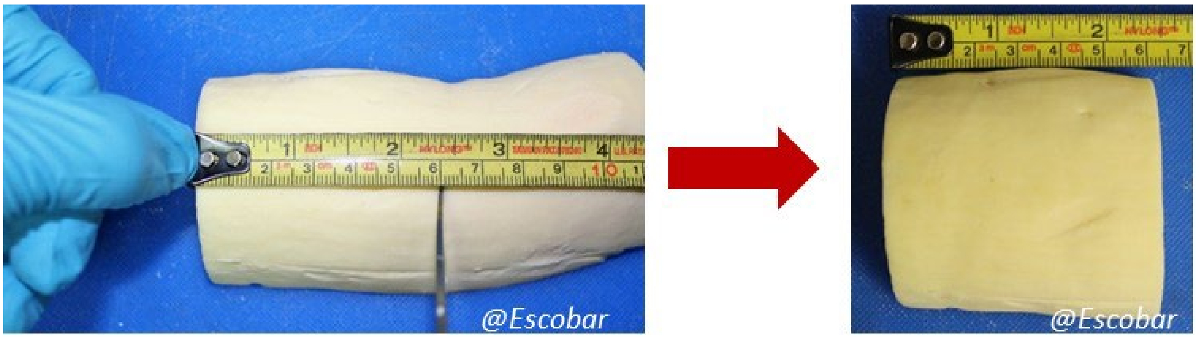

Figure 4: Length of the half cylinder for boiling: 6 cm

Figure 4: Length of the half cylinder for boiling: 6 cm

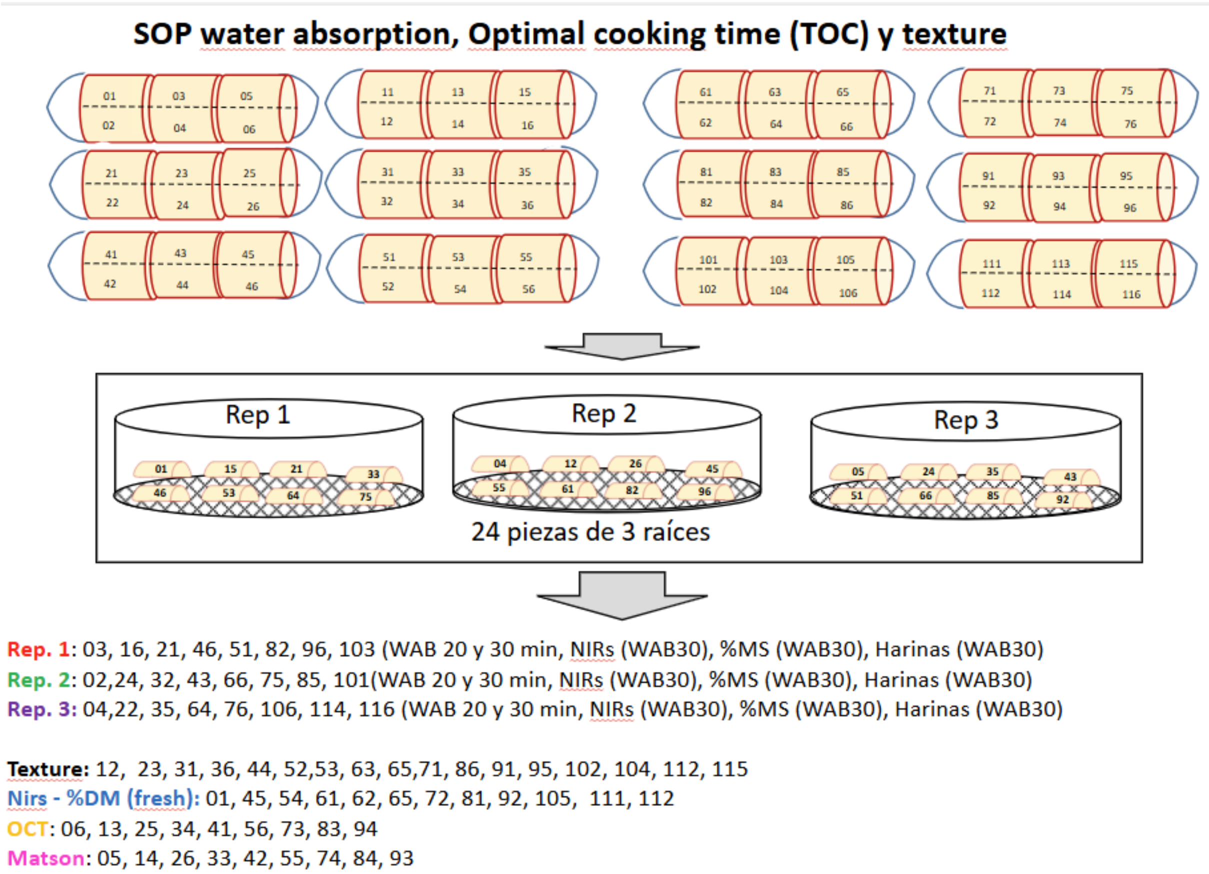

Figure 5. Example of cassava root cutting to prepare samples for concurrent phenotyping of various cooking quality attributes (texture-extrusion; water absorption replications 1, 2 and 3; NIRS; dry matter; optimum cooking time (OCT); cooking time by Mattson cooker). A total of 12 roots (of same genotype harvested from the same field on the same day) are used, from which 72 pieces (half-cylinders) are cut. The pieces are numbered in advance (in order proximal end to central to distal end: 01 to 06 for root 1, 11 to 16 for root 2, etc. until 111 to 116 for root 12), and distributed semi-randomly to the various lab analyses. This cutting plan ensures that all lab analyses are carried out on homogeneous batches of root pieces, all comparable among each other and representative of the genotype.

Place the 18 pieces (half-cylinders) in a cooking pot with boiling water, and cook for exactly 18 minutes. It is recommended to do a staggered cooking, whereby the 18 pieces are cooked in three batches of six pieces. This facilitates the exact control for all the pieces, of the cooking time (18 minutes) and of the cooling time (10 minutes) after cooking and before texture analysis. For texture analysis, it is not necessary to identify the 18 pieces individually because the aim is to calculate the average of the data from the 18 pieces. Nevertheless, it is recommended to record the diameter and length of the pieces for an optional experimental normalization of texture data later.

6 TEXTURE MEASUREMENT AT BOILING TIME 18 MINUTES

Place the 18 pieces of root prepared for texture analysis in boiling water, and cook for 18 minutes exactly. It is recommended to do a staggered cooking, as described in section 5. At 18 minutes of boiling, remove the pieces and allow them to cool for exactly 10 minutes before performing the texture-extrusion test. During cooling, place the pieces in a closed container to limit the loss of moisture by evaporation (Fig 6).

Figure 6: Cooling down of boiled cassava pieces for 10 minutes in a closed container to minimize moisture loss before texture analysis

Equipment: Texture analyser. For this SOP, a TA-XTPlus (Stable Microsystems) equipped with a 50kg load cell was used.

Method: Extrusion using Ottawa cell with 5-blade grid

Pre-test speed	**2 mm/s**
Test Speed	**1 mm/s**
Trigger force (when the probe touches the surface of the sample)	**1000 g**
Target distance	**20 mm**
Temperature of test	**40 – 50 °C** in heart of product

Following the root cutting protocol above (section 5), one cassava root yields 6 pieces (half-cylinders 6 cm long x 2.5 cm diameter) for boiling. Use at least three cassava roots from each genotype for texture measurements, so that you have 18 pieces of boiled cassava per genotype.

- Boil the 18 pieces for 18 minutes (T18).
- After cooling (10 minutes), analyze the 18 pieces with the fibers positioned perpendicular to the blades of the extrusion grid (Fig 7 & Fig 8).

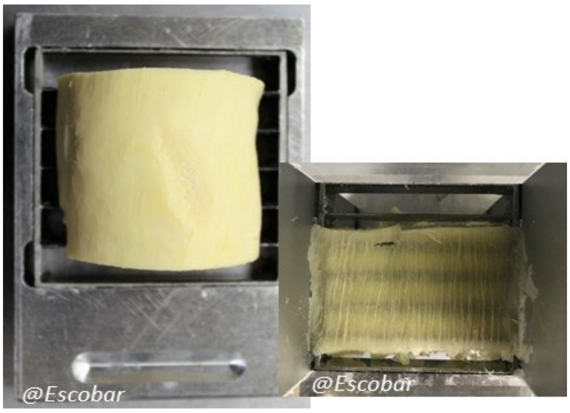

Figure 7: Fibers perpendicular to the blades

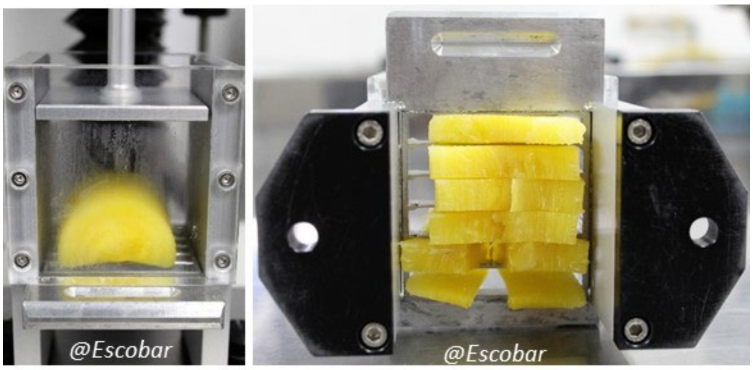

Figure 8: Texture analysis with fibers perpendicular to the blades

<u>Grid used for the texture-extrusion test:</u> The standard extrusion grid provided by Stable Microsystems for the TA-XTPlus texture analyser comes with 8 blades. However, with 8 blades the extrusion of boiled cassava roots exceeds the maximum load (50 kg) of the instrument. Consequently, an ad-hoc 5-blade grid was designed (Fig 9) to replace the standard 8-blade grid.

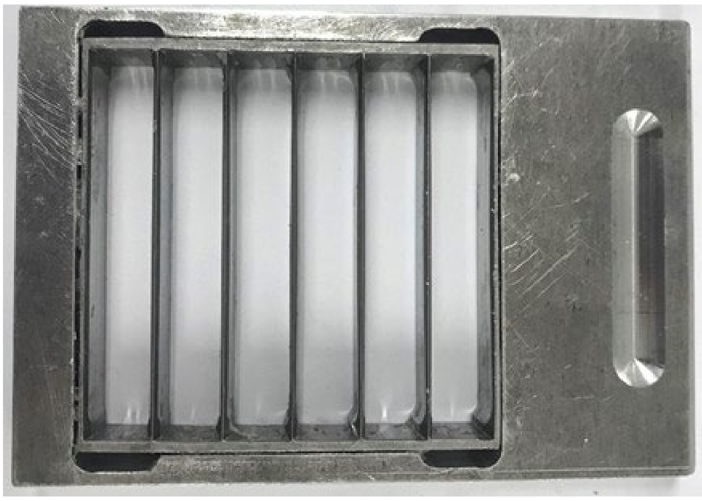

Figure 9: Ad-hoc 5-blade grid used for texture-extrusion analysis of boiled cassava roots

The settings of the texture-extrusion test are shown below (Fig 10).

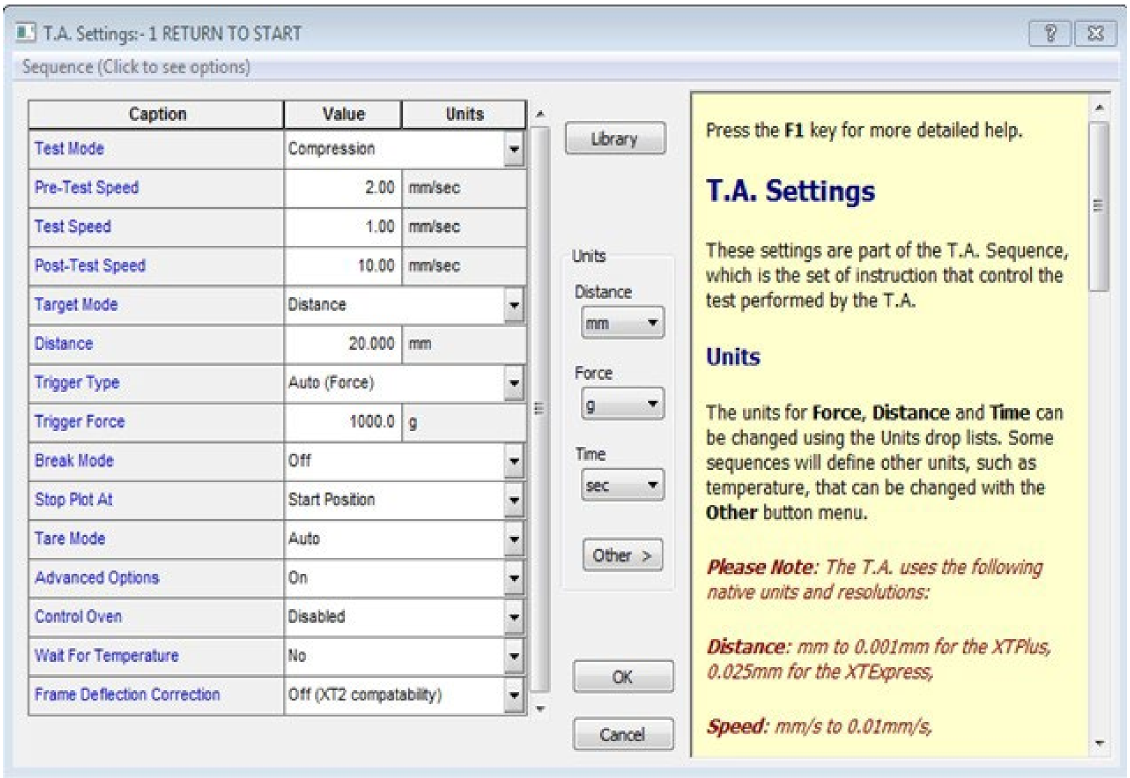

Figure 10: Parameters for the texture analysis by extrusion of boiled cassava roots

7 EXPRESSION OF TEXTURE ANALYSIS RESULTS

7.1 Summary of parameters from texture-extrusion analysis

Parameters to analyze from the texture-extrusion curves (Fig 11) are summarized in Table 1.

Table 1: Parameters to analyse from the texture-extrusion curves of boiled cassava

Parameter	Unit	Definition
Initial gradient	g/mm	Slope of the texture curve at the beginning of the extrusion. The slope should be recorded between 0 and 1 mm travel distance (based on preliminary experiments showing that with longer distances, e.g. 0 to 2 or 0 to 3 mm, in some cases the texture curve ceases to be straight, and/or peaks and throughs start to appear). Initial gradient may be interpreted as the elastic deformation of the sample (Young's modulus), i.e. the initial deformation the sample can undergo before elements of its structure start to break (and dissipate energy).

Max. force	g	Maximum force recorded during the extrusion experiment. Maximum force may be related to the sensory hardness perceived by sensory analysis panellists.
Distance at Max. force	mm	Distance at which the maximum force occurs during the extrusion experiment. A short distance at Max. force indicates that "something" breaks in the structure of the sample during the extrusion. In contrast a long distance at Max. force indicates that the sample deforms without breaking during extrusion, thus indicating a smoother texture (possibly related to a softer, more melting or mealy sensory perception of the texture).
End force at 20 mm	g	Force at the end of the extrusion, i.e. force at the maximum travel distance of 20 mm.
Area under curve	g.mm	Full area under the curve, i.e. between 0 and 20 mm travel distance. This area represents the work (energy) required to carry out the extrusion test.
Linear distance	g.mm	Linear length of the extrusion curve from 0 to the maximum distance (20 mm). The linear distance can give an indication of the behaviour of the fibers within the sample; for example a sample with more fibers resisting breaking will show more peaks and troughs, and hence a longer linear distance.
End force / Maximum force ratio	(-)	Ratio calculated as follows: End force divided by Maximum force. This parameter gives an indication of the drop in hardness of the sample after the maximum force is reached. A large drop can indicate samples with a harder outer layer protecting a softer center; whereas a small drop can indicate a more homogeneous level of hardness between the center and the outer parts of the sample.

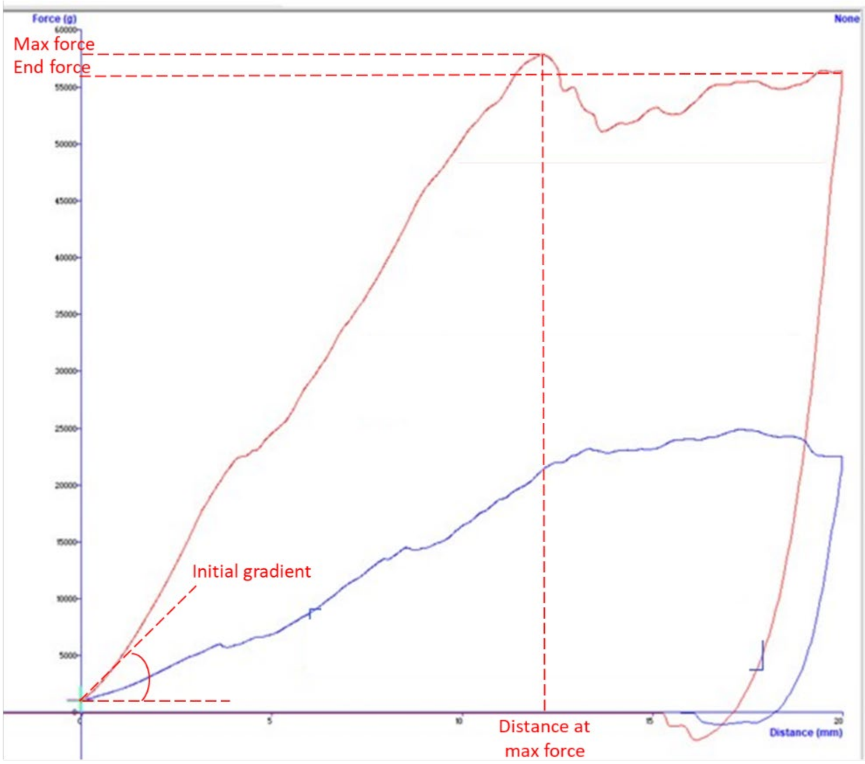

Figure 11: Example of two texture-extrusion curves of boiled cassava (fibers parallel to the blades of the extrusion grid).

7.2 Optional (under experimental development): Normalization of the texture-extrusion parameters

Due to natural variations between cassava roots, it is not always possible to prepare half-cylinders for boiling and texture, with exactly the same target radius of 2.5 cm. Because the force recorded by the texture analyser during the extrusion test depends on the size of the half-cylinders, it may be necessary to normalize the texture parameters related to force measurements, by taking into account the dimensions of the root samples. This section describes an optional normalization procedure of the texture-extrusion parameters (although still under development and testing).

A possible normalization factor is the initial surface (S) of the half-cylinder in contact with the extrusion grid, i.e.:

S = l x d

With: l = length of the half-cylinder = 60 mm (length fixed by the SOP)
d = diameter of the half-cylinder. *d* needs to be measured for each sample and reported in the template for reporting texture data (Table 6 in Appendix).

Units: Length (l) and diameter (d) to be expressed in mm, and S in mm^2.

The normalized parameters are then calculated as follows (Table 2):

Normalized parameter = Parameter / S

Table 2: Optional: Normalized parameters to calculate from the texture-extrusion curves of boiled cassava

Parameter	**Unit**	**Definition**
Normalized Initial gradient	(g/mm)/ mm^2	Slope of the texture curve at the beginning of the extrusion, normalized by the initial surface of the sample in contact with the extrusion grid. The slope should be recorded between 0 and 1 mm travel distance (based on preliminary experiments)
Normalized Max. force	g/mm^2	Maximum force recorded during the extrusion experiment, normalized by the initial surface of the sample in contact with the extrusion grid
Distance at max. force	mm	Distance at which the maximum force occurs during the extrusion experiment
Normalized End force at 20 mm	g/mm^2	Force at the end of the extrusion, i.e. at the maximum travel distance of 20 mm, normalized by the initial surface of the sample in contact with the extrusion grid
Normalized Area under curve	g.mm)/mm^2	Full area under the curve, i.e. between 0 and 20 mm travel distance, normalized by the initial surface of the sample in contact with the extrusion grid. This area represents the work (energy) required to carry out the extrusion test.

Normalized Linear distance	(g.mm)/ mm^2	Linear length of the extrusion curve from 0 to the maximum distance (20 mm), normalized by the initial surface of the sample in contact with the extrusion grid. The linear distance can give an indication of the behaviour of the fibers within the sample; for example a sample with more fibers resisting breaking will show more peaks and throughs, and hence a longer linear distance.
End force / Maximum force ratio	mm^{-2}	Ratio calculated as follows: End force divided by Maximum force. This parameter gives an indication of the drop in hardness of the sample after the maximum force is reached. A large drop can indicate samples with a harder outer layer protecting a softer center; whereas a small drop can indicate a more homogeneous level of hardness between the center and the outer parts of the sample.

8 Critical points and Notes on the texture procedure

The trigger force is high (1000 g) due to the half-cylinder shape of the sample: For most samples, the surfaces of the half-cylinder are not parallel to the surface of the moving probe. Consequently below 1 kg, the probe is still adjusting to get in full contact with the cylinder; during that initial phase of compression, the data recorded relates to the shape of the half-cylinder, not to the texture of the sample; hence it is not relevant and is not recorded (to avoid confusion and errors during data analysis).

We have tested various trigger forces and found that 1000 g ensures that the whole surface of the cylinder is in contact with the probe, before the beginning of the measurement.

Also, because the extrusion distance is fixed (2 cm, due to the 2.5 cm radius of the smallest half-cylinder samples), if we trigger too early (with a trigger force lower than 1000g), the piece of root goes through the grid only partially and we cannot capture all the information we need on the texture of the sample (and we get more variability due to the shape of the half-cylinders, not due to their texture).

Difference between two determinations carried out simultaneously by the same analyst on the same sample should not exceed the following limits:

- Dimensions: lengths and diameters: ± 0.1 cm (= 1 mm).

The standard deviations for all measurements need to be assessed and included in the reports for RTBfoods.

9 Test report

The test report shall indicate the method used and the results obtained (cf. template in table 6 in Annex). In addition, it shall mention operating conditions not specified in the present SOP or modified from the SOP, as well as any circumstances that may have influenced the results.

The test report shall include all details necessary for the complete identification of the sample, in particular the full identification code according to the guidelines of the SOP *Sampling and allocation of standardized codes (WP2 and WP3).*

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APPENDICES

9.1 Appendix 1: Revision record

Date	Responsible person	Description of change

9.2 Appendix 2: Example of texture-extrusion test results and Anova showing the discriminance of the test

Table 3: Example of the beginning of a texture-extrusion dataset, showing 18 replications of the first two genotypes and the first five replications of the third genotype. The complete dataset includes 30 genotypes.

Field ID	Date	Test ID	Genotype	Gradient F-T 1:2	Max force	Distance at Max force	End force at 20mm	Area F-T 1:4	Linear Distance F-T 1:4	End force:Max force (%)
2	14012021	02_GUA24_1	GUA24	924.5	18264.7	14.9	14582.3	227849.3	21906.1	79.8
2	14012021	02_GUA24_2	GUA24	1952.0	14809.3	16.5	14057.1	220627.9	19504.2	94.9
2	14012021	02_GUA24_3	GUA24	1804.8	16739.9	10.9	11222.1	249031.6	23415.2	67.0
2	14012021	02_GUA24_4	GUA24	2609.5	49704.6	16.1	31030.0	495798.8	93325.6	62.4
2	14012021	02_GUA24_5	GUA24	609.3	9087.3	20.0	9087.3	120506.2	14841.4	100.0
2	14012021	02_GUA24_6	GUA24	772.5	17035.4	14.9	15748.0	260459.8	20128.1	92.4
2	14012021	02_GUA24_7	GUA24	817.6	23396.7	19.9	23365.1	209822.6	25219.4	99.9
2	14012021	02_GUA24_8	GUA24	1000.2	17129.9	8.8	16072.7	216440.4	29677.8	93.8
2	14012021	02_GUA24_9	GUA24	1996.0	24485.7	13.6	21311.5	336949.6	33334.8	87.0
2	14012021	02_GUA24_10	GUA24	2812.6	23262.6	11.5	17232.3	332219.7	29801.5	74.1
2	14012021	02_GUA24_11	GUA24	620.4	17106.3	16.8	16109.2	238278.7	18224.3	94.2
2	14012021	02_GUA24_12	GUA24	1481.9	18385.7	12.1	17143.9	276164.5	23684.2	93.2
2	14012021	02_GUA24_13	GUA24	710.1	15506.9	14.4	13897.3	213674.7	17764.0	89.6
2	14012021	02_GUA24_14	GUA24	530.7	15019.0	19.3	15018.9	173819.1	15193.8	100.0
2	14012021	02_GUA24_15	GUA24	2046.0	11086.8	11.2	9283.5	175025.9	14658.0	83.7
2	14012021	02_GUA24_16	GUA24	617.9	14034.9	11.9	12530.7	189212.1	17454.4	89.3
2	14012021	02_GUA24_17	GUA24	928.6	12062.0	19.9	12054.7	191335.1	17109.5	99.9
2	14012021	02_GUA24_18	GUA24	592.6	9301.9	20.0	9301.9	127006.2	10398.9	100.0
3	15012021	03_PER183_1	PER183	1576.1	24874.6	20.0	24874.6	261387.9	26611.9	100.0
3	15012021	03_PER183_2	PER183	782.7	16625.6	20.0	16625.6	164472.6	21135.5	100.0
3	15012021	03_PER183_3	PER183	-118.1	10011.2	20.0	10008.9	98109.2	9534.6	100.0
3	15012021	03_PER183_4	PER183	991.8	19213.2	20.0	19213.2	230058.7	19114.0	100.0
3	15012021	03_PER183_5	PER183	661.4	15321.4	19.8	15172.3	174991.8	15347.2	99.0
3	15012021	03_PER183_6	PER183	409.4	14028.2	19.8	13946.1	145111.1	14567.8	99.4
3	15012021	03_PER183_7	PER183	524.3	14830.8	20.0	14830.8	158911.1	14934.0	100.0
3	15012021	03_PER183_8	PER183	2163.0	45331.6	19.8	45207.9	462750.3	57379.3	99.7
3	15012021	03_PER183_9	PER183	664.0	17045.5	20.0	17045.5	147631.0	19132.2	100.0
3	15012021	03_PER183_10	PER183	853.3	20139.5	19.8	20088.5	192984.3	19987.0	99.7
3	15012021	03_PER183_11	PER183	1061.2	37252.4	20.0	37252.4	380712.7	40700.3	100.0
3	15012021	03_PER183_12	PER183	930.3	18127.8	20.0	18127.8	207396.3	18389.5	100.0
3	15012021	03_PER183_13	PER183	955.2	28369.4	20.0	28369.4	196562.9	27765.6	100.0
3	15012021	03_PER183_14	PER183	306.0	35068.6	20.0	35051.2	185403.2	34128.7	100.0
3	15012021	03_PER183_15	PER183	306.2	19158.1	19.8	19141.3	183259.2	19500.5	99.9
3	15012021	03_PER183_16	PER183	205.8	15370.4	20.0	15370.4	125870.4	14696.5	100.0
3	15012021	03_PER183_17	PER183	363.8	9020.4	20.0	9020.4	87875.9	8485.2	100.0
3	15012021	03_PER183_18	PER183	72.1	8389.3	20.0	8389.3	73197.3	7747.2	100.0
4	18012021	04_PER496_1	PER496	617.5	47742.1	20.0	47738.8	289971.6	47180.8	100.0
4	18012021	04_PER496_2	PER496	1636.5	21838.2	19.6	21762.9	214067.1	26212.5	99.7
4	18012021	04_PER496_3	PER496	1282.5	23568.6	19.4	23277.2	198486.9	30335.6	98.8
4	18012021	04_PER496_4	PER496	753.8	9899.8	20.0	9899.8	61972.1	10406.5	100.0
4	18012021	04_PER496_5	PER496	1506.7	50088.5	19.2	49639.3	365469.5	57416.3	99.1

Table 4: Statistical accuracy of texture attributes – example of Gradient

	Genotype	N	Min (g/mm)	Max (g/mm)	Mean (g/mm)	Std Err	CV, mean
Initial Gradient (g/mm)	GUA24	18	530.7	2812.6	1268.2	175.8	0.14
	PER183	18	-118.1	2163.0	706.0	129.4	0.18
	PER496	18	62.1	1636.5	934.4	118.8	0.13
	VEN208	18	147.8	2621.2	1140.2	186.0	0.16
	CM5948-1	18	374.5	2975.0	1186.2	193.2	0.16
	IND135	18	-66.4	424.4	169.9	34.9	0.21
	COL1505	18	107.8	2047.3	1048.7	133.5	0.13
	COL2246	33	-224.8	2732.6	1046.2	116.3	0.11
	PER368	15	274.4	1108.5	735.5	69.4	0.09
	COL1516	17	66.2	1401.3	771.7	79.8	0.10
	VEN77	18	-77.6	1456.3	527.0	99.1	0.19
	COL1722	18	220.1	1562.9	817.0	81.0	0.10
	COL2627	18	86.1	2174.5	981.5	133.6	0.14
	SM593-5	18	260.4	2312.6	1085.6	149.0	0.14
	VEN117B	10	428.8	1472.0	871.5	91.4	0.10
	CM6370-2	18	335.9	2811.3	1176.1	140.4	0.12
	PER234	18	558.2	2293.9	1057.7	107.6	0.10
	IND 129	18	78.3	2251.0	796.8	125.6	0.16
	COL2089	18	372.5	3060.7	1833.3	219.3	0.12
	COL 1736	18	139.3	2057.1	952.4	131.8	0.14
	CUB46	18	-181.2	1153.2	456.8	75.1	0.16
	VEN25	18	499.7	2809.1	1845.3	170.9	0.09

Table 5: ANOVA of textural parameters – example of Gradient

Source	DF	Sum of squares	Mean square	F ratio	Pr > F
Model	21	55206409	2628877	7.8	**< 0.0001**
Error	377	126861218	336502		
Total corrigé	398	182067627			

Genotype	Mean (g/mm)	Std error	Lower 95% (g/mm)	Upper 95% (g/mm)	Groups

VEN25	1845.3	136.7	1576.5	2114.2	A				
COL2089	1833.3	136.7	1564.4	2102.1	A	B			
GUA24	1268.2	136.7	999.3	1537.0	A	B	C		
CM5948-1	1186.2	136.7	917.4	1455.1	A	B	C	D	
CM6370-2	1176.1	136.7	907.3	1445.0	A	B	C	D	
VEN208	1140.2	136.7	871.4	1409.1		B	C	D	E	
SM593-5	1085.6	136.7	816.8	1354.5			C	D	E	
PER234	1057.7	136.7	788.9	1326.6			C	D	E	
COL1505	1048.7	136.7	779.9	1317.6			C	D	E	
COL2246	1046.2	101.0	847.7	1244.8			C	D	E	
COL2627	981.5	136.7	712.6	1250.3			C	D	E	
COL 1736	952.4	136.7	683.6	1221.3			C	D	E	
PER496	934.4	136.7	665.5	1203.2			C	D	E	
VEN117B	871.5	183.4	510.8	1232.2			C	D	E	F
COL1722	817.0	136.7	548.2	1085.8			C	D	E	F
IND 129	796.8	136.7	5287.0	1065.7			C	D	E	F
COL1516	771.7	140.7	495.0	1048.3			C	D	E	F
PER368	735.5	149.8	441.0	1030.0			C	D	E	F
PER183	706.0	136.7	437.1	974.9			C	D	E	F
VEN77	527.0	136.7	258.1	795.8				D	E	F
CUB46	456.8	136.7	188.0	725.7					E	F
IND135	169.9	136.7	-98.9	438.8						F

9.3 Appendix 3: Template of the test report for texture-extrusion

Table 6: Template of the test report for texture-extrusion of boiled cassava.

Description:	**Characterization of optimum cooking time and texture of boiled cassava by texture-extrusion**
Trial ID	20-xx
Type of sample:	Boiled cassava
Test:	Texture-extrusion
SOP used (title):	…
Location:	CIAT
Analyst:	Andrés Escobar

Key	Code WP2	Date of analysis (yy.mm.dd)	Genotype	Age at harvest (month)	Piece of root number	Code texture analyzer	Cooking time (min)	Gradient (g/mm)	Max force (g)	Distance at Max force (mm)	End force at 20mm (g)	Area (g*mm)	Linear Distance (g*mm)	End force:Max force Ratio (%)	Diameter of the half cylinder (mm)	Length of the half cylinder (mm)
1	20G01M10P01	20.02.24	CM7436-7	M11	1		T18	1223.8	32680.0	20.0	32664.3	295992.5	35717.1	100.0		
2	20G01M10P02	20.02.24	CM7436-7	M11	2		T18	1121.4	27700.0	20.0	27700.0	282925.7	33925.8	100.0		
3	20G01M10P03	20.02.24	CM7436-7	M11	3		T18	1181.2	29660.9	20.0	29660.9	376949.3	34280.2	100.0		
4	20G01M10P04	20.02.24	CM7436-7	M11	4		T18	1524.0	45812.3	20.0	45812.3	510743.5	53420.6	100.0		
5	20G01M10P05	20.02.24	CM7436-7	M11	5		T18	1728.8	56435.1	17.8	50037.7	705524.7	65967.8	88.7		
6	20G01M10P06	20.02.24	CM7436-7	M11	6		T18	2636.6	61132.4	20.0	61132.4	682537.1	89646.6	100.0		
7	20G01M10P07	20.02.24	CM7436-7	M11	7		T18	3062.6	42588.9	20.0	42588.9	419373.0	52528.7	100.0		
8	20G01M10P08	20.02.24	CM7436-7	M11	8		T18	663.5	27065.0	19.6	26942.3	339662.2	32154.5	99.5		
9	20G01M10P09	20.02.24	CM7436-7	M11	9		T18	1186.1	22188.2	20.0	22188.2	247063.3	24165.5	100.0		
10	20G01M10P10	20.02.24	CM7436-7	M11	10		T18	1847.2	25419.9	20.0	25418.9	321318.5	33881.1	100.0		
11	20G01M10P11	20.02.24	CM7436-7	M11	11		T18	620.7	27971.6	20.0	27971.6	319089.0	40400.7	100.0		
12	20G01M10P12	20.02.24	CM7436-7	M11	12		T18	2720.3	43845.7	20.0	43834.4	556209.2	56206.9	100.0		
13	20G01M10P13	20.02.24	CM7436-7	M11	13		T18	94.9	17881.5	20.0	17881.5	212083.4	19998.1	100.0		
14	20G01M10P14	20.02.24	CM7436-7	M11	14		T18	682.8	22342.7	19.3	22290.9	248475.0	25091.3	99.8		
15	20G01M10P15	20.02.24	CM7436-7	M11	15		T18	2220.0	22162.7	17.6	21648.1	340062.9	27704.9	97.7		
16	20G01M10P16	20.02.24	CM7436-7	M11	16		T18	1511.3	33061.2	16.6	24250.7	375851.5	42112.2	73.4		
17	20G01M10P17	20.02.24	CM7436-7	M11	17		T18	1795.6	45336.3	14.1	36410.9	591319.3	57401.6	80.3		
18	20G01M10P18	20.02.24	CM7436-7	M11	18		T18	1450.8	27909.6	20.0	27909.6	326145.4	33944.9	100.0		
19	20G02M10P01	20.02.25	COL2246	M11	1		T18	2965.7	31340.3	13.4	26890.5	478575.6	35335.3	85.8		
20	20G02M10P02	20.02.25	COL2246	M11	2		T18	892.9	23100.0	9.0	19726.7	341001.0	35520.2	85.4		
21	20G02M10P03	20.02.25	COL2246	M11	3		T18	1523.9	25889.1	8.6	17413.2	328647.1	40327.9	67.3		
22	20G02M10P04	20.02.25	COL2246	M11	4		T18	1729.6	32906.7	17.0	29650.1	492037.8	43177.9	90.1		