Relationship between Sensory and Instrumental Stretchability of Pounded Yam

Abomey-Calavi, Benin, September 2024

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This report has been written in the framework of the RTB Breeding project, Quality-component (under CIRAD coordination), as a continuation of work initiated under the RTBfoods project.

To be cited as:

Laurent ADINSI, Laurenda HONFOZO, Francis HOTEGNI, Penelope PEDE, Oluwatoyin AYETIGBO, Santiago ARUFE, Christian MESTRES, Dominique DUFOUR and Noël AKISSOE, (2024). *Relationship between Sensory and Instrumental Stretchability of Pounded Yam,* Cotonou, Bénin: RTB Breeding, Scientific Report, 13 p. https://doi.org/10.18167/agritrop/00785

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.

Acknowledgments: This work was supported by the RTB Breeding project, through a sub-grant from the International Potato Center (CIP) to the French Agricultural Research Centre for International Development (CIRAD), Montpellier, France, incorporated in the grant agreement INV-041105 between CIP and the Bill & Melinda Gates Foundation (BMGF).

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ABSTRACT

Extensibility as stretching behavior of pounded yam is one of the most important sensory texture attributes of pounded yam. Apart from varietal effect and pounding conditions, stretchability may depend on the quantity of water added during pounding as well as the water content of the raw yam and cooked yam. All things being equal, it is therefore important for the processor to have a method of controlling the addition of water during pounding in order to reach acceptable stretchable texture and avoid consumer rejection. The SOP for instrumental measurement of stretchability has been developed, however, the relationship between sensory and instrumental stretchability is poorly known. This report aims to establish such relationship, and thereby provide an efficient alternative screening tool which can be used for screening large populations of yam genotypes intended for advanced breeding and eventual adoption. Two instrumental methods (Kieffer dough extensibility test and oscillatory rheology) and sensory analysis (quantitative descriptive analysis) were applied to assess the stretchability of pounded yam from ten yam landraces. Desirable pounded yam has a mean dry matter of 30.4% (db). Raw yam varieties with high dry matter (> 40%) require a higher amount of added water "i.e. high ratio of water to yam" during pounding (P) (59.8 to 69.2%) while those with dry matter ranging from 26.2 to 37.3% were associated to the low P (from 0 to 22%). A significant relationship was found between P and dry matter of raw yam (R^2 = 0.78). Sensory and instrumental analyses exhibited significant varietal effect. Stretchability perceived by the consumers can be predicted by distance at peak max and G'-G" crossover parameters. These relationships are potential phenotyping tools for quality evaluation of varieties intended for pounded yam.

Key Words: ***Dioscorea*****, Kieffer dough, Viscoelastic properties, High-throughput screening**

1 INTRODUCTION

Pounded yam is a glutinous dough and a very popular food made from yam, with a particular texture. It is prepared by peeling of yam, washing, slicing, cooking and pounding to desirable texture. In order to have a uniform consistency, water was added to adjust the dry matter during pounding based on producer skill. Based on preliminary observations, we found that yam variety affect the texture of final product through its intrinsic composition, mainly the dry matter which is presumably the main determinant of the quantity of added water. The texture attributes of pounded yam as perceived by the consumers have been discussed in detail in literature and have been recognized as drivers of liking. Among the texture attributes, to date, only few studies have attempted to generate validated relationships between them and biophysical properties of pounded yam to be used by breeders to screen germplasm. For instance, texture profile analysis was applied on pounded yam by Otegbayo et al. (2006) and the authors reported the ability to this method to measure softness/hardness of pounded yam in a way similar to a trained sensory panel while other texture attributes such as stretchability, moldability, stickiness and smoothness were not sufficiently considered in this method. Recently, two other instrumental methods (uniaxial extensibility and lubricated squeezing flow) were applied to assess the extensional properties of pounded yam (Arufe et al., 2024). However, none of the instrumental methods were significantly correlated to sensory texture attributes. Another method using Kieffer dough extensibility rig and able to measure the stretching behavior as extensibility of pounded yam is currently being developed. It was successfully applied to dough (Petrović et al., 2015). However, it needs to be correlated to sensory analysis. This study aimed to find a way to define the quantity of water added during pounding, and then to establish relationship between extensibility measured by Kieffer dough method and the sensory stretchability perceived by the consumers.

2 METHODOLOGY

2.1 Plant materials sampling

Plant materials comprised landraces yam varieties obtained from Benin farmers' fields. They are Agatou, Dodo, Efourou, Irindou, Kokoro, Laboko, Ofegui and Wete varieties of *D. rotundata,* while Aga and Kpete were *D. alata* species.

2.2 Pounded yam preparation

Two yam tubers were separated at their proximal and distal ends, then each cut longitudinally into halves. Thus, two batches were obtained per variety, each consisting of each half of each tuber (inter-crossing). From each batch, cubes of about 2 cm dimension were cut from both representative central sections. 900 g of the yam cubes are weighed for each batch and placed in steam cooker containing 500 ml of water. The yam cubes are cooked for 23 min and pounded with yam pounder. During pounding, one liter is left at the disposal of a skilled processor so that she can add water as needed to obtain a desirable uniform texture. Consequently, the processor decides when to add water, the quantity and the pounding duration. At the end, the total volume of water used is measured and the pounding duration recorded.

2.3 Pounded yam characterization

2.3.1 Sensory analysis of pounded yam

Stretchability, moldability and sweetness attributes were considered for the quantitative descriptive analysis, with 12 panelists. The panelists scored the randomly coded pounded yam samples for each sensory attributes in triplicates on an unstructured 10 cm line scale. The samples were served at around 50+2°C and the panellists immediately assessed the texture attributes for 2 to 3 min and, after that, the sweetness. Sensory evaluation took approximately 5 minutes, and three sensory sessions were performed for a sample.

2.3.2 Texture analysis

Stretchability properties of pounded yam were determined by Texture Analyser TA. XT Plus (Stable Micro System Surrey, U.K.) coupled with Kieffer Extensibility Rig. Measurements were performed in ten replicates at 45 °C using load cell of 5 kg and following operating parameters: pre-test speed: 2 mm/s; test speed 3.3 mm/s; post-test speed 10 mm/s; distance: 40-mm; trigger force:auto-2 g. The parameters extensogram peak force (N), extensibility (mm) and extension area (energy, N.mm) were collected.

2.3.3 Rheological properties

The rheological behaviour of the pounded yam sample was evaluated using a rheometer (HAAKE Viscotester iQ Air) equipped with parallel planes geometry with a ridged surface to avoid any sliding effect. The measurements were carried out at 30 °C and the temperature of the sample was controlled by means of Peltier effect system connected to a refrigerant (Viscotherm VT2, Anton Paar GmBH, Graz, Austria). For each variety, three replicates were performed with 3-5 measurements per replicate. A subsample of 10 g was placed between the two plates and allowed to stand for 60 s before the measurements, while the excess of pounded yam was removed. Analysis was carried out at a constant frequency of 1 Hz, while strain amplification, varied between 0.1% and 1000%. The storage modulus (G’, a measure of elastic response) and loss modulus (G’’, a measure of viscous response) crossover and the corresponding strain were collected.

2.3.4 Dry matter

Dry matter was determined on raw yam tubers, cooked yam and pounded yam by oven drying at 105 °C to constant weight according to AOAC method (1984).

3 Results

3.1 Change in dry matter of yam during processing and percentage of added water

The mean dry matter (DM) of fresh yam (26.2 to 43.3.%), cooked yam (24.2. to 41.7%) and pounded yam (23.5 to 34.2%) and the ratio of water added to pounded yam (P) (0 to 69.2%) exhibited significant varietal effect (Table 1). Cooking decreased DM by 0.1 (Dodo) to 4.1% (Kokoro). During pounding, based on P, the yam varieties could be classified into two groups. One composed of the *D. rotundata* species with highest DM (> 40%) requiring a high P (59.8 to 69.2%), while the second group includes the two studied *D. alata* and three *rotoundata* species and were characterized by the DM of fresh yam ranging from 26.2 to 37.3% and the low P from 0 to 22%. However, DM of pounded yam did not follow the same clustering profile in relation to P. Indeed for 60% of yam varieties, pounded yam had DM higher than 30% (31.2 to 34.2%) while for the rest of the varieties including two *D. alata* and two *rotoundata*, DM varied between 23.5 to 29.2%.

Table 1: Change in dry matter (DM) of yam during pounding processing and ratio of water to yam

	DM_fresh (%)	DM_cooked yam (%)	DM_pounded yam (%)	P (%)
LABOKO	43.3[a]	41.7[a]	34.2[a]	62.9[a]
IRINDOU	42.7[a]	40.7[a]	33.1[a]	59.8[a]
KOKORO	42.7[a]	38.6[ab]	33.1[a]	61.0[a]
OFEGUI	40.8[a]	39.6[ab]	32.3[ab]	64.2[a]
WETE	41.0[a]	39.0[ab]	31.2[abc]	69.2[a]
EFOUROU	37.3[ab]	36.4[b]	32.5[ab]	22.2[b]
KPETE	32.1[bc]	30.5[c]	29.2[abc]	6.3[b]
AGATOU	29.4[c]	27.6[cd]	27.5[bcd]	0.0[b]
DODO	26.5[c]	26.4[cd]	27.0[cd]	0.0[b]
AGA	26.2[c]	24.2[d]	23.5[d]	0.0[b]

Note: Mean values with different letters in the same column are significantly different (P<0.05). Note that for fresh yam varieties with DM below 30%, no water was added to the pounded yam dough during preparation

Abbreviation: DM, Dry Matter; P, stands for the ratio of water to yam and is calculated from $P=Q_{water}/(Q_{fresh}*DM_{fresh})$. Q_{water} is the quantity of water to be added when preparing/pounding the dough (g), Q_{fresh} is the weight or quantity of peeled yam (g), DM_{fresh} is the dry matter content of the fresh tuber

3.2 Prediction of percentage of added water during pounding

Pearson correlation revealed a linear, positive and significant relationship between ratio of water to yam (P) and the dry matter of fresh yam (DM) (R^2 = 0.78). We observed that when DM of fresh yam is lower than 31.47%, no water is added during pounding. In addition, to improve the prediction of P, multilinear regression was performed and DM of fresh yam and DM of pounded yam were considered as explicative variables. The coefficient of determination was significantly improved (P < 0.0001) from 0.78 to 0.81 (Table 1). The new model is :

P = -73.58+5.047*DM_fresh (%)**-2.44*DM** expected pounded yam.

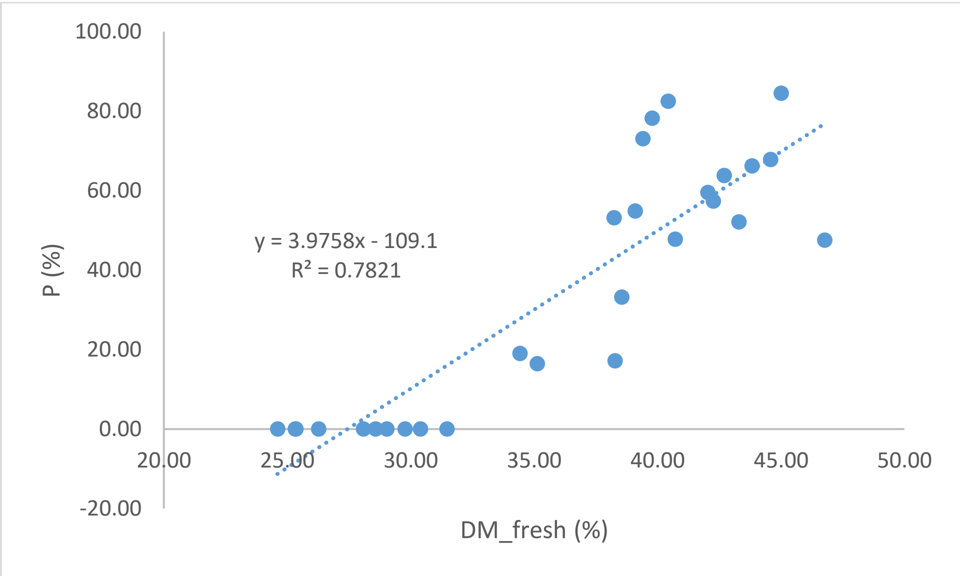

Figure 1: Linear relationship between the percentage of added water during pounding and dry matter of fresh yam.

3.3 Sensory profiling of pounded yam

There were significant differences between yam varieties for the mean scores of stretchability, softness and sweetness (Table 2). Laboko, Kpete and Efourou generally showed the highest scores (>7) for stretchability, softness and sweetness respectively. Concerning the lowest score, for stretchability and sweetness they were attributed to Aga, while the hardest variety was Kokoro.

Table 2: Mean values of sensory attributes of pounded yam

Products	Strechability	Softness	Sweetness
AGA	2.2^{c}	5.1^{bcd}	3.5^{e}
AGATOU	7.2^{ab}	8.5^{a}	6.4^{abc}
DODO	6.9^{ab}	7.8^{ab}	6.5^{ab}
EFOUROU	8.3^{ab}	6.7^{abcd}	7.6^{a}
IRINDOU	5.9^{ab}	4.4^{cd}	4.7^{cde}
KOKORO	5.3^{bc}	3.7^{d}	3.9^{de}
KPETE	7.8^{ab}	7.8^{ab}	7.1^{ab}
LABOKO	9^{a}	7.1^{abc}	7^{ab}
OFEGUI	6.9^{ab}	4.7^{bcd}	6^{abc}
WETE	7.4^{ab}	6.2^{abcd}	5.5^{bcd}

Mean values with different superscript letters in the same column are significantly different ($p<0.05$).

3.4 Stretchability of pounded yam from Kieffer dough test

The mean extensogram peak force (0.07–0.28 N), extensibility (4.7 – 13 mm) and extension area (0.08 – 0.62 N.s) measured on pounded yam, exhibited significant varietal difference. Laboko had the highest value for the three parameters while the *D. alata* varieties (Aga and Kpete) had the lowest values for extensogram peak force and extensibility. Regarding energy, the lowest value was attributed to *D. alata* (Aga and Kpete) as well as some *D. rotoundata* (Dodo, Efourou, Kokoro and Wete).

Table 3: Mean values of extensogram peak force; extensibility and extension area of pounded yam

Products	Extensogram Peak force (N)	Extensibility (mm)	Extension Area (Energy) (N.s)
AGA	0.07^{b}	4.7^{c}	0.08^{b}
DODO	0.09^{b}	6.9^{bc}	0.14^{b}
EFOUROU	0.16^{ab}	9.2^{b}	0.29^{b}
IRINDOU	0.27^{a}	7.4^{bc}	0.34^{ab}
KOKORO	0.22^{ab}	8.0^{b}	0.31^{b}
KPETE	0.1^{b}	8^{b}	0.17^{b}
LABOKO	0.28^{a}	13^{a}	0.62^{a}
OFEGUI	0.24^{ab}	9^{b}	0.37^{ab}
WETE	0.22^{ab}	7.2^{bc}	0.28^{b}

Mean values with different superscript letters in the same column are significantly different ($p<0.05$).

3.5 Oscillatory rheological profiling of pounded yam

The G’-G’’ crossover values exhibited significant differences in pounded yam samples. Laboko showed a lowest value in G’-G” crossover and highest value in G’-G” strain. An opposite behaviour was observed for Aga.

Table 4: Storage and loss moduli crossover of pounded yam

Products	G'-G" crossover (kPa)	G'-G" crossover strain (%)
AGA	2.9[a]	63.3[e]
DODO	1.9[ab]	118.6[de]
EFOUROU	1.7[ab]	280.9[c]
IRINDOU	2.6[ab]	244.9[c]
KOKORO	2.1[ab]	246.1[c]
KPETE	1.4[ab]	199.6[cd]
LABOKO	1.1[b]	416.7[a]
OFEGUI	1.8[ab]	352.5[b]
WETE	2.1[ab]	253.1[c]

Mean values with different superscript letters in the same column are significantly different ($p<0.05$).

3.6 Relationship between sensory attributes and stretchability, and other instrumental parameters

Pearson correlation revealed that among the textural and rheological parameters, extensibility and G’-G” crossover parameters were significantly correlated to stretchability scored by consumers. A positive and significant relationship was observed with distance at peak max and G’-G” crossover strain, while it was negative for G’-G” crossover.

Table 5: Pearson correlation between sensory profiling of pounded yam and stretchability measured by Kieffer dough test

Variables	Extensogram Peak force	Extensibility	Extension Area (Energy)	G’-G crossover	G’-G” crossover strain
Strechability	0.386	**0.781**	0.583	**-0.880**	**0,700**
Softness	-0.424	0.253	-0.087	-0.619	-0,056
Sweetness	-0.004	0.615	0.295	**-0.841**	0,441

Significant relationships at 5% level are bolded

4 CONCLUSION

Sensory stretchability as extensible texture behaviour of pounded yam is correlated to extensibility, and may represent instrumental stretchability. The amount of water to be added during pounding is known through the dry matter of raw and boiled yam. However, there is an asymptomatic level of 31.5% which determines the varieties requiring water or not during pounding. Texture analyses and dynamic rheology of pounded yam are the potential phenotyping tools for pounded yam quality evaluation. These analyses make it possible to avoid sensory studies which require a lot of time and resources.

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