Screening of yam genotypes based on crumbliness of boiled yam

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

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Abstract

The key quality traits of boiled yam mainly include white color, sweet taste and the crumbly texture. The latter, as a key trait for boiled yam acceptance, is highly variety dependent. The study aimed at classifying yam genotypes regarding their crumbliness for boiled yam. Ten (10) landraces and 23 hybrids were used, among them nine were harvested in two zones (Bassila, Dassa, Djougou Massi). Consequently, 42 samples were considered for this study. Textural analysis as well as dry matter content analysis were carried out. In addition, some of the genotypes (nine) were subjected to quantitative descriptive analysis (QDA). The textural parameters, the dry matter content of yam and the sensory crumbliness of boiled yam enabled discriminating the genotypes (p-value <0.0001). Using predicted crumbliness based on textural parameter LD_{Peak}/A_{Peak} and the sensory thresholds of boiled yam, yam genotypes were classified in good (9 genotypes), medium (13 genotypes) and poor (20 genotypes) quality clusters. This classification was used to identify yam genotypes which are promising (good and medium). However, further investigations have to be done for a better understanding of the crumbliness of boiled yam which is not yet well mastered since only 36% of sensory crumbliness was explained by the predicted crumbliness.

Keywords: **yam genotypes, predicted crumbliness, selection, promising genotypes, breeding**

1 INTRODUCTION

Boiled yam is obtained by peeling, slicing, washing and cooking, either by steaming or boiling yam tubers. Although all varieties of yams can be boiled, some are not preferred due to their non-crumbly texture, and therefore, they do not meet consumer demands (Adinsi et al, 2024a). This is why, nowadays, the protocol for the selection, releasing and adoption of yam varieties takes strong account of user preferences for specific trait/qualities. As far as boiled yam is concerned, the predominant quality trait is the crumbliness which leads the criteria for acceptance or the rejection of varieties. From this point of view, the screening of yam varieties is important for clustering/classification of genotypes regarding the three levels of quality which are good, medium and poor quality. Based on previous studies, the sensory crumbliness of boiled yam can be predicted using the textural parameters such as LD_{Peak}/A_{Peak} (Honfozo *et al.,* 2024) and the consumer acceptance from the sensory thresholds (Adinsi *et al.*, 2024b). This enables the prediction of the quality of yam for boiling regarding the crumbly texture, and at the same time classify the genotypes by identifying the promising ones. The study aimed to screen yam genotypes intended for boiling and to facilitate release of new promising varieties.

2 METHODOLOGY

2.1 Plant material sampling

Plant materials used for screening comprised yam landraces (10 genotypes) as well as hybrids (23 genotypes). These materials were obtained from Biorave center-UAC (breeding center) in Massi and farmers' field in three locations (Dassa-Zoumè, Bassila and Djougou). They include 18 *D. rotundata* and 15 *D. alata* species and were harvested on December 2024 (Table 1).

Table 1: Plant materials

Genotypes	Species	Landraces	Hybrids	Origin			
				Bassila	Dassa-Zoumè	Djougou	Massi
Kpotchebim	*D. rotundata*	×				×	
TDr1000344 (Idoro)*	*D. rotundata*		×			×	
Makpa Tolaha*	*D. rotundata*	×				×	
Odo*	*D. rotundata*	×			×		
Assoura*	*D. rotundata*	×		×			
TDrA39-2003	*D. rotundata*		×				×
Bakaro*	*D. rotundata*	×				×	
Assinaga*	*D. rotundata*	×				×	
TDrA5-2003*	*D. rotundata*			×			×
TDa1520050	*D. alata*		×				×
TDr8902665*	*D. rotundata*		×	×			×

TDrA65-2003	*D. rotundata*		×				×
TDr1443002*	*D. rotundata*		×	×			×
TDr1100497	*D. rotundata*		×			×	
Kalé	*D. rotundata*	×				×	
TDa1510080	*D. alata*		×				×
TDr 1440001	*D. rotundata*		×	×			
TDr1440045	*D. rotundata*		×				×
Kpèguèlèhoun*	*D. alata*	×		×			
TDa1510043*	*D. alata*		×		×		×
Kpouna/Laboko	*D. rotundata*	×		×			
TDa1510152	*D. alata*		×				×
Mètchassa*	*D. alata*	×		×			
TDa0000194	*D. alata*		×				×
TDa1520008*	*D. alata*		×		×		×
TDa1515030*	*D. alata*		×		×		×
TDr1414005	*D. rotundata*		×				×
TDa1520002*	*D. alata*		×		×		×
TDa1515032	*D. alata*		×				×
TDa1508044*	*D. alata*		×		×		×
TDa1511008	*D. alata*		×				×
TDa1506142	*D. alata*		×				×
TDa1510119*	*D. alata*		×		×		×

Legend: genotypes with the sign * are also used for QDA analysis

2.2 Boiled yam preparation

Standard cooking procedures were employed to ensure consistency (Adinsi et al, 2021a). Yam tubers were peeled and cut in disks of 3 cm thickness. A punch was used to cut out cubic samples having 2.5 cm length, in each disk. The cubic samples (about 20 g per sample) were steam cooked for 38 min using a steamer.

2.3 Boiled yam characterization

2.3.1 Texture analysis of boiled yam

Penetration test was performed according to Adinsi *et al*. (2021a) protocol using a texturometer (model TA-XT plus, Stable Micro Systems, Godalming, UK). The same cooking batch was used for quantitative descriptive analysis (QDA) and texture measurement. New texture parameters were defined as follows: F_{5mm} (N), Fpeak (N), D_{peak} (mm), A_{Peak} (N.mm), A2 (N.mm), LD_{Peak}, LD2 (N.mm), LD_{Peak}/A_{Peak} (1/(N·mm)), LD_{Total}/A_{Total} (1/(N·mm)), IF (https://doi.org/10.18167/agritrop/00846).

2.3.2 Dry matter content of yam tubers

Dry matter content was determined in triplicate by oven drying fresh yam tubers according to Adesokan *et al.* (2020).

2.3.3 Sensory analysis of boiled yam

The crumbliness of boiled yam was evaluated on nine samples (Table 1) through the quantitative descriptive sensory analysis (QDA), with 11 trained panelists. The panelists scored the randomly coded boiled yam samples on a 0–10 cm unstructured line scale using anchor descriptors for 0 (lowest intensity of the attribute) and 10 cm (highest intensity of the attribute). The samples were served at around 50 ± 2 °C, and the panelists immediately assessed the crumbliness for 2–3 min. Sensory evaluation took approximately 5 min per sample and was duplicated (Adinsi et al, 2021b). Genotypes involved in QDA analysis are followed by the * symbol in Table 1.

3 Results

3.1 The effect of yam specie and location on the dry matter content of raw yam and textural parameters of boiled yam

The dry matter content (DMC) and all textural parameters revealed significant differences among genotypes (landraces and hybrids) considered in the study (Table 2). The dry matter is discriminatory between the species (*D. rotundata, D. alata*), among genotypes (landraces and hybrids) and between locations Massi and Bassila. Indeed, genotypes belonging to *D. alata* species registered the lowest DMC (Table 3).

LD_{Peak}/A_{Peak} texture parameter discriminated between the species and among genotypes but not discriminatory between the locations (Table 3).

Table 2: Dry matter from raw yam and textural parameters of boiled yam from different genotypes

Genotypes	DM (%)	F5mm (N)	Fpeak (N)	Dpeak (mm)	Apeak (N.mm)	A2 (N·mm)	LDPeak (-)	LD2 (-)	LDPeak/Apeak (1/(N·mm))	LDTotal/Atotal (1/(N·mm))
Kpotchebim	32.6^{efg}	3.5 ^{a}	8.6^{a}	9.6^{abcd}	36.3 ^{a}	2.7^{abc}	14.7^{a}	1.2^{ab}	0.4^{l}	0.4^{o}
TDr1000344 (Idoro)	35.0 ^{d}	2.6^{bcde}	6.5^{bc}	9.7^{abcd}	26.5^{bc}	1.8^{bcdefg}	13.6^{bcde}	0.8^{abcde}	0.5^{kl}	0.5^{lmno}
Makpa Tolaha	37.9^{ab}	2.8^{bc}	6.3^{bc}	9.3^{d}	25.8^{cd}	3.7^{a}	13.1^{cdefgh}	1.6^{a}	0.5^{kl}	0.5^{mno}
Odo	35.5^{cd}	2.7^{bcd}	6.1^{cd}	9.4^{bcd}	25.4^{cd}	3.3^{ab}	13.1^{cdefgh}	1.2^{ab}	0.5^{jkl}	0.5^{lmno}
Assoura	39.5^{a}	3.2 ^{ab}	7.9^{ab}	9.8^{abcd}	33.4^{ab}	1.6^{bcdefg}	14.4^{ab}	0.4^{bcde}	0.4^{l}	0.4^{no}
TDr A39-2003	34.0^{de}	2.4^{cdef}	5.6^{cdef}	9.5^{abcd}	23.8^{cde}	2.3^{abcde}	13.0^{cdefgh}	1.0^{abcd}	0.6^{jkl}	0.5^{klmno}
Bakaro	37.8^{ab}	2.3^{cdefghi}	5.6^{cdef}	9.3^{cd}	22.1^{cdefgh}	2.5^{abcd}	12.9^{defgh}	1.2^{ab}	0.6^{hijkl}	0.6^{jklmno}
Assinaga	35.8^{cd}	2.2^{cdefghij}	5.4^{cdefgh}	9.7^{abcd}	22.8^{cdefg}	1.4^{cdefg}	13.2^{cdefgh}	0.6^{bcde}	0.6^{hijkl}	0.6i^{jklmno}
TDrA5-2003_Bassila	33.0^{ef}	2.2^{cdefghijk}	5.2^{cdefgh}	9.5^{abcd}	21.5^{cdefgh}	2.1^{abcdef}	12.9^{defgh}	0.8^{abcde}	0.6^{hijkl}	0.6^{ijklmno}
TDa 1520050	28.0^{lmnop}	2.4^{cdefg}	6.3^{bc}	9.9^{ab}	25.8^{cd}	0.6^{efg}	14.1^{abc}	0.2^{cde}	0.6hijkl	0.6i^{jklmno}
TDr8902665_Bassila	32.2^{fg}	2.2^{cdefghijk}	5.5^{cdefg}	9.7^{abcd}	22.8^{cdefg}	1.3^{cdefg}	13.2^{cdefg}	0.5^{bcde}	0.6^{ijkl}	0.6^{jklmno}
TDr A65-2003	35.5^{cd}	2.0^{defghijkl}	5.1^{cdefgh}	9.7^{abcd}	21.5^{cdefgh}	1.2^{cdefg}	13.1^{cdefgh}	0.5^{bcde}	0.6^{hijkl}	0.6^{ijklmno}
TDr1443002_Massi	33.0^{ef}	2.0^{efghijk}l	5.0^{cdefgh}	9.6^{abcd}	20.6^{cdefgh}	1.5^{bcdefg}	12.9^{defgh}	0.8^{abcde}	0.6^{hijkl}	0.6^{ijklmno}
TDr1443002_Bassila	30.9^{ghij}	2.0^{efghijk}l	4.9^{cdefghi}	9.6^{abcd}	20.3^{cdefgh}	1.4^{cdefg}	12.9^{defgh}	0.6^{bcde}	0.7^{ghijkl}	0.6^{ijklmno}
TDr 1100497	28.7^{klmno}	2.1^{defghijkl}	5.7^{cdef}	9.9^{abc}	23.1^{cdef}	0.7^{defg}	13.4^{bcdefg}	0.2^{cde}	0.6^{hijk}l	0.6^{ijklmno}
TDrA5-2003_Massi	37.1^{bc}	2.0^{efghijkl}	5.1^{cdefgh}	9.8^{abcd}	21.2^{cdefgh}	0.8^{cdefg}	13.1^{cdefgh}	0.3^{bcde}	0.7^{hijkl}	0.6^{ijklmno}
Kalé	31.2^{ghi}	1.7^{hijklmno}	4.4^{defghi}j	9.6^{abcd}	17.7^{efghij}	1.4^{cdefg}	12.7^{defgh}	0.7^{bcde}	0.7^{fghijkl}	0.7^{ghijklmno}

TDa1510080	26.1^{qrs}	$1.7^{ghijklmno}$	4.4^{efghij}	9.9^{a}	$18.6^{defghij}$	0.2^{g}	13.5^{bcdef}	0.1^{e}	1.0^{abcdef}	$1.1^{abcdefg}$
TDr 1440001	30.3^{hijk}	$1.6^{ijklmno}$	4.4^{efghij}	9.6^{abcd}	17.2^{efghij}	1.5^{bcdefg}	12.7^{defgh}	0.6^{bcde}	$0.8^{fghijkl}$	$0.7^{ghijklmno}$
TDr8902665_Massi	32.1^{fg}	2.3^{cdefgh}	6.1^{cde}	9.9^{a}	25.6^{cd}	0.4^{fg}	13.7^{abcd}	0.1^{cde}	0.5^{jkl}	0.5^{klmno}
TDr1440045	30.9^{ghij}	$1.7^{hijklmno}$	4.2^{fghijk}	9.4^{abcd}	17.0^{efghij}	1.3^{cdefg}	12.5^{fgh}	0.8^{abcde}	$0.9^{cdefghijk}$	$0.8^{defghijklm}$
kpèguèlèhoun	29.0^{klmn}	$1.8^{fghijklmn}$	$4.5^{defghij}$	9.8^{abcd}	$18.7^{defghij}$	0.7^{defg}	12.9^{efgh}	0.3^{bcde}	$0.8^{fghijkl}$	$0.7^{ghijklmno}$
TDa1510043_Massi	27.7^{mnopq}	1.6^{jklmno}	4.1^{fghijk}	9.8^{abcd}	17.1^{efghij}	0.5^{efg}	13.0^{cdefgh}	0.3^{bcde}	$0.9^{abcdefghi}$	$0.9^{bcdefghij}$
Kpouna/Laboko	38.0^{ab}	1.6^{jklmno}	3.9^{ghijk}	9.3^{d}	15.0^{hij}	2.5^{bcd}	12.1^{h}	1.1^{abc}	$0.8^{defghijk}$	$0.8^{fghijklmn}$
TDa1510152	26.4^{pqr}	1.5^{jklmno}	4.0^{fghijk}	9.8^{abcd}	16.4^{efghij}	0.4^{fg}	13.0^{cdefgh}	0.3^{bcde}	1.1^{abcde}	1.1^{abcdef}
Mètchassa	29.6^{ijkl}	$1.9^{efghijklm}$	5.1^{cdefgh}	9.9^{a}	21.4^{cdefgh}	0.3^{fg}	13.4^{bcdefg}	0.1^{de}	0.7^{ghijkl}	$0.7^{hijklmno}$
TDa 0000194	33.2^{ef}	$1.7^{ghijklmno}$	5.0^{cdefgh}	9.9^{a}	$19.6^{cdefghi}$	0.4^{fg}	13.4^{bcdefg}	0.1^{de}	$0.7^{fghijkl}$	$0.7^{hijklmno}$
TDa1520008_Dassa	24.4^{st}	1.4^{lmno}	3.6^{hijk}	9.7^{abcd}	15.1^{hij}	0.6^{defg}	12.9^{defgh}	0.4^{bcde}	1.3^{ab}	1.2^{abc}
TDa1515030_Massi	28.9^{klmn}	1.5^{jklmno}	3.9^{fghijk}	9.8^{abcd}	16.3^{fghij}	0.7^{defg}	12.9^{defgh}	0.3^{bcde}	$1.0^{abcdefgh}$	$1.0^{abcdefghi}$
TDr1414005	31.4^{fgh}	1.6^{jklmno}	4.0^{fghijk}	9.7^{abcd}	16.3^{fghij}	1.1^{cdefg}	12.6^{defgh}	0.5^{bcde}	$0.8^{efghijk}$	$0.8^{efghijklmn}$
TDa1520002_Dassa	28.4^{lmno}	1.6^{jklmno}	4.0^{fghijk}	10.0^{a}	17.0^{efghij}	0.1^{g}	13.1^{cdefgh}	0.03^{e}	$0.9^{abcdefghi}$	$0.9^{abcdefghij}$
TDa1510043_Dassa	29.4^{ijklm}	1.3^{mno}	3.0^{jk}	9.7^{abcd}	13.0^{ij}	0.6^{defg}	12.5^{fgh}	0.4^{bcde}	1.2^{abc}	1.2^{abcd}
TDa1515030_Dassa	27.5^{nopq}	1.1^{no}	3.2^{ijk}	9.7^{abcd}	12.7^{ij}	0.7^{defg}	12.5^{fgh}	0.4^{bcde}	$1.0^{abcdefg}$	$1.0^{abcdefgh}$
TDa1520008_Massi	25.1^{rs}	1.1^{no}	2.6^{k}	9.7^{abcd}	11.2^{j}	0.6^{defg}	12.3^{gh}	0.4^{bcde}	1.3^{a}	1.3^{ab}
TDa1515032	26.1^{qrs}	1.5^{klmno}	4.0^{fghijk}	10.0^{a}	17.1^{efghij}	0.2^{g}	13.0^{cdefgh}	0.1^{e}	$0.8^{defghijk}$	$0.8^{defghijklm}$
TDa1508044_Massi	23.1^{t}	1.4^{lmno}	3.8^{ghijk}	9.8^{abcd}	15.6^{ghij}	0.5^{efg}	12.8^{defgh}	0.3^{bcde}	$0.9^{bcdefghij}$	$0.9^{cdefghijk}$
TDa1511008	27.0^{opq}	1.3^{mno}	2.9^{jk}	9.8^{abcd}	12.9^{ij}	0.5^{efg}	12.5^{efgh}	0.3^{bcde}	1.1^{abcde}	1.1^{abcdef}
TDa1508044_Dassa	30.3^{hijk}	1.5^{lmno}	3.7^{ghijk}	9.8^{abcd}	15.7^{fghij}	0.4^{efg}	12.7^{defgh}	0.2^{bcde}	$0.9^{bcdefghij}$	$0.9^{cdefghijkl}$

TDa1520002_Massi	29.3^{jklm}	1.2^{no}	3.1^{jk}	9.8^{abcd}	12.8^{ij}	0.5^{fg}	12.6^{defgh}	0.2^{bcde}	1.2^{abcde}	1.1^{abcde}
TDa1506142	26.2^{qrs}	1.5^{lmno}	3.7^{hijk}	9.9^{abc}	15.7^{fghij}	0.4^{fg}	12.9^{defgh}	0.1^{cde}	$0.9^{cdefghijk}$	$0.8^{defghijklm}$
TDa1510119_Dassa	26.2^{pqr}	1.1^{no}	2.9^{jk}	9.9^{abc}	12.2^{ij}	0.3^{fg}	12.7^{efgh}	0.1^{cde}	1.2^{abcd}	1.2^{abcd}
TDa1510119_Massi	27.8^{mnopq}	1.1^{o}	2.8^{jk}	10.0^{a}	11.8^{j}	0.1^{g}	12.7^{defgh}	0.05^{e}	1.3^{a}	1.3^{a}
p-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Legend: The word (Bassila, Massi, Dassa) following the name of the genotype in some cases indicates the location of harvest.
Variables with different superscript letters in each column are significantly different at P<0.05 level

Table 3: DM and LD peak/A peak as affected by yam species, types (landraces or hybrids) and harvest location

Variables	DM (%)	LDPeak/Apeak (1/(N·mm))
D. rotundata	33.9^{a}	0.62^{b}
D. alata	27.3^{b}	0.99^{a}
Landrace	34.6^{a}	0.61^{b}
Hybrid	29.3^{b}	0.87^{a}
Massi	34.0^{a}	0.61^{a}
Bassila	32.0^{b}	0.63^{a}
Massi	27.0^{a}	1.09^{a}
Dassa	27.7^{a}	1.08^{a}

Variables with different superscript letters in each column are significantly different at P<0.05 level

3.2 Observed and predictive crumbly scores of boiled yam

The crumbly score of boiled yam from genotypes subjected to QDA analysis varied between 5.3 and 7.6, respectively for Assoura and Bakaro, both being landraces. The ANOVA by variety associated to the crumbliness is significant (p-value < 0.0001). Regarding the predicted crumbliness, ($y = 3.8311*LD_{Peak}/A_{Peak} + 2.5214$) previously reported (Honfozo et al, 2024), it varied from 4.2 to 7.5, estimated respectively for Assoura and TDa510119. The scatter plot from observed sensory crumbliness versus predicted crumbliness indicated that only 36% of the sensory crumbliness is explained by the predicted one (Figure 1). Although the correlation coefficient (r=0.60) is significant with a pvalue of 0.01, LD_{Peak}/A_{Peak} does not sufficiently explain the sensory crumbliness.

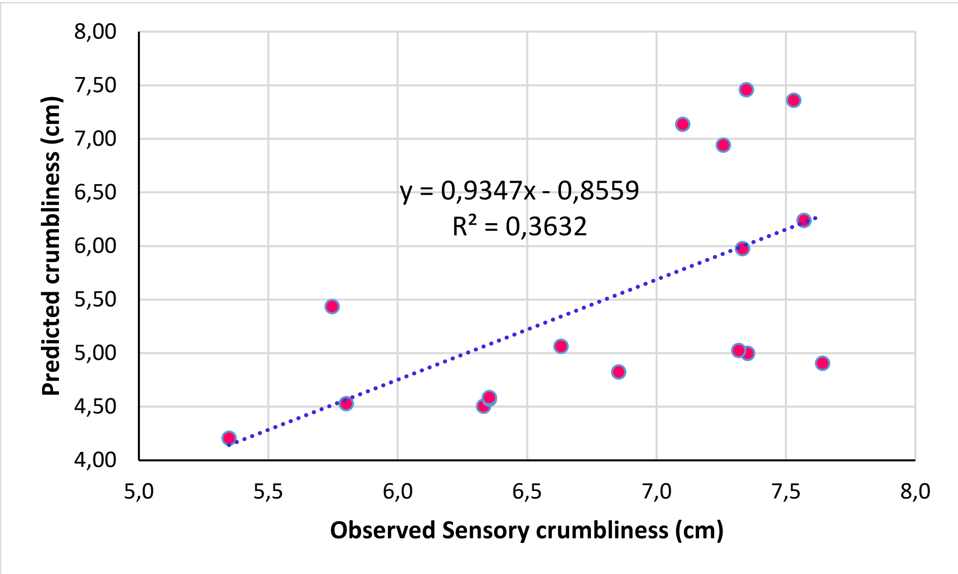

Figure 1: Relation between observed sensory and predicted crumbliness

3.3 Screening of yam genotypes for boiling based on crumbliness thresholds

As crumbliness is the most important trait for boiled yam quality, the predicted crumbliness scores were considered to classify yam genotypes according to sensory crumbliness thresholds (Adinsi *et al.,* 2024b). The optimal sensory threshold for boiled yam was above 6.6 while the acceptable threshold was higher than 5.4 (Adinsi *et al.,* 2024b). Considering these thresholds, samples with predicted crumbliness scores above 6.6 were classified as good quality, those with crumbliness scores in the ranges of 5.4 and 6.0 were considered medium quality and the ones with crumbliness values inferior to 5.4 were clustered as poor quality (Table 4). As the harvest location affected the dry matter and the texture parameters, the same sample could be classified in different groups based on predicted crumbliness scores (Table 4).

The screening of genotypes based on the crumbliness scores of derivate boiled yam revealed that the group of good genotypes comprised only hybrids of *D. alata* species, medium group consisted of 2 landraces (1 *D. rotundata* and 1 *D. alata*), *D. rotundata* (3) hybrids and *D. alata* (8) hybrids while the group of bad genotypes comprised more *D. rotundata* (10) hybrids, 8 landraces (7 *D. rotundata* and 1 *D. alata*) and 2 *D. alata* hybrids. Genotypes classified as good and medium (Table 4) could all be considered as promising genotypes regarding the crumbliness scores of boiled yam. However, it is important to mention that these varieties did not reflect exactly the crumbliness perceived but probably the softness of the product. Indeed, the boiled yam crumbliness is not yet well assessed neither by the sensory analysis nor by textural measurements (R=0.60). Therefore, the crumbliness needs to be better investigated to really include in the final list of promising genotypes all varieties which have potential behaviour regarding crumbliness and which are highly liked by consumers.

Table 4: Classification of genotypes based on crumbliness of boiled yam

Good	Medium	Bad
TDa1510080	TDr1440001	Kpotchebim
TDa1510152	kpèguèlèhoun	Assoura
TDa1511008	TDr1414005	Makpa Tolaha
TDa1520002_Massi	Kpouna/Laboko	TDr1000344 (Idoro)
TDa1510119_Dassa	TDa1515032	Odo
TDa1510043_Dassa	TDa1506142	TDr8902665_Massi
TDa1520008_Dassa	TDr1440045	TDrA39-2003
TDa1510119_Massi	TDa1508044_Dassa	TDr8902665_Bassila
TDa1520008_Massi	TDa1508044_Massi	TDr1100497
	TDa1520002_Dassa	Assinaga
	TDa1510043_Massi	Bakaro
	TDa1515030_Massi	TDa1520050
	TDa1515030_Dassa	TDrA65-2003
		TDr1443002_Massi
		TDrA5-2003_Bassila
		TDrA5-2003_Massi
		Mètchassa
		TDr1443002_Bassila
		TDa0000194
		Kalé

Legend: The word following the name of the genotype in some cases indicates the location of harvest.

4 CONCLUSION

Releasing new yam varieties involves a good screening of yam genotypes available which has to be focused on a specific product, as a given variety cannot be suitable for all yam products. The different genotypes of the current study are classified into good, medium and poor categories regarding the crumbliness. Given that the crumbliness of boiled yam is not well mastered at sensory level as well as instrumental level, the classification of genotypes should be better investigated using more efficient crumbliness assessment parameters.

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