Field Scientific Report

Evaluation of the Suitability of New Yam Genotypes to RTB Users' Needs and Preferences, at UAC-FSA in Benin

Gender Equitable Positioning, Promotion and Performance, WP5

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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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Acronyms, abbreviations and definitions

ANOVA:	Analysis of variance
RTB:	Roots, tubers and bananas
WP:	Work package
BMGF:	Bill & Melinda Gates Foundation
CIRAD:	Centre de coopération internationale en recherche agronomique pour le développement
PMU :	Project Managing Unit
SOP:	Standard operating procedure
JAR :	Just-About-Right

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ABSTRACT

Boiled yam key quality attributes stand for crumbly, easy to break, and sweet taste. This study assessed the acceptance thresholds of these quality attributes. Overall liking was associated to sweet taste, crumbliness and easy to break (r values 0.502, 0.291 and -0.087, respectively). These parameters and selected biophysical parameters highly discriminated the boiled yam from cultivars. A high crumbliness and sweet taste are preferred (sensory scores above 6.19 and 6.22 for crumbliness and sweet taste on a 10 cm unstructured line scale, respectively), while a too high easiness to break is disliked (sensory scores ranging from 4.72 to 7.62). Desirable biophysical targets were between 5.1 and 7.1 N for penetration force, dry matter around 39% and sugar intensity below 3.62 g/100g. Some improved varieties fulfilled the acceptable thresholds. The acceptable thresholds of sensory attributes for boiled yam assessed through the instrumental measurements are promising for yam breeders.

Key Words: yam varieties; consumer acceptability threshold; sensory attributes; texture; varietal adoption; high throughput phenotyping

1 INTRODUCTION

The adoption of new varieties depends greatly on consumers' acceptance. To date, no study has generated validated relationships between sensory attributes and biophysical variables of boiled yam to be used by breeders to screen germplasm. Preferred varieties can be readily identified if the thresholds (acceptable range) of major quality traits were available. Additionally, appropriate high- or medium-throughput phenotyping protocols are required for timely and cost-effective screening of quality traits in breeding germplasm. Unfortunately, there is limited information on thresholds of boiled yam quality attributes.

Understanding sensory attributes through robust and objective instrumental parameters with clearly-defined thresholds is critical for efficient (rapid and early) screening of germplasm to ensure the adoption of new varieties. This study aimed to establish robust relations between sensory attributes and biophysical/instrumental variables and to determine the acceptance thresholds for screening and selecting yam germplasm.

2 CONTEXT

2.1 Product profile

Important yam quality characteristics include smooth size/length, heavy weight, and shape tuber. Processing characteristics during boiled yam process were easy to peel, no discolouration, cooking time, viscosity of cooking water and no spots. For the ready to eat boiled yam, important characteristics were colour, crumbliness/mealiness/softness, stickiness, sweet taste odour and after cooking stability.

Table 1. Main characteristics to be included in the evaluation for boiled yam (identified from other WP1).

Level	Characteristics
Raw yam	Smooth, size, heavy weight and tuber shape
Processing	Easy to peel, no discoloration, cooking time, viscosity of cooking water and nonappearance of spots
Boiled yam	**White/yellowish***, **easy to break***, **crumbly/mealy***, sticky, **sweet*,** yam flavored and with aftercooking stability

* Quality traits to focus on during WP5 activities (consumer testing, QDA, etc.)

3 METHODOLOGY

3.1 Trial composition clones analysed and locations

Plant materials comprised landraces and improved yam varieties obtained from Benin and Nigeria farmers' fields and research centres. The improved TDa 1520002, TDa 1520050 from matured clones of water yam species and some landraces (Aga, Kpètè) belong to *D. alata,* while the other landraces (Dodo, Irindou, Kodjèwé, Kratchi, Laboko) are *D. rotundata* species.

3.2 WP5 Processing evaluation methodology

Standard cooking procedures were employed to ensure consistency (Adinsi et al., 2021). Yam tubers were sliced into three equal sections (proximal, middle, distal). Only the middle section is used in this study. After peeling, a punch was used to take cubic samples having 2.5 cm sides. The cubic

samples (about 20 g) were steam cooked for 38 min in 2 L of tap water in stainless steel saucepans using a gas cooker.

3.3 Measurements on raw yam harvested

Dry matter content was determined by oven drying on fresh tubers according to Adesokan et al. (2020).

Soluble sugars were extracted at ambient temperature in aqueous medium and separated by HPLC according to Mestres et al. (2019).

3.4 Measurements on intermediate products and/or final products characterization in the laboratory or on the field

Penetration and double compression tests were performed according to Adinsi et al (2021). using a texturometer (model TA-XT plus, Stable Micro Systems, Godalming, UK) on the samples collected from the same cooking batch used for quantitative descriptive analysis.
Dry matter content was also determined by oven drying on fresh tubers according to Adesokan et al. (2020).

3.5 Quantitative Descriptive Analysis (QDA)

Crumbly, easy to break and sweet attributes were used for the quantitative descriptive sensory analysis, with 13 trained panellists. The panellists scored the randomly coded boiled yam samples for each sensory attribute 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.

4 CONSUMER TESTING

4.1 Consumer testing design according the number of clones/products to be evaluated

Overall liking data were collected using a nine-point hedonic scale with 113 consumers, aged 18 to 70 years old, including 54.9% males. In addition, the 3-point “Just About Right” (JAR) test (1=Too weak, 2=JAR, 3=Too strong) was performed on crumbliness, easiness to break and sweetness.

5 RESULTS

5.1 Consumer testing

5.1.1 Using classical “consumer testing”

Overall liking

The varieties' overall liking of boiled yam significantly differed. Laboko was the most preferred variety, while Aga and Irindou the lowest

Table 2. Mean overall liking scores for the seven boiled yam samples tested

Variety type	Samples name	Overall liking score (1 to 9 scale)
Landrace	Dodo	6.0^{bc}
	Kratchi	6.6^{b}
	Irindou	5.6^{c}
	Kodjèwé	6.2^{bc}
	Wété	6.4^{b}
	Laboko	8.0^{a}
	Aga	5.7^{c}

Mean values with different superscript letters are significantly different ($p<0.001$).

5.1.2 Segmentation of consumers into groups of similar overall liking

The Agglomerative Hierarchical Clustering (AHC) analysis using Ward's method and automatic truncation indicated that consumers were clustered into three clusters as illustrated in Figure 1. All varieties except Aga were liked (scores between 5.1 and 7.7) by the consumers in Cluster 1 which represents the second largest group "Aga dislikers" (35.4% of the consumers). Cluster 2 liked all boiled yam and grouped 48.7% of consumers. Consumers in Cluster 3 represent the smallest group of consumers (15%) who disliked very much Irindou and had a slight dislike for Kodjèwé. Irrespective of the clusters Laboko and Kratchi varieties scored above 6.

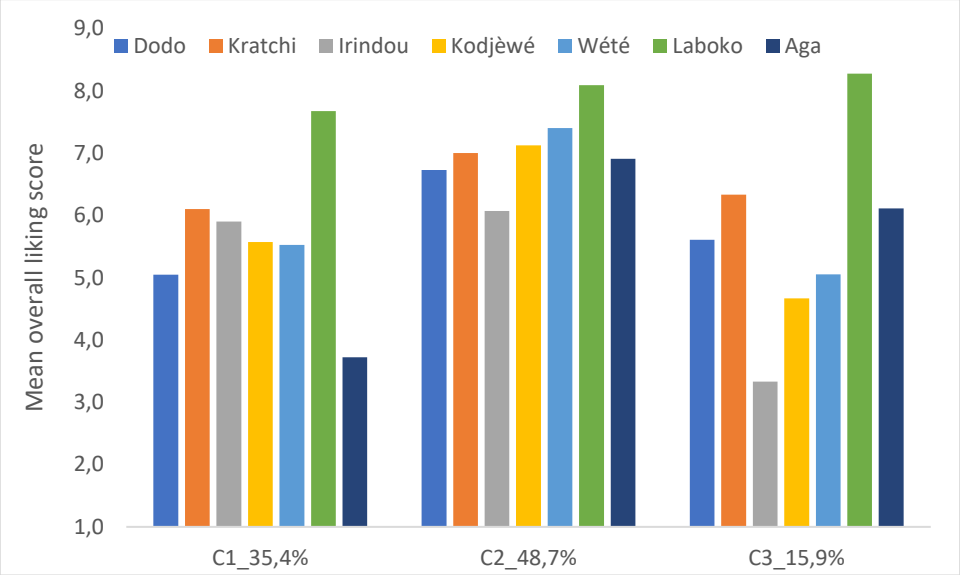

Figure 1**.** Mean overall liking of the boiled yam samples by consumer cluster type (%)

5.1.3 Penalty analysis based on Just About Right test (JAR) test to identify drivers of liking

Penalty analysis was performed to point out how many scores of overall liking were significantly lost because the characteristic was not evaluated JAR by at least 20% of the consumers. The penalty values of boiled yam ranged from 0.39 to 1.23. The variety Laboko was considered as the best by processors and consumers and was not penalized by any descriptor while Irindou sample was more penalized for the all descriptors tested (Figure 2). Sweet taste is the most penalizing descriptor for boiled yam while colour is the least.

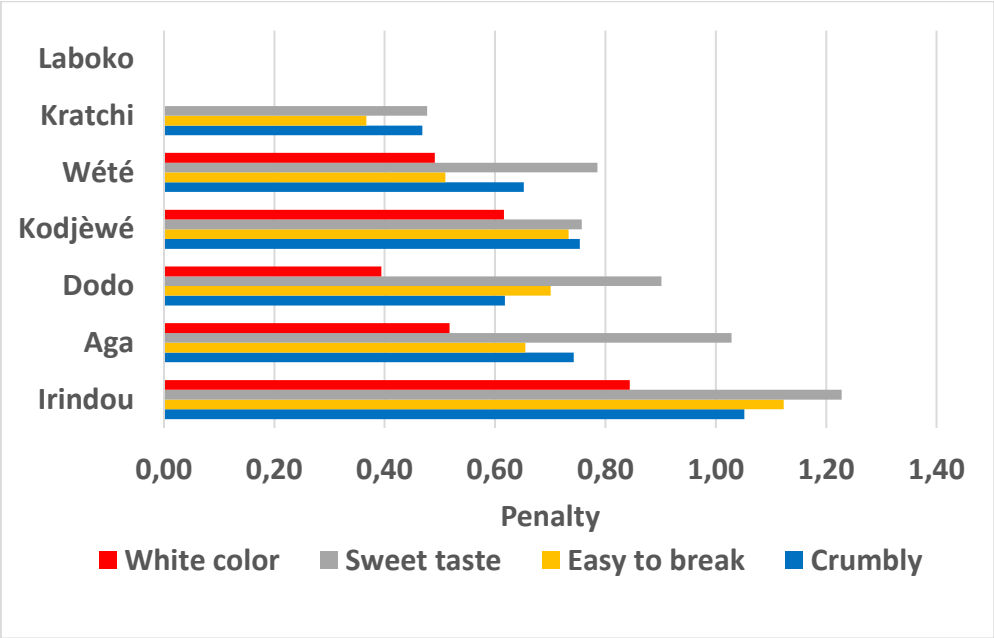

Figure 2**.** Penalties of overall liking of consumers

5.2 Quality attributes of boiled yam from quantitative descriptive analysis

There were significant differences between yam varieties for the mean scores of crumbliness, easiness to break, and sweetness (Table 3). D. alata genotypes (TDa 1520002, TDa 1520050 and Aga) generally showed the highest scores (> 7) for both crumbliness and 'easiness to break' compared with D. rotundata clones but had lower sweet taste (< 5 vs. > 6). Laboko had a high crumbliness (7.2) for a D. rotundata but median easiness score (5.9).

Table 3. Mean values of sensory attributes of boiled yam

Variety type	Sample name	Crumbly	Easy to break	Sweet taste
Landrace	Dodo	6.4^{abcd}	7.3^{a}	6.3^{ab}
	Kratchi	5.9^{bcd}	5.8^{b}	6.2^{ab}
	Irindou	5.7^{cde}	4.6^{cd}	6.1^{abc}
	Kodjèwé	4.5^{e}	4.4^{d}	6.8^{a}
	Wété	5.3^{de}	4.6^{cd}	6.1^{abc}
	Laboko	7.2^{ab}	5.9^{bc}	6.7^{a}
	Aga	7.1^{abc}	7.5^{a}	4.6^{cd}
Improved	TDa 1520050	7.1^{abc}	7.8^{a}	4.8^{bcd}
	TDa 1520002	7.8^{a}	7.8^{a}	3.7^{d}

Mean values with different superscript letters in the same column are significantly different ($p<0.001$).

5.3 Biophysical characteristics of boiled yam

Boiling decreased Dry matter (DM) by 0.4% for TDa 1520050 to 4.5% for Wété. The mean penetration (4.9–9.7 N) and compression (28.5–84.7 N) forces measured on boiled yam, and the DMR, exhibited significant varietal. Regarding sugars, saccharose (96.2%), glucose (2.4%), fructose (0.9%) and galactose (0.5%) were identified in the raw yam. The sugar intensity of raw yam, expressed as saccharose equivalent, varied from 2.8 g/100g in Irindou to 5.1 g/100g for Dodo.

Table 4. Mean values of biophysical parameters of boiled yam

Variety type	Samples name	Hardness_boiled (N)		Sugar intensity_ raw (g/100g, dry solid, SE†)	Dry matter (g/100, wet solid)	
		Penetration	Compression		Raw	Boiled
Landrace	Dodo	6.8^{c}	58.4^{b}	5.1	32.9^{b}	30.0^{d}
	Kratchi	6.8^{c}	64.0^{b}	3.7	38.8^{a}	34.8^{c}
	Irindou	8.5^{b}	84.7^{a}	2.8	39.9^{a}	37.0^{b}
	Kodjèwé	9.7^{a}	79.7^{a}	nd	39.9^{a}	36.0^{bc}
	Wété	8.1^{b}	81.6^{a}	4.5	39.7^{a}	35.2^{bc}
	Laboko	6.0^{cde}	45.6^{c}	3.1	42.1^{a}	39.4^{a}
	Aga	5.8^{de}	39.4^{cd}	3.8	31.4^{bc}	30.4^{d}
Improved	TDa 1520050	4.9^{e}	28.5^{d}	nd	30.3^{c}	29.9^{d}
	TDa 1520002	5.3^{e}	42.0^{cd}	nd	28.3^{c}	27.4^{d}

nd: not determined; Mean values with different superscript letters in the same column are significantly different ($p<0.001$).

5.4 Relationships within and between sensory attributes and biophysical characteristics of boiled yam

Penetration and compression forces were negatively and significantly correlated to the sensory texture attributes. Although some correlations between overall liking and sensory attributes or instrumental texture parameters were relatively high, none reached statistical significance. Moreover, the easiness to break was significantly and negatively correlated with dry matter (DM) of raw and boiled yam. Correlations between the DM and the penetration and compression forces were relatively high, but non-significant. There seems to be a negative correlation between the sugar intensity of raw yam and the sweetness of boiled yam while an unexpected negative correlation was found between sweet taste and crumbly.

Table 5. Pearson correlation between sensory attributes, overall liking and biophysical data

Variables	Overall liking	Crumbly	Easy to break	Sweet taste
Penetration force	-0.338	**-0.939**	**-0.893**	**0.694**
Compression force	-0.328	**-0.874**	**-0.899**	0.658
DM of raw yam	0.593	-0.639	**-0.852**	**0.862**
DM of boiled yam	0.631	-0.522	**-0.817**	**0.805**
Sugar intensity_raw	-0.226	-0.151	0.443	-0.061

DM: Dry matter, Numbers in bold represent significant correlation ($P \leq 0.05$);

5.5 Determining thresholds for Acceptability to serve breeders

The acceptable texture (60% JAR) was characterised based on the sensory analysis (0–10 scale), by scores between 5 and 8 for the easiness to break and above 6 for the crumbliness. Based on biophysical parameters, acceptable easiness to break was characterised by penetration force between 5 and 9 N and the DM of raw yam between 33 and 40%. At the same time, the crumbliness was judged acceptable if the penetration force was below 7 N. Regarding sweetness, the acceptable level was associated with a sensory score above 6, a sugar intensity of raw yam below 4 g/100g and a DM of raw yam around 39%.

The ranges obtained for some biophysical parameters can exclude each other, thus making impossible the simultaneous satisfaction of the relevant traits. A possible solution is to considered overall liking score and to calculate a weighed selection index (SI) which is considered for each variety as its deviation from the optimum Δ_{OL}(obs→opt) of overall liking (OL). It is calculated using the regression coefficient (β) between consumers' overall liking and relevant parameters as a weight. Accordingly, the deviation ($Value_{observed}$ - $Threshold_{optimal}$) of each parameter from the optimal thresholds/desirable target is standardized and SI is calculated as follows:

$\Delta OL(Vai \rightarrow opt) = \boldsymbol{SI} = \sum_{i=1}^{n}\left(\boldsymbol{\beta_i} \times \left(\boldsymbol{Value_{observed_i}} - \boldsymbol{Threshold_{optimal_i}}\right)\right)$, where "i" stands for each relevant parameter in the predictive models explaining consumers' overall liking. A variety with high SI score is considered as the best.

Table 6. Acceptability thresholds for sensory attributes and biophysical parameters of raw and boiled yam

Sensory attributes	JAR level (%)	Sensory score		Penetration force (N)		Sugar intensity_raw (g/100g, dry basis)	DMR (g/100g_oven)	
		Min	Max	Min	Max		Min	Max
Easy to break†	60	5 (4.72) §	5 (5.29)	8 (7.9)	9 (8.6)	nd	38 (38.4)	40 (39.6)
		7 (7.04)	8 (7.62)	5 (5.1)	6 (5.8)	nd	33 (33.2)	35 (34.5)
Crumbly‡	60	> 6 (6.19)		< 7 (7.1)		nd		
Sweet taste‡	60	> 6 (6.22)		Nd		< 4 (3.62)		> 39 (39.2)

†Quadratic function; ‡Linear function; nd: not determined; DMR: Dry matter of raw yam;

§In brackets, the observed threshold and out brackets, the rounded value of threshold

6 CONCLUSIONS

It is possible to test different yam genotypes to select those that show acceptable threshold of crumbliness, easiness to break and in a less extent sweetness. Furthermore, the use of a selection index (SI) is promising and helpful to select yam varieties that are close to optimal levels of overall liking simultaneously across a set of relevant traits.

7 ARCHIVING RAW DATA (UPLOADING TO CIRAD WEBSITE)

Please arrange the data of each type in excel and upload to the Cirad website and fill the table below. Per category (see table 9 below) try as much as you can to put the data in single excel files using different sheets if necessary.

https://collaboratif.cirad.fr/share/page/site/RTBfoods/documentlibrary#filter=path%7C%2FWP5%7C&page=1 [A folder structure on the RTBFoods dataverse platform has to be created]

Table 7. Overview of WP5 raw data uploaded

N°	Type of raw data	Nr of files and names of the files	Uploaded? (Y/N)
1	Trial agronomic data		
2	Evaluation with champion processors of roots, intermediate products and final food products		
3	Processing diagnostics data		
4	Laboratory data physiochemical and functional properties on fresh harvest and final and (if applicable) intermediate products		
5	Laboratory QDA		
6	Consumer testing data (classical consumer testing using JAR or Tricot with or without JAR)		

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