Field Scientific Report

Evaluation of the Suitability of New Genotypes to RTB Users' Needs and Preferences regarding Matooke, at NARL in Uganda

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
Tricot :	Triadic comparisons of technologies (citizen science approach)
CATA :	Check-All-That-Apply
JAR :	Just-About-Right
Complete WP 5 expriment	A set of varieties that are evaluated from planting, to processing with champion processors and consumer testing with 100+ consumers.

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ABSTRACT

Work Package 5 activities aimed to evaluate whether the qualitative indicators of the consumer preferred characteristics of steamed matooke can be predicted by quantitively laboratory-assessed indicators of those characteristics. Four genotypes; improved hybrid NARITA 4 and NARITA17 together with two local genotypes- Kibuzi and Nakitembe were tested with 300 Consumers in the field and also characterized in the Laboratory using instrumental, biochemical and descriptive sensory panel of 12 members. Consumers scored matooke from landraces as the most liked. The CATA test showed that the most important characteristics were smooth mouth feel, soft to the touch, not sticky, moldable, deep yellow color, attractive, good matooke taste, and smell. Principal component analysis confirmed that most of the preferred sensory characteristics were associated with the local genotypes whilst the less preferred characteristics were associated with hybrids. Qualitative indicators of the consumer preferred characteristics of steamed matooke can be predicted by quantitative laboratory assessment. The strong associations observed between laboratory-assessed and consumer-based characteristics (moldable by touch, and yellowness) suggest the possibility of predicting consumer characteristics using quantitative laboratory sensory assessments. The study demonstrated that the laboratory-based methods can be used to predict the consumer acceptance of the new matooke genotypes.

Keywords: laboratory assessment; matooke quality; high throughput phenotyping; varietal adoption; efficient breeding; improved hybrids vs. landraces

1 INTRODUCTION

The aim of WP5 for matooke was to evaluate whether the qualitative indicators of the consumer preferred characteristics of steamed matooke can be predicted by quantitively laboratory-assessed indicators of those characteristics. This would help the breeding Programs to predict end user traits early enough in the breeding process leading to efficient sorter and cheaper variety development process. The matooke WP5 leveraged on the activities of the already on the NAROs established on farm evaluation trails in four locations (southwestern, Mid western and Central Uganda) each with 91 Matooke genotypes. A pre-screening exercise by NARO picked two most promising Genotypes- NARITA 4 and NARITA17 and these together with two local genotypes- Kibuzi and Nakitembe were tested with 300 Consumers in the field and also characterized in the Laboratory using instrumental, biochemical and descriptive sensory panel of 12 members.

2 CONTEXT

2.1 Product profile

During work Package 1 surveys identified main characteristics of matooke at farm by Rae, during processing and Final product as shown in Table 1

Table 1. Main characteristics to be included in the evaluation for each food Product Profile (identified from other WPs).

Characteristic category	High quality characteristics
1. Raw material characteristics *(agronomic, post-harvest)*	Big Fingers
	Big Bunch
	Yellowish/creamish colour
	Shiny light green finger colour
	Disease free/spotless
2 *Processing characteristics* *of raw material for the product quality during processing (technological, physicochemical)*	Yellowish/creamish Pulp
	Easy to peel
	Big fingers
	Soft peel
	Soft pulp
	Straight/slightly curved fingers
	Relatively little sap
4 *Characteristics of cooked/ready to eat final product* (to look at, touch, smell, taste, texture in mouth)	Soft Texture
	Good smell
	Yellow colour
	Good matooke taste
	Holds together when mashed

The matooke WP5 activities focused on bunch weights, figure characteristics, colour of the cooked pulp, texture and matooke taste.

3 METHODOLOGY

3.1 Trial composition clones analyzed and locations

Four matooke genotypes; improved hybrids; NARITA4 and NARITA17, and landraces Nakitembe and Kibuzi) were used for this study (Table 2). Southwestern -Mbarara, Midwestern- Hoima Central-Buwambo.

Table 2. Overview of the trials and genotypes used

Complete experiment (Complete WP5 activtity) [Can coincide with trial location]	Trial year	Trial location	Genotypes	Crop program official denomination / Local name	Reasoning for including the variety	Comments
On farm evaluation of advanced improved matooke hybrids	2019	Southwestern, Mid-western and Central Uganda	2	*Improved Matooke hybrids NARITA 4, NARITA17*	*The two hybrids are advanced selections under on-farm evaluation*	*The NARITA hybrids had passed the existing pre-screening criterion of NATRO Uganda*
			2	*Nakitembe, Kibuzi*	Best local landrace, as identified by end users	*Often used as local checks by the breeding programe*

Quantitative Descriptive Analysis (QDA)

Parts of the same samples (Nakitembe, Kibuzi, NARITA 4 and NARITA17) were transported to the laboratory for analyzing the quantitative indicators by descriptive sensory analysis and instrumental analyses. The sensory indicators were measured using a trained panel of 8 males and 4 females. The sensory parameters assessed were: softness by touch, mouth feel, taste, moldability, smell, texture, attractiveness, hardness by touch and color. The panelists were staff of the National Agricultural Research Laboratories (NARL). Samples were evaluated and scored against the developed descriptors (19). The appearance of matooke was described by color and homogeneity of the color, while the texture was described by firmness, moistness and smoothness all by mouth, while hardness by touch and moldability were by touch (19). Prior to testing, the samples from the four genotypes were prepared and served according to a protocol developed at the Food Biosciences Laboratory of NARL. One sample was served at a time (temperature above 85^0C) on disposable plates and presented with a glass of water for rinsing their mouths. Panelists were each seated in individual booths that had sinks where they would rinse their mouths between tasting the samples. Panelists were only signaled to start tasting the samples when the temperature of the similar sample termed the *reference sample* read 75^0C. A thermometer was inserted to read the core temperature.

The laboratory instrumental parameters were: hardness assessed with a texture analyzer (TMS-PILOT texturometer) color coordinates assessed with a Minolta chromameter (CR-100 or CR-200) with an 8 mm measuring head L*(Raw), b*(Raw), L*(Cooked) and b*(Cooked) (19).

3.2 Agronomic evaluation (List the parameters evaluated)

At harvest, agronomic characteristics that include; Bunch weights(BW), Number of clusters per bunch,(NoC), Fruit Length(FL) and fruit curvature (CV) were measured.

3.3 WP5 Processing evaluation methodology

3.3.1 Flowchart of the processing

Matooke are processed according to the figure 1 below.

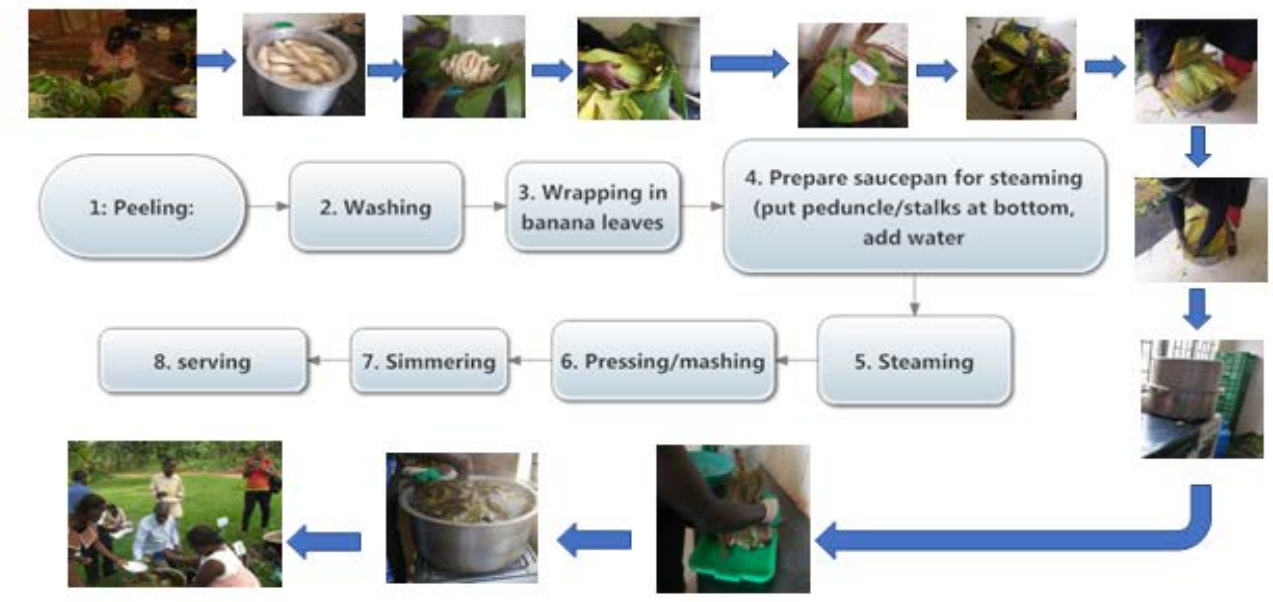

Figure 1. A flow chart of matooke processing (source: *Pricilla MARIMO* et al., 2020).

3.4 Measurements on Raw material harvested

NA

3.5 Measurements on Intermediate products and/or final products characterization in the laboratory or on the field

NA

Table 3. Sample collection for laboratory analysis for each complete WP5 experiment (processing steps example for matooke)

	Sample collection for laboratory analysis			Quantitative processing data collection		
Process description	**Collection point (Y/N)**	**Quantity needed**	**Pattern of stabilization**	**Yield**	**Productivity/ level of drudgery**	**Quality**
Raw material	*Yes*		*Fresh*	*Weighing*		*Pairwise ranking*
Step1: *Peeling*	*Yes*	*0.5*	*Fresh/drying*	*Weighing*	*Duration (5.635) Minuts*	*Pairwise ranking*
Step2: *Washing*	*Yes*			*Weighing*	*Duration in minutes*	
Step3: *Wrapping in banana leaves*	*Yes*					
Step 4: *Prepare saucepan for steaming*	*Yes*			*Weighing*	*Duration in minutes*	
Step 5: Steaming	*Yes*			*Weighing*	*Duration in hours*	
Step 5: Mashing/pressing	*Yes*			*Weighing*	*Duration in minutes*	
Step 6: Simmering	*Yes*			*Weighing*	*Duration in minutes*	
Step 7: Serving				*Weighing*		
End product	*Yes*	*0.5*	*Cooked sample*	*Weighing*	*	*Pairwise ranking*

Note: The distance between the testing sites in the fields is over 200Km. with exception of central region, where the distance from the laboratory is about 25KM. The exercise was, therefore, logistically challenging, and expensive.

Table 4. Overview of laboratory measurements related to the WP5 work

Parameter measured	Methodology used to measure the parameter	On intermediate food product produced in the lab based on fresh material from the WP5 trails (Y/N)	On final food product produced in the lab based on fresh material from the WP5 trails (Y/N)	On intermediate food product processed by the champion processors from the WP5 trails (Y/N)	On final food product processed/ prepared by the champion processors from the WP5 trails (Y/N)
Instrumental texture (hardness)	Double compression	NA	Y	NA	Y
Instrumental colour	Chroma	NA	Y	NA	Y

Parameter measured	Methodology used to measure the parameter	On intermediate food product produced in the lab based on fresh material from the WP5 trails (Y/N)	On final food product produced in the lab based on fresh material from the WP5 trails (Y/N)	On intermediate food product processed by the champion processors from the WP5 trails (Y/N)	On final food product processed/ prepared by the champion processors from the WP5 trails (Y/N)
Homogeneity of color by sight	Sensory	NA	Y	NA	Y
Firmness by mouth	Sensory	NA	Y	NA	Y
Moistness by mouth	Sensory	NA	Y	NA	Y
Smoothness by mouth	Sensory	NA	Y	NA	Y
Hardness by touch	Sensory	NA	Y	NA	Y
Moldability by touch	Sensory	NA	Y	NA	Y
Stickiness by touch	Sensory	NA	Y	NA	Y
Sweetness	Sensory	NA	Y	NA	Y
Astringency	Sensory	NA	Y	NA	Y
Sourness	Sensory	NA	Y	NA	Y
Matooke aroma	Sensory	NA	Y	NA	Y

3.6 Quantitative Descriptive Analysis (QDA) measurements

The parameters measured by trained sensory panel were; Homogeneity of color by sight, Firmness by mouth, Moistness by mouth, Smoothness by mouth, Hardness by touch, Moldability by touch, Stickiness by touch, Sweetness, Astringency, Sourness and Matooke taste.

3.7 Processing evaluation with champion processors

3.7.1 Processing localities

The matoke Processing/Preparation was done at three sites; Kashaka-Mbarara in Southwestern, Bulindi-Hoima in Mid western and Buwambo- Luwero in central Uganda

3.7.2 Selecting processors (champion processors)

The sampling strategy followed the established NARO-Banana Breeding evaluation sites. The processors were selected through local council systems based their expertise in preparing matooke.

3.7.3 Evaluation of the processing with the 'champion processors'

Green mature cooking bananas were harvested, peeled, wrapped in banana leaves, steamed under same cooking conditions and mashed. All the 4 varieties were steamed in one big saucepan as separate bundles marked with distinct colour strings to ease identification. The samples were coded with different digits and small portions served at warm temperatures to the consumers to evaluate.

Monitoring times and quantities, product yield and relative amount of drudgery

One processing champion supported by three helpers at each site prepared steamed-mashed matooke from four varieties each using the same process they normally use. The processors were given 1 bunch per genotype per site for cooking. At each processing step, the processors were asked to indicate the characteristics that they perceive as indications that a banana variety will make a good or poor quality steamed-mashed matooke. In addition, during processing, the duration of each processing step was measured up to simmering and serving.

4 CONSUMER TESTING

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

The steamed matooke samples were presented to a panel of 300 consumers, 172 of whom were females. The consumers were recruited from Mbarara (99 consumers), Hoima (100 consumers) and Wakiso (101 consumers) districts in southwestern, western, and central Uganda, respectively.The panel first evaluated the visual appearance and tactile characteristics on a 9-point hedonic scale using a list of characteristics previously generated with matooke users . Samples were then tasted one at a time to assess overall liking, flavor, sweetness, texture, mouthfeel and aftertaste. The consumer panel assessed the characteristics color, softness by touch and mouth feel using a Just-About-Right (JAR) scale, while a check-all-that-apply (CATA) test was used to confirm the importance of the characteristics in the overall liking of the product.

5 RESULTS

5.1 Agronomic performances of the clones in the WP5 trials.

The bunch weights, number of clusters, finger length and figure circumference and curvature of the improved genotypes (NARIT 4 and NARITA 17) fell within the acceptable range as capture in work package 1 implying that with respect to these characteristics, the genotypes are acceptable by the end users (Table 5).

Table 5 Agronomic characteristics of selected hybrids under evaluation

Cultivar	BW	NoC	FL	FC	CV
Nakitembe	23.1	8	14	12	0.9
NARITA 15	20.1	7	21	12	1
NARITA 16	17.09	6	14	12	1
NARITA 17	29.9	10	19	15	0.8
NARITA 18	28.4	11	18	12	0.7
NARITA 19	25.8	12	17	12	0.9
NARITA 4	22.5	9	19	11	0.9

5.2 Processing diagnostics: quantities and times to determine product yield and productivity

Genotypes differed in Peeling time hybrids taking more time than the compared with the landraces. No differences were observed across the genotypes with respect to Washing, Wrapping and simmering (Table 6).

Table 6 Duration (minutes) of the unit operations in matooke processing

	Time for peeling/m	Time for washing/m	Time for wrapping/m	Steaming time/h	Pressing time/m	Simmering time/h
NARITA4	5.6 ab	0.9 a	3.6 a	2.8 a	5.5 ab	1.3 a
Nakitembe	2.3 a	1.5 a	3.5 a	1.7 a	4.4 b	0.9 ab
NARITA 17	4.9 ab	13.6 a	1.9 a	1.8 a	17.3 a	0.9 ab
Kibuzi	3.8 b	2.8 a	3.3 a	2.5 a	3.5 b	0.9 ab
Pr> F(Model)	0.4	0.5	0.9	0.6	0.3	0.4

5.3 Evaluation of the processing by champion processors: product quality

Consumers characteristics and their matooke consumption habits

Over half of the consumer panelists in all districts were female with exception of Hoima (Table 7). Over 70% were married with families. More than 60% of consumers in Mbarara and Hoima practiced farming whereas in Wakiso it was only 30%. All the consumers interviewed were Matooke eaters, with over 30% eating matooke every day. The most common form of preparing matooke was steaming followed by boiled fingers locally known as *katogo.*

Table 7 Socio economic profiles of consumers interviewed in all the districts

Variables	Total sample	Location		
	All (n=300)	Mbarara (n=99)	Hoima (n=100)	Wakiso (n=101)
Average age (years)	36.6	37.4	33.8	38.6
Education level (yrs. in school)	7.6	7.0	6.9	8.8
Gender (%)				
Male	42.7	43.4	54.0	30.7
Female	57.3	56.6	46.0	69.3
Marital status (%)				
Single	19.7	16.2	16.0	26.7
Married	72.0	73.7	80.0	62.4
Divorced/separated	4.7	6.1	3.0	5.0
Widow	3.7	4.0	1.0	6.0
Occupation of the consumer				
Farmer	54.2	62.2	67.4	31.5
Full time salary employed	6.9	5.1	7.1	8.7
Part time wage employed	6.6	4.1	7.1	8.7
Self-employed	30.2	17.6	16.3	47.8
Other	2.1	1.0	2.0	3.3
Consumption frequency of matooke (%)				
Every day	30.0	51.5	9.0	29.7
Once a week	10.7	6.1	21.0	5.0
Several times a week	48.7	35.4	52.0	58.4
Once a month	3.3	2.0	8.0	0.0
Several times a month	7.3	5.1	10.0	6.9
Forms in which matooke is consumed (%)				
Steamed mashed	43.0	39.0	46.0	44.6
Boiled mashed	15.0	18.0	12.0	14.9
Katogo	35.0	35.0	35.0	33.2
Roasted	4.0	4.0	5.0	5.1
Empogola	3.0	5.0	2.0	2.3

The consumers scored steamed matooke product from Nakitembe and Kibuzi as the most liked whereas that from hybrids NARITA17 and NARITA 4 were the least preferred, particularly the later (Table 8).

Table 8 Overall liking of the steamed matooke in all the districts

Genotypes	(Mean Overall liking scores*) (n =300 consumers)	Groups**		
Nakitembe	7.446	A		
Kibuzi	7.089	A		
NARITA17	5.676		B	
NARITA 4	4.992			C

***Overall liking was rated on a nine-point scale from 1 = dislike extremely, to 9 = like extremely. **Different letters correspond to the products, which are significantly different. Tukey test (p<0.05).*

The descriptive for the liking data and the JAR variables are shown in Figure 2. The colour parameter (Figure 2A) was scored in a 'JAR' category ranging from too light to too dark. Over 70% of the consumers thought that all the steamed matooke products from all genotypes possessed the colour as they liked with exception of NARITA 4 where 25% thought the product was too dark.

With respect to softness in hand (Figure 2B), steamed matooke product from hybrid NARITA 17 showed higher percentages of the JAR responses in comparison to NARITA 4. Consumers considered hybrid NARITA 17 to be soft as they liked while NARITA 4 is regarded as relatively too soft. Furthermore, they also indicated that NARITA 4 was rough (Figure 2B). Regarding mouthfeel (Figure 2C) NARITA 17 showed a similar performance to that of Kibuzi, whereas a minority of consumers liked NARITA 4 as it is.

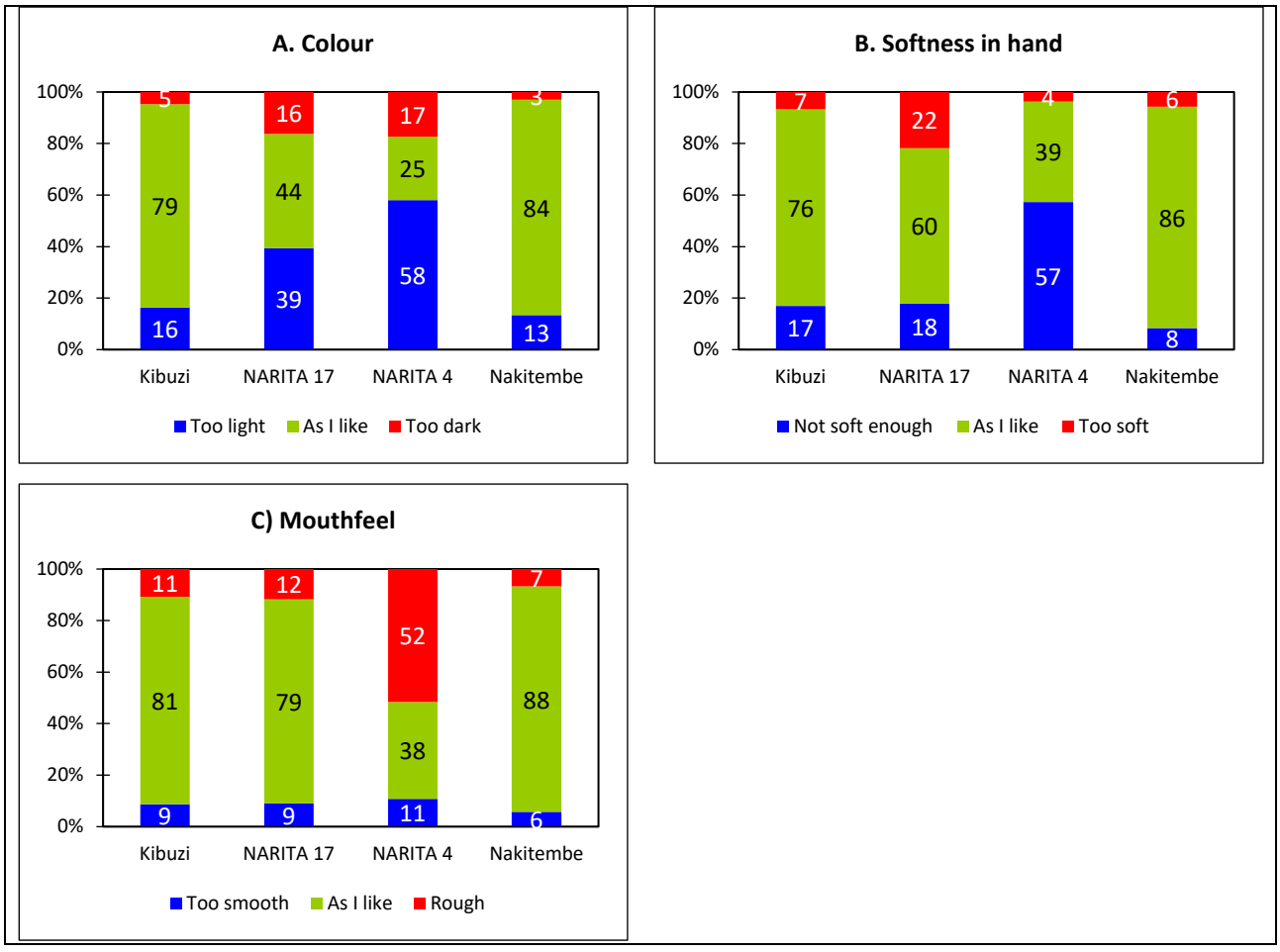

Figure 2 Percentage of consumers rating A) colour B) softness in hand and C) mouthfeel using the JAR scale

Results of the CATA test showed that the most important characteristics, as indicated by the number of citations, were softness, smooth mouth feel, good matooke taste, mouldability, nice smell, uniform texture, delay in hardening, attractiveness, and deep yellow colour. A comparison of the list of characteristics of the different matooke genotypes are presented in Table 9. The genotypes that have the most citations for the most liked characteristics were Nakitembe, Kibuzi and NARITA17 respectively. Significant differences for the most liked characteristics were observed between the landraces and hybrid genotypes (Table 9).

Table 9 Frequency of citations of the quality characteristics by consumers (n=300)

Varieties	Nakitembe	Kibuzi	NARITA 17	NARITA 4	Total
Easy to digest	127	112	85	50	374
Not attractive	15	28	106	160	309
Appealing/attractive	204	199	94	52	549
Mixed colors	20	24	65	89	198
No smell	25	34	90	111	260
Cools quickly	19	46	63	148	276
Moldable	218	207	155	97	677
Flat taste	36	34	69	79	218
Pale yellow	35	39	86	123	283
Mild sugary taste	10	11	16	7	44
Watery	4	4	33	1	42
Blackish	1	4	17	19	41
Not compact (crumbles on plate)	4	14	15	61	94
Sap like taste	19	24	64	68	175
Hard	13	26	21	143	203
Brownish	1	2	5	7	15
Sticky between fingers	105	85	138	65	393
Uniform/even texture	217	200	114	53	584
Soft	249	232	194	98	773
Does not harden quickly	208	168	123	60	559
Smooth mouth feel	258	215	152	90	715
Good matooke taste	234	220	141	93	688
Deep yellow colour	185	180	73	37	475
Nice smell	214	200	132	90	636
Overall liking	7.446	7.089	5.676	4.992	25.203

Significant differences were also observed between landraces and improved hybrids with respect to the most relevant traits (Table 10). For these relevant traits, Nakitembe and Kibuzi were always

significantly better than NARITA 17 (the best of the two hybrids). For some traits of intermediate relevance based on number of citations (hardness and time to cook) there were no significant differences between Kibuzi and NARITA 17.

Table 10 Mean intensities of the sensory attributes, acceptability of the steamed matooke from consumers

Sensory attributes	Nakitembe	Kibuzi	NARITA 17	NARITA 4
Appealing attractive	0.68[a]	0.66[a]	0.31[b]	0.17[c]
Blackish	0.00[b]	0.01[b]	0.06[a]	0.06[a]
Brownish	0.00[a]	0.01[a]	0.02[a]	0.02[a]
Cools quickly	0.06[c]	0.15[b]	0.21[b]	0.49[a]
Deep yellow	0.62[a]	0.60[a]	0.24[b]	0.12[c]
Does not harden quickly	0.69[a]	0.56[b]	0.41[c]	0.20[d]
Easy to digest	0.42[a]	0.37[a]	0.28[b]	0.17[c]
Flat taste	0.12[b]	0.11[b]	0.26[a]	0.26[a]
Good matooke taste	0.78[a]	0.73[a]	0.47[b]	0.31[c]
Hard	0.04[b]	0.09[b]	0.07[b]	0.48[a]
Mild sugary taste	0.03[a]	0.04[a]	0.05[a]	0.02[a]
Mixed colors	0.07[c]	0.08[c]	0.22[b]	0.30[a]
Moldable	0.73[a]	0.69[a]	0.52[b]	0.32[c]
Nice smell	0.71[a]	0.67[a]	0.44[b]	0.30[c]
No smell	0.08[b]	0.11[b]	0.30[a]	0.37[a]
Not attractive	0.05[c]	0.09[c]	0.35[b]	0.53[a]
Not compact (crumbles on plate)	0.01[b]	0.05[b]	0.05[b]	0.20[a]
Pale yellow	0.12[c]	0.13[c]	0.29[b]	0.41[a]
Sap like taste	0.06[b]	0.08[b]	0.21[a]	0.23[a]
Smooth mouth feel	0.86[a]	0.7[2b]	0.51[c]	0.30[d]
Soft	0.83[a]	0.77[a]	0.65[b]	0.33[c]
Sticky between fingers	0.35[b]	0.28b[c]	0.46[a]	0.22[c]
Uniform even texture	0.72[a]	0.67[a]	0.38[b]	0.18[c]
Watery	0.01[b]	0.01[b]	0.11[a]	0.00[b]

[abc]mean values in a row followed by different letters represent significant differences ($p<0.05$)

Preference mapping of the sensory characteristics

PCA was conducted using the estimated means for the sensory characteristics of the steamed matooke. The first two dimensions described 99.3% of the variability. The first dimension (F1) confirmed that most of the preferred characteristics (smooth mouth feel, nice smell, deep yellow, good matooke taste, uniform texture) are associated with the local genotypes Nakitembe and Kibuzi. Meanwhile, the second dimension (F2) was characterised by less preferred characteristics (sap like taste, no smell, mixed colour, not attractive, pale yellow, cools quickly and hard food) that are associated with hybrids NARITA 4 and NARITA17 (Figure 3A). These relationships can be clearly seen on a bi-plot of correspondence analysis, which show associations between the type of steamed matooke product and product characteristics.

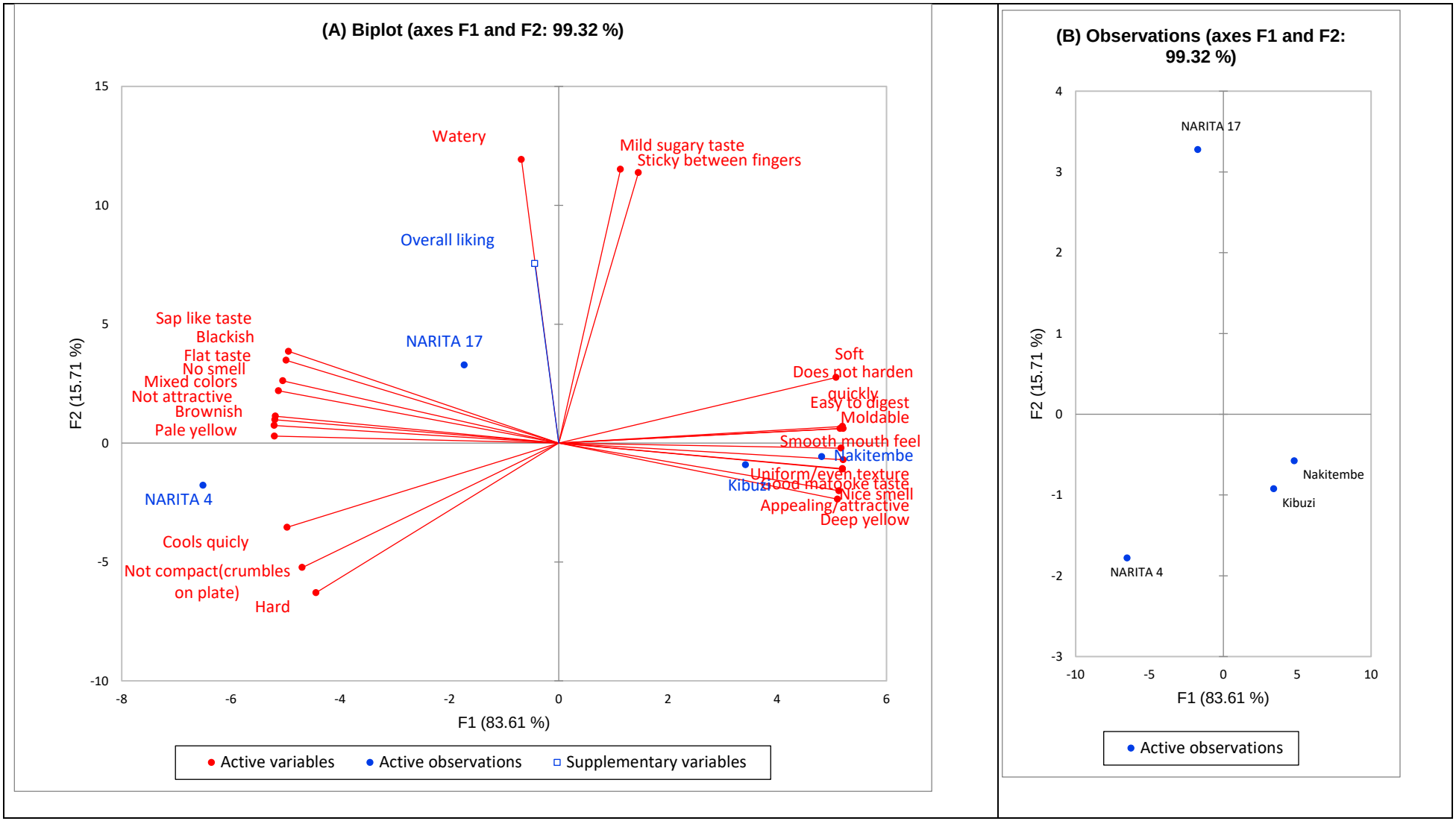

Figure 3 Graphical representation of loadings of the sensory characteristics of steamed matooke samples from consumers.

(A) Biplot based on the PCA of results from sensory analysis on steamed matooke consumers linked. (B) External preference mapping based on the results of the PCA. The axes represent the first (F1 dimensions) and the second (F2 dimensions) of the PCA performed on the results from the sensory analysis

Lab-based evaluation for Quantitative Descriptive Analysis (QDA)

Whereas the previous section presents the field-based findings, this section describes corresponding lab-based analyses. The same samples were also evaluated by panelists at the laboratory for quantitative indicators(n=12) for their liking of Moistness by mouth, Smoothness by mouth, hardness by touch, Moldability by touch, Stickiness by touch, Matooke Aroma, Hardness (Table 11). Results show that there is significant difference between local variety Nakitembe and hybrids in terms of color (Table 5). The hybrids are not significantly different from local varieties in terms of textural characteristics like firmness, moisture, moldability (apart from NARITA 4), smoothness (apart from Kibuzi) and stickiness, whereas in terms of the taste, panellists rated hybrid NARITA 17 taste characteristics such as sweetness, astringency, sourness and aroma not significantly different from local varieties (Table 11).

Table 11 Mean scores for sensory attributes, acceptability of the steamed matooke from panellists

Descriptors	NAKITEMBE	KIBUZI	NARITA 17	NARITA 4
Yellow	9.00^{a}	7.33^{b}	6.78^{bc}	5.67^{c}
Homogeneity of colour by sight	9.33^{a}	8.11^{ab}	6.78^{bc}	5.67^{c}
Firmness by mouth	2.00^{a}	3.11^{a}	2.33^{a}	3.89^{a}
Moistness by mouth	7.00^{a}	6.56^{a}	6.67^{a}	5.00^{a}
Smoothness by mouth	9.00^{a}	5.67^{b}	7.78^{a}	7.56^{a}
hardness by touch	2.33^{b}	3.67^{ab}	2.56^{b}	5.00^{a}
Moldability by touch	9.56^{a}	8.56^{a}	9.00^{a}	6.78^{b}
Stickiness by touch	4.44^{a}	5.56^{a}	5.89^{a}	4.33^{a}
Sweetness	2.00^{a}	0.89^{ab}	1.22^{ab}	0.33^{b}
Astringency	0.67^{a}	1.11^{a}	0.56^{a}	0.89^{a}
Sourness	0.44^{a}	1.00^{a}	0.67^{a}	0.56^{a}
Matooke Aroma	8.89^{a}	7.33^{ab}	8.11^{ab}	6.78^{b}

^{abc}mean values in a row followed by different letters represent significant differences ($p<0.05$).

Sensory descriptor scoring scale according Nowakunda et al., 2019

Potential of the quantitatively assessed quality indicators to predict consumer characteristics

The PCA of the textural, colour and matooke taste attributes from consumers (qualitatively assessed indicators) were integrated with results from the laboratory parameters to perform the potential of QDA to predict consumer preferred characteristics. This explained 91.27% of the total variability. Principal component 1 (PC1) explains 83.61% and PC2 explains 15.71% of the variation (Figure 3). The results revealed that colour characteristic as assessed by the consumers is strongly associated with the laboratory assessed colour indicators (Figure 4). With respect to texture, the consumers assessed textural characteristics namely moldability, smoothness in the mouth, softness are also strongly correlated with the quantitatively assessed textural indicators (Figure 4). Matooke taste as assessed by consumer panel (CP) is strongly associated with smooth texture, deep yellow colour which are the characteristics associated with landraces laboratory sensory assessment (CP) (Figure 4).

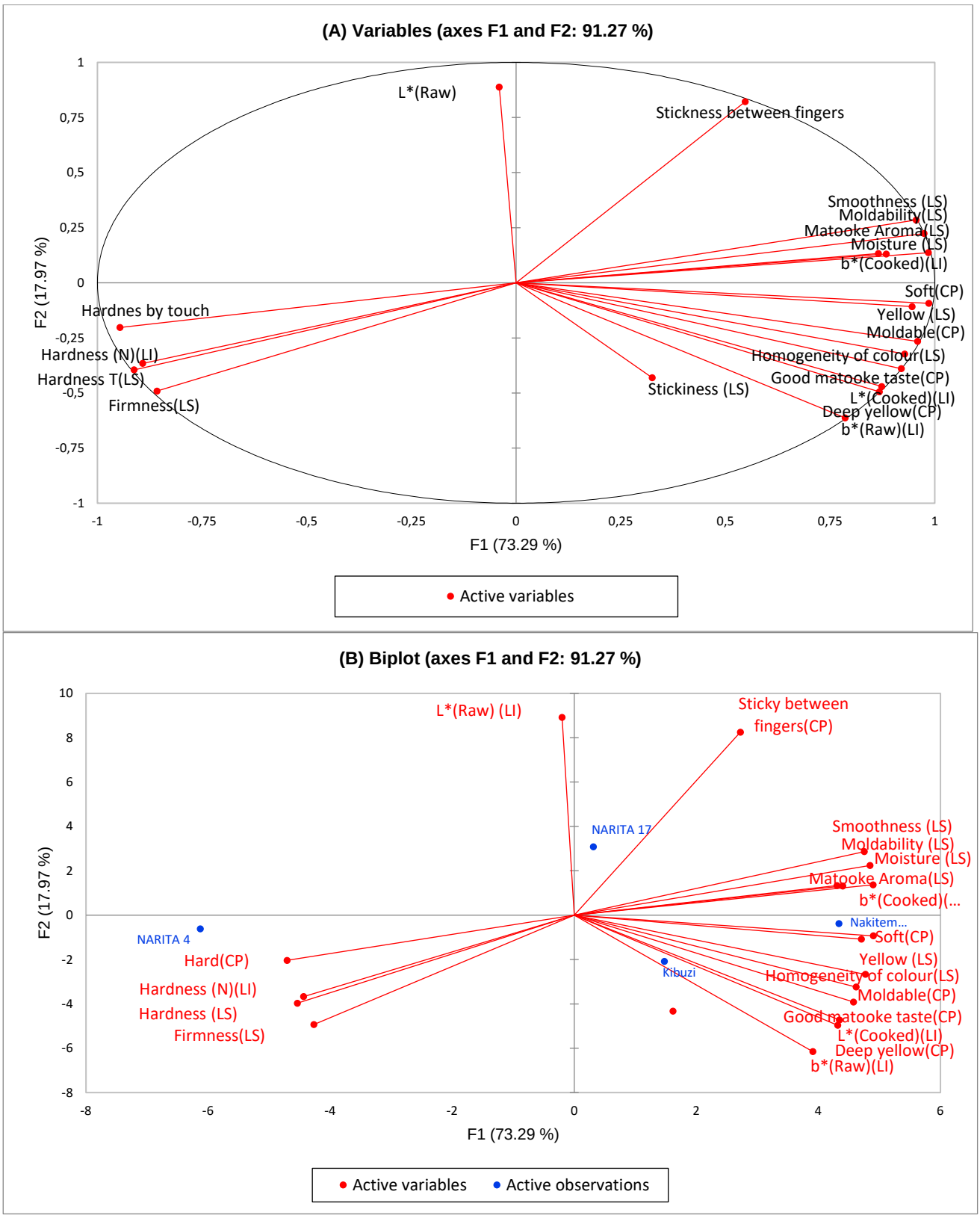

Figure 4 Graphical representation of samples from both the sensory characteristics of steamed matooke samples from consumers and laboratory assessed parameters.

Symbols represent: CP, Consumer filed data; LS, laboratory sensory; LI, laboratory instrument data

(A) Biplot based on the PCA of results from sensory analysis on steamed matooke consumers linked with the laboratory assessed parameters. (B) External preference mapping based on the results of

the PCA. The axes represent the first (F1) and the second (F2 dimensions) of the PCA performed on the results from the sensory analysis.

6 DISCUSSION AND CONCLUSION

Most smallholder banana farmers produce specific varieties which might not be what is demanded in the market. Consumers of matooke have specific characteristics that they desire in matooke (Akankwasa et al., 2021) and failure to supply what is needed may give banana traders a hard time to engage in the market and result in unmet demand. This study revealed that consumers preferred steamed matooke from landraces Nakitembe and Kibuzi whereas that from hybrids NARITA17 and NARITA 4 was the least preferred, particularly the later. The steamed matooke products from these landraces were characterised by the liked attributes including colour, softness and mouth feel while hybrids lacked the intensity that is desired by the consumers (to a lesser degree in NARITA 17). The yellow color of the steamed matooke product influences consumer's opinion of its taste, softness and the willingness to choose the variety with that particular colour. Matooke genotypes that lack yellow colour are often rated inferior to the landrace varieties and rejected (Tumuhimbise et al., 2020; Nowakunda et al., 2004, Ssali et al., 2012; Akankwasa et al., 2016). Consumers of steamed matooke associate yellow colour with good taste and if the product's colour does not match consumer expectation, consumers will regard the product to taste differently and substandard. This explains, along with several other relevant traits, the wide differences in overall liking scores between the NARITAs and the landrace varieties in this study. This suggests that these landraces can be used as references to define the biochemical indicators of colour and texture. In studies by Kuntashula et al., 2012 and Marimo, et al., 2020, consumers demonstrated preference for local varieties in terms of food taste and colour and these were frequently cited as the major reasons for their survival for so long in the market and on farmers' fields. Steamed matooke is expected to have a flat 'matooke taste'.

The study demonstrates that consumer preferences for steamed matooke is driven by several preferred product characteristics such as deep yellow colour, good matooke taste and nice smell and often, each characteristic, individually contributes to the product choice. In other studies, investigating cooking bananas, consumers preferred varieties with superior *sensory characteristics (taste, flavor, texture and colour*) (Nowakunda, 2000; Endrizzi et al., 2015; Akankwasa et al., 2020; Madala, 2021). This study shows that there is a large gap between steamed matooke product from the landrace varieties and the matooke hybrids under evaluation with respect to the textural attributes (softness, hardness, moldability, smoothness in the mouth and uniform/even texture). This highlights the importance of texture as a selection criterion. This result is similar to past studies that identified texture, and the related mouthfeel of a product as playing an essential role in how consumers evaluate a product (Jeltema et al., 2016; Pellegrino et al., 2020). In steamed matooke, texture influences tactile but also visual attributes such as uniformity or evenness after mashing, which affects the appearance and consequently the acceptability.

The study has demonstrated that the laboratory-based method can be used to predict the consumer acceptance of the new matooke genotypes. The strong associations observed between laboratory assessed and consumer characteristics (moldable, hardness, softness and yellowness) suggests that the approach is better because it is quick and low cost to generation of data compared with large scale consumer sensory panels. Holman and Hopkins, 2021, while investigating the use of conventional laboratory-based methods to predict consumer acceptance of beef and sheep meat confirmed that these approaches are advantageous because of their reproducibility, low cost, rapid generation of data and technical ease compared with the use large scale consumer sensory panels. While investigating important sensory attributes that affect consumer acceptance of sorghum porridge, Aboubacar et al. (1999) reported that the gel consistency, a laboratory measured attribute showed some association with consumer rating for porridge texture. Also, the porridge colour as assessed by consumers correlated significantly with Hunter L and E values. The strong correlations observed between textural and colour properties both in the laboratory and the field meant that what consumers want can be predicted by laboratory results.

7 ARCHIVING RAW DATA (UPLOADING TO CIRAD WEBSITE)

Data will be organised and uploaded

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