Updated Correlation Coefficient between Sensory and Instrumental Textural Quality Measurement of Pounded Yam

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Bolanle OTEGBAYO, Bowen University, Iwo, Osun State, Nigeria

Oluyinka ORONIRAN, Bowen University, Iwo, Osun State, Nigeria

Ayomide ALAMU, Bowen University, Iwo, Osun State, Nigeria

Abiola TANIMOLA, Bowen University, Iwo, Osun State, Nigeria

Oluwatoyin AYETIGBO, CIRAD, Montpellier, France

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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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Oluwatoyin AYETIGBO (CIRAD) and Adinsi Laurent (FSAS, UAC, Benin)

This document has been reviewed by	
Bolanle OTEGBAYO (Bowen University) Oluwatoyin AYETIGBO (CIRAD)	23/10/2024 23/10/2024
Final validation by	
Oluwatoyin AYETIGBO (CIRAD) Zoé DEUSCHER	04/11/2024 04/11/2024

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ABSTRACT

This study aimed to understand the consumers' demand for the quality characteristics of yam food products and the quality attributes associated with the consumers preferred and non-preferred pounded Yam. Descriptive sensory evaluation (QDA) on sensory texture profiling analysis (STPA), consumer acceptability, instrumental textural quality evaluation (TPA) and extensibility (Kieffer dough (KDGE), cohesiveness were the key instrumental parameters, others were gumminess, chewiness, adhesiveness and stickiness) and correlation between instrumental and sensory parameters and threshold of acceptability of the textural parameters were all evaluated. Pounded yam samples from *D. rotundata* were described as smooth, cohesive and stretchable, promising yam genotypes which compared favourably in terms of sensory attributes with Meccakusa which was used as a check were TDr1617811 and TDr 1544004. Pounded yam samples from *D.alata* genotypes were not stretchable, lumpy and slightly mouldable however pounded yam samples from Oweigbo had very small lumps, were not stretchable but were rated more preferred among pounded yam samples from *D.alata*. There were correlations between STPA (QDA) and TPA parameters and instrumental extensibility (KDGE) and sensory stretchability (r^2=0.70). Discriminant analysis showed clear discrimination between *D.rotundata* and *D.alata* in terms of stretchability, smoothness, and extensibility. The results validated the use of KDGE to measure stretchability in pounded yam in contrast to TPA. There was correlation between the STPA and consumer acceptability test, for the four sensory attributes (smoothness, mouldability, stretchability, colour) R^2 values ranged between 0.54 and 0.88. All the textural quality attributes revealed a quadratic relationship between sensory score from QDA and percentage of 'Just about right'(JAR) scale while a linear correlation was observed for colour. The maximum threshold of acceptability for smoothness of pounded yam at 50% level of acceptability at JAR scale was 9.2. Threshold for Mouldability score (at 48% of consumers scoring as JAR mouldability) was 9.2. Mouldability scores below 9 are considered unacceptable. For colour, threshold analysis showed that colour scores higher than 2.0 (60%) and 3.1 (50%) was considered too dark and unacceptable for most consumers. Threshold for stretchability score was between 2.3 -7.5 (50%) while at 60%, it was between 3.0 - 6.7. QDA scores outside the threshold were deemed unacceptable, however the optimum QDA score for stretchability for pounded yam was about 5.0.

Key Words: Pounded yam, Consumer acceptability, Extensibility, Threshold, Colour, Smoothness, Stretchability, Mouldability

1 SENSORY EVALUATION

Materials: 21 yam genotypes of variable food quality were collected from IITA Yam breeding unit. The list of the yam genotypes is presented in Table 1.

Table 1 : List of yam genotypes collected for experiment.

SN	CLONES	Species
1	TDr1525151	*D. rotundata*
2	TDr1612901	*D. rotundata*
3	TDr1544004	*D. rotundata*
4	TDr1542027	*D. rotundata*
5	TDr1680007AB	*D. rotundata*
6	TDr1617604	*D. rotundata*
7	TDr1621016	*D. rotundata*
8	TDr1682003	*D. rotundata*
9	TDr1617811	*D. rotundata*
10	TDr 8902665	*D.rotundata*
11	Meccakusa	*D.rotundata*
12	TDa1662006	*D. alata*
13	TDa160805	*D. alata*
14	TDa1401829	*D. alata*
15	TDa Oweigbo (Check)	*D. alata*
16	TDa1723011	*D. alata*
17	TDa160403	*D. alata*
18	TDa150611446	*D. alata*
19	TDa1723003	*D. alata*
20	TDa1729002	*D. alata*
21	TDa1748002	*D. alata*

Method :

a) Sample preparation
b) Sensory evaluation was conducted on the pounded yam samples produced from the 21 yam genotypes listed above by 20 re-trained panellists. The number of panellists was increased to 20 and new panellists were recruited and trained extensively to conduct the sensory descriptive evaluation of pounded yam samples produced from the yam genotypes. The key attributes that were assessed were : Cohesiveness/ mouldability, stretchability, smoothness. The sensory evaluation was conducted as described in Otegbayo *et al.* (2020) (https://mel.cgiar.org/reporting/download/report_file_id/17815)

Result :

The pounded yam samples from *D. alata* samples were generally (Figure 1) described as having small lumps (mean score of 5.69), not mouldable, not stretchable, and yellow-cream in colour (Table 2a). However, among these samples, TDa 1729002 and TDa1662006 was described as smooth and mouldable but not stretchable. Pounded yam from *D. rotundata* genotypes were generally described as smooth, mouldable and stretchable (Table 2b). Their colour ranged between off white and yellow.

Table 2a : Descriptive sensory evaluation of yam genotypes from D. *alata*

D. alata	Smoothness	Moudability/Cohesiveness	Stretchability	Colour
TDa1729002	7.21±0.21^{b}	6.76±0.00^{b}	2.94±0.00^{b}	3.76±0.08^{e}
TDa17223003	5.13±0.18^{d}	2.76±0.18^{f}	0.53±0.00^{cd}	5.18±0.26^{d}
TDa150611446	5.44±0.21^{d}	2.21±0.21^{g}	0.44±0.21^{d}	1.82±0.08^{h}
TDa160403	7.79±0.21^{a}	3.38±0.21^{e}	0.59±0.00^{cd}	5.88±0.17^{c}
TDa1401829	5.95±0.00^{c}	5.95±0.00^{c}	2.74±0.17^{b}	1.98±0.04^{h}
TDa1662006	7.88±0.18^{a}	7.38±0.18^{a}	4.13±0.18^{a}	2.75±0.07^{f}
TDa1748002	3.45±0.17^{f}	4.05±0.00^{d}	0.83±0.17^{c}	6.48±0.06^{b}
TDa160804	5.96±0.27^{c}	2.31±0.00^{g}	0.38±0.00^{d}	7.38±0.33^{a}
TDa1732011	3.63±0.18^{f}	2.13±0.18^{g}	0.63±0.18^{cd}	2.38±0.11^{g}
TDa Oweigbo	4.42±0.28^{e}	0.38±0.00^{h}	0.58±0.28^{cd}	1.08±0.00^{i}
Mean	5.69	3.73	1.38	3.87
SD	1.59	2.28	1.36	2.21
SE	0.50	0.72	0.43	0.70

Smoothnes (Big lumps=0, small lumps=5, no lumps=10), mouldability (not mouldable=0, slightly mouldable=5, mouldable=10), stretchability (not stretchable=0, slightly strechable=5, stretchable =10), mouldability, colour (white=1. off-white =2, cream=3, light yellow= 4, yellow = 5,light grey= 6, grey 7, light brown= 8 brown =9).

Table 2b : Descriptive sensory evaluation of yam genotypes from D. *rotundata*

D. rotundata	Smoothness	Moudability/Cohesiveness	Stretchability	Colour
TDr1617811	8.45±0.17^{c}	9.17±0.17^{b}	7.14±0.00^{c}	3.55±0.04^{bc}
TDr1542027	10.00±0.00^{a}	8.46±0.00^{c}	2.50±0.27^{g}	3.35±0.05^{c}
TDr1612901	9.23±0.54^{b}	8.65±0.28^{c}	4.04±0.27^{f}	1.62±0.00^{g}
TDr89026665	9.22±0.23^{b}	9.84±0.22^{a}	8.59±0.22^{a}	2.28±0.04^{e}
TDr16892003	9.81±0.27^{a}	8.46±0.00^{c}	2.31±0.00^{g}	2.58±0.06^{d}
TDr1621016	4.55±0.04^{e}	5.60±0.16^{f}	5.60±0.16^{e}	2.67±0.13^{d}
Meccakusa	9.17±0.17^{b}	7.98±0.17^{d}	6.19±0.00^{d}	2.60±0.16^{d}
TDr1544004	8.93±0.17^{bc}	7.26±0.17^{e}	2.26±0.17^{g}	3.40±0.16^{bc}
TDr1680007AB	9.13±0.18^{b}	9.25±0.00^{b}	8.23±0.04^{a}	3.58±0.11^{b}
TDr1617604	7.26±0.17^{d}	7.50±0.17^{e}	7.74±0.17^{b}	3.93±0.04^{a}
TDr1525151	9.12±0.00^{b}	9.70±0.01^{a}	7.79±0.21^{b}	2.00±0.09^{f}
Mean	**8.62**	**8.35**	**5.67**	**2.87**
SD	**1.53**	**1.24**	**2.49**	**0.74**
SE	**0.46**	**0.37**	**0.75**	**0.22**

Smoothness (Big lumps=0, small lumps=5, no lumps=10), mouldability (not mouldable=0, slightly mouldable=5, mouldable=10), stretchability (not stretchable=0, slightly strechable=5, stretchable =10), mouldability, colour (white=1. off-white =2, cream=3, light yellow= 4, yellow = 5,light grey= 6, grey 7, light brown= 8 brown =9).

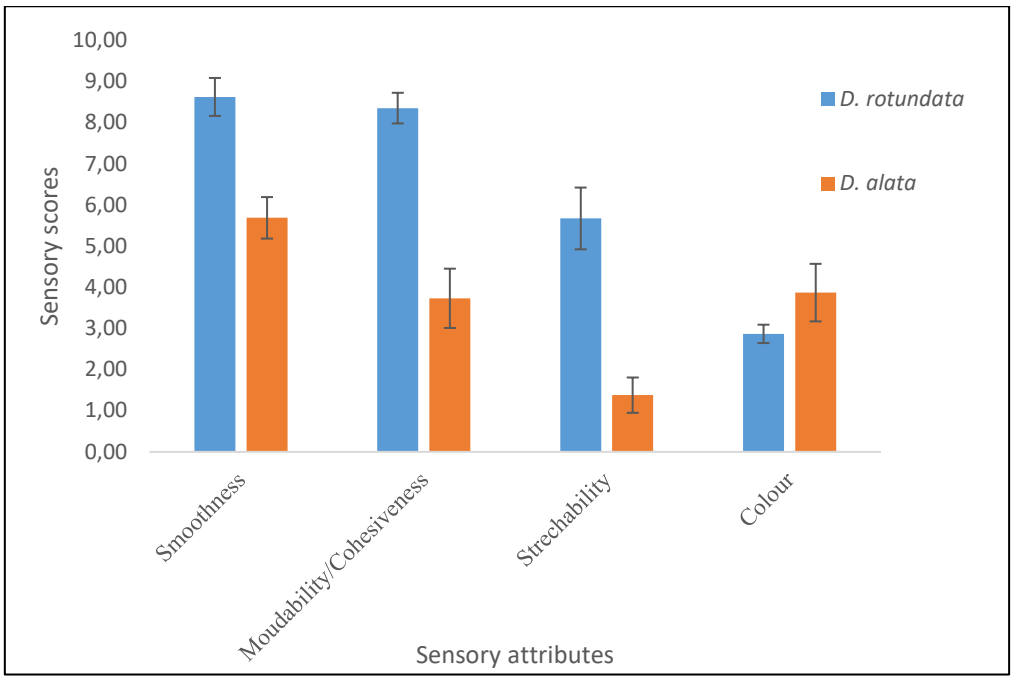


Figure 1 : Mean sensory evaluation result of pounded yam from 21 genotypes of *D. rotundata* and *D. alata.*

1.1 Principal Component Analysis for *D. alata and D. rotundata*

The first two principal components (PC1 and PC2) are the most important, together explaining 87.599% of the total variance (Table 2c). This indicates that a two-dimensional scatter plot of these components will capture most of the variability in the data.

The scatter plot generated from PC1 and PC2 was used for visualizing the data, as it reflects the major patterns and relationships within the dataset (Figure 2a and 2b). The scatter plot illustrates how each sample varies across the principal components, revealing patterns and relationships among the samples based on their measured characteristics. Samples with similar profiles clustered together, and the vectors of the variables show which attributes are most influential in differentiating the samples.

Component 1 (X-axis) and Component 2 (Y-axis) represent the first two principal components, which together explained a significant portion of the variance in the data (60.394% for PC1 and 27.205% for PC2, totally 87.599%). The values on these axes are the scores for each sample on the respective principal components.

Samples that are close to each other in the plot have similar profiles or characteristics based on the measured variables. For instance, TDa160403 and TDa1748002 are positioned close to each other, indicating they have similar attributes based on the PCA.

The variables (Colour, Smoothness, Mouldability, Cohesiveness, Stretchability) are projected as vectors. The direction and length of these vectors indicate how strongly each variable influences the principal components. For example, Colour and Smoothness have longer vectors, indicating they have a strong influence on PC2.

Colour: Positioned towards the upper left quadrant, suggesting it has a high positive influence on PC2 and a slight negative influence on PC1. Samples like TDa160403 and TDa1748002 had higher score (5.88, 6.48) in Colour, from the sensory evaluation, this colour is Grey.

Smoothness: Positioned towards the upper right quadrant, suggesting a positive influence on both PC1 and PC2. Samples like TDa1729002 and TDa1662006 scored high in Smoothness.

Mouldability and Cohesiveness: Positioned towards the center, indicating a moderate influence on both PC1 and PC2. Samples around the center are likely balanced in these attributes.

Stretchability: Positioned towards the lower left quadrant, suggesting a high negative influence on both PC1 and PC2. Samples like TDa15611446 and TDa160804 were described as not stretchable.

Table 2c: Principal component analyses for *D.alata.*

D.alata Principal Components Analysis		
PCA Summary		
PC	**Eigenvalue**	**% variance**
1	2.41578	60.394
2	1.0882	27.205

	PC 1	**PC 2**
Smoothness	0.49901	0.29959
Moudability/Cohesiveness	0.60526	0.10149
Strechability	0.61189	-0.19111
Colour	-0.10115	0.9292

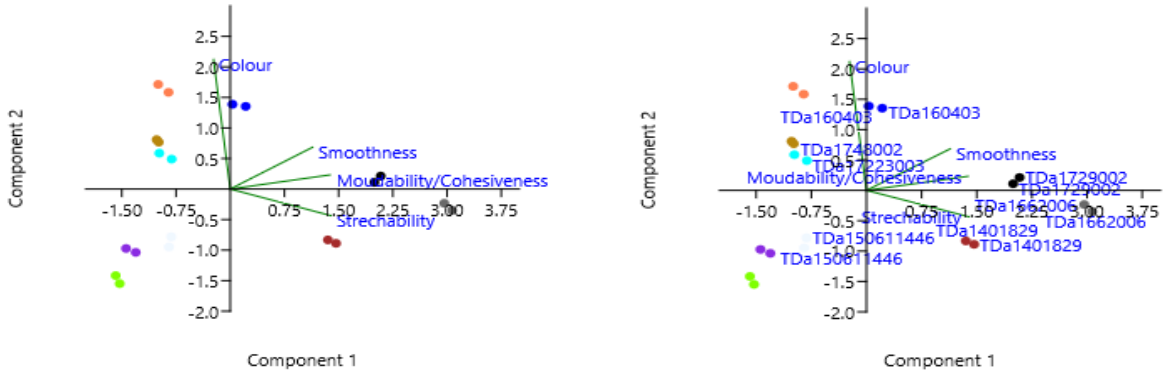


Figure 2a: Scatter plots for *D.alata*

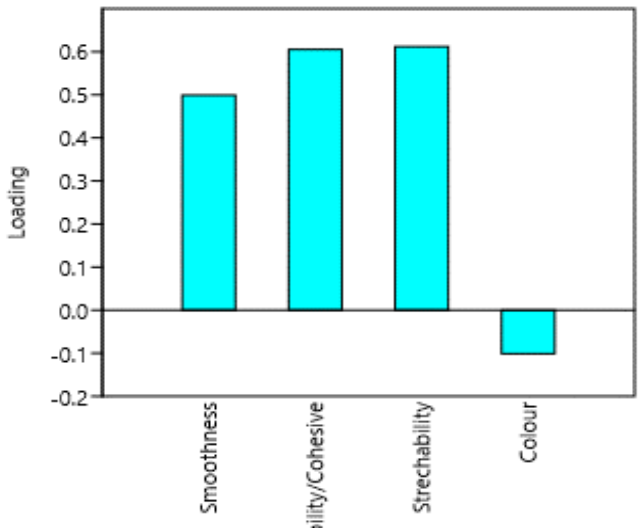


Figure 2b: Loading plots for *D.alata*

The PCA scatter plot provides valuable insights into the relationships and variability among the samples based on their key attributes (Figure 2c and 2d). PC1 and PC2 explain 75.504% of the total variance, indicating that these two components capture a substantial portion of the variability in the data (Table 2d).
The PCA results highlight the key attributes driving variability in the dataset, with Smoothness and Mouldability/Cohesiveness being crucial for PC1 and Stretchability for PC2.
Each point represents a sample and its position reflects its scores on PC1 and PC2. Samples close to each other have similar characteristics based on the measured attributes.
PC1- High Positive Loadings: Smoothness (0.63982), Mouldability/Cohesiveness (0.70182). PC1 differentiates samples primarily based on Smoothness and Mouldability/Cohesiveness. Samples with high scores on PC1 will have high smoothness and cohesiveness but may have lower Colour scores.
Principal Component 2 (PC2): High Positive Loading: Stretchability (0.89277). Moderate Positive Loading: Mouldability/Cohesiveness (0.22937), Colour (0.2084). Moderate Negative Loading: Smoothness (-0.32699). PC2 primarily differentiates samples based on Stretchability. Samples with high scores on PC2 will have high stretchability, while those with low scores will have higher Smoothness.

Table 2d : Principal component analyses for *D. rotundata*.

***D. rotundata* Principal Components Analysis**			
		PCA Summary	
PC		**Eigenvalue**	**% variance**
	1	1.82953	45.738
	2	1.19064	29.766
		PC 1	**PC 2**
Smoothness		0.63982	-0.32699
Moudability/Cohesiveness		0.70182	0.22937
Strechability		0.12142	0.89277
Colour		-0.28867	0.2084

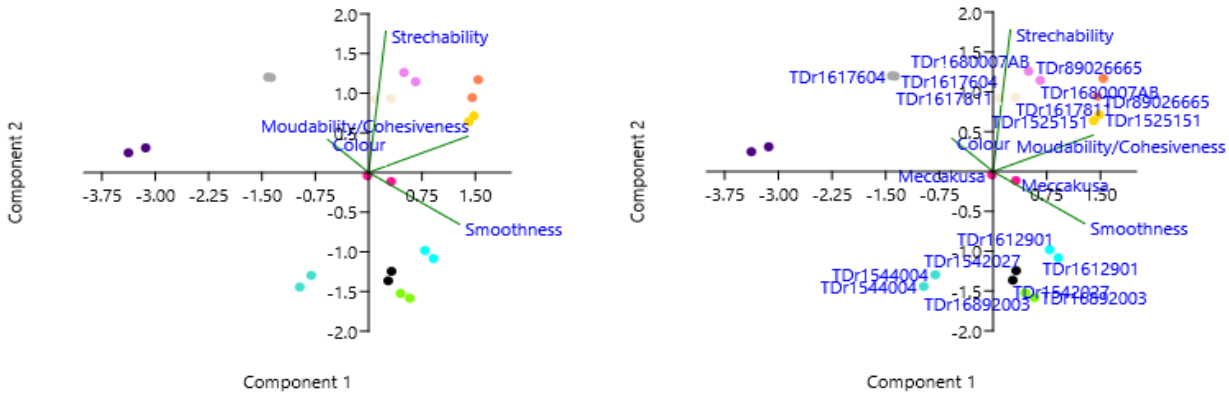


Figure 2c: Scatter plots for *D. rotundata*.

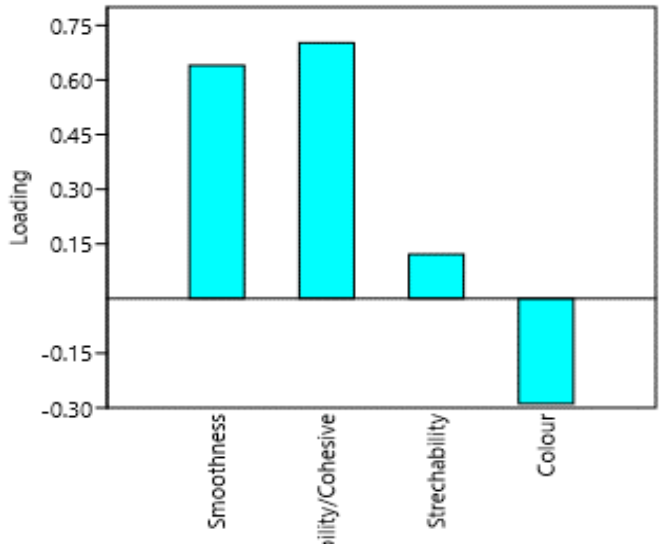


Figure 2d: Loading plots for *D.rotundata.*

1.2 Cluster analysis

There were two distinct clusters (Figure 2e). Cluster 1 consist distinctly of *D. alata* yam genotype, which were not stretchable while Cluster II comprise distinctly *D. rotundata* with moderate to high stretchability and colour which ranged from off-white to yellow, however, this cluster also have 3 TDa genotypes (TDa 1729002, TDa 1662006, TDa 1401829), they were in this cluster in terms of their colour (yellow, off white, cream)

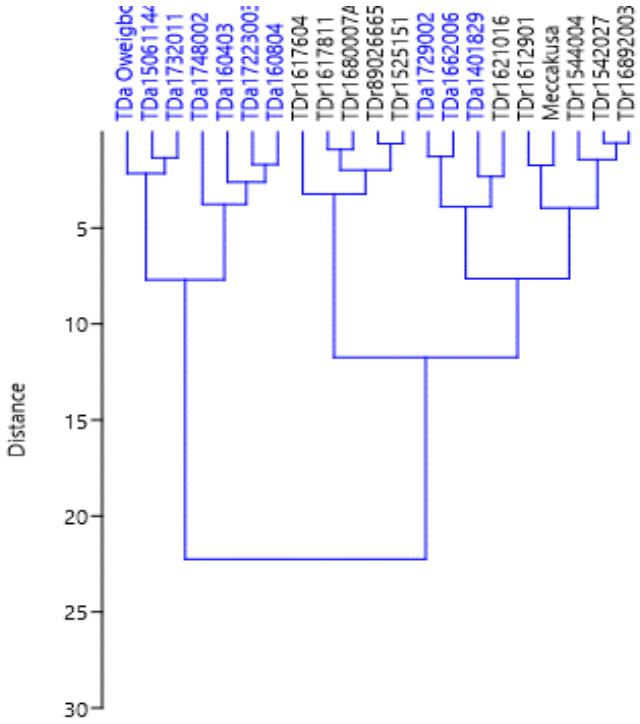


Figure 2e : Dendrogram of sensory properties of *D. rotundata* and *D.alata* species.

2 INSTRUMENTAL TEXTURE ANALYSIS

Texture profile Analysis (TPA) was carried out on the pounded yam samples from the yam genotypes. The pounded yam samples were prepared according to the procedure described under the sensory evaluation section. The instrumental evaluation was done by means of a Texture Analyzer (TVT 6700, Perten Instruments, USA) using the Texture Profile Analysis (TPA) method described in the RTBfoods standard operation procedure (Otegbayo *et al*., 2022) 8 replicates were done per sample. The parameters measured were hardness, adhesiveness, stringiness, gumminess, chewiness and cohesiveness (Table 3)

Table 3 : Instrumental Texture analysis of pounded yam samples from yam genotypes.

Level	Hardness	Adhesiveness	stickiness	chewiness	Gumminess	Cohesiveness	Springiness
Meccakusa	2814.88^{hi}	-1713.2^{ef}	-565^{cde}	41.08^{ghi}	333.05^{hi}	0.125^{d}	0.117^{fgh}
TDa160403	2546.57 ^{hi}	-782.2 ^{bc}	-451.33 ^{bc}	21.79^{ijk}	150.40^{j}	0.064^{ij}	0.126^{efg}
TDa160805	3033.67^{gh}	-484.5 ^{ab}	-506.75 ^{bcd}	11.60 ^{jk}	169.85^{j}	0.059^{j}	0.075^{ijk}
TDa1401829	3495.43^{g}	-903.6^{bc}	-548.57 ^{cde}	20.55^{ijk}	254.88^{ij}	0.069^{hij}	0.067^{jk}
TDa1662006	5017.71^{cd}	-1887 ^{efg}	-1277.143 ^{hi}	52.12 ^{fgh}	428.07g^{h}	0.086^{fghi}	0.098^{ghij}
TDa1723003	2604.75 ^{hi}	-901.75 ^{bc}	-546.33 ^{cde}	21.61^{hijk}	217.39^{ij}	0.079^{fghij}	0.066^{ijk}
TDa1729002	5336.20	-1546.67 ^{de}	-1329.11 ^{i}	42.96 ^{ghi}	477.21f^{g}	0.092^{fg}	0.089^{ij}
TDa1732011	4813.50^{de}	-531 ^{ab}	-261.6667 ^{a}	74.24^{ef}	350.39^{hi}	0.069^{ij}	0.133^{def}
TDa1748002	4106.63^{f}	-2311.50 ^{gh}	-1112.667gh	41.62 ^{ghi}	333.91^{hi}	0.076g^{hij}	0.139^{def}
TDa1506111446	3449.56^{g}	-108.6667 ^{a}	-217.7143^{a}	11.31^{k}	191.75^{j}	0.056^{j}	0.061^{k}
TDaOweigbo	774^{j}	-2546 ^{h}	-302.5 ^{ab}	85.62^{e}	344.15h^{i}	0.253^{a}	0.349^{a}
TDr1525151	5295.20^{cd}	-2003.6^{fg}	-1334.40 ^{if}	138.85 ^{c}	981.29^{b}	0.192^{bc}	0.126^{ef}
TDr1542027	6305.80^{b}	-542.7778 ^{b}	-604.2 ^{cde}	64.97 ^{ef}	676.07^{de}	0.112^{de}	0.097^{hi}
TDr1544004	5580^{c}	-1213.143 ^{cd}	-667.25 ^{def}	41.01^{ghi}	493.09^{fg}	0.089^{fgh}	0.083^{ijk}
TDr1612901	6983.13^{a}	-532.25 ^{ab}	-702.125 ^{ef}	60.12 ^{efg}	701.14^{d}	0.099^{ef}	0.086^{ijk}
TDr1617604	2279^{i}	-2648.50 ^{h}	-682.5 ^{def}	126.56^{cd}	576.01^{ef}	0.263^{a}	0.219^{b}
TDr1617811	4248^{ef}	-1721.25^{ef}	-818.5^{F}	118.43^{d}	814.57^{c}	0.192^{bc}	0.145^{cde}
TDr1621016	2670.86 ^{hi}	-2572.6 ^{h}	-1024.14 ^{g}	59.07^{efg}	382.19^{ghi}	0.171^{c}	0.173^{c}
TDr1680007	6782^{ab}	-1199.60 ^{cd}	-696 ^{def}	188.65^{a}	1418.04^{a}	0.209^{b}	0.143^{def}
TDr1682003	4222.14^{ef}	-1169.80 ^{cd}	-670.4286 ^{def}	33.98 ^{hij}	414.28^{gh}	0.098^{ef}	0.081^{ijk}
TDr89026665	5133.38^{cd}	-4134.833^{i}	-1659.125^{j}	164.60^{b}	988.05^{b}	0.195^{b}	0.157^{cd}

The TPA parameters all showed good discriminant trend by genotypes. The most discriminant TPA parameters are the cohesiveness, hardness and gumminess. The least discriminant are the springiness and adhesiveness. While springiness has been shown to corelate with stretchability of pounded yam (DOI: 10.1111/j.1745-4603.2007.00101.x), the TPA springiness may be less representative as a direct measurement of stretchability as measured by the new KDGE procedure recently developed in the RTB Breeding project.

2.1 Principal component analysis:

The first two components of the score plot of the PCA (figure 3a) explained 81.2 % of the variation of data. The dry matter (DM) of fresh and pounded yam (PY) were significantly associated with chewiness, gumminess and hardness of PY and sensory stretchability, smoothness and mouldability as seen with genotypes TDr1680007, TDr1525151, TDr1617811 and TDr89026665. TDa Oweigbo and TDr1617604 are uniquely associated with springiness, cohesiveness and the DM of boiled yam. The rest of the rotundata genotypes and all the alata genotypes (excluding TDa Oweigbo) were adhesive, and sticky in nature, but also negatively significantly associated with poor stretchability and mouldability. Its noteworthy that Meccakusa, a landrace which was used as a check *D. rotundata* which ordinarily has a good, pounded yam quality was surprisingly classified alongside intermediate quality pounded yam, On the other hand, Oweigbo, a good quality check alata genotype was rightly classified alongside intermediate quality for pounded and close to the best genotypes TDr1680007, TDr1525151, TDr1617811 and TDr89026665 with relatively high hardnesss, smoothness, mouldability and stretchability.

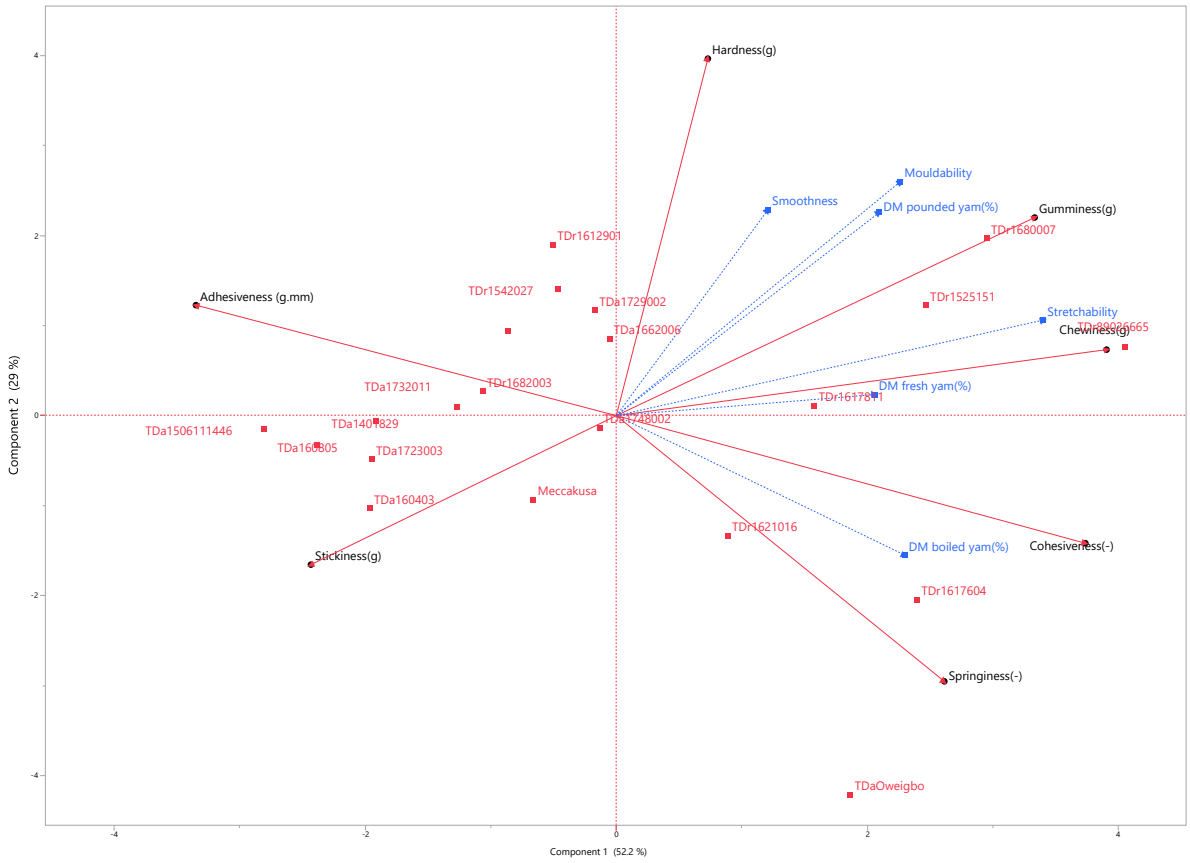


Figure 3a : PCA of TPA + sensory + DM according to 3-class hierarchy cluster.

2.2 Discriminant analysis

From figure 3b, it is clear that the yam genotypes were significantly different from each other in terms of their instrumental textural attributes. The yam varieties TDa Oweigbo, TDr1617604, TDr1680007 showed good discriminance in the TPA parameters. Other genotypes such as Meccakusa, TDr1621016, TDr1617811 were also fairly discriminant, while the rest of the *D.rotundata* and all the *D.alata* were clustered together.

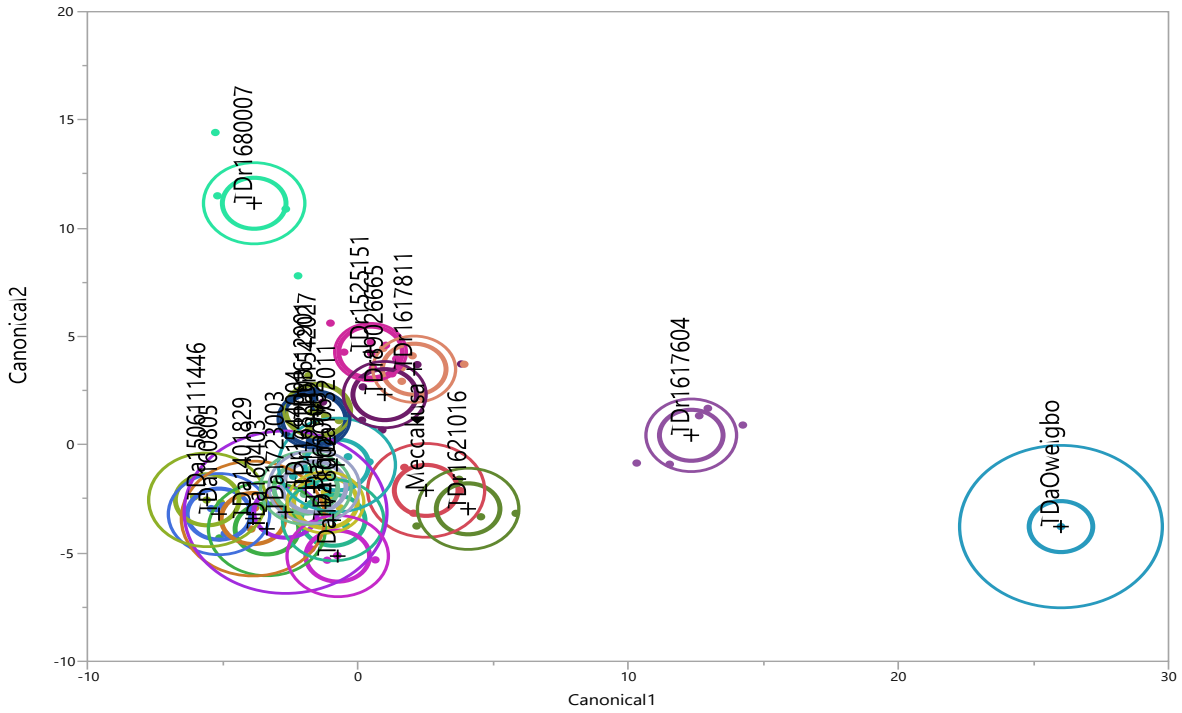


Figure 3b : Discriminant chart of pounded yam from 21 yam genotypes.

2.3 Hierarchical classes

Classification according to hierarchy (figure 3c) did not show a very clear distinction between and *D.rotundata* genotypes. This may be due to the fact that some *D.alata* genotypes had good textural attributes which compares favourably with the *D.rotundata* genotypes that have good textural quality. It was also observed that some *D.rotundata* genotypes also had textural attributes that were not preffered by consumers (bad textural quality) were in the same group as *D.alata* genotypes whose textural quality were not preffered by the consumers (bad textural quality).

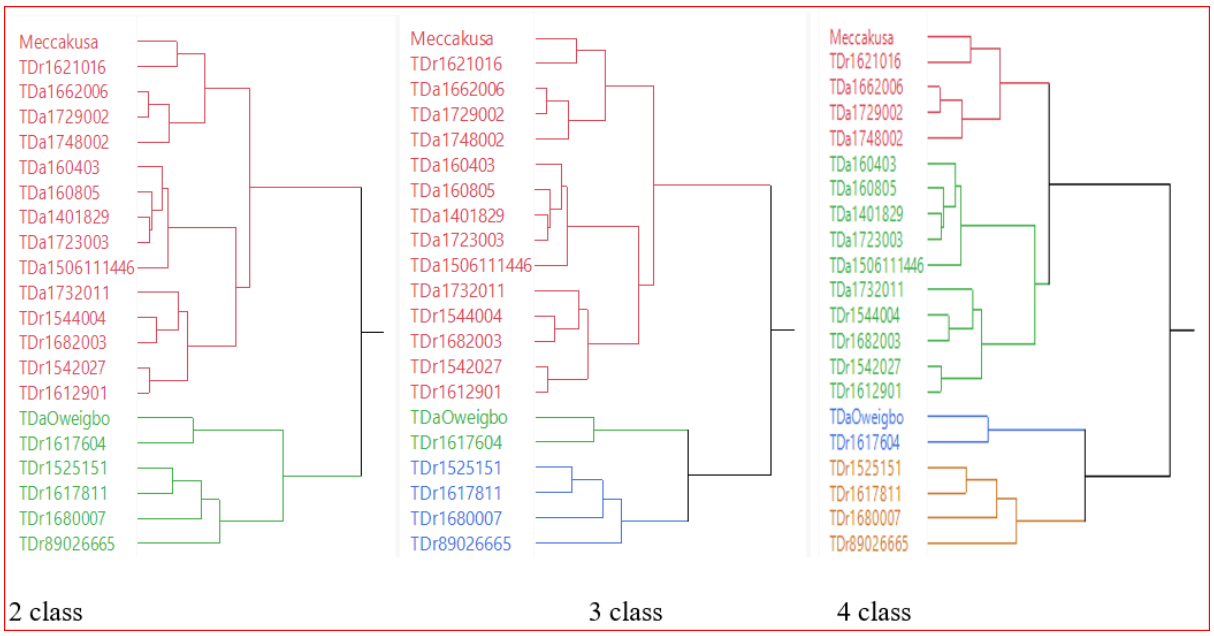


Figure 3c : Hierarchical classification of TPA parameters from pounded yam samples.

3 CORRELATIONS BETWEEN INSTRUMENTAL TEXTURAL QUALITY (TPA) AND SENSORY TEXTURAL QUALITY (STPA) AND DM OF YAM GENOTYPES

From table 4: Significant correlations exist between the sensory parameters (STPA) and ITPA parameters. Smooth pounded yam correlated with instrumental hardness and gumminess. Mouldablity of the pounded yam correlated with instrumental hardness but negatively related to stickiness. Pounded yam samples that were stretchable correlated with instrumental cohesiveness, gumminess and chewiness, but negatively related to instrumental adhesiveness and stickiness. The hardness of pounded yam samples by TPA is significantly correlated with Dry matter of pounded yam and not fresh or boiled yam. The sensory mouldability and stretchability is significantly correlated with DM of both fresh and pounded yam. The sensory mouldability and stretchability is significantly correlated with DM of both fresh and pounded yam.

Table 4 : Correlations between sensory textural attributes and DM of fresh, boiled and pounded yam.

	Smoothness	Moudability	Stretchability	DM fresh yam(%)	DM boiled yam(%)	DM pounded yam(%)
Hardness(g)	**0.5543**	**0.6422**	0.3014	0.1353	-0.2061	**0.5713**
Adhesiveness (g.mm)	-0.0160	-0.2975	**-0.5797**	-0.1682	-0.3808	-0.1887
Stickiness(g)	-0.2828	**-0.5905**	**-0.5644**	-0.0055	0.1372	-0.3711
Chewiness(g)	0.3445	**0.5503**	**0.8060**	**0.5775**	**0.5647**	**0.6085**
Gumminess(g)	**0.5720**	**0.7400**	**0.7853**	**0.5544**	0.3473	**0.7241**
Cohesiveness(-)	0.1809	0.3347	**0.6962**	**0.5660**	**0.7041**	0.3321
Springiness(-)	-0.2526	-0.1915	0.2011	0.2388	**0.6145**	-0.1253
	Smoothness	**Moudability**	**Stretchability**	**DM fresh yam(%)**	**DM boiled yam(%)**	**DM pounded yam(%)**
Hardness(g)	0.0091	0.0017	0.1842	0.5588	0.3701	0.0068
Adhesiveness (g.mm)	0.9450	0.1903	0.0059	0.4660	0.0885	0.4126
Stickiness(g)	0.2141	0.0048	0.0077	0.9810	0.5532	0.0976
Chewiness(g)	0.1262	0.0097	<.0001	0.0061	0.0076	0.0034
Gumminess(g)	0.0067	0.0001	<.0001	0.0091	0.1229	0.0002
Cohesiveness(-)	0.4326	0.1381	0.0005	0.0075	0.0004	0.1413
Springiness(-)	0.2693	0.4056	0.3822	0.2972	0.0030	0.5884

4 EXTENSIBILITY MEASUREMENT

The extensibility was performed on yam genotypes listed in table 5.

Table 5 : List of genotypes used for instrumental extensibility determination of yam genotypes.

	*Genotype	Specie	Ascension type
1	Oweigbo	alata	landrace
2	TDa1401829	alata	hybrid
3	TDa1662006	alata	hybrid
4	TDa1729002	alata	hybrid
5	TDa1732011	alata	hybrid
6	TDa1748002	alata	hybrid
7	TDa17223003	alata	hybrid
8	TDa150611446	alata	hybrid
9	TDr1525151	rotundata	hybrid
10	TDr1542027	rotundata	hybrid
11	TDr1544004	rotundata	hybrid
12	TDr1612901	rotundata	hybrid
13	TDr1617604	rotundata	hybrid
14	TDr1617811	rotundata	hybrid
15	TDr1621016	rotundata	hybrid
16	TDr1680007AB	rotundata	hybrid
17	TDr16892003	rotundata	hybrid
18	TDr89026665	rotundata	hybrid
19	Meccakusa	rotundata	landrace

*Genotypes TDa160403 and TDa160805 have no usable data

Procedure: Extensibility of the pounded yam samples made from the yam genotypes was determined with the TA XT2i texture analyser with a Kieffer Doug extensibility rig was after adjusting the dry matter (DM) of the pounded yam samples to 30% addition of water to the pounded yam samples from the yam genotypes that the fresh tubers had DM of above 30%. The SOP used is being finalized soon (https://collaboratif.cirad.fr/share/page/site/RTBfoods/document-details?nodeRef=workspace://SpacesStore/de634b09-c8d9-4b80-b1e2-54a3177a34cf). About 7 to 27 measurements per replicate were collected, and two replicates per genotype were considered. Measurements were made when dough strands were at temperature of about 40 °C. extensibility (mm), **extension area (N.mm), extensogram peak force(N)** of the pounded yam samples were determined. The results were analysed statistically by principal component analysis, discriminant analysis and hierarchical classification (cluster analysis).

Result: Table 6a showed that TDr 89026665 had the highest extensogram peak of 0.265 N, followed by Meccakusa (0.146 N) with TDa17223003 N having the least value. TDr1525151 was the most extensible (highest extensibility of 6.547 mm). The least extensible was Oweigbo (0.605 mm). In terms of the extension area TDr 89026665 had the highest (0.908 N.mm) while oweigbo had the least (0.037N.mm. Generally, *D.rotundata* varieties had better extensibility than *D.alata* varieties.

One way ANOVA of the extensibility parameters all showed significant differences in extensibility among the yam genotypes, with most of the *D. rotundata* yams having significantly higher values than *D. alata* yams. The extensibility was the most discriminant parameter. There was good repeatability between measurement replicates (P>0.05), especially for extensibility. In terms of interspecies differences, there was significant difference in extensibility between *D. rotundata* and *D.alata*, with D. rotundata having higher extensibility parameters than *D.alata* (table 6b). However, there was no significant difference between hybrids and landraces ascensions.

Table 6a : Extensogram peak force, extensibility and extension area of pounded samples from yam genotypes.

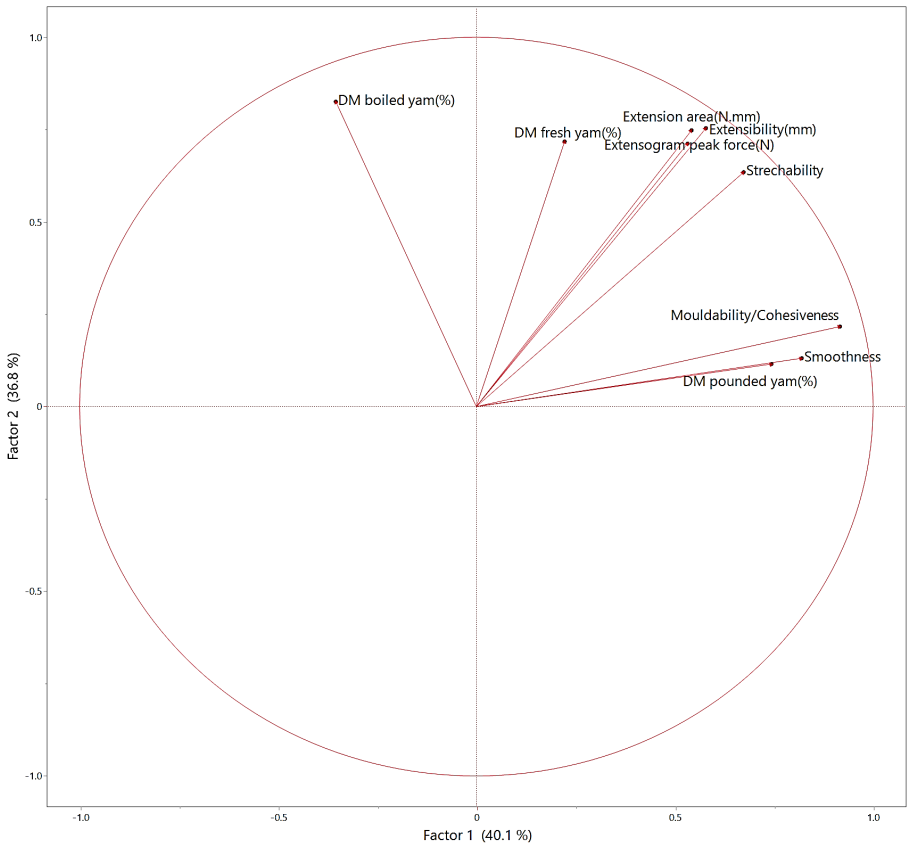
Level	Extensogram peak force(N)	Extensibility(mm)	Extension area(N.mm)
Meccakusa	0.147 c	4.265 c	0.464 c
Oweigbo	0.066 ij	0.605 g	0.037 e
TDa1401829	0.085 fghij	1.105 fg	0.068 e
TDa1662006	0.070 ij	1.017 fg	0.061 e
TDa1729002	0.089 efghi	1.140 fg	0.085 e
TDa1732011	0.093 defgh	1.047 fg	0.067 e
TDa1748002	0.112de	0.982 fg	0.072 e
TDa17223003	0.065 j	0.817 fg	0.046 e
TDa150611446	0.067 ij	1.266 fg	0.069 e
TDr1525151	0.192b	6.547a	0.779b
TDr1542027	0.100 defg	2.245 e	0.167 de
TDr1544004	0.078 hij	1.000 fg	0.057 e
TDr1612901	0.109 de	0.938 fg	0.072 e
TDr1617604	0.112d	2.865 de	0.229d
TDr1617811	0.103 def	3.092 d	0.205 d
TDr1621016	0.092defgh	1.511f	0.104 de
TDr1680007AB	0.192b	5.890 b	0.673 b
TDr16892003	0.077ghij	0.993 fg	0.060 e
TDr89026665	0.265a	5.535 b	0.908a

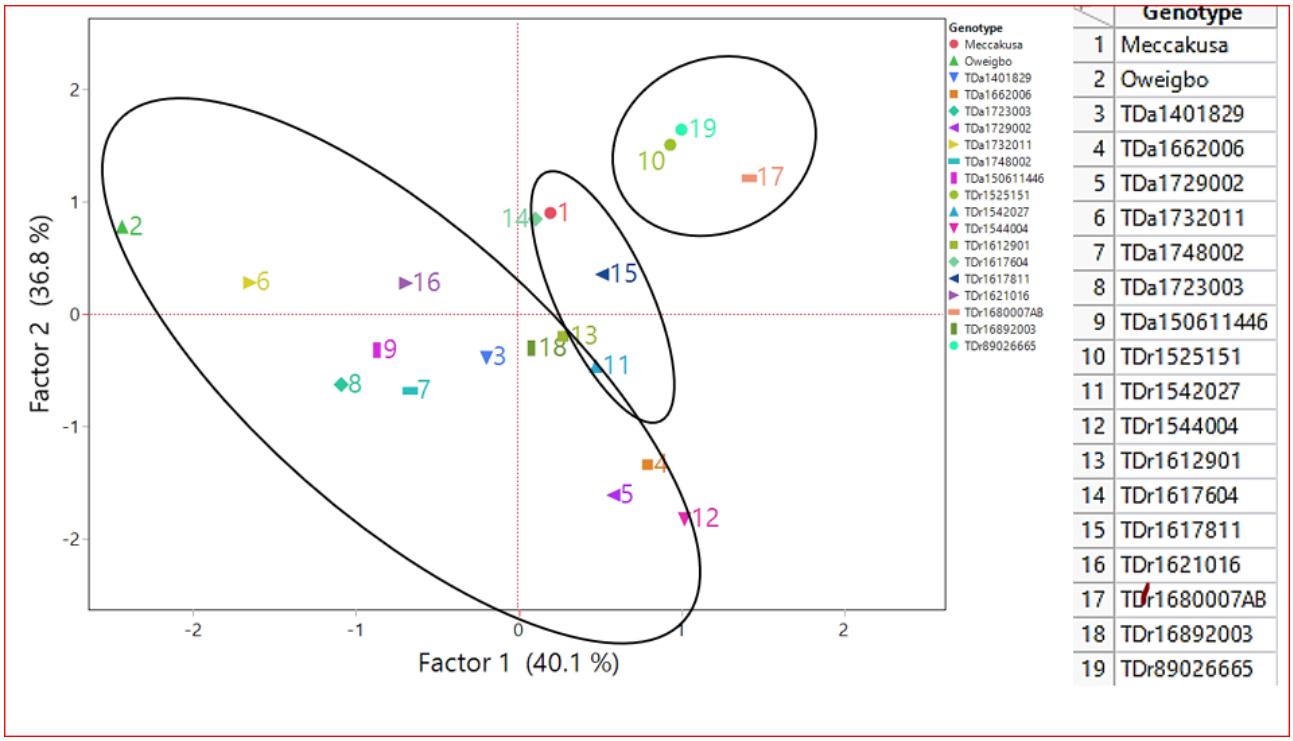
Table 6b : Extensogram peak force, extensibility and extension area of pounded samples from yam genotypes by ascension and species.

Level	Extensogram peak force(N)	Extensibility(mm)	Extension area(N.mm)
Species			
D.alata	0.078b	1.017b	0.064b
D.rotundata	0.135a	3.359a	0.378 a
Ascension			
Hybrid	0.112 a	2.434 a	0.310 a
Land race	0.111 a	2.9431 a	0.254 a

4.1 Principal Component analysis:

The result was also subjected to principal component analysis (figure 4a). The result showed that the first two components of the score plot of the PCA factor analysis explained 76.9 % of the variation of data. The genotypes TDr1525151, TDr1680007AB, TDr89026665, Meccakusa, TDr1617811, TDr1617604 are well associated with the component sector with high extensibility, extension area (extension work done), extensogram peak force (hardness), stretchability, smoothness, cohesiveness/moldability, and fresh yam dry matter. The genotypes TDr1612901, TDr16892003, TDa1662006, TDa1729002 and TDr1544004 are situated in adjacent component space with low extensibility and DM.





	Genotype
1	Meccakusa
2	Oweigbo
3	TDa1401829
4	TDa1662006
5	TDa1729002
6	TDa1732011
7	TDa1748002
8	TDa1723003
9	TDa150611446
10	TDr1525151
11	TDr1542027
12	TDr1544004
13	TDr1612901
14	TDr1617604
15	TDr1617811
16	TDr1621016
17	TDr1680007AB
18	TDr16892003
19	TDr89026665

Figure 4a : PCA of KDGE + sensory + DM according to 3-class hierarchy cluster. ***Genotypes TDa160403 and TDa160805 have no usable data.***

4.2 Discriminant analysis

From figure 4b, the discriminant analysis **t**he genotypes TDr1525151, TDr1680007AB, TDr89026665, Meccakusa, TDr1617811, TDr1617604 and TDr1542027 with high extensibility are very discriminant from the rest of the remaining genotypes with intermediate-to-low extensibility which are clustered together and show little discrimination among one another

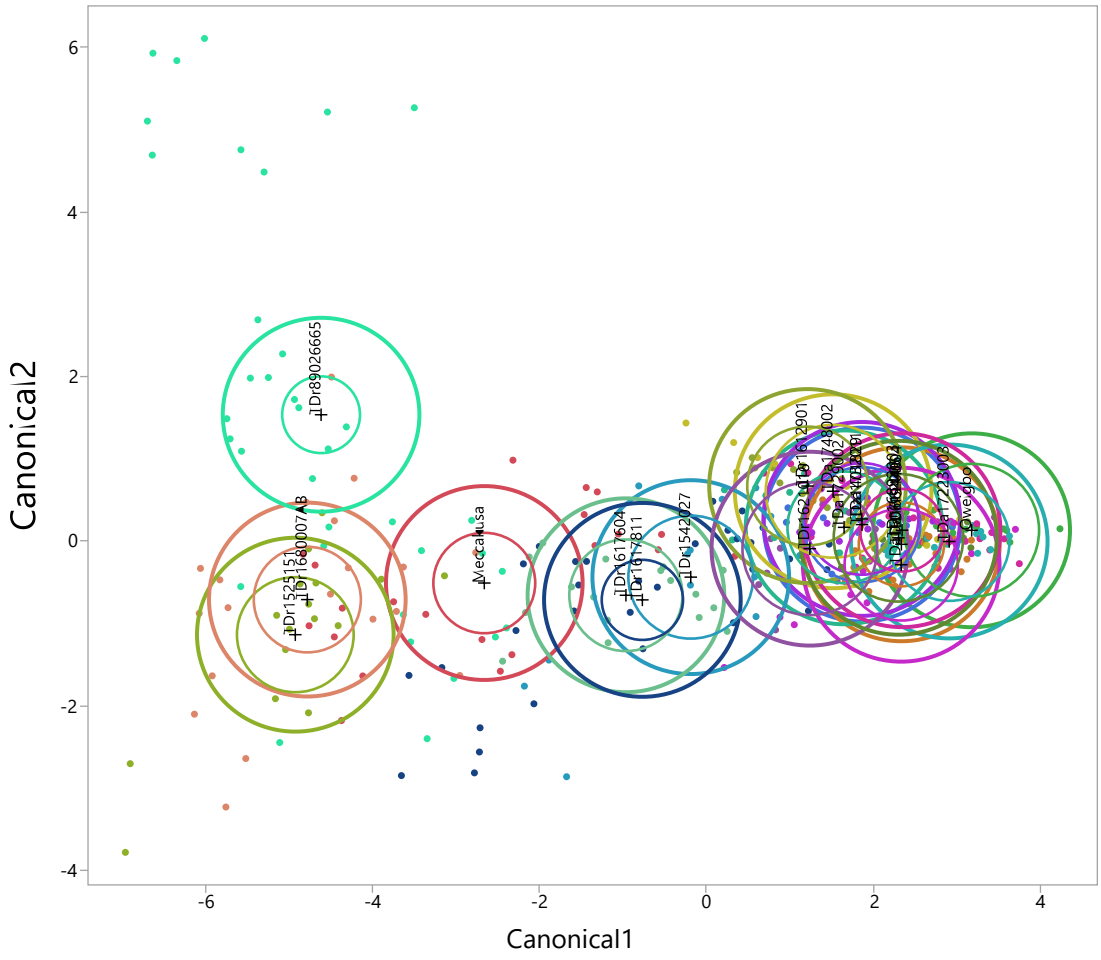
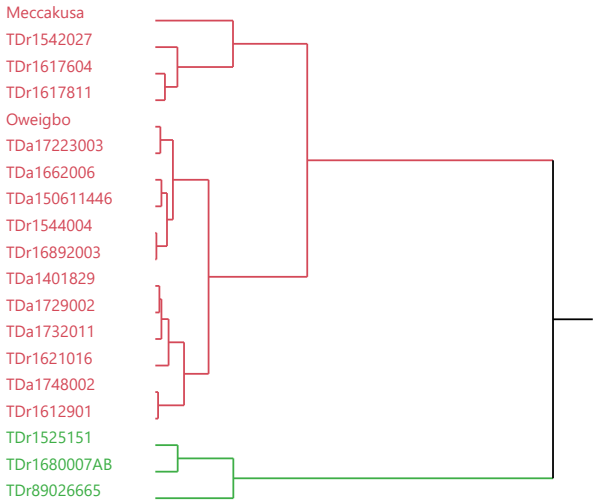


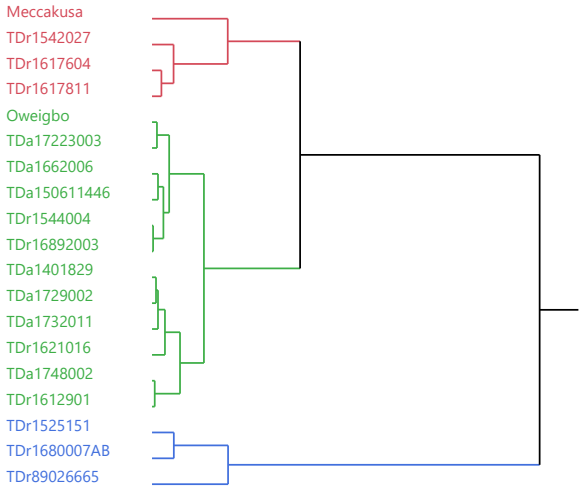
Figure 4b : Discriminant chart of pounded yam from 19 yam genotypes.

4.3 Hierarchical classes

Classification according to 2-class clustering did not show a very clear distinction between *D. alata* and *D. rotundata* genotypes (Figure 4c). This may be due to the fact that some *D. alata* genotypes (such as TDa150611446, TDa1729002 and TDa1401829) are considered to have intermediate extensibility similar to intermediate *D. rotundata* genotypes (such as TDr1621016). In same vein, some *D. rotundata* genotypes had poor extensibility (such as TDr16892003 and TDr1612901) similar to the poor *D. alata* genotypes (such as TDa17223003 and TDa1748002). Using the KDGE procedure (not yet published) has consistently produced separate clustering of *D. alata* and *D. rotundata* pounded yam texture when fewer and very contrasted genotypes were considered. Classification according to a 3-class cluster shows that TDr1525151, TDr1680007AB and TDr89026665 are considered as the best genotypes with highest extensibility. Meccakusa (control landrace), TDr1617811, TDr1617604 and TDr1542027 are considered as the genotypes with good extensibility. The rest of the genotypes have intermediate to poor extensibility. Unexpectedly, TDa Oweigbo, a control landrace was clustered along with poorly extensible genotypes, but this may imply an experimental anomaly.



2-class clustering



3-class clustering

Figure 4c : Hierarchical KDGE pounded yam parameters.

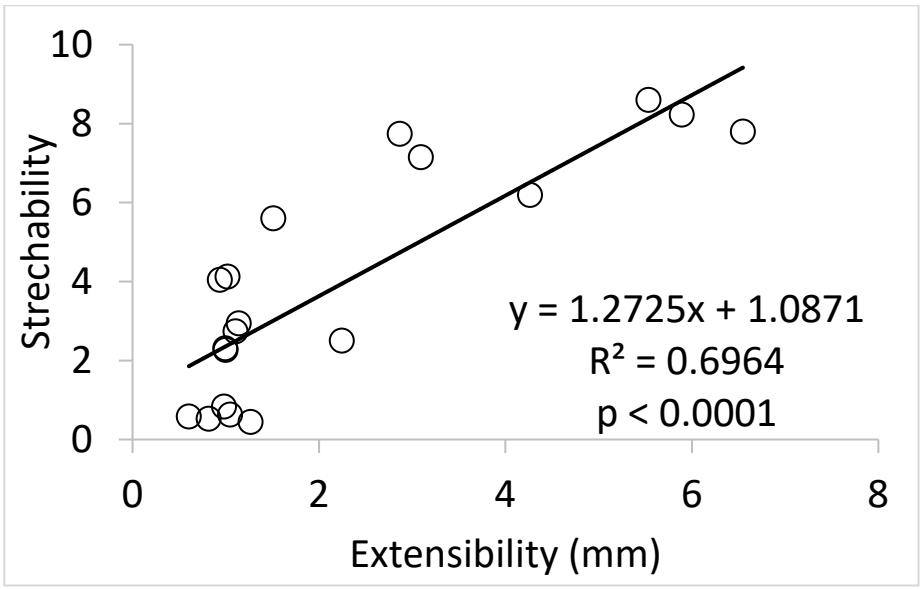
5 CORRELATIONS BETWEEN KDGE, SENSORY ATTRIBUTES AND DM OF POUNDED YAM FROM 19 GENOTYPES OF YAM

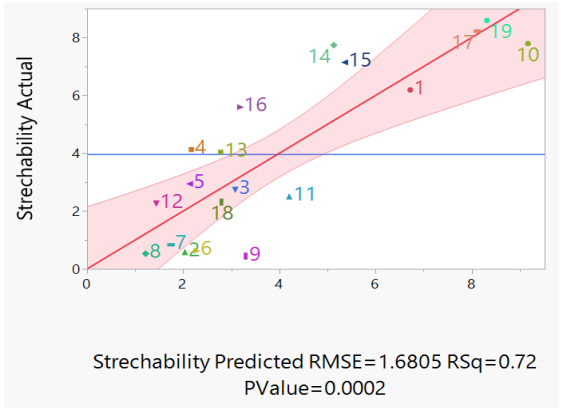
Pounded yam with good extensibility and extension work done are significantly associated with smooth, mouldable and cohesive doughs that are stretchable (Table 7a and 7b). Therefore, the stretchability of pounded yam may be estimated from instrumental extensibility measurements (see figure 5). The dry matter (DM) of the fresh yams contribute significantly to the extensibility of the pounded yams, and the DM of the pounded yam directly correlates with how extensible the pounded yam dough is. Since stretchability significantly relates the most with extensibility and the extensibility is significantly influenced by DM of fresh yam, the sensory stretchability score of pounded yam can thus be estimated by multi-linear regression as shown in equation below. The predicted versus actual stretchability shows a significant model (p = 0.002) with no definite pattern of residual versus predicted plot.

Table 7a : Correlations between KDGE, sensory attributes and DM of pounded yam from 19 genotypes of yam.

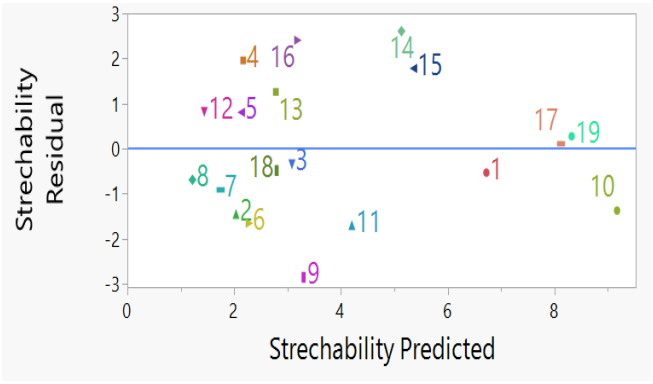
	Smoothness	Mouldability/Cohesiveness	Strechability	DM fresh yam(%)	DM boiled yam(%)	DM pounded yam(%)
			Coefficient			
Extensogram peak force(N)	0.4337	**0.5917**	**0.7562**	0.4335	0.2947	0.4133
Extensibility(mm)	**0.5164**	**0.6280**	**0.8345**	**0.5771**	0.3419	**0.5106**
Extension area(N.mm)	**0.4807**	**0.5845**	**0.7836**	**0.4901**	0.3187	0.4258
			P value			
Extensogram peak force(N)	0.0636	**0.0076**	**0.0002**	0.0637	0.2206	0.0786
Extensibility(mm)	**0.0236**	**0.0040**	**<.0001**	**0.0097**	0.1520	**0.0255**
Extension area(N.mm)	**0.0372**	**0.0086**	**<.0001**	**0.0332**	0.1835	0.0691

Significant at 5% level. *Genotypes TDa160403 and TDa160805 have no usable data*





Predicted versus actual stretchability plot



Residual error versus predicted plot for the prediction of stretchability

-0.491683207

+ 1.3141169526 • Extensibility(mm)

+ 0.0578237197 • DM fresh yam(%)

+ (Extensibility(mm) - 2.255844949) • ((DM fresh yam(%) - 29.943375025) • -0.050709268)

R^2 = 0.7236, Adjusted R^2 = 0.6683

Figure 5 : Multi-linear regression equation to estimate stretchability of pounded yam from 19 genotypes.

Table 7b : Correlations between KDGE and TPA textural parameters of pounded yam from 19 yam genotypes.

	Extensogram peak force(N)	Extensibility(mm)	Extension area(N.mm)
	coefficients		
Hardness(g)	0.3557	0.2752	0.2794
Adhesiveness (g.mm)	**-0.5376**	-0.3884	**-0.4906**
Stickiness(g)	**-0.5572**	-0.4107	**-0.4997**
Chewiness(g)	**0.7743**	**0.7974**	**0.7810**
Gumminess(g)	**0.7597**	**0.7934**	**0.7613**
Cohesiveness(-)	0.4498	**0.5470**	**0.5026**
Springiness(-)	0.1126	0.1075	0.1172
	P value		
Hardness(g)	0.1350	0.2541	0.2467
Adhesiveness (g.mm)	**0.0176**	0.1003	**0.0330**
Stickiness(g)	**0.0132**	0.0807	**0.0294**
Chewiness(g)	**<.0001**	**<.0001**	**<.0001**
Gumminess(g)	**0.0002**	**<.0001**	**0.0002**
Cohesiveness(-)	0.0534	**0.0154**	**0.0283**
Springiness(-)	0.6461	0.6612	0.6329

The extensibility of pounded yam was significantly related to its cohesiveness, chewiness and gumminess. Most *D. rotundata* varieties often produce extensible and cohesive pounded yam, while most *D. alata* varieties produce less extensible pounded yam samples that are usually fracturing. However, in the experiment being reported now, we could not find a significant relationship between TPA hardness and KDGE extensogram peak force.

In summary on the extensibility of the pounded yam activity, One-way ANOVA analysis showed significant differences among the extensibility textural quality of pounded yam among the yam genotypes and between the yam species, but no significant difference between hybrids and landraces. Hierarchical clustering, PCA and discriminant analyses classified the genotypes considered as having high extensibility, intermediate/fair extensibility, and those with poor extensibility. Significant correlations have been found between stretchability of pounded yam and the instrumental extensibility parameters. There were also significant relationships between TPA parameters such as chewiness and gumminess and KDGE extensibility parameters. Multi-linear regression model to estimate stretchability was significant by considering extensibility and DM fresh yams.

6 POUNDED YAM CONSUMER ACCEPTABILITY

The consumer acceptability study was aimed at understanding the consumers' demand for the quality characteristics of yam food products and the quality attributes associated with the consumers' preferred and non-preferred pounded yam (Table 8).

Materials : Consumer acceptability studies was conducted on pounded yam samples prepared from seven yam genotypes of from two yam varieties. About 120 consumers assessed the pounded yam samples prepared from the 7 yam genotypes from *D. alata* and *D. rotundata* species: Oweigbo (landrace, *D.alata*), TDa 160403, TDr 1544004, Meccakusa (landrace D.rotundata), TDa 1723003, TDr 1617811, TDr 1680007AB The yam genotypes were of variable food quality (colour and textural quality) in terms of their pounded yam (from very good to poor).

Method : It was carried out on pounded yam samples prepared from the yam varieties as described by Forsythe *et al.,* (2021). Methods used include a hedonic test, just-about-right (JAR) test, and check-all-that-apply (CATA) test. Consumers (*n = 120*) were asked individually to assess the appearance and textural quality

of each Pounded yam sample, one after the other randomly and score the overall liking of the products using a nine-point hedonic scale (from 1. “Extremely dislike, to 9. “Extremely like”). Consumers assessed their perception on the intensity of characteristics such as smoothness, mouldability, stretchability and colour identified as priority traits using the 3-point JAR “Just About Right” scale e.g. (1 = “not dark enough, not moudable enough”, 2= “Just About Right” and 3 = “Very stretchable, too smooth”) for each of the Pounded yam product samples. A range of quality characteristics that best described each Product sample as observed by the consumers were assessed using a “Check-All-That-Apply” (CATA) approach and preferences on the pounded yam samples were given.

The CATA quality characteristics is presented below based on the users’ preferences from previous survey consisting of the most liked and the least liked quality characteristics related to the appearance and texture between fingers of pounded yam.

Table 8 : Quality characteristics identified during the previous survey for building the CATA table.

	Quality characteristics of pounded yam product
List of **the most liked** characteristics	**Appearance** - White - Yellow **Stretchability** - Stretchable **Texture when touching** - No lumps - Mouldable - Smooth
List of **the least liked** characteristics	**Appearance** - Grey -Brown **Texture when Touching** - Lumps - Not smooth - Not stretchable - Not mouldable

Data analysis: Analysis of variance (ANOVA) was carried out to identify significant differences in Overall liking scores between the Seven Pounded yam samples as tested by 120 consumers. Multiple pairwise comparisons were applied using the Tukey test, with a confidence interval of 95% at $p < 0.05$ (n=120 consumers). For each Pounded yam sample, the number of consumers who judged each specific characteristic either Just All Right (JAR), not enough or very much was counted, and the percentage of consumers (*out of 120*) determined. A Principal Component Analysis (PCA) was used to describe the relationships between frequencies of citation of CATA sensory characteristics and the mean Overall liking scores for each Pounded yam sample. All statistical analyses were performed using XLSTAT 2019 software (Addinsoft).

Results:

6.1 Overall liking of the product samples

The Overall liking scores for each Pounded yam sample as perceived by consumers in Bowen University (n=120 consumers) using ANOVA is as presented in the tables 9a-e below. Overall liking scores was set as the dependent variable and Pounded yam samples as Qualitative explanatory variable, using a Turkey test with

a confidence interval of 95% for means separation and multiple comparison. The overall liking for appearance and texture of the pounded yam samples were significantly different in the seven pounded yam samples at a significant level of $p<0.05$ (one-way ANOVA) (Table 9a – e).

The analysis of variance of the yam samples showed that there is significant differences in the color, stretchability, mouldability, smoothness as well as the overall liking of the pounded yam products from the seven yam genotypes used. The overall liking of the pounded yam product indicated that TDa160403 was similar to TDa1723003 however, the two *D. alata* varieties differ significantly from their counterpart TDa Oweigbo which compared favourably with *D. rotundata* yam genotype TDr1544004. In all, **TDa160403** was ranked the least liked product while **TDr1617811** was rated highest overall liked product followed by **TDr Meccakusa** and then TDa Oweigbo.

In appearance, the color of *D. alata* species and *D. rotundata* yam genotypes were paired in the different significant groups. *D. alata,* TDa Oweigbo compared favourably and is not significantly different from TDr1617811 and TDr Meccakusa which are *D. rotundata* species. The color of TDa160403 was not significantly different from TDr1680007AB and TDr1544004 is similar to TDa1723003 significantly. The genotype TDa160403 also had the least ranking score in terms of likeness for colour while TDa Oweigbo was scored highest liked in color by the consumers followed by TDr1617811 and then TDr Meccakusa.

The smoothness of pounded yam samples prepared from TDr1680007AB and TDr1544004 were not significantly different. However, the scoring for both genotypes was significantly different from the group of TDr1617811 and TDr Meccakusa even though the genotypes are of *D rotundata* variety. The textural attribute of TDa Oweigbo in terms of smoothness, on the other hand, was found not to be significantly different from both TDr1680007AB and TDr1544004 genotypes. The least liked in terms of smoothness by the consumers was pounded yam sample prepared from **TDa160403** yam genotype while smoothness of TDr Meccakusa was ranked highest followed by **TDr1617811** and then **TDa Oweigbo**.

Mouldability in TDr1617811 and TDr Meccakusa yam genotypes were found not to be significantly different from each other but significantly different from TDr1544004 and TDr1680007AB which are both not significantly different from each other as well as TDa Oweigbo. Though the stretchability of the pounded yam samples prepared from TDr1617811 yam genotype is significantly different from that of TDr1544004, both genotypes were found not be significantly different from TDr Meccakusa. On the other hand, the stretchability of TDa Oweigbo, though different from TDa1723003 and TDa160403 in stretchability, was not significantly different from TDr1680007AB and TDr1544004.

The yam genotype that the pounded yam sample had the least score in mouldability and stretchability respectively was T**Da1723003** while T**Dr1617811** was scored highest liked in terms of mouldability and stretchability, followed by TDr Meccakusa and then **TDr1544004,** respectively.

Table 9a : *Mean product overall liking scores for the assessed pounded yam samples.

**Category	Means	Groups			
TDa160403	4.1217	A			
TDa1723003	4.5847	A			
TDr1680007AB	5.3782		B		
TDr1544004	5.9123		B	C	
TDa Oweigbo	6.2920			C	
TDr Meccakusa	7.1681				D
TDr1617811	7.3667				D

*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. Turkey test ($p<0.05$).

Table 9b : *Mean overall liking scores for the color of the assessed pounded yam samples.

**Category	Mean	Groups				
TDa160403	4.4348	A				
TDr1680007AB	4.5462	A	B			
TDr1544004	5.2807		B	C		
TDa1723003	5.5254			C		
TDr Meccakusa	6.8053					D
TDr1617811	6.8417					D
TDa Oweigbo	7.3717					D

*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. Turkey test (p<0.05).

Table 9c : *Mean overall liking scores for the smoothness of the assessed pounded yam samples.

**Category	Means	Groups			
TDa160403	4.4522	A			
TDa1723003	5.2627		B		
TDr1680007AB	5.7143		B	C	
TDr1544004	6.1404			C	
TDa Oweigbo	6.4513			C	D
TDr1617811	7.1750				D
TDr Meccakusa	7.2566				D

*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. Turkey test (p<0.05).

Table 9d : *Mean overall liking scores for the mouldability of the assessed pounded yam samples.

**Category	Means	Groups			
TDa1723003	3.7034	A			
TDa160403	3.9478	A			
TDa Oweigbo	6.0000		B		
TDr1680007AB	6.0420		B		
TDr1544004	6.3684		B		
TDr Meccakusa	7.3805			C	
TDr1617811	7.5250			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. Turkey test (p<0.05).

Table 9e : *Mean overall liking scores for the stretchability of the assessed pounded yam samples.

**Category	Means	Groups				
TDa1723003	3.6525	A				
TDa160403	3.7130	A				
TDa Oweigbo	5.2743		B			
TDr1680007AB	5.3782		B			
TDr1544004	5.7456		B	C		
TDr *Meccakusa*	6.5044			C	D	
TDr1617811	6.6667				D	

*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. Turkey test (p<0.05).

6.2 Segmentation of consumers into groups of similar overall liking

In order to create homogeneous clusters of consumers who have similar overall liking scores for the appearance and textural properties of the pounded yam samples prepared from the seven yam genotypes, Agglomerative Hierarchical Clustering (AHC) analysis was carried out and thus the randomly selected consumers were classified into similar groups . The Agglomerative Hierarchical Clustering analysis of the mean overall liking scores for each of the quality characteristics were used to identify the three groups of consumers - C1, C2 and C3. There were significant differences ($P < 0.001$) in the overall liking of the three clusters (Figure 6a - 6j) in both appearance and texture of the pounded yam samples.

The AHC analysis for the consumers indicated that clusters C1, C2 and C3 are TDa Oweigbo, TDr Meccakusa, TDr 1544004 & TDr 1617811 likers, TDr 1617811 likers and TDa 160403 dislikers with 33%, 53% and 14% consumers respectively for the mean overall product liking. The consumer clusters for mean stretchability shows that C1, C2 and C3 are TDr 1617811 likers, TDR 1544004, TDr Meccakusa & TDr 1617811 likers and TDa 160403 dislikers having 56%, 9% and 35% consumers in the clusters respectively.

Mouldability clustering also had three clusters, C1 (TDa Oweigbo, TDr Meccakusa, TDr1544004 & TDr1617811 likers), C2 (TDa160403 dislikers) and C3 (TDa Oweigbo, TDr Meccakusa & TDr1617811 likers) with 48%, 27% and 25% consumers in the clusters respectively; while the consumer clustering in smoothness shows C1 - TDr Meccakusa, TDr1544004 & TDr1617811 likers with 57% consumers, C2 which are TDr1617811 likers with 33% consumers and 10% of the consumers who are TDr1680007AB dislikers.

The consumer clusters for overall liking in terms of the pounded yam samples' colour showed that 30% of the consumers in C1 as TDr1680007AB dislikers, 60% in C2 as TDa Oweigbo, TDr Meccakusa, & TDr1617811 likers and TDa Oweigbo & TDr1617811 likers who are 10% of the consumers in C3.

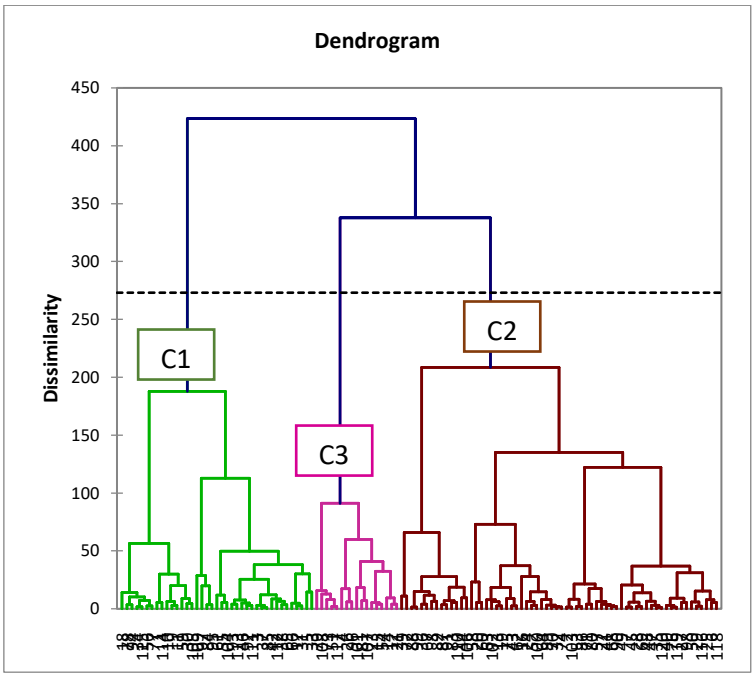
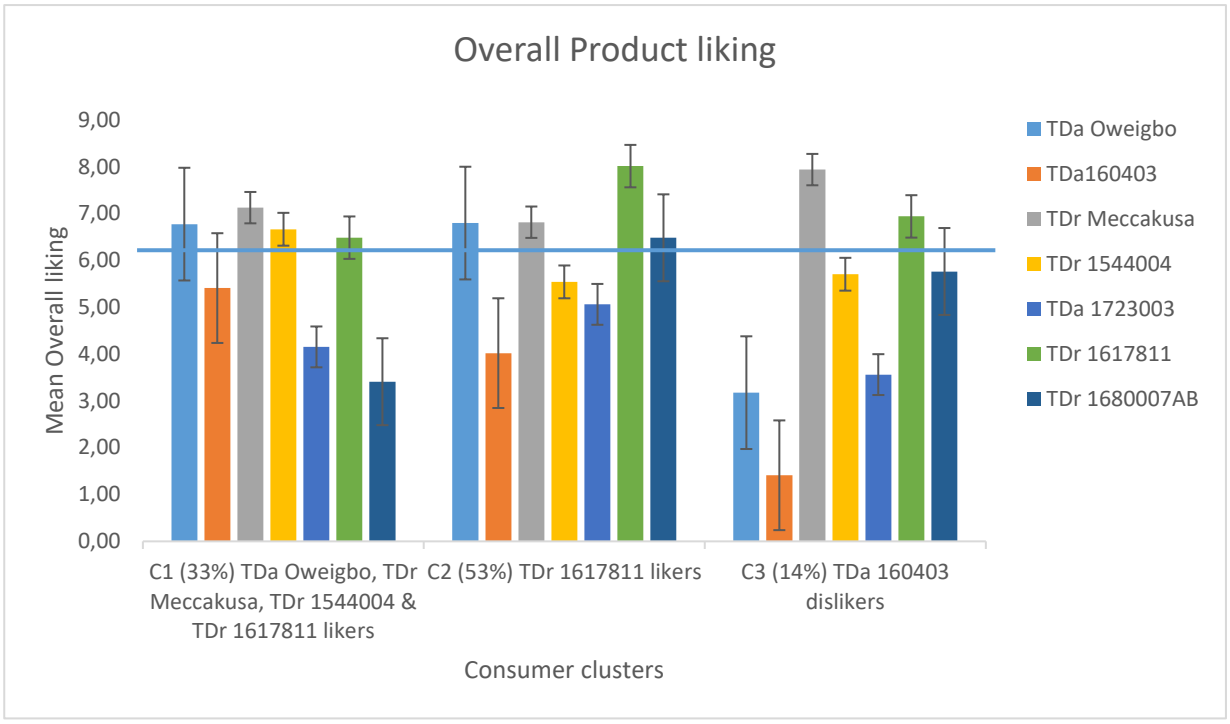


Figure 6a : Clustering of the consumers based on their overall product liking scores of the pounded yam.



* error bars represent the standard error.

Figure 6b : Mean overall product liking of the pounded yam samples by consumer cluster.

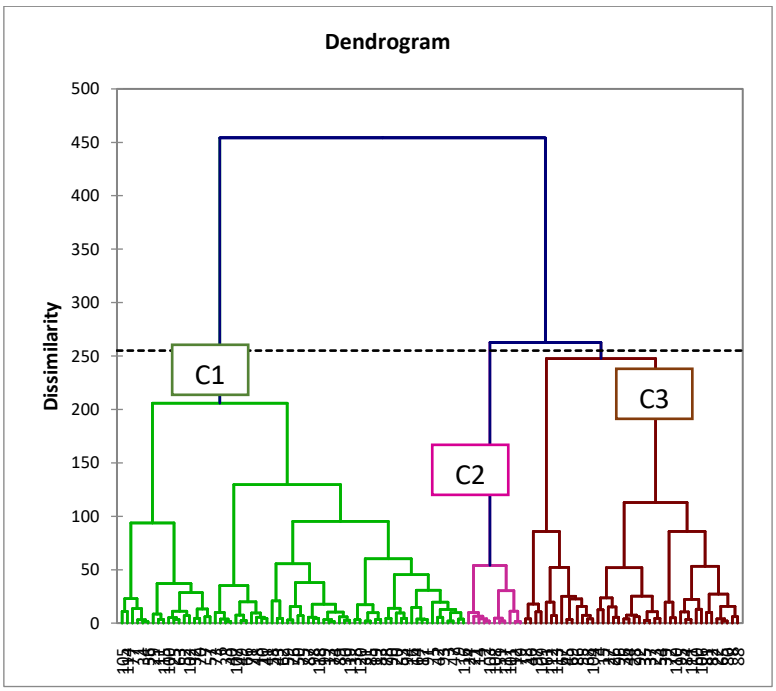
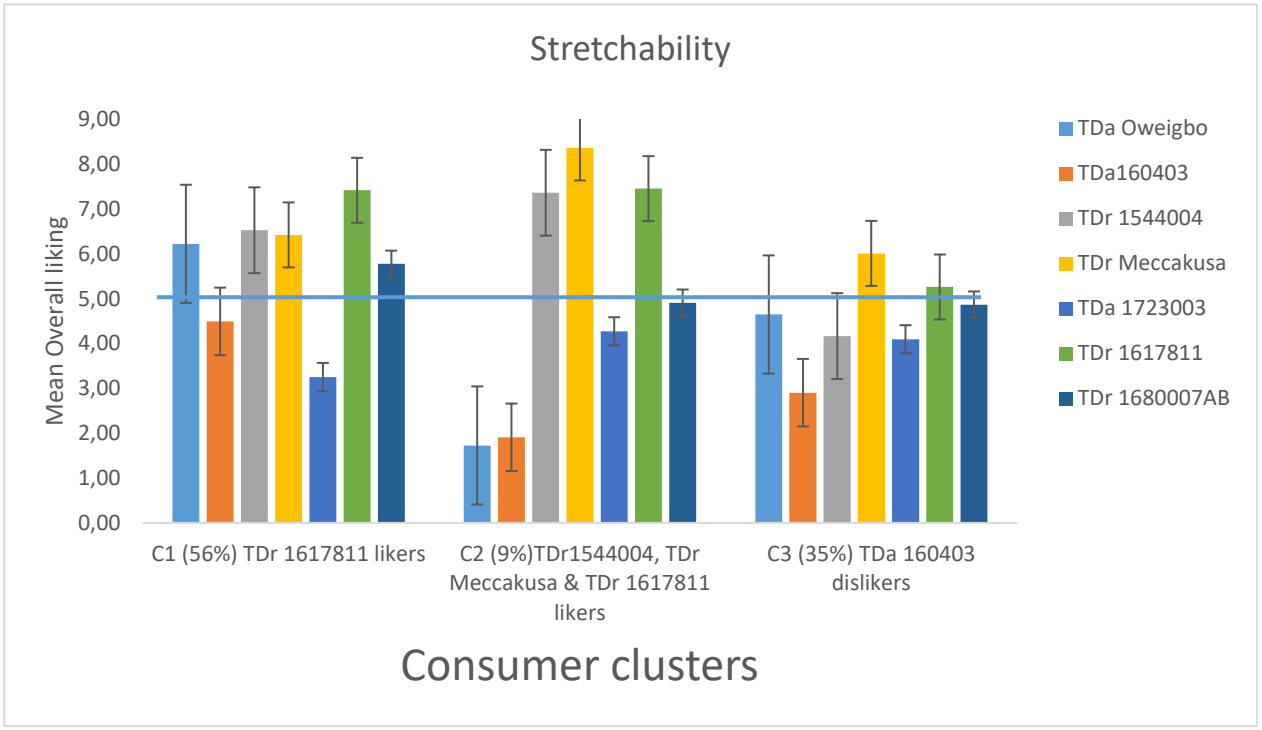


Figure 6c : Clustering of the consumers based on their overall liking scores for stretchability of the pounded yam samples.



error bars represent the standard error.

Figure 6d : Mean overall liking for stretchability of the pounded yam samples by consumer cluster.

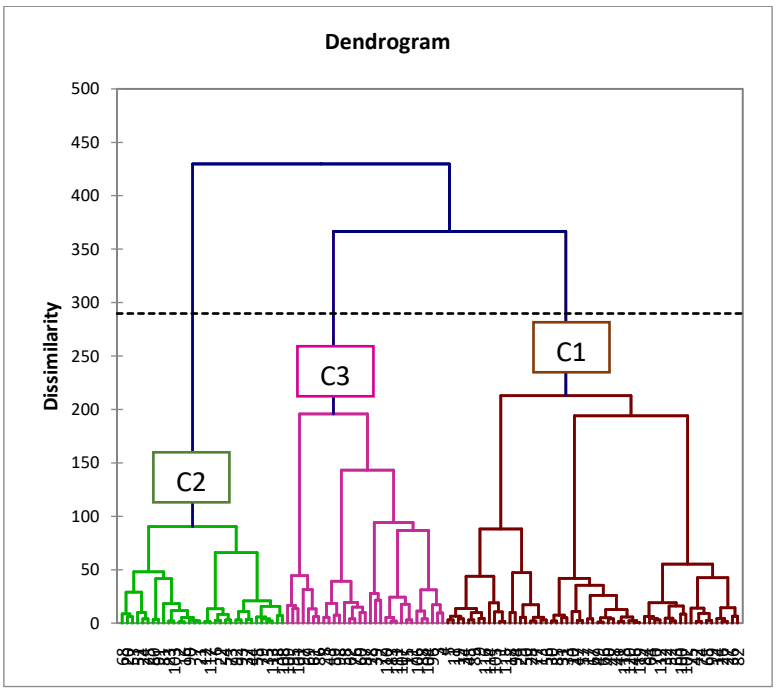


Figure 6e : Clustering of consumers based on their overall liking scores for mouldability of the pounded yam samples.

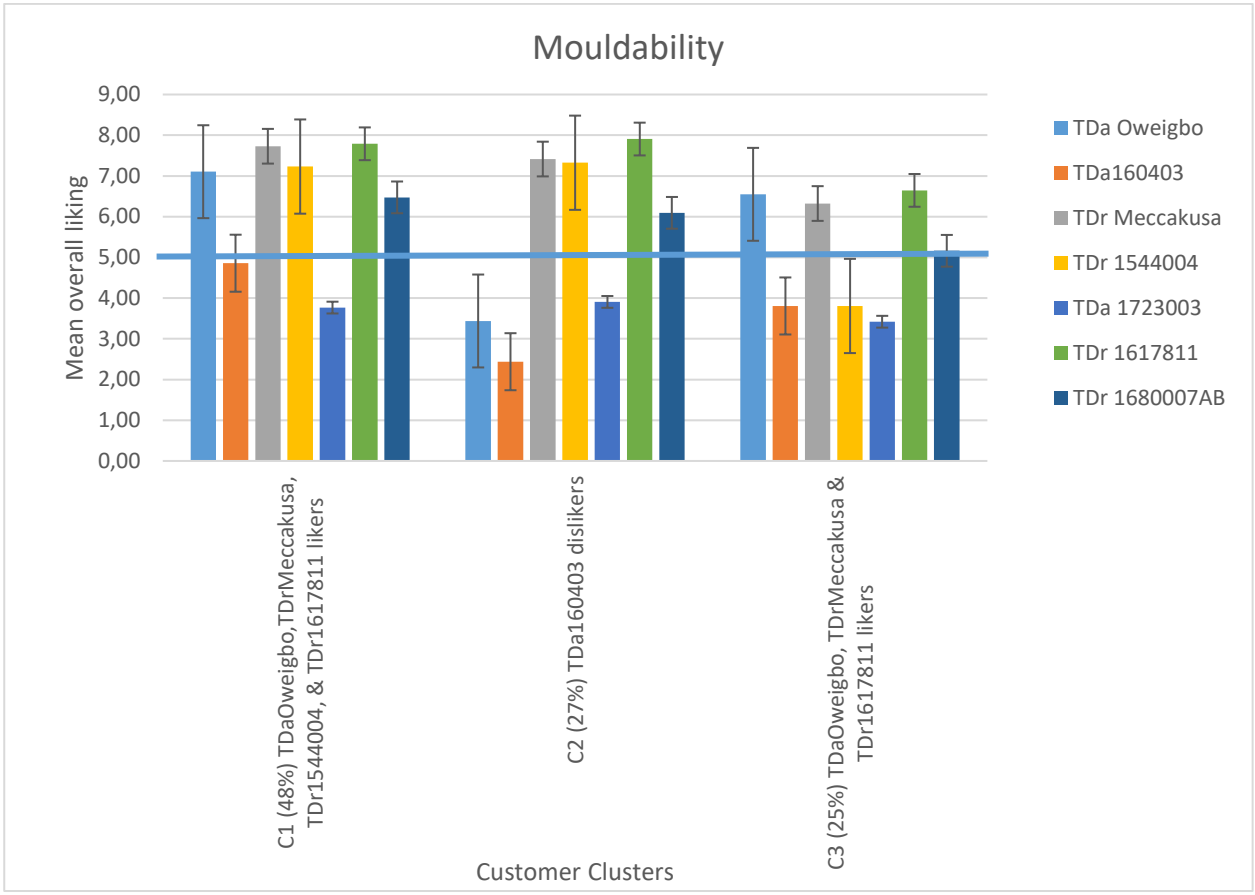


Figure 6f : Mean overall liking for mouldability of the pounded yam samples by consumer cluster.

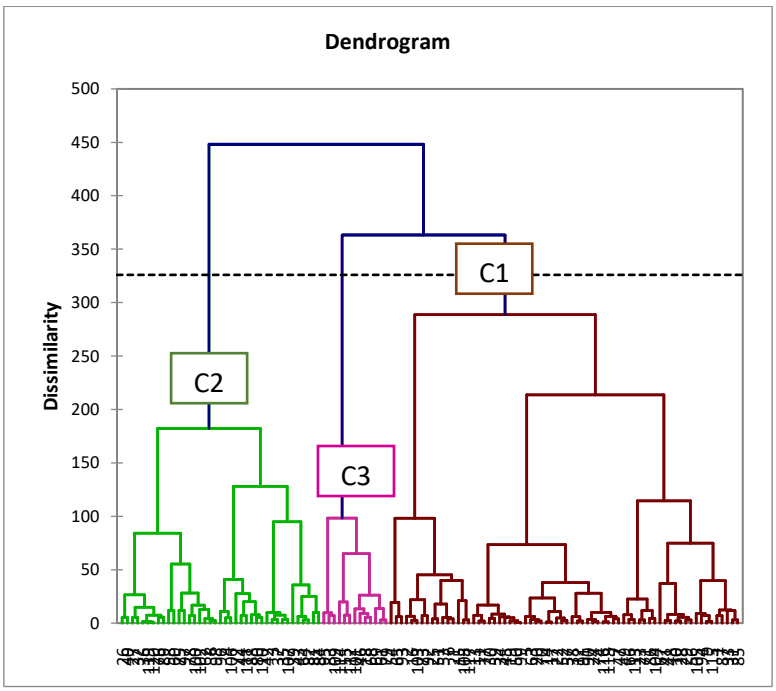
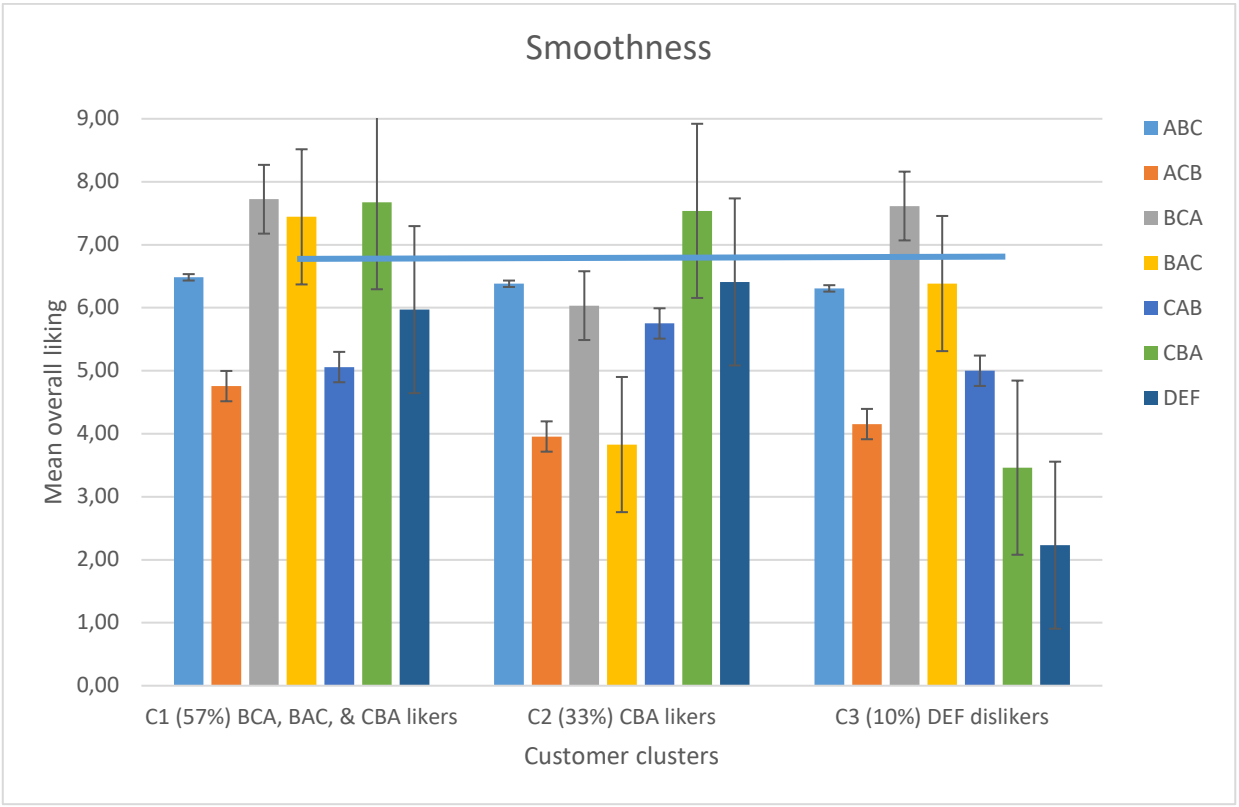


Figure 6g : Clustering of consumers based on their overall liking scores for smoothness of the pounded yam samples.



ABC-TDa Oweigbo, ACB-TDa160403, BCA-TDr Meccakusa, BAC-TDr1544004, CAB-TDa1723003, CBA-TDr1617811, DEF-TDr1680007AB

Figure 6h : Mean overall liking for smoothness of the pounded yam samples by consumer cluster.

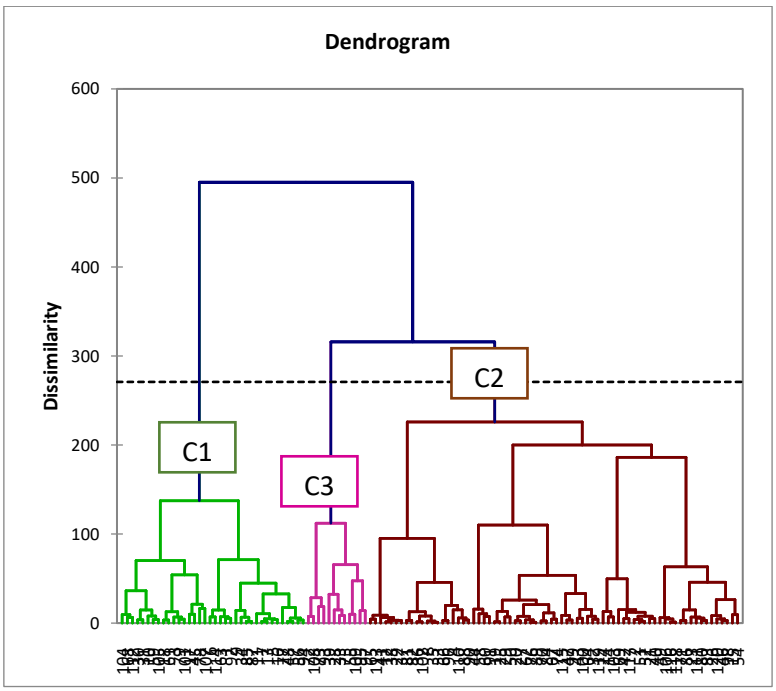
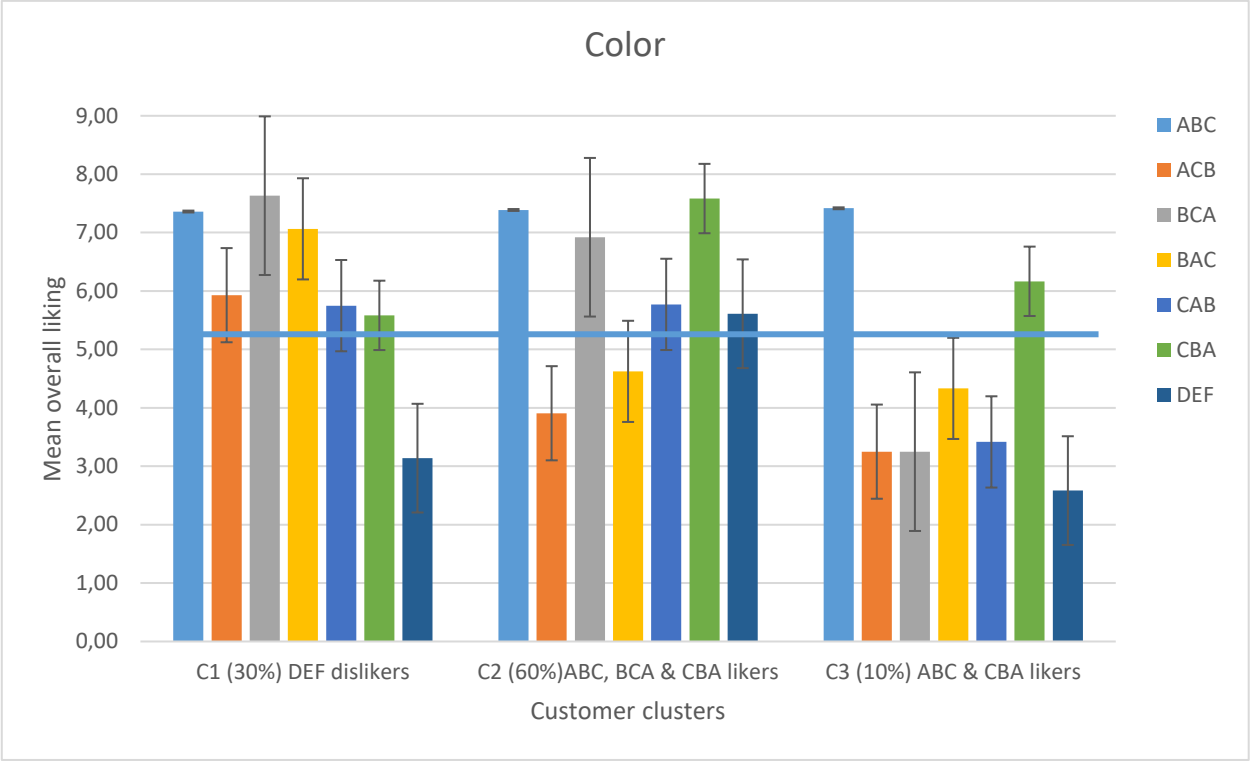


Figure 6i : Clustering of consumers based on their overall liking scores for the colour of the pounded yam samples.



ABC-TDa Oweigbo, ACB-TDa160403, BCA-TDr Meccakusa, BAC-TDr1544004, CAB-TDa1723003, CBA-TDr1617811, DEF-TDr1680007AB

Figure 6j : Mean overall liking for colour of the pounded yam samples by consumer cluster.

6.2.1 Demographic characteristics and Consumption attitude of consumers

Table 10 shows the demographic characteristics of consumers. 120 consumers assessed each of the pounded yam sample from the 7 genotypes with 42.5% of the consumers being female and male, 57.5%. The mean age of the consumers was 19 years and the age bracket with the largest percentage was 18-25 years having 60.8%. Majority of the consumers were from the Yoruba ethnic group which could be due to the fact that the survey location is Yoruba ethnic dominated. About 84.2% of the respondents were single and 13.3% were married. Out of the 120 respondents, 62.5% were students, 5.0% were civil servants and15% employed.

Table 10 : Demographic characteristics of consumers.

Characteristics		Total
	Number of consumers (n)	120
Gender	Female (%) Male (%)	42.5% (51) 57.5% (69)
Age	18-25 years old (%) 26-35 years old (%) 36-45 years old (%) 46-55 years old (%)	60.8% (73) 5.0% (6) 5.0% (6) 4.2% (5)
Ethnicity	Yoruba (%) Hausa (%) Igbo (%) Others (%)	70.8% (85) 0.8% (1) 2.5% (3) 11.7% (14)
Marital status	Single (%) Married (%) Widower (%)	84.2% (101) 13.3% (16) 0.8% (1)
Occupation	Student (%) Artisanship (%) Civil servant (%) Employed (%)	62.5% (75) 0.8% (1) 5.0% (6) 15.0% (18)
Consumption frequency	Daily (%) Several times a week (%) Once a week (%) Several times a month (%) Once a month (%)	0.8% (1) 2.5% (3) 31.7% (38) 18.3% (22) 46.7% (56)
Consumption form	With soup (%) With stew only (%) Without soup/stew (%)	98.3% (118) 0.8% (1)
Occasion of consumption	Breakfast (%) Lunch (%) Dinner (%)	6.7% (8) 65.0% (78) 27.5% (33)

Consumption frequency showed that about 31.7% of the respondents consumed pounded yam once a week, 2.5% consume it several times a week, 46.7% once a month and 18.3% several times in a month. The response on consumption pattern showed that 98.3% of the consumer take pounded yam with soup such as efo riro, okro, egusi etc. while 0.8% consume pounded yam with stew only. About 6.7% of the respondents consume pounded yam during breakfast time while majority, 65.0% consume it during lunch time and 27.5% as dinner. The perception of consumers was grouped per clusters.

In general, the percentage of the consumer cluster by gender as presented in figure 7, for the overall product liking, it showed that 64.71% of the C3 TDa 160403 dislikers were females, 62.50% of the TDr 1617811 likers were males while about 58.97% of the TDa Oweigbo, TDr Meccakusa, TDr 1544004 & TDr 1617811 likers were males.

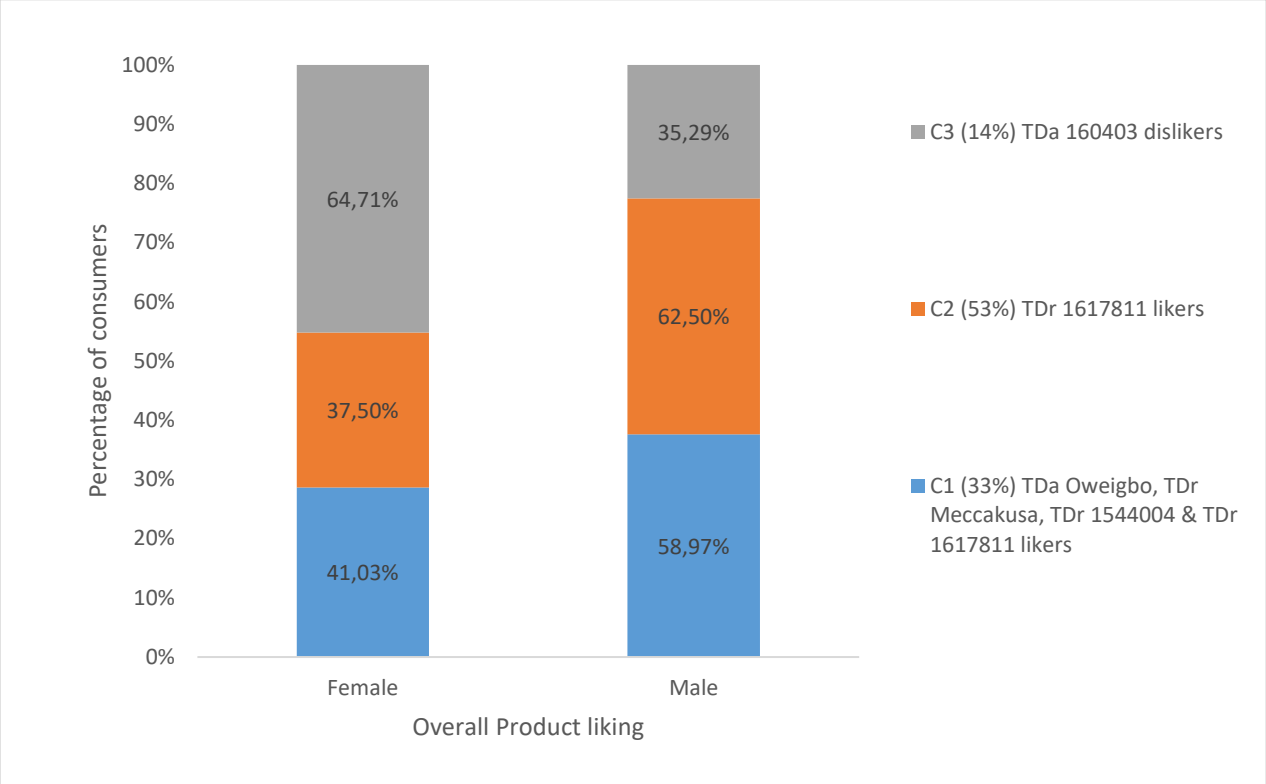


Figure 7 : Percentage of consumer cluster type by gender.

6.3 A Just About Right test (JAR)

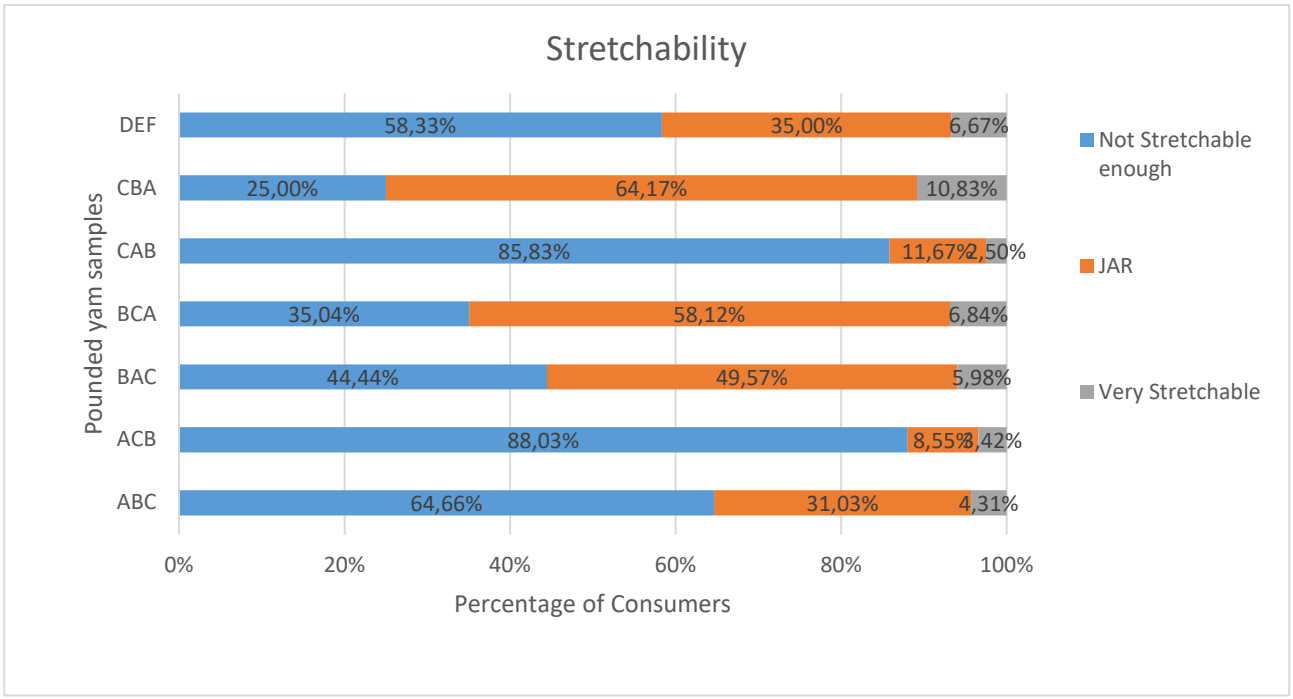
Just about right (JAR) scale was used to determine the optimum level of intensity as perceived by the consumers for *some* important sensory quality characteristics of the Pounded yam samples. Consumers were asked to give their perception of the Stretchability, Colour, Smoothness, and Mouldability of each Pounded yam sample, by using a 3-point JAR scale (1 = "not enough", 2= "Just About Right" and 3 = "Too smooth etc"). Using a PivotTable, the percentage of consumers who scored each Pounded yam sample as *"not enough", or as "JAR Just About Right", or as "Too smooth etc."* was calculated. Percentage of consumers who scored the three specific sensory characteristics as presented below.

6.3.1 Stretchability

Table 11a and Figure 8a shows the percentage of consumers' stretchability perception of pounded yam samples. About 64.17% of the consumers rated TDr1617811 as 'Just about right' followed by TDr Meccakusa with 58.12% of the consumers. Only 10.83% and 6.84% of the consumers rated TDr1617811 and TDr Meccakusa as very stretchable, respectively. On the contrary, 25% of the consumers rated TDr1617811 as 'not stretchable enough' while 88.03% of the consumers rated TDa160403 as 'not stretchable enough' and 8.55% rated it as 'Just about right.

Table 11a : Percentage of consumers' stretchability perception of pounded yam samples.

Pounded yam products	Not Stretchable enough	JAR	Very Stretchable
TDa Oweigbo	64.66%	31.03%	4.31%
TDa160403	88.03%	8.55%	3.42%
TDr1544004	44.44%	49.57%	5.98%
TDr Meccakusa	35.04%	58.12%	6.84%
TDa1723003	85.83%	11.67%	2.50%
TDr1617811	25.00%	64.17%	10.83%
TDr1680007AB	58.33%	35.00%	6.67%



Key: ABC-TDa Oweigbo, ACB-TDa160403, BCA-TDr Meccakusa, BAC-TDr1544004, CAB-TDa1723003, CBA-TDr1617811, DEF-TDr1680007AB

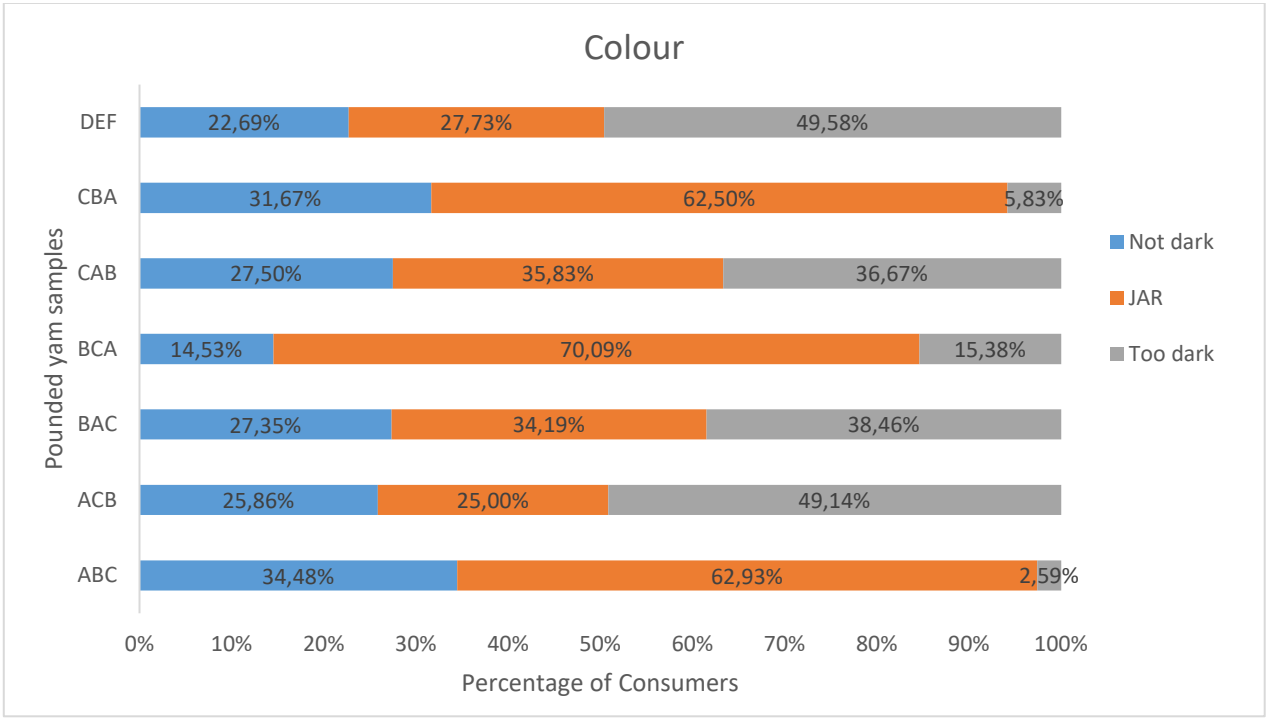
Figure 8a : Percentage of consumers' stretchability perception of pounded yam samples.

6.3.2 Colour

The colour of the pounded yam as perceived by the consumers (Table 11b and Figure 8b)showed that TDr Meccakusa and TDa Oweigbo were rated 'not dark' by 14.53% and 34.48%, respectively. Pounded yam samples prepared from TDa Oweigbo, TDa160403 and TDr1680007AB were rated 'too dark' by 2.59%, 49.14% and 49.58% of the consumers, respectively. Pounded yam samples prepared from **TDr1617811, TDa Oweigbo**, and TDr Meccakusa had 62.50%, 62.93% and 70.09% consumers rated them as 'just about right' colour, respectively.

Table 11b : Percentage of consumers' colour perception of pounded yam samples.

Pounded yam products	Not dark	JAR	Too dark
TDa Oweigbo	34.48%	62.93%	2.59%
TDa160403	25.86%	25.00%	49.14%
TDr1544004	27.35%	34.19%	38.46%
TDr Meccakusa	14.53%	70.09%	15.38%
TDa1723003	27.50%	35.83%	36.67%
TDr1617811	31.67%	62.50%	5.83%
TDr1680007AB	22.69%	27.73%	49.58%



Key: ABC-TDa Oweigbo, ACB-TDa160403, BCA-TDr Meccakusa, BAC-TDr1544004, CAB-TDa1723003, CBA-TDr1617811, DEF-TDr1680007AB

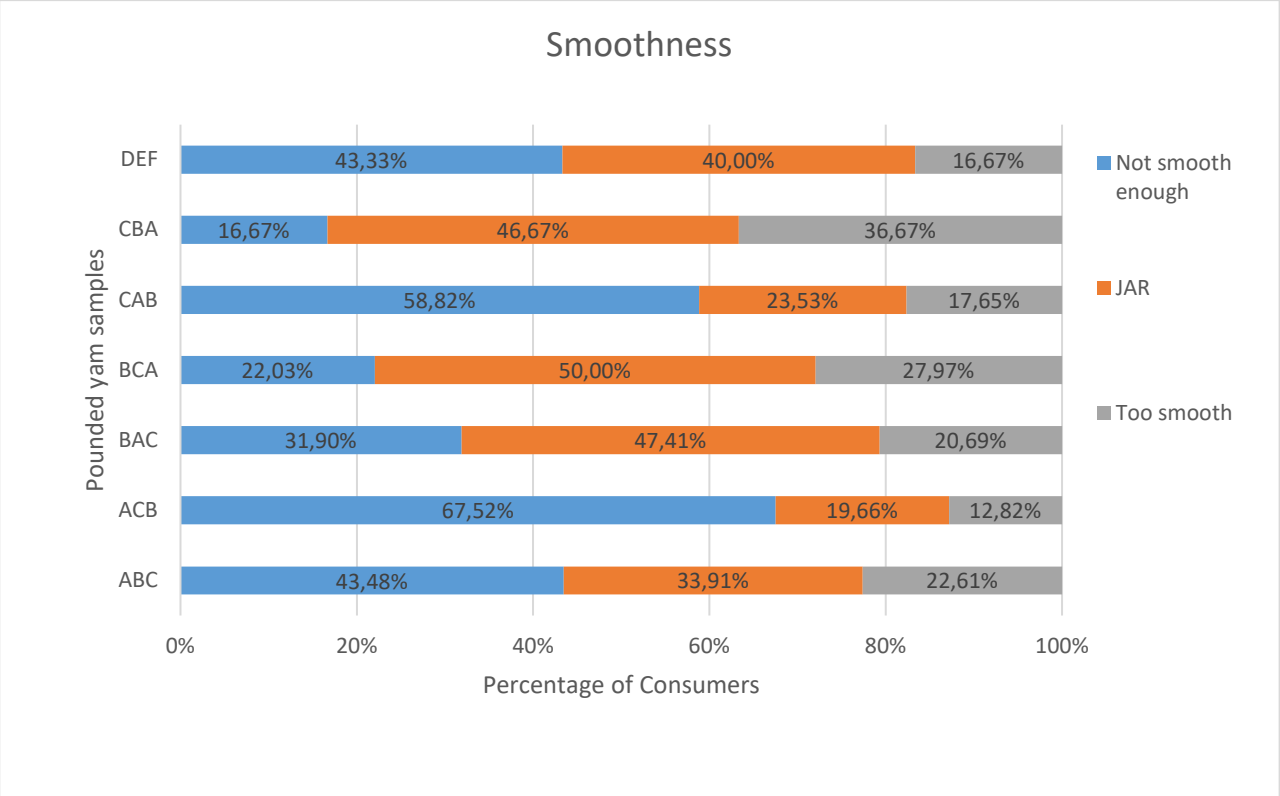
Figure 8b : Percentage of consumers' colour perception of pounded yam samples.

6.3.3 Smoothness

The smoothness of the pounded yam samples (Table 11c and Figure 8c) from TDr1680007AB, TDa Oweigbo, TDa1723003, and TDa160403 were ranked 'not smooth enough' by high percentage of 43.33%, 43.48%, 58.82% and 67.52% consumers respectively while TDr Meccakusa and TDr1617811 were rated 'very smooth' by high percentage of the consumers with 27.97% and 36.67%, respectively. In smoothness, about 46.67%, 47.41% and 50.00% of the consumers perceived TDr1617811, TDr1544004 and TDr Meccakusa as 'just about right' respectively.

Table 11c : Percentage of consumers' smoothness perception of pounded yam samples.

Pounded yam products	Not smooth enough	JAR	Too smooth
TDa Oweigbo	43.48%	33.91%	22.61%
TDa160403	67.52%	19.66%	12.82%
TDr1544004	31.90%	47.41%	20.69%
TDr Meccakusa	22.03%	50.00%	27.97%
TDa1723003	58.82%	23.53%	17.65%
TDr1617811	16.67%	46.67%	36.67%
TDr1680007AB	43.33%	40.00%	16.67%



Key: ABC-TDa Oweigbo, ACB-TDa160403, BCA-TDr Meccakusa, BAC-TDr1544004, CAB-TDa1723003, CBA-TDr1617811, DEF-TDr1680007AB

Figure 8c : Percentage of consumers' smoothness perception of pounded yam samples

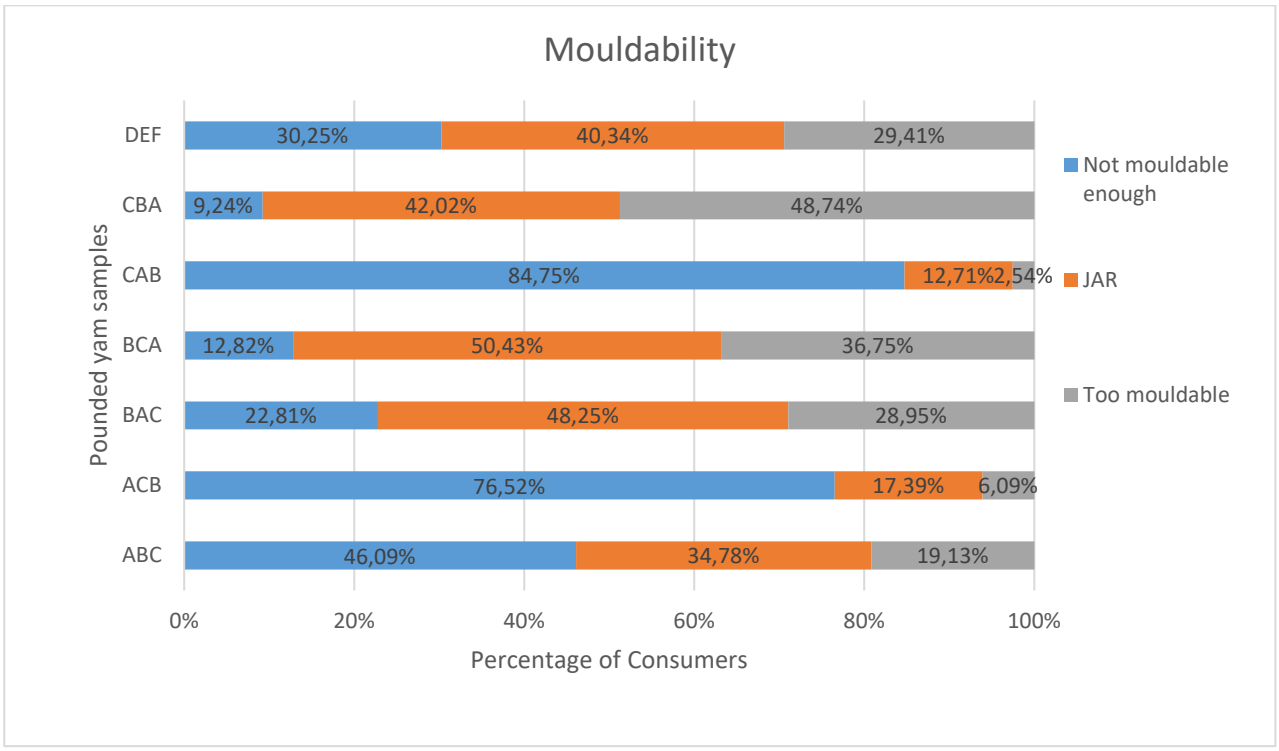
6.3.4 Mouldability

Mouldability in the pounded yam samples (Table 11d and Figure 8d)showed that samples TDa Oweigbo, TDa160403, and TDa1723003 were perceived 'not mouldable' by high percentage, 46.09%, 76.52% and 84.75% of the consumers respectively while, TDr Meccakusa and TDr1617811 had the highest percentage of consumers, 36.75% and 48.74% rated as 'very mouldable' respectively. About 40.34%, 42.02%, 48.25% and

50.43% of consumers, perceived TDr1680007AB, TDr1617811, TDr1544004 and TDr Meccakusa as JAR - 'just about right' respectively.

Table 11d : Percentage of consumers' mouldability perception of pounded yam samples.

Pounded yam products	Not mouldable enough	JAR	Too mouldable
TDa Oweigbo	46.09%	34.78%	19.13%
TDa160403	76.52%	17.39%	6.09%
TDr1544004	22.81%	48.25%	28.95%
TDr Meccakusa	12.82%	50.43%	36.75%
TDa1723003	84.75%	12.71%	2.54%
TDr1617811	9.24%	42.02%	48.74%
TDr1680007AB	30.25%	40.34%	29.41%



Key: ABC-TDa Oweigbo, ACB-TDa160403, BCA-TDr Meccakusa, BAC-TDr1544004, CAB-TDa1723003, CBA-TDr1617811, DEF-TDr1680007AB

Figure 8d : Percentage of consumers' mouldability perception of pounded yam samples.

6.4 Check All That Apply (CATA) test

The objective of the CATA test was to show the relationship between hedonic Overall liking scores for each Pounded yam sample and the frequencies of citation of each CATA sensory characteristic by the consumers. After scoring the Overall liking and the perception of some specific sensory characteristics (Table 12),

consumers choose the most appropriate terms among about 20-25 sensory characteristics that described each of the Pounded yam samples better.

The frequency of citations given by consumers to describe each Pounded yam sample were calculated and presented in Table 5 below. The sensory characteristics most frequently cited by the consumers such as 'no lumps', 'white', 'mouldable', 'smooth', etc. were considered the best for describing pounded yam products as indicated with different colours in the table below. The least used terms had low citations by the consumers.

TDa Oweigbo pounded yam sample was described by the consumers as 'white' with 75 citations, 'mouldable', 'smooth no lumps' with citations of 44, 39 respectively and 'slightly stretchable' by 20 even though some consumers perceived it having 'small lumps' and 'not stretchable' with 43 and 34 citations. Similar quality characteristics were used to describe TDa160403 as 'not stretchable' with frequency of citation being 62, 'not mouldable' with 54 citations, 'small lumps' 42, 'not smooth' 40, 'off white' 40, and 'light brown' 23 citations.

Pounded yam sample prepared from TDr Meccakusa was described using quality characteristics such as 'smooth no lumps' with 66, 'mouldable' 72, 'stretchable' 47, 'cream colour' 33, and 'light yellow' 30 citations. TDr1544004 had 50 frequency of citation as perceive 'smooth no lumps', 28 for 'slightly stretchable', 29 as 'stretchable', 35 'slightly mouldable', 46 'mouldable', 'cream colour' 20, 'light yellow' 31 and 'yellow' 30 citation frequency.

However, TDa172300 was termed 'small lumps' with 52 citations, 'not stretchable' 71, 'not smooth' 36, 'not mouldable' 66 and 'off white' 43 citations as compared to TDr1617811 which was perceived 'smooth no lumps' with 79 citations, 'stretchable' 64, 'mouldable' 90, 'cream colour' 38 and 'light yellow' 37 citations.

The consumers described TDr1680007AB as 'smooth no lumps' and 'mouldable' with 57 and 65 citations but 'not stretchable' and 'off white' with frequency of citation of 38 and 28, respectively.

The citation frequency for overall product quality attributes shows that pounded yam sample TDr1617811 had the highest mean value of 7.37 by the consumers followed by TDr Meccakusa with a mean of 7.08.

Table 12 : Frequency of citations of each quality characteristic by the consumers.

Pounded yam product codes	Oweigbo	TDa160403	Meccakusa	TDr1544004	TDa1723003	TDr1617811	TDr1680007AB	Total
Big Lumps	7	23	4	5	3	2	2	46
Small lumps	43	42	12	14	52	5	17	185
Not smooth	19	40	9	23	36	7	21	155
Smooth/ no lumps	39	21	66	50	33	79	57	345
Not Stretchable	34	62	17	19	71	13	38	254
Slightly Stretchable	20	7	23	28	9	18	27	132
Stretchable	18	7	47	29	11	64	28	204
Not Mouldable	29	54	6	10	66	10	15	190
Slightly Moudable	23	14	16	35	20	5	20	133
Mouldable	44	22	72	46	11	90	65	350
White	75	15	12	10	18	9	5	144
Off White	13	40	24	10	43	15	28	173
Cream Colour	9	9	33	20	9	38	17	135
Light Yellow	5	2	30	31	1	37	14	120
Yellow	5	4	13	30	1	11	2	66
Light Grey	6	13	3	2	23	2	19	68
Grey	2	12	4	5	7	0	7	37
Light Brown	0	23	2	3	7	1	9	45
Brown	0	3	1	2	3	1	5	15
Mean Overall liking color	7.38	4.45	6.77	5.33	5.53	6.84	4.57	
Mean Overall liking smoothness	6.43	4.43	7.16	6.15	5.28	7.18	5.71	
Mean Overall liking mouldability	5.98	3.94	7.28	6.37	3.71	7.53	6.03	
Mean Overall liking stretchability	5.26	3.70	6.46	5.78	3.64	6.67	5.38	
Mean Product Overall liking	6.28	4.10	7.08	5.93	4.55	7.37	5.38	

6.5 Sensory mapping of the sensory characteristics

Principal component analysis (PCA) was used to summarize the relationships between CATA colour and textural characteristics of the Pounded yam samples, and mean Overall liking of each product scored by all the consumers (Figure 9a-9c). The PCA plot for the consumers explained 87.92% of the variance of the sensory characteristics with the first and second axes accounting for 72.88% and 15.04%, respectively. Most of the variance was explained by the first axis.

The quality characteristics on the PCA plan for the consumers shows axis 1 having 'mouldable', 'yellow', 'cream colour', 'slightly stretchable', 'smooth no lumps', 'stretchable', and light yellow related to pounded yam samples prepared from *D. rotundata* species which includes Meccakusa (BCA), TDr1544004 (BAC), TDr1617811 (CBA), TDr1680007AB (DEF) genotypes. The second axis indicates qualities such as 'big lumps', 'not mouldable', 'not smooth', 'not stretchable', 'light grey', 'light brown', 'brown', and 'off white' that were used to describe the *D. alata* species which includes TDa160403 (ACB) and TDa1723003(CAB) though TDa Oweigbo (ABC) was described as 'white', 'slightly mouldable' and 'small lumps'.

The mean product overall liking scored by consumers was related to the high quality characteristics such as 'yellow', 'slightly stretchable', and 'mouldable' on the right part of the PCA biplot box, which were associated to the liked TDr genotype pounded samples which though are on the same axis, are in different quadrants. TDr genotypes Meccakusa, and TDr1617811 (CBA) are closely related than TDr1680007AB (DEF) and TDr1544004 (BAC). TDa1723003(CAB) and TDa160403 (ACB) were found in the same quadrant closely as opposed to TDa Oweigbo on a distant separate quadrant.

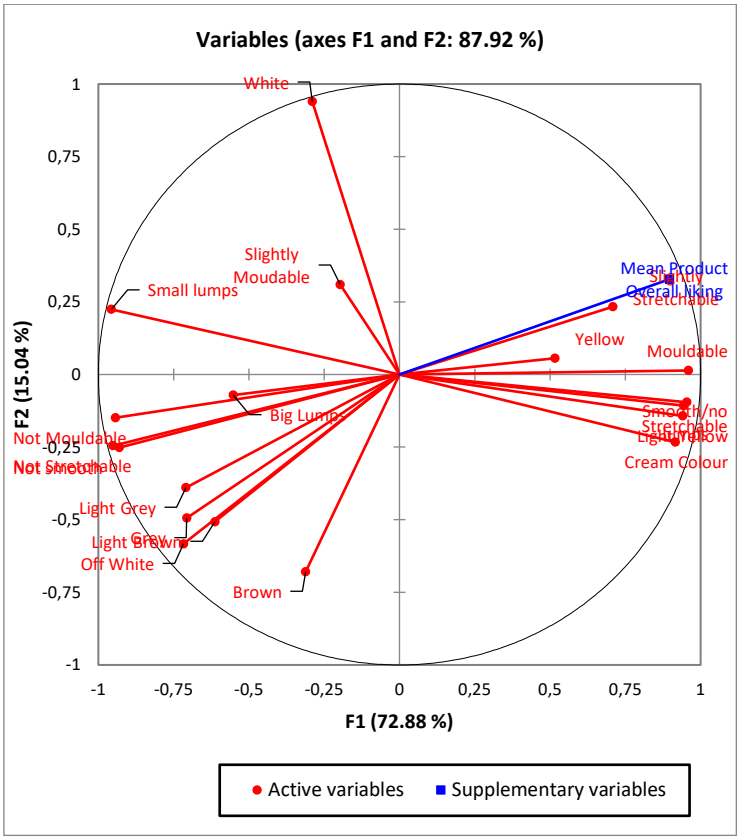
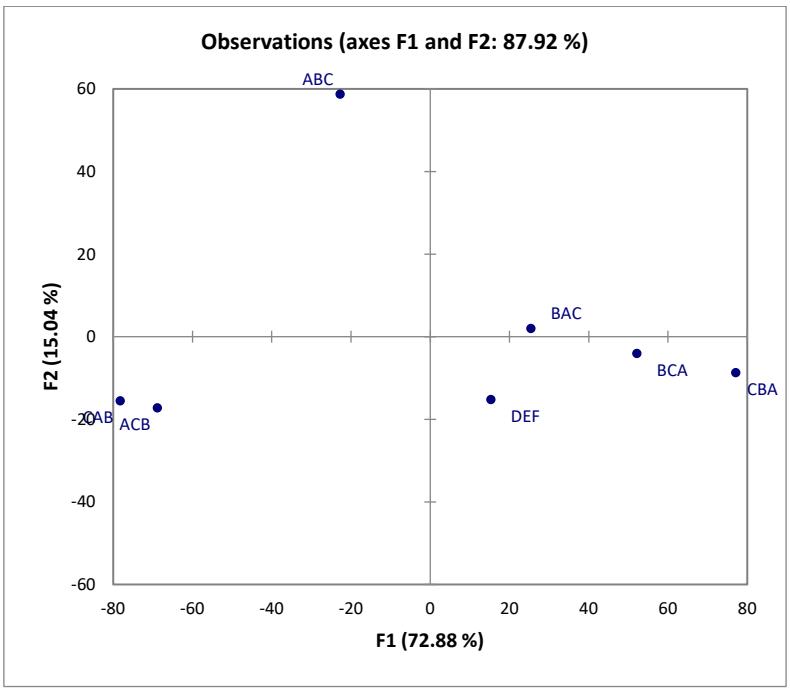


Figure 9a : Quality characteristics on PCA biplot box for perception of pounded yam samples.



Key: ABC-TDa Oweigbo, ACB-TDa160403, BCA-TDr Meccakusa, BAC-TDr1544004, CAB-TDa1723003, CBA-TDr1617811, DEF-TDr1680007AB

Figure 9b : PCA plot for of the pounded yam samples prepared from the yam genotypes.

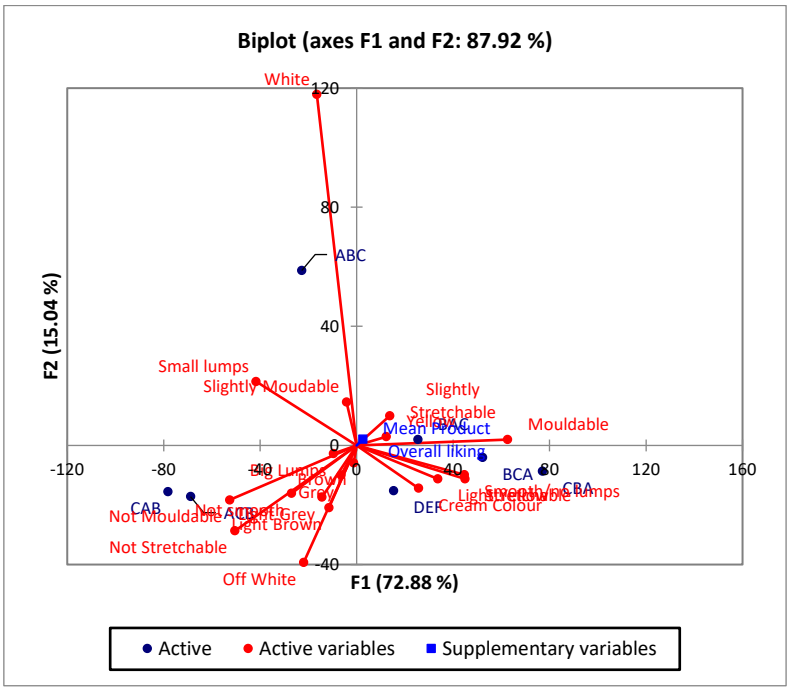


Figure 9c : Mapping of the quality characteristics and the overall liking of the product samples by consumers.

7 DISCUSSION AND CONCLUSION

The pounded yam samples prepared from the 7 yam genotypes from both *D. rotundata* and *D. alata,* used in this study were assessed by 120 consumers with varying perception. The pounded yam samples were prepared from the 7 yam genotypes with different textural quality characteristics. **TDr1617811 and TDr Meccakusa** were the highly preferred yam variety that gave pounded yam with good textural quality preferred by the consumers. Though both are *D. rotundata*, TDa Oweigbo a *D. alata* genotype compared favorably with these *D,rotundata* varieties. TDa160403 was least preferred yam variety based on the perception of consumers who rated it low due to its poor pounded yam quality with the lowest mean overall liking score of 4.12 by the consumers, mainly because it was found 'not stretchable', 'not mouldable', etc. in textural quality and perceived 'too dark' and rated 'off white' by the consumers.
The terms that better described good quality pounded yam preferred by the consumers were stretchable, smooth, mouldable, and white/yellow depending on the yam flesh colour. These were used to describe pounded yam samples from TDr Meccakusa, TDr1617811 and TDr1544004.

Conclusively, the high quality characteristics related to a high mean product overall liking by the consumers and associated to the most liked Pounded yam samples with good varieties were 'smooth', 'mouldable', 'stretchable', as shown on the right part of the PCA plan. Conversely, the low quality characteristics related to a low mean overall liking by the consumers as on the opposite left part of the PCA plan, and associated to the least liked Pounded yam sample with low quality varieties are 'grey'/'too dark', 'not stretchable', 'big/small lumps'.

8 THRESHOLD ANALYSIS

Procedure: Based on the result of consumer acceptability The thresholds of sensory attributes were computed by linking the intensity of sensory attributes to their "satisfied" level of JAR. The percentage of consumers who judged pounded yam to be JAR (corresponding to 2 on the JAR scale) was linked to the intensity scored in QDA, and the relationship was fitted with a linear/quadratic function. The score of attributes at which the percentage of consumers who judged the pounded yam to be JAR was above 70% or 50% or 60% was assessed to stand for optimal and acceptable levels, respectively. Multiple linear regression was also applied to predict overall liking by the overall liking of each sensory attributes and considering a better two-variable model. All analyses were performed using XLSTAT (version 2016.02.28451, Addinsoft, Paris, France).
Results: All textural sensory attributes revealed a quadratic relationship between sensory score from QDA and percentage of JAR level while, a linear correlation was observed for colour. The thresholds of sensory attributes of pounded yam were evaluated considering 50 (acceptable) and 70% (optimal) JAR levels. For the four attributes, R^2 values ranged between 0.54 and 0.88. Based on scale (0-10) used in sensory analysis the optimal texture of pounded yam was scored above 9.1 and equal 4.9 for mouldability and stretchability.
In terms of the stretchability of the 7 yam genotypes the response on stretchability of pounded yam (from the consumer report on JAR stretchability) showed that the proportion of consumers that scored the 7 genotypes as having JAR stretchability varied between 10.1 % to 64.2 %. The least proportion scored JAR was for genotype TDa 160403 (ACB), and the highest proportion scored JAR was for genotype TDr 1617811 (CBA). The genotypes TDr 1617811 (CBA), TDr MECCAKUSA (BCA) and TDr 1544004 (BAC) surpass the 50 % satisfied consumers threshold to accept the pounded yam stretchability. Threshold for stretchability score at 50% of consumers scoring was between 2.3 -7.5 (fig 10a), while at 60% of consumers scoring as JAR stretchability was between 3.0 - 6.7 (fig 10b). QDA scores outside the threshold are deemed unacceptable. The optimum QDA score for stretchability for pounded yam is about 5.0. for 70% of satisfied consumers
In terms of colour the proportion of consumers that scored the 7 genotypes as having JAR color varied between 25 % to 70.1%. The least proportion scored JAR was for genotype TDa 160403 (ACB), and the highest proportion scored JAR was for genotype TDr MECCAKUSA (BCA). The genotypes TDr 1617811 (CBA), TDr MECCAKUSA (BCA) and TDa OWEIGBO (ABC) exceeded the 50 % satisfied consumers threshold to accept the pounded yam colour.

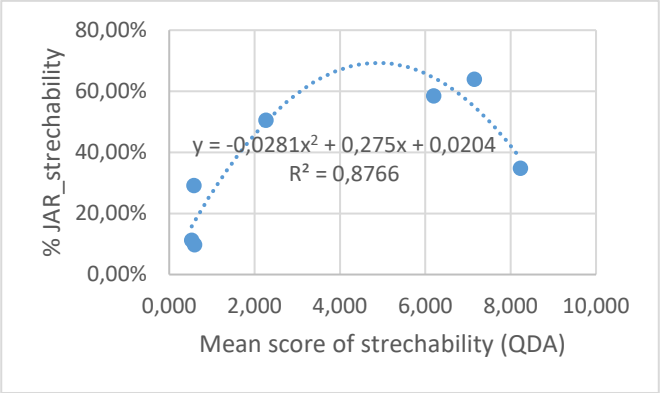
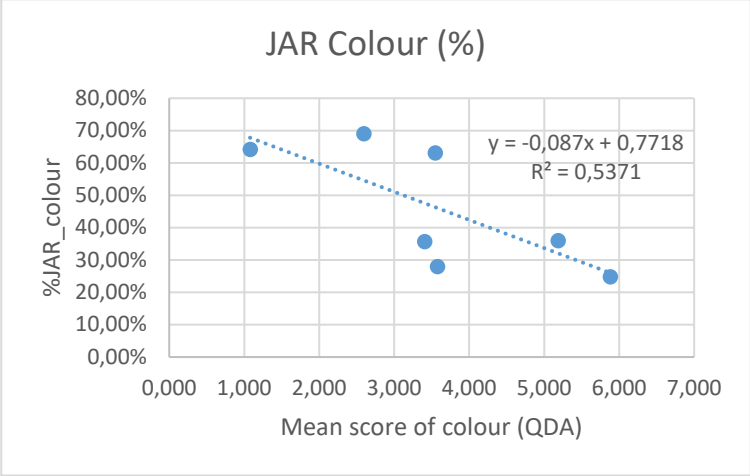


Figure 10a: Threshold of acceptability for stretchability of Pounded yam acceptability for stretchability of Pounded yam at 50%.

The Threshold for Colour score at both 50% (fig 10c) and 60% (fig 10d) of consumers scoring as JAR was 3.1 and 2.0 respectively. Colour scores higher than 2.0 (60%) and 3.1 (50%) was considered too dark and unacceptable for most consumers.



(c)

Figure 10c : Threshold of acceptability for colour of Pounded yam

For smoothness, the proportion of consumers that scored the 7 genotypes as JAR smoothness was between 20.8 % to 50.8 %. The least score for JAR was for genotype TDa 160403 (ACB), and the highest proportion scored JAR was for TDr MECCAKUSA (BCA). TDr MECCAKUSA (BCA) is the only one which exceeded the 50 % satisfied consumers threshold to accept the pounded yam smoothness. Threshold for Smoothness score (at 50% of consumers scoring as JAR smoothness) is 9.2. Smoothness score below 9 is considered unacceptable. The maximum threshold of acceptability for smoothness of pounded yam at 50% level of acceptability at JAR is 9.2 (figure 10 e). **For this graph (10e) we agree that this is not the correct graph, but the anomaly might have been from bad scores from consumers who scored; probably they did not understand the scoring system for this particular trait. We have noted this, and this will be improved on and corrected in the next phase of RTB Breeding project**

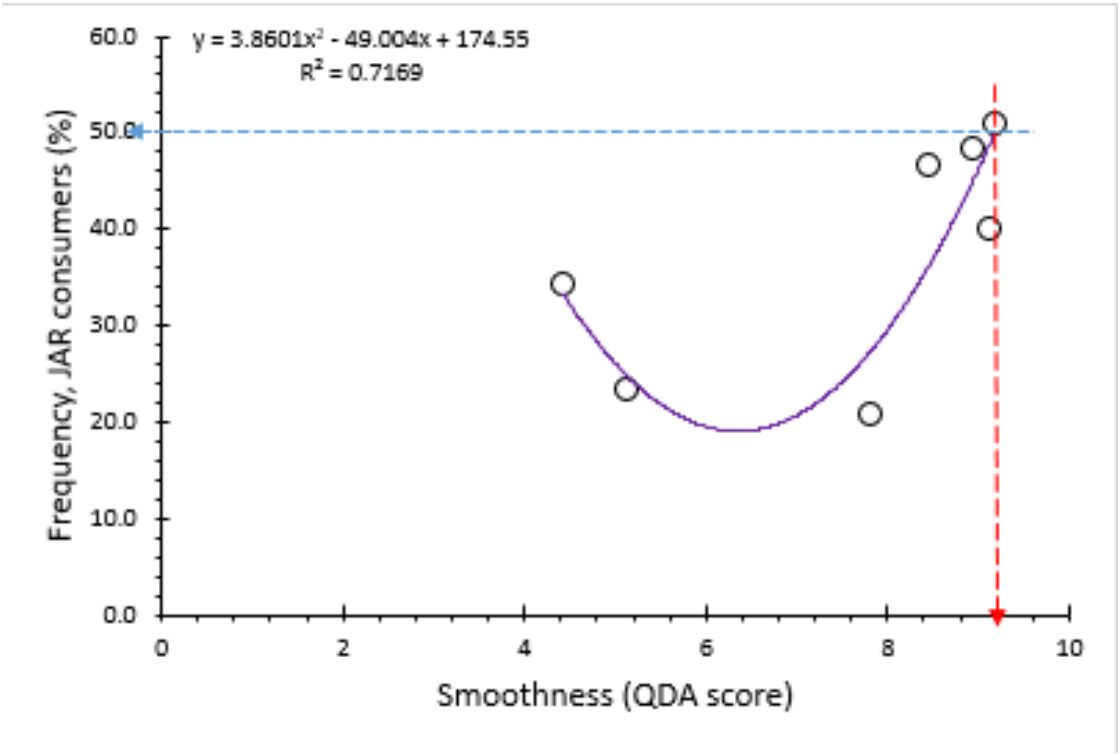


Figure 10e : Threshold of acceptability for smoothness of Pounded yam.

In terms of mouldability of the pounded yam samples shows the proportion of consumers that scored the 7 genotypes as JAR mouldability was between 12.7 % to 50.43 % (Table 11d). The least proportion scored JAR was for genotype TDa 1723003 (CAB), and the highest proportion scored JAR was for genotype TDr MECCAKUSA (BCA). There were no genotypes which exceeded the 50 % satisfied consumers threshold to accept the pounded yam mouldability.

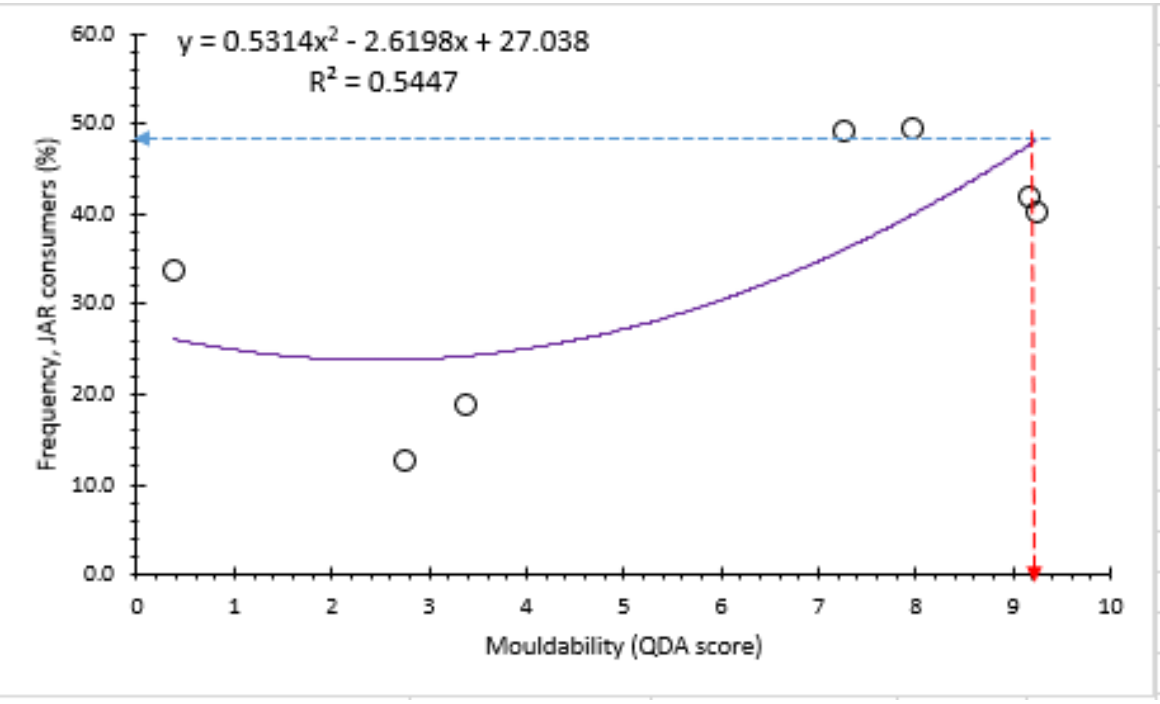


Figure 10f : Threshold of acceptability for mouldability of pounded yam.

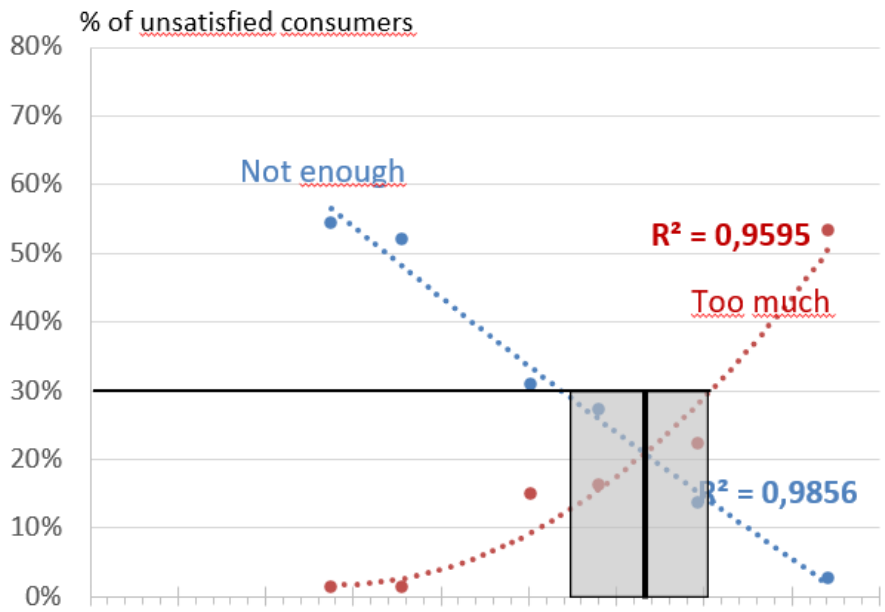
Threshold for Mouldability score (at 48% of consumers scoring as JAR mouldability) is 9.2. Mouldability scores below 9 are considered unacceptable. Table 13 summarises the threshold analysis. Multiple linear regression revealed that overall liking of the pounded yam samples was determined by the overall liking of colour and of mouldability (R^2 = 0.73; Overall liking = 0.5+0.3*overall liking color+0.5*overall liking mouldability).

Table 13 : Summary of threshold of acceptablity of pounded yam.

	Colour	Mouldability	Stretchability		Smoothness
	Mean	Mean	Min	Max	Mean
Optimal sensory score (70% JAR)	< 0.8	> 9.1	4.9		< 2.6 or = 10
Acceptable sensory score (50%)	< 3.1	> 6.7	2.3	4.9	< 3.45 or >
			4.9	7.5	9.2

The observed variances in this report will be improved upon in the next phase of the project.

The method below suggested by Zoé DEUSCHER is noted and will be explored in the next phase where we will improve on this work and use this alternative method



9 REPORT ON YAM GENOTYPES WITH SUPERIOR QUALITY TRAITS

Promising genotypes from *D. rotundata* :TDr1617811, TDr 1544004, these ones compared favourably well with Meccakusa that was used as check in terms of all the sensory attributes: colour, stretchability, mouldability and smoothness. In terms of extensibility which is one of the key quality parameters in pounded yam TDa150611446, TDa1729002 and TDa1401829) are considered to have intermediate extensibility similar to intermediate *D. rotundata* genotypes (such as TDr1621016). In same vein, some *D. rotundata* genotypes had poor extensibility (such as TDr16892003 and TDr1612901) similar to the poor *D. alata* genotypes (such as TDa17223003 and TDa1748002).

Hence promising genotypes that can be recommended are:

D.rotundata: TDr1617811, TDr 1544004

D.alata: TDa150611446, TDa1729002 and TDa1401829

APPENDICES

Annex 1: Sensory evaluation form

Sensory profile evaluation FORM for Pounded yam

Sensory attributes of pounded yam.

Name: ..... Date: .....

Please examine these samples of pounded yam and assess them for their food quality attributes as indicated below. Please you can tick your response/ or put the scores

for the texture attribute / characteristic of the product as you have been trained to do.

			Sample code:										
TEXTURAL QUALITY													
Smoothness	Big lumps	0											
	Small lumps	5											
	No lumps	10											
Mouldability/Cohesiveness	Not mouldable	0											
	Slightly mouldable	5											
	Mouldable	10											
Strechability	Not stretchable	0											
	Slightly stretchable	5											
	Stretchable	10											
COLOUR													
	White	1											
	Off- white	2											
	Cream colour	3											
	Light yellow	4											
	Yellow	5											

Light grey	6
Grey	7
Light brown	8
Brown	9