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Instrumental procedures to assess the extensibility of pounded yam and relationship with sensory stretchability and consumer preferences

Running title : Instrumental measurement of stretchability of pounded yam

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Abstract

BACKGROUND: Stretchability is the most important sensory textural attribute considered by consumers of pounded yam. It is important both for the processor during pounding and for the consumer during consumption to measure this attribute while screening large populations of yam genotypes intended for advanced breeding and eventual adoption. Texture determined by sensory evaluation and consumer perception is time consuming and expensive. It can be instrumentally mimicked by texture analyser, thereby providing an efficient alternative screening tool.

RESULTS: Two instrumental methods (uniaxial extensibility and lubricated squeezing flow) were applied to assess the extensional properties of pounded yam. In order to evaluate the accuracy, repeatability and discrimination of the methods, six yam genotypes with contrasting extensional properties, previously evaluated by 13 panellists in terms of stretchability and moldability and by 99 participants randomly selected in terms of overall liking, were used. Both

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methods allowed the discrimination of different genotypes as a function of extensional properties. Principal components showed that the genotypes were grouped within separate components associated with specific sensory attributes and their related instrumental texture parameters. Moreover, significant correlations were found between uniaxial extensibility textural attributes, bi-extensional viscosity and consumer overall liking. However, the sensory attributes were not significantly correlated with instrumental data and consumer overall liking.

CONCLUSION: Bi-extensional viscosity and uniaxial extensibility attributes can be used to discriminate and screen yam genotypes for their strechtability characteristics.

Keyword: bi-extensional viscosity; uniaxial extensibility; consumer likeability; mid-throughput phenotyping; breeding efficiency

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INTRODUCTION

Pounded yam is a glutinous dough made by boiling or steaming and pounding tubers (from different *Dioscorea* species) into a consistent homogeneous food product. It is consumed mostly in West African countries[1]. The sensory texture attributes that are most considered by consumers of pounded yam are stretchability (the viscoelastic sensory perception of the pounded yam's ability to extend when deformed by tensile pull between the fingers before structural failure.), moldability (the sensory perception of the ability of the pounded yam to be rolled between the palms of the hands while retaining cohesion), stickiness, smoothness, and hardness in that order[2-4].

Technically, stretchability of foods is sometimes erroneously considered as *elasticity*[4]. However, from a rheological point of view, elasticity only refers to the solid character of a sample, and viscosity refers to its liquid character. Food products are therefore considered as viscoelastic materials that have both properties[5]. In addition, food products do not recover completely after deformation. Taking into account consumer information[6], instrumental measurement of stretchability in pounded yam could be more related to extensibility. Extension is involved in many food processes and it induces a deformation of the structural entities (molecules, aggregates, droplets, etc.).[7]

Stretchability of pounded yam is measured qualitatively by applying tensional pull of the pounded yam bolus between fingers of both hands[3]. Good association of sensory texture (qualitative) with instrumental texture (quantitative), evidenced by significant correlations between them, would be useful to develop more efficient screening protocols. Instrumental approaches to estimate sensory texture scores[8] of pounded yam would enable mid-throughput screening of large segregating populations for consumer preferred textural quality in the breeding pipeline. To the best of the authors' knowledge, main works dealing with instrumental texture evaluation of pounded yam have been performed using Texture Profile Analysis (TPA)[1,9], extrusion and tack tests[4], or back extrusion [9]. Relationship with sensory evaluation has only tentatively been performed with TPA[1] and extrusion[4]. TPA has been considered as a simple, repeatable, flexible and versatile procedure to characterize textural quality of pounded yam[1], but it has a few disadvantages. TPA and extrusion tests cannot measure extensibility of

food materials, but they measure other parameters like hardness, cohesiveness, adhesiveness, springiness and resilience instrumentally by simulating the biting action of the jaws[10].

Extensional texture attributes such as stretchability can be measured by an extensograph, or a texture analyser using a standard uniaxial extension deformation system such as a Kieffer dough and gluten extensibility (KDGE) rig with thin strands of samples kept lubricated on a Teflon mold at fixed temperature[11]. The three important parameters measured are peak force (N), extensibility (mm) and extension area (N·mm), which are related to the viscoelastic components of a dough. A KDGE system is expensive, and when unavailable, other extensional texture protocols can be developed to measure extensibility of doughs as a proxy to stretchability that is measured sensorily. Two of such tests are extensibility measured by uniaxial compression of the dough sheet, and biaxial extensional viscosity related to Hencky's bi-axial strain.

The theoretical basis of extensibility measured by uniaxial compression relies on the deformation of a sheet of fixed thickness by compression of a ball probe until sufficient force ruptures the sheet structure, and the material fails irrecoverably. The attributes measured are similar to that of a KDGE system. However, with a ball probe, a pastry/tortilla burst rig is used, rather than a KDGE rig. Uniaxial extension protocols offer the advantages that they are easy to perform, the deformations are homogeneous, and they produce accurate, repeatable results. Nonetheless, they require samples with high viscosity, expensive accessories, and operation under low deformation rate [12].

Biaxial extension by lubricated squeezing flow (LSF) is conducted by squeezing a sample between two parallel plates in lubricated conditions, where the upper plate is moving vertically downwards while the other is fixed and the sample contact area increases as the deformation length increases[5]. In practice, three squeezing geometries may be used: (a) the upper and lower disks have the same diameter as the un-squeezed sample, (b) the upper compression disk and the sample have the same diameter, but the lower plate is much larger and (c) both the upper and lower compression disks are much larger than the sample[13]. Bi-extensional viscosity (BEV) is derived based on calculation of force-displacement extension curves into stress-strain data and taking cognizance of geometry of the sample[14].

Several reports are made in literature on the use of LSF to measure BEV as a tool for quality of wheat dough[15], cassava dough[16], steamed bread dough[17], and mozzarella cheese[18]. To the

best of the authors' knowledge, no works have been reported on discrimination of yam genotypes based on extensional texture attributes and finding relationships between instrumental and sensory texture and consumer tests of pounded yam. Particularly, no work has reported the use of extensional textural properties such as extensibility and BEV to describe stretchability of pounded yam. Indeed, the extensibility protocol by uniaxial compression of thin pounded yam dough sheets is unavailable in the literature, since the KDGE protocol is the more popular method used to determine extensibility of dough foods.

The work therefore aimed at: a) developing alternative medium-throughput protocols that can be used to describe the sensory stretchability of pounded yam by using instrumental textural techniques that measure the extensional properties of pounded yam; b) assessing the accuracy, repeatability and discriminating power of the new protocols; and c) determining the relationship between the instrumental extensional texture and sensory texture attributes and consumer overall liking.

MATERIALS AND METHODS

Plant material

Mature tubers from six contrasting landrace yam varieties (*Aga*, *Dodo*, *Irindou*, *Kratchi, Laboko* and *Wete*) were collected from farmers' fields in district of Dassa (7°45'N, 2°10'E) located in central part of Benin (West Africa). Among these landraces, only *Aga* belongs to *D. alata* species while the others are *D. rotundata*. Amylose[19] and total starch content[20] of all samples were determined, the values varied from 16.6 to 31.9 g amylose/g starch and from 70.3 to 81.5 g starch/100 g dry solid, respectively.

Pounded yam preparation for instrumental and sensory textural analysis

Pounded yam was prepared using Standard Operating Procedure (SOP)[6]. Samples were peeled, washed and cut into pieces before being boiled in water for about 23 min and then pounded using a trademarked yam pounding machine (QZP/6000 model, Cheerfengly Ind. Co. Ltd, Taipei, Taiwan).

Instrumental textural determination of uniaxial extensibility

Extensibility of pounded yam samples was measured using the SOP[21], after preparing the pounded yam by the standard method[6]. Briefly, 43-50 g of pounded yam was rolled into dough balls and allowed to relax stress and equilibrate temperature in an incubator (WTC binder,

Tuttlingen, Germany) at 55 ºC for about 12 min. The dough balls were rolled into 1.5 mm thick sheets using a pasta roller (Model 150 mm Deluxe, Italy).

The texture analyser (TA.XTplus, Stable microsystems) settings used were: compression mode, spherical probe P/1SP, HDP/TPB pastry/tortilla rig, load module of 5 kg, pre-test speed of 5 mm/s, test speed of 1 mm/s, post-test speed off 10 mm/s, trigger force 0.0493N (5 g), target mode: distance, distance: 40 mm. Two different batches of cooking per genotype were considered. Three to eight measurements per cooking replicate were collected depending on the difficulty of handling the material. The extensibility of the pounded yam made from tubers having very poor sheet-forming ability may be difficult to measure using this protocol. For instance, the variety *Aga* was not amenable to this protocol as it was too brittle to form a sheet, while the variety *Irindou* was slightly difficult but manageable to roll into a sheet. Measurements were made at 30 ºC. The parameters measured are hardness (N), extensibility (mm) and area between t_o and F_{max} (extensional area, N·mm).

Instrumental textural determination of bi-extensional viscosity (BEV)

BEV of pounded yam made from all the six genotypes was determined by a LSF protocol[22] with some modifications. Briefly, after the pounded yam was prepared by the standard method[6], the dough was flattened and a cylindrical mold (14 mm height, 20 mm diameter) was used to cut out the dough into a fixed geometry. The mold was fully lubricated *a priori* with paraffin oil (CAS Number 8012-95-1) to avoid the sticking of dough to the probe, facilitate demolding afterwards, and ensure that friction was minimized insomuch that only extensional deformation is registered during measurements[13]. The molded dough was wrapped with plastic film to reduce dehydration, and placed in the incubator at 55 °C for about 10 - 15 min. Then, it was gently demolded and lubricated with paraffin oil.

The texture analyser settings used were: compression test mode, test probe: P/20P cylindrical, load module: 5 kg, pre-test speed: 60 mm/min, test speeds: 6, 12 & 120 mm/min, post-test speed: 600 mm/min, trigger force: 0.25 N (25 g), target mode: distance, distance: 13 mm. Two different batches of cooking per genotype and at least 4 measurements per cooking was collected at each test speed. Measurements were made at 30 ºC. The force (N), distance (mm) and time (min) were captured. This protocol in particular is not limited to good sheet-forming ability of pounded yam and could therefore be used for all studied genotypes.

Sensory evaluation and consumer overall liking

Yam tubers were peeled and after cutting off the proximal and distal portions, the remaining part of the tuber was sliced and cut to a thickness of 20 mm by 20 mm. Diced yam (450g) was cooked during approximately 20 min with 250 ml of water. Thereafter, the pounding was performed with yam pounder for 4 min, with intermittent stops after the first 2 min and then 1 min later, to bring together the scattered yam pieces (using a plastic spoon) for homogenous pounding. The temperature of pounded yam immediately after pounding was around 68°C. In order to maintain a warm temperature for the pounded yam samples prior to evaluation, batches of pounded yam were made and stored in an insulated container, which was kept at a temperature of 45°C by putting it in box connected to electricity to keep sample temperature constant. A 3-digit codes was assigned to each sample (10-15 g) which was presented monadically to panellists and consumers for sensory evaluation and consumer testing respectively.

A quantitative descriptive analysis (QDA) was conducted with 13 trained panellists who scored pounded yam for stretchability and moldability by using a 0 – 10 cm semi-structured scale. The panel evaluated 18 samples of pounded yam from six yam varieties int three sessions/replicates per sample according to Otegbayo et al.[6]. The overall liking of pounded yam samples was evaluated according to Honfozo et al.[23] by using a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) in two rural Benin districts, namely Dassa (7°45'N, 2°10'E) and Glazoué (7°58'N, 2°18'E). Participants (n = 99) were randomly selected and aged from 18 to 70 years old, with 48.5% males and 51.5% females.

Statistical analysis

Statistical analysis was conducted using JMP Pro 15 statistical software (SAS Institute Inc., NC, USA) and XLSTAT to determine statistical accuracy, repeatability, analysis of variance (ANOVA), Pearson correlations, hierarchical classification and external preference mapping. Good accuracy was determined as low values of coefficient of variation and standard error of the mean. The measurements were considered repeatable when a standard difference t-test gave a non-significant P value ($P \geq 0.05$). Tukey's test was used for multiple comparison to find means that were significantly different from each other ($P \leq 0.05$). If significant value was lower it was indicated accordingly. Pearson correlation were considered significant when $p \leq 0.10$, if lower, it was indicated *, **, *** significant at $P \leq 0.1$, 0.05 and 0.001, respectively. External preference mapping considered the hierarchical classification of consumers based on overall liking score and PCA from sensory and instrumental data.

Ethical clause

Sensory evaluation and consumer overall liking were assessed and approved by the *Comité National d'Ethique pour la Recherche en Santé* of Benin under the approval number 16 of May 06th 2020 and the CIRAD Ethics Committee (H2020 ethics self-assessment procedure). Samples were prepared according to good hygiene and manufacturing practices. Participants were informed *a priori* 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 panellists and from consumers.

RESULTS

Instrumental textural attributes

Three different parameters (hardness, extensibility and extension area) were measured after performing the aforementioned uniaxial extensibility method (Table 1). The coefficient of variation of the mean (CV_{mean}) varied from 5-14 % for hardness, 4-19 % for extensibility and 8-23 % for the extensional area. The highest values for the three parameters were observed in *Laboko* and *Kratchi*, while the lowest were observed in *Dodo* except for extensibility where *Irindou* showed the lowest value (2.4 mm).

Preliminary assays for the LSF method were carried out on four genotypes in order to determine the best compression speed for determination of BEV. A biaxial strain of 1 (dimensionless) was selected based on the low standard deviation and steady state achieved by the applied stress (data not shown). Raw data obtained at compression speeds of 6 mm/min, 12 mm/min and 120 mm/min, and analysed at a biaxial strain of 1, lead to BEVs at a strain rate (speed of deformation of the dough) of 0.026, 0.053 and 0.532 s^{-1} respectively (Fig. 1). BEV decreased with the increase of strain rate, a typical shear-thinning behaviour observed for pastry doughs[22]. Descriptive statistics and ANOVA analysis are shown in Table 2. CV_{mean} varied from 4 to 17% for 0.026 s^{-1}, and from 7 to 33% for 0.053 s^{-1}. BEV values of the 6 genotypes obtained at a biaxial strain of 1 and strain rate of 0.532 s^{-1} ranged from $0.53 \cdot 10^5$ to $2.53 \cdot 10^5$ Pa·s, with CV_{mean} from 2 to 20% (Table 2).

Sensory analysis and consumer overall liking of pounded yam

Results of sensory evaluation and consumer overall liking of pounded yam are presented in Table 3. In terms of stretchability, *Kratchi, Laboko* and *Dodo* were considered as the preferred

ones and *Aga* was considered the least preferred one. For moldability, *Dodo* and *Aga* were most preferred by the panellists, while *Irindou* was the least preferred.

Ninety-nine randomly selected participants evaluated the overall liking of different genotypes of pounded yam, Table 3. Results showed that *Laboko* was *liked very much* (8 on the 9-point hedonic scale), *Kratchi* and *Wete liked moderately*, *Irindou* and *Dodo liked slightly* and *Aga disliked slightly*.

Hierarchical cluster analysis (Ward's method) indicated that based on overall liking score, the consumers can be clustered into three groups. The largest consumer cluster 3 gathered 42.4% of consumers followed by cluster 2 (30.3%) and cluster 1 (27.3%) (Fig. 2a). The consumers of clusters 2 and 3 prefer in descending order, the pounded yam from Laboko, Kratchi, Wété, Irindou and Dodo (result not shown) but with the difference in overall liking score. For consumers of cluster 1, the order was Laboko, Kratchi, Dodo, Wété and Irindou,. The consumers of clusters 3 and 2 preferred no mouldable with a not too high bi-extensional viscosity and hardness pounded yam samples (Fig. 2 a and b). Regarding consumers of cluster 1, it liked a not too high stretchable and extensible pounded yam. Most of the consumers (80-100%) were satisfied by the textural properties of Laboko and Kratchi, while Dodo was judged acceptable by 20 to 40% of the consumers (Fig. 2 a and c). On the other hand, few consumers (0-20%) were satisfied with the textural properties of Irindou and Wete samples. All uniaxial extensibility texture attributes and bi-extensional viscosity appeared closely related on the first axis and the sensory attributes were plotted on a different component (Fig. 2b).

The varieties were classified into three hierarchies to represent *good*, *intermediate* and *poor* genotypes for making pounded yam (Figures 3a and 3b).

DISCUSSION

Instrumental textural attributes

Significant differences among genotypes were found for the three variables obtained after performing the uniaxial extensibility method. Tukey's test showed that for hardness and extensional area three different groups were obtained whilst for extensibility every genotype was significantly different from the others. The main limitation of this method was the impossibility to form a sheet that could be measured for samples that break easily (*e.g. Aga*).

Regarding LSF results, 0.053 s^{-1} was the worst strain rate in order to analyse BEV in the case of pounded yam if we consider that it has the largest CV_{mean}. However, highly significant differences between genotypes were detected in all strain rates. The strain rate with the highest discriminating capacity (lower associated P-value) was 0.532 s^{-1}. Tukey's test showed that, independent of the strain rate, *Laboko* was always significantly different (higher BEV value) compared to the other genotypes (Table 2). Based on these statistical results, a compression speed of 120 mm/min and a biaxial strain of 1 (which led to a strain rate of 0.532 s^{-1}) were selected as the best conditions in order to evaluate the BEV of pounded yam. Moreover, this method has two main advantages: first, its rapidity (one measurement is done in less than 1 minute); and second, the ease of sample preparation (*i.e. Aga* was analysed without any problem whereas it could not be evaluated with the uniaxial extensibility method due to the inability of this genotype to form a sheet of 1.5 mm thickness). In the case of analysis of six genotypes, four significantly different groups were obtained: *Laboko* (a) had the highest BEV followed by *Kratchi* (b), *Irindou*, *Wete* and *Aga* (c), while *Dodo* (d) had the lowest BEV.

The comparison of results obtained by either uniaxial extensibility or LSF method lead to the conclusion that both methods are in agreement in terms of classification of genotypes with best extensional properties. As observed in Tables 1 and 2, both methods classified *Laboko* and *Kratchi* as the preferred genotypes, and *Irindou* and *Dodo* as the less preferred ones (note here that no comparison between the methods could be carried out for *Aga*). Akissoe et al.,[4] already reported different textural instrumental quality of pounded yam from different genotypes.

Sensory analysis and consumer overall liking of pounded yam

Sensory and overall liking results show that the six selected studied genotypes can be considered as contrasting genotypes in terms of stretchability, moldability and overall liking. These results were considered a good dataset to evaluate if instrumental textural methods can be used to predict sensory properties and consumer preferences.

Relation between instrumental textural properties, sensory properties and consumer preferences

Table 4 shows the correlations between instrumental uniaxial extensibility attributes (extensional area, hardness and extensibility), sensory attributes and consumers' overall liking. Note here that these results were obtained without taking into account the *Aga* genotype due to the impossibility of this dough to form a sheet for measurement with the uniaxial extensibility

method. The three extensibility attributes measured using the uniaxial extensibility method were significantly correlated between themselves ($p \leq 0.02$) indicating that all the attributes are representative of dough properties. They were also significantly related to overall liking, with hardness being the one with the highest correlation ($p \leq 0.001$). Moreover, extensional area and hardness were also significantly related to BEV ($p \leq 0.022$ and $p \leq 0.037$, respectively, data not shown). This implies that consumers prefer pounded yam with appropriate hardness and extensional properties. Significant correlations have been found between TPA parameters, extensograph parameters, KDGE parameters and biaxial extension strain hardening index of steamed bread dough in the work of Yue et al.[17].

The correlations between BEV, sensory attributes (moldability and stretchability) and consumer overall liking are shown in Table 5. There was a significant ($p \leq 0.1$) correlation between BEV and overall liking. However, the relationships between BEV and sensory properties failed to reach statistical significance. A significant relationship was also observed between stretchability and overall liking, which confirmed that stretchability is a key sensory property for pounded yam evaluation.

Significant correlations were found between instrumental textural properties and consumer overall liking, but not with sensory attributes. On the other hand, sensory attributes were correlated with overall liking. This may be linked to the low number of contrasting yam genotypes in the current work and further analyses should be performed to further ascertain these relationships using a higher number of samples showing very contrasting textural properties.

Laboko was uniquely classified separate from other genotypes by both extensional protocols, since it is considered as a good genotype for pounded yam. *Kratchi* and *Wete* were clustered as intermediate genotypes, while *Dodo* and *Irindou* are clustered as the poor genotypes for pounded yam by the extensibility protocol. For the LSF protocol, *Aga* and *Dodo* were classified as genotypes of poor quality, while *Kratchi*, *Irindou* and *Wete* were clustered as the intermediate quality genotypes in making pounded yam, and *Laboko* as the best.

While LSF has been used to study deformation and flow behaviour of dough food products in several studies[15-17], the procedure has never been considered as a tool to discriminate root, tuber and banana (RTB) genotypes according to their finished food products' texture. Our

research provides a novel perspective into the use of texture in discrimination of RTB genotypes as a way to screen them and promote advanced clones for breeding for textural qualities preferred by consumers of RTB food products. In this context, it has been shown that BEV and uniaxial extensibility properties can be used to discriminate yam genotypes based on their pounded tuber texture. The methods presented for characterization of extensional properties by instrumental assays were significantly correlated with overall liking of consumers. This correlation is important because it indicates that breeders could utilize these instrumental assays for the selection of genotypes that are appreciated by consumers, thus increasing the impact of breeding programs.

This instrumental approach offers clear advantages over the time-consuming and expensive sensory assessments or consumer preference surveys. However, no significant correlations were found between instrumental textural attributes and sensory data of stretchability and moldability determined by QDA. Taking into account that stretchability has been significantly correlated with overall liking, it seems clear that more studies have to be carried out with a higher number of highly contrasting genotypes in order to have a larger dataset to confirm the suitability of these techniques for extensional properties characterisation. These studies would also contribute with further understanding of the relationship between instrumental and sensorial data.

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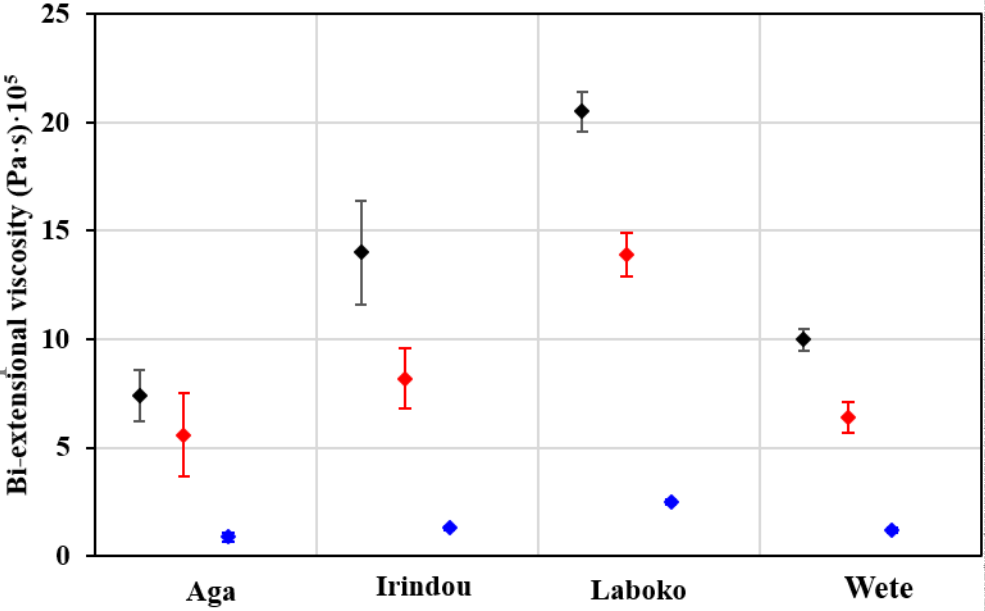
Figure Captions

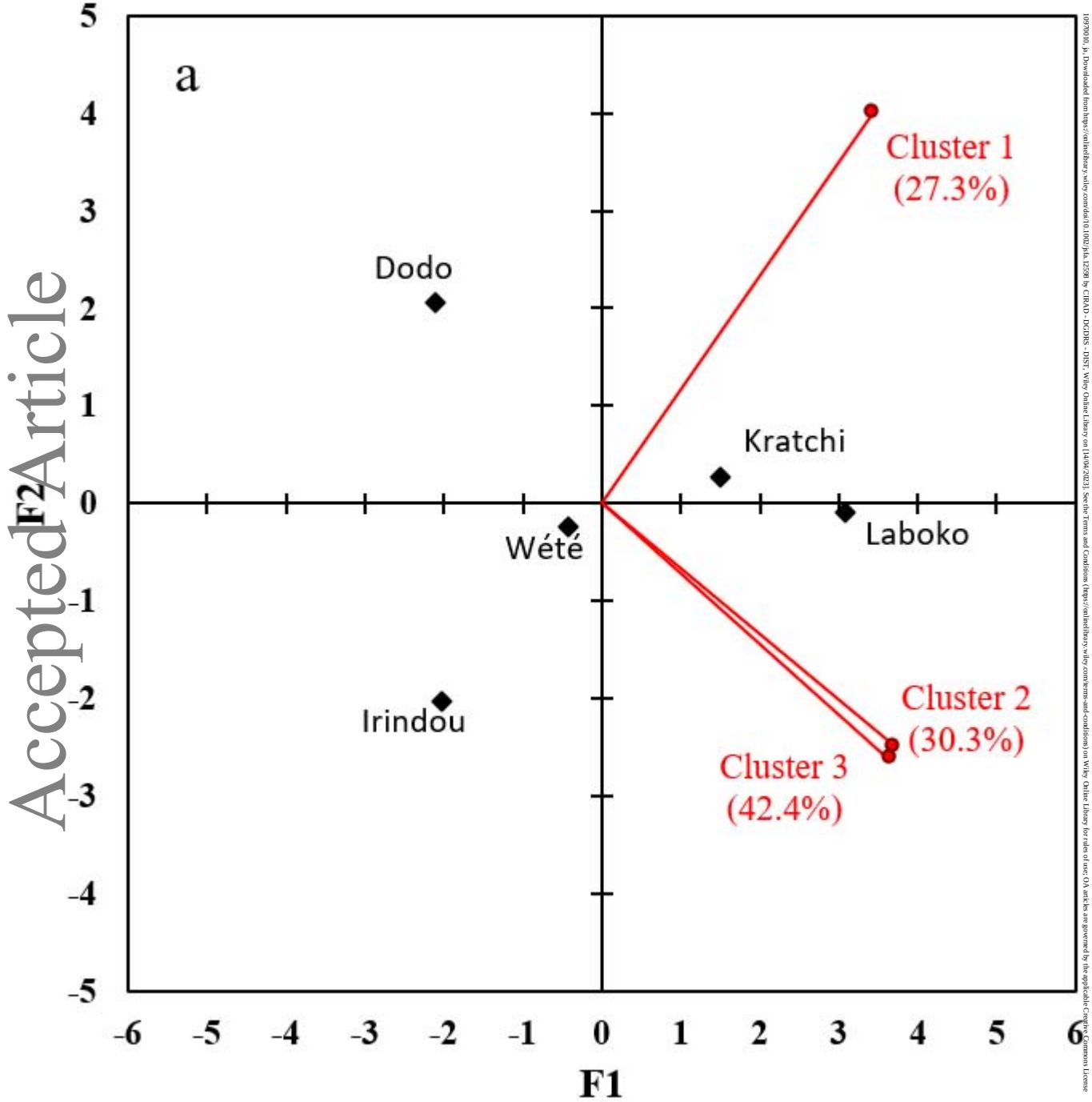
Figure 1. Bi-extensional viscosity at three different strain rates (♦ 0.026 s^{-1}, ♦ 0.053 s^{-1} and ♦ 0.532 s^{-1}) and biaxial strain of 1 for pounded yam.

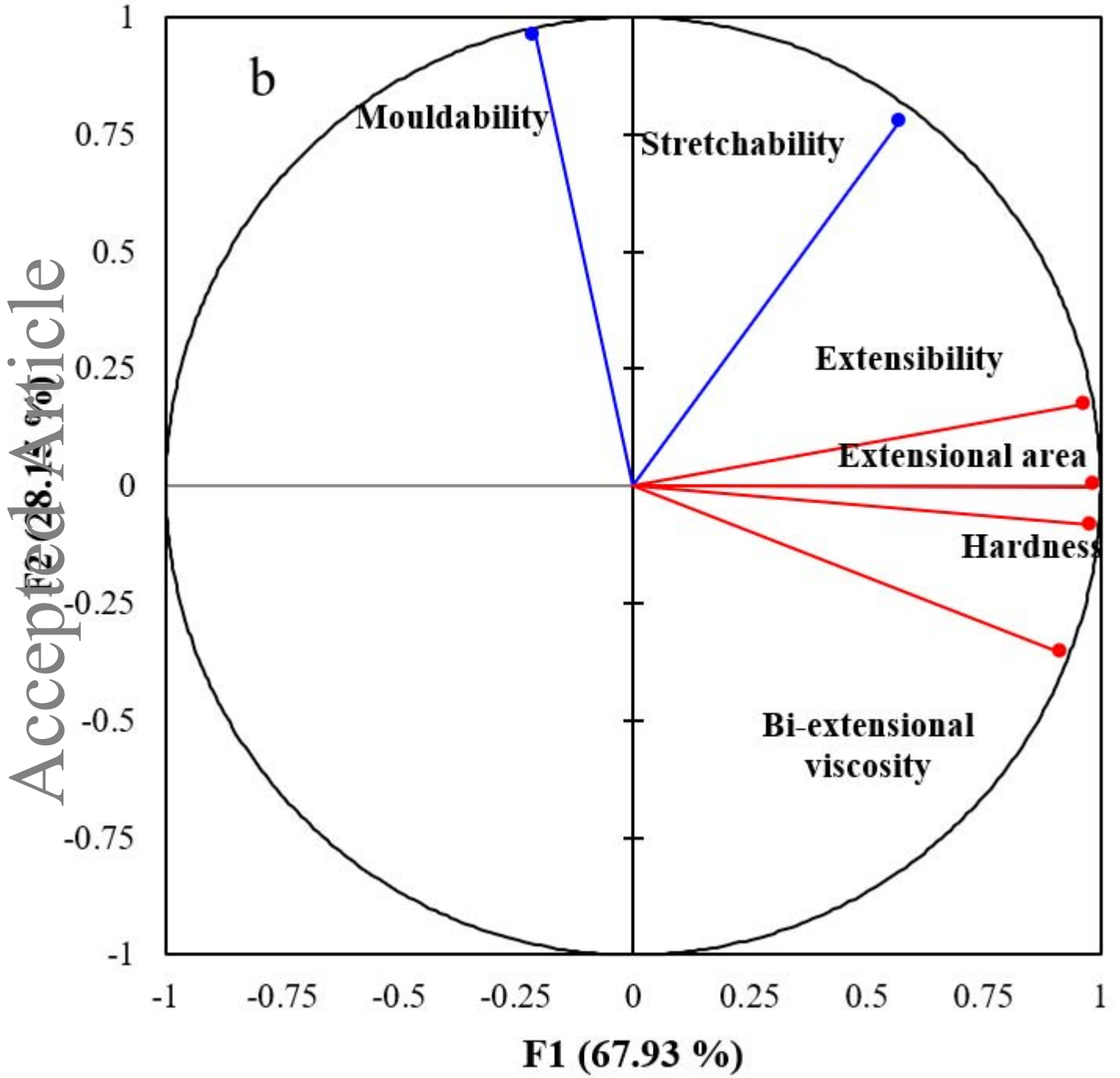
Figure 2. Preference (a), sensory texture attributes and instrumental texture parameters (b) maps and contour plot (c) of pounded yam

Figure 3a. Clustering of yam genotypes based on bi-extensional viscosity of pounded yam.

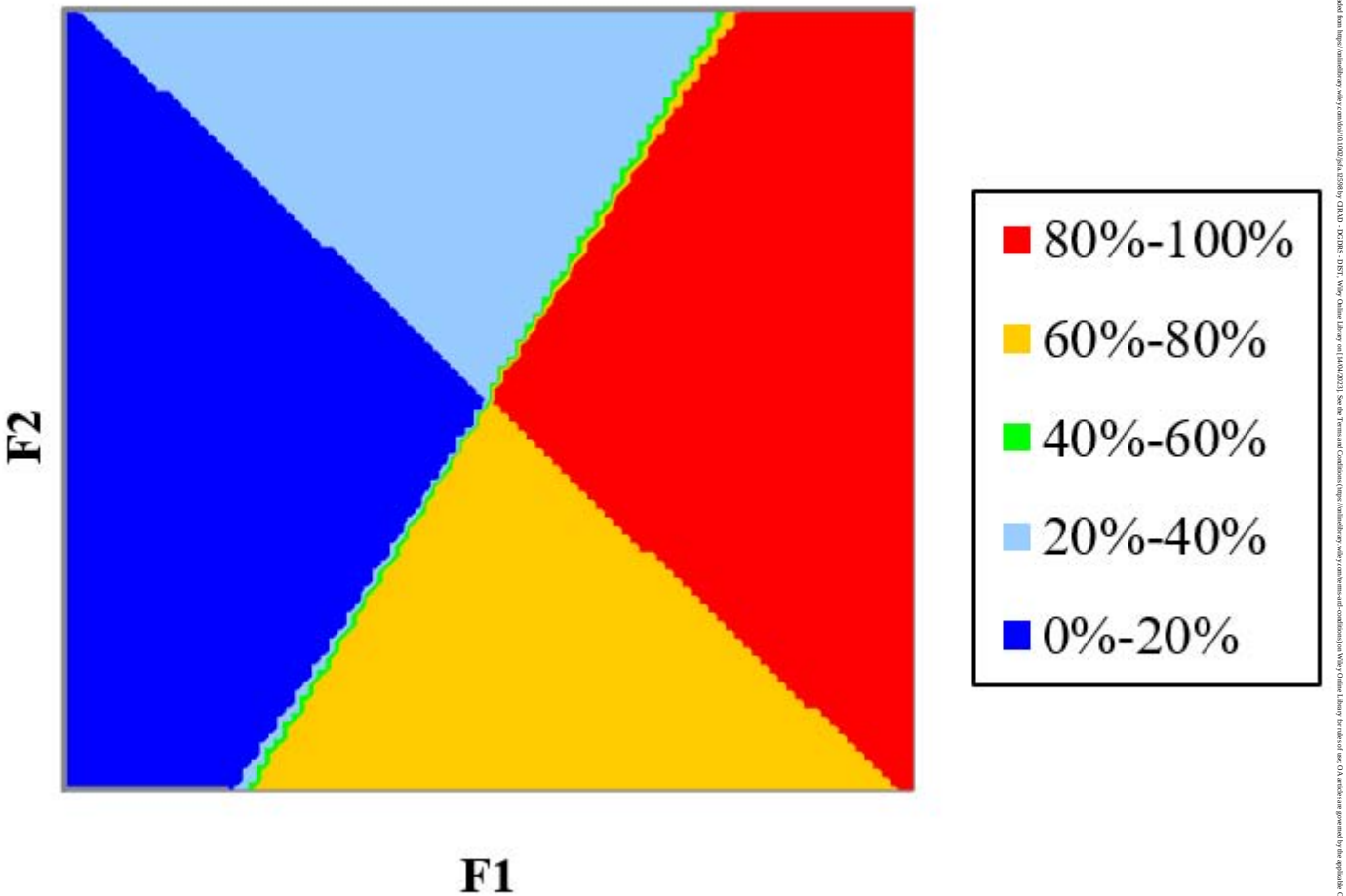
Figure 3b. Clustering of yam genotypes based on extensibility properties of pounded yam.

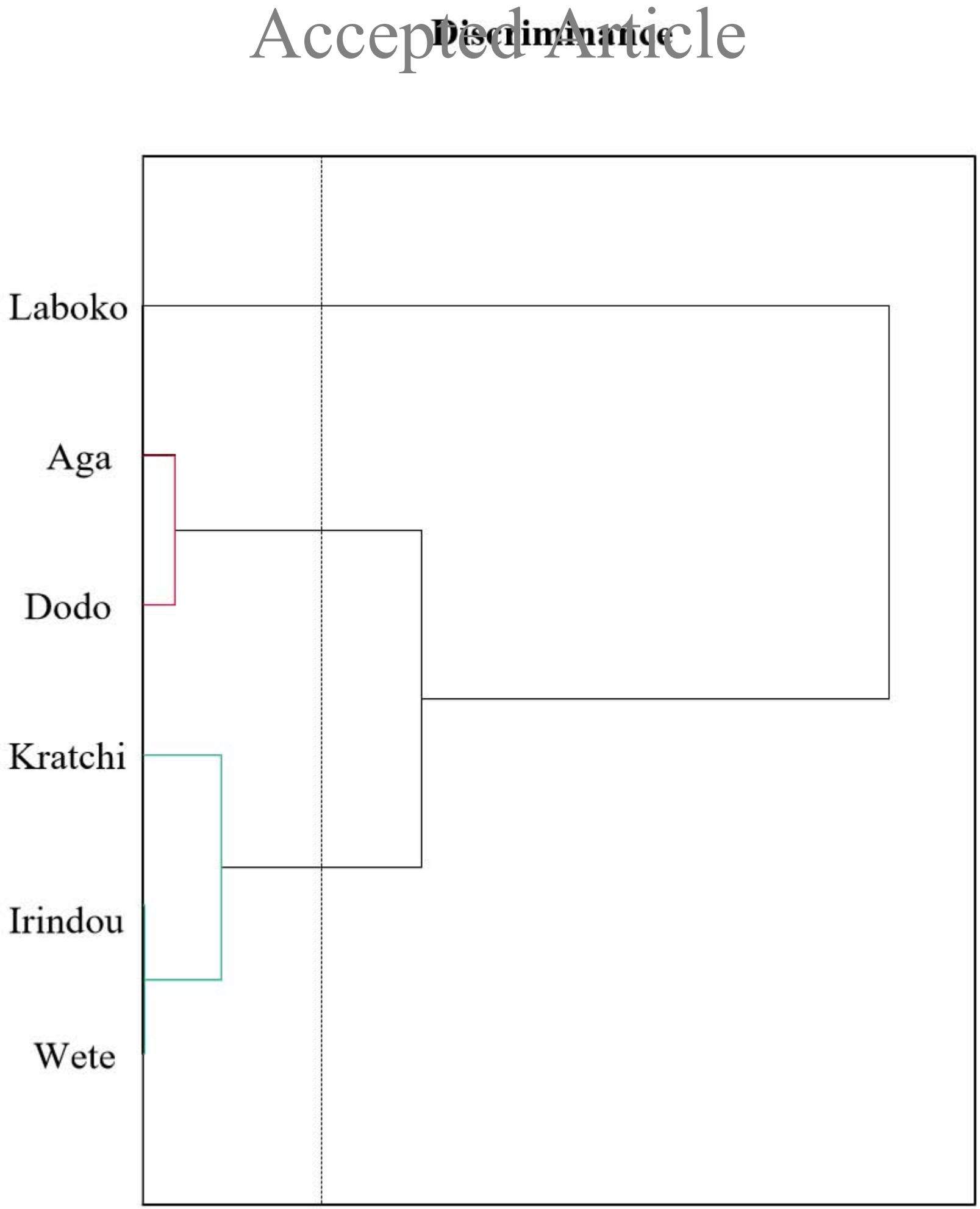






c





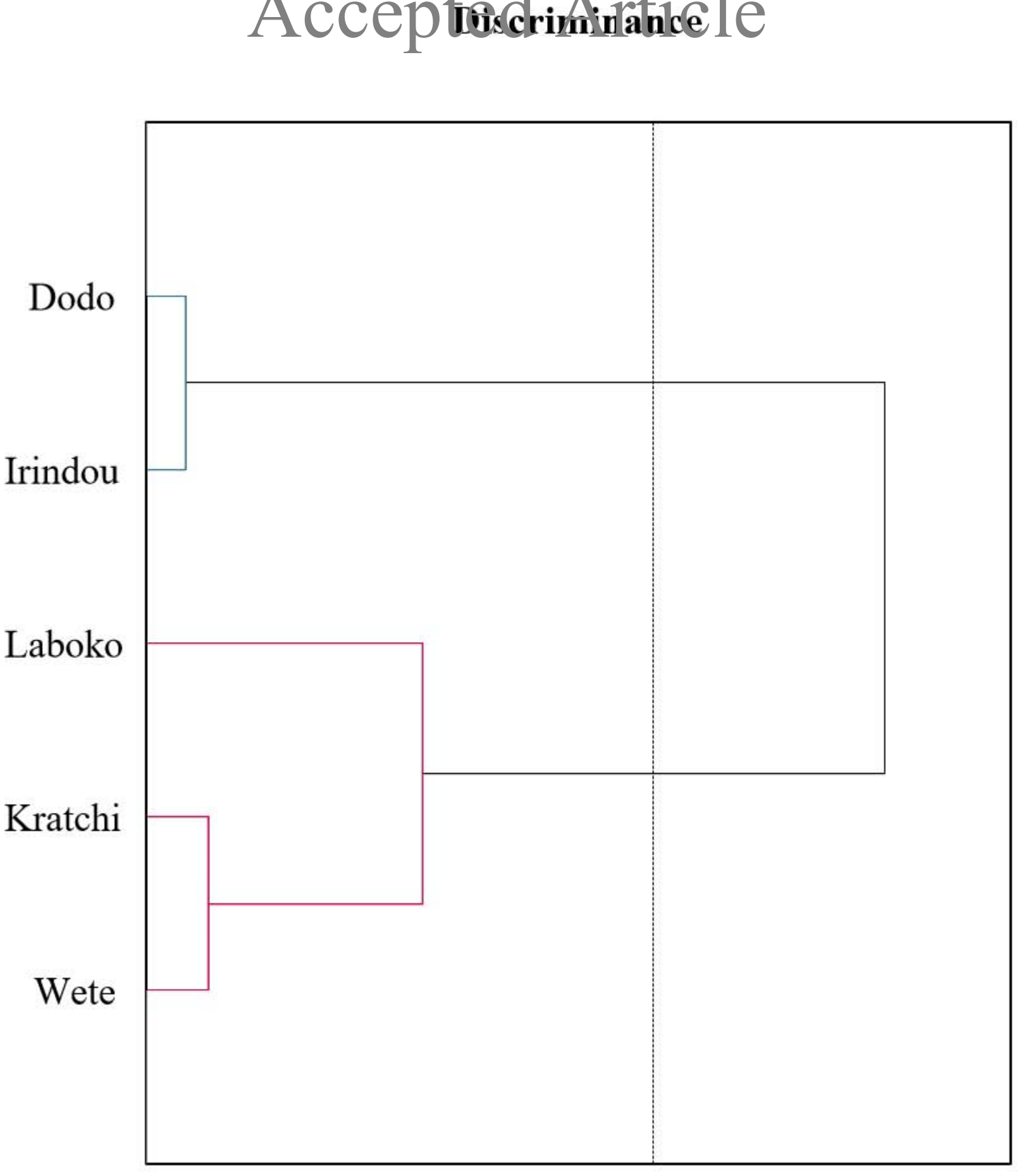


Table 1. Descriptive statistics and ANOVA for instrumental uniaxial extensibility texture parameters related to extensibility properties of pounded yam from six genotypes[£].

Genotypes	Hardness (N)			Extensibility (mm)			Extensional area (N.mm)		
	Mean	**SD_{mean}**	**CV_{mean} (%)**	**Mean**	**SD_{mean}**	**CV_{mean} (%)**	**Mean**	**SD_{mean}**	**CV_{mean} (%)**
Aga	nd	nd	nd	nd	nd	nd	nd	nd	nd
Dodo	0.24^{c}	0.02	6	5.6^{d}	0.3	5	0.88^{c}	0.07	8
Irindou	0.43^{c}	0.04	10	2.4^{e}	0.5	19	0.92^{c}	0.21	23
Kratchi	1.58^{a}	0.08	5	15.1^{b}	0.6	4	10.94^{b}	0.98	9
Laboko	1.84^{a}	0.25	14	18.0^{a}	0.8	4	20.18^{a}	2.86	14
Wete	1.07^{b}	0.06	5	11.1^{c}	0.4	4	5.61^{c}	0.43	8
F value	23.30***			96.67***			26.61***		

[£]Data are presented as mean, standard deviation of the mean and coefficient of variation of the mean. Values in a column with different superscript letters are significantly different at the $p \leq 0.05$ level. nd – not determinable

*** significant at P<0.001.

Table 2. Descriptive statistics and ANOVA for bi-extensional viscosity of pounded yam at different strain rates and biaxial strain of 1 using the lubricated squeezing flow method[£].

Strain Rate (s^{-1})	Genotypes	Bi-extensional viscosity (Pa·s)			F value
		Mean·10^{-5}	SD_{mean}·10^{-5}	CV_{mean} (%)	
0.026	*Aga*	7.42^{b}	1.21	16	13.04***
	Irindou	13.99^{b}	2.39	17	
	Laboko	20.46^{a}	0.86	4	
	Wete	9.96^{b}	0.46	5	
0.053	*Aga*	5.55^{b}	1.86	33	10.75***
	Irindou	8.17^{b}	1.37	17	
	Laboko	13.88^{a}	0.95	7	
	Wete	6.37^{b}	0.67	10	
0.532	*Aga*	0.90^{cd}	0.18	20	28.25***
	Irindou	1.30^{c}	0.15	12	
	Laboko	2.53^{a}	0.14	5	
	Wete	1.22^{c}	0.08	7	
	Dodo	0.53^{d}	0.02	3	
	Kratchi	1.76^{b}	0.44	2	

[£]Data are presented as mean, standard deviation of the mean and coefficient of variation of the mean. Values in a column with different superscript letters are significantly different at the $p \leq 0.05$ level.
*** significant at $P<0.001$.

Table 3. Descriptive statistics and ANOVA of sensory analysis and overall liking of pounded yam[£].

Genotypes	Stretchability	Mouldability	Overall Liking
Aga	3.3±1.1[a]	7.9±0.5[b]	4.1±0.2[a]
Dodo	7.6±0.2[b]	8.0±0.4[b]	6.0±0.2[b]
Irindou	4.4±0.7[a]	4.5±1.0[a]	6.2±0.2[b]
Kratchi	8.0±0.2[b]	5.7±0.8[a,b]	7.9±0.1[d]
Laboko	7.7±0.6[b]	5.8±0.7[a,b]	8.0±0.1[d]
Wete	5.7±0.6[a,b]	6.1±0.2[a,b]	7.3±0.1[c]

[£]Data are presented as mean, standard deviation of the mean and coefficient of variation of the mean. Values in a column with different superscript letters are significantly different at the $p \leq 0.05$ level.

Table 4. Pearson correlation coefficients and P-values (within parenthesis) for instrumental uniaxial extensibility texture parameters, sensory texture attributes and overall liking of pounded yam.

Variables	Extensional area (N·mm)	Hardness (N)	Extensibility (mm)	Mouldability (score)	Stretchability (score)	Overall liking (score)
Extensional area (N·mm)	1 (0)					
Hardness (N)	0.941 (0.017)**	1(0)				
Extensibility (mm)	0.934 (0.020)**	0.964 (0.008)*	1(0)			
Mouldability (score)	-0.185 (0.765)	-0.287(0.640)	-0.022 (0.972)	1(0)		
Stretchability (score)	0.547 (0.340)	0.480 (0.413)	0.652 (0.234)	0.579 (0.306)	1(0)	
Overall Liking (score)	0.900 (0.037)**	0.993(0.001)***	0.965 (0.008)***	-0.256 (0.678)	0.472 (0.422)	1(0)

*, **, *** significant at $P \leq 0.1$, 0.05 and 0.001, respectively

Table 5. Pearson correlation coefficients and P-values (within parenthesis) for bi-extensional viscosity, sensory texture attributes and overall liking of pounded yam.

Variables	Bi-extensional viscosity (Pa·s)	Moldability (score)	Stretchability (score)	Overall liking (score)
Bi-extensional viscosity (Pa·s)	1 (0)			
Moldability (score)	-0.599 (0.209)			
Stretchability (score)	0.404 (0.426)	-0.051 (0.924)	1 (0)	
Overall liking (score)	0.730 (0.100)*	-0.579 (0.229)	0.768 (0.075)*	1 (0)

* significant at $P \leq 0.1$