Short Communication

Received: 23 December 2022 Revised: 12 March 2023 Accepted article published: 8 April 2023 Published online in Wiley Online Library:

(wileyonlinelibrary.com) DOI 10.1002/jsfa.12606

# Sensory characterization of the perceived quality of East African highland cooking bananas (*matooke*)

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## Abstract

**BACKGROUND: It has recently become increasingly evident that banana projects in Uganda need to consider consumer preferences as part of the breeding process to increase the acceptability of new cultivars. A trained panel used quantitative descriptive analysis (QDA) as a tool to assess the sensory characteristics of 32 cooking bananas (*matooke*). The aim was to investigate which sensory characteristics best describe matooke.**

**RESULTS: Fourteen descriptors were generated. The preferred attributes of *matooke* were high-intensity yellow color, homogeneous distribution of yellow color, good *matooke* aroma, highly moldable by touch, moist and smooth in the mouth. Analysis of variance revealed significant differences in the yellowness, homogeneity of color, firmness, moistness, smoothness, *matooke* aroma, hardness, and moldability across the genotypes ($P < 0.05$). Principal component analysis (PCA) showed strong positive correlations between yellowness and homogeneity of the color ($R = 0.92$). Smoothness in the mouth and moldability by touch were strongly and positively correlated ($R = 0.88$). Firmness in the mouth was well predicted by hardness to touch ($R^2 = 0.85$). The *matooke* samples were ranked into two sensory clusters by agglomerative hierarchical clustering (AHC).**

**CONCLUSION: The study showed attribute terms that could be used to describe *matooke* and also revealed that QDA may be used as a tool during the assessment and selection of new cooking banana hybrids to identify relevant sensory attributes because of its ability to discriminate among the banana hybrids.**


**Keywords:** sensory profiling; *matooke*; banana hybrids; quantitative descriptive analysis; breeding efficiency

## INTRODUCTION

The East African High Bananas (*Musa* spp.) are a staple crop grown mainly in tropical areas in Africa as a source of food and livelihood for many households.[1] In Uganda, over 20 million people are said to benefit from bananas.[2] The crop is locally known as *matooke* and it is consumed in all parts of the country.[3]

Despite its relevance, the crop faces challenges from pests and diseases, decreasing soil fertility, drought, and a gradual decrease in yields that threatens its production.[4] Breeders base their argument of breeding on this foundation to ensure the sustainability of the crop by developing improved varieties that are resistant to the most devastating pests and diseases and thus increase yields.[5,6] Breeding for crop improvement, however, can impact the sensory quality of new products.[5] Insufficient attention to quality can cause considerable resistance from consumers in terms of perception and acceptability, reducing the adoption of improved genotypes by farmers.[7] Ugandan consumers prefer *matooke* that has a yellow color, is soft, and possesses a distinctive *matooke* aroma.[3,8,9] Most developed hybrids lack these traits.

To date, only seven cooking banana hybrids have been released in Uganda by the national banana breeding program of the National Agricultural Research Organisation (NARO).[10] This could be attributed to the long time it takes to obtain seed, evaluate and select the resulting progenies and, eventually, identify and

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release new banana varieties. The less-preferred quality characteristics of the new hybrids such as pale yellow color, hard texture, astringent taste, lumpiness, and absence of *matooke* aroma has resulted in their rejection by farmers and/or consumers.[7,8]

Few studies on the acceptability of cooking banana hybrids have been conducted in Uganda.[8,11] Among those studies, none has attempted to define and quantify the quality characteristics. Quantitative descriptive analysis (QDA) has been used in other studies to assess the sensory quality of food.[12] It is beneficial in many ways including the generation of a language and product terms that are commonly used and understood by consumers. It gives objective results in terms of characterization in a short period of time once the panel is recruited, screened, and trained, and is intended to estimate the typical behavior of consumers.[9,13] This study was intended to define *matooke* characteristics that translated into perceived quality using QDA, a method proposed by Sidel and Stone.[9] Understanding the description of *matooke* quality from the consumer point of view is essential for the development and selection of new hybrids adopted by farmers and accepted by consumers. Quantitative descriptive analysis is used to identify and provide information about key sensory characteristics and their intensities in food.[14]

The main objectives of this study, therefore, were to (i) develop and validate a *matooke* sensory lexicon using a trained panel; (ii) determine which sensory attributes were most important in the description of *matooke*, and (iii) define the sensory profile of *matooke*.

## MATERIALS AND METHODS

### Materials

*Cooking banana samples*

Thirty-two cooking banana (*matooke*) genotypes, both bred hybrids (hereafter 'hybrids') and landraces, representing a diverse range of phenotypic characteristics, were used in this study (Table 1). Genotypes were selected to include germplasm with good, medium, and poor-quality traits and were replicated once, twice, three times, or four times depending on availability in the field (Table 1). Fruits from these genotypes were collected for a period of 3 years (2019, 2020, and 2021). *Matooke* bunches were harvested from two banana breeding sites: the National Agricultural Research Laboratories (NARL)-Kawanda and the International Institute of Tropical Agriculture (IITA)-Sendusu.

*Sample preparation*

Thirty-two *matooke* genotypes were used in this study. They were harvested a day before the evaluation, labeled, and delivered to the food preparation laboratories. They were prepared according to a standard protocol for sensory evaluation of *matooke* developed at the Food Biosciences Laboratory.[15] The samples were peeled, washed, wrapped in banana leaves, steamed at boiling temperature (100 °C for about 75 min), mashed, and resteamed for about 60 min at a very low fire just to keep them from cooling.[15]

### Panel selection

Training procedures followed the guidelines defined by Murray *et al.*[16] and the RTBfoods sensory analysis manual.[17] The participants who consented to the study included both males and females in the categories of scientists, technicians, and research assistants working at NARL. All participants were between the age of 18 and 60 years.[16,17]

*Training on basic tastes, ranking, and odor identification*

The training sessions were organized following instructions in the RTBFoods training manual.[17] The participants were subjected to a series of pre-screening tests to assess their ability to detect the tastes and intensities of given samples. Training included identification of the four basic tastes and an impression: sweet, sour, salty, bitter, and astringency.[18,19]

In another session, participants were presented with 'masked' bottles that contained different odors to allow them to assess which particular odors were present by only smelling when they opened the lids, and to assess their sensory acuity levels.[17-19] Twelve panelists who performed well through the prescreening tests were advanced to the next stage – vocabulary development.

*Generation of vocabulary for descriptive sensory evaluation*

Participants were presented with five *matooke* samples selected on the basis of their known sensory differences and were asked to describe them using common terms that related to their sensory characteristics according to appearance, texture, color, taste, and aroma.[18,19] A detailed list of words was generated and the panel had to agree on those that were synonyms.[20]

The participants practiced use of the chosen words by scoring them against given *matooke* samples and a structured scale. Only those terms that were considered appropriate descriptors for *matooke* were added to the vocabulary. Participants received thorough training on the attributes, definitions, measurement procedure, and scale development. To acquaint the panelists with the terminology and to train them to use the scale and perform well (repeatable and homogenous with the panel), the training lasted 5 days, taking 8 hours each day. Fourteen attribute terms/descriptors for the evaluation of *matooke* samples were developed by 12 panelists (Table 2).

*Development of scales and performance of the panel*

For each of the samples tested during the training, the panelists' scores and the range of the scores were noted. For all the attributes, the scores ranged between 0 to 10, where 10 indicated high intensity, and 0 indicated low intensity of the attribute on the category scale. The individual differences that exist among assessors is the reason this scale was used to enable them to rate intensity scores of the attributes but a discrete scale allows easy evaluation of the performance of the panel. These were used to develop a structured discrete scale (0–10) that was used to quantitatively describe the attributes. The performance of the panelists was evaluated to check their repeatability and agreement with the panel. Repeatability was considered effective for an attribute if the difference between two observations (replicate) was equal to or less than 3 on a scale of 0 to 10. Agreement was considered to be reached if the difference between the average score of the panel and that of each panelist is less than or equal to 3 on a scale of 0 to 10. Finally, a panelist was considered qualified when he or she is both repeatable and in agreement with the panel.[19]

### Quantitative descriptive analysis of *matooke*

The samples were evaluated and scored for appearance, texture, taste, impression, and aroma using the descriptors that were developed for sensory evaluation on *matooke* (Table 2).

During each tasting session, five *matooke* samples were evaluated (four samples and one replicate).[15] Panelists were served one sample each time (at a temperature of above 85 °C), which

  

**Table 1.** Dates and number of times different *matooke* cultivars (both hybrids and landraces) were assessed

| Cultivar | ID | Reps | Tasting-a | Tasting-b | Tasting-c | Tasting-d |
|---|---|---|---|---|---|---|
| **HYBRIDS** | | | | | | |
| 17914S-24 | A1 | 1 | 25/09/2019 | | | |
| 27914S-18 | A2 | 1 | 25/09/2019 | | | |
| 29586S-4 | A3 | 1 | 09/02/2021 | | | |
| 29820S-4 | A4 | 1 | 17/09/2019 | | | |
| NARITA2 | N2 | 1 | 26/09/2019 | | | |
| NARITA4 | N4 | 3 | 17/09/2019[a] | 09/02/2021 | | |
| NARITA6 | N6 | 1 | 26/09/2019 | | | |
| NARITA7 | N7 | 4 | 01/10/2019 | 02/10/2019 | 02/02/2021[a] | |
| NARITA8 | N8 | 5 | 18/09/2019[a] | 24/09/2019[a] | 02/02/2021 | |
| NARITA11 | N11 | 2 | 26/09/2019[a] | | | |
| NARITA12 | N12 | 3 | 27/01/2021[a] | 02/02/2021 | | |
| NARITA14 | N14 | 2 | 03/10/2019[a] | | | |
| NARITA15 | N15 | 2 | 18/09/2019 | 24/09/2019 | | |
| NARITA17 | N17 | 2 | 24/09/2019 | 25/09/2019 | | |
| NARITA18 | N18 | 3 | 18/09/2019 | 27/01/2021 | 09/02/2021 | |
| NARITA19 | N19 | 1 | 27/01/2021 | | | |
| NARITA21 | N21 | 2 | 01/10/2019 | 02/10/2019 | | |
| NARITA23 | N23 | 2 | 09/02/2021[a] | | | |
| NARITA24 | N24 | 2 | 01/10/2019[a] | | | |
| **LANDRACES** | | | | | | |
| Enzirabahima | ENZ | 1 | 17/09/2019 | | | |
| Kabucuragye | KAB | 2 | 02/10/2019 | 03/10/2019 | | |
| Kibuzi | KIB | 2 | 24/09/2019 | 24/11/2020 | | |
| Kisansa | KIS | 3 | 15/12/2020 | 17/12/2020[a] | | |
| Mbwazirume | MBW | 2 | 24/11/2020[a] | | | |
| Mpologoma | MPO | 1 | 17/12/2020 | | | |
| Musakala | MUS | 3 | 18/09/2019 | 15/12/2020[a] | | |
| Muvubo | MUV | 2 | 25/09/2019[a] | | | |
| Nakawere | NKW | 3 | 02/10/2019[a] | 02/02/2021 | | |
| Nakinyika | NAK | 4 | 24/11/2020 | 15/12/2020 | 17/12/2020 | 27/01/2021 |
| Nakitembe | NKT | 2 | 17/09/2019 | 17/12/2020 | | |
| Nandigobe | NAN | 1 | 24/11/2020 | | | |
| Nfuuka | NFU | 3 | 26/09/2019 | 01/10/2019 | 15/12/2020 | |

[a] Tasted twice in the same day (r1 and r2 in Fig. 2).

was labelled with a random three-digit code. A similar sample known as the 'reference sample' was placed on a separate plate and a thermometer was inserted to read the core temperature.[15] The panelists were not allowed to start the tasting until the reference sample core temperature was 75 °C. Environmental conditions were controlled by the use of sensory booths. Panelists were provided with a score sheet, a list of *matooke* definitions and descriptors (Table 2), and water for rinsing their mouths between the evaluation of samples.[15]

### Statistical analysis

The relationships between the descriptive sensory variables were analyzed using XLSTAT version 2019.4.1.63353. A one-way ANOVA was performed to determine significant differences between clusters, obtained from agglomerative hierarchical clustering (AHC). For that, there is no other factor involved. Principal component analysis (PCA) was used to describe the sensory characteristics of cooking bananas and visualize differences between them, and AHC was performed to assess the *matooke* sensory classification.

## RESULTS

### Sensory characteristics of matooke

The PCA plot in Fig. 1 explained 83.50% of the total variability, with principal component 1 (PC1) accounting for 53.54% and PC2 for 29.97%. PC1 indicated strong associations between yellowness and homogeneity of color ($R = 0.92$), yellowness and *matooke* aroma ($R = 0.88$), as well as between homogeneity of color and *matooke* aroma ($R = 0.81$). On the other hand, the associations between sweetness and yellow ($R = 0.52$), and sweetness and *matooke* aroma ($R = 0.56$) were not as strong. In the bottom-right quadrant, moldability by touch and smoothness in the mouth were also found to be strongly associated ($R = 0.88$), whereas moistness in the mouth was found to be only moderately correlated with smoothness in the mouth ($R = 0.53$), moldability by touch ($R = 0.53$), and stickiness by touch ($R = 0.59$). Finally,

**Table 2.** *Matooke* definitions and descriptors

| | Attributes | Definition | How to measure? | Scale |
|---|---|---|---|---|
| **Appearance** | Yellow | Color of the surface of the sample from light yellow to bright yellow | When you receive the sample, observe the surface and evaluate the intensity of the color and its homogeneity | 0: No yellow<br>10: yellow |
| | Homogeneity of color | Uniformity of color of the surface of the sample | | 0: heterogeneous<br>10: homogeneous |
| **Texture in mouth** | Firmness | Mechanical textural attribute relating to the force required to achieve a given deformation, penetration, or breakage of a product. | Put a part of the sample in your mouth, evaluate during the first bite (between molars) how hard the sample is. | 0: soft<br>5: firm<br>10: hard |
| | Moisture | Perception of moisture content of a food by the tactile receptors in the mouth and also in relation to the lubricating properties of the product | Put a part of the sample in the mouth, chew and evaluate the quantity of water within the sample. | 0: Dry<br>10: Moist |
| | Smoothness | Geometrical textural attribute relating to lack of presence of particles in a product | Put a part of the sample in mouth, chew it and after 5 chews, evaluate between tongue and palate the number and the size of the particles. | 0: lumpy<br>5: grainy<br>10: smooth |
| **Texture by touch** | hardness | Mechanical textural attribute relating to the force required to achieve a given deformation, penetration, or breakage of a product. | Take a part of the sample between fingers and evaluate how hard the sample is | 0: soft<br>5: firm<br>10: hard |
| | Moldability | Mechanical textural attribute relating to the degree to which a substance can be deformed before it breaks | Try to make a ball (agglomerate) of the sample and evaluate how easy it is to deform or break the sample | 0: crumbly<br>10: moldable |
| | Stickiness | Mechanical textural attribute relating to the force required to remove material that sticks to the fingers | Put a part of the sample between thumb and index fingers and using tapping motions, evaluate the amount of product adhering on them | 0: non sticky<br>10: sticky |
| **Taste** | Sweetness | Basic taste produced by dilute aqueous solutions of natural or artificial substances such as sucrose | Put a part of the sample in the mouth and evaluate the intensity of taste of sugar | 0: no intensity<br>5: medium intensity<br>10: high intensity |
| **Impression** | Astringency | Complex sensation, accompanied by shrinking, drawing or puckering of the skin or mucosal surface in the mouth, produced by substances such as kaki tannins or sloe tannins | Put a part of the sample in the mouth and evaluate the intensity of astringency impression due to the sample | 0: low intensity<br>5: medium intensity<br>10: high intensity |
| | Sourness | Gustatory complex sensation, generally due to presence of organic acids | Put a part of the sample in the mouth and evaluate the intensity of the sourness | 0: low intensity<br>5: medium intensity<br>10: high intensity |
| **Aroma** | *Matooke* | Aroma of the local *matooke* | Put a part of the product and by retro-olfaction evaluate the presence and the intensity of this specific aromas | 0: no intensity<br>5: medium intensity<br>10: high intensity |
| | Pumpkin | Aroma of pumpkin | | YES/NO |
| | Grassy | Aroma of fresh grass | | YES/NO |

PC2 showed that hardness by touch and firmness in the mouth were strongly associated ($R = 0.92$).

According to the PCA biplot (Fig. 2), the top-right quadrant separated and described cultivars on the basis of high intensity of yellow, homogeneity of the color, sweetness, and high intensity of *matooke* aroma. A few hybrids were found to be associated with these characteristics (N7a, N17a, N17b, N24r1, N24r2), which implies that they were evaluated by the panel to be as good as the landraces. The quadrants on the left were mainly hybrids characterized by hardness by touch and firmness in the mouth. They were also not yellow, nor homogenous in color, lacked a *matooke* aroma, had low moldability, and stickiness and were not smooth.

### Sensory classification of *matooke*

The dendrogram in Fig. 3 shows the presence of two clusters for the 68 assessed samples. The two clusters differed significantly. Cluster 1, which consisted mainly of hybrids with the exception

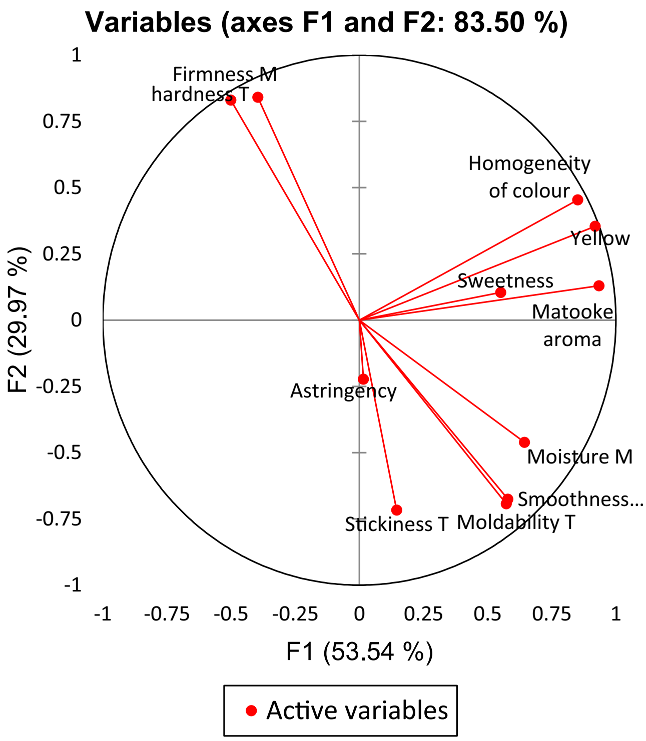


**Figure 1.** Principal component analysis of sensory attributes for *matooke*: M = measured in the mouth, T = measured by touch.

of three landraces, was characterized by hardness, firmness in the mouth, non-yellow color, non-homogenous color, no *matooke* aroma and low intensity of sweetness. With the exception of six hybrids, cluster 2 was mainly landraces characterized by a yellow homogenous color, good *matooke* aroma, sweetness, and high moldability. Agglomerative hierarchical clustering also categorized the samples into two groups: A for the landraces and B for the hybrids (Fig. 4). Figure 4 also summarizes the results from the ANOVA. Except for stickiness, significant differences ($P < 0.05$) between the averages of hybrids and landraces were found for all traits (perception of yellowness, homogeneity of the color, firmness in mouth, moistness in mouth, and smoothness in the mouth, hardness by touch, moldability by touch, sweetness, and *matooke* aroma).

## DISCUSSION

Overall, the attributes that best described *matooke* were a yellow color, homogeneity of color, moistness in the mouth, smoothness in the mouth, moldability by touch, and a *matooke* aroma. These are the attributes preferred by consumers as reported by previous studies.[3,8,10] Nowakunda and Tushemereirwe[8] reported inferior consumption attributes in the improved bananas, which explained their low acceptability. Ssemwanga and colleagues[21] found similar results when they investigated eating qualities that could have adverse effects on improved bananas. In this study, most hybrids were characterized as being excessively hard by touch and firm in the mouth, which are attributes not preferred by consumers, as reported by other authors.[8,21] During the

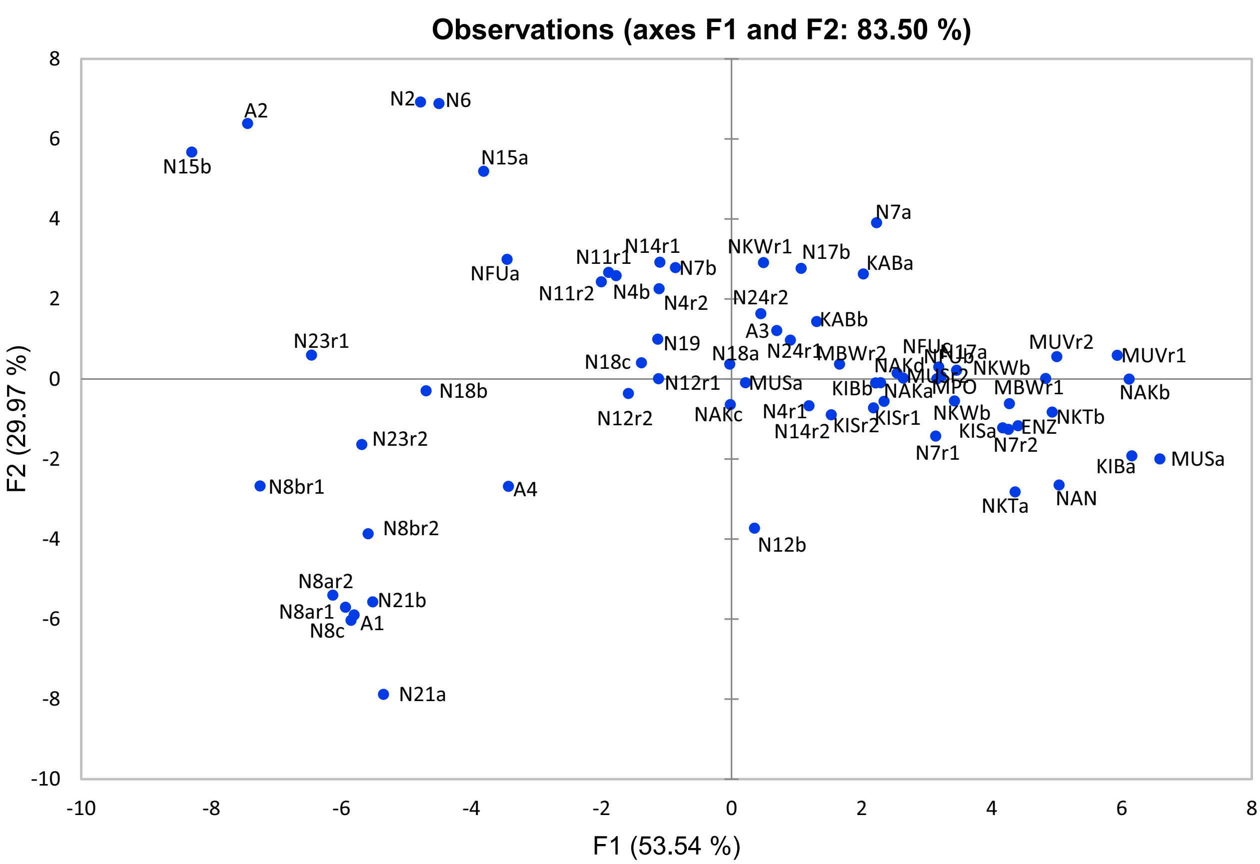


**Figure 2.** Principal component analysis biplot showing the relationships between *matooke* cultivars and sensory attributes.

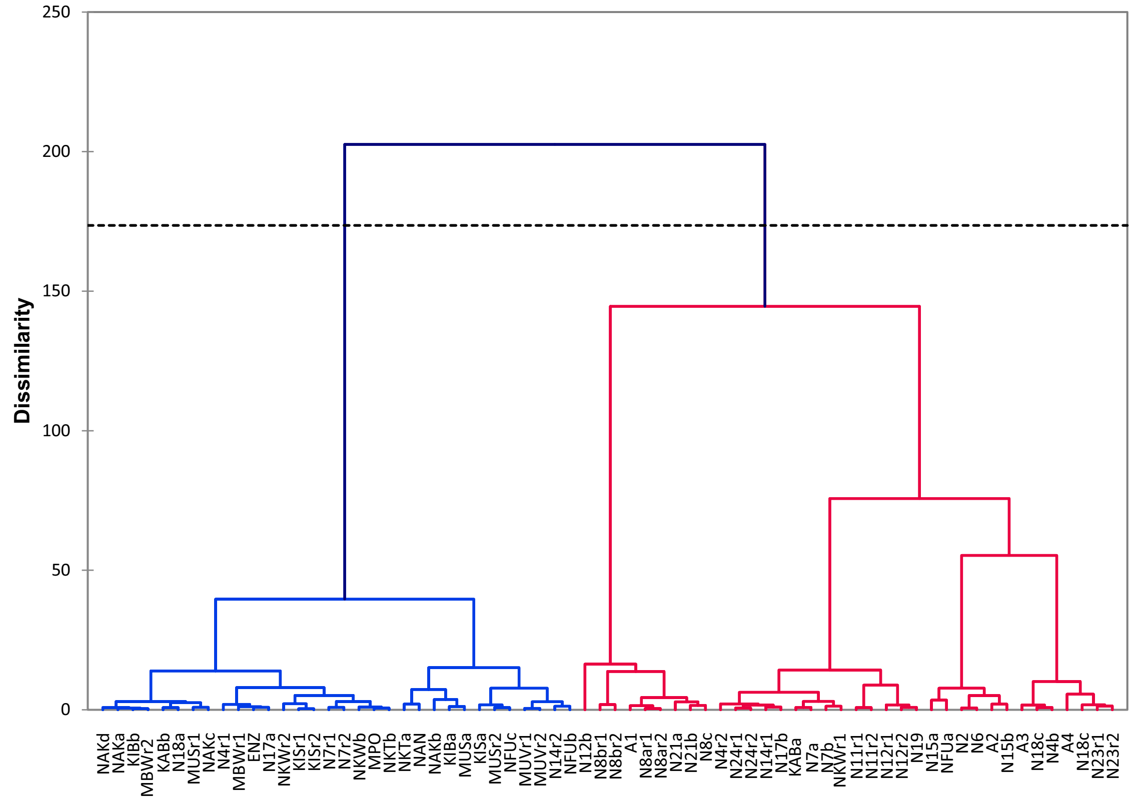


**Figure 3.** Agglomerative hierarchical clustering dendrogram showing segments of *matooke* samples.

assessment of relevant traits for selection of new cooking banana genotypes, Tumuhimbise *et al.*[22] emphasized the possession of acceptable sensory attributes alongside yield and resistance to diseases as a critical requisite, suggesting that new cultivars with a high yellow intensity, a uniformly distributed yellow color, and a good *matooke* aroma were more likely to be accepted by consumers. The hybrids that were clustered with landraces such as NARITA 7 showed similarity in the characteristics, which implied that their sensory quality was not different from that of the landraces.

This was confirmed by Marimo *et al.*[23] where NARITA 7 was seen to have scored highly for consumer acceptability in a number of

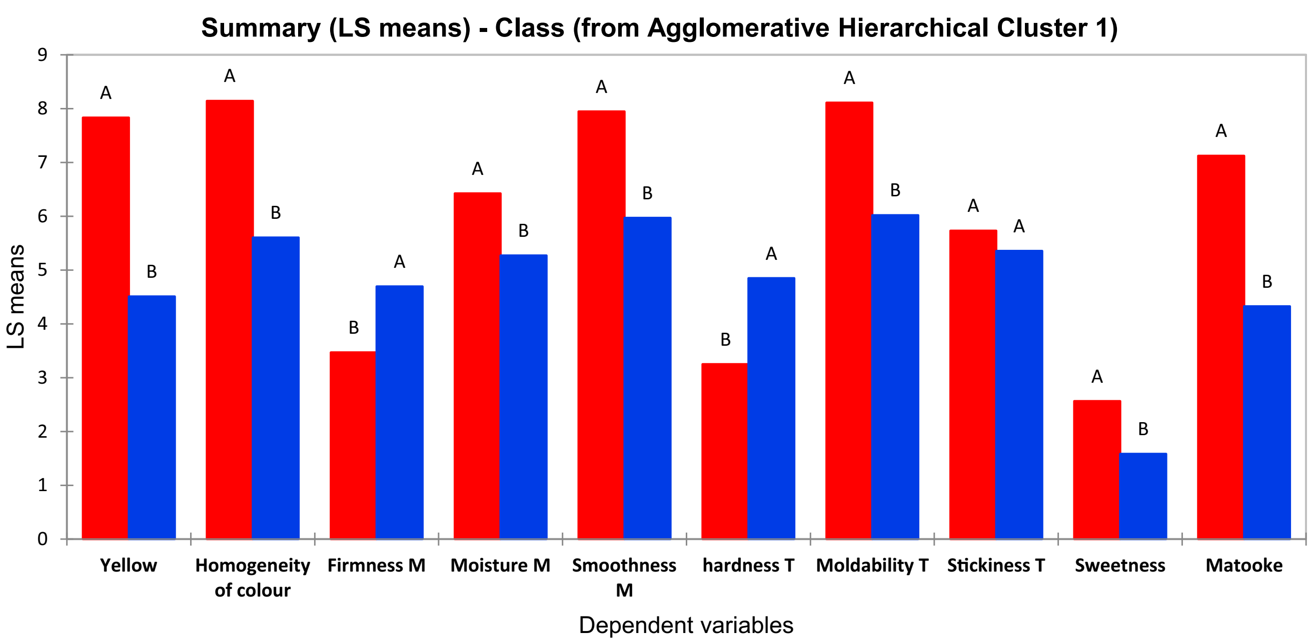


**Figure 4.** Analysis of variance of the two groups (hybrids = 1 and landraces = 2 where M indicates measured in the mouth, and T by touch).



  

locations where it was tested. Its yellow color, soft texture, and aroma contributed to this favorable score.

The current study linked sensory characteristics to *matooke* quality and revealed that texture in the mouth could be predicted by texture in the hand. The significant genetic variation for yellowness, homogeneity of the color, firmness, moistness, smoothness, hardness, and moldability also suggests potential for improvement of these traits by breeding. The study demonstrated the importance of application of sensory descriptors to define *matooke* quality. The next steps should be to explore which sensory attributes might be correlated with more easily implemented instrumental measures, and also assessment for minimum and maximum threshold values of acceptability for these attributes in order to screen for hybrids. This study further confirmed the generalized difference in sensory attributes between the average of hybrids and landraces. This study will help breeders to select new hybrids with defined *matooke* quality characteristics at even earlier stages in the breeding process.

## AUTHOR CONTRIBUTIONS

Conceptualization, Data Curation, Investigation: Elizabeth Khakasa Formal Analysis: Elizabeth Khakasa, Christophe Bugaud Funding acquisition: Kephas Nowakunda Methodology: Elizabeth Khakasa, Christophe Bugaud, Nelly Forestier-Chiron Samples for the study: Brigitte Uwimana, Ivan Kabiita Arinaitwe Supervision: Charles Muyanja, Robert Mugabi, Kephas Nowakunda Writing original draft: Elizabeth Khakasa Writing ± Review & Editing: Elizabeth Khakasa, Charles Muyanja, Robert Mugabi, Christophe Bugaud, Nelly Forestier-Chiron, Brigitte Uwinama, Ivan Kabiita Arinaitwe, Kephas Nowakunda.

## ACKNOWLEDGEMENTS

The authors are grateful to the staff of the National Agricultural Research Laboratories for participating in the study, Mr Ngabirano Wilber and Ms Jennifer Lalam Acam for delivering *matooke* bunches to the laboratories, and the grant opportunity INV-008567 (formerly OPP1178942): Breeding RTB Products for End User Preferences (RTBfoods), to the French Agricultural Research Centre for International Development (CIRAD), Montpellier, France, by the Bill & Melinda Gates Foundation (BMGF): https://rtbfoods.cirad.fr. Previous versions of this paper and the ideas in it benefited greatly from suggestions and comments by the co-authors. The editorial comments by Hernán Ceballos and Dominique Dufour as well as the final proofreading of the manuscripts by Clair Hershey improved greatly the quality of this manuscript.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## ETHICS STATEMENT

The research described in this manuscript has been approved by the National Research Ethics Committee accredited by the Uganda National Council for Science and Technology. Written informed consent was obtained for all the study participants and is available.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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