



BREEDING INNOVATION AND INTEGRATION FUND: CONSUMER TESTING REPORT

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TABLE OF CONTENTS

ABSTRACT	6
1. INTRODUCTION	9
2. METHODOLOGY	10
2.1 Study Area	10
2.2 Sampling protocol	10
2.3 Variety selection.....	11
2.4 Sensory Analysis	12
2.4.1 Consumer testing	12
2.5 Data analysis	14
3. RESULTS	15
3.1 Consumer preferences without clustering.....	15
3.2 Sweetpotato and cassava preferences among homogenous consumer clusters	16
3.2.1 Steamed sweetpotato in Uganda	16
3.2.2 Boiled Sweetpotato in Mozambique	17
3.2.3 Cassava <i>fufu</i> in Nigeria	17
3.3 Drivers of sweetpotato and cassava preferences by homogenous consumer clusters	18
3.4 Sociodemographic characteristics associated with clusters	24
4. DISCUSSION	27
4.1 Recomendations	28
5. REFERENCES	29

LIST OF TABLES

Table 1: Varieties selected for the study using archived descriptive sensory analysis data collected in 2022.	11
Table 2. Sweetpotato varieties selected for the study in Mozambique.	12
Table 3. Cassava varieties selected for the study in Nigeria.	12
Table 4. Summary of mean positive and negative impact of significant CATA terms by fufu consumer clusters in rural Nigeria.	24
Table 5. Sociodemographic characteristics and sweetpotato consumption patterns associated with the three consumer clusters.	24
Table 6. Sociodemographic characteristics and sweetpotato consumption patterns associated with the two consumer clusters in Mozambique.	25
Table 7. Sociodemographic characteristics and fufu consumption patterns associated with the four consumer clusters in Nigeria.	26

LIST OF FIGURES

Figure 1. Similarities and differences among data collection approaches used among countries participating in the study.....	14
Figure 2. Flow diagram summarising the data analysis steps used in the study.	14
Figure 3. Average overall liking for steamed sweetpotato samples served to consumers in urban areas of Kampala (n = 100 for day 1, n = 95 on day 2) and rural areas of Kabarole in Uganda (n = 121 for day 1, n = 104 for day 2); Overall liking was rated on 9-point.	15
Figure 4. Average overall liking for boiled sweetpotato samples served to consumers in urban areas of Maputo, Mozambique (n = 132) by genotype; Overall liking was rated on 9-point hedonic scales from 1 – dislike extremely to 9- like extremely anchored at 5 – neither like nor dislike.....	16
Figure 5. Average overall liking for fufu samples prepared from 8 cassava genotypes served to consumers in rural areas of Imo and Abia State, Nigeria (n = 102); Overall liking was rated on 9-point hedonic scales from 1 – dislike extremely to 9- like extremely anchored by 5 – neither like nor dislike.....	16
Figure 6. Consumer clusters by steamed sweetpotato sample preference as rated on a 9point Likert scale in rural and urban Uganda (n = 221)	17
Figure 7. Consumer clusters by steamed sweetpotato sample preference as rated on a 9point Likert scale in urban Mozambique (n = 130).....	17
Figure 8. Consumer preferences for cassava fufu samples rated by consumers (n=100) in rural Nigeria on 9-point scale by cluster.	18
Figure 9. Mean drops (y-axis) and accompanying consumer frequency (x-axis) for samples consumers indicated to be being much less (<3, indicated by blue font) or much more (>3 indicated by red font) in various sensory characteristics. Separate graphs are plotted for each of the consumption clusters 1, 2 ,3 denoted by the same labels. Consumers of steamed sweetpotato (n= 221) rated sweetness, firmness and mealiness on 5-point Just-About-Right scales anchored at 3 (JAR) in rural Kabarole and urban Kampala, Uganda. Critical minimum threshold set at 20% consumers and 2 unit mean drop and the most important drivers of liking are located to the right of dotted line and above the red line are most important drivers of liking.	19
Figure 10. Mean drops and accompanying consumer frequency associated with boiled sweetpotato samples being perceived as having less than (JAR <3, indicated by blue) or too much (JAR > 3, indicated by red) of various sensory characteristics as rated by consumers of boiled sweetpotato in urban Mozambique (n= 132) on 5-point JAR scales anchored at 3 (JAR). Separate graphs are plotted for each of the consumption clusters 1 and 2 denoted by the same labels. Critical minimum threshold set at 20% consumers and 1 unit mean drop and the most important drivers of liking are located to the right of dotted line and above the red line are most important drivers of liking.	20
Figure 11. Mean drops and accompanying consumer frequency associated with boiled sweetpotato samples for various sensory characteristics as rated by consumers of boiled sweetpotato in urban Mozambique (n= 132) on Check-all-that-apply question. Separate graphs are plotted for each of the consumption clusters 1, 2 denoted by the same labels. Critical minimum threshold for impact set at 20% consumers and 1 unit mean drop and the most important drivers of liking and disliking. Descriptors with a positive impact are located in the shaded area above the green line while those with negative impact are located in the shaded area below the red line.	22
Figure 12. Mean drops and accompanying consumer frequency associated with fufu samples for various sensory characteristics as rated by consumers of boiled sweetpotato in rural Nigeria (n= 100) on Check-all-that-apply question. Separate graphs are plotted for each of the consumption clusters 1, 2, 3 and 4 denoted by the same labels. Critical minimum threshold for impact set at 20% consumers and 1 unit mean drop and the most important drivers of liking and disliking. Descriptors with a positive impact are located in the shaded area above the green line while those with negative impact are located in the shaded area below the red line.	23

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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ABSTRACT

Sweetpotato and cassava are important food crop targets for transforming livelihoods in Mozambique, Nigeria and Uganda. To effectively deliver new crop varieties, there is need to explore and characterize consumption groups based on evaluation of newly bred genotypes (advanced or released) in comparison with leading or existing varieties on market. We investigated preference clusters among consumers of steamed sweetpotato in Uganda, boiled sweetpotato in Mozambique and the fermented cassava product, *fufu*, in Nigeria and characterized them by their sensory preferences, sociodemographic characteristics and product consumption habits. In Uganda, three clusters emerged: the first (n= 24%) comprised youths that uniquely disliked a white-fleshed genotype; the second (n= 49%) comprised rural residents who did not dislike any genotype; the third (n= 25%) comprised men traders who did not like orange-fleshed genotypes. Sweetpotato consumers in Mozambique were separated into two clusters: one (n= 52%) comprised occasional consumers of sweetpotato who liked all genotypes while the other (n= 48%) comprised frequent consumers of sweetpotato who were more critical about the sensory quality of the sweetpotato. *Fufu* consumers in Nigeria were clustered into four groups: the first one (n= 15%) comprised adults who uniquely disliked *GOVERNOR* for reasons unrelated to sensory quality; the second one (n = 25%) comprised occasional *fufu* consumers who were not primarily farmers, were influenced by texture characteristics and uniquely disliked TME 419; the third (n= 18%) consisted of breakfast consumers of *fufu* whose preferences were driven by colour and disliked UMUCASS37; the last one (n= 42%) comprised lunchtime consumers of *fufu* whose preferences were influenced by colour. This information emphasizes the need for market segmentation to facilitate effective breeding.

Key Words (10 maximum):

Sweetpotato, cassava, *fufu*, penalty analysis.

1. INTRODUCTION

Root and tuber crops have a strong hold in the agri-food systems of countries in the global south given their multiple roles as human food, animal feed, and source of income (Scott, 2021). The increment in their production growth rate in terms of the quantity harvested annually and the area under production during past decades, especially in Africa, facilitated adoption to population surges, and relief during drought, humanitarian and economic crises. Commonly root and tuber crops in Africa is grown to supply food in the household or sell to earn an income in both urban and rural areas.

Sweetpotato and cassava are among the crops with highest production and utilization in Nigeria, Mozambique and Uganda (Scott, 2021). Globally, Nigeria alone is considered the leading producer of root and tuber crops in general, and cassava, in particular. Uganda is among the biggest producers of sweetpotato in the world. While cassava is a perennial crop, sweetpotato has a short growth cycle (Truong et al., 2018) making it a suitable emergency crop in areas that are affected by environmental disasters and political disruptions like Mozambique. Both crops are versatile given the products and traditional dish recipes they are used to make; roots can be boiled, steamed or fried, dried into flours which can be pasted, sweetpotato roots can be pureed for use as baby food or baking raw material. In West Africa, cassava roots can be fermented to make *fufu* or *gari* which is used to make *eba*. These agronomic and food preparation qualities further contribute to the crops' popularity as income generating and food crops in these countries.

Breeding for sweetpotato and cassava in African countries has evolved. Having started with the aim to increase crop production, breeding programs later played a critical role in biofortification efforts to improve vitamin A and iron deficiency problems in the region (Low et al., 2017). Upon recognizing the challenge of limited adoption (Thiele et al., 2021), breeding programs are now expressing interest in considering eating qualities of genotypes during breeding selections (Lindqvist et al., 2024, Laurie et al., 2023). The people who eat the food products, consumers, are critical in defining the food quality since they are usually the final end-users of the crop. Even as an intervention, the eating quality of food is crucial for acceptance, and in the case of crops, adoption and utilization. Therefore, studies to better understand the consumers of these root crops in these countries would provide the breeding program with guidelines and recommendations on how to effectively breed to meet their (consumer) needs.

Several efforts have been implemented to facilitate consumer demand-driven selection in breeding trials of cassava in Nigeria and sweetpotato in Uganda and Mozambique. For Nigeria, sensory characteristics of *fufu*, a product prepared from wet fermented cassava paste, influencing gender-specific consumer preferences have been posited (Chijioke et al., 2021). They include appearance, texture and smell characteristics with smoothness, not sticky, easy to swallow and drawable being associated with preferred cooked *fufu* paste among both men and women. In Uganda, the gendered product profile of steamed and boiled sweetpotato was established and included several sensory characteristics: good colour, sweetness, mealiness, firmness, non-fibrousness (Mwanga et al., 2021). Findings in Mozambique revealed that consumers liked sweetpotato that had good dry matter, good smell, and firm and smooth texture but disliked watery, tasteless, light, soft, spongy, and pale-yellow sweetpotato (Mayanja et al., 2023). However, the study in Mozambique also indicated that consumer preference trends were not universal and varied among consumption clusters or groups. Further, consumption clusters varied by various socio-demographic characteristics excluding biological sex which was the construct for the gender term applied in Uganda and Nigeria. Therefore, there is a need to identify and explore consumption preference clusters for each product and country and classify by the sensory characteristics they prioritise and their socio-demographic characteristics.

The current study investigated the types of preference clusters among consumers of steamed sweetpotato in Uganda, boiled sweetpotato in Mozambique and *fufu* in Nigeria and characterized them by their priority preference characteristics, sociodemographic and product consumption patterns. It is expected that this information will guide breeders better on the most critical characteristics that they should focus on and establishment of strategies to meet the needs of critical but hidden needs of consumers at the point of dissemination.

2. METHODOLOGY

2.1 Study Area

In all three countries, study areas were selected to ensure inclusion of individuals from a diverse range of socio-demographic characteristics by identifying areas near major food markets that served a wide scope of the residential area. In addition, fields from which sweetpotato and cassava were grown were located near the consumer testing locations to reduce the influence of metabolic changes related to sensory characteristics that could occur during long periods of transportation. In Uganda, consumer testing was conducted in urban areas in Kampala city (central region) and rural areas in Kabarole (western region). In Kampala, consumer testing was conducted at Lugooba village, Kawempe division while in Kabarole, the testing was conducted at Kijura town council. Kawempe and Kijura areas were selected for consumer evaluations due to their proximity to the respective fields where the genotypes had been planted; for example, Kawempe's proximity to research station in Namulonge (appx. 21 km) and Kijura to the Rwebitaba zonal agricultural and development institute - RweZARDI (appx. 20 km). In spite of their proximity to the research station, these areas had received limited interventions of research technologies from the nearby agricultural research stations. In Mozambique, the study was conducted at the *Instituto de Investigação Agrária de Moçambique* (IIAM) campus, in the urban area of Maputo City, targeting urban consumers. This location is near the most densely populated neighborhoods (Mavalane and Maxaqueni) in Maputo and there are also two major markets. People pass by the gate of the institute on their way to the market. In Nigeria, the study was carried out in Imo State of the South-east region of Nigeria. The locations of activities were Isinweke and Umulumuaku where fufu is a main staple. Breeding teams had previously conducted on-farm trials of cassava in these areas.

2.2 Sampling protocol

The study aimed to recruit 120 participants for each location. In Uganda, prior to the study, the research team visited each of the sites to identify respondents who were willing to participate and jointly scheduled the date and time for the activity with the local leaders. Being an urban area with a dense population, Kawempe had enough households to apply the sampling protocol, hence one only village, Lugooba, was selected for the study. On the other hand, three villages in Kabarole (Kyeitamba B, Kihoora and Kataraka) of Kijura Parish had to be combined to constitute enough households to apply the protocol, due to the sparse distribution of households. Household lists including details about the head of household (gender and contact) in each location were obtained from government appointed Village Health Trainers (VHTs) in Kijura and democratically elected village chairperson in Kawempe. The lists were digitalized by entering them in MSExcel, and each household was assigned a unique three-digit number, and then the households in the list were put in random order. Households with different members but sharing a household head were considered as separate households. Household representatives were contacted by phone following the random order, introduced to the goal of the planned consumer testing activity, notified about the scheduled dates and asked to confirm their availability. Households with no phone contact on file were physically contacted. In cases where the contact person was unavailable, they were asked to nominate another adult member to represent the household. This process continued until the participation of 120 households was confirmed in each of the two study areas. In Kijura, 422 households were contacted to reach the target of 120 households with confirmed participation (28 % response rate). This response rate was similar to the one in Kawempe. Therefore, the final list for each area consisted of 120 households with diverse sociodemographic characteristics. All recruitments were done in collaboration with the respective local leaders of the two study areas.

In Mozambique, consumer testing was conducted from 17 to 21 June 2024. To get participants from diverse backgrounds, three mobilizers recruited passersby in front of IIAM campus main gate on two days. Selected and agreeable passersby were briefly introduced to the consumer testing activity and invited to participate. Recruited participants who were familiar with boiled sweetpotato, available and expressed interest in participating were randomly

assigned to enumerators. In total 132 willing adult consumers were successfully recruited. All participants were invited to fill consent form for participation in the evaluation.

In Nigeria, similar to Uganda, a complete list of residents was obtained from the local leaders and entered in MSExcel and randomized ahead of the study. With the help of a field guide, the team contacted the first selected 120 households (60 households in each location) and invited them to participate in the study with 100% response rate owing the existing collaboration between the residents and NRCRI.

2.3 Variety selection

For Uganda, archived quantitative descriptive analysis (QDA) data collected on genotypes from the CIP breeding pipeline for the seasons 2021 – 22 were screened to identify genotypes that consistently displayed specific sensory traits across geographical location and season. The selected genotypes had varying sensory trait packages and met consumer preferences to varied extents (Table 1). In total, eight genotypes were selected and planted on-station at the National Crops Resources Research Institute in Namulonge and Rwebitaba ZARDI. In Namulonge, at harvest, there were no roots for UGP 20170490-966, so it was replaced with NASPOT 13 O. The eight final genotypes selected for the study and the rationale are shown in Table 1 below.

Table 1: Varieties selected for the study using archived descriptive sensory analysis data collected in 2022.

Genotype	Flesh colour	Selection Rationale	
		Sensory profile	TEQS ¹
UGP 2017 0490-966	OFSP	Predominant pumpkin aroma / flavor	0
Beauregard	OFSP	Predominant pumpkin aroma / flavor	0
UGP2017 0117-14 / D20	OFSP	Mealy OFSP	4
NASPOT 13 O	OFSP	Moderate	
NASPOT 8	OFSP	Leading market variety	4
UGP2017 0910-24	WFSP	Mealy, sweet, WFSP	4
UGP2017 0902-54	WFSP	Very mealy, very firm, not sweet	
UGP2017 0907-31	WFSP	Moderate	
NAROSPOT 1	WFSP	Leading market variety	4

TEQS : total eating quality score indicating the extent to which consumer sensory quality preferences sweetpotato are met 0 (none met) – 4 (completely met)

The stations have different topologies and climates but similar onset of the seasons. In Namulonge (altitude: 1160 masl) the genotypes were planted on September 25, 2023, and harvested on 15-April-2024, while In Rwebitaba (altitude: 1531 masl), the genotypes were planted on October 4, 2023 and harvested on 28-May-2024. Samples from Namulonge served the urban respondents in Kampala while those from Rwebitaba served the rural respondents in Kabarole. Upon harvest, storage roots were sorted to remove damaged ones, and those of extreme sizes. The roots were then washed with portable water to remove dirt and debris, placed on clean banana leaves in a single layer to air-dry overnight, packed in woven sacks the following morning and transported under ambient conditions to respective sites for consumer testing.

In Mozambique, five sweetpotato varieties that were expected to cover a wide range of the consumer preference space were selected from sensory profiles data that had been conducted prior with trained sensory panels (Table 2). The selected five varieties included two that were expected to have most preferred sensory profiles, two with least preferred sensory profiles and one with moderately preferred sensory profile as shown in the table 2 below. The varieties were

growing on trial established at Nwalate Farm (26°1'12" S, 32°12'0"E), district of Boane, Maputo province. It was planted on 15th January 2024 and harvested on 16th June 2024. The roots were harvested after 5 months.

Table 2. Sweetpotato varieties selected for the study in Mozambique.

Variety classification	Variety name	Flesh colour	Selection criteria	Source
Landrace	N`santimuni	Yellow	Preferred/Mealy	Breeding trials
Landrace	Secai	White	Preferred/ Mealy	Breeding trials
Released variety	Olga	Purple	Intermediate	Breeding trials
Released variety	Victoria	Orange	Not preferred/not mealy	Breeding trials
Released variety	Ken	Orange	Not preferred/not mealy	Breeding trials

In Nigeria, first, cassava roots of 17 genotypes of the NCRP trial at the National Root Crop Research Institute (NRCRI) Umudike were harvested at maturity of 12 months. Because the number was too large to conduct consumer tests, processing diagnostics were conducted next to select a smaller subset to use for consumer testing. The processing diagnostic was conducted with two women and a man who evaluated the genotypes by a series of pairwise ranking questions at different processing stages, finalized with overall liking rating of on a 9-point hedonic scale. To minimize processor fatigue, the processing was conducted in randomized batches of 5, 4, 4, and 4 genotypes per day over four days. Following the processing diagnostics, seven cassava genotypes including landraces and checks which covered the consumer preference space: most-, moderately- and least preferred genotypes (Table 3) were selected from the original 17 to include in consumer tests. These were: BABA 70, TME 419 (check), GOVERNOR, NWAOCHA5 (local check), TMS 98/0505, NO HUNGER, and UMUCASS 37.

Table 3. Cassava varieties selected for the study in Nigeria.

Variety classification	Variety name	Flesh colour	Selection criteria (Consumer preference)	Source
BABA 70	IBA000070	WHITE	PREFERED	NRCRI
TME 419	TME419	WHITE	GENERALLY ACCEPTED CHECK	NRCRI
GOVERNOR	GOVERNOR	WHITE	PREFERED LAND RACE	NRCRI
NWAOCHA	NWAOCHA	WHITE	PREFERED LAND RACE	NRCRI
TMS 98/0505	TMS 98/0505	WHITE	LESS PREFERED WHITE ROOT	NRCRI
NO HUNGER	TMS-IBA164773	DEEP YELLOW	LESS PREFERED	NRCRI
UMUCASS 37	UMUCASS 37	YELLOW	LESS PREFERED YELLOW ROOT	NRCRI

2.4 Sensory Analysis

2.4.1 Consumer testing

In each the test sites in Uganda, consumer tests were conducted on two days. Participants evaluated 5 samples each day with two sweetpotato genotypes (UGP20170910-24 and NASPOT 8) repeated on both days. To prepare, the roots were peeled and cooked in five separate locally fabricated saucepans following local community practice (Nakitto et al., 2022). In Kampala, samples were wrapped in banana leaves, placed over banana stalk matting in the saucepans and covered with additional layers of banana leaves then steamed over local stoves filled with red hot charcoal. In Kabarole, sweetpotato roots were similarly peeled, wrapped and placed in saucepans but steamed over three stone fireplace with burning wood. Once the steam was emitted above the heap of banana leaves covering the saucepan (approximately one hour of steaming time on charcoal stove and 45minutes on the three stone fireplace), material was carefully uncovered to press and check if they had become soft enough and ready. Once ready, sweetpotato samples were put

off the fire and, in their heap, carried out of the saucepans to serve. Each piece of root was wrapped separately in aluminium foil pre-labelled with a unique random code assigned to the sample.

Ethical approval for human participation in this study was obtained from the *Centre de Coopération Internationale en Recherche Agronomique pour le Développement* (French Agricultural Research Centre for International Development), CIRAD, Ethics committee. The questionnaire used in this study was similar to the one used prior with a few modifications (Annex 1) to include information about the respondents' history of selling or growing sweetpotato. Trained enumerators helped to administer the questionnaire to the recruited respondents per 2.1.1. using appropriate local languages – mostly Luganda in Kampala and Lutooro in Kabarole. At the beginning of the interview, enumerators sought informed consent (Annex 2). Each individual participant was assigned a unique 6- letter / digit code. Samples were served one by one for evaluation. Each respondent was provided with a fresh bottle of drinking water to rinse their mouths between samples. Respondents rated the overall-, color-, and aroma- liking for each sample on nine-point hedonic scale ranging from 1 (“dislike extremely”) to 9 (“like extremely”), anchored at 5 (neither like nor dislike). They also rated samples for sweet taste, firmness and mealiness on five-point just-about-right (JAR) scale ranging from 1 (too little) to 5 (too much), anchored at 3 (just-about-right). All data were entered in compusense (Compusense Inc., Guelph, Canada). Upon completing the interview, respondents were given a small token amounting to about 5000 (local currency) on average.

For Mozambique, consumer testing was conducted on two days with different participants. All samples were freshly prepared on each day. Damage free and medium sized sweetpotato roots (200-350 g), were selected and labeled with 3-digit code (randomly generated using MS Excel). The roots were washed twice using a sponge to remove soil, sand, and other extraneous matter, and some roots were trimmed to remove black spots and the ends of each root associated with sap oxidation. The cleaned unpeeled roots were placed in different saucepans, then water was added until all the roots were submerged, then covered with a lid and boiled on firewood until they get ready. To recognize whether the sweetpotato was ready, a wooden toothpick was used to probe in the middle of each root. The root was considered cooked when the toothpick was pushed through the center of the root with minimum resistance.

Ten students from Eduardo Mondlane University, faculty of Agronomy were recruited and trained for one day (8 hours) on the questionnaire and technical aspects of the activity including how data should be captured, types of research questions: 9-point Likert scale, just-about-right and check-all-that-apply questions should be administered and ratings entered using tablets, how to seek informed consent and complete accompanying consent forms, as well as good hygienic practices. At each interview, the trained enumerators sought informed consent and administered the questionnaire with samples served labelled, one at a time. Respondents rated samples on; a 9-point Likert scale (from 1 Extremely dislike, to 9 Extremely Like) for overall impression after looking, touch, smell, and taste the boiled sweetpotato; 5-point Just-about-right (JAR) for colour, sweetness, firmness, mealiness and fibrousness; and Check-all-that-apply (CATA) test for 22 sensory terms that consumers use to describe cooked sweetpotato. A total of 132 adult consumers (70 Male and 62 Female age, ≥18 years), who were familiar with boiled sweetpotato participated in the study.

In Nigeria, to prepare fufu, 10 kgs sample raw roots representing each genotype was processed. The raw roots were peeled, washed, and fully submerged in clean water for three days at room temperature to ferment. Following fermentation, the roots were retrieved and sieved to retain the filtrate, which was left to settle before decanting the excess water. The sediment was placed in a muslin bag for dewatering and subsequently processed into fufu by cooking the paste and stirring over a flame for approximately 10 minutes. The water-to-paste ratio was maintained at 100 mL of water per 70 g of fufu paste. The prepared fufu dough from different genotypes was molded into 35 g balls and randomly coded with three-digit numbers to minimize bias during consumer texting.

NRCRI, holding a national mandate for root and tuber crop research in Nigeria, oversaw the ethical clearance for the study. The food samples were prepared under hygienic conditions and respondents provided written informed consent prior to participation. Respondents assessed samples for overall liking, smoothness, color, softness, and moldability on a 9-point hedonic scale. Additionally, 22 attributes were considered in the Check-All-That-Apply (CATA) questions. The

study was conducted in Imo State, southeastern Nigeria, where fufu is a staple food. A total of 102 consumers from various households participated, comprising 58 women and 44 men.

There were some differences among the countries in the sense of the data collection strategies (Figure 1). The differences were informed by cultural context and historical experiences conducting similar activities. For example, in Mozambique, they are still exploring and comparing the suitability of JAR and CATA for the purpose of conducting forensic analysis on advanced and released sweetpotato genotypes. In Uganda and Nigeria, the most suitable of the two methods given the breeding needs and cultural context have already been identified.

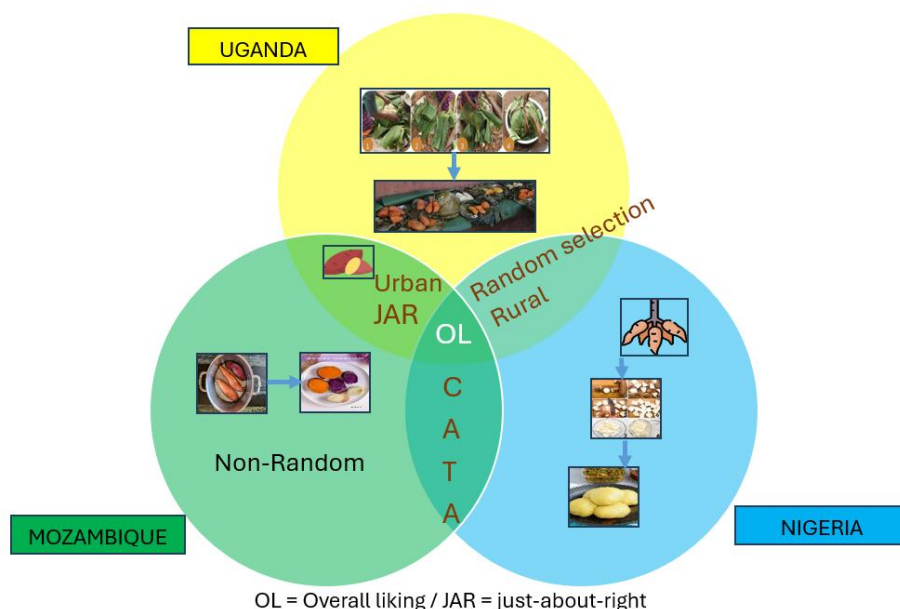


Figure 1. Similarities and differences among data collection approaches used among countries participating in the study.

2.5 Data analysis

Data analysis for all the countries followed three main steps summarized in [Figure 2](#). First consumers were clustered in homogenous groups based on overall-liking ratings using Agglomerative Hierarchical Clustering (AHC) procedure in XLSTAT (Adinsoft). Then penalty analysis using JAR or CATA data was conducted to explore the characteristics that drive liking or disliking among the clusters in each country separately. To conduct penalty analysis for both Uganda and Mozambique, the 5 point just-about-right scale was collapsed into 3 categories by combining the lower end points (1 and 2), and upper point scales (4 and 5) (Ortega-Heras et al., 2019). Using CATA, only attributes that were selected at least 5% times but not more than 45% times (Mozambique) or 50% times (Nigeria) by all consumers in each country and discriminated samples using Cochran’s Q ($p < 0.05$) were included in the penalty analysis procedure. Lastly, Logistic regression was conducted with clusters as dependent variables and sociodemographic characteristics as explanatory variables (logit model). All analyses were done separately for each country.



Figure 2. Flow diagram summarising the data analysis steps used in the study.

In Uganda, clustering was conducted using data collected on the first day (day 1) for both study areas. Since the same participants were invited to participate on both days, sociodemographic data provided on the first day was considered more reliable. In Mozambique data were collected for the same samples across two days with different participants and all the data collected were collated to generate consumer clusters. In Nigeria, all data were collected for the same samples on a single day and were used altogether to generate the clusters. Consumers that were missing overall liking ratings or CATA data were excluded from analysis. These included two consumers in Nigeria whose overall liking data were missing and two and three consumers in Mozambique and Nigeria, respectively, whose CATA data were missing.

While conducting penalty analysis using CATA data in Mozambique, terms like no smell, thick, tasteless, blackish, hard, attractive, good smell, sweet, and nutritious (vitamin A) were excluded for the reasons stipulated earlier. In Nigeria, excluded terms were easy to cut, easy to swallow, heavy weight, moderately soft, smooth, not rise, too hard, and dark in colour.

3. RESULTS

3.1 Consumer preferences without clustering

For consumers in Uganda, average overall liking ratings for sweetpotato samples in Kabarole and Kampala across the two days of evaluation are illustrated in Figure 3. In both locations, the most liked cooked sweetpotato sample belonged to cream-fleshed genotypes, UGP2017 0910-24 and NAROSPOT 1. One of the white-fleshed genotype, UGP2017 0907-31 was slightly liked in both locations while the other UGP2017 0902-54 was disliked. Among orange-fleshed genotypes, D20 and NASPOT 8 were both well liked in the two locations, however, D20 was rated higher than NASPOT 8 on the day when they were evaluated together in Kampala. Other orange-fleshed genotypes including Beaugard, NASPOT 13 O, UGP 2017 0490-966 were disliked in both locations.

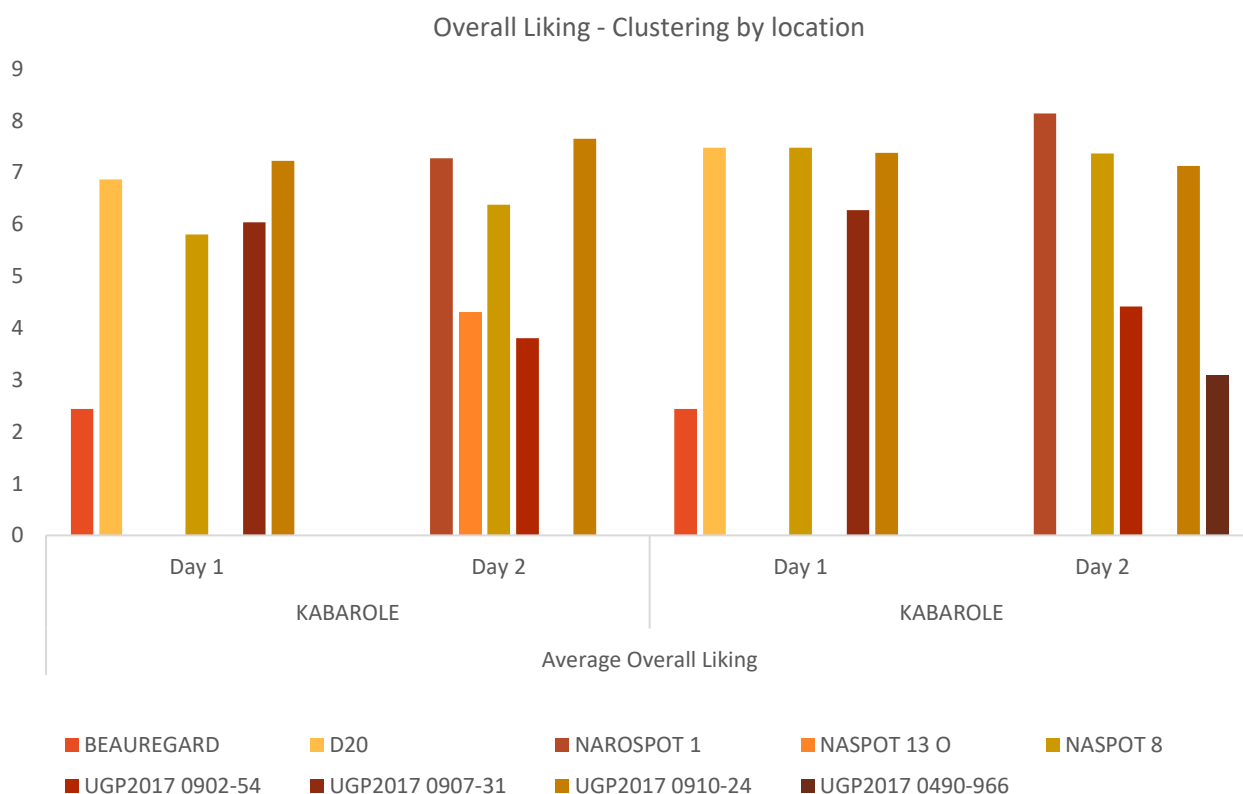


Figure 3. Average overall liking for steamed sweetpotato samples served to consumers in urban areas of Kampala (n = 100 for day 1, n = 95 on day 2) and rural areas of Kabarole in Uganda (n = 121 for day 1, n = 104 for day 2); Overall liking was rated on 9-point.

In Mozambique, all samples of boiled sweetpotato in Mozambique were liked except *Victoria*, for which consumers assigned an ambivalent score as shown in Figure 4. As expected, *Victoria* and *Ken* were the least preferred and *N'satimuni* and *Secai* were the most preferred.

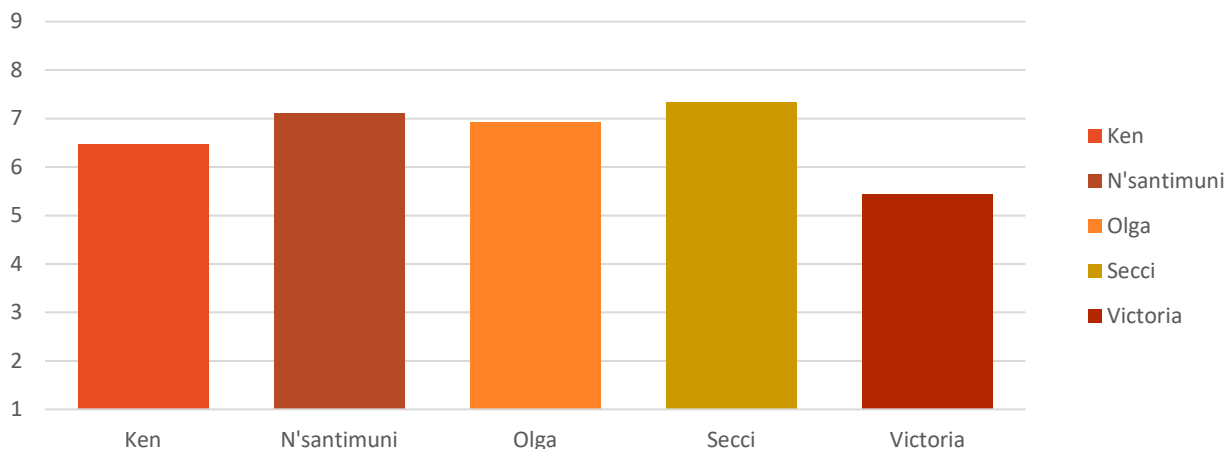


Figure 4. Average overall liking for boiled sweetpotato samples served to consumers in urban areas of Maputo, Mozambique (n = 132) by genotype; Overall liking was rated on 9-point hedonic scales from 1 – dislike extremely to 9- like extremely anchored at 5 – neither like nor dislike.

Fufu consumers in Nigeria liked BABA70, *Governor*, *Nwaocha*, TME419 and TMS 98/0505, with TME 419 being most liked (Figure 5). On the other hand, *NO HUNGER* and UNUCASS 37 were disliked.

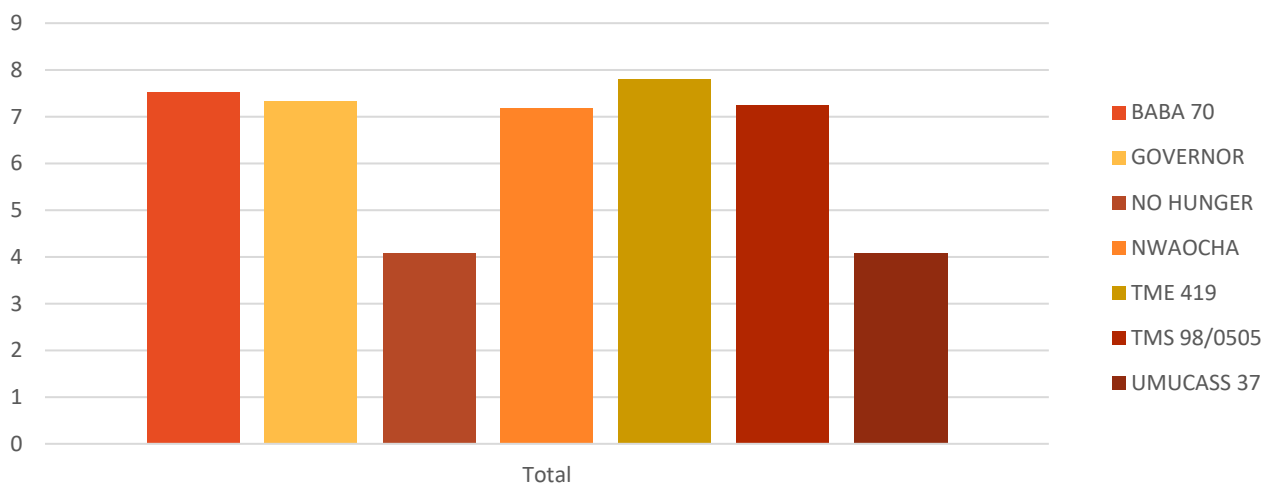


Figure 5. Average overall liking for fufu samples prepared from 8 cassava genotypes served to consumers in rural areas of Imo and Abia State, Nigeria (n = 102); Overall liking was rated on 9-point hedonic scales from 1 – dislike extremely to 9- like extremely anchored by 5 – neither like nor dislike.

3.2 Sweetpotato and cassava preferences among homogenous consumer clusters

3.2.1 Steamed sweetpotato in Uganda

Upon clustering, consumers in Uganda, Mozambique and Nigeria were separated in homogenous clusters by their liking patterns. In Uganda, three clusters emerged (Figure 6), the first one comprising about 24% of consumers with demonstrated a unique dislike for UGP2017 0907-31. The second cluster comprising nearly half of the consumers (49%) did not demonstrate a unique dislike for any sample. And the last cluster, comprised slightly over a quarter of the consumers and displayed a unique aversion towards orange fleshed genotypes with an average score less than 6 for all orange-fleshed genotypes.

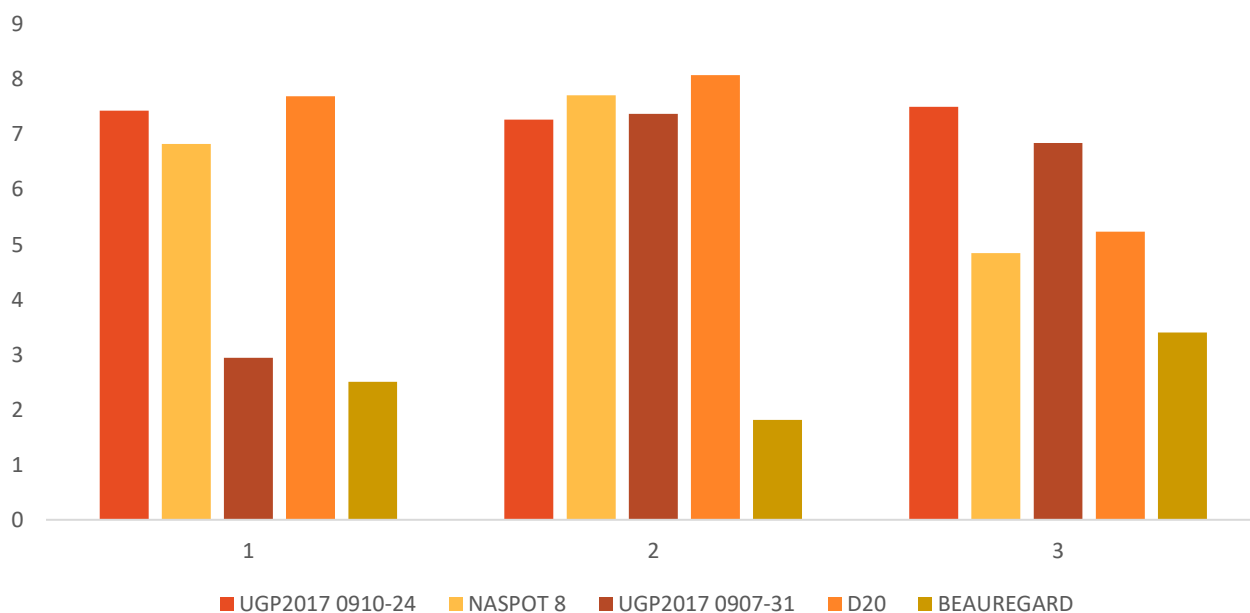


Figure 6. Consumer clusters by steamed sweetpotato sample preference as rated on a 9point Likert scale in rural and urban Uganda (n = 221)

3.2.2 Boiled Sweetpotato in Mozambique

In Mozambique, clustering revealed two homogenous consumer groups (Figure 7); over half (52%) were in the group that did not display dislike towards any of the samples and the rest were in a group that did not particularly like the orange-fleshed genotypes; *Ken and Victoria*.

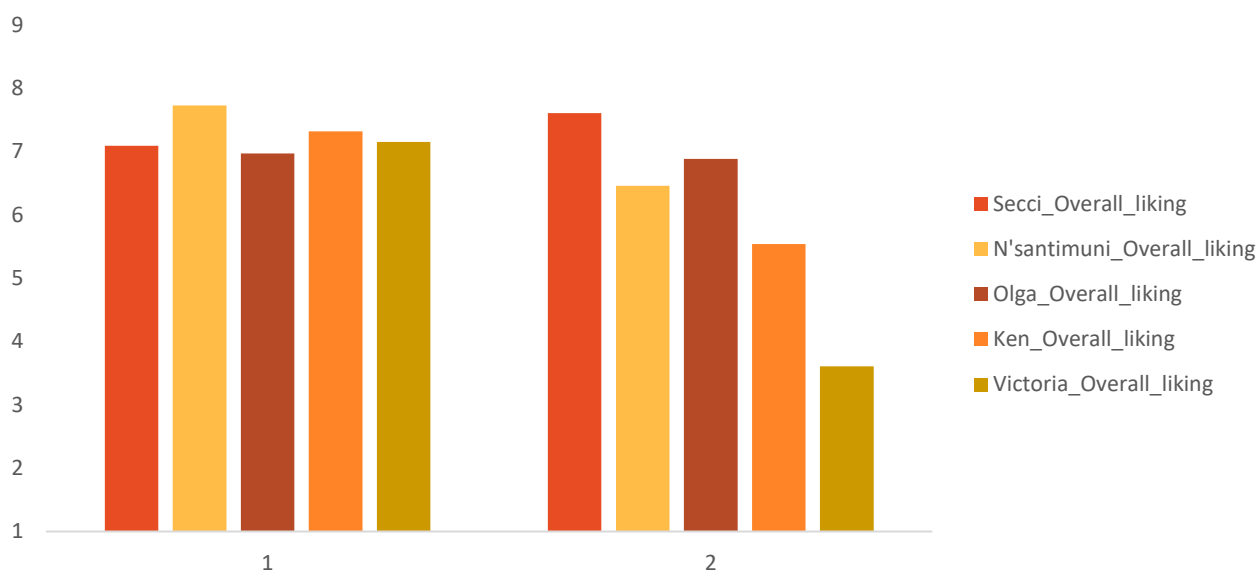


Figure 7. Consumer clusters by steamed sweetpotato sample preference as rated on a 9point Likert scale in urban Mozambique (n = 130)

3.2.3 Cassava fufu in Nigeria

Clustering with *fufu* consumers in Nigeria yielded four clusters (Figure 8). While all clusters disliked *NO HUNGER*, 15% of consumers in cluster 1 uniquely disliked *GOVERNOR*, 25% of consumers grouped in cluster 2 particularly disliked TME 419, 18% of consumers in cluster 3 uniquely disliked UMUCASS 37, and cluster 4 did not dislike any additional genotype besides *NO HUNGER*.

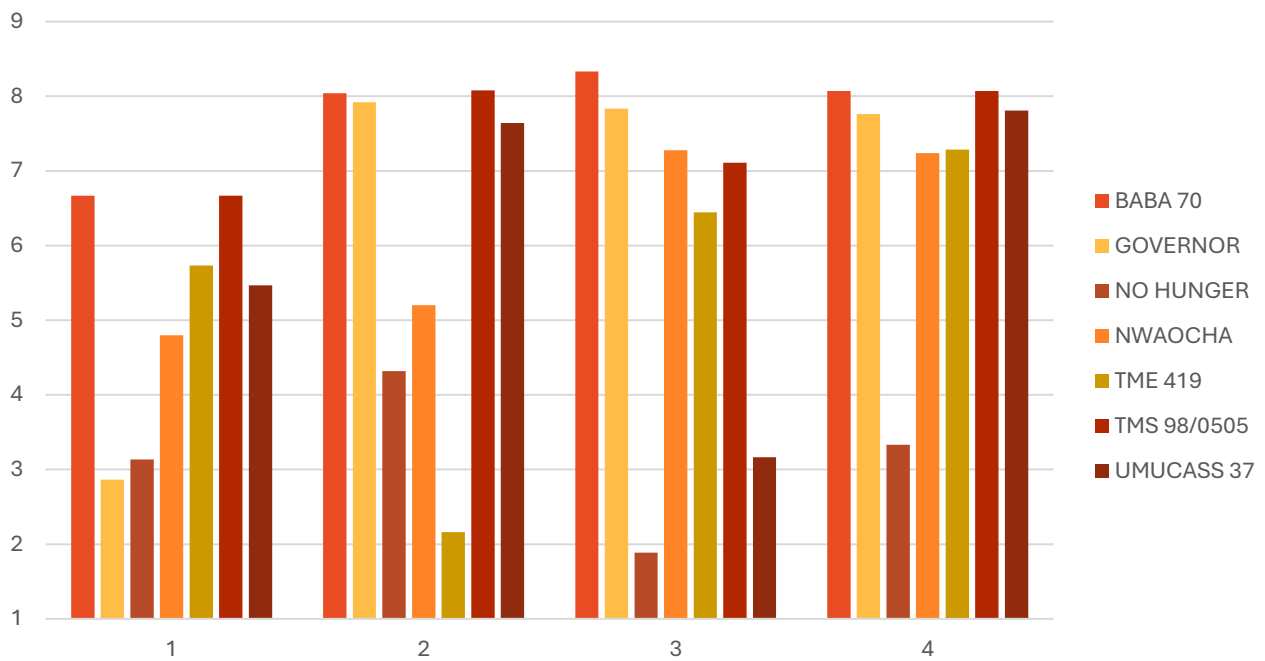


Figure 8. Consumer preferences for cassava fufu samples rated by consumers (n=100) in rural Nigeria on 9-point scale by cluster.

3.3 Drivers of sweetpotato and cassava preferences by homogenous consumer clusters

Penalty analysis was conducted using data generated from the just-about-right question in Uganda and Mozambique. To identify the most important sensorial reasons underlying consumers' reduction in overall liking (mean-drop) minimum critical threshold of 20% consumers accompanied by 2 unit mean drop in overall liking was set. In Uganda consumers in all three clusters penalized genotypes for being less sweet, less firm or less mealy than they would like (Figure 9). Since each of the three clusters indicated a dislike to different groups of samples, it indicates that consumers have different ranges of sweetness, firmness and mealiness that appeal to them.

For Mozambique, minimum critical threshold for penalty analysis using just-about-right data was set at 20% consumers accompanied by 1 unit mean drop in overall liking. Consumers in cluster 1 penalized samples for not having a dark enough colour while those in cluster 2 additionally penalized samples for not being sweet enough, firm enough or mealy enough (Figure 10).

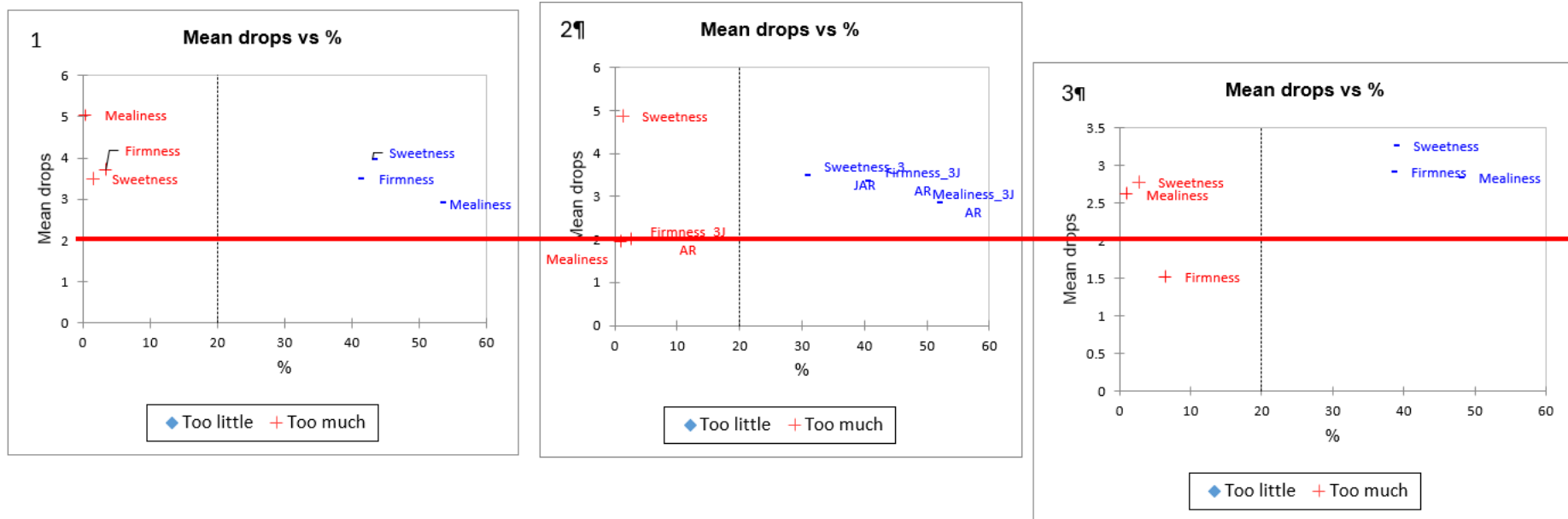


Figure 9. Mean drops (y-axis) and accompanying consumer frequency (x-axis) for samples consumers indicated to be being much less (<3, indicated by blue font) or much more (>3 indicated by red font) in various sensory characteristics. Separate graphs are plotted for each of the consumption clusters 1, 2, 3 denoted by the same labels. Consumers of steamed sweetpotato (n= 221) rated sweetness, firmness and mealiness on 5-point Just-About-Right scales anchored at 3 (JAR) in rural Kabarole and urban Kampala, Uganda. Critical minimum threshold set at 20% consumers and 2 unit mean drop and the most important drivers of liking are located to the right of dotted line and above the red line are most important drivers of liking.

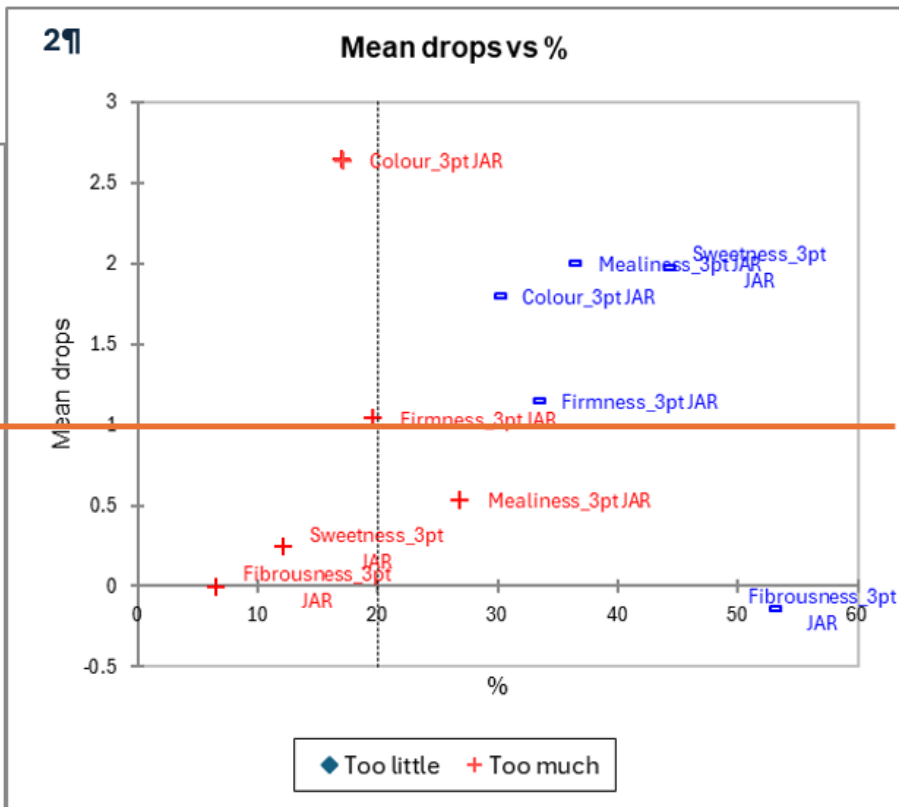
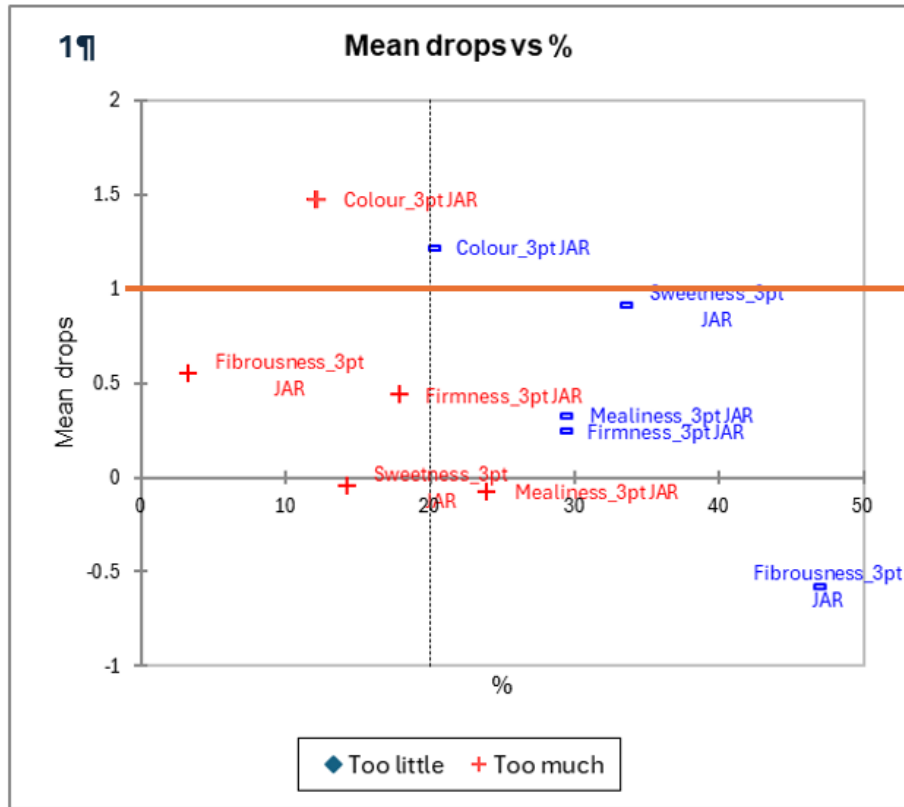


Figure 10. Mean drops and accompanying consumer frequency associated with boiled sweetpotato samples being perceived as having less than (JAR <3, indicated by blue) or too much (JAR > 3, indicated by red) of various sensory characteristics as rated by consumers of boiled sweetpotato in urban Mozambique (n= 132) on 5-point JAR scales anchored at 3 (JAR). Separate graphs are plotted for each of the consumption clusters 1 and 2 denoted by the same labels. Critical minimum threshold set at 20% consumers and 1 unit mean drop and the most important drivers of liking are located to the right of dotted line and above the red line are most important drivers of liking.

Additionally, penalty analysis was done using data from CATA questions in Mozambique and Nigeria. In both countries, critical minimum threshold for impactful sensory descriptors was set at 1-unit negative or positive change in mean overall liking accompanied by 20% of consumers. Descriptors associated with a positive change and thereby increase in overall liking have an overall positive impact while those associated with a negative change thereby a decrease in overall liking have an overall negative impact. In Mozambique, using CATA data for penalty analysis, no sensory characteristics reached the minimum threshold for positive or negative impact for consumers in cluster 1 did (Figure 11). On the other hand, no sensory characteristics met the minimum threshold for positive impact but orange colour had a significant negative impact for consumers in cluster 2. This is in line with the varietal preferences since consumers in cluster 2 did not like any of the two orange-fleshed genotypes.

In Nigeria, based on the penalty analysis using CATA data, all consumer clusters rated samples described as having high starch content higher on the scale for overall liking but lower for those described as being sticky. This was the trend associated with cluster 1 (Figure 12). Cluster 2 additionally rated samples associated with butter cream colour with higher liking and not easy to mould and too soft with lower liking. Cluster 3, was also associated buttercream colour with higher liking along with draw little, and white. On the other hand, samples that were penalized for liking were described as being sticky and yellow. Cluster 4 also penalized samples that were sticky and yellow but rated overall liking higher for samples that were associated with having high dry matter (Figure 16). All consumers like *fufu* with high starch that is not sticky. While a large proportion of consumers (cluster 2, 3, and 4) like butter-cream colour, almost an equally large proportion of consumers (cluster 3 and 4) do not like yellow *fufu*.

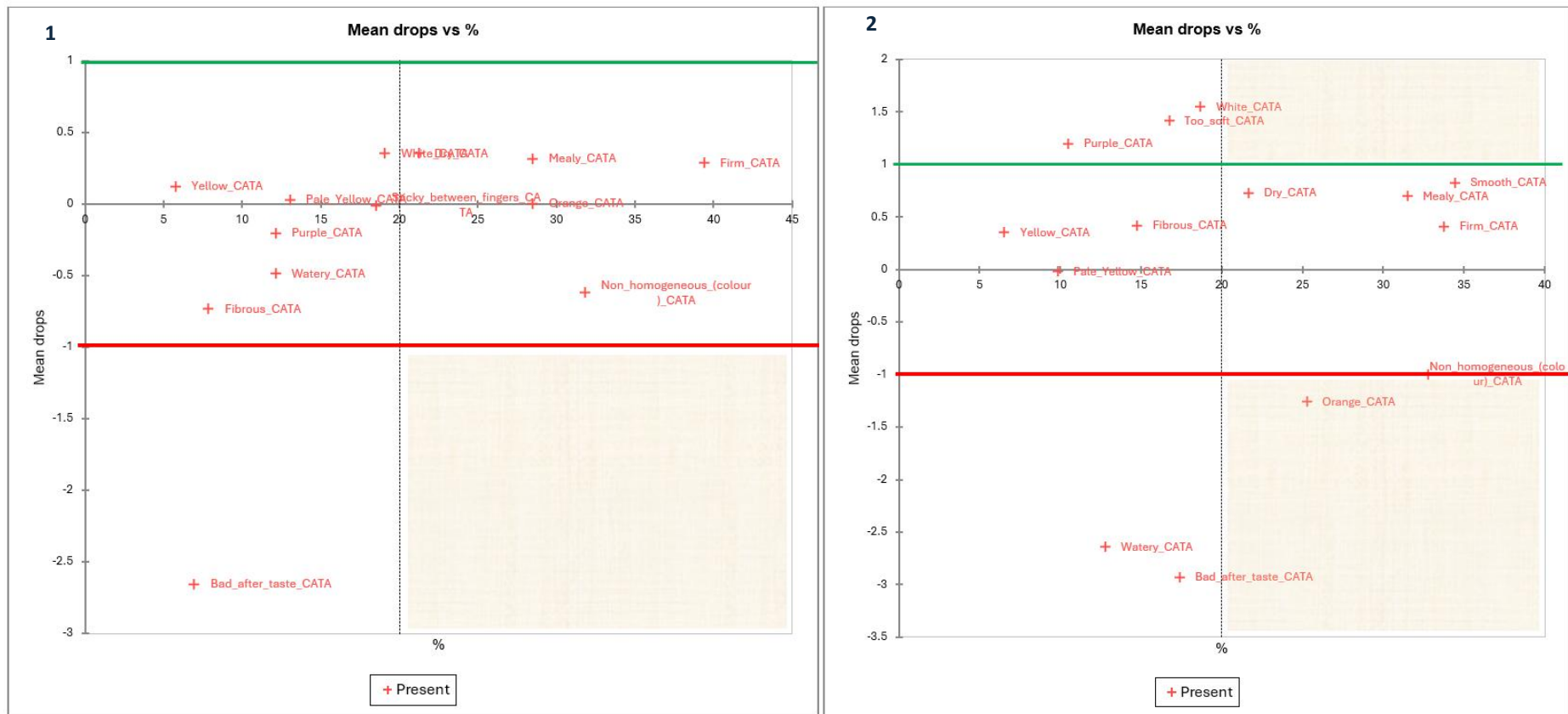


Figure 11. Mean drops and accompanying consumer frequency associated with boiled sweetpotato samples for various sensory characteristics as rated by consumers of boiled sweetpotato in urban Mozambique (n= 132) on Check-all-that-apply question. Separate graphs are plotted for each of the consumption clusters 1, 2 denoted by the same labels. Critical minimum threshold for impact set at 20% consumers and 1 unit mean drop and the most important drivers of liking and disliking. Descriptors with a positive impact are located in the shaded area above the green line while those with negative impact are located in the shaded area below the red line.

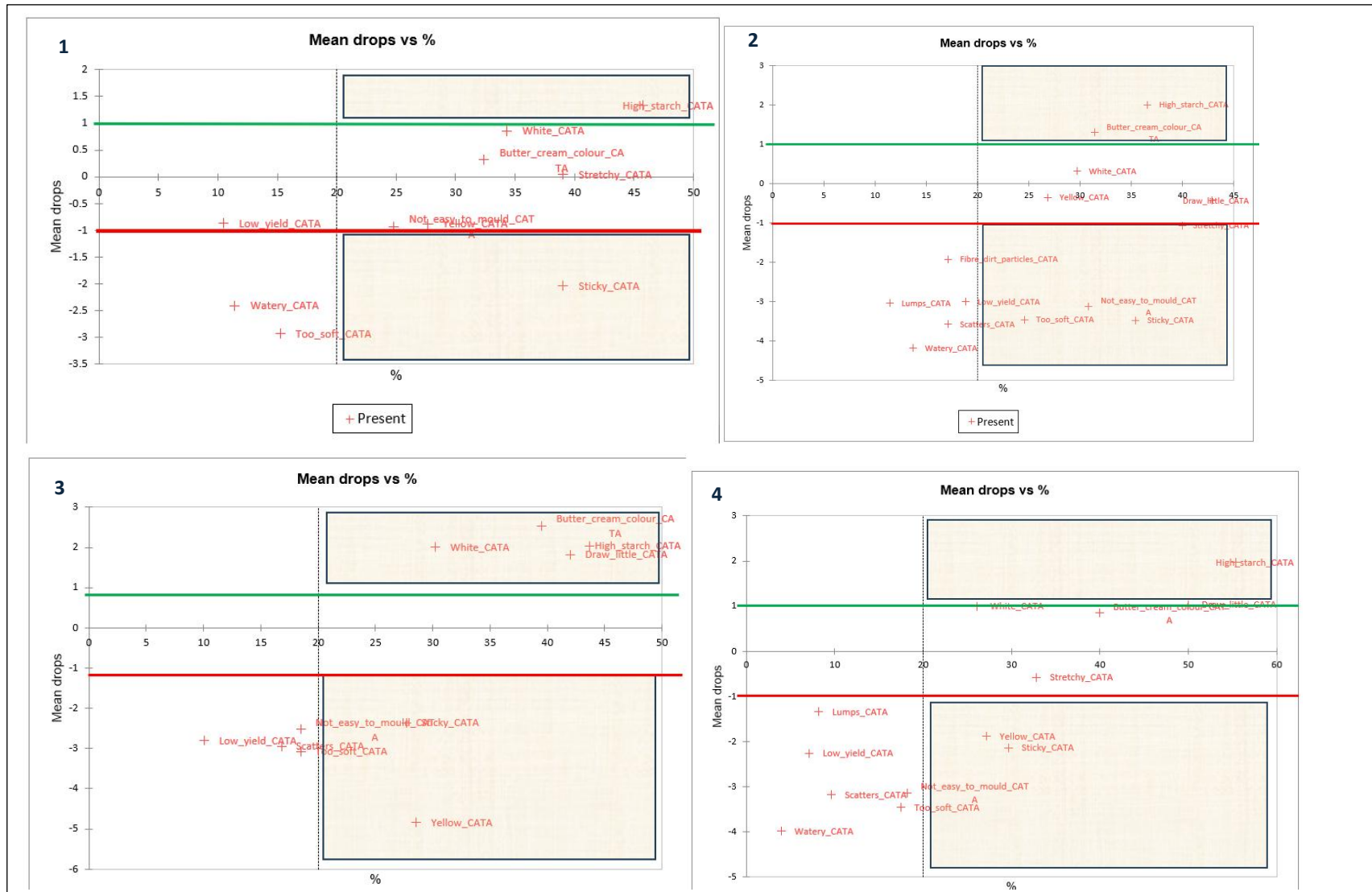


Figure 12. Mean drops and accompanying consumer frequency associated with fufu samples for various sensory characteristics as rated by consumers of boiled sweetpotato in rural Nigeria (n= 100) on Check-all-that-apply question. Separate graphs are plotted for each of the consumption clusters 1, 2, 3 and 4 denoted by the same labels. Critical minimum threshold for impact set at 20% consumers and 1 unit mean drop and the most important drivers of liking and disliking. Descriptors with a positive impact are located in the shaded area above the green line while those with negative impact are located in the shaded area below the red line.

In summary (Table 4), preferences for cluster 3 and 4 appear to be highly influenced by colour while preferences among consumers in cluster 2 appear to be highly influenced by texture characteristics. Uniquely, cluster 1 seems to be influenced by the fewest sensory characteristics.

Table 4. Summary of mean positive and negative impact of significant CATA terms by fufu consumer clusters in rural Nigeria.

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Positive impact				
Butter-cream colour	NS	1.3 (31)	2.5 (40)	NS
white	NS		2.0 (30)	1.0 (26)
High starch	1.3 (46)	2.0 (37)	2.0 (44)	2.0 (55)
Draw little	NS	NS	1.8 (42)	1.0 (50)
Negative impact				
Yellow colour	NS	NS	-4.8 (29)	-1.9 (27)
sticky	-2.0 (39)	-3.5 (35)	-2.4 (28)	-2.1 (29)
stretchy	NS	-1.1 (40)	NS	NS
Not easy to mould	NS	-3.1 (31)	NS	NS
Too soft	NS	-3.5 (25)	NS	NS

CATA terms that did not reach the minimum critical threshold for impact (20% consumers 1-unit change in mean overall liking) for a given cluster are denoted by “NS” in the cluster column.

3.4 Sociodemographic characteristics associated with clusters

In Uganda, consumers of steamed sweetpotato grouped in cluster 1 is associated with a smaller proportion of older individuals (Table 5), compared to those in cluster 2. Cluster 3 is associated with a lower proportion of women and previous trading experience compared to cluster 2.

Table 5. Sociodemographic characteristics and sweetpotato consumption patterns associated with the three consumer clusters.

Factor	Cluster 1 V Cluster 2 (ref)		Cluster 3 V Cluster 2 (ref)		Cluster 1 V Cluster 3 (ref)	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Location						
Kabarole	1.439 (0.628 – 3.296)	0.389	0.491 (0.224 – 1.080)	0.077	2.928 (1.158 – 7.403)	0.023
Kampala (ref)						
Age group						
Senior	0.180 (0.051 – 0.633)	0.008	0.453 (0.136 – 1.504)	0.196	0.398 (0.086 – 1.837)	0.238
Adult	0.420 (0.191 – 0.923)	0.031	0.890 (0.410 – 1.933)	0.769	0.472 (0.196 – 1.134)	0.093
Youth (ref)						
Sex						
Female	0.776 (0.378 – 1.591)	0.488	0.439 (0.237 – 0.968)	0.049	1.619 (0.735 – 3.568)	0.232

Male						
Consumption						
Frequent	1.448 (0.687 – 3.651)	0.330	0.866 (0.433 – 1.731)	0.683	1.673 (0.741 – 3.775)	0.216
Occasional						
Farming status						
Farmer	0.632 (0.206 – 1.937)	0.422	0.744 (0.262 – 2.116)	0.579	0.850 (0.289 – 2.501)	0.767
Never farmed						
Trading status						
Trader	1.783 (0.789 – 3.832)	0.170	2.190 (1.012 – 4.736)	0.046	0.794 (0.327 – 1.925)	0.261
Never traded						

In Mozambique, individuals who consumed boiled sweetpotato less frequently were more likely to be grouped in cluster 2, compared to those in cluster 1 (Table 6).

Table 6. Sociodemographic characteristics and sweetpotato consumption patterns associated with the two consumer clusters in Mozambique.

Factor	Cluster 2 V Cluster 1 (ref)	
	OR (95% CI)	p-value
Occupation		
Formal	0.646 (0.232 – 1.794)	0.401
Informal	0.901 (0.323 – 2.513)	0.842
None (ref)		
Age group		
Senior	0.893 (0.303 – 2.628)	0.837
Adult	1.033 (0.433 – 2.465)	0.941
Youth (ref)		
Sex		
Female	1.284 (0.599 – 2.754)	0.520
Male		
Consumption		
Frequent	0.418 (0.190 – 0.920)	0.030
Occasional		
Wealth status		
High Income	0.625 (0.219 – 1.785)	0.380
Low-income	0.666 (0.252 – 1.760)	0.412
Middle-income (ref)		
Trader	1.783 (0.789 – 3.832)	0.170
Never traded		

For fufu consumers in Nigeria, compared to cluster 4, consumers in other clusters were associated with an increased likelihood to eat *fufu* at breakfast than lunch (Table 7). Cluster 1—in addition was associated with increased likelihood of being adults than youths. Consumers in cluster 2 were less likely to be frequent consumers of *fufu* and less likely to be primarily farmers for an occupation, compared to those in cluster 4. Consumers in cluster 3 had no additional significant associations compared to cluster 4, besides the occasion on which *fufu* is mostly consumed.

Table 7. Sociodemographic characteristics and fufu consumption patterns associated with the four consumer clusters in Nigeria.

Factor	Cluster 1 V Cluster 4 (ref)		Cluster 2 V Cluster 4 (ref)		Cluster 3 V Cluster 4 (ref)	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Age group						
Senior	0.197 (0.023 – 1.670)	0.136	0.368 (0.047 – 2.890)	0.342	0.329 (0.044 – 2.475)	0.280
Adult	0.420 (0.019 – 0.968)	0.046	0.456 (0.070 – 2.986)	0.413	0.436 (0.081 – 2.335)	0.332
Youth (ref)						
Sex						
Female	3.553 (0.738 – 17.095)	0.114	1.974 (0.551 – 7.064)	0.296	2.971 (0.788 – 11.200)	0.108
Male						
Consumption						
Frequent	1.448 (0.687 – 3.651)	0.330	0.147 (0.031 – 0.697)	0.016	0.941 (0.134 – 6.597)	0.951
Occasional						
Common meal						
Breakfast	16.734 (1.198 – 233.661)	0.036	12.944 (1.678 – 99.867)	0.014	8.581 (1.137 – 64.746)	0.037
Dinner	3.539 (0.521 – 24.022)	0.196	2.060 (0.428 – 9.911)	0.367	1.835 (0.364 – 9.245)	0.462
Inbetween meal		0.995	0.354 (0.015 – 8.303)	0.519	4.535 (0.164 – 118.473)	0.364
Lunch (ref)						
Farming status						
Not Primarily farmer	1.139 (0.173 – 7.486)	0.892	0.216 (0.216 – 0.996)	0.045	2.207 (0.343 – 14.186)	0.405
Primarily farmer (ref)						
Occupation type						
Formal	1.103 (0.004 – 30.590)	0.954	0.956 (0.083 – 10.996)	0.971		
Informal	11.882 (0.705 – 200.115)	0.086	1.768 (0.171 - 18.325)	0.633		
None (ref)						

4. DISCUSSION

The study revealed homogenous clusters of sweetpotato consumers in Uganda and Mozambique and *Fufu* consumers in Nigeria, grouped by their sensory preferences. The clusters were characterised by the most important sensory characteristics influencing preferences, and also defined them by socio-demographic characteristics and product consumption patterns. In Uganda, three groups, all of which penalized sweetpotato samples that were considered inadequately sweet, firm or mealy. Genotypes and socio-demographic characteristics were more representative of clusters. Cluster 1 was associated with youths, and uniquely disliked a white-fleshed genotype (UGP2017 0907-34). Cluster 2 was the largest group and did not indicate a unique dislike for any of the genotypes. Besides, consumers in this group were more likely to be from Kabarole (rural). Cluster 3 did not particularly like any of the orange-fleshed genotypes given the outright dislike for Beauregard and NASPOT 8 and ambivalence towards D20. In addition, consumers in cluster 3 were more likely to be men with trading experience.

Given the penalty analysis results from Uganda, all the three clusters penalized sweetpotato for being less sweet, less firm and less mealy than they desired indicating that while the same characteristics are important for all clusters, the level desired may vary by cluster. In addition, since the consumers varied in the genotypes they dislike could be indicative of possible trade-offs. These trade-offs could be influenced by factors outside the sensory characteristics. Cluster 3 of men traders penalized orange fleshed genotypes perhaps the demand in the market is low and there isn't enough information about their possible marketability. Cluster 1 of young people who are usually more open to trying out new things preferred the OFSP NASPOT 8 and D20 to UGP2017 0907-31

Sweetpotato consumers in Mozambique were separated into two clusters that varied in regards to the preferred genotypes, sensory drivers of preference and consumption frequency. Cluster 1 liked all the samples and only penalized those that they described as being non-homogenous, indicating minimal influence of sensory characteristics on their preferences. Additionally, they were more likely to consume sweetpotato occasionally. Consumers in cluster 2 were more frequent consumers of sweetpotato who indicated a particular dislike for orange-fleshed genotypes. In summary cluster 1 comprises occasional consumers of sweetpotato which explains why they are less critical about the samples with generally less preferred sensory profiles compared to the frequent consumers in cluster 2. This observation highlights the importance of using CATA questions with individuals who are frequent consumers as they are more likely to understand how to associate the terms with their product perceptions.

Fufu consumers in Nigeria were clustered into four groups. The groups were differentiated by their genotype preferences, sensory drivers of preference, socio-demographic characteristics and *fufu* consumption habits. The first cluster showed a unique dislike for *GOVERNOR*. Their preference did not appear to be informed by sensory characteristics since they only penalised samples for being sticky but favoured starchy samples. However, the sensory drivers are misaligned with the varietal preference since sensory profiles using the same data do not indicate *GOVERNOR* as being particularly sticky. This shows the possibility of non-sensory-based reason informing the non-preference for this genotype. Additionally, the consumers were more likely to be adults. Cluster 2 showed a particular dislike for TME 419 and their preferences were highly influenced by textural characteristics. Consumers in cluster 2 were likely to eat *fufu* occasionally and not be primarily farmers. Consumers in cluster 3 indicated a specific dislike for UMUCASS37 whose preferences were driven by colour and ate *fufu* mostly at breakfast. Most consumers belonged to cluster 4 which did not uniquely dislike any genotype but whose preferences were highly influenced by colour and were more likely to consume *fufu* at lunch. In brief there are two broad groupings of *fufu* consumers depending on the meal at which they commonly eat *fufu* and the type of sensory characteristics that most inform their preferences.

4.1 Recommendations

The clear dislike for orange fleshed sweetpotato genotypes is evidence for considering flesh colour when defining sweetpotato market segments in both locations. However, in Mozambique, unlike Uganda both the genotypes selected to represent those with least preferred sensory profiles were orange. In future such studies should include orange fleshed genotypes with representing both most preferred and least preferred sensory profiles to confirm the findings.

While it is clear that sensory characteristics are important drivers of preference, there are instances where it is unclear which specific ones are driving preference for certain varieties. Such is the case with one of the clusters in Nigeria (cluster 1) with the variety, *GOVERNOR*. This could mean that either important sensory characteristics for this group may have been excluded from the list during analysis or that non-sensory factors were more important for this choice. In cognition of possible influence of non-sensory factors to liking, sensory analysis should be complemented with other information.

In Nigeria, it emerged that two main factors differentiated consumer groups: occasion at which consumers most commonly eat *fufu* (lunch or breakfast) and the most important sensory module influencing liking. The people who eat *fufu* for lunch and are more sensitive to colour are in the biggest group. This means that prioritising the improvement of *fufu* colour would be more effective.

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