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Priority quality traits for gendered sweetpotato breeding in Mozambique

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Introduction: Sweetpotato breeders strive to develop varieties that address productivity challenges farmers face in sub-Saharan Africa (SSA). However, adoption of these varieties is low, partly attributed to limited attention to attributes desired by the end-users.

Methods: This study sought to identify the key traits preferred by eight women processors and 426 consumers (180 male, 246 female) in Manhiça, Marracuene and Maputo districts, Mozambique. Processing diagnostics and consumer studies evaluated two local varieties ('Lilas', 'N'santimuni') and two improved varieties ('Alisha', 'Irene'). Data from processors were analyzed using content analysis and summary statistics. Consumer hedonic data were analyzed using clustering and regression models, while Penalty analysis and Multiple correspondence analysis were performed for the Just-about-right and Check-all-that-apply tests respectively.

Results: Processors prioritized mealiness, sweet taste, not fibrous, good sweetpotato smell, ease of peeling, easy to cook and good appearance for the boiled root. 'N'santimuni' was the most preferred variety for processing. Consumers preferred 'N'santimuni' and 'Lilas' because of their high dry matter, pleasant sweetpotato smell, firmness in the hand, smoothness when eating and sweet taste. 'Alisha' and 'Irene' were the most penalized for low scores on sweetness, mealiness, and firmness. Women consumed sweetpotato more frequently than men and had better discernment of sweet taste, homogeneity and colour. Also, youth and more educated consumers disliked improved varieties more than adults and lower income consumers.

Discussion: Processors and consumers strongly indicated their preference and importance of quality attributes such as mealiness, sweet taste, firmness for boiled sweetpotato. However, such traits are rarely included in breeding designs. Breeding programs can thus be enhanced by studies of biophysical and chemical parameters of sweetpotato. This will enable quantification incorporation of these quality attributes.

KEYWORDS

sweetpotato, preferred, end-user traits, gender, breeding, Mozambique

1. Introduction

Sweetpotato (*Ipomoea batatas* Lam.) is an important food and income security crop in many developing nations. In Mozambique, sweetpotato is the fifth most important food crop (Low et al., 2007; Andrade et al., 2016a) and white-fleshed farmer varieties dominate the market. However, sweetpotato's contribution to food and income has not been fully realized, due to

climate variability and low productivity; attributed to poor quality seed and to pests and diseases (Grüneberg et al., 2015). Since 2011, breeders in Mozambique have been developing new varieties targeting different market segments, populations, and environments to address these challenges and enhance sweetpotato performance (Andrade et al., 2017; Makunde et al., 2018).

The Sweetpotato breeding program in Mozambique aims to develop nutritious varieties for drought-prone areas in Southern Africa. The focus was to reduce Vitamin A deficiencies affecting 71% of children under the age of five (Nutrition Division in Department of Community Health, 2003). The major breeding partners are the Instituto de Investigação Agrária de Moçambique (IIAM) and the International Potato Center (CIP). Over the years, significant advancements in sweetpotato breeding techniques, such as participatory varietal selection (PVS), accelerated breeding scheme (ABS), heterosis exploiting breeding schemes (HEBS), and high-throughput phenotyping (e.g., remote sensing), have led to the development of superior productive and nutritious varieties (Andrade et al., 2017; Makunde et al., 2018; Gasura et al., 2021; Jogo et al., 2021a,b).

Consequently, CIP and IIAM have released 28 varieties comprising mostly OFSP as well as purple and white fleshed varieties. Despite these breeding efforts, the uptake of improved sweetpotato varieties in Mozambique remains relatively low, with less than 40% uptake (McEwan et al., 2021). For instance, only a few of the released varieties are actively grown and local varieties command over 60% of the market share (Jogo et al., 2021a,b). The low adoption of these varieties is primarily attributed to a strong emphasis on nutrition and agronomic traits at the expense of end-user preferences (Jenkins et al., 2018).

End-users' preferences for sweetpotato varieties are influenced by a range of traits, including sensory characteristics of the final products (Brouwer, 2021). While some of the preferred characteristics align across the value chain, others are not negotiable and vary from user to user, driving variety adoption. For example, eating quality traits such as taste and dry matter content influence farmer's adoption and dis-adoption of orange-fleshed sweetpotato (OFSP) varieties in Mozambique (Jogo et al., 2021a,b). Also, urban consumers considered high dry matter content to be an important characteristic for OFSP varieties to compete with local varieties (Brouwer, 2021). Conversely, infants and mothers prefer OFSP with low dry matter. Such polarity in preference within the household unit further challenges the suitability of OFSP varieties even at the lowest social structure (Tumwegamire et al., 2004).

In order to promote the uptake of new breeding innovations, several studies have advocated for an interdisciplinary approach to understand end-user's preferences better, and integrate newly identified characteristics into breeders' product profiles (Thiele et al., 2021; Troullaki et al., 2021). Furthermore, a review by Thiele et al. (2021) highlighted the lack of evidence in understanding and addressing gendered differences in quality and post-harvest traits for roots, tubers, and bananas. To address this gap, contemporary approaches such as gendered food mapping of crop value chains, processing diagnostics and descriptive sensory analysis have been adopted to systemically inform product design (Dufour et al., 2021; Forsythe et al., 2021). Using this approach, Mwanga et al. (2021) found that women preferred quality and culinary traits such as sweet taste and shape while men preferred marketing traits like big sweetpotato roots. The traits preferred by women were related to local varieties whereas men prioritized improved, high-yielding varieties, which aligns to findings for potato in Uganda (Mudege et al., 2021).

In Mozambique, a gendered mapping study was conducted in 2019 in Manhiça, and Marracuene districts, and the city of Maputo, to examine the sweetpotato value chain (Mayanja et al., 2021). This study uncovered significant differences in preferred characteristics among different actors in the value chain and by gender. The sweetpotato chain is characterized by farmers/producers, traders, processors and consumers. Producers prioritized raw sweetpotato with a 'fresh smell' and rich in 'vitamin A'. Traders and food vendors emphasized characteristics such as 'no sprouts', 'absence of black spots' and 'medium-sized roots'. Consumers, on the other hand, had high preferences for boiled roots that were 'firm', 'mealy', had a 'good aroma', and were 'easy to cook'. Certain trait preferences were gendered; only women valued 'no fiber' at the processing and final product stages while men prioritized traits such as 'sweet taste' for raw roots, and 'firmness' for the boiled roots. Caution was made on preferred traits like high yield because though deemed positive for income generation; the trait could potentially decrease women's access to productive resources and increase their labor burden. Similarly, early maturity was viewed as beneficial for addressing low food supplies after extended dry periods, but had negative implications for labor demand.

Another study conducted by Mulwa et al. (2021) in Mozambique also highlighted gender differences in preferred traits with women prioritizing vitamin-A, taste, and marketability while men focused on agronomic traits such as disease and drought resistance. Both studies recommended that breeders take into account gender and value chain actor differences in trait prioritization.

As a follow-up to these studies, processing diagnostic and consumer analyzes for boiled sweetpotato were conducted in September 2021, incorporating an intersectional lens. The specific objectives of the studies were to identify the most desired and least desired characteristics for (i) processing and (ii) consumption of boiled sweetpotato. The findings from these analyzes aimed to update the gendered sweetpotato product profile and traits dictionary. By better understanding the end-user's needs, these findings will contribute to improved design and deployment of new varieties that align with users' preferences leading to increased adoption.

2. Methodology

2.1. Study location

Manhiça and Marracuene are among the top sweetpotato producing districts in Mozambique, while the city of Maputo has both peri-urban and urban consumers (Figure 1). These locations were suitable for the study and enabled understanding of the desired sweetpotato traits by sex, age and wealth categories. Respondents from districts of Manhiça and Marracuene represented rural consumers which enabled comparison with urban respondents from Maputo. These districts also had high investment by CIP and IIAM in promoting the 28 released sweetpotato varieties.

The study was conducted in two stages using a mixed methods approach adapted from Forsythe et al. (2021). In the first stage, participatory processing diagnostics were conducted followed by consumer tests in the second stage. The processing diagnostics were done in the rural districts of Manhiça and Marracuene, while the consumer study was conducted in both the rural districts (Manhiça and Marracuene) and in the city of Maputo.



FIGURE 1 Map of Mozambique showing study areas of Manhica, Marracuene and Maputo.

TABLE 1 Description of materials used in the study.

| Material | Source | Selection Criteria* | Classification |
|-------------|-----------------|---------------------|-----------------------|
| Lilas | Farmer's fields | Preferred | Local, purple fleshed |
| N'santimuni | Farmer's fields | Most Preferred | Local, white fleshed |
| Irene | Breeding trials | Not preferred | Improved, Orange |
| Alisha | Breeding trials | Intermediate | Improved, Orange |

*Based on findings from the Gender Mapping Study (Mayanja et al., 2021).

We obtained pre-ethical approval from the local government and department of agriculture who allocated us extension agents and agricultural officials to join the study team, in compliance with the ethical approval. Local leaders too approved the study. We also obtained individual signed consent from the respondents.

2.2. Study materials

Four varieties that had previously been identified in the gender mapping study: 'Lilas', 'Alisha', 'Irene' and 'N'santimuni' were sourced for the study (Table 1).

'Lilas' and 'N'santimuni' are farmer varieties with no known breeding history and origin. 'Lilas' is a predominantly purple fleshed variety that we suspect to have escaped from breeding trials. 'N'santimuni' on the other hand is white fleshed. The storage roots of both these varieties do not disintegrate when boiled and remain firm; which endears them to consumers. These varieties are commonly grown in Marracuene and Manhica districts.

'Alisha' and 'Irene' are improved varieties released by the breeding program in 2016 and 2011, respectively. Both varieties have a light orange flesh color. Storage roots of 'Alisha' maintain a firm texture after boiling while 'Irene' is hard (Tumwegamire et al.,

2014). Both 'Alisha' and 'Irene' are selections from open pollinated polycross nurseries with Ejumula and Kakamega as a female parent respectively; but their male parents are unknown (Andrade et al., 2016b).

Roots of local varieties were prepared and evaluated within 48 h of harvesting in Marracuene and Manhiça. Roots from improved varieties were evaluated within 72 h. For Maputo, all varieties were prepared and evaluated between 72 and 96 h of harvesting. This is similar to the usual time lag between harvest and consumption for consumers in rural and urban areas.

2.3. Participatory diagnostic study

Participatory processing diagnosis was conducted with eight women processors: four processors from Manhiça and four from Marracuene as guided by Bouniol et al. (2017). The processors were purposely selected with the aid of agricultural extension agents using two criteria, viz. experienced in the preparation of boiled sweetpotato and operating a small food vending business; as guided by findings from the gender mapping study (Mayanja et al., 2021). Before commencing the processing diagnostics, the processors were briefed about the expected activities, and also helped to assemble the equipment and samples in their own designated spot in the study locations. Each of the eight processors worked with a facilitation team comprising a food scientist, a social scientist and a laboratory technician. In each location, the four varieties were prepared simultaneously, but in different cooking pots. The four varieties were evaluated for their processing and sensory qualities as guided by Bouniol et al. (2017). Experimental data were taken on raw root weight, cooking time and peeling yield (after cooking). Also, data were collected about preferences and indicators of good and bad characteristics at each processing step. Peeling yield was only evaluated in Manhiça following procedural insights obtained in the processing diagnostic study in the preceding study site (Marracuene). The processors participated in sensory assessment of the sweetpotato they had just prepared and were asked to rank the traits in order of preference.

2.4. Consumer study

To obtain the sample size, we were guided by the methodology described by Forsythe et al. (2021) which recommends that at least 300 consumers from both rural and urban settings evaluate the test varieties. In addition, for the hedonic tests, a large sample size of at least 75 consumers per test, is necessary to approximate normality for valid statistical inferences (Lim, 2011). All testing locations were easily accessible (mostly open grounds in public areas), and consumers were recruited by invitation by local extension agents. Respondents had to meet the following criteria: above 18 years of age, frequent consumers of boiled sweetpotato, and had no adverse reaction to sweetpotato.

The four test varieties were evaluated by consumers who were segmented by age (youth and adults), sex, income (high, medium, low), and location (district, urban, and peri-urban). The samples were prepared as described in section 2.1.3. They were then presented to the respondents in a randomized manner using a randomizer generated in Microsoft Excel software.

Consumers were individually requested to look, touch, smell, and taste each sample, in a randomized order and then provide their assessment (Fliedel et al., 2016). Data were collected on socio-economic characteristics, sweetpotato consumption patterns, overall liking—using the 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely) anchored at 5 (neither like nor dislike). The scale was selected because of its reliability and discriminability (Peryam and Pilgrim, 1957; Lim, 2011). Data were also collected on the 5-point Just About Right (JAR) scale ranging from 1 (much too little) to 5 (much too much) for intensity of color, taste, firmness and mealiness. The JAR was used to ascertain the influence of different sensory attribute intensities of the test varieties on consumer overall liking (McBride, 1985). Finally, the check-all-that-apply (CATA) test was applied using 26 descriptors. The CATA enables sensory characterization of the samples by associating them with positive and/or negative characteristics as perceived by the consumers (Dooley et al., 2010; Ares and Jaeger, 2015). At the end, consumers were invited to give their opinion and preferences on the four boiled sweetpotato samples, explaining why they liked some varieties and disliked others.

2.5. Characteristics of the consumers

A total of 426 consumers (246 women and 180 men) participated in testing boiled sweetpotato samples, of which 170 were youths and 256 were adults. Most respondents had attained secondary education ($p < 0.0001$). Almost three-quarters of the participants (71.0%) perceived that they were in the middle-income category (Table 2). A plurality of participants (38.6%) identified as members of the Shangaan/Shangani ethnic group.

2.6. Data analysis

Data from the processing diagnostics was analyzed using content analysis, simple ranking and statistical means.

The consumer acceptance of the four boiled sweetpotato varieties was assessed using several statistical analyzes by sex, age and location. Only the models that were statistically significant were reported. Initially, a one-way analysis of variance (ANOVA) was conducted to analyze the differences in overall liking among the varieties. Mean values were then compared using the Tukey test, with a confidence interval of 95% at a significance level of $p < 0.05$.

To identify the distinct consumer sub-groups based on their preferences, a Hierarchical Cluster Analysis (HCA) was performed (Delgado and Guinard, 2011). This analysis grouped consumers with similar liking patterns together. Subsequently, a multinomial logistic regression analysis was conducted to establish associations between the consumer clusters obtained from the HCA and socio-demographic characteristics of the consumers.

The JAR test assessed the intensity of the four most important sensory characteristics for each sample. The JAR data was analyzed using pivot tables, and the percentage of consumers who rated each attribute as JAR was calculated. Any attribute was considered JAR if it received a JAR intensity rating by $\geq 50\%$ of the consumers. The JAR results were further subjected to a penalty analysis to identify attributes that had the greatest impact on varietal overall liking (Pagès et al., 2014).

TABLE 2 Socio-economic demographic characteristics of sweetpotato consumers.

| Characteristic | Marracuene (n = 136) | Manhiça (n = 139) | Maputo City (n = 157) | χ^2 | P value |
|-------------------------------|----------------------|-------------------|-----------------------|----------|---------|
| | n (%) | | | | |
| Sex | | | | | |
| Male | 44 (22) | 63 (45) | 73 (48) | 8.296 | 0.016 |
| Female | 92 (68) | 76 (55) | 78 (52) | | |
| Age category | | | | | |
| Youth | 55 (40) | 55 (40) | 60 (40) | 0.025 | 0.988 |
| Adults | 81 (60) | 84 (60) | 91 (60) | | |
| Education level | | | | | |
| None | 20 (15) | 15 (11) | 3 (2) | 49.604 | <0.0001 |
| Primary | 56 (41) | 49 (35) | 28 (18) | | |
| Middle | 9 (7) | 9 (6) | 7 (5) | | |
| Secondary | 34 (25) | 45 (32) | 66 (44) | | |
| University | 17 (12) | 21 (15) | 47 (31) | | |
| Perceived wealth category | | | | | |
| Better off than others (high) | 12 (9) | 10 (7) | 12 (8) | 1.816 | 0.770 |
| Same as others (medium) | 91 (67) | 100 (72) | 111 (74) | | |
| Worse off than others (low) | 33 (24) | 20 (21) | 28 (18) | | |

For the CATA test, data was preprocessed to eliminate attributes that were selected by fewer than 5% of the respondents (such as bad aftertaste, blackish, tasteless (bland), thick, pale yellow, and purple) or by more than 45% of the respondents (such as attractive, vitamin-rich) and attributes that did not discriminate between the varieties were identified and removed using Cochran's Q test (including fibrous, good sweetpotato smell, no smell, not sweet enough, sticky between fingers, too soft, and non-uniform texture) from the analysis. Mealy and dry texture were found to be redundant for many varieties, so dry texture was removed in favor of mealy; as it is often cited by consumers as an important characteristic (Mudege et al., 2021; Mwangi et al., 2021).

To further explore the relationship between the CATA terms, the respondents' socio-economic characteristics, and their response to overall liking; a Multiple Correspondence Analysis (MCA) was conducted using XLSTAT software. The CATA terms were treated as active variables, while the respondents' gender and location (district) were considered qualitative **Supplementary variables**. The overall liking ratings were included as quantitative **Supplementary variables**.

All statistical analyzes were performed using **Xlstat (2021)** software (Addinsoft) and Stata Ver. 17.

3. Results

3.1. Processing diagnostics and quality characteristics

3.1.1. Raw sweetpotato processing and quality characteristics

Improved varieties 'Alisha' and 'Irene' had the highest average root weight (0.41 and 0.25 kg), respectively. While 'Lilas' and 'N'santimuni' weighed 0.20 and 0.15kgs. 'Alisha' was significantly heavier than

'N'santimuni' ($p < 0.05$). Boiling time and yield after boiling was not significantly different for all the four varieties in both locations. However, the yield after peeling for 'Irene' (80%) was significantly lower ($p < 0.05$) compared to the rest of the varieties whose yield ranged between 88 and 90%.

The most cited preferred and less preferred characteristics of raw sweetpotato prioritized by processors in Manhiça and Marracuene (Table 3) are the same in the two locations, but with different order of preference and description of indicators.

Among superior quality characteristics, processors in both Manhiça and Marracuene districts highlighted medium size and high dry matter (described as firm and heavy in the hands). Processors in Marracuene also mentioned no dents, smooth skin and heaviness.

For undesirable sweetpotato characteristics, processors in both Manhiça and Marracuene districts highlighted not sweet, watery roots, and tasteless. The characteristic 'no sweetpotato smell' was only prioritized in Marracuene district while damaged root was only highlighted in Manhiça. Only processors in Marracuene were familiar with the variety, 'Lilas' which could explain the opinion of one processor in Manhiça who ranked it lowest. Overall, 'N'santimuni' was perceived to be the best candidate for preparing boiled sweetpotato.

3.1.2. Boiled sweetpotato processing characteristics

The good and undesirable characteristics of boiled sweetpotato according to processors in Marracuene and Manhiça are shown in Table 3. Processors in both districts ranked mealiness and good sweetpotato smell among their most preferred sweetpotato sensory characteristics. Others were not fibrous, good appearance and firm to touch. Sweet taste was emphasized in Manhiça. Processing characteristics appreciated by the processors were: easy, fast (<30 min) and evenly cooked. Watery roots was one of the undesirable processing characteristics

TABLE 3 Good and undesirable quality characteristics of raw and boiled sweetpotato in Manhiça and Marracuene.

| Location | Raw sweetpotato | | Boiled sweetpotato | |
|------------|--|---|--|---|
| | Good quality | Undesirable quality | Good quality | Undesirable quality |
| Manhiça | ¹ Medium size ¹ Heavy (high dry matter) ³ Good smell ³ Sweet taste ³ Good appearance (no damage) | ¹ Not sweet ¹ Damaged root ¹ Watery ⁴ Not heavy- low dry matter ⁴ Bad appearance | ¹ Mealy ¹ Good sweetpotato smell ¹ Sweet taste ⁴ Good appearance ⁴ Cooks easily (fast) | ¹ Not sweet ¹ No sweetpotato smell ¹ Watery ⁴ Small roots size ⁴ Not mealy ⁴ Difficulties to peel ⁴ Too dark color ⁴ Fibrous |
| Marracuene | ¹ Firm in hands (high dry matter) ² No dents ² Smooth skin ² Heavy ⁵ Medium size ⁵ Thin skin ⁵ Good smell | ¹ Watery ¹ No sweetpotato smell ³ Tasteless (bland) ⁴ Small size ⁵ Bad taste, ⁵ Black spots ⁵ Many dents | ¹ Mealy ² Good sweetpotato smell ² No dents ² Firm ⁵ Cooks easily ⁵ Not fibrous ⁵ Easy to peel ⁵ Soft ⁵ Good appearance | ¹ Watery ² Many dents ³ Small roots size ³ Too dark ³ Fibrous ³ Big root size ³ Too dark |

Number in superscript indicates priority of characteristic.

in Marracuene. In Manhiça, the key undesirable characteristics were: not sweet, watery, and lacking the good sweetpotato smell.

Overall, in Manhiça, 'N'santimuni' was the most preferred variety, followed by 'Lilas', 'Irene' and 'Alisha' in descending order. 'N'santimuni' was liked because it was mealy, had a good sweetpotato smell and good appearance (pale yellow). 'Alisha', one of the recently released varieties, lacked a good sweetpotato smell and good taste, had high dry matter, and was fibrous.

In Marracuene, the processors ranked both 'N'santimuni' and 'Irene' as their most preferred while 'Lilas' was the least preferred boiled sweetpotato variety. According to the processors, the two favorite varieties were mealy, had a good sweetpotato smell and sweet taste. In addition, 'Irene' had a good appearance (red skin, orange flesh) and was perceived to have vitamins. The downside for 'Lilas' could have been the dark purple flesh color which some processors were seeing for the first time.

3.2. Consumer acceptability of boiled sweetpotato

3.2.1. Consumption patterns

The most common way to eat sweetpotato was in the boiled form ($p=0.43$), and most respondents consumed it more than 4 days in a week ($p=0.080$) in the boiled form at breakfast (Table 4). Women consumed sweetpotato more frequently than men did ($\chi^2=12.069$ ($p=0.017$)).

3.2.2. Overall liking

The overall liking for the four test varieties was first analyzed using ANOVA and later with HCA. Results from the ANOVA revealed that 'N'santimuni' and 'Lilas' were the most liked varieties with a hedonic score of 7.4 (like moderately) while 'Irene' and 'Alisha' were liked slightly with a hedonic score of 6.5. The difference between the two scores was significant ($p<0.0001$).

3.2.3. Overall liking—hierarchical cluster analysis

Three distinct clusters were obtained from the HCA (Figure 2). Cluster 1 comprised consumers who liked all the varieties with a hedonic score >7 (All likers). Consumers in cluster 2 did not like 'Irene' and scored it 2 on the hedonic scale ('dislike very much'). This cluster also comprised consumers who liked 'Alisha' slightly; but was named 'Irene dislikers'. Consumers in cluster 3 had a dislike for 'Alisha' and scored it 2 on the hedonic scale; hence the cluster was named as 'Alisha' dislikers'. Most of the consumers (73%) were in cluster 1 with a minority in clusters 2 (16%) and 3 (11%). 'Lilas' and 'N'santimuni' were liked in all three clusters (>7 on the hedonic scale).

3.2.4. Logistic regression of consumers clusters obtained from HCA

The associations between consumer clusters obtained from HCA and social demographic characteristics of consumers were as shown in Table 5. Each additional year of schooling was associated with a 7% increase in the likelihood of a consumer to be an 'Irene' disliker' ($p=0.037$). Residents of Maputo city were 53% ($p=0.023$) and 65% ($p=0.012$) less likely to be 'Irene' and 'Alisha' dislikers' respectively; compared to being in the 'all likers' cluster. On the other hand, residents of Marracuene were 44% less likely to be in the 'Irene' dislikers cluster ($p=0.088$) than the 'all-likers' clusters.

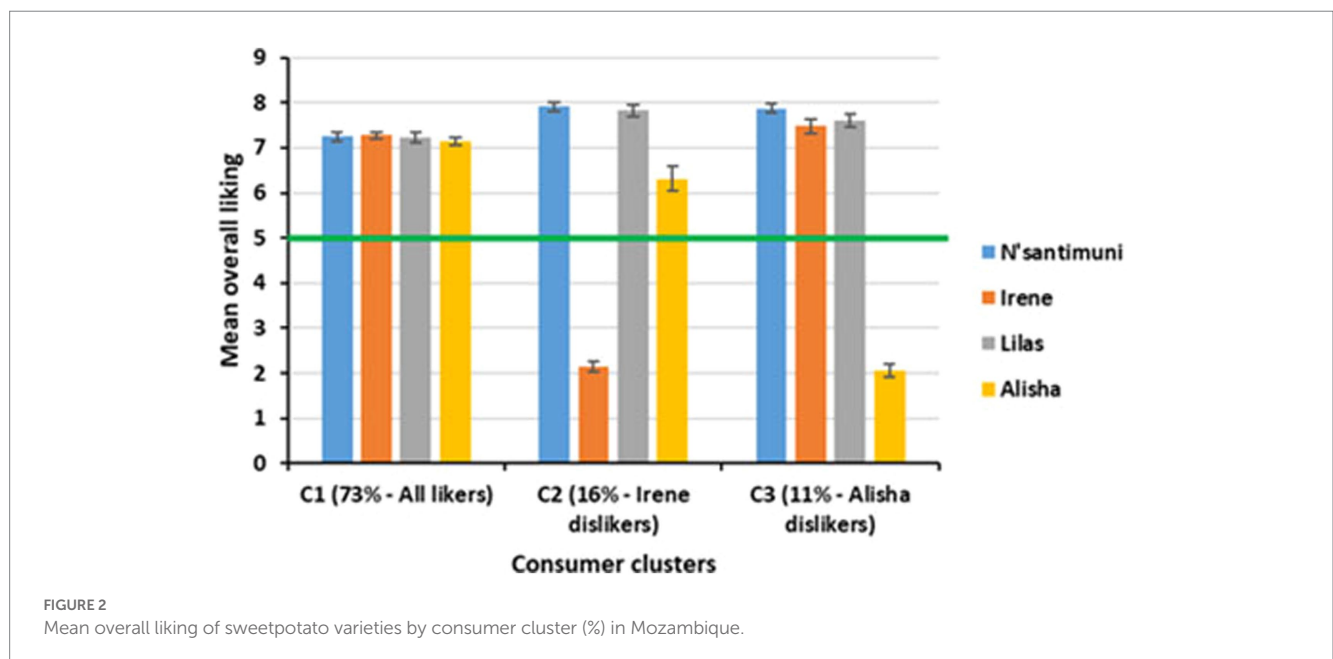
Consumers who perceived their wealth status to be worse off than others were 53% ($p=0.086$) and 12% ($p=0.085$) less likely to be among the 'Irene' and 'Alisha' dislikers clusters respectively, compared to the 'all-likers' clusters. Youth on the other hand were 78% ($p=0.089$) more likely to be among 'Alisha' dislikers cluster than adults.

3.2.5. Just about right test

The assessment of color, sweetness, firmness and mealiness of boiled sweetpotato roots by all consumer categories is presented in Table 6. Generally, there were variations in perception of attribute

TABLE 4 Sweetpotato consumption patterns for consumers by location.

| Characteristic | Marracuene (n = 136) | Manhiça (n = 139) | Maputo city (n = 157) | χ^2 | P value |
|----------------------------|----------------------|-------------------|-----------------------|----------|---------|
| | n (%) | | | | |
| Consumption frequency | | | | | |
| Every day | 11 (8) | 12 (9) | 13 (9) | 14.706 | 0.080 |
| Several times a week | 45 (33) | 37 (17) | 37 (22) | | |
| Once a week | 18 (13) | 36 (26) | 36 (17) | | |
| Several times a month | 40 (29) | 27 (19) | 27 (30) | | |
| Once a month | 22 (16) | 27 (19) | 27 (22) | | |
| Common form of consumption | | | | | |
| Mixed with other foods | 0 (0) | 0 (0) | 4 (3) | 12.976 | 0.043 |
| Mashed | 0 (0) | 0 (0) | 1 (1) | | |
| Plain boiled | 133 (98) | 139 (100) | 145 (96) | | |
| With sauce | 3 (2) | 0 (0) | 1 (1) | | |
| Meal type | | | | | |
| Breakfast | 98 (72) | 116 (83) | 124 (82) | 8.923 | 0.178 |
| Lunch | 16 (12) | 10 (7) | 13 (9) | | |
| Dinner | 1 (1) | 0 (0) | 2 (1) | | |
| Snack | 21 (5) | 13 (9) | 12 (8) | | |



intensity by location and sex. ‘N’santimuni’ and ‘Irene’ were perceived to be JAR for color by all consumers regardless of sex or location ($\geq 50\%$ of consumers). ‘Lilas’ color was not JAR according to women and men consumers in Maputo (both 44%) and Marracuene (47 and 39% respectively). Just under 50% of men consumers in Manhiça indicated the color of ‘Alisha’ was JAR (49%).

‘N’santimuni’ was JAR for sweetness in Manhiça and Maputo, while ‘Lilas’ was considered JAR for sweetness in Marracuene. Similarly, men in Maputo and women in Manhiça also rated ‘Lilas’ JAR for sweetness. Only women in Manhiça rated the sweetness of

‘Irene’ as JAR. Sweetness of ‘Alisha’ was JAR for men in both Maputo and Marracuene as well as for women in Manhiça.

Firmness of ‘N’santimuni’ was JAR according to consumers in Maputo and Manhiça. ‘Lilas’ was JAR for firmness as rated by men in both Maputo and Marracuene and women in Manhiça. Only women in Maputo gave ‘Alisha’ a JAR rating for firmness while ‘Irene’ did not have the right firmness according to all consumers (32–43%). N’santimuni more often than other varieties met the intensity expectations of the consumers. None of the varieties was JAR for mealiness ($< 50\%$ of consumers).

TABLE 5 Associations between consumer clusters obtained by HCA and socio-demographic characteristics among consumers in Mozambique (n = 426)¹.

| Factor | 'Irene' dislikers cluster (n = 69) | p | 'Alisha' dislikers cluster (n = 46) | p |
|-------------------------------|---------------------------------------|-------|--|-------|
| | OR (95% CI) ² | | OR (95% CI) ² | |
| Years of schooling | 1.071 (1.004–1.142) | 0.037 | 1.040 (0.963–1.123) | 0.317 |
| District | | | | |
| Maputo city | 0.471 (0.236–0.901) | 0.023 | 0.352 (0.156–0.791) | 0.012 |
| Marracuene | 0.557 (0.284–1.092) | 0.088 | 0.553 (0.260–1.176) | 0.124 |
| Manhiça (reference) | 1.00 | | 1.00 | |
| Sex | | | | |
| Male | 0.776 (0.446–1.350) | 0.369 | 0.710 (0.365–1.380) | 0.312 |
| Female (reference) | 1.00 | | 1.00 | |
| Age group | | | | |
| 18–35 years (Youth) | 1.333 (0.765–2.322) | 0.311 | 1.783 (0.917–3.469) | 0.089 |
| >35 years (reference) | 1.00 | | 1.00 | |
| Wealth perception | | | | |
| Better than others | 0.915 (0.344–2.431) | 0.858 | 1.739 (0.629–4.807) | 1.139 |
| Worse than others | 0.468 (0.197–1.115) | 0.086 | 0.878 (0.365–2.109) | 0.085 |
| Similar to others (reference) | 1.00 | | 1.00 | |

Data were analyzed using complex sample module. ¹Result of multiple logistic regression with consumer obtained clusters by HCA (All-likers (reference), 'Irene' dislikers cluster and 'Alisha' dislikers cluster) as dependent variable; R^2 (McFadden) = 0.045. ²OR, odds ratio; CI, confidence interval.

TABLE 6 JAR results showing appreciation of boiled sweetpotato characteristics by all consumers categorized by location and sex.

| How do you appreciate the following characteristics of the variety you tested? | | Categorization by sweetpotato variety and gender (%) | | | | | | | |
|--|-------------|--|-------|---------|-------|---------|-------|----------|-------|
| | | N'santimuni | | 'Irene' | | 'Lilas' | | 'Alisha' | |
| | | Women | Men | Women | Men | Women | Men | Women | Men |
| Color | Maputo city | 62.82 | 72.60 | 69.23 | 78.08 | 43.59 | 43.84 | 50.0 | 57.3 |
| | Manhiça | 69.74 | 65.08 | 77.63 | 71.43 | 53.95 | 52.38 | 53.95 | 49.21 |
| | Marracuene | 55.43 | 56.82 | 75.00 | 77.27 | 46.74 | 38.64 | 58.7 | 59.09 |
| Sweetness | Maputo city | 57.69 | 50.68 | 38.46 | 49.32 | 43.59 | 50.68 | 47.44 | 54.79 |
| | Manhiça | 60.53 | 63.49 | 56.58 | 46.03 | 65.79 | 47.62 | 51.32 | 34.92 |
| | Marracuene | 47.83 | 45.45 | 44.57 | 40.91 | 52.17 | 50.00 | 41.30 | 50.00 |
| Firmness | Maputo city | 52.56 | 58.90 | 32.05 | 32.88 | 44.87 | 53.42 | 50.00 | 41.10 |
| | Manhiça | 61.84 | 55.56 | 38.16 | 33.33 | 55.26 | 42.86 | 43.42 | 36.51 |
| | Marracuene | 45.65 | 45.45 | 39.13 | 43.18 | 43.48 | 50.00 | 39.13 | 40.91 |
| Mealiness | Maputo city | 38.46 | 42.47 | 23.08 | 28.77 | 30.77 | 36.99 | 32.05 | 41.10 |
| | Manhiça | 42.11 | 34.92 | 26.32 | 30.16 | 44.74 | 33.33 | 36.84 | 33.33 |
| | Marracuene | 27.17 | 40.91 | 33.70 | 38.64 | 31.52 | 34.09 | 27.17 | 31.82 |

Table 7; Figure 3 show results from penalty analysis for the test varieties. Taking 25% frequency and 1.0 unit mean drop as the minimum acceptable values to penalize a variety for an attribute, 'N'santimuni' (30%), 'Irene' (57%) and 'Alisha' (33%) were penalized for not being mealy enough. Consumers penalized 'Irene' (27%) 'Alisha' (34%) and 'Lilas' (26%) for not being sweet enough. 'Lilas' (28%) and 'Irene' (51%) were penalized for not being firm enough while 'Alisha' (35%) was penalized for being too firm. Improved varieties received higher penalties than local ones for three of the four test attributes.

3.2.6. Mapping of sensory characteristics

Preliminary analysis revealed gendered differences only for Manhiça and Marracuene districts. The maps obtained from Multiple Correspondence Analysis (MCA) show three main factors. The positive side of the first factor, F1, is characterized by firm, mealy, and sweet taste attributes while its negative side is characterized by watery texture (Figure 4). The second factor, F2, is characterized by hard and non-homogenous color on its positive side and smooth on its negative side (Figure 4). The third and last factor, F3, is characterized by yellow

TABLE 7 Results from penalty analysis for the test varieties.

| Variety | JAR category | Mean drop | | | |
|-------------|--------------|-------------|-------------|------------|-----------|
| | | Color | Sweetness | Firmness | Mealiness |
| 'Alisha' | Too little | 1.7 (41%) | 2.2 (34%) | 1.8 (23%) | 1.0 (33%) |
| | Too much | 2.0 (4.7%) | 0.5 (19.7%) | 1.1 (35%) | 0.8 (33%) |
| 'Irene' | Too little | 2.3 (15%) | 2.3 (27%) | 2.1 (51%) | 1.5 (57%) |
| | Too much | 1.8 (10.6%) | 0.8 (27%) | 1.0 (13%) | 0.1 (13%) |
| 'Lilas' | Too little | 0.7 (8%) | 1.6 (26%) | 1.1 (28%) | 0.7 (33%) |
| | Too much | 0.6 (46%) | 0.1 (22%) | 0.0 (24%) | 0.3 (32%) |
| N'santimuni | Too little | 0.7 (33%) | 1.3 (22%) | 1.1 (23%) | 1.1 (30%) |
| | Too much | 0.9 (3%) | 0.0 (24%) | -0.1 (23%) | 0.0 (33%) |

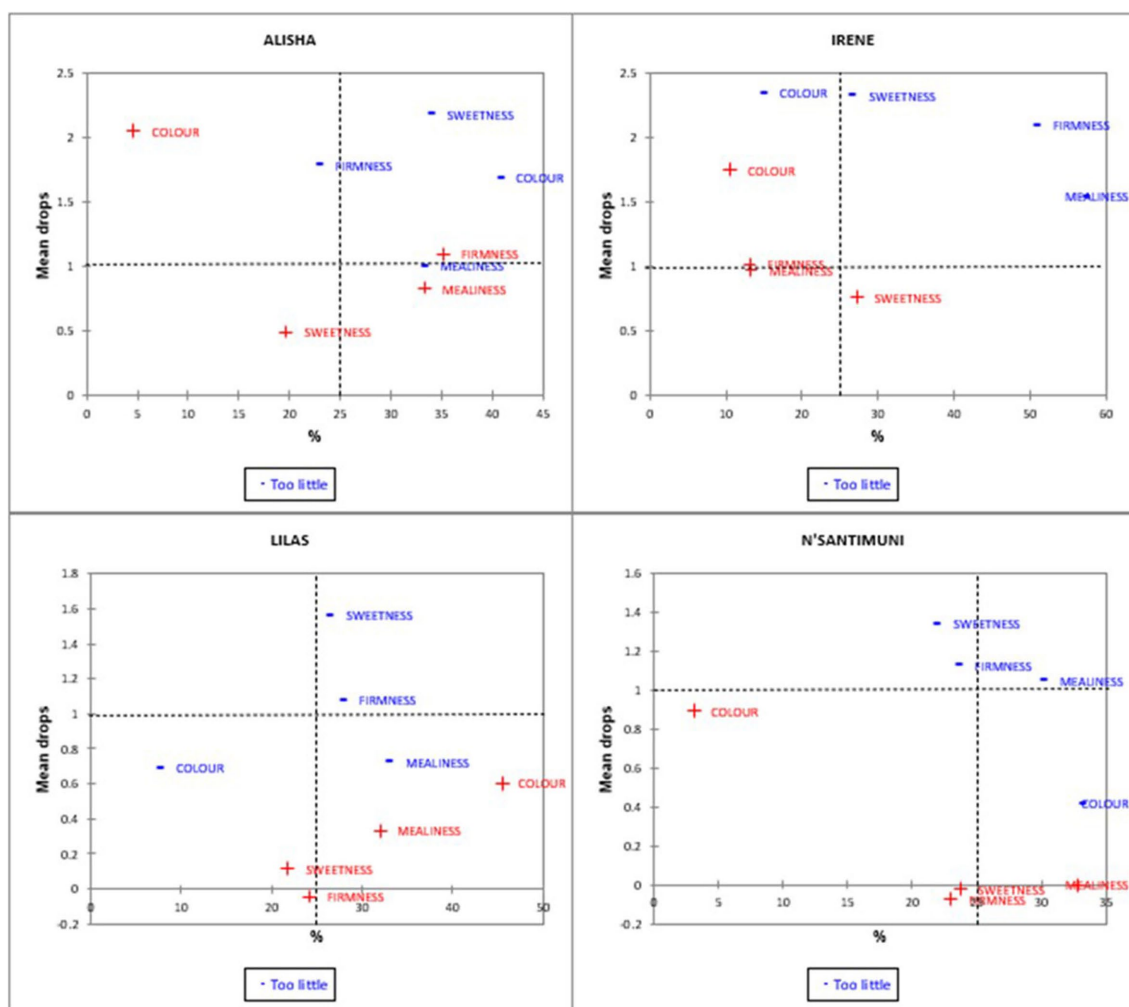


FIGURE 3 Penalty plots of the mean drop in overall liking (penalty) versus percentage of consumers who classified each variety in consumer test (n = 426), as 'too little' or 'too much' of each product attribute.

on its positive side and orange color on its negative side (Figure 5). 'Alisha' was associated with being non-homogenous, yellow and hard (Figure 4, Q I). Both 'Lilas' and 'N'santimuni' were described as firm, mealy, sweet and smooth (Figure 4, Q II). They were also positioned

in the same quadrant with overall liking. 'Irene' was most closely associated with a watery texture and orange in color (Figure 4, Q III). Women checked attributes like non-homogenous much more frequently than men did.

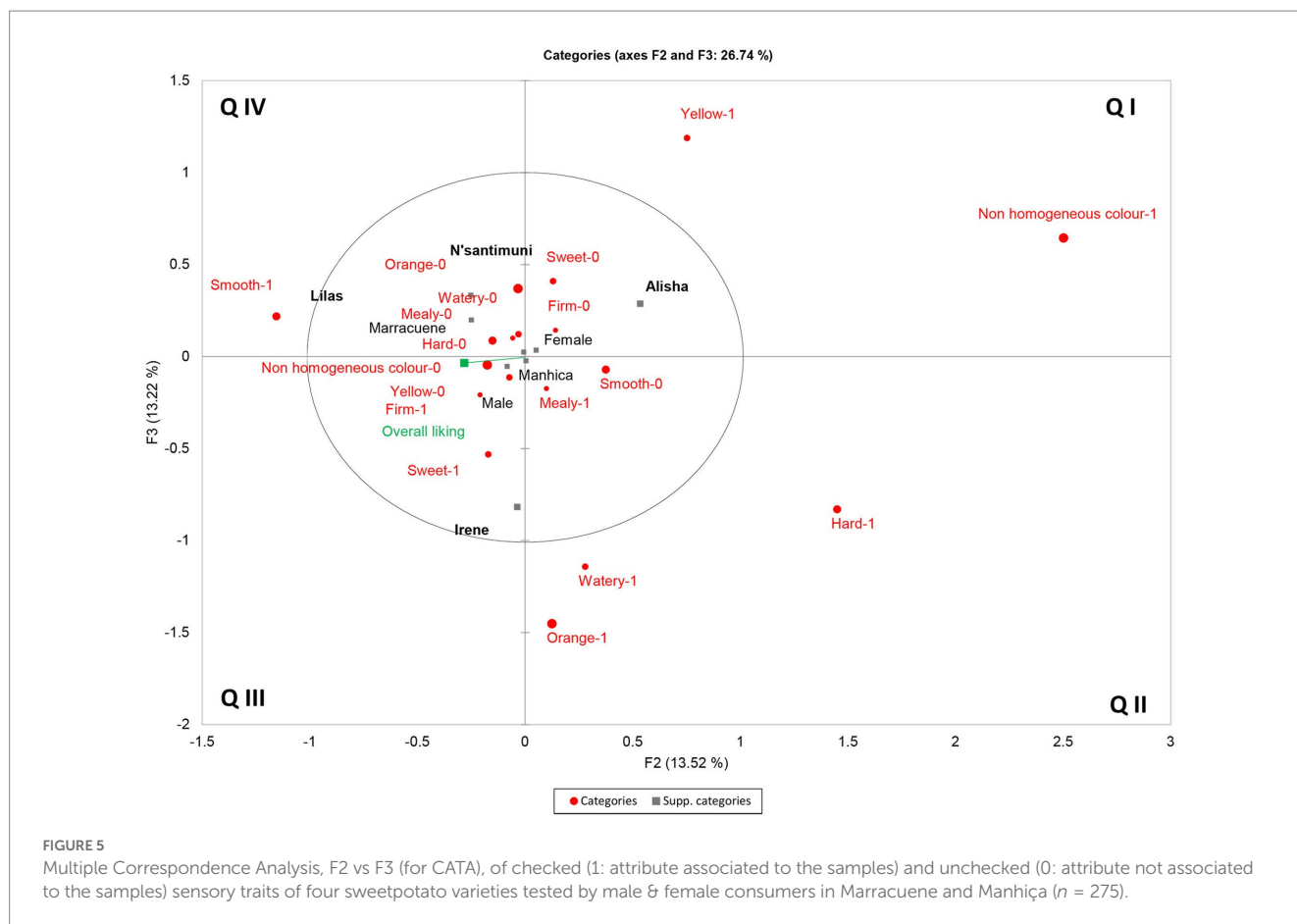


FIGURE 5

Multiple Correspondence Analysis, F2 vs F3 (for CATA), of checked (1: attribute associated to the samples) and unchecked (0: attribute not associated to the samples) sensory traits of four sweetpotato varieties tested by male & female consumers in Marracuene and Manhica ($n = 275$).

JAR for mealiness, the purple fleshed variety 'Lilas' was not penalized for not being mealy enough.

With regards to sweet taste, only processors in Manhica district held it in high regard. Likewise, consumers were only satisfied with the sweet taste intensity of 'N'santimuni' and penalized the rest of the test varieties for not being sweet enough. Firmness was an important attribute for Marracuene processors, as conceded to by most consumers. In this regard, only 'N'santimuni' was perceived to have the preferred intensity of firmness.

'N'santimuni' was the most liked variety by processors and consumers, in line with findings from the gendered food mapping study (Mayanja et al., 2021). The consumers preferred N'santimuni due to its superior textural properties. The variety has a firm texture and does not crumble after boiling. The roots are not sticky and watery after boiling. These good textural properties resulted in mealiness of the roots when chewed by the consumers. In addition, boiled roots of N'santimuni were sweet, meeting the consumer's expectations.

In Marracuene, 'Irene' tied with 'N'santimuni' in the first position. The processors described it as mealy, and has a good sweetpotato taste with a sweet taste. Conversely, 'Irene' was the least preferred variety for consumers (by sex and location) and was described as watery, tasteless, soft and lacking a good sweetpotato smell. In Marracuene district, processors disliked 'Lilas's dark purple color. This could be because they were not used to purple flesh color and do not know the therapeutic value of anthocyanins present in the storage roots (Li et al., 2019). Consumers also mentioned that 'Lilas' was blackish in color, but this did not affect their overall liking for the variety. These

findings contribute to earlier postulations by Dufour et al. (2021) who state that preferred attributes may differ among value chain actors and could call for differentiated market segments.

While improved OFSP varieties address an important nutrition gap, continuous breeding improvements should be considered. The fact that two out of the three distinct consumer clusters were designated to 'Alisha' and 'Irene' dislikers further confirms this need. Also, delivery strategies of improved varieties need to be cognizant of the need for protracted promotion messages especially to the more educated consumer segments who are more likely to be among the 'dislikers'. Nonetheless, the fact that OFSP varieties are more likely to be accepted by consumers in the 'worse off' wealth category presents an opportunity to advance these varieties, which are a cheaper method to address vitamin A deficiency (Low et al., 2017). All consumer categories rated 'Irene' JAR for color, which is an important and positive factor for the OFSP breeding program.

Consumers in Maputo were more amenable to 'Alisha' compared to the rural districts. This could largely be attributed to the concerted promotion of OFSP varieties undertaken earlier (Brouwer, 2021) but also to our assumption that there are some market segments that are more receptive to improved varieties than others. Breeders should thus continuously strive to develop Vitamin A rich varieties that are less watery, fibrous and have a nice characteristic sweetpotato taste. It is also important to note that people may like a variety more in one place than another because the acceptability of food depends on many individual and environmental factors (Maina, 2018). Based on the significant differences of the most and least preferred varieties across

locations; it is highly likely that different varieties can satisfy end-user requirements of each location. Consequently, improving our understanding of the market segmentation could improve design, development, promotion and uptake of varieties (Ojwang et al., 2023).

The local varieties were the most preferred by consumers, with most urban consumers opting for 'N'santimuni' and rural consumers going for 'Lilas'. The preferred characteristics in both varieties were similar, implying that good dry matter, mealiness, good sweetpotato smell, firmness, sweet taste and smoothness while eating are important quality characteristics to include in the product profile. These findings are similar to those from the gendered food mapping studies in Mozambique and Uganda (Mayanja et al., 2021; Mwangi et al., 2021).

Women had a higher rating for sweetness, similar to findings by Mwangi et al. (2021). Women also had better discernment than men of least preferred traits such as non-homogenous color and hard texture. These findings further strengthen the association of traits to gendered roles and responsibilities, in this case aligning sweet taste to women's role in food preparation and food provision. Women stood out as the most frequent consumers of boiled sweetpotato compared to men. They equally prioritized both local varieties, i.e., 'N'santimuni and Lilas; while men distinctly preferred the former. This further affirms the importance of the crop to women, not only as producers but also as consumers, further cementing the need to consider their preferred attributes in breeding product design (Weltzien et al., 2019).

4.1. Lessons for breeders

Clearly, the improved varieties, though respected for their attributes, especially pro-vitamin A-rich, need further improvement to meet consumer preferences. Candidate clones designed to replace the current market-leading varieties will need to pay greater attention to quality traits for which 'Alisha' and 'Irene' were penalized, i.e., they should be mealier, sweeter, firmer and less fibrous. These quality traits are important drivers of sweetpotato variety acceptance for processors, consumers and other end users. This will require protracted studies of biophysical and chemical parameters of sweetpotato to quantify and enable better understanding of these quality attributes. Also, 'Lilas' and 'N'santimuni' could be benchmarked for mealiness, sweetness and firmness by the breeding program.

The Mozambique breeding program should develop gendered targeted product profiles in consideration of the importance to cater for sex, age and location differentiated preferences for crop characteristics and varieties. This would require identifying emerging market segments while drawing lessons from Uganda that has advanced in this arena (Ssali et al., forthcoming). Further, breeders need to consider the dominant form of utilization of sweetpotato as a breakfast accompaniment and incorporate traits like 'cooks fast' and 'medium size roots' in the product profile.

Also, the greater likelihood of educated consumers to dislike improved varieties needs to be underscored, as well as the different preferences of women and men. McDougall et al. (2022) argue that such gendered trait preferences are not only more complex than previously perceived but are likely to be overlapping and more nuanced. Girard et al. (2021) also note that integration of gender, health and nutrition in variety delivery strategies are important for the uptake of new (especially; vitamin A-rich) varieties. This implies that breeders involve multidisciplinary teams for product advancement at each stage gate/breeding stage to ensure that all traits important to

women and youth are included for better varietal acceptance; which may not be easy but a must.

'Lilas' offers breeders a window in the development of nutritious and therapeutic varieties, since the purple color is associated with richness in anthocyanins (Tanaka et al., 2017). Consumers in the 'worse than others' wealth category in Maputo moderately liked 'Alisha', which could be an avenue to reach them with OFSP varieties.

5. Conclusion

Breeders, agronomists, food and social scientists need to come together to jointly design strategies for improving the design of innovative products from the breeding pipeline. This will require continuous interaction with the end users to ascertain and integrate their desired crop product needs. Using Artificial Intelligence, new technologies and value addition strategies specifically designed to appeal to the end-users may be the game-changer since the world is getting more technologically savvy. Scientists from the Consortium of International Agricultural Research Centers (CGIAR) have noted that promoting socially equitable varieties like nutritionally improved varieties risks creating a yield penalty compared to the best agronomic varieties which could reduce their adoption (Kholová et al., 2021). Consequently, future variety dissemination strategies should take these factors into consideration.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://mt.co.ug/cip_202109_diagnosticstudy_mozambique.

Ethics statement

The studies involving humans obtained pre-ethical approval from the Mozambique Ethical Approval Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in the study.

Author contributions

SM, ST, DO, GM, AN, and MA contributed to conception and design of the study. MN and DO organized the schematics and figures. SM, ST, DO, GM, and AN wrote the first draft of the manuscript. RS reviewed the first version. MN, GM, and AN wrote sections of the manuscript. All authors contributed to manuscript revision, read and approved the submitted version.

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Conflict of interest

DO was employed by MOOD Technologies; a commercial entity.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fsufs.2023.1233741/full#supplementary-material>

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