WILLINGNESS TO PAY FOR QUALITY TRAITS AND IMPLICATIONS FOR SWEETPOTATO VARIETY BREEDING: CASE OF MOZAMBIQUE

Technical Report

NOV
2023

Chalmers K. Mulwa; Alda Tomo; João Mudema; Godwill Makunde; Maria Andrade; Reuben Ssali; Naico Abdul; Hugo Campos

CIP INTERNATIONAL POTATO CENTER
CGIAR
IIAM
Sweet GAINS
BILL & MELINDA GATES foundation

Willingness to Pay for Quality Traits and Implications for Sweetpotato Variety Breeding: Case of Mozambique

Technical report

Authors:

Chalmers K. Mulwa[1]; Alda Tomo[2]; João Mudema[2]; Godwill Makunde[3]; Maria Andrade[3]; Reuben Ssali[4]; Naico Abdul[3]; Hugo Campos[5]

[1]International Potato Center, Kenya
[2]Mozambique Institute of Agricultural Research (IIAM)
[3]International Potato Center, Mozambique
[4]International Potato Center, Uganda
[5]International Potato Center, Peru

November 2023

Willingness to Pay for Quality Traits and Implications for Sweetpotato Variety Breeding: Case of Mozambique. Technical report

DOI: 10.4160/cip.2023.11.003

International Potato Center
P.O. Box 1558, Lima 12, Peru
cip@cgiar.org • www.cipotato.org

Citation:
Mulwa, C.K.; Tomo, A.; Mudema, J.; Makunde, G.S.; Andrade, M.I.; Ssali, R.T.; Abdul, N.; Campos, H. 2023. *Willingness to pay for quality traits and implications for sweetpotato variety breeding: case of Mozambique. Technical report***.** International Potato Center. DOI: 10.4160/cip.2023.11.003

Design and Layout:
Communications Department

November 2023

CIP also thanks all donors and organizations that globally support its work through their contributions to the CGIAR Trust Fund: www.cgiar.org/funders

Contents

List of tables

List of figures

Acronyms

BED	Bayesian efficient designs
BFFD	Blocked fractional factorial design
CIP	International Potato Center
DCE	Discrete Choice Experiments
FDG	Focal Group Discussion
FFD	Fractional Factor Design
G-MNL	Generalized multinomial logit model
IAI	The Integrated Agricultural Survey
IIA	Independence of irrelevant alternatives
IIAM	The National Agricultural Research Institute
MIXL	Mixed multinomial logit models
MNL	Multinomial logit model
MRS	Marginal rates of substitution
OFSP	Orange-fleshed sweetpotato
PFSP	Purple-fleshed sweetpotato
RUM	Random Utility Model
RUT	Random Utility Theory
SDG	Sustainable Development Goals
S-MNL	Scale multinomial logit model
VAD	Vitamin A deficiency
WTP	Willingness to pay

Acknowledgements

This study was implemented by a team of researchers from the International Potato Centre (CIP) and the Mozambique Institute of Agricultural Research (IIAM). The team is grateful for the financial support from the SweetGAINS project funded by Bill and Melinda Gates Foundation (BMGF).

We would also like to thank all key stakeholders in the study area who participated in the focus group discussions and interviews for this study. We appreciate the tireless cooperation we received from the district staff and local leaders throughout the study without which it would have been difficult to complete the field work promptly. Our gratitude also goes to fellow researchers and experts who contributed in any way throughout the development of this research project. Lastly, we highly recognize and pass our sincere gratitude to all concerned government officials who provided consent to undertake field work in their respective areas of jurisdiction.

Executive summary

Despite decades of research and dissemination of improved sweetpotato varieties, these varieties are not yet cultivated at scale and the development goals of improved food security and livelihoods remain elusive. This is despite demonstrated impacts of such technologies in combating food and nutrition insecurity, amidst global challenges like climate change. Growing evidence shows that end-user acceptance of improved varieties is critical in the widespread adoption of such varieties, and inclusion of the heterogenous preferences for diverse sets of end-users in the variety development process is therefore critical. With global changes in weather and consumption patterns, end-users are now demanding varieties that are more suitable to their unique consumption needs, production environments, new market demands and have desired processing characteristics. As a consequence, we are rethinking breeding programs to move from the traditional focus on agronomic gains such as increased yields and yield protection, to the consideration of more nuanced quality-related traits that appeal to targeted populations.

This study sets out to explore the decision-making behavior of Mozambican sweetpotato producers in variety selection, and the implicit value placed on different sweetpotato traits, including the often ignored but crucial quality traits. The aim of the study is to identify the economic value of such traits and how they are traded off in variety selection decisions, to allow for prioritization in breeding efforts. To achieve this, we adopted an exploratory sequential design in a predominantly quantitative mixed-method design. First, based on the insights from a gender disaggregated qualitative assessment among sweetpotato growers and consumers and in consultation with breeding experts from Mozambique, the most preferred sweetpotato variety traits in the regions of study were established. These traits were then used in the design of a choice experiment, implemented among 860 sweetpotato producers spread across four sweetpotato growing regions in the country. Finally, a generalized multinomial logit model was used to estimate the implicit economic valuation of each of the considered traits, as well as the heterogenous valuation of such traits across gender, education and age of respondent groups.

Results from the study show that producers have a high preference for quality-related traits, with preference for vitamin A content being higher than that for drought tolerance, while dry matter content is valued about the same as drought tolerance. While scoring significantly lower than vitamin A, drought tolerance and dry-matter content, other quality-related traits like root size and sweet taste also have significant positive values implying their importance in informing sweetpotato variety choice. In terms of gender heterogeneity, flesh color is highly valued among the women sub-sample. The study identifies vitamin A, dry-matter content, sweet taste, and medium-to-big root size, as the key preferred quality traits in Mozambique, in that order. The results imply that these quality traits should be pursued as a suite in breeding objectives, in combination with essential agronomic traits such as high yields and drought tolerance, for higher acceptance and demand of improved sweetpotato varieties across the country.

1. Introduction

Sweetpotato (*Ipomoea batatas* [L.] Lam.) is one of the most important crops for food and nutritional security in sub-Saharan Africa. It is a dual-purpose crop, in which young leaves and storage tuber roots are widely consumed by many people in the region, constituting a critical source of carbohydrates, dietary fibers, minerals such as phosphorus, iron and calcium, and vitamins A, B and C (Echodu *et al.*, 2019). Due to its nutritional richness, good adaptability under low rainfall conditions and poor soils, and the ability to produce reliable yields with minimal inputs and labor, sweetpotato is considered a promising root and tuber crop to improve the health, food security and livelihoods of resource-poor farmers (Abidin *et al.*, 2017; Andrade et al., 2017; Labarta, 2012; Low *et al.*, 2020; McEwan *et al.,* 2022). In Mozambique, the crop is among the most important staple crops, and it is the second most important root and tuber crop after cassava, where it is normally cultivated on small plots of land across a wide range of agro-ecological conditions, primarily for family subsistence (MADER, 2021). In 2020 alone, sweetpotato production among small and medium-scale farmers in Mozambique reached 448,633 tons produced on a total of 60,229 hectares (MADER, 2021).

Sweetpotato is particularly relevant in the context of Mozambique where rural development is still challenged by chronic malnutrition, poverty, household vulnerability to food and nutritional security and the impacts of climate change (Manuel *et al*., 2020; FAO, 2016; USAID, 2021). People depending on agriculture for their livelihoods in the country are among the poorest, with the incidence of poverty being quite high among farmers (54.7%) and agricultural workers (47.3%). Mozambique also has extremely high levels of chronic malnutrition; about 6% of children under-five are acutely malnourished, 43% of these are stunted, while more than 65% of them have deficiencies of essential micronutrients like vitamin A (MISAU, INE, & ICFI 2011; USAID, 2021). Both acute food insecurity and acute child malnourishment have worsened from 3.6% in 2013 to 29.9% in 2019 and from 1.9% in 2013 to 12.3% in 2019, respectively (INE, 2020).

Sweetpotato is uniquely positioned to address most of these challenges. The crop's agronomic attributes allow for high yields in relatively short growing periods under rain-fed systems with minimal labor and inputs, thus enhancing food security and improving livelihoods (Fiorella *et al.*, 2016; Low *et al.*, 2017). The surplus produce can be easily sold for cash by poor families to augment livelihoods, while biofortified varieties such as the orange-fleshed sweetpotato (OFSP) and purple-fleshed sweetpotato (PFSP) varieties provide important micronutrients such as vitamin A and anthocyanins, respectively (Andrade *et al.*, 2017; Bao & Fweja, 2020; Jenkins *et al*., 2015; Labarta, 2012; Montilla *et al*., 2011; Salawu *et al*., 2015; Suda *et al*., 2003; Zhu *et al.*, 2018). In addition to potential impacts in fighting food insecurity and poverty, sweetpotato is also a critical crop in empowering women. In most of the crop's production regions in sub-Saharan Africa, women are heavily engaged in the sweetpotato value chain as producers, intermediaries and retailers (Cunguara *et al*., 2022; Artur *et al*., 2021; Echodu *et al*., 2019). Transformations in sweetpotato agro-systems therefore provide opportunities to improve women's welfare, a critical development goal.

Many technologies developed over the years have often failed to achieve widespread adoption, mainly due to poor matching to individual farmer's specific needs (Anderson *et al*., 2019). Traditionally, the development of new crop varieties has been driven primarily by considerations for agronomic varietal traits such as yield, disease and pest tolerance and agro-climatic suitability, overlooking other traits that are relevant for wider acceptability. Recent evidence shows that, within the context of agricultural technology adoption, preference for quality traits is a key driver to technology choice (Kosmowski *et al*., 2020; Wendmu *et al*., 2022), with an established strong relationship between these traits and preference for landraces over improved varieties (Jenkins *et al*., 2018;

Thiele *et al*., 2021; Mulwa et al., forthcoming). Such quality traits are however diverse, with some relating to sensory attributes such as taste and dry-matter content, visual attributes such as root shape, texture and size, nutrition attributes such as vitamin A content, etc., (Mulwa et al., forthcoming). Given that only a subset of these traits can be incorporated into breeding objectives in combination with "must-have" agronomic traits, it is imperative to understand which key quality traits to prioritize for maximum impact on variety acceptance and adoption.

This study was undertaken as part of the Sweetpotato Genetic Advances and Innovative Seed Systems (SweetGAINS) project, a flagship program at the International Potato Center aimed at modernizing sweetpotato breeding and seed systems in Africa. The study utilizes a discrete choice experiment, designed through an iterative mixed-methods approach, to understand variety choice behavior by sweetpotato farmers in Mozambique, and the implicit valuation attached to each of these various traits. To contribute to the discourse on prioritization of quality traits in breeding process, the study considers five quality traits drawn from the various categories described above and one agronomic trait (drought tolerance), identified as an important trait in prior qualitative studies, to understand how farmers trade off these traits in deciding which varieties to plant within a production season. Results from the study are critical in informing the prioritization of traits in the crop variety development within the project, to drive higher acceptability and adoption of new varieties from breeding pipelines.

2. Methodology

2.1 Study area

Data for the study were obtained from five districts spread over three provinces in southern and central regions of Mozambique. The five districts, namely Massinga in Inhambane province; Nhamatanda and Búzi in Sofala province; and Mossurize and Macate in Manica province, were purposely selected for inclusion in the study based on sweetpotato production and commercialization potential, following a similar qualitative study conducted in the regions to elicit gender-disaggregated trait preferences (see Mulwa et, al. 2021). The selected districts have also benefited from several sweetpotato research and development interventions and represent the diverse agro-ecological and heterogenous production and consumption conditions in Mozambique. The map of the study area is shown in Figure 1.

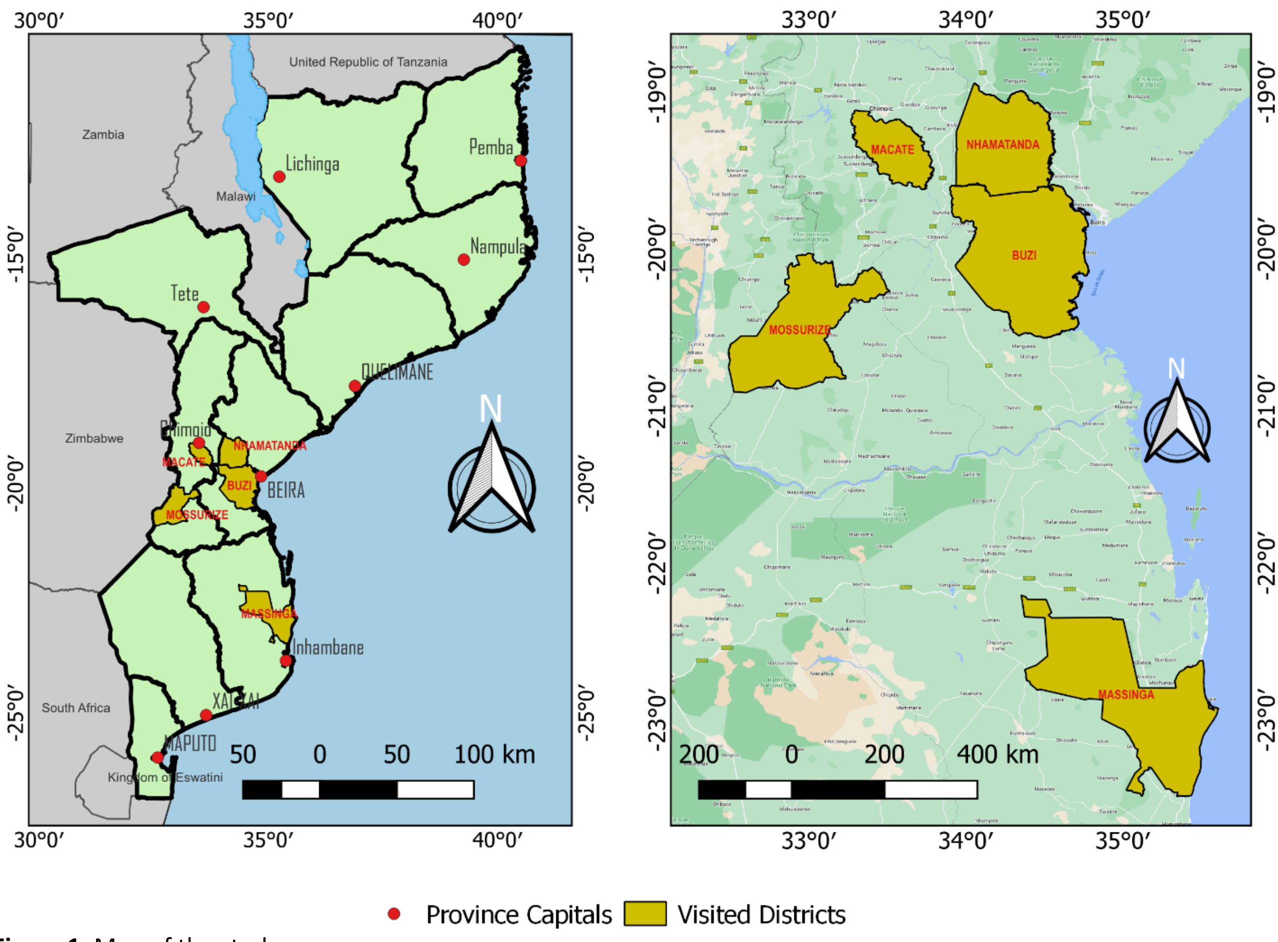

Figure 1. Map of the study area

The district of Macate is within the medium-altitude eastern side of Manica province, characterized by an average rainfall around 1,000-1,200 mm per annum, concentrated between November and March, with a growing period of 120-180 days and the dry season from April until October. The main food crops grown in the district are maize, sorghum, cassava, sesame, groundnuts, cowpeas, sweetpotato and rice. Mossurize district, on the other hand, is located in the Manica highlands, a plateau along the border with Zimbabwe. Precipitation in the area is regular with 600-1,500 mm per annum between November and March with a dry season from April until the end of October. The main food crops grown in the district are maize, root tubers (sweetpotato and cassava), beans, peanuts, vegetables, soya, sesame, and sunflower. The district falls in a typically highly food secure zone due to very good climatic conditions (FEWS NET, SETSAN & USAID, 2014). The third district of study, Búzi, lies along the coastal plains in Sofala province and has a tropical, humid climate with average annual precipitation of about 750-800 mm per year from November through the end of March where rice is mainly grown in the swampy areas of the district. The dry season is from April until October and is characterized by cultivation of maize, vegetables, and sweetpotatoes. The district falls within a moderate risk of food insecurity, given access to diverse food production options.

On the other hand, Nhamatanda district is located in central-west Sofala province, and has two distinct climates, a savannah tropical rainy climate to the east and tropical temperate humid to the west, both with dry and rainy season. It has an average annual precipitation of about 856 mm per year from November through to the end of March with the dry season running from April until October. The main food crops are maize, sorghum, cassava, sesame, groundnuts, cowpeas, sweetpotato, beans, vegetables and rice. This district falls into two distinct livelihood zones: the self-sufficient zone with low risk of food insecurity and the zone characterized by moderate risk of food insecurity. Lastly, Massinga district is located in eastern-central Inhambane Province, covering areas that range from a lowland coastal zone through to inland highlands. The average rainfall ranges from 750 to 1250 mm per annum in the coastal area, from 500-750 in intermediary and interior areas. The main food crops in the district include cassava, sweetpotatoes, maize, cowpeas, groundnut, sorghum, sesame, cowpeas, Bambara nuts, rice and vegetables.

2.2 Study design

The study employed a discrete choice experiment (CE) framework in evaluating farmers' sweetpotato variety trait preferences and the implicit valuation attached to each of these traits to elicit an order of priority in informing variety choice. An iterative mixed-methods approach was adopted in the design to reduce the risk of design error and bias, and to ensure validity of the study findings across different settings (Creswell & Creswell, 2018; Hammett *et al*. 2014). First, insights from a qualitative study conducted to identify traits preferred by both female and male sweetpotato producers and consumers (see Mulwa et al, 2021 for details) across the study area were used to identify six traits for inclusion in the choice experiment as attributes, and the levels assigned to these attributes. Considering the emphasis of the study on quality-related traits, five out of these are quality traits, including size of the root, color of the root flesh, dry-matter content, taste, and vitamin A. Drought tolerance, an agronomic trait, was also included in the CE design for two reasons; first, comparison scores from the previous qualitative assessments revealed that drought tolerance was the most preferred agronomic trait across market segments, and second, inclusion of the trait allows for the comparison of the relative valuation of quality traits to key agronomic traits, a secondary objective of the study. Finally, to help in eliciting the marginal willingness to pay for each attribute, a seventh attribute on the cost of the sweetpotato variety vine was included in the design (See Table 1).

Table 1. Key attributes in the choice experiment design

Attribute	Description	Level	Reference
Drought tolerance	The ability of a sweetpotato variety to have high vigor with leavy canopy moisture stress	Not tolerant, Tolerant	Not tolerant
Root size	Observation based on relative root size	Small, Medium, Big	Small
Flesh color	Observation based on cut sweetpotato roots to reveal the flesh color	White, Purple, Yellow, Orange	White
Dry-matter content	Proportion in terms of weight of sweetpotato tuber after extracting all water content	Low, High	Low
Taste	The extent of sweet taste of the root	Not sweet, Medium sweet, Very sweet	Not sweet
Vitamin A	Whether the root has Vitamin A content or not	No vitamin A, Has vitamin A	No vitamin A
Vine price (Mt/kg)	Sweetpotato vine price in Meticals per 1 kg bag. The price of vines ranges from 5 to 20 Mt/kg, including for both local and improved varieties	5, 10, 15, 20	-

In the CE design process, the choice of the experimental design is critical. The full factorial design, which includes all the possible combinations of attributes and levels under consideration, is the most ideal to achieve unbiased results. However, such a design is impractical as it results in too many options to present to a particular farmer. Most empirical studies utilize the fractional factorial design (FFD), which presents a structured way of choosing various choice sets from within the FFD, and still maintains independence of the choice scenarios. Such a design could also result in too many choice scenarios for samples with limited education, and a blocked fractional factorial design (BFFD) utilized in such cases to block the number of scenarios to present to a particular choice agent (farmer in or case), and there ensure salience while maintaining orthogonality in the overall design. A recent development has been the emergence of the Bayesian efficient design (BED), which utilizes prior estimates and hypothesized distributions of the attributes under consideration to create designs that require fewer choice scenarios to achieve accurate predictions of choice behavior (see van Cranenburgh & Collins, 2019). Such a design, however, requires these priors to be established from existing literature, or smaller pilots prior to the main study.

This study adopted the BED approach, with a pilot first conducted with about 60 farmers in a village within the study area (later excluded from sampling for the main study) to establish the prior parameters associated with the seven attributes, with the BFFD being used in the pilot. The final design consisted of 12 choice scenarios (hereafter choice sets) each containing three sweetpotato varieties profiles (variety 1, 2, and 3) and an “opt out” option, to allow a respondent to select neither of the presented three alternatives in a particular choice set. Given a large segment of the population under study is uneducated, the study adopted visual aids to represent the various choice attributes (variety traits) and raise understanding among the respondents (see Figure 2 for an example of a typical choice set presented to a respondent in the study).

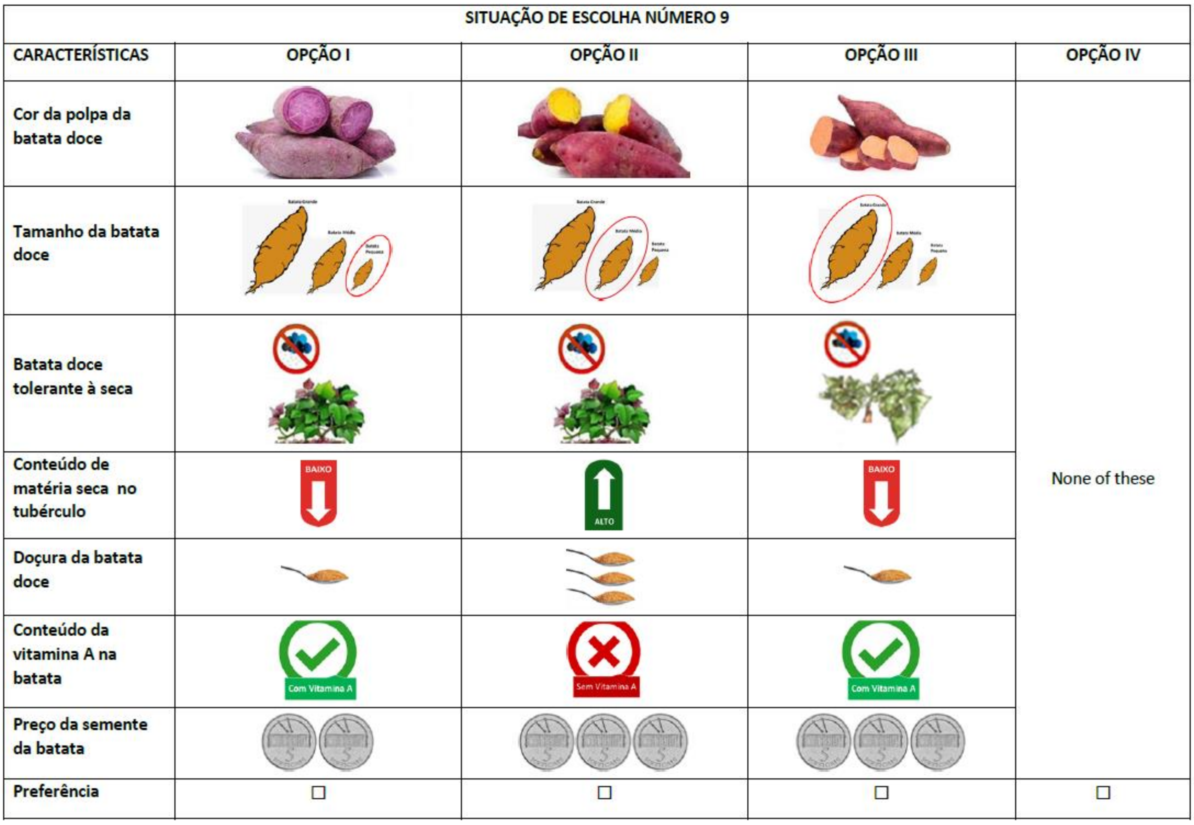

Figure 2. Example of a choice card presented to farmers

In addition to the CE, the respondents also filled out an exit survey on important demographic and socioeconomic data, as well as to establish actual varieties grown by respondent households, and important traits informing variety selection. The surveys were conducted at the end of the CE sessions to avoid bias.

2.3 Sampling and protocols

The Bayesian Efficient Design (BED) estimated using Ngene software (ChoiceMetrics, 2018) determined a sample of 900 farmers to be sufficient to estimate farmers' variety choice behavior with the design described in the section above. To distribute this sample across the selected study area, a multi-stage random sampling procedure was used. First, the ideal sample size in each district was estimated independently using the Yamane's simplified formula for proportions, which assumes 95% confidence level and a maximum variability, based on the population growing sweetpotato per district (Israel, 1992) i.e.,

$$n_i = \frac{N_i}{1+N_i(e)^2} \qquad (1)$$

Where n_i is the ideal sample size in district i, N_i is the population of sweetpotato producers in district i and e is the level of precision, which is assumed to be 5%. Then, the sample size in each district was adjusted based on the shares estimated based on the ideal sample size for each district to accommodate the total sample of 900 participants (Table 2).

Table 2. Estimates of the sample size per district

District	Sweetpotato grower households	Ideal sample size	Adjusted Sample
Mossurize	11,969	387	247
Macate	4,571	368	235
Búzi	350	187	119
Nhamatanda	586	238	152
Massinga	540	230	147
Total	18,016	1,410	900

Data sources: INE, 2020; IAI, 2021.

Within each selected district, sweetpotato producing wards and villages were randomly selected for the study, making-up a total of 18 villages across the study areas. For the identification of households for sampling within the villages, the local leaders and/or the local extension officers were asked to submit a list of names of farmers, both men and women, engaged in sweetpotato root/vine production, from which farmers were randomly selected to participate in the study.

In terms of data collection protocols, up to two data collection sessions were organized within each of the selected villages, in which the selected sweetpotato growers were invited to participate. A data collection session was conducted with a group of about 8-12 farmers, with each individually making a choice on preferred variety based on their preference and based on descriptions by the facilitator. In the session, the group of participating farmers were first taken through a general introductory phase by the trained facilitators, in which the purpose of the study was explained, the oral consent to participate in the study obtained, and the procedures of the experiment explained. The administration of the choice experiment exercises consisted of following steps: first, prior to each session, the sequence of choice sets was randomly established to allow for the variation in the sequencing across the study and minimize order effects. Using a large poster representative of each choice set (see Figure 2, for example) the facilitators then took the group through the attributes and levels of each "variety" within a particular choice set, and then invited the participants to individually make a choice of the preferred variety in a smaller paper version of the choice set in the poster. The participants were arranged in a "lab-in-the-field" set up, discouraging collaboration in choice making. After all the choice sets were covered for that particular session, the participants were then taken through an exit survey in a one-on-one interview using trained enumerators.

2.4 Analytical methods

Discrete choice models are widely used to analyze the choice behavior of economic agents based on the random utility theory (RUM) (McFadden, 1974). Under RUM, and based on the choice experiment design described above, producer i $(i = 1, \dots, 900)$ derives utility U from an observed choice of alternative $j (j = 1, \dots, 4)$ in a choice set $s (s = 1, \dots 12)$. Given a choice set s with J alternatives, the utility function can be written as

$$U_{isj} = \beta_i x_{isj} + \mathcal{E}_{isj} \qquad (2)$$

Where U is agent i's latent utility for choosing alternative j in choice set s; x_{isj} is a vector of explanatory variables including sweetpotato variety traits under consideration and their interactions with relevant individual level variables; β is a vector of utility weights attached to the explanatory variables to be estimated; and $\mathcal{E}_{isj}$ is the stochastic error term capturing unexplained utility.

Various models have been advanced in the literature on the estimation of the utility weights, β_i, depending on the assumptions over the error term ε_{isj} and the relationship among the trait preferences. Under the popular multinomial logit model (MNL) (McFadden, 1974), ε_{isj} is assumed to be independently and identically distributed (*iid*) with extreme value type 1 distribution, and the preferences for observed trait attributes are assumed to be homogenous. The *iid* assumption imposes a restriction that the unexplained utility from one alternative is independent of the portion of unexplained utility from another alternative, which is unlikely as such alternatives are jointly considered in the choice process. The second assumption leads to the independence of irrelevant alternatives (IIA) property, which is also unreasonable as some segments of agents care more about some trait attributes than others, and will therefore switch among subsets of alternative varieties that possess their most valued traits (Fiebig et al., 2010). The assumption of homogeneity in preferences can therefore not hold in a case such as ours.

Failure to model preference heterogeneity in understanding agent choice behavior is therefore likely to lead to severely biased estimates. Similarly, estimation of average preference parameters only, as is the case with MNL, may lead to missing of traits that appeal to certain segments of the targeted population, an important aspect in segmenting the market for targeted variety development and dissemination. Consequently, modeling preference heterogeneity has gained traction in the choice behavior literature (Fiebig et al., 2010; Louviere et al., 2008), with various models advanced that introduce heterogeneity in their specification. For instance, the mixed multinomial logit model (MIXL) (McFadden & Train, 2000) relaxes the IIA assumption inherent in the MNL model to allow for heterogeneity in the preferences for observed trait attributes. In this model, the utility weights from equation (2) are modelled as, $\beta_i = \beta + \eta_i$, where β is the vector of mean attribute utility weights in the population and the term η is a random vector of agent *i*-specific deviations from the mean assumed to have a multivariate normal distribution $\mathrm{MVN}(0, \Sigma)$, and which captures residual preference heterogeneity.

Recent criticism of MIXL posit that much of the heterogeneity in attribute weights is due to variance in utility across individuals, with some agents exhibiting more randomness in choice behavior than others, and less due to residual preference heterogeneity (Fiebig et al., 2010). This has given rise to the scale multinomial logit (S-MNL) model, which models utility weights as $\beta_i = \beta\sigma_i$, with the scaling factor σ_i differing across individuals but not across choices, thus scaling the utility vector β proportionately across agents (Kassie et al., 2017; Louviere et al., 2008). To overcome the limitations of MIXL and account for the scaling factor in S-MNL, recent developments have nested the two models to come up with the generalized multinomial logit model (G-MNL) (Fiebig et al., 2010). Utility weights in the G-MNL are modelled as

$$\beta_i = \beta\sigma_i + \gamma\eta_i + (1-\gamma)\sigma_i\eta_i \qquad (3)$$

Where γ is a scale parameter ranging from 0 to 1 which governs how the variance of residual preference heterogeneity varies with scale in a model that includes both sources of heterogeneity and σ_i is the individual-specific scale of the idiosyncratic error. The extreme cases of γ=1 or γ=0 give rise to two special cases of G-MNL; G-MNL-I (where $\beta_i = \beta\sigma_i + \eta_i$) and G-MNL-II (where $\beta_i = \beta\sigma_i + \sigma_i\eta_i$) respectively, while $\Upsilon \in [0,1]$ represents the full G-MNL model (see Kassie et al., 2017). Given that σ_i captures the individual-specific scale of idiosyncratic error, it is assumed to be positive and thus follows a log-normal distribution with standard deviation τ and mean $\bar{\sigma} + \theta z_i$, where $\bar{\sigma}$ is a normalizing constant and z_i is a vector of individual-specific characteristics that explain why σ_i differs across agents (Gu et al., 2013). As τ tends to 0, G-MNL approaches MIXL, while for τ>0, G-MNL approaches S-MNL. From the preceding model specifications and design, the outcome variable is defined as $y_{isj} = 1$ if agent i chooses alternative $j(j = 1,..,4)$ in choice set $s(\mathrm{s} = 1, \dots, 12)$ and $y_{isj} = 0$ if otherwise. The

G-MNL maximized simulated log-likelihood of observing agent i choosing a sequence of choices $\{y_{isj}\}_{s=1}^{S}$ is thus given by:

$$SLL\ (\beta,\gamma,\tau,\theta,\Sigma)=\sum_{i=1}^{N} ln\left\{\frac{1}{R}\sum_{r=1}^{R}\prod_{s=1}^{S}\prod_{j=1}^{J}Pr\left(\text{choice}_{is}=j|\beta_i^{[r]}\right)^{y_{isj}}\right\} \qquad (4)$$

where $\beta_i^{[r]}=\beta\sigma_i^{[r]}+\gamma\eta_i^{[r]}+(1-\gamma)\sigma_i^{[r]}\eta_i^{[r]}$ and $\sigma_i^{[r]}=\exp\left(\bar{\sigma}+\theta z_i+\tau\upsilon^{[r]}\right)$; $\eta_i^{[r]}$ and $\sigma_i^{[r]}$ are the R simulated random and pseudo-random draws for η_i and σ_i, respectively; and $j|\beta_i^{[r]}$, the probability of agent i choosing alternative j in choice set s is given as, $j|\beta_i^{[r]}=\frac{exp(\beta_i{}'x_{isj})}{\sum_{j=1}^{J_{is}}exp(\beta_i{}'x_{isj})}$.

Lastly, from equation (3), willingness to pay (WTP) for a variety trait attribute j in the G-MNL is estimated as the ratio of the attribute's utility and the coefficient of the cost attribute i.e., $\left[\beta_j\sigma_i+\gamma\eta_{ij}+(1-\gamma)\sigma_i\eta_{ij}\right]/\left(\phi\sigma_i+\gamma\eta_{\phi i}+(1-\gamma)\sigma_i\eta_{\phi i}\right)$ (5)

where ϕ is the mean cost coefficient in the population, other terms are as defined before. Both equations (4) and (5) are estimated in Stata using the *gmnl* package (Gu et al., 2013). Equation (5) is estimated in the willingness to pay space, which is more behaviorally appealing as it gives WTP estimates that are reasonable, compared to WTP estimation in utility space which yields estimates that are unreasonably large (Fiebig et al., 2010; Greene, 2009; Kassie et al., 2017).

3. Results and discussion

This section presents and discusses empirical results from the study. It comprises the description of socio-demographic of sampled sweetpotato growers, the G-MNL model estimations for trait attribute preferences in variety choice, willingness to pay (WTP) for variety traits, and heterogeneity in both variety trait preferences and WTP estimates.

3.1 Sample characteristics

Table 3 summarizes the socio-demographic characteristics of the sampled sweetpotato growers disaggregated by gender and location. Overall, the majority of the respondents (94.14%) reported farming was their main occupation and the overall median annual income[1] is around USD150. The dominance of farming as the main occupation of the participants is similar across the districts regardless of the gender.

Table 3. Characteristics of sweetpotato growers across gender and location

Characteristic	District					Overall (n=860)
	Massinga (n=95)	Macate (n=211)	Mossurize (n=261)	Nhamatanda (n=156)	Búzi (n=137)	
Gender (%)						
Male	27.37	54.98	40.23	28.85	26.28	38.14
Female	72.63	45.02	59.77	71.15	73.72	61.86
Age (years)						
Male	58.6	37.4	43.7	51.1	50.8	44.4
Female	41.7	39	39.8	44.8	46	42.1
All	46.5	38.1	41.4	46.7	47.2	43
Education						
Male	4	6.8	5.5	5.1	6.6	5.9
Female	4.5	4	4	3.1	3.9	3.9
All	4.3	5.6	4.6	3.7	4.6	4.7
Farming main occupation (%)						
Male	88.46	96.55	93.33	100	88.89	94.51
Female	89.86	95.79	94.87	97.30	90.10	93.98
All	89.47	96.21	94.25	98.08	89.78	94.19
HH Income (Mtn)	10,000	18,050	9,500	5,250	5,000	9,000

Source: Survey data, 2022; HH = household; Mtn = Meticals

The sampled sweetpotato growers for the study were mainly women, estimated at 62% of the full sample of sweetpotato growers. The overall participant age was about 43 years, while in terms of education, Macate and Nhamatanda districts had the highest and lowest education attainment levels, respectively, with women being less educated than men across the full sample.

[1] A median income was used instead of a mean as a descriptive statistic for income, since it more representative of the sample, given that the observations of the income are highly skewed with an extremely high kurtosis.

3.2 Survey-based stated sweetpotato variety and trait preferences

3.2.1 Sweetpotato variety preferences

Study participants were asked in the exit survey to list their three most preferred varieties among the available varieties in their settings, and ones they had cultivated in their farms within the previous two years. Overall, the top preferred varieties across the five districts were Secae, Chibachengwe and Polpa, in that order, preferred by 27%, 24% and 21% of interviewed farmers, respectively (Table 5). While the top five preferred varieties are the same for both male and female sweetpotato growers, the order of preference differs across gender. The most preferred variety for men is Secae (33.9%), followed by Chibachengwe (24.5%), Polpa (22.9%), Cori (14.7%) and Cenoura (11.6), while most preferred varieties for women were Chibachengwe (24.3%), Secae (22.6%), Polpa (20.2%), Cenoura (15.8%) and Cori (12.2%), in that order.

Table 4. Gender disaggregated sweetpotato variety preferences

	Men (n=327)		Women (n=526)		Overall (n=853)	
Rank	Variety name	%	Variety name	%	Variety name	%
1	Secae	33.9	Chibachengwe	24.3	Secae	27.0
2	Chibachengwe	24.5	Secae	22.6	Chibachengwe	24.4
3	Polpa*	22.9	Polpa*	20.2	Polpa*	21.2
4	Cori	14.7	Cenoura*	15.8	Cenoura*	14.2
5	Cenoura*	11.6	Cori	12.2	Cori	13.1
6	Mudzipaeca	8.9	Meno a Guebuza*	10.3	Meno a Guebuza*	9.0
7	Meno a Guebuza*	7.0	Tumanze	8.9	Mudzipaeca	8.3
8	Chibiquirai waene	5.8	Mudzipaeca	8.0	Tumanze	6.7
9	Chigurapine	4.9	White-fleshed	5.9	Chibiquirai waene	5.3
10	Yellow-fleshed	4.3	Chibiquirai waene	4.9	White-fleshed	4.8

Data Source: Survey data, 2022

Note: The superscript* denotes a variety presumed to be a released but unidentified variety[2] while absence of this indicates the variety is a landrace

The top ten preferred varieties vary considerably across the study districts (see Table 5). While some varieties are commonly preferred across districts, a considerable number of these show heterogenous preferences across districts.

[2] Released but unidentified, are some varieties that have some features consistent with improved varieties but where it was not possible to compare them to the officially released varieties. For instance, Cenoura and Polpa are orange-fleshed, meaning that are not landrace, but is not yet known which improved variety they are.

Table 5. Sweetpotato variety preferences by district

Rank	Massinga (n=90)	Macate (n=210)	Mossurize (n=261)	Nhamatanda (n=155)	Búzi (n=137)	Overall (n=853)
1	White-Fleshed (30%)	Secae (95.7%)	Chibachegwe (79.0%)	Cenoura* (28.4%)	Meno a Guebuza* (56.2%)	Secae (27%)
2	Ester[IP] (27.8%)	Polpa* (39.5%)	Cori (42.5%)	Tumanze (25.2%)	Mudzipaeca (29.2%)	Chibachegwe (24.4%)
3	Yellow-Fleshed (18.9%)	Cenoura* (17.6%)	Polpa* (16.1%)	Ndabwera na Nzeru Zanga (20.0%)	Cenoura* (25.6%)	Polpa* (21.2%)
4	Polpa* (17.8%)	Tumanze (8.1%)	Chibiquirai waene (15.3%)	Julia [IP] (19.4%)	Derunde (17.5%)	Cenoura* (14.2%)
5	Irene [IP] (14.4%)	Buadara (4.3%) *	Chigurapine (14.9%)	Mudzipaeca (18.1%)	Polpa* (15.3%)	Cori (13.1%)
6	Xipone (14.4%)	Africare (3.3%)	Amelia[IP] (9.2%)	Gina[IP] (16.8%)	Musotcha (13.9%)	Meno a Guebuza* (9.0%)
7	Sumaia[IP] (12.2%)	Dambarare (1.0%)	Chimarata (8.4%)	Nhamandui (14.2%	Isaura Nyusi* (11.0%)	Mudzipaeca (8.3%)
8	Alisha[IP] (4.4%)	Gloria[IP] (1.0%)	Chigura Badza (7.3%)	Kabalire Tsogolo (12.9%)	Muforça (9.5%)	Tumanze (6.7%)
9	Gloria[IP] (4.4%)	Guardara (1.0%)	Olga [IP] (4.2%)	Polpa* (12.3%)	Secae (7.3%)	Chibiquirai waene (5.3%)
10	Nhamandui (4.4%)	Mudzipaeca (1.0%)	White-Fleshed (3.1%)	Secae (11.0%)	Purple-Fleshed (5.8%)	White-Fleshed (4.8%)

Source: Survey data, 2022

Note: **[IP]**Indicates an improved/released variety; *****indicates a variety presumed to be released but unidentified; other varieties are landraces.

For instance, Chibachengwe is highly preferred in Mossurize, where more than 79% of the participants in the study mention this variety as one of their top-three preferred varieties, yet it is not among the top ten preferred varieties in the other districts. Similarly, in Búzi, about 56% of the participants indicated Meno a Guebuza as their top three preferred variety yet it is still not among the ten most preferred varieties in the other districts. Massinga district appears to have the highest proportion of respondents preferring improved varieties, perhaps pointing to high dissemination of such varieties in the district.

3.2.2 Sweetpotato variety trait preferences

From the most preferred varieties, further analyses were conducted for the three most preferred traits associated with these preferred varieties. Results of this analysis show that most preferred traits across the considered varieties are good taste, high yield, high dry matter content, vitamin A content, flesh color, drought tolerance and good aroma, in that order.

Table 6. Most preferred traits associated with the most preferred varieties

Obs	Variety	First Trait	Second Trait	Third Trait
1	Secae	Good Taste	High Dry Matter Content	High Yields
2	Chibachengwe	Good Taste	High Dry Matter Content	High Yields
3	Polpa	Good Taste	Vitamin A	Flesh Color
4	Cenoura	Good Taste	High Dry Matter Content	Vitamin A
5	Cori	Good Taste	High Dry Matter Content	High Yields
6	Meno a Guebuza	Good Taste	High Dry Matter Content	Early Maturity
7	Mudzipaeca	Good Taste	High Dry Matter Content	High Yields
8	Tumanze	Good Taste	High Yields	High Dry Matter Content
9	Chibiquirai waene	Good Taste	High Dry Matter Content	High Yields
10	White-fleshed	Good Taste	High Yields	Vitamin A
11	Chigurapine	High Yields	High Dry Matter Content	Good Taste
12	Yellow-fleshed	Good Taste	Flesh Color	High Yields
13	Ndabwera na Nzeru zanga	Good Taste	High Yields	High Dry Matter Content
14	Julia	Good Taste	High Yields	High Dry Matter Content
15	Ester	Good Taste	Vitamin A	High Yields
16	Amelia	Good Taste	High Dry Matter Content	Vitamin A
17	Purple-fleshed	Good Taste	High Dry Matter Content	Flesh Color
18	Gina	Good Taste	High Yields	Drought Tolerance
19	Derunde	Good Taste	Good Aroma	High Yields
20	Nhamandui	Good Taste	High Yields	High Dry Matter Content
21	Chigura Badza	High Dry Matter Content	Good Taste	High Yields

Among these traits, good taste, high yield and high dry-matter content appear to be the top priority traits. These findings are similar to those obtained by Mulwa et al. (2021) using a qualitative approach in a subset of the study area, and further affirms the validity of the chosen traits for inclusion in the choice experiment design.

3.3 Choice experiment-based revealed variety trait preferences

3.3.1 Sweetpotato variety attributes and variety demand

The results from the estimation of the generalized multinomial logit model indicate that sweetpotato varieties that are rich in vitamin A, tolerant to drought, yield medium-to-big sized roots, have high dry matter content, and are very sweet, are the most likely varieties to be adopted by farmers (Table 7).

Table 7. Trait preferences and sweetpotato variety demand

Trait preference	Mean parameter estimate β	Std error	
Medium root size	0.404***	0.085	
Big root size	0.550***	0.052	
Purple-fleshed root	-0.125*	0.070	
Yellow-fleshed root	0.0657	0.069	
Orange-fleshed root	-0.245***	0.067	Tau = 0.759 (0.069)
Drought tolerance	0.629***	0.073	Gamma =-0.702 (0.074)
Dry matter content	0.342***	0.051	Observations=29,718
Medium sweet root	-0.0480	0.069	
Very sweet root	0.264***	0.057	
Vitamin A	2.427***	0.145	
Cost of vine (Mt/90kg bag)	0.0562***	0.005	
Heterogeneity in respondent gender			
Gender*Medium root size	-0.141	0.201	
Gender*Big root size	-0.198*	0.115	
Gender*Purple-fleshed root	-0.168	0.179	
Gender*Yellow-fleshed root	0.203	0.149	
Gender*Orange-fleshed root	-0.139	0.157	
Gender*Drought tolerance	-0.141	0.154	
Gender*Dry matter content	0.0790	0.127	
Gender*Medium sweet root	0.109	0.168	
Gender*Very sweet root	0.0546	0.151	
Gender*Vitamin A	0.778***	0.280	
Heterogeneity in respondent age			
Age*Medium root size	0.00724	0.005	
Age*Big root size	0.00627**	0.003	
Age*Purple-fleshed root	-0.00361	0.004	
Age*Yellow-fleshed root	0.00253	0.004	Tau = 0.473 (0.067)
Age*Orange-fleshed root	-0.00632	0.004	Gamma =-0.00750 (0.123)
Age*Drought tolerance	-0.00255	0.004	Observations=29,718
Age*Dry matter content	-0.00601*	0.003	
Age*Medium sweet root	-0.00709	0.005	
Age*Very sweet root	-0.00163	0.004	
Age*Vitamin A	0.0113**	0.006	
Heterogeneity in respondent education			
Education*Medium root size	0.0262	0.027	
Education*Big root size	0.0440***	0.016	
Education*Purple-fleshed root	-0.0576**	0.023	
Education*Yellow-fleshed root	-0.00285	0.022	
Education*Orange-fleshed root	-0.00497	0.022	
Education*Drought tolerance	0.0173	0.019	
Education*Dry matter content	0.0218	0.017	
Education*Medium sweet root	-0.0286	0.023	
Education*Very sweet root	-0.0356*	0.018	
Education*Vitamin A	0.241***	0.031	

*** p<0.01, ** p<0.05, * p<0.1

Based on the outputs of the estimated model, which indicated potential heterogeneity around big root size, orange flesh color, dry-matter content, and very sweet taste, additional analysis was performed to examine how much of the unobserved heterogeneity around the mean estimates of these trait preferences might be explained by observable individual specific characteristics. As such, the G-MNL model was re-estimated including components of interaction of these trait preferences with the age, education and gender of the respondents (for details, see the second part of Table 7). The results indicate that these individual specific variables contribute for significative variations in average levels of vitamin A, root size, dry matter content and taste trait preferences.

The gender of the respondent was found to significantly explain variation in big root size and vitamin A, with women preferring big sized roots while men are more interested in vitamin-A-rich varieties. Women's preferences for big sized sweetpotato roots could be explained through gender lens in the context of the study. First, women are responsible for meal preparation, and they may prefer bigger roots as they are relatively easier to process. Also, bigger roots tend to have higher market value, and considering that sweetpotato is more of a women-managed crop, women, more than men, appreciate the relatively higher income as a result of the market demand for big roots. On the other hand, the results suggest that the age of the respondent significantly explain variation in the preference of root size, vitamin A and dry-matter content, with older respondents preferring big sized roots with vitamin A but lower dry-matter content compared to their younger counterparts. This could perhaps be due to the need for micronutrients and soft to eat roots among the older consumers. Lastly, education is positively correlated with root size and vitamin A, but negatively correlated with purple color (compared to white) and very sweet roots. Preference for vitamin A and low/medium sweetness is, perhaps, an indication of nutrition consciousness among higher educated consumers who demand nutritious roots with low sugar content.

3.3.2 Willingness to pay for variety traits and implications for prioritization

Willingness to pay (WTP) estimates provide the rate of substitution between significant variety trait attributes and vine cost, with negative estimates accounting for preference disutility (Kassie et al., 2017). The results of estimations in Figure 3 indicate that the implicit price of vitamin A is the highest among the considered traits in the study, followed by the price for drought tolerance, dry matter content, root size, and taste. The demand for flesh color appears to be insignificant, implying that end-users are least interested in this trait, compared to the other traits under consideration. Expectedly, the cost parameter is negative indicating a disutility associated with additional vine cost, hence preference for cheaper vines.

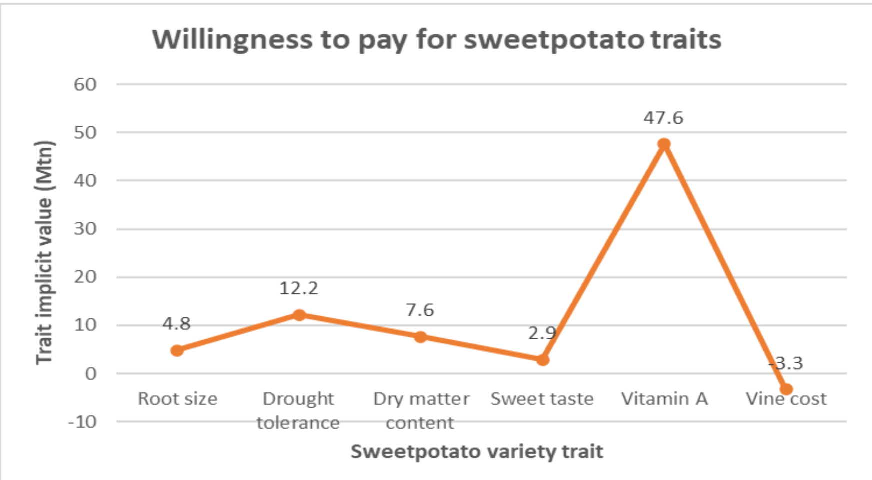

Figure 3. Willingness to pay for sweetpotato variety traits

Taking drought tolerance as the reference trait (the most highly rated agronomic trait from the qualitative studies), farmers are willing to pay a premium for vitamin A that is about four times the amount they are willing to pay for drought tolerance. This may not be surprising, given reported levels of malnutrition in the study area (Jenkins et al., 2015). However, the measure of WTP for vitamin A may be confounded by the nutrition information 'treatment', given that respondents were taken through the importance of the trait before making their choices. This could explain the higher rank accorded to the trait from these revealed preferences in the choice experiment, as compared to the stated preference as elicited from the exit survey. Still, the finding is of particularly importance as it points to the role of nutrition information in the demand for varieties rich in micro-nutrients. On the other hand, the WTP for dry-matter content is only about 1.6 times less than for drought tolerance, pointing to the importance of this quality trait relative to key agronomic traits such as drought tolerance. The most pronounced deviation in WTP for quality traits compared to that of drought tolerance is observed for root size and taste trait preferences; the WTP for root size is about 2.6 times less than for drought tolerance while that for taste is about 4.2 times less. Sweetpotato producers therefore appear to care about Vitamin A more than drought tolerance, have about the same valuation for drought tolerance as that for dry matter content, and have lower valuations for root size and taste, compared to drought tolerance.

Similar to the previous analysis, various traits were interacted with gender, education and age of the respondent to understand the portion of unobserved heterogeneity that can be explained by observable individual-specific characteristics (Table 9).

Table 8. Willingness to pay for variety traits and heterogeneity

	Mean parameter β	Std error
Trait preference		
Root size	4.761***	0.488
Flesh color	-0.404	0.313
Drought tolerance	12.18***	1.203
Dry-matter content	7.636***	0.915
Taste	2.872***	0.495
Vitamin A	47.62***	2.927
Cost	-3.296***	0.061
Observed heterogeneity		
Gender*root size	-0.512	0.560
Gender*flesh color	-0.773*	0.470
Gender*drought tolerance	4.628***	1.659
Gender*dry matter content	5.390***	1.286
Gender*taste	1.950***	0.747
Gender*vitamin A	7.765***	2.269
Age*root size	0.0659***	0.019
Age*flesh color	-0.000393	0.016
Age*drought tolerance	0.0835	0.056
Age*dry matter content	-0.0668	0.044
Age*taste	0.0135	0.026
Age*Vitamin	0.314***	0.085
Education*root size	0.715***	0.118
Education*flesh color	0.190**	0.091
Education*drought tolerance	0.396	0.309
Education*dry matter content	0.677***	0.245
Education*taste	-0.237	0.145
Education*vitamin A	5.944***	0.618
Observations	29,718	

*** p<0.01, ** p<0.05, * p<0.1

The results show that women seem to be willing to pay more for the flesh-color trait, while men are willing to pay more for most of the other traits, including drought tolerance, dry matter content, taste and vitamin A. It is not clear if this is driven by liquidity between men and women since the choice experiment was not incentivized with real payments, and analysis at respondent level may not tease out the household level liquidity between male-headed and female-headed households. Similarly, older respondents seem to be willing to pay more for root size and vitamin A traits, while more educated respondents are willing to pay more for root size, flesh color, dry-matter content, and vitamin A traits.

4. Summary of key findings and conclusions

This study aimed at identifying the traits that are most preferred by sweetpotato farmers in Mozambique and provide a formal basis for their prioritization in breeding efforts, focusing largely on quality traits. The study uses an iterative process encompassing qualitative and quantitative methods and combines both revealed and stated preferences for sweetpotato variety traits as a robustness check for obtained results. Based on recent qualitative insights, the study focuses largely on the often-ignored quality traits and how they influence variety acceptance and adoption, culminating in important results for both sweetpotato and larger crop breeding programs, as well as seed dissemination programs.

Stated preferences from the survey indicate good taste, high yields, high dry-matter content and drought tolerance as the key traits preferred by the interviewed respondents. The choice experiment, based largely on quality traits, reveal that farmers have a high preference for quality-related traits with preference for vitamin A being higher than that for drought tolerance, while dry-matter content is valued about the same as drought tolerance. Good taste and dry-matter content are equally highly valued by producers. Triangulation between the stated and revealed preferences thus confirms the importance of these quality traits in variety demand. While vitamin A is ranked lower among the most preferred traits in the survey, the trait is shown to have the highest implicit value from the choice experiment. This could partly be explained by the fact that experiment participants were informed about the importance of the trait in combating vitamin A deficiency (VAD), thereby inducing a nutrition information type of effect. This points to the importance of availing nutrition information to enhance acceptance of vitamin-A-rich varieties such as the orange-fleshed sweetpotato (OFSP) varieties, as observed elsewhere (see Mulwa et al., 2022).

The findings from this study have profound implications for sweetpotato breeding and seed dissemination programs. Quality traits are as important as agronomic traits in driving demand for new, improved sweetpotato varieties. Agronomic gains in new varieties should therefore be pursued in combination with important quality traits, to ensure inclusive and widespread adoption of these varieties. Such quality traits may be prioritized based on the implicit valuation of each trait, in the Mozambican context, as observed from the estimated marginal WTP for these traits. Finally, while the vitamin A trait is highly ranked, its implicit value is confounded with nutrition information pointing to the importance of dissemination of nutrition information in the promotion of such varieties for higher acceptance.

References

Abidin, P. E., Carey, E., Mallubhotla, S., and Sones, K., 2017. *Sweetpotato Cropping Guide*. Nairobi: Africa Soil Health Consortium.

Alpizar, F., Carlsson, F. and Martinsson, P., 2001. Using choice experiments for non-market valuation. *Working papers in economics/Göteborg University, Dept. of Economics;* no. 52.

Anderson, J., Karuppusamy, R., Neumann, P., Miller, H. and Tamara, R., 2019. *Smallholder households: Distinct segments, different needs* (Vol. 111). CGAP Focus Note.

Andrade, M. I., Ricardo, J., Naico, A., Alvaro, A., Makunde, G.S., Low, J., Ortiz, R. and Grüneberg, W. J., 2017. Release of orange-fleshed sweetpotato (*Ipomoea batatas* [l.] Lam.) cultivars in Mozambique through an accelerated breeding scheme. *The Journal of Agricultural Science*, 155(6), 919–929.

Artur, L., Cunguara, B., Rafael, R., Tomo, A., and Padil, A., 2021. *Gender and environment sensitive analysis for the common beans value chain in Maputo and Gaza provinces*. Technical Report. SOCODEVI. Maputo.

Bao, B. and Fweja, L., 2020. Evaluation of the potential of freshly bred orange-fleshed sweetpotato varieties in combating vitamin A deficiency. *Tanzania Journal of Science*, 46(1), 1–8.

Botzen, W. W. and van Beukering, P. J., 2018. Geographical scoping and willingness-to-pay for nature protection. *Journal of Integrative Environmental Sciences*, 15(1), 41–58.

Carlsson F., Frykblom P., Lagerkvist C. J., 2007. Consumer benefits of labels and bans on GM foods-choice experiments with Swedish consumers. *Am. J. Agric. Econ.*, 89, 152–161.

ChoiceMetrics. 2018. Ngene 1.2 USER MANUAL & REFERENCE GUIDE: The Cutting Edge in Experimental Design.

Clark, M. D., Determann, D., Petrou, S., Moro, D. and de Bekker-Grob, E. W., 2014. Discrete choice experiments in health economics: a review of the literature. *Pharmacoeconomics*, 32(9), 883–902.

Coast, J., Al-Janabi, H., Sutton, E. J., Horrocks, S. A., Vosper, A. J., Swancutt, D. R. and Flynn, T. N., 2012. Using qualitative methods for attribute development for discrete choice experiments: issues and recommendations. *Health economics*, 21(6), 730–741.

Cunguara, B., Tomo, A., Cunguara, E. and Manga, I., 2022. *Market Analysis in Barada and Estaquinha under RECOMOSA Project*. Technical Report.

Cunguara, B. and Wellington. 2019. *Assessing the impact of CIP's Sweetpotato Program in Mozambique: A review*. Technical Report.

de Bekker-Grob, E. W., Ryan, M. and Gerard, K., 2012. Discrete choice experiments in health economics: a review of the literature. *Health economics*, 21(2), 145–172.

Durán, R., Farizo, B. A. and Vázquez, M. X., 2015. Conservation of maritime cultural heritage: A discrete choice experiment in a European Atlantic Region. *Marine Policy*, 51, 356–365.

Echodu, R., Edema, H., Wokorach, G., Zawedde, C., Otim, G., Luambano, N., Ateka, E. M. and Asiimwe, T., 2019. Farmers' practices and their knowledge of biotic constraints to sweetpotato production in East Africa. *Physiological and molecular plant pathology*, 105, 3–16.

FAO, 2016. *FAPDA Fact Sheet on Food and Agriculture Policy Trends*. Mozambique.

Farrar, S., Ryan, M., Ross, D. and Ludbrook, A., 2000. Using discrete choice modelling in priority setting: an application to clinical service developments. *Social science & medicine*, 50(1), 63–75.

Fiorella, K. J., Chen, R. L., Milner, E. M. and Fernald, L. C., 2016. Agricultural interventions for improved nutrition: A review of livelihood and environmental dimensions. *Global Food Security*, 8, 39–47.

Hammett, D., Twyman, C. and Graham, M. 2014. *Research and Fieldwork in Development*. Routledge.

INE (Instituto Nacional de Estatística), 2020. *Indicadores Básicos de Agricultura e Alimentação 2015-2019.* Maputo, Moçambique.

Israel, G. D. 1992. *Determining sample size.* Program Evaluation and Organizational Development. IFAS, University of Florida, PEOD-6. November.

Jenkins, M., Shanks, C. B., Brouwer, R., and Houghtaling, B. 2018. Factors affecting farmers' willingness and ability to adopt and retain vitamin A-rich varieties of orange-fleshed sweetpotato in Mozambique. *Food Security*, 10(6), 1521–1523. https://doi.org/10.1007/s12571-018-0866-4

Jenkins, M., Byker Shanks, C. and Houghtaling, B., 2015. Orange-fleshed sweetpotato: Successes and remaining challenges of the introduction of a nutritionally superior staple crop in Mozambique. *Food and Nutrition Bulletin*, 36(3), 327–353.

Kassie, G. T., Abdulai, A., Greene, W. H., Shiferaw, B., Abate, T., Tarekegne, A., and Sutcliffe, C. 2017. Modeling Preference and Willingness to Pay for Drought Tolerance (DT) in Maize in Rural Zimbabwe. *World Development*, 94, 465–477. https://doi.org/10.1016/j.worlddev.2017.02.008

Kløjgaard, M. E., Bech, M. and Søgaard, R., 2012. Designing a stated choice experiment: the value of a qualitative process. *Journal of Choice Modelling*, 5(2), 1–18.

Kosmowski, F., Alemu, S., Mallia, P., Stevenson, J., and Macours, K. (2020). *Shining a Brighter Light: Comprehensive Evidence on Adoption and Diffusion of CGIAR-Related Innovations in Ethiopia. Rome: Standing Panel on Impact Assessment (SPIA)* (Issue October).

Labarta, R., 2012. *The genetic improvement of potato and sweetpotato in Sub-Saharan Africa.* Report to the diffusion and impact of improved varieties in Africa (DIIVA) project, Nairobi.

Low, J. W., Mwanga, R. O. M., Andrade, M., Carey, E., and Ball, A-M., 2017. Tackling vitamin A deficiency with biofortified sweetpotato in sub-Saharan Africa. *Global Food Security*, 14, 23–30.

Low, J. W., Ortiz, R., Vandamme, E., Andrade, M., Biazin, B., and Grüneberg, W. J. 2020. Nutrient-dense orange-fleshed sweetpotato: advances in drought tolerance breeding and understanding of management practices for sustainable next-generation cropping systems in Sub-Saharan Africa. *Frontiers in Sustainable Food Systems.* 4:50.

MADER (Ministério da Agricultura e Desenvolvimento Rural). 2021. *Inquérito Agrário Integrado 2020*. Moçambique: MADER.

Manuel, L., Tostão, E., Vilanculos, O., Mandlhate, G. and Hartley, F., 2020. *Economic implications of climate change in Mozambique*. SA-TIED Working Paper #136. September.

McEwan, M. A., van Mourik, T. A., Hundayehu, M. C., Asfaw, F., Namanda, S., Suleman, I., Mayanja, S., Imoro, S. and Etwire, P. M., 2022. Securing Sweetpotato Planting Material for Farmers in Dryland Africa: Gender-Responsive Communication Approaches to Scale Triple S. In *Root, Tuber and Banana Food System Innovations* (pp. 353–388). Springer, Cham.

Ministerio da Saúde (MISAU), Instituto Nacional de Estadística (INE) and ICF International (ICFI). 2011. *Moçambique Inquérito Demográfico e de Saúde 2011.* Calverton, Maryland, USA: MISAU, INE and ICFI.

Montilla, E. C., Hillebrand, S., and Winterhalter, P., 2011. Anthocyanins in purple sweetpotato (Ipomoea batatas L.) varieties. Montilla, E. C., Hillebrand, S., and Winterhalter, P. (2011). Anthocyanins in purple sweetpotato (*Ipomoea batatas* L.) varieties*. Fruit Veg. Cereal Sci. Biotechnol.* 5, 19–24.

Mulwa, C. K., Heck, S., Maru, J., Mwema, J., and Campos, H. 2022. Effect of nutrition awareness on utilization of orange-fleshed sweetpotato among vulnerable populations in Kenya. *Food Security.* https://doi.org/10.1007/s12571-022-01326-4

Mulwa, C. K., McEwan, M., Mussa, H., Ogero, K., Rajendran, S. and Wanjohi, L., 2021. *Gender-differentiated trait preferences for sweetpotato varieties in Tanzania*. A Focus Group Discussion Report.

Mulwa C. K., Mudema, J., Madroba, G., Abdul, N., Makunde, G., and Andrade, M., 2021. *Gender-differentiated trait preference for sweetpotato varieties in Mozambique: A Focus Group Discussion Report*. Lima, Peru: International Potato Center.

Olaosebikan, O., Kulakow, P., Tufan, H. A., Madu, T., Egesi, C. N. and Teeken, B., 2018*. A case study of cassava trait preferences of men and women farmers in Nigeria: Implications for gender-responsive cassava variety development.* International Institute of Tropical Agriculture.

Ryan, M., Gerard, K. and Amaya-Amaya, M., 2008. Discrete choice experiments in a nutshell. In *Using discrete choice experiments to value health and health care* (pp. 13–46). Springer, Dordrecht.

Salawu, S. O., Udi, E., Akindahunsi, A. A., Boligon, A. A. and Athayde, M. L., 2015. Antioxidant potential, phenolic profile and nutrient composition of flesh and peels from Nigerian white and purple skinned sweetpotato (Ipomea batatas L.). *Asian J. Plant Sci. Res*, 5(5), 14–23.

Suda, I., Oki, T., Masuda, M., Kobayashi, M., Nishiba, Y. and Furuta, S., 2003. Physiological functionality of purple-fleshed sweetpotatoes containing anthocyanins and their utilization in foods. *Japan Agricultural Research Quarterly: JARQ*, 37(3), 167–173.

Teeken, B., Olaosebikan, O., Haleegoah, J., Oladejo, E., Madu, T., Bello, A., Parkes, E., Egesi, C., Kulakow, P., Kirscht, H. and Tufan, H. A., 2018. Cassava trait preferences of men and women farmers in Nigeria: implications for breeding. *Economic Botany*, 72(3), 263–277.

USAID. 2021. *Viable Sweetpotato Technologies in Africa.* https://www.usaid.gov/mozambique/fact-sheets/viable-sweetpotato-technologies-africa-vista

Viney, R., Lancsar, E. and Louviere, J., 2002. Discrete choice experiments to measure consumer preferences for health and healthcare. *Expert review of pharmacoeconomics & outcomes research*, 2(4), 319–326.

World Health Organization, 2009. *Global prevalence of vitamin A deficiency in populations at risk 1995-2005:* WHO global database on vitamin A deficiency.

Zhu, H. M., Li, R., Su, X. D. and Zhu, M. J., 2018. Morphology of anthocyanin vacuolar inclusions (AVIs) in purple sweetpotato. *Euro. J. Horticult. Sci.*, 83, 364–373.

WWW.CIPOTATO.ORG

For more information, please contact CIP Headquarter. Av. La Molina 1895, La Molina. Apartado 1558, Lima 12, Peru.

5-11-3496017 *cip-cpad@cgiar.org* *www.cipotato.org* | *@cipotato* *@Cipotato* *@cip_potato*

CIP thanks all donors and organizations that globally support its work through their contributions to the CGIAR Trust Fund: www.cgiar.org/funders