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Research Paper

Willingness to Pay for Better-quality Sweet Potato Varietal Traits in Kenya

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Abstract
This study purposed to explore farmers' willingness to pay (WTP) for better-quality sweet potato varietal traits in western Kenya using the discrete choice experiment (DCE) approach. Six better-quality varietal traits, namely: yield level, tolerance to pests and diseases, sweetness of the flesh, colour of the flesh, maturity period and price change, were evaluated with empirical data from 400 randomly selected farming households in the study area. Data analysis from different choice models (the standard multinomial logit (MNL), scaled multinomial logit (S-MNL), mixed multinomial logit (M-MNL) and the generalized multinomial logit (G-MNL) models) found that the generalized multinomial logit (G-MNL) model, which accounts for both taste and scale factors had the best fit for the choice data at convergence compared to all the other models. In addition, farmers in the study area were found to have a positive attitude towards better-quality sweet potato varietal traits and were willing to contribute positive amounts in support of programs that improve varietal traits. Greater policy efforts therefore need to be directed towards increasing farmer participation in sweet potato breeding programs so that more demand-driven traits are developed.
***Key words**: Willingness to pay, choice experiment, sweet potato, generalized multinomial logit*

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I. Introduction

Sweet potato (*Ipomoea batatas L. Lam)* is a root plant that belongs to the morning-glory family (e.g. Kays, 2004). It is one of the most important crop for food, feed and vegetable crop in most developing nations, and accounts for about 97 percent of the global production (e.g. Kay, 2004; Westby et al., 2003). Developing nations produce about 131 million tonnes per year on approximately 9 million hactres and obtain average estimated yields of about 13.7 tonnes per hectare (e.g. FAOSTAT, 2009, 2015). It is also ranked as fifth economically important crop after rice, wheat, maize, and cassava; sixth in dry matter production; seventh in digestible energy production; and ninth in protein production among the developing nations (e.g. Thottappilly and Loebenstein, 2009; Kidmose et al., 2007).

Farmers grow different sweet potato varieties depending on their preferences for varietal traits (e.g. Makini et al., 2018; Momanyi et al., 2016). They distinguish these varieties based on their morphological, botanical and agronomic traits such as variations in the vines, leaves, flowers, and storage root characteristics (e.g. Callie, 2008; Ekanayake, 1990; Makini et al., 2018). Ordinarily, sweet potatoes are herbaceous perennial plants with branching and creeping vines that bear alternate heart-shaped leaves and medium-sized flowers of varying colours depending on variety. The storage roots are generally long and tapered, with a smooth skin that is either white, brown, purple or red. Flesh colours also vary from white to yellow, orange, purple and even cream/beige for some varieties. In terms of growth, sweet potatoes may be erect, semi-erect, or spreading, with vine systems rapidly expanding in a horizontal manner. The main varieties produced and consumed around the globe include the yellow (YFSP), white (WFSP), orange (OFSP) and the purple fleshed sweet potato (PFSP). Yellow, orange and white fleshed varieties are very popular among farmers even though the purple fleshed variety is also increasingly gaining popularity due to Anthocyanins compounds, which have medicinal value as anti-oxidants and cancer preventing agents (e.g. Callie, 2008; Ekanayake, 1990; Huaman, 1991; Odendo and Ndolo, 2002).

While research and extension programs have been initiated on the development and diffusion of better sweet potato varieties in order to address some of these challenges, the uptake of the improved varieties has also generally remained low (e.g. Asrat et al., 2009; Dankyi and Agyekum, 2007; Githunguri et al., 2007). According to research (e.g. Asrat et al., 2009; Dankyi and Agyekum, 2007; Edmeades, 2003; Owusu and Donkor, 2012; Kibwage et al., 2009). This is, in part, attributed to the fact that improved varieties tend to lack crop-specific traits that farmers consider important as crops are a composite bundle of multiple attributes (e.g. Wale et al, 2005, Smale et al., 2001; Edmeades et al., 2008; Badstue et al., 2003).

As regards sweet potato, such bundle of traits may include both production characteristics such as disease and pest resistance, early maturity and adaptability to harsh environments (e.g. Manu–Aduening et al., 2005; Odendo and Ndolo, 2002; Opiyo, 2011) and consumption characteristics such as taste, colour and seed quality (e.g. Wale et al., 2005). Smale et al. (2001) also argue that farmers choose crop varieties based on a set of attributes that best responds to production constraints, assures consumption preferences and satisfies specific market requirements. This is what is referred to as the crop-specific attributes hypothesis, which is highlighted by some researchers (e.g. Adesina and Zinnah, 1993; Adesina and Baidu-Forson, 1995; Adesina and Seidi, 1995) as suggesting that farmers' choice decisions of a particular crop variety are not only driven by profit maximisation, but rather complex decision-making processes that are affected by crop, agronomic, socio-economic and psychological variables (e.g. Willock et al., 1999). Moreover, farmers also grow crops that satisfy their needs and that once there is harmony between the needs and variety attributes, the result is varietal preference and land allocation decision (e.g. Wale and Mburu, 2006).

In Kenya, enhancing sweet potato production and productivity is indispensable for reducing hunger and food insecurity. In order to achieve this, the involvement of smallholder farmers in sweet potato production is essential. Moreover, the development, release, and the availability of sweet potato varieties with farmer-preferred traits is also important in motivating farmers to devote substantial amount of resources in the cultivation of sweet potato. Despite high investments so far in the development of high-yielding sweet potato varieties, the uptake of these varieties by smallholder farmers in the country has been low. While both farm and farmer characteristics have been important in influencing farmers' choice decisions for different crop varieties, the role of varietal traits has only received limited attention in the empirical literature.

Generally, there are studies that have looked at farmers varietal preferences for beans (e.g. Tekalign et al., 2016), cassava (e.g. Acheampong et al., 2013; Teeken et al., 2018), chickpea (e.g. Goa et al., 2017), cotton (e.g. Sanou et al., 2019), cowpea (e.g. Alidu et al., 2019; Ishikawa et al., 2019), maize (e.g. Sanchez-Toledano et al., 2017; Tadesse et al., 2014; Ajambo et al., 2017), sweet potato (e.g. Dibi et al., 2017), finger millet (e.g. Owere et al., 2014), onion (e.g. Tadesse, 2008), pigion peas (e.g. Otieno, 2008; Tsusaka et al., 2018), quinoa (e.g. Gamboa et al., 2018), rice (e.g. Hanis et al., 2012; Mansaray et al., 2018; Joshi and Bauer, 2006), strawberry (e.g. Yue et al., 2014), sugarcane (e.g. Sumbele et al., 2018), tomatoes (e.g. Skreli et al., 2017) and yams (e.g. Dansi et al., 2013) among others. These studies are however inadequate (e.g. Sanchez-Toledano et al., 2017; Gamboa et al., 2018; Teeken et al., 2018; Sanou et al., 2019) in informing policy decisions on crop variety improvements because individual preferences for product traits tend to be unstable and vary with crop, place and the period of time under consideration (e.g. Sonou et al., 2019; Tsusaka et al., 2018). As a result, crop-specific studies focusing on individual preferences are therefore important so that they can further our understanding about specific crop traits that ought to be considered in plant breeding programs.

This study was therefore an attempt to evaluate farmers WTP for sweet potato varietal traits in Kenya with a case application to smallholder farmers in Western Kenya (i.e. Busia, Bungoma, Kakamega and Vihiga Counties). Western Kenya was in this case been purposively chosen because of its importance in sweet potato production in the country and also the fact that farmers in the region are known to grow different varieties of sweet potato. The study also used the discrete choice experiment method to achieve the objective of the study following Gamboa et al. (2018), Mansaray et al. (2018), Sanchez-Toledano et al. (2017) and Skreli et al. (2017). The method was chosen because of its robust nature in allowing respondents to make trade-offs between different varietal traits of crop under investigation (e.g. Sanchez-Toledano et al., 2017). Thus, the DCE was in this case used to evaluate farmers' trade-offs for six sweet potato varietal traits, namely: yield level, flesh sweetness, flesh colour (orange, white, yellow or purple), tolerance to pests and diseases, maturity period and price. These traits, which were derived from the empirical literature and from discussions with experts, were broadly evaluated based on whether they were local or improved varieties so that farmers could express their preferences.

The rest of the paper is structured as follows. Section 2 sets out the theory of the study. Section 3 describes the experimental design. Section 4 presents the model estimation results and interpretation and section 5 concludes.

II. Analytical theory

2.1 Multinomial logit model (MNL)

The development of the multinomial logit (MNL) model by McFadden (1974) provided a statistical framework for modeling how varying policy attributes contribute to the probability of choice. The model has been widely used in applied economics owing to its computational simplicity and closed-form model specification. It assumes that choices are consistent with the independence of irrelevant alternatives (IIA) property such that for any individual, the ratio of choice probabilities of any two alternatives is unaffected by the utilities of any other alternatives (e.g. Louviere *et al*., 2010). The MNL model is based on an indirect utility function where the indirect utility derived by respondent from alternative in choice set *C* is:

(1)

where is the observable deterministic component and is the unobserved stochastic component. is a function of both the attributes of the alternative options and the status quo in choice set () and the characteristics of the respondent (). Respondent chooses alternative if for all in *C*. As such, the probability of choosing alternative by respondent is:

= (2)

The estimation of Equation (2) requires that assumptions about the distributions of the error terms be made. For the MNL model, the errors are assumed to be independently and identically distributed () with a Type 1 extreme value distribution (McFadden, 1974). This suggests that the probability of choosing alternative by respondent is:

(3)

where is a scale parameter that is inversely proportional to the variance of the error term. This parameter is not separately identified and thus, it is generally assumed to be equal to one, which implies constant error variance (e.g. Ben-Akiva and Lerman, 1985). As such, the log-likelihood function takes the form:

(4)

where the value of is one if the respondent chooses alternative and zero otherwise. Equation (4) is estimated through a maximum likelihood procedure (e.g. Hensher *et al*., 2015). Given the important restrictions in the MNL model because of the rigidity of its error structure, other formulations have been developed with more flexible error term distributions such as the mixed logit (MXL), scaled-multinomial logit (S-MNL) and the generalized-multinomial logit (G-MNL) models.

2.2. The mixed multinomial logit model (M-MNL)

Nowadays, the MXL model has largely replaced the MNL model in analyzing discrete choice data. The model was developed to account for the intuitive fact that respondents as decision-makers in a survey differ from each other. Thus, it is able to account, among others, for random taste variation and correlation in unobserved preference factors of individuals (e.g. Hensher *et al*., 2015). Therefore, the utility respondent receives from a choice alternative is algebraically formulated as before as follows:

(5)

where the deterministic component is a linear function of the policy attributes in vector and the vector of utility weights for each attribute, but is now partitioned into a mean part () and individual deviation (), thus giving equation (6):

(6)

Following Train (2009), the probability of choosing alternative by respondent expressed by a vector of policy attributes is obtained by integrating the distribution density over the range of parameter values, thus:

(7)

The utility function of each respondent has some random taste parameters with values that depend on the values of the parameters and of an underlying distribution , where w is the information or variance-covariance matrix. As Hensher and Green (2003) note, the choice of distribution strongly affects the properties of the model. As such, random taste parameters induce correlation across choices made by the same respondent, but maintain the advantageous logit probability. In effect, is Gumbel and therefore the choice probability remains logit conditional on the parameter draw. The MXL formula is thus a weighted average of the MNL probability calculated at different values of . The weight is the probability density of over respondents with mean and variance-covariance matrix . Since Equation (8) does not have a closed form solution, it is estimated by simulated maximum likelihood methods (e.g. McFadden and Train, 2000). In view of the fact that the MXL formulation still maintains the MNL model assumption that the idiosyncratic error term is , it is unable to account for scale heterogeneity. To account for the potential effect of scale heterogeneity, the S-MNL model has been developed which relaxes the assumption (e.g. Fiebig *et al*., 2010).

2.3. The scaled multinomial logit (S-MNL)

The MXL model only accounts for the unobserved taste heterogeneity in the deterministic component of utility. Typically, the scale factor , which is inversely related with the error variance , is normalized to one to allow estimation of the model. Past studies (e.g. Louviere and Eagle, 2006) suggests that such a constant scale of the error distribution may not be appropriate in explaining individual choice behaviour. Thus, Fiebig *et al*. (2009) developed alternative modelling methods that could accommodate the variance across respondents in the random component of utility, namely the S-MNL and G-MNL model. In the S-MNL model, the error variance is allowed to be heterogeneous in the population so that the utility that respondent derives from alternative can be written as follows:

(8)

where β denotes a vector of average population attribute parameters, refers to the individual's specific standard deviation of the idiosyncratic error term that captures scale heterogeneity, denotes a vector of the observed explanatory variables, and is as before the stochastic error that is over the alternatives and individuals (Fiebig *et al*., 2009). The individuals' scaling factor has to be restricted to be positive and this is attained through the use of an exponential transformation (e.g. Fiebig *et al*., 2009; Greene and Hensher 2010), that is:

(9)

where denotes the mean parameter related to the error variance, is the coefficient associated with the unobserved scale heterogeneity, and refers to the unobserved individual heterogeneity related to the scale that is standard normally distributed. Since is unidentified separately from , is normalized as . Thus, larger parameter values for show a greater degree of scale heterogeneity (Fiebig *et al.,* 2009). The S-MNL model is estimated through a simulated maximum likelihood procedure.

2.4. The generalized multinomial logit model (G-MNL)

The need to account for both taste and scale heterogeneity in one and the same model led to the development of the G-MNL model (e.g. Keane *et al.,* 2006; Fiebig *et al.,* 2010; Greene and Hensher , 2010). The G-MNL model nests both the MXL and S-MNL model. First operationalized by Fiebig *et al.* (2010) and subsequently by Greene and Hensher (2010), the marginal utility for alternative for the G-MNL model is represented as follows:

(10)

where takes any value between 0 and 1 and where:

(11)

In Equation (11), denotes the mean parameter of scale variance, is as before a parameter of unobserved scale heterogeneity, and is a standard normal distribution representing the unobserved scale heterogeneity. Ignoring and in the extreme case where takes the value 0, Equation (11) collapses to:

(12)

suggesting that scale impacts equally upon both the mean and standard deviation parameters. Fiebig *et al.* (2010) refer to this model as G-MNL II. If on the other extreme equals 1, Equation (11) is equal to:

(13)

suggesting that the scale factor impacts only upon the mean attribute parameters. Fiebig *et al.* (2010) refer to this model as G-MNL I. Values of between 0 and 1 suggest that scale impacts both the mean and standard deviation parameters, but to different extents. Returning to , if and all , then the model collapses to the standard MNL model. If is estimated to take the value 1, then the marginal utilities obtained from the model would collapse to the MXL model. Similarly, if all simultaneously equal 0, then the model collapses to the scaled version of the MNL model, namely the S-MNL model (Fiebig *et al.,* 2010), such that the marginal utilities obtained from the model would algebraically be given as:

(14)

and the final empirical model, with attributes only, as:

(15)

where is the alternative specific constant representing the utility of growing sweet potatoes relative to the 'none' option. The betas () and the delta () refer to the vector of coefficients related to yield, sweetness, colour, tolerance, fiber, maturity and price traits. From the equation above, the average implicit prices or mean willingness to pay (WTP) for any given varietal trait relative to the 'none' option is computed as: (e.g. Hanneman, 1984).

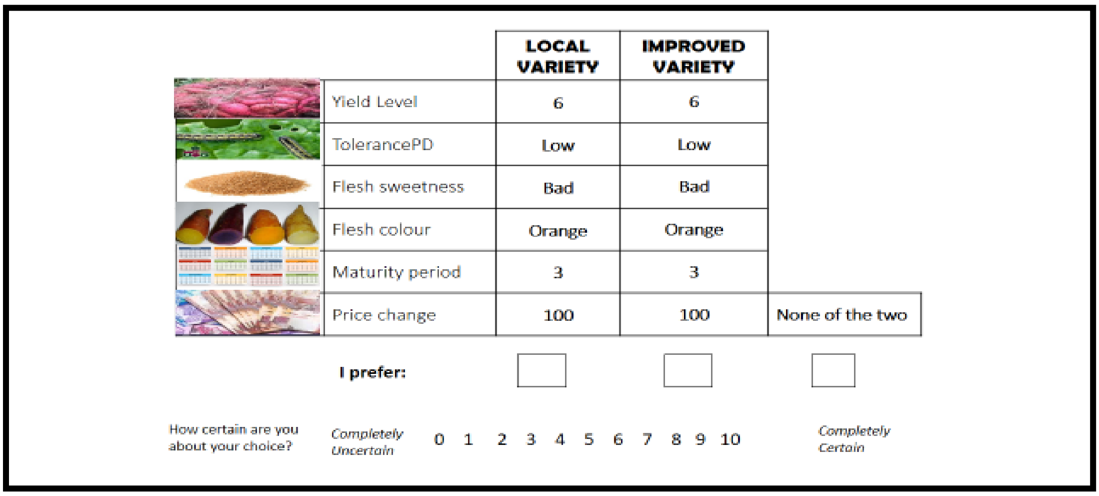
III. Experimental design

In DCEs, respondents are presented with alternative descriptions of policy interventions, differentiated by different combinations of attribute levels. Respondents are then asked to choose their preferred alternative. For each choice made, the alternative selected is assumed to yield a higher level of satisfaction than that rejected. This enables the probability of an alternative being chosen to be modelled in terms of the attribute levels used to describe the policy intervention. In this paper, respondents were presented a series of variety traits that include: yield level, tolerance to pests and diseases, sweetness of the flesh, colour of the flesh, maturity period and price. Respondents were asked to choose their most preferred varietal alternative. Based on expert interviews in an open-ended pretest , different levels for the selected varietal traits were selected as shown in Table 1 below.

Table 1: Descriptions and levels of the chosen attributes

Attribute	Description	Levels
Yield	The amount of sweet potato out per hectare	Level 1: 6 tons/hactre Level 2: 10 tons/hactre Level 3: 14 tons/hactre
Tolerance	Forbearance to common crop pests and diseases	Level 1: High Level 2: Medium Level 3: Low
Sweetness	Taste of the sweet potato flesh.	Level 1: Good Level 2: Average Level 3: Bad
Colour	Colour appearance of the sweet potato flesh.	Level 1: Orange Level 2: Yellow Level 3: White
Maturity	Period sweet potato takes to mature.	Level 1: Upto 3 months Level 2: Upto 5 months Level 3: Upto 7 months
Price	Change in price per unit of output.	Level 1: 100 Level 2: 200 Level 3: 300

There were also different alternative varietal scenarios created by combining these six variables based on their different attribute levels. Because respondents cannot be shown all different choice options, the number of possible combinations was reduced to 10 choice sets of 10 choice tasks each based on an orthogonal fractional factorial design generated in the statistical software *Ngene*, enabling the estimation of main effects and two-way interactions. Each respondent was randomly shown one of these 10 choice sets of 10 choice cards. Each choice card shows two hypothetical choice alternatives describing a future policy scenario along with the option to choose none of the two. Inclusion of this latter 'status quo' alternative is instrumental to be able to estimate welfare measures that are consistent with demand theory (Bateman et al., 2003). It was emphasized that respondents would not have to pay anything extra if they choose the opt-out. An example of a choice card is presented in Figure 1.



The design of the choice experiment mainly comprised three sections. The first section was intended to measure respondents' general knowledge on sweet potato varietal traits so as to familiarize them with the attributes of interest that were being evaluated. The second section contained questions for DCE analysis that were designed to elicit respondents' WTP for sweet potato varietal traits by estimating trade-offs between price and the other attributes. In this case, common photographs of the attributes were also inserted in the DCE cards to enhance respondents' understanding regarding the attributes. The final part elicited socio-demographic information of the respondents such as age, gender, education and income. The choice experiment instrument was first pre-tested and subsequently implemented between October – December 2019 through 400 in-person interviews in Western Kenya. The response rate was 100%, which is not unusual for this kind of stated preference research in a developing country (Whittington, 1998). A predetermined random sampling plan was used to obtain respondents for the survey. Trained local enumerators were also used for the interviews to ensure choice scenarios were presented to respondents in a more informative way. The enumerators had instructions to limit all explanations to facts so as to minimize the introduction of any interviewer bias. Moreover, respondents were given adequate time to understand and answer each question so as to enhance the validity of responses obtained. The results are presented in the following section.

IV. Results And Discussions

4.1 Descriptive results

Descriptive results of the socio-demographic and farm characteristics of the survey sample are presented in Table 2. As shown, the mean age of the respondents was 45 years with men accounting for the largest share (78%) of the respondents. Most respondents (93%) had primary and post-primary level of education with only 11% and 14% of the respondents having had access to farm credit and agricultural extension services, respectively. On average, the distance to a reliable input/output market centre was about 3kms with membership to farm organizations having a share of 16% of the interviewed farmers. Land holdings were, on average, 0.37 acres with household heads having a farming experience of about The study also found that 62% of the respondents were growing improved sweet potatoes varieties with 36% of the respondents saying they grew sweet potatoes more than once in a year. Moreover, the study also found that 95% of the interviewed farmers produced sweet potatoes for commercial purposes. As to the source of the sweet potato vines, the study found that 35% of the farmers sourced vines from their own farms. On average, sweet potato production was about 1.91 tonnes that fetched an average income of about KES 11,702.

Variable	Mean/proportion	Std error	Min	Max
Age (years)	45	13.31	20	85
Gender (1=male)	0.78	0.41	0	1
Education (1=educated)	0.93	0.25	0	1
Access to farm credit (1=access)	0.11	0.31	0	1
Access to agricultural extension (1=access)	0.14	0.35	0	1
Membership to farm organizations (1=member)	0.16	0.37	0	1
Sweet potato variety grown (1=improved)	0.62	0.48	0	1
Frequency of growing sweet potatoes (1=more than once)	0.36	0.48	0	1
Sweet potato use (1=commercial purposes)	0.95	0.22	0	1

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Source of sweet potato vines (1=own farm)	0.35	0.77	0	1
Quantity of sweet potato harvest (tonnes)	1.91	15.23	0	300
Sweet potato income (KES)	11,702	2,114	0	180,000
Distance to reliable input/output market (Kms)	3.07	0.71	0.1	7

Table 2: Socio-demographic and farm characteristics of the survey sample

Table 3. shows farmers perceptions about the severity of challenges faced in sweet potato production. As shown in the table, 81% of the farmers felt that lack of extension services a major problem facing sweet potato farming in the study area. This was followed by unavailability of farm credit (76%), yield variability (67%), input quality (58%), input availability (54%) and price variability (50%). However, low incidences of flooding (18%) and droughts (22%), exploitation by middlemen (22%) and theft of produce were some of the least challenges they faced by farmers in sweet potato production.

Table 3: Severity of challenges faced in sweet potato farming among the survey respondents

Variable	Proportion	Std error	Min	Max
Labour scarcity	0.31	0.46	0	1
Yield variability	0.67	0.47	0	1
Frequent droughts	0.22	0.41	0	1
Frequent floods	0.18	0.38	0	1
Extension services	0.81	0.39	0	1
Input quality	0.58	0.49	0	1
Input availability	0.54	0.50	0	1
Credit availability	0.76	0.43	0	1
Market for produce	0.30	0.46	0	1
Price variability	0.50	0.50	0	1
Road network	0.30	0.46	0	1
Theft of produce	0.29	0.45	0	1
Middlemen	0.22	0.41	0	1

As for the importance of different sources of information for sweet potato farming, the results are shown in Table 5. The study found that friends (91%) were the important source of information, followed by relatives (87%), and radio (68%). However, farmers association (31%), television (30%), input dealers (30%), extension agents (27%) and newspapers (23%) were the least important sources of information in sweet potato production.

Table 4: Importance sources of information used in sweet potato farming in the study area

Variable	Proportion	Std error	Min	Max
Friends	0.91	0.29	0	1
Relatives	0.87	0.34	0	1
Newspaper	0.23	0.42	0	1
Radio	0.68	0.47	0	1
Television	0.30	0.46	0	1
Input dealer	0.30	0.46	0	1
Farmer association	0.31	0.46	0	1
Extension agent	0.27	0.44	0	1

4.2 Econometric results

Choice data for the study was analyzed using NLOGIT software version 5. The utility functions were specified as linear functions of the choice attributes with an alternative specific constant (ASC), also included in the utility functions to represent the difference in utility between respondents' choice of the provided choice alternatives (local variety or improved variety) and the status quo option when all attributes are equal. The ASC was included in the model as dummy variables with the provided choice alternatives being coded as one and the status quo option as zero (Tarfesa and Brouwer, 2012). In addition, following Greene et al. (2006), the random price parameter was assumed to follow a constrained triangular distribution to ensure a negative sign on the price parameter. However, a normal distribution was defined for the other random parameters. Although the main model for the study was the G-MNL, both MXL and the S-MNL models were estimated alongside the standard MNL model to compare the results emanating from the study. To begin with, choice shares across the three alternatives (i.e. for local variety, improved variety and the status quo option) were analyzed and as shown in Table 5, there was a positive attitude among respondents towards improved sweet potato variety since the alternative was chosen in 62% of the cases compared to the local variety option that was chosen in 34% of the cases. Majority of those who chose none of the two (3.6%) explained that they did not mind any of the sweet potato varieties.

Table 5: Choice shares across the alternatives in the discrete choice experiment

Description	Proportion	Standard Error	95% Confidence Interval	
Local variety	0.340	0.007	0.326	0.355
Improved variety	0.624	0.008	0.609	0.639
Status quo	0.036	0.003	0.030	0.041

Table 6 presents the estimation results of the standard MNL, S-MNL, MXL and the G-MNL models. The standard MNL is usually estimated before the S-MNL, MXL and G-MNL models as it generates the initial start values for the means of the coefficients and sets the starting values for the standard deviations (e.g. Hole, 2007). As shown in the table, the results are basically as expected with coefficient estimates showing the expected signs and acceptable levels of statistical significance. The ASC parameter is positive, which implies that respondents, on average, prefer the cultivation of either of the two sweet potato varieties as opposed to the status quo option of no cultivation at all. Moreover, positive coefficients of the survey attributes (i.e. yield, tolerance and both sweetness and colour of the flesh) imply that farmers derive higher utility from the improvement of such sweet potato varietal traits. The negative sign of the maturity period and price change attributes indicate that farmers derive lower utility from their sweet potato production when the maturity period is longer and price change high. The standard deviations of the random parameters are also significant meaning that there is considerable unobserved preference heterogeneity in the survey sample.

As for the models estimated in the study, there is substantial improvement in model fit that is seen at the convergence of the models (in terms of log-likelihood, McFadden Pseudo R^2 and the Akaike information criteria) when moving from the standard MNL model to the G-MNL model. Notably, the MNL model does not account for both taste and scale factors and when taste factors were accounted for through the MXL model (which by formulation accounts for taste factors only), the model fit improved by 38.06 points in the log likelihood, 0.27 points in the Pseudo R^2 and 62.10 points in the Akaike information criterion. This means that it was important to account for taste heterogeneity in the study.

Table 6: Regression estimates of the utility functions for sweet potato varietal traits in the study area

Characteristics	MNL		MXL		S-MNL		G-MNL	
Mean estimate of random attribute parameters	**Coefficient**	**Std error**	**Coefficient**	**Std error**	**Coefficient**	**Std error**	**Coefficient**	**Std error**
ASC (1 = non status quo)	2.806***	0.167	3.338***	0.190	4.358***	0.469	4.263***	0.283
Yield level (1 = high)	0.041***	0.007	0.038***	0.009	0.044***	0.007	0.042*	0.023
Tolerance to pests and diseases (1 = high)	0.079***	0.027	0.076**	0.039	0.073***	0.024	0.084**	0.038
Sweetness of flesh (1 = good)	0.106***	0.029	0.097*	0.055	0.116***	0.025	0.104***	0.029
Colour of flesh (1 = appealing)	0.038	0.028	0.020*	0.011	0.046*	0.026	0.028*	0.016
Maturity period (1 = longer)	-0.052***	0.014	-0.057**	0.029	-0.035***	0.012	-0.053**	0.025
Price change (1 = high)	-0.0003	0.0003	-0.0007	0.000	-0.001*	-0.001	-0.0002*	0.000
Standard deviation of random parameters								
ASC			0.139*	0.079			4.632***	0.532
Yield level			0.051**	0.026			0.069**	0.036
Tolerance to pests and diseases			0.115*	0.067			0.162***	0.042
Sweetness of flesh			0.037***	0.009			0.088*	0.050
Colour of flesh			0.126*	0.070			0.010***	0.002
Maturity period			0.138**	0.072			0.011**	0.006
Price change			0.042*	0.024			0.001*	0.001
Model summary statistics								
Log-likelihood.	-3246.79		-3208.73		-3197.44		-3136.86	
LR chi-square	101.15		2371.44		2394.02		2515.18	
Prob > chi square	0.0000		0.0000		0.0000		0.0000	
McFadden Pseudo R^2	0.0432		0.2698		0.2724		0.2862	
Scale (tau) parameter τ	-		-		0.8247***		0.069***	
Akaike Information Criteria (AIC)	6507.60		6445.50		6410.90		6303.70	
Number of observations	4000		4000		4000		4000	
Parameters	7		14		8		15	

*Explanatory notes: ASC alternative-specific constant, which is a dummy for the respondent choosing to grow sweet potatoes as opposed to not growing; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.*

Again, when the scale factors were accounted through the S-MNL model (which by formulation accounts for scale factors only), the model fit improved by 49.35 points in the log likelihood, 0.23 points in the Pseudo R^2 and 96.70 points in the Akaike information. Over and above the MXL, the model fit for the S-MNL model improved by 11.29 points in the log likelihood, 0.003 points in the Pseudo R^2 and 34.40 points in the Akaike information. This implies that there was considerable scale heterogeneity in the survey sample. The fact that the model fit for the S-MNL was better when compared to that of the MXL model and also the significant *tau* () parameter means that scale factors were much more important than the taste factors in the study. Accounting for both scale and taste factors in the study using the G-MNL model further improved the model fit by 110.93 points in the log likelihood, 0.24 points in the Pseudo R^2 and 203.90 points in the Akaike information. The significant *tau* () parameter also in this further confirms that scale factors were indeed much more important than the taste factors in the study. Owing to its better performance, the G-MNL model was thus used to derive the welfare estimates for the study.

Estimates of WTP and standard errors were calculated using the Delta procedure, as earlier indicated. As shown in Table 7, it is evident that the WTP estimates are positive and statistically significant all the models, which means that sweet potato farmers in the study area are willing to contribute positive amounts in support of a policy or program that improves the afore mentioned varietal attributes. Of much interest is the fact that when no taste and scale factors are accounted for in the choice analysis, as is the case with the MNL model, the welfare value is highest for the yield attribute (KES 64.44) and lowest for the flesh colour attribute (KES 12.95). When taste factors have been accounted for in the MXL model, the welfare value is highest for the sweetness of the flesh attribute (KES 234.67) and lowest for the colour of the flesh attribute (KES 100.85). After accounting for the scale factors using the S-MNL model, the welfare value becomes highest in the sweetness of the flesh attribute (KES 313.40) and lowest for the maturity period attribute (KES 100.28). In the case where both taste and scale factors have been accounted for through the G-MNL model, the welfare value is still highest in the sweetness of the flesh attribute (KES 334.70) but lowest for the colour of the flesh attribute (KES 108.29). The results suggest that farmers in the survey sample highly valued the sweetness of the sweet potato flesh more than the other attributes. While this was followed by tolerance to pest and diseases and then yield level, choice could be made between flesh colour and maturity period attributes owing to the indifference observed. Notably, MNL model provided the most conservative WTP estimates for the choice attributes as opposed to the MXL, S-MNL and G-MNL models. Moreover, differences in the welfare values seem to suggest that welfare estimation process was highly sensitive to model specifications, notwithstanding the significant heterogeneity in taste and scale across the individuals.

Table 7: WTP estimates for the different sweet potato varietal traits in the study area

Characteristics	MNL		MXL		S-MNL		G-MNL	
	WTP	95% CI	WTP	95% CI	WTP	95% CI	WTP	95% CI
Yield level	64.44**	28.02	137.58**	4.77	128.43**	1.11	138.36*	5.45
Tolerance	50.86***	4.32	187.09**	1.67	184.25*	1.8	142.17***	6.53
Sweetness of flesh	33.08**	14.70	234.67***	3.46	313.40***	3.97	334.70**	8.50
Colour of flesh	12.95*	7.23	100.85*	4.79	116.91**	1.26	108.29**	6.73
Maturity period	32.92***	3.25	128.06*	7.44	100.28**	1.13	118.20*	2.33

*Explanatory notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.*

V. Conclusions

In this study, farmers' WTP for sweet potato varietal traits were examined using the discrete choice experiment models, namely, the standard MNL, MXL, S-MNL and the G-MNL models. The discrete choice experiment method used in this study provides a good application of a bottom-up research approach aimed at solving the myriad problems affecting farmers in the developing world. While the approach can be used to fine-tune the existing technologies, it was in this case used to generate information about farmers' WTP for technologies that improve sweet potato crop varietal traits.

With the empirical results suggesting that farmers in the study area had a positive attitude towards improved sweet potato varieties compared to the local varieties, it would therefore be critical for the relevant agencies to expand their outreach programs for the new sweet potato varieties that have been developed. Since the results also seem to suggest that farmers significantly tend to derive higher utility from the improvement of the sweet potato varietal traits such yield, tolerance to pests and diseases, sweetness of the flesh and shortening of the crop maturity period, more breeding efforts should focus on activities that improve the concerned traits. While this happens, the corresponding breeding efforts should not lead to pricey varietal products as this may limit the uptake of improved crop varieties.

There was also unobserved preference heterogeneity noted in the survey respondents and what this means is that breeding of the sweet potato varieties to better ones has to take into account any inherent heterogeneities among the farmers. As for the models estimated in the study, the G-MNL model accounting for taste and scale factors had the best fit for the choice data at the convergence in terms of log-likelihood, McFadden Pseudo R^2 and the Akaike information criteria when compared to S-MNL, MXL and the MNL models. It is therefore recommended that future choice studies analyzing varietal trait improvement should consider using the G-MNL model. However, further studies are recommended on how these models compare with other crop varietal improvement data.

Finally, the study found that sweet potato farmers in the study area were willing to contribute positive amounts in support of a policy or program that improves varietal attributes. Out of different modelling frameworks, the study found that farmers highly valued the taste of the sweet potato flesh more than all the other attributes. This was followed by tolerance to pest and diseases and then yield level choice with room for choice being left out for between flesh colour and maturity period attributes. While the MNL model provided the most conservative WTP estimates for the choice attributes, different models yielded different WTP estimates, which means that the computation of the welfare values was highly sensitive to model specifications. In the future, more studies could however be undertaken to understand the welfare values that famers may attach to the different levels of choice attributes.

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